Situation Assessment Report on the

PREVENTION OF PLASTIC AND RESIN PELLET LEAKAGE FROM FORMAL AND INFORMAL RECYCLING FACTORIES

HANOI, VIETNAM

RRC.AP
Regional Resource Centre for Asia and the Pacific

Regional Knowledge Centre for Marine Plastic Debris

ERIA
Economic Research Institute for ASEAN and East Asia

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This study was conducted for the Regional Knowledge Centre for Marine Plastic Debris (RKC-MPD), Economic Research Institute for ASEAN and East Asia (ERIA)

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Acronyms

ABS	Acrylonitrile Butadiene Styrene
AIT RRCAP	Asian Institute of Technology Regional Resource Centre for Asia and the Pacific
ASEAN	Association of Southeast Asian Nations
BAT	Best Available Technology
BEP	Best Environmental Practice
CAGR	Compound Annual Growth Rate
DARD	Department of Agriculture and Rural Development;
DH	Department of Health
DOC	Department of Construction
DOF	Department of Finance
DONRE	Department of Natural Resources and Environment
DPI	Department of Planning and Investment
ERIA	Economic Research Institute for ASEAN and East Asia
HDPE	High-Density Polyethylene
LDPE	Low-Density Polyethylene
MARD	Ministry of Agriculture and Rural Development
MOC	Ministry of Construction
MOF	Ministry of Finance
MOIT	Ministry of Industry and Trade
MONRE	Ministry of Natural Resources and Environment
MPI	Ministry of Planning and Investment
MSW	Municipal Solid Waste
NGO	Non-Governmental Organization
PA	Polyamide
PE	Polyethylene
PET	Polyethylene Terephthalate
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl Chloride
RKC-MPD	Regional Knowledge Centre for Marine Plastic Debris
RPET	Polyethylene Terephthalate
SUP	Single-use Plastic
SWM	Solid Waste Management
SWT	Solid Waste Treatment
URENCO	Urban Environment Company

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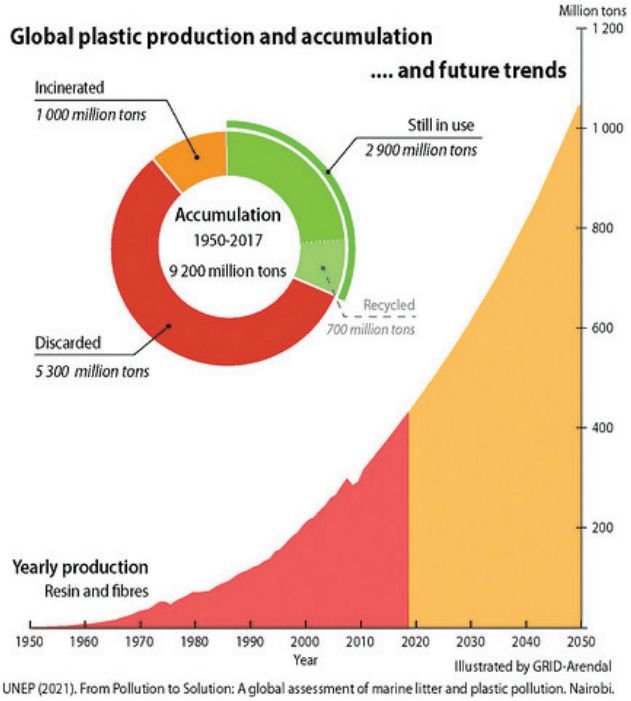
Introduction

1.1 Background

Approximately 70–80% of marine plastics originate from mismanaged land-based sources, which are transported from land to the sea through various means, such as floods, water canals, rivers, or coastlines. The mismanagement of plastics along the value chain, including pellet production, transportation, conversion, product use, disposal, and recycling, contributes to this issue. Given the pervasive use of plastics in daily life, environmental plastic loss can occur at any stage of application or mismanagement. Common sources of marine plastics include littered and improperly disposed packaging; consumer products from industries, homes, markets, and institutions; and items such as beach debris, paints, pellets, and road dust. Effective management of plastics throughout the value chain entails implementing measures to reduce waste generation, thereby ensuring proper containment and transportation, environmentally friendly disposal, and efficient recycling practices.

Plastics entering the marine environments are of varying physical and chemical properties; sources, size, shape, colour, chemical composition, etc. Plastics in marine environment are typically classified as macro plastics (size > 5 mm in size but not limited to any size class) and micro plastics (less than 5 mm in size). Though physical methods, ultraviolet (UV) degradation and biological action into microplastics over time, macro plastics may typically breakdown into microplastic—often called land based secondary microplastics when fragmentation occurs on land and marines based secondary plastics when fragmenPlastics entering marine environments have varying physical and chemical properties, including source, size, shape, colour, and chemical composition. Plastics in marine environments are typically classified as macroplastics (>5 mm in size,

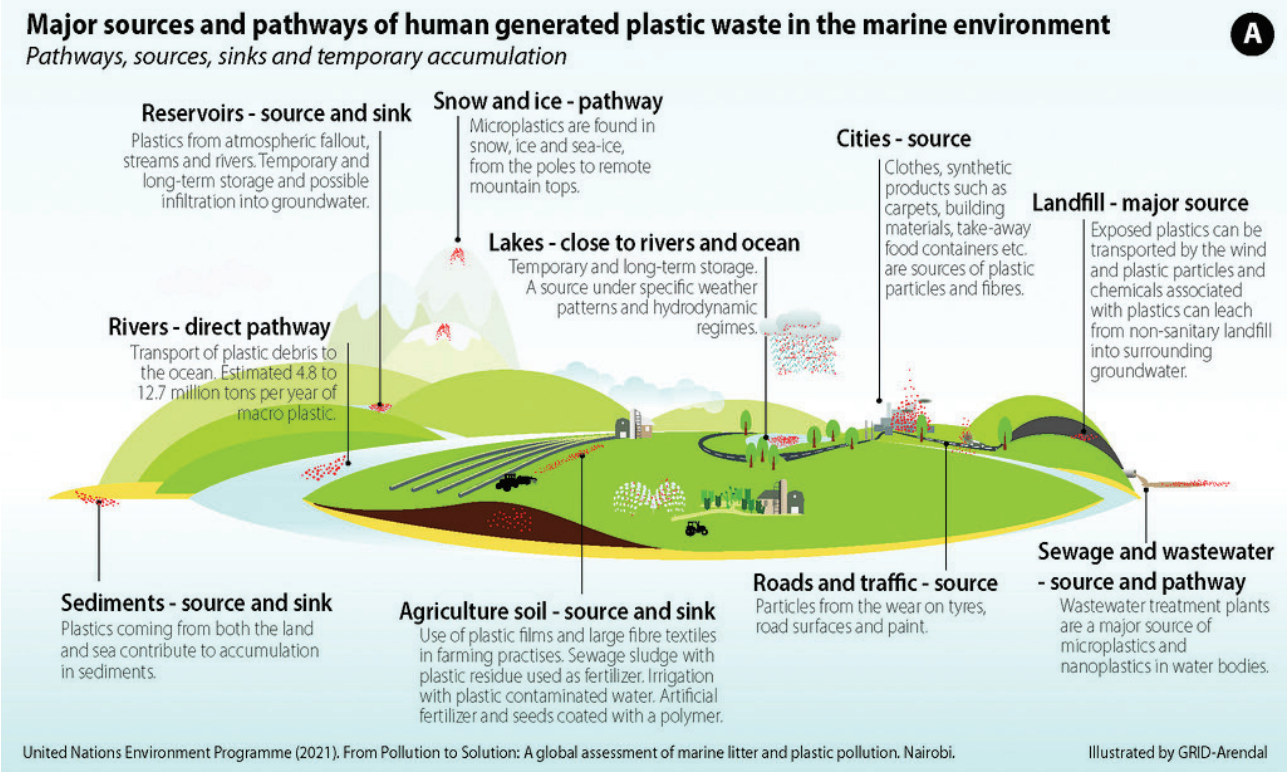
Figure 1. Global plastic production, accumulation, and future trends (Sources: UNEP 2021, adapted from Jambeck et al. 2018; Plastics Europe 2019; Geyer 2020. Illustrated by GRID-Arendal)



Quick global figures (infographs)

- In 2019, ~6.1 Mt of plastic waste leaked to aquatic environment globally.
- In 2021, the size of the world plastic market was estimated at 593 billion USD.
- From 2022 to 2030, it is expected an increase in the compound annual growth rate (CAGR) of 3.7% .
- Packaging was the dominant use of primary plastics, with 42% of plastics entering the use phase.
- The average global consumption of plastic is 45 kg/ person/year, equivalent to an increase of 4% annually in the period from 2005 to 2015.
- Approximately 13 Mt (4%) of waste plastics generated each year are exported beyond their country for recycling and disposal.
- The major exporters are the United States, Europe and Japan, representing 73% of global plastics waste exports (UN, 2017).

Figure 2. Major sources and Pathways of human generated plastic waste in marine environment (Source: United Nations Environmental Programme (2021. From Pollution to Solution: A global assessment of marine litter and plastic pollution. Nairobi. (Illustrated by GRID-Arendal)[1]



but not limited to any size class) or microplastics (less than 5 mm in size). Through physical methods, ultraviolet degradation, and biological action on microplastics over time, macroplastics typically break down into microplastics, often called land-based secondary microplastics when fragmentation occurs on land and marine-based secondary plastics when fragmentation occurs within marine environments. Primary microplastics (i.e. manufactured microplastics) may also directly enter the marine environment from multiple sources. Intentional and unintentional sources of primary and land-based secondary microplastics sources include tire abrasions, textiles, plastic pellet losses, cosmetics, marine coatings, road markings, and city dust.

The sources, transport, and pathways of land-based marine plastics are diverse and present significant challenges for one-stop countermeasures to prevent their leakage into marine environments. Plastic waste produced at the source is transported to the final receiving media, such as soils and oceans, which is facilitated by the direct and indirect occurrences of human and non-human agents, including wind, water or flooding, direct discharge of wastewater in drains, and direct discharge. Municipal Solid Waste management in major cities across Southeast Asia faces challenges in coping with the pace of plastic waste production. policy issues, underinvestment or financing in waste management infrastructure, unavailability of appropriate technologies, and behaviour change issues, among others (Lau et al., 2020). The mismatch between plastic waste generation and plastic waste management solutions has contributed to fast-growing plastic hotspots of plastic pollution and marine plastics (Borrelle et al., 2020). More than half the plastic waste generated in Vietnam remains uncollected (~3.6 Mt/year). The region's fast-growing cities are responsible for an average of 60% of the

1 Marine litter mainly comes from land-based sources, including agriculture, wastewater treatment plants, construction, transportation, unnecessary, avoidable, and problematic plastic products and polymers, and a wide variety of personal and health care products. Approximately 60% of microplastic leakage is from uncontrolled waste streams (UNEP 2018c; IRP 2019; van Truong et al., 2019; Geyer, 2020; The Pew Charitable Trusts and SYSTEMIQ, 2020).

plastic waste leakage from municipal waste systems into the environment (UNESCAP, 2020). Multiple studies have underscored the highly complex and challenging systems required to effectively manage marine plastics. Multi-stakeholder and multilevel participation by governments, cities, development finance institutions, the private sector, grant funders, private investors, academics, civil society, and community organisations are necessary to deliver effective solutions to the marine plastic problem. Cities face immediate pressure to solve rising waste costs, create strong economic and green job growth opportunities, and reduce waste-related public health concerns and costs stemming from problems such as stormwater drainage blockages. Urban areas are confronted with the urgent task of addressing the escalating expenses related to waste management.

1.2 Context

Among the various solutions proposed for managing plastic pollution, mechanical recycling of post-consumer plastic stands out as a highly recommended approach for curbing marine plastic pollution. This method effectively retains the value and material of post-consumer plastics, while also contributing to a reduction in the production of virgin materials. Informal recyclers also play a significant role in recapturing valuable plastics and reintegrating them into a value loop using reverse logistics.

Despite the significant benefits of mechanical recycling in the management of post-consumer plastics, recent studies have highlighted its potential drawbacks. Without proper preventive measures, mechanical recycling could become a significant source of primary and secondary microplastic pollution (Suzuki et al., 2022; Brown et al., 2023). The mechanical recycling process involves handling plastic waste, size reduction, and physical processes, all of which pose inherent risks of plastic leakage into the environment in various forms, such as fragments, flakes, pellets, strands, and powders.

Plastics, including macro- and microplastics, can be intentionally or unintentionally lost at various points during recycling. This may include pellet losses, or the release of low-value plastics excluded from the recycling and handling processes. Furthermore, plastic waste is generated during the manufacturing process, including nonconforming parts, runners, and trim waste, which are pieces that cannot be used in new parts owing to quality or specification limitations. Some industries may regrind this waste and incorporate it into virgin resins within customer-specified limits. Without proper containment, clean-up, or remediation measures, unrecovered plastics may accumulate in the immediate environment and ultimately enter the marine environment. Addressing these challenges requires stringent measures throughout the recycling process to minimise plastic leakage and environmental pollution.

The informal recycling sector plays a significant role in Vietnam's plastic recycling landscape, particularly in Hanoi, which focuses primarily on recycling domestically generated plastic waste. Craft villages, often concentrated in specific areas or clusters based on their specialisation in plastic-related crafts, are integral to this sector. Much of the recycling activity in these villages relies on the plastic collected by waste scavengers. Craft villages are vital drivers of socioeconomic progress in many parts of Vietnam, contributing to increased income and improved livelihoods for local populations. However, informal recyclers and craft villages typically operate as family businesses or small-scale enterprises that specialise in recycling discarded plastics and other waste materials. They often work within limited production spaces, leading to the inefficient use of raw materials and fuel. In addition, there is often a lack of awareness regarding environmental conservation during production processes.

Owing to their setup and operations, these entities face challenges such as low capital investments and financing. They primarily employ intermediate plastic processing technologies and old, entry-level machines and equipment, often relying on manual labour. This results in suboptimal efficiency of material handling and production objectives. Poor processing system conditions, coupled with the low quality of recyclable plastic input materials, contribute to the accumulation of plastic waste and microplastics in discharged effluents. Unfortunately, most of these production facilities lack measures to control pollution, treat waste, and ensure labour protection. Consequently, informal recycling and craft villages are associated with environmental pollution challenges, including plastic pollution from their

Figure 3. Project activity flow and implementation

1. **Desk research**
   - Context analysis
   - Value chain and process mapping
   - Stakeholder mapping

2. **Scoping, site visits & consultation**
   - Site/facility visits & interviews craft villages,
   - Process assessment and evaluations
   - Expert consultations and interviews; Hanoi City government officers, DONRE, civil NGOs

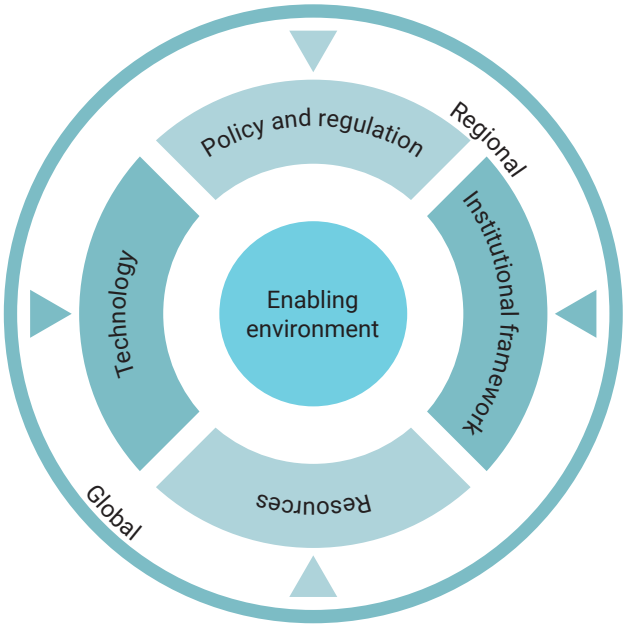
3. **Expert review and consultation and workshop**
   - Review of findings of assessment report
   - Review of draft guidelines & best prcatice

4. **Finalisation and regional dissemination workshop**
   - Draft final draft guidelines,
   - Expert workshop and dissemination
   - Discussion of best prcatice and way forward

operations (Nguyen, 2020). Addressing these issues requires concerted efforts to improve infrastructure, technology, awareness, and regulatory oversight in the informal recycling sector and craft villages.

Among informal recyclers, the challenge of mismanaged plastic waste generation arises primarily from the recycling businesses' focus on obtaining high-value plastics, often neglecting the impact of residual waste and low-value plastics on the environment. In Vietnam's informal recycling craft villages, an estimated 25–30% of plastic waste processing results in discarded material, with approximately 7 million litres of wastewater discharged daily into open dumps and waterways without proper treatment (Yeoh, 2020). Factors, such as the lack of specific laws and regulations, the use of rudimentary technologies that do not meet technical and environmental protection standards, and low production efficiencies, contribute to the significant health and environmental costs associated with these activities.

Managing the various forms of residual waste generated in plastic recycling craft villages and factories is critical to reduce pollution from plastic recycling enterprises and craft villages. In addition to disposing microplastic-loaded sludge in landfills, many recyclers have limited options for properly containing and treating microplastic-loaded effluents and washing water, often resorting to dumping on land or channelling through drainage systems. Given Hanoi's susceptibility to urban flooding, the combination of plastic pollution and poor waste management systems can facilitate the leakage and transport of plastics into the aquatic environment. Urban floods may transport mismanaged plastics and untreated wastewater containing microplastics from domestic and industrial settings into rivers and seas. For instance, densely populated districts such as Thanh Xuan, Hoang Mai, and Thanh Tri are drained by lakes such as To Lich, Lu, Set, and Kim Nguu. A World Bank-funded study on urban flooding and pollution in selected hotspots in Hanoi identified 280 wastewater discharge points (mostly domestic) along the Tolich River. Additionally, over 1,500 wastewater discharge points were identified along the Nhue, Day, and Tich Rivers, with more than 900 discharge points from residential drainage and over 650 discharge points from sources such as industrial and service activities, hospitals, craft villages, farms, and animal husbandry. Developing plastic recycling and industry best practices informed by situational assessment studies is essential to minimise the risks of micro- and macroplastic losses to the environment. Remedial measures should include

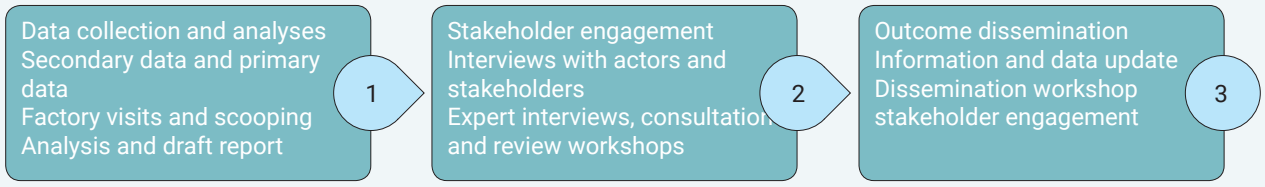


cleaning and disposing of pellets when spillage occurs.

1.3 Approach & framework

To develop targeted interventions to address plastic pollution and leakage challenges in informal recycling facilities and craft villages, this study was conducted to assess the situation from an integrated configural analytical perspective. This approach considers plastic pollution and leakage problems from recycling facilities as a complex interaction of various interconnected factors and elements. The assessment was primarily qualitative without quantifying the quantity of plastics leaking from recycling processes in the facilities, enterprises, or craft villages involved in the study.

The study recognised that plastic pollution and leakage issues arise from a combination of factors, including technological availability and access, prevailing policies and regulatory regimes, institutional mechanisms, and access to various resources. The interplay between these factors, whether considered in isolation or in combination, creates an environment that enables plastic recycling in Hanoi. By understanding and addressing these interconnected factors, tailored interventions can be developed to support, promote, and alleviate the plastic pollution and leakage challenges in the informal recycling sector and craft villages. Notwithstanding exogenous factors, such as global and regional policy directions, market forces also influence how internal plastic recycling business is carried out. Hence, such actions justify why, how, where, and what plastics and pellets are leaked from formal and informal facilities, enterprises, and craft villages. The study adopted a simplified three-step approach to 1) collect and analyse data and information, 2) engage key stakeholders, and 3) disseminate the outcomes of the study.



1 **Data collection & analyses** was combined with site visits, scoping exercises, consultation meetings, and interviews to systematically collect, map, analyse, and understand the governance frameworks for plastic recycling and pollution management in Vietnam at both national and city levels. Both quantitative and qualitative data were collected on the state of plastic pollution, initiatives, and economic and social settings that influenced the conduct of informal recycling businesses in craft villages. Preliminary mapping of the types of recycling, value chain configurations and networks, and process operations of craft villages was carried out to understand handling and flow along the processing line. This information is useful for understanding the context, status, and sources of plastic loss in formal and informal recycling. Available relevant project reports and publications were reviewed and analysed. Authoritative, publicly available secondary data sources, directories, and databases were accessed. Nevertheless, we leveraged our wide network and collaboration with local partners and various industry associations to gain access to factories and firms in an ethical and socially responsible manner. Multiple scoping exercises, site visits, and interviews were arranged with keystone recycling enterprises and craft villages with the support of the city implementation partners of the project, the Vietnam Cleaner Production Centre. Discussions and interviews were conducted with relevant departments and city authorities to present, discuss, validate, guide, inform, and reconcile the preliminary findings of this study on on-ground practices. Discussions, interviews, and observations made during visits to informal recycling facilities and craft villages provided further insights for fine-tuning the preliminary outcomes of the study.

2 **Stakeholder engagement:** The participation of key stakeholders in plastic recycling is critical to achieve the objectives of this study. The stakeholders were mapped and shortlisted against various data themes drawn from the desk study. Stakeholder consultations were carried out at three-step complementary levels with support from our city implementing partner in the project, the Vietnam Cleaner Production Centre.

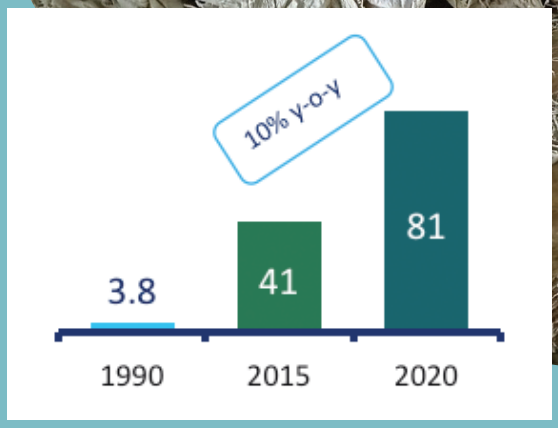
Initial scoping and site visits missions: Stakeholder engagement was initiated through discussions, interviews, and scoping visits with selected key primary stakeholders. Discussions and interview consultations were held with the identified relevant stakeholders, including the Vietnam Institute of Strategy and Policy for Industry and Trade under the Ministry of Industry and Trade (MOIT), the Environmental Impact Assessment Department, Hanoi Department of Environmental Protection, Hanoi's DONRE-MONRE, informal plastic recycling craft enterprises in selected craft villages, and representatives of non-governmental organizations (NGO). Site visits, discussions, and consultations were conducted.

Expert consultation and review workshop: A broad stakeholder and expert review workshop was convened in Hanoi to present and review the preliminary assessment findings. The experts that participated in the workshop were from the city government, academia, private sector, international and local NGOs, civil society, and private consultants.

Regional consultation and brainstorming workshop: The third level was the regional-level project consultation and dissemination workshop held to facilitate the sharing of project outcomes among key stakeholders of the project from project six (6) cities (Hanoi, Iloilo, Manila, Nonthaburi, Pattaya, and Vientiane). Stakeholder engagement activities primarily involved brainstorming sections where the key findings, best practices, and challenges of each city and region at large were discussed.

3 **ASEAN wide dissemination Workshop:** The workshop was held to engage and disseminate key findings and lessons learned from the project for ASEAN cities and to discuss the way forward. The workshop was also used as a platform to share knowledge, lessons learned, raise awareness, and promote best practices for preventing plastic and resin pellet leakage from factories and the informal recycling sector in the ASEAN. A total of 37 key experts and representatives from the city government, along with experts anad stakeholders from associations of plastic recyclers and plastic industries, institutional consultants, and relevant private sector stakeholders, academia, cleaner production centres, civil society groups, and international non-governmental organizations were invited to participate.

Chapter 2



Plastic recycling landscape in Hanoi

- 1.8 million tonnes of annual plastic waste
- 58 kg/capita/year go to waste.
- Population: 8.2 million MSW generated: 2.6 MT/yr Plastic generated (in MSW): 0.5 MT/yr Plastic recycled (in MSW): 0.1 MT/yr
- According to the Ocean Conservancy, 60% of all plastic waste found in the ocean comes from only five Asian countries, including Vietnam.
- while the remaining 7% comes from waste generated within the country (but is recycled in craft villages where proper environmental practices are not applied).
- About 90% of the plastic waste recycled through formal processes is imported
- Estimated plastic leakage of 4,7 kg/capita/year. plastic waste leaked into the ocean in 2018.
- This is due to low collection rates outside city centers, high littering rates and open burning of waste prior to collection.

IUCN-EA-QUANTIS (2020)

Plastic production, use and waste management.

- The plastic industry has the highest growth rate in Vietnam with an annual growth rate of 16-18% (after telecommunications and textiles)
- According to Vietnam Institute of Strategy and Policy for Industry and Trade, 0.28 to 0.73 Mt of plastic wastes leak into the ocean annually due to inadequate collection and management system

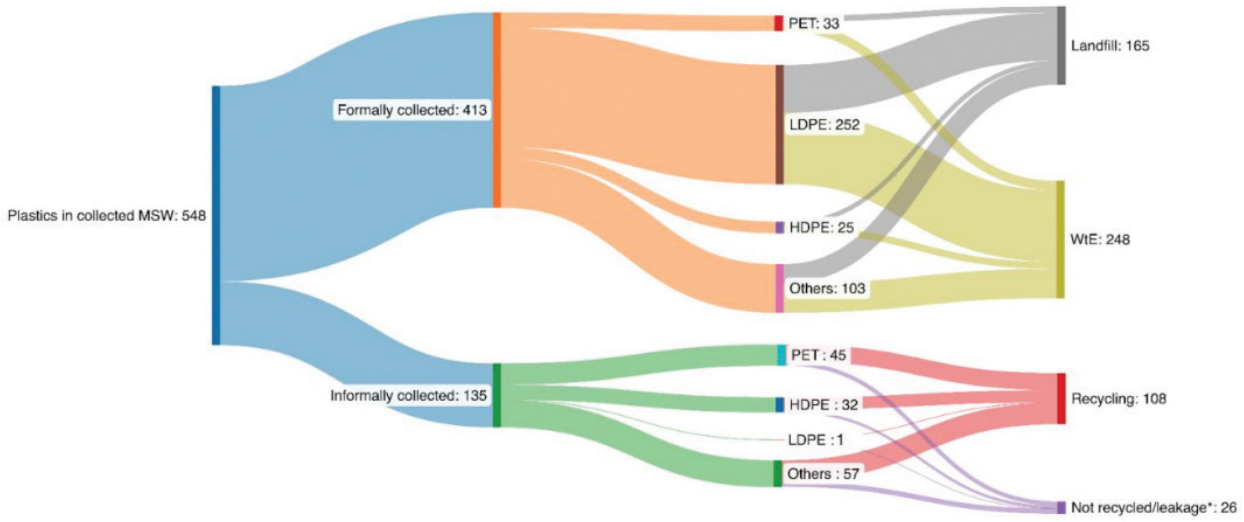
2.1 Formal and informal recycling value chain and network configurations

Post-consumer plastic recycling in Hanoi has various actor categories including waste generators, formal and informal waste collectors, aggregators, and formal and informal recyclers. These actors are organised in clusters within the broad recycling system, based on specialisations, material and product output, and geographic locations with complex interconnections and interactions, both vertically and horizontally. Their operations, relationships, collaborations, and interactions include not only material flow but also information flow, and knowledge transfers are supported within systems and networks. These configurations affect how and what materials are collected and processed, what technologies are best suited, market information about specific polymers, and regulatory changes. Understanding the interplay between formal and informal sectors and their connections, collaborations, and operational methods within

Hanoi Capital (Key figures)

Hanoi the second largest city of Vietnam
Estimated total population (2021): 8,418,883 people
Area : 3,358.6 km^2
Hanoi has 30 district-level administrative units. 12 urban districts, 17 suburban districts and 1 township
The dense and urbanized heart of the city center and the peri-center is mainly located within the bend in the river, on the right bank
579 commune-level administrative units: 383 communes, 175 wards and 21 towns.
Dong Da district has the highest population density of >40,000 people/km^2,
Thanh Xuan district with a density of >33,000 people/km2.
Hai Ba Trung district Cau Giay districts are also of growing population density.

Figure 4. Flow of plastic within municipal solid waste in Hanoi (thousand tonnes per year).[3] (Source: The Circulate Initiative, 2023)



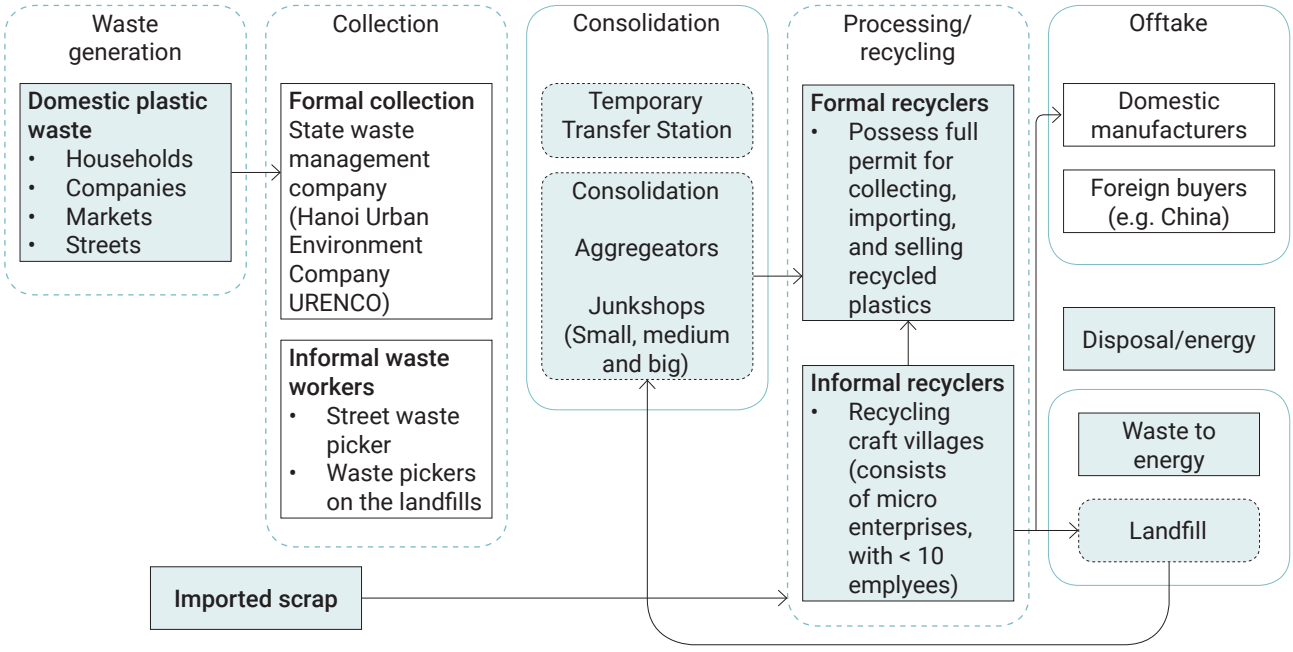
the recycling ecosystem is crucial for developing effective strategies to improve recycling rates, sustainability, and overall waste management.

Notably, the informal plastic waste recycling sub chain plays a pivotal role in Hanoi's recycling landscape, recovering domestic recyclable plastic waste, and facilitating the recycling of approximately 20% of domestically collected recyclable plastics. However, a large amount of plastic collected through formal recycling waste management channels is typically sent to landfills or energy plants. The formal waste sectors are described as "consisting of either public or private enterprises which are professionally managed and licensed to operate following regulations designed to protect the local and national environment and public health". In contrast, the informal waste sectors refer to "individuals or enterprises who are involved in private sector recycling and waste management activities which are not sponsored, financed, recognized, supported, organized, or acknowledged by the formal solid waste authorities, or which operate in violation of or in competition with formal authorities". The informal sector collection has traditionally coexisted with formal municipal waste services from Urban Environment Company (URENCO) and 17 private companies. Although Hanoi has a decent waste collection rate, estimated at approximately 90%, the role of its established informal recycling sectors contributes substantially to improving domestic recycling. The informal sector collects and recycles approximately 25% of the total plastic in the city's municipal solid waste. High-value post-consumer recyclable plastics are retrieved from the solid waste of households, institutions, markets, factories, etc., prior to disposal. Between 1200 and 1400 thousand tons of plastics are disposed of per year in landfills.

Formal recycling, Vietnam's economic transformation, embracing globalisation, and Vietnam's shift towards urbanisation, has spurred the expansion of Hanoi's informal waste collectors, simultaneously influencing the gender dynamics within this group and shaping the nature of their tasks. Working alongside formal waste management with an entrepreneurial orientation, informal waste workers in Hanoi enhance the reverse logistics of recyclable plastics by retrieving high-value post-consumer plastics for recycling. Estimates indicate that approximately 22,500 informal waste collection workers are spread across the nine urban districts of Hanoi. However, according to official reports, the number of cases documented

2 Figures are rounded to the nearest whole number and may not sum because of rounding. The share of plastics collected in Hanoi is calculated based on an 91% MSW collection rate. *'Not recycled/leakage' refers to plastic waste collected, but not recycled due to contamination or the collectors being unable to sell low-value plastics to aggregators.

Figure 5. Stakeholders in recycled plastics value chain in Hanoi



in 2008 was approximately 10,000 (Mitchell, 2008). The livelihood and income of informal waste workers are contingent on the availability and access to high-quality recyclable post-consumer plastics. Various categories of informal waste workers, who are at the base of the informal recycling chain hierarchy, include waste pickers who work on the street picking high-value plastics from rubbish before collection by waste collectors. At Nam Son landfill, "ve chai" or waste pickers primarily operate between midnight and early morning to retrieve recyclable plastic materials and other high-value recyclable plastics for sale. An estimated 800–1,000 waste pickers work in this capacity at night. Official regulations mandate the registration and use of safe clothing when performing duties. The waste collection crews of formal municipal waste collection trucks also retrieve valuable recyclable materials, including plastics, for sale to junkshops and informal plastic scrap dealers. The majority of waste collectors (75% in 2006) working in Hanoi originated from Vietnam's Red River Delta's Xuan Truong district in Nam Dinh Province, formerly known as Nam Ha Province. The retrieved recyclable plastics are then sold to numerous intermediaries, including junkshops, traders, transporters, and aggregators. Hanoi contains approximately 800 informal junkyards. Recyclable plastics are usually transported to informal recycling facilities in the Hanoi suburbs, where clusters of craft villages specialise in the recycling of materials. Notably, the presence of thousands of itinerant buyers, or "đồng nát", collecting recyclables with a high value further encourages individuals, businesses, and accommodations to sort their waste. Details of the stakeholders in the four stages are shown in Figure 5.

In addition to the informal waste collection system in Vietnam, the process of collecting plastic waste has been socialised in the form of bidding in provinces and localities; therefore, URENCO focuses only on the transportation of waste to the Xuan Son and Nam Son landfills (according to MOIT). However, these collection companies are still subsidiaries of URENCO. They typically have designated collection points throughout the city, where households and businesses can collect waste.

2.1.1 Informal workers: waste pickers and itinerant buyers

Informal waste workers engaged in recovering recyclable materials, especially plastics, directly from primary waste generators such as households, markets, institutions, factories, and landfills, often rely on manual and labour-intensive methods for collection. Equipped with carts, such as bicycles, push carts, and motorised carts, these workers gather plastic materials, focusing primarily on

high-value plastics that can yield significant income when traded. Some workers sell directly to junk shops, whereas others temporarily store their collected plastics to accumulate large volumes before selling. This storage practice allows them to sort plastics, aiming for improved negotiation leverage and increased purchase prices from junk shops. However, a lack of access to secure storage spaces limits this approach.

Conversely, some junk shops agree with waste pickers to store and document their daily output. This system operates based on established trust and social connections between waste pickers and junk shops, facilitating effective management of recyclable materials and creating opportunities for advantageous transactions based on accumulated volumes and plastic polymer types. The collected plastics undergo a pre-sorting process that may involve dismantling to some extent. This includes removing films and labels from multilayer packaging and composite plastic materials. Additionally, certain electronic equipment containing high-value composite materials are dismantled, with individual parts sold separately to maximise their value. This practice enhances the value of the materials obtained from sales. However, without proper measures, the plastic scraps, labels, and low-value plastics generated during the process may leak into the environment. Measures are required to address this issue and ensure the handling and disposal of all plastic waste generated during the recycling process.

2.1.2 Recyclable plastic traders: junkshops, consolidation centres, and transporters

Fundamentally, junk shops, scrap dealers, traders, and consolidators operate at the junctions of informal waste workers and mechanical recyclers. They engage in coordinated transactions, receive pre-sorted recyclable plastics from informal waste workers, and transfer these materials to recyclers. This intermediary role facilitates the flow of pre-sorted recyclable plastics from informal waste workers to recycling facilities, thereby connecting the efforts of informal waste workers to mechanical recycling processes. Small- and medium-sized junk shops foster collaborative partnerships with informal waste workers. Recyclable plastics are procured in limited quantities directly from these workers. Subsequently, they gather, sort, and transfer these materials to aggregators and then to informal recyclers and recycling villages. This process ensures that recyclable plastics acquired in small amounts are prepared and channelled towards large entities for further handling and recycling. In Hanoi, recyclable plastic aggregators often perform minimal sorting or processing of plastics but concentrate on accumulating large quantities of recyclable materials prior to selling them to informal recyclers and craft villages. Functionally, like junkshops, the operations of aggregators primarily revolve around amassing recyclable plastics from different junkshops and often act as intermediaries between small junkshops for plastics and large recycling

At the end of 2018 799 scrap collection facilities have been identified throughout Hanoi. Scrap refers to a general term encompassing recovered recyclable materials including plastics and metals. Waste collection facilities are present in all districts, both in urban and suburban areas. The average distribution distance between scrap collection facilities in Hanoi is in the range of 500–1000 m.[2] This is the distance corresponding to the service radius of urban utility services. The collection facilities are located along the roads, which are convenient for transporting to the recycling facilities located in the neighbouring provinces of Hanoi. Therefore, although spontaneously formed, scrap collection facilities have an ideal service radius as the recycling points in urban areas. Currently, most waste treatment facilities are concentrated in the Soc Son district, where the Nam Son solid waste treatment (SWT) zone is also located. Approximately 77% of Hanoi's domestic waste is received daily here. In the inner city of Hanoi, most of the waste collection facilities are concentrated in the Dong Da district, and this is also the place where the first waste collection facilities in Hanoi are located.

3 https://sti.vista.gov.vn/tw/Lists/TaiLieuKHCN/Attachments/296922/CVt69S382020032.pdf

Figure 6. Stakeholder networks identify based on the locations and methods used for material recovery

Scrap buyers: Those who often buying sorted dry recyclable materials from householders and then transport to recycling shops (scrap dealers) of some kind

Street-based waste pickers: Secondary waste materials are picked either from the waste thrown in the streets or from the mixed waste in the public garbage bins

Dumpsite-based waste pickers: Secondary raw materials are picked on or near the dumpsites before being disposed of

Street cleaning workers (sweepers): They can be found working with a handcart and broom at night.

Waste collection crews: They collect secondary raw materials from vehicles transporting waste from collection points to disposal sites/landfills

Junkshops, aggregators, traders and transporters: Those who buy scrap and then sell it for profit

Craft villages: Secondary raw materials are transported to craft villages (paper, plastic, and metal), then materials are recycled into usable products then sell it on for profit. Most of the technologies used by craft villages

Recycling enterprises: Those who buy secondary raw materials from scrap dealers. These materials are processed and recycled into new products

facilities or processors. Consolidation centres located at major landfill sites such as Nam Son in Soc Son District and Xuan Son in Sơn Tây receive retrieved recyclable plastics from the landfills. Typical operational activities of junkshops, aggregators and consolidators are as follows: transportation of plastics; dismantling; pre-sorting; sorting into polymer types, colours, and grades; baling; and storage. However, depending on market demand and output quality, few aggregators engage in prewashing and cleaning.

Based on the locations and methods used for material recovery, the mapped plastic recycling stakeholder networks in Hanoi are shown in Figure 6.

2.1.3 Recycling craft villages

Craft villages in Vietnam have a rich history and have evolved significantly over time, boasting diverse specialties within their territories. These villages typically operate on a small scale, often consisting of fewer than ten individuals, and focus on recycling post-consumer plastics. Recyclable plastics used as feedstock in these villages were predominantly sourced from domestic post-consumer waste collected from households, institutions, businesses, factories, and landfills. Plastic collection and recycling activities within craft villages form a production chain aimed at supplying recycled plastic to local areas and surrounding regions. These materials were obtained through transactions involving municipal waste collectors, markets, junk shops, and aggregators.

In cases where access and collaboration with intermediaries, such as junk shops and aggregators, pose challenges, craft recycling villages establish their own networks to collect recyclable plastic and other materials. Rather than relying on external intermediaries to supply recyclable materials, these villages created their own systems for collecting materials directly. By adopting a backward integration strategy, they directly involved themselves

in the collection process, bypassing the need for intermediaries and external sources. This approach provides increased control over the collection process and ensures a steady supply of feedstock necessary for recycling.

Craft villages produce recycled plastic pellets for markets in China, whereas some sell them to local small-scale manufacturers within the village or other locations to produce cost-effective items such as plastic bags, cups, foam boxes, and similar products. Some large craft villages, however, occasionally process imported waste, with large villages often trading directly with formal recyclers. High-value recyclable post-consumer plastics, mainly polyethylene terephthalate (PET), low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), and polystyrene (PS), are primarily processed, whereas low-value or difficult-to-recycle plastics are often rejected. In Hanoi, there are many craft villages that recycle post-consumer plastics, such as Tan Trieu village, Trieu Khuc commune (Thanh Tri district), Trung Van ward (Nam Tu Liem district), Tu Chau village, Lien Chau commune (Thanh Oai district), Xa Cau village, Quang Phu Cau commune (Ung Hoa district), Tien Duoc, and Kim Lu communes (Soc Son district).

Raw plastic materials are collected from many localities through waste collection networks from provinces and cities across the country. After collection, these wastes are usually classified as HDPE, PP, PS, and PET. During the recycling process, by-products from cleaning and granulation are directly discharged into the water source, causing severe chemical and micro-plastic pollution. Even more difficult-to-recycle wastes are disposed of by incineration or indiscriminate burial. Although it is a hard job, with many potential risks for the workers themselves, and even pollutes the environment, collecting and recycling scrap has contributed to creating jobs and increasing income for people for a long time. However, most plastic recycling households in craft villages only produce two main types of granules: white grade-A granules used to make plastic boxes, straws, plastic strings, or

Scrap generation
• The input of recycled plastic raw materials in the market is supplied by both imported plastic scrap and domestic recyclable plastic scrap. • Imported Scrap: Vietnam is one of the largest plastic scrap importers globally. The amount of plastic scrap imported each year in Vietnam is 615,000 tonnes (MOIT). Nevertheless, tightening restrictions have limited the flow of imports in recent years. • Illegal imports of plastic scrap and tax evasion on scrap shipments remain a regulatory challenge in Vietnam. There is a lack of clarity on the regulation against plastic scrap imports, based on interviews conducted on the ground • Domestic scrap: Vietnam has high potential in increasing its domestic rate of plastic recycling.
Collection
• While urban areas generate more waste, solid waste collection rates are much higher in urban areas compared to rural areas. • At household level, waste is generally not sorted at source. • Collection of domestic scrap is predominantly carried out by itinerant waste pickers, e.g. approximately 6000 recyclers and waste pickers in Hanoi • Waste that do not get scavenged or recycled typically go into landfills (~80% of collected solid waste), which are major sources of pollution. About 85% of the 450 landfills in Vietnam are not sanitary.
Processing
• Plastic recyclers in Vietnam are dominated by the informal sector, which are often recycling craft villages. • Types of plastics which are recycled in Vietnam are limited to 'high-value' plastics, given the predominance of informal plastic recyclers and use of low-tech machinery.
Offtaking
• Extended recyclers: Face challenges in securing high quality supply of recyclable plastic waste, as current supply of high-value plastics is dominated by informal sector. • Plastic product manufacturers: The market for post-consumer resin (recycled plastic pellets) are limited and constrained to few markets.

white plastic bags, and low-grade grade-B granules, which are slightly grey and used to make all kinds of ropes and pipes. Production technology is mainly labour-intensive, using manual, simple, and rudimentary processing machines and technologies. Moreover, the quality of the input materials is often low, with the majority of processing facilities lacking measures to control pollution and waste treatment. For example, survey data in Duoc Ha village, Tien Duoc Commune (Soc Son, Hanoi), show that investment in machinery ranges from tens of millions (handmade machinery) to several hundred million dong (new machinery imported from China). However, given the unique traditional operational characteristics, market position, and concerns regarding potential lock-ins, only a limited number of factories in recycling villages choose to invest in suitable machinery and technologies. These investments aim to enhance product quality to meet the market demand and reduce environmental pollution. Fear and concern about potential technological lock-ins influence the decision-making process, leading to only a few factories making such strategic investments despite the potential benefits for their products and the environment. The mechanical recycling of plastics in craft villages involves a series of operational processes that begin with material reception, storage, debaling, sorting, crushing, flaking, washing, drying, bagging, and transportation. In these processes, water and input plastic materials are processed and transferred between the processing units. Consequently, pollution may occur in the ambient environment of the preceding units and facilities. These include unintended plastic loss from processing units and wastewater. Without proper measures, these emissions leak into the soil, air, and water, posing increased microplastic pollution issues which have become a major drawback for many recycling villages.

2.2 Recycled plastics market structure and participation of formal and informal recyclers

Vietnam has a dynamic plastic recycling sector with formal and informal participants of varying capacities. The plastic industry, contributing 6.7% to gross domestic product in 2019, anticipates high growth, projected at a 10% CAGR by 2023. Domestic plastic resin production meets only 26% of the demand, necessitating the import of 7.5 Mt. This gap presents a significant opportunity for the recyclable plastic industry. The Vietnam Institute of Strategy and Policy for Industry and Trade under the MOIT noted that the domestic demand for primary plastic materials increased by over 10% per year against a supply growth rate of less than 3% per year. A World Bank market study reveals that 3.9 Mt of PET, LDPE, HDPE, and PP plastics are consumed annually in Vietnam, but only 33% are recycled, resulting in a substantial 75% loss of material value (equivalent to $2.2–2.9 billion, 2.62 Mt). Full recycling potential is estimated at $3.4 billion, the current rate yields only $872 million annually[4]. Hence, there is a need to bridge the shortfall in the supply of raw materials (resins) for domestic plastic product manufacturers in Vietnam. Given the stringent regulations restricting the import of recyclable scrap plastics due to quality issues, Vietnam finds itself in a distinctive position to boost domestic plastic recovery efforts, thereby addressing existing supply shortages. Nevertheless, substantial investment is required for domestic post-consumer recycling resin production to enhance the capacity, technology, and quality, particularly for informal recycling enterprises. Recent studies involving 312 stakeholders, including consumers, producers, and waste service providers in the plastic materials, pulp, and paper sectors, revealed a notable interest among plastic sector stakeholders in a material market characterised by enhanced access and increased participation by respondents[5].

Hanoi is a major post-consumer plastic recycling hub in Vietnam that hosts formal and informal plastic recycling enterprises. Actors along the recycling chain have intricate connections with diverse levels of access, participation, and barriers, all of which influence market access and profitability in the recycling sector. With a disparate market structure, the informal plastic recycling market is characterised by unequal levels of investment, access to markets, resources, information, and market power. These factors affect the actor's profit level. Actors with access to plastic resources, efficient recycling processes, and an awareness of market demand

4 World Bank Group 2021. Market Study for Vietnam: Plastics Circularity Opportunities and Barriers. Marine Plastics Series, East Asia and Pacific Region. Washington DC.

5 https://p4gpartnerships.org/sites/default/files/2019-07/materials%20marketplace%20final%20report.pdf

may achieve higher profits than those with limited resources or information. In terms of material flow and price setting, there is an apparent hierarchy that places informal waste pickers at the base and consolidators and informal recyclers at the top. The pricing of various polymers is predominantly determined by top-level actors (aggregators, off-takers, and recyclers) high up in the hierarchy, leaving those at the base with limited influence on the material's price.

The post-consumer plastic material pricing structure is characterised by a top-down approach, in which decision-making power lies with high-tier participants, often marginalising their input and bargaining capacity at low levels of the market hierarchy. The hierarchy mimics an asymmetric market dynamic in price setting; informal waste workers (pickers) and junk shops at the base and middle levels of the hierarchy face challenges because of their limited control over the pricing mechanisms for plastic materials. Despite international market volatility influencing plastic material prices, establishing a well-defined pricing structure is crucial. This structure ensures the competitiveness and sustainability of all participants in the recycling industry. Similarly, information asymmetry regarding in-demand recyclable polymer types in the market and their prices can result in poor hand recovery and losses due to polymer rejection. This situation is particularly prominent among informal waste workers (on streets and landfills), truck drivers, and itinerant buyers who trade valuable recyclable plastic with junkshops. Typical occurrences involve the illegal disposal or poor handling of low-value plastics, plastic films removed from bottles, and rejects from offsite sorting prior to selling to junkshops.

2.3 Prioritization of plastic types and technology choices for plastic processing

2.3.1 Demand forecast and future price of recycled plastics

Vietnam's self-production of plastics remains low, with only partial fulfilment of demand: 15% for PP, 30% for PET, and 50% for polyvinyl chloride (PVC), as of 2019[6]. Economists predict continued competition between polyethylene terephthalate (RPET) and polyolefins for cheap virgin plastics. Various factors, such as government policies and recycling technology, affect the scrap market. Since 2020, increased factory operations have led to PE oversupply, thereby hindering price and profit–margin growth. Global bans on single-use plastics may impact demand, potentially affecting the competition for recycled products with cheap PE types. Historically, the PP narrow market began to stabilise as manufacturers expanded their production capacity. The oversupply of primary PET, akin to PE, poses challenges for RPET manufacturers amid the shifting supply-demand dynamics. Despite potential price increases for RPET, consumer willingness to pay remains uncertain, complicating market conditions. Overall, primary PET prices are expected to remain low due to oversupply, which presents challenges for RPET manufacturers.

During the initial five months of 2022, Vietnam imported approximately 3.08 million metric tons of plastic materials, with a total value of nearly $5.63 billion, equating to an average of $1,823.5 USD per tonne. This represented a marginal increase of 0.5% in volume, 12.2% in turnover, and 11.7% in price compared to the corresponding period in 2021. Notably, South Korea emerged as the leading supplier, experiencing a significant surge of 47.4% in volume and 46.6% in value, totaling $1.31 billion, which accounted for over 24% of the total volume and import turnover. Conversely, imports from China decreased by 7.1% in volume, while turnover increased by 7.8%, reaching $1.11 billion. China's imports constituted 17.6% of the total volume and 19.8% of the total import turnover.

In the initial four months of 2022, there were significant fluctuations in import volumes across various plastic materials: PE decreased by 3.9%, PET by 10.3%, ethylene-vinyl acetate by 4.5%, PP by 7.2%, PVC by 15%, PS by 7.2%, and ABS by 1.6%. Despite rising import prices due to factors like oil price hikes and increased transportation costs, demand for plastic resins in Vietnam continues to rise. Government regulations on scrap material imports have redirected demand towards domestically

6 Progess Report No 1 - Project on provision of services and equipment (turnkey) for tow pilot facilities to be located at Phan Boi and Minh Khai craft village - Vietnam.

Table 1. Import of plastic materials in the first 5 months of 2022

Market	5/2022	Compared to 4/2022 (%)	5 months of 2022	5 months of 2021 (%)	Proportion (%)
Total import turnover	3,084,776	0.46	5,625,076,297	12.12	100
South Korea	757,731	47.42	1,306,015,360	46.55	24.56
China	542.272	-7.13	1,113,347,647	7.76	17.58
Saudi Arabia	374,182	-19.03	526,069,064	-5.99	12.13
Thailand	276,988	2.82	448,298,296	13.52	8.89
Japan	119,357	-11.68	286,088,756	0.94	3.87
America	131,345	-32.44	286,511,265	-3.48	4.26
Malaysia	94,994	-7.57	174,303,571	6.35	3.08
Singapore	87,909	3.27	159,277,192	7.08	2.85
Taiwan (China)	350,65	-5.31	756,832,093	5.47	11.37
India	53,764	18.50	79,337,700	44.76	1.74
U.A.E	56,919	-24.37	78,870,817	-17.36	1.85
Indonesia	48,242	15.26	75,737,534	30.39	1.56
Russia	37,953	118.23	47,486,067	147.28	1.23
Germany	7,277	-22.67	45,515,288	-13.46	0.24
Kuwait	34,031	0.60	44,097,712	15.43	1,10
Qatar	28,251	-17.54	39,189,717	-0.15	0.92
Philippines	13,248	18.94	19,129,108	30.60	0.43
Belgium	4,53	-2,64	12,377,832	25.51	0.15
Brazil	3,827	-5.27	11,616,364	22.80	0.12
Canada	5,981	-22.03	8,364,856	-7.17	0.19
France	2,298	-58.22	9,264,362	-31.14	0.07
Netherlands	3,249	-45.72	8,364,856	-31.39	0.11
Italia	2,155	-32.66	7,107,557	-21.37	0.07
England	1,293	-21.73	5,530,821	0.29	0.04
Hongkong (China)	2,942	13.90	5,449,011	-5.s98	0.01

Calculated according to the data published on 11/6/2022 of the General Department of Customs[7]

Table 2. Price of plastic materials imported from China in the first 5 months of 2022

Plastic material	Price (USD/ton)	Increase (%)
PVC	1,461	12.1
PET	1,150	20.2
PP	1,467	2.7

sourced recycled plastics, which are notably cheaper than virgin plastics. This underscores the considerable potential for producing recycled plastic pellets in Vietnam, given the high market demand. Import prices of certain plastic materials from China in the first five months of 2022 are expected to significantly rise compared to the same period last year, according to data from the General Department of Customs (Table 2).

Meanwhile, the price of PP recycled plastic pellets is only about 1/3 (PP homopolymer ~413.7 USD/ton and PP copolymer

7 https://vinanet.vn/thuong-mai-cha/thi-truong-nhap-khau-nguyen-lieu-nhua-5-thang-dau-nam-2022-759287.html

Table 3. The latest price list of recycled plastic granules 8/2022[8]

No.	Plastic granules	Unit price (VND/kg)	Unit price (USD/kg)
1	Recycled plastic granules PP homopolymer	9,680	0.41
2	Recycled plastic pellets PP copolymer	10,120	0.43
3	Recycled PE plastic pellets	17,800	0.76
4	Black PE recycled plastic pellets	14,000	0.6
5	ABS recycled plastic pellets	25,000 - 60,000	1.07 - 2.56
6	HDPE recycled plastic pellets	11,000	0.47
7	HDPE BLOW MOLD recycled plastic pellets	11,200	0.48
8	Recycled PVC granules	25,000 - 40,000	1.07 - 1.7

~432.4 USD/ton) (Table 6). The above information shows that in the near future, opportunities and potential for the market of recycled plastic products are still very large.[8]

2.3.2. Quality and demand of recycled and virgin resins

The quality disparity between the recycled and virgin resins is notable. During plastic processing, which involves heat and pressure, the plastic undergoes modifications. Heat is essential for liquefying the plastic to mould it, whereas pressure is necessary to shape the liquid consistently. However, the application of heat and pressure strains the molecular structure of plastics. The molecular structure weakens with each processing cycle. Compared with recycled resins, virgin resins typically exhibit a stronger molecular structure and perform better under the correct design and processing conditions.

Despite the superior performance of virgin resins, the primary advantage of recycled resins is their cost-effectiveness. According to the Vietnam Plastics Association, incorporating recycled materials into production at a rate of 35–50% annually can lead to a reduction in production costs of more than 15% for plastic firms. This segment has significant potential for applications in food packaging and PET bottles.

Another critical consideration is material consistency. Achieving consistent material properties with recycled resins is challenging, and only a few manufacturers in North America have successfully reduced material variability. Most pallets made of recycled resins exhibit material variability, making them strong for one day and weak for the next, and vice versa.

8 https://ianfa.vn/bang-bao-gia-hat-nhua-tai-che-moi-nhat-6-2021/

Chapter 3

Mapping of operational activities and potential sources of leakage

3.1 Mechanical recycling processes and potential plastic and pellet leakage

Recycling of post-consumer plastics remains a major potential solution for retaining the value of used plastics for long-term use while reducing the production of virgin plastics. However, recycling-related macro- and microplastic leakages into the marine environment result from unmanaged losses associated with handling of recovered post-consumer recyclable plastic transfer along the recycling process. The recycling of recovered post-consumer plastics involves the transfer of plastics through various stages of the recycling process, during which various operations are performed to process and improve the condition and quality of recycled plastics. The recovered post-consumer plastics undergo pre-processing, processing, and post-processing handling which involve various operations. Throughout the various stages of pre-processing, processing, and post-processing handling, various actors employ diverse processes to advance plastics into the value chain. Of note are the forms and manner by which recovered post-consumer recyclable plastics by informal waste pickers and junkshops may leak back into the environment due to poor handling during recycling. Careful analysis of the operational characteristics and causes of losses is crucial to understand the potential options for the improvement and prevention of plastic losses and leakage from the various phases of the recycling process. Consequently, the losses at each point are influenced by specific factors and deficiencies unique to each stage of the recycling operation. It is important to include indirect activities in the recycling process that contribute to the transfer of plastic across the entire recycling value chain.

> "An efficient recycling of spent polymers should not only ensure an efficient recycling of the carbon. It should also aim at minimizing the consumption of energy and the production of waste over the life cycle of the product. This generally implies to operate through the smallest recycle loop possible. Depending on the quality and purity of the waste, the priority should therefore be given to reuse, then reprocessing (mechanical recycling), then depolymerization to the monomer, then conversion to a hydrocarbon feedstock and, as last resort, energy recovery".
>
> — Lange, J P., 2021

3.1.1 Post consumer plastics pre-processing

The pre-processing steps, depending on the source of the plastic materials, may include storage, sorting, pre-cleaning, compressing, baling to clean grade, sorting, and preparing plastics based on polymer types (and colours) prior to processing. Informal waste workers, junk shops, and aggregators in Hanoi are the main initiators of pre-processing operations that recover post-consumer plastic for recycling. Informal waste workers, scrap dealers, and junk shops, mainly at the base of plastic recovery, carry out pre-processing of plastics to enhance the value of the plastic materials at sale. Pre-processing is also carried out in recycling craft villages to further sort, grade, and clean plastic materials received from multiple suppliers who value their post-consumer recyclable plastic feedstock into the same polymer streams prior to mechanical processing. Owing to the high specialisation of craft villages in Hanoi, the plastic materials received are mostly pre-sorted into similar plastic material streams by aggregators, and sorting is mainly reduced. In addition, recyclable plastic materials purchased from industries for recycling in craft villages often require minimal sorting and cleaning. However, certain processors perform dismantling, sorting, and cleaning before actual processing, although the extent of these activities depends on the condition of the input materials and the desired output. Managing losses during pre-processing is relatively more feasible

compared to the challenges posed by small-sized plastics that may escape during the processing stage.

Typically, the processing stage involves several steps such as flaking, crushing, grinding, additional sorting, washing, drying, and palletization. Although the specific steps may vary among different mechanical recycling processes, they generally include size reduction, in the case of handling across multiple stages. This complexity in the process, along with the use of water for cleaning, increases the risk of loss and leakage of macro- and microplastics. The plastic pellets produced as outputs from the processing stages were further bagged, stored, and transported in the post-processing phase. The assessment results revealed variations in the occurrence and causes of leakage between informal waste pickers and entities such as junk shops, mechanical recyclers, and processors. Issues arise from spillage, loss, and leakage of recycled plastic pellets during bagging, storage, and transport. In the intermediary stages involving small and medium junk shops as well as aggregators engaged in dismantling, baling, sorting, and transportation, there are instances of losses and leakage of both macro- and microplastics. This stems from the inadequate implementation of proper housekeeping practices, which are essential for preventing and containing losses and leakage.

3.1.2 Losses from temporary storage, dismantling operations

These losses may occur at various stages of the recovery, handling, and processing of the reverse logistics operations, although with varying degrees of likelihood. In terms of the characteristics of losses and leakage from pre-processing, informal waste workers, scrap dealers, and small and medium junkshops, there is a high likelihood of macro- and microplastic scraps and low-value plastic leakage due to dismantling, mishandling, or illegal disposal of rejected plastics. Poor storage conditions and transportation of collected plastics are also potential sources of loss. Poor storage conditions are characterised by heaps of post-consumer plastic unclosed spaces near drains, floodplains, and watercourses with high risks of loss to the environment. Although unintentional, the incidence of losses and leakages can be mitigated through effective preventive measures, particularly in the context of storage-related issues. In the absence of appropriate measures, factors such as floods and wind can exacerbate these losses, leading to environmental ramifications. Implementing proactive strategies to enhance storage conditions is essential for curbing the inadvertent release of materials and preventing adverse environmental impacts. Some large junkshops and consolidators carry out volume reduction by pressing and bailing before selling off takers. Pressing and bailing processes are generally less risky sources of plastic scrap leakage compared to other processes such as sizing, shredding, grinding, and washing.

3.1.3 On site and off-site sorting

Offsite pre-sorting is carried out by informal waste pickers who rummage through their collected recyclable materials to separate and eliminate low value, non-recyclable materials prior to selling to junkshops. The effectiveness of offsite sorting largely depends on the knowledge of the waste picker about the in-demand recyclable polymer, and their access to the buyers who accept these types of plastics. Commonly observed are the challenges of proper handling and disposal of rejected or non-recyclable or low-value plastic materials by informal waste pickers— illegal dumping is a widespread practice. In recycling craft villages and facilities (onsite), manual and semi-mechanized sorting process involves manual handpicking of visually identifiable high-value recyclable plastic as it moves on a conveyor belt. Predominantly female workers conduct manual sorting in designated areas within the facility, a method known for its effectiveness despite being time-consuming and challenging, especially in confined spaces. Space limitations and speculative inventory decisions may affect sorting quantity and categorization. However, sorting plastics into distinct quality streams, polymer types, and colours adds value and meets recycling plant specifications. Sorted plastics, aligned with off-taker demands, may enhance sales value and increase profit. Residual waste generated during sorting varies based on each facility's business orientation, client demands, and processing capacity. It includes rejected fractions like specific plastic films, non-recyclable polymers, and coloured packaging. While sorting poses a low risk of plastic loss, proper handling, and disposal of rejected

fractions are crucial to minimize environmental impact.

3.1.5 Grinding, shredding/flaking, washing and drying

Various plastic polymers are recycled into recyclates of various quality grades by mechanical recycling plant craft villages. These recyclers gather post-consumer plastics from local dealers and conduct primary sorting into monopolymer streams and colours and subsequently shred or ground them into flakes or shreds for washing and drying. The resulting flakes and shreds are exported to neighbouring countries like Vietnam and Thailand as high-value secondary raw materials. Quality control ensures low contamination of flakes, which are used in various products such as clothing, automobile seat covers, and household items. Various handling processes during shredding and washing contribute to the loss of plastic materials into the environment. Integrated shredding and washing units may help reduce the risk of plastic material release during handling; however, they may not be suitable for all production configurations. Plastic material loss occurs during the loading, grinding, and discharging of shredded plastics and flakes. Dust release is common in open grinder designs, especially in old models, contributing to airborne plastic particles settling on the surrounding equipment and surfaces. The inhalation of these particles poses a risk to workers, particularly in facilities with poor ventilation. Investment in dust capture and filtering devices is crucial for mitigating this hazard, although it may incur additional costs for recycling facilities.

3.1.6 Melting, extruding, pelletising or granulating, and moulding

Plastic pelletising is a vital step in recycling as it transforms sorted plastic flakes into pellets suitable for manufacturing. This process typically involves the melting and compounding of clean flakes using extruders. In Hanoi, strands and underwater pelletisers are commonly used, and some recyclers incorporate a second extrusion stage to remove impurities. Despite efforts to minimise heat loss using insulation sleeves, extruder environments remain warm. Plastic losses occur at various stages including hopper loading, extrusion, cutting, startup cleaning, and downtime. In addition, microplastic

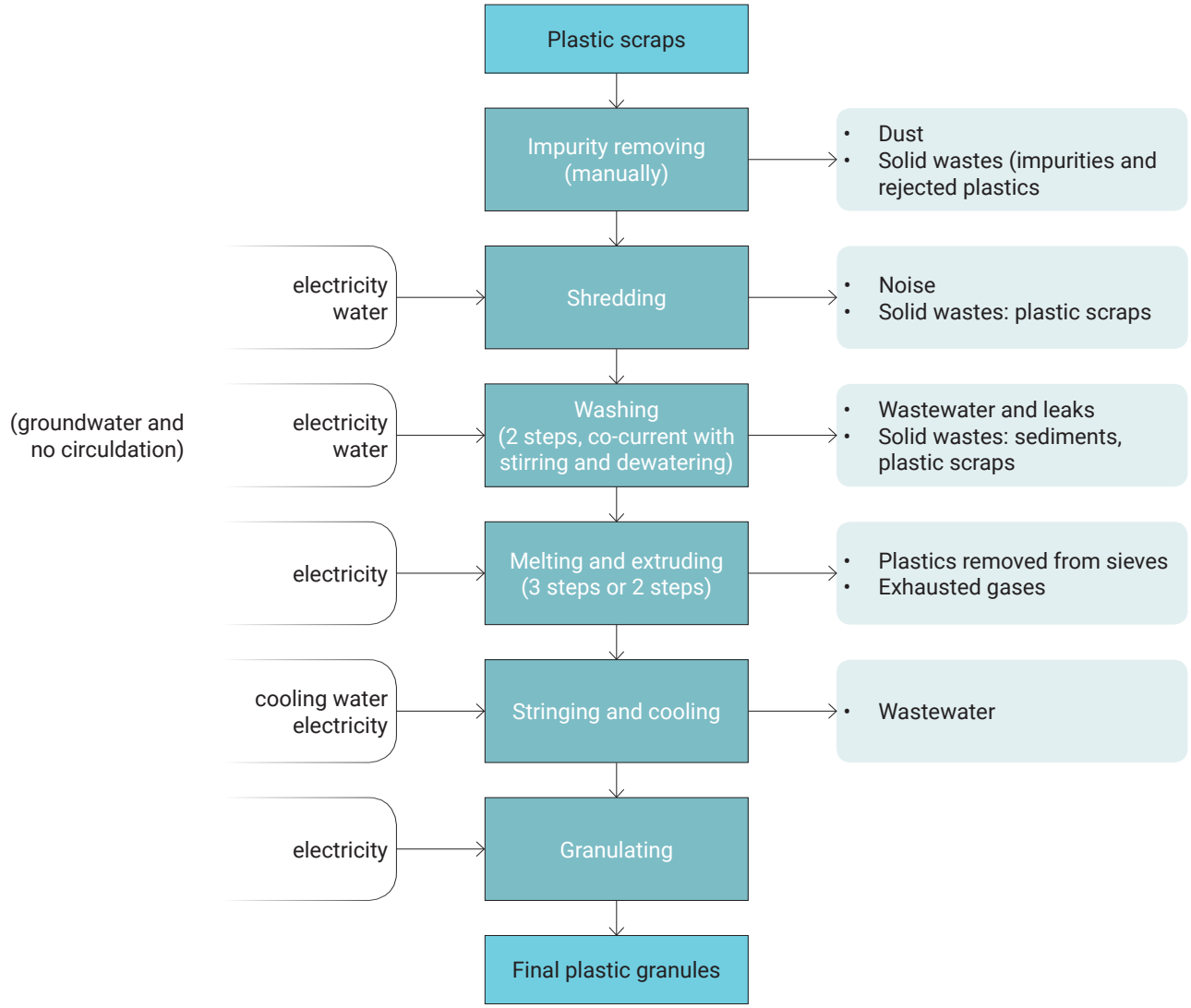
particles may be present in cooling water baths. Careful handling and efficient extrusion are essential to address these challenges. Plastic losses include extrusion lumps, pellet losses, startup cleaning waste, and rejected extrudates. Mitigation measures include optimising the extrusion process, enhancing cutting techniques, and effectively managing extrudate rejection. The regular maintenance of cooling water baths is crucial for preventing the accumulation of microplastic particles. These measures collectively contribute to improving the efficiency and sustainability of the pelletising process, thereby ensuring an effective plastic recycling system.

3.1.7 Waste management in recycling facilities

Solid waste

Various types of waste produced in recycling facilities must be properly managed and disposed according to relevant regulations. In addition to general and organic wastes, recycling facilities produce electronic waste (WEEE), which is obtained from multicomponent plastic product separation. Recycling facilities must be properly equipped with multiple disposal bin systems with adequate training provided to workers to effectively segregate and dispose of waste. Electronic and hazardous

Figure 7. Plastic waste recycling process in craft villages in Hanoi and potential for plastic leakage at each production stage



materials must be separated, properly handled, and disposed of according to regulatory provisions. General waste, rejected plastics, organic waste from leftover food, yard waste, and sludge must be properly segregated and disposed.

Waste water

Wastewater, which predominantly originates from material-washing processes, is a significant byproduct of mechanical recycling. Flake washing is a major contributor to the substantial volume of waste generated. Owing to the presence of considerable amounts of microplastics, the management of wash wastewater is imperative. Both informal and formal recycling facilities are tasked with the treatment and management of large volumes of wastewater in compliance with existing regulations and standards. Effective treatment and management protocols are essential for mitigating the potential environmental hazards associated with the discharge of microplastics into water bodies or drains. Therefore, recycling facilities must implement appropriate wastewater treatment measures to ensure that the discharged water meets regulatory requirements and poses minimal risks to the environment and public health. Responsible handling and treatment of wastewater in the recycling industry is imperative.

Air pollution

Managing air quality is a critical aspect of recycling facility waste management to ensure worker and environmental health. In addition to mitigating plastic waste dust from shredding and grinding, maintaining the ambient air quality is essential. The extrusion compounding pelletising process involves melting plastic flakes and emitting various pollutants such as CO, NOx, SOx, odours, and hydrocarbons from incomplete combustion. Additionally, filter combustion can produce soot, smoke, CO, methane, volatile organic compounds, polycyclic aromatic hydrocarbons, and heavy metals such as lead and mercury. Unintentionally generated pollutants such as polychlorinated dibenzodioxins and furans or polychlorinated biphenyls can also emerge from filter burning. Intentional waste burning is strictly discouraged owing to the release of persistent pollutants such as mercury and dioxins, which pose risks even when deposited far from their source.

3.2 Case example insights from practices in craft villages

In general, Vietnam's plastic recycling industry is limited and does not meet demand. The MONRE stated that, thus far, the rate of sorting plastic waste at the source is very low, mainly based on the force of scrap collection and some SWT facilities that separate plastic from solid waste. Currently, plastic recycling facilities are all small-scale, have outdated rudimentary recycling technologies, and have insufficient financial capacity to improve and upgrade the recycling process to meet the actual waste generation trend. Thus, the recycling efficiency is low, the product quality is not consistent, and leads to pollution of air, water, and soil environments. Vietnam must still import up to 80% of its raw materials for production. The total amount of plastic scrap purchased each year is only approximately 10% of the total residual plastic waste because the plastic recycling market in Vietnam has not yet been developed.

Due to environmental and labour concerns, many countries restrict plastic imports. For example, in Vietnam, over half of imported plastic goes to informal craft villages[9], where it is handled on a small scale, often resulting in significant waste. Approximately 25–30% of this plastic is discarded, with 7 million litres of washing effluent discharged daily without proper treatment. Washing and melting processes consume excessive water and energy and emit smoke. Approximately 20% of plastic becomes worthless and is either dumped or burned, contributing to rubbish accumulation and air pollution. Untreated water containing detergent residues is discharged into waterways, whereas burning plastic releases harmful pollutants such as dioxins and furans. Workers in these facilities face hazardous conditions due to inadequate protective equipment. Overall, the local air and water pollution stems primarily from the manufacturing activities of these recycling facilities..

3.2.1 Case study—Village A

Village A specialises in recycling post-consumer plastic waste through shredding, crushing, and

9 https://theconversation.com/heres-what-happens-to-our-plastic-recycling-when-it-goes-offshore-110356

melting, which causes significant pollution and health issues for residents and the surrounding area. Most recycling facilities use manual methods, where plastic waste is mixed into large bags and scattered throughout the factory. This process involves simple washing, shredding, and drying and transportation to other facilities. A polluted environment can lead to infectious diseases and water contamination.

Figure 8. Percentage of types of plastic collected (a) and households participating (b) in the collection and recycling sector in Village A

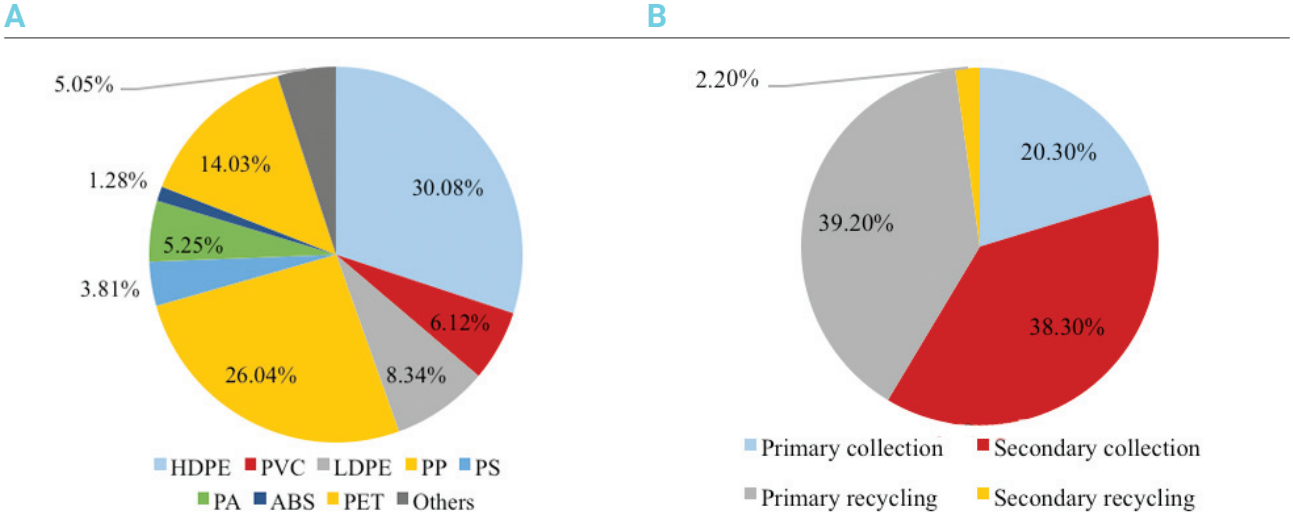
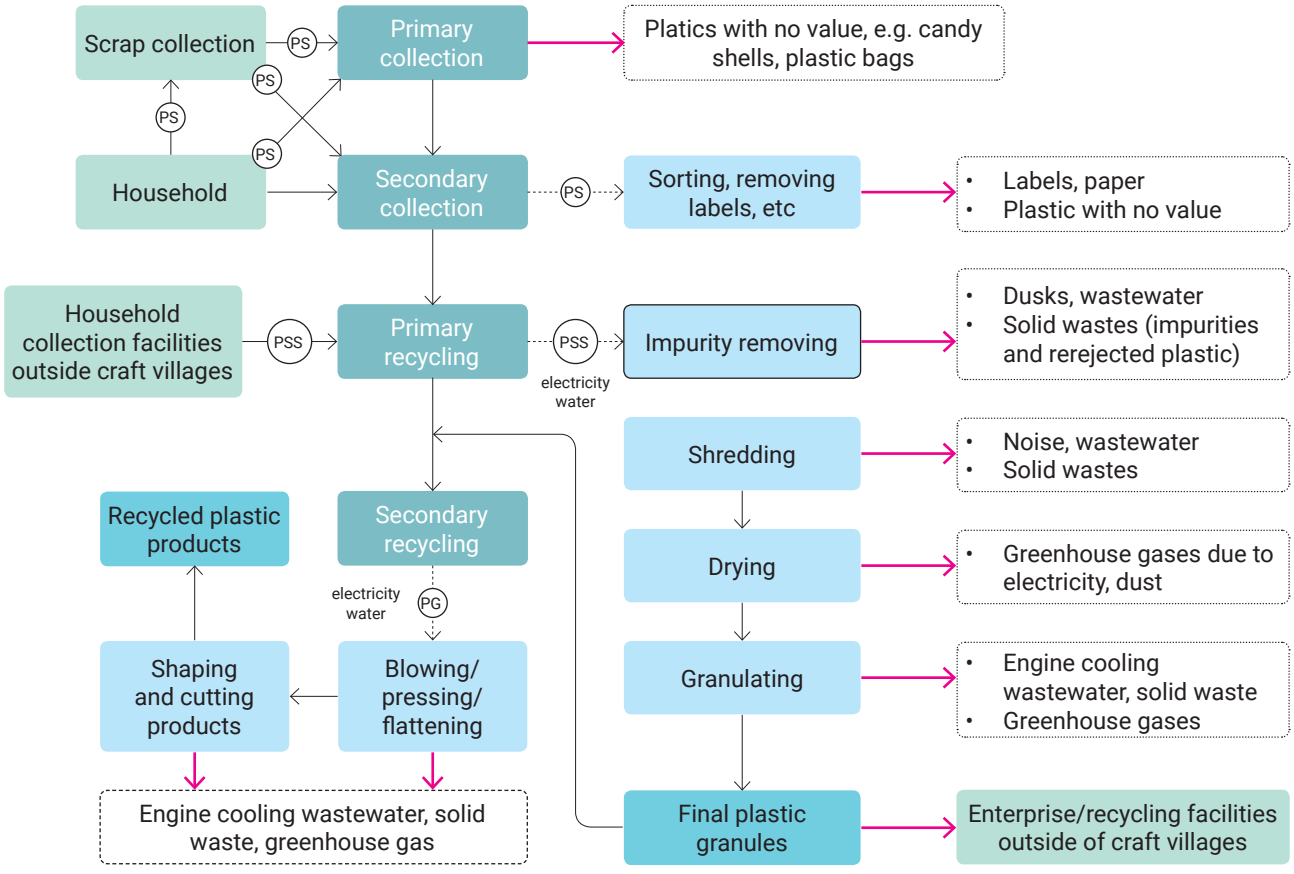


Figure 9. Characteristics of recycling process flow and emissions in case study Village A



Notes: ⇢ Process of each stage; → Plastic leakage potential
PS = Plastic scrap; PSS = Plastic scrap after sorting; PG = Plastic granules

Despite the solid construction of sewers, the village still suffers from foul odours owing to the large volume of untreated wastewater discharged directly into the sewer system from both production and household activities. The survey results show that the average amount of plastic collected and recycled in Village A in 2020 was 174 tons/day. Most of the plastic scraps collected and recycled are commonly used plastics such as HDPE, PET, LDPE, PP, PVC, and PS. The amount of HDPE collected is 52.34 tonnes, accounting for 30.08%, followed by PP plastic at 45.31 tonnes and accounting for 26.04%, PET plastic at 24.41 tonnes and accounting for 14.03%, LDPE plastic at 14.51 tonnes and accounting for 8.34%, and PVC at 10.65 tonnes and accounting for 6.12%. Other plastics such as PS, polyamide (PA), and ABS made up a negligible percentage (see Figure 8).

Currently, 222 families (households) in Village A participate in the plastic collection and recycling sectors, a considerable increase since 2014. There are four main types of plastic-related activities in this craft village: Primary collection, secondary collection, primary recycling, and secondary recycling (Figure 8). Primary plastic recycling is prevalent (39,2%), followed by secondary collection, accounting for 38.3%. Primary recycling accounted for 20.3%, whereas very few households participated in secondary recycling (2.2%).

The plastic collection and recycling activities in craft village A formed a chain of production and supply of recycled plastic for the local and surrounding areas (Figure 9):

- Primary collection includes facilities that only collect plastic from households and small scrap collectors, and then resell scrap plastic to other businesses without sorting the plastics or removing labels.
- Secondary collection includes households and facilities that collect scraps from primary collection facilities in craft villages and other areas of the city. They then sort the plastic scrap and resell the sorted plastics to other business establishments.
- Primary recycling includes production households that collect waste from secondary collectors in craft villages and from other establishments in the city. Plastic products are sold to other establishments responsible for processing and forming other products such as plastic bags and chairs.
- Secondary recycling includes households that produce recycled plastic products using available technologies, which often generate engine-cooling wastewater, solid waste, and greenhouse gases. The end products were fully recycled plastic products, including plastic bags, chairs, plastic tables, and cups.

Research shows that solid waste, which arises from four types of collection and recycling, ranges from 18 to 104 kg/ton of finished products of each type. Primary collection (Type 1) and secondary collection levels (Type 2) generate less solid waste than the other two types generate. The main component of solid waste is dirt that adheres to scrap plastic, plastic shells, packaging covers, and stickers. Primary and secondary collections only collect scrap. Primary and secondary recycling generate wastewater and greenhouse gases, of which primary recycling (type 3) generates 137 kg of CO2e/ton of plastic waste and secondary recycling (type 4) generates 387.67 kg of CO2e/ton of plastic products.

3.2.2 Case study—Village B

On the one hand, plastic waste recycling has improved the lives of thousands of people in the suburban area of Village B in Hanoi. On the other hand, it has significantly caused plastic pollution to the environment and HAS affected people's health.

Figure 10. A small area where plastic waste is collected and sorted in Village B (Source: Internet)

Black incense was used as a craft in Village B. Many households in the area collect and dispose of plastic waste because of the incense industry's erratic income.

Households in Village B used anything made of plastic, including water pipes, roofing sheets, cans, barrels, pots, bottles, automobile or motorcycle frames, and tiny plastic caps. They were then gathered, categorised, and recycled. Every day, more than 100 households collect and process nearly 70 tons of scrap from neighbouring provinces (according to 2018 data), most of which comes from Hanoi. Plastic waste is diverse in type but mostly consists of soft drink and mineral water bottles. On average, households can earn 3 million to 10 million VND by selling plastic scrap. However, to reduce transportation costs, non-recyclable items are illegally dumped along highways or burned, which has a significant negative impact on residents' quality of life owing to the smell of burning plastic. People are affected daily by the constant sounds of plastic crushers. Hundreds of households live in a severely polluted environment with hundreds of tonnes of waste around the commune.

3.2.3 Case study —Commune C

Tien Commune C is well known for washing sacks and producing recycled plastic granules. Currently, none of the 47 households working in communes have an environmental impact assessment report certified by the competent authority and have no commitment or plan to protect the environment; 100% of the facilities do not have permits but discharge wastewater, thereby causing heavy pollution.

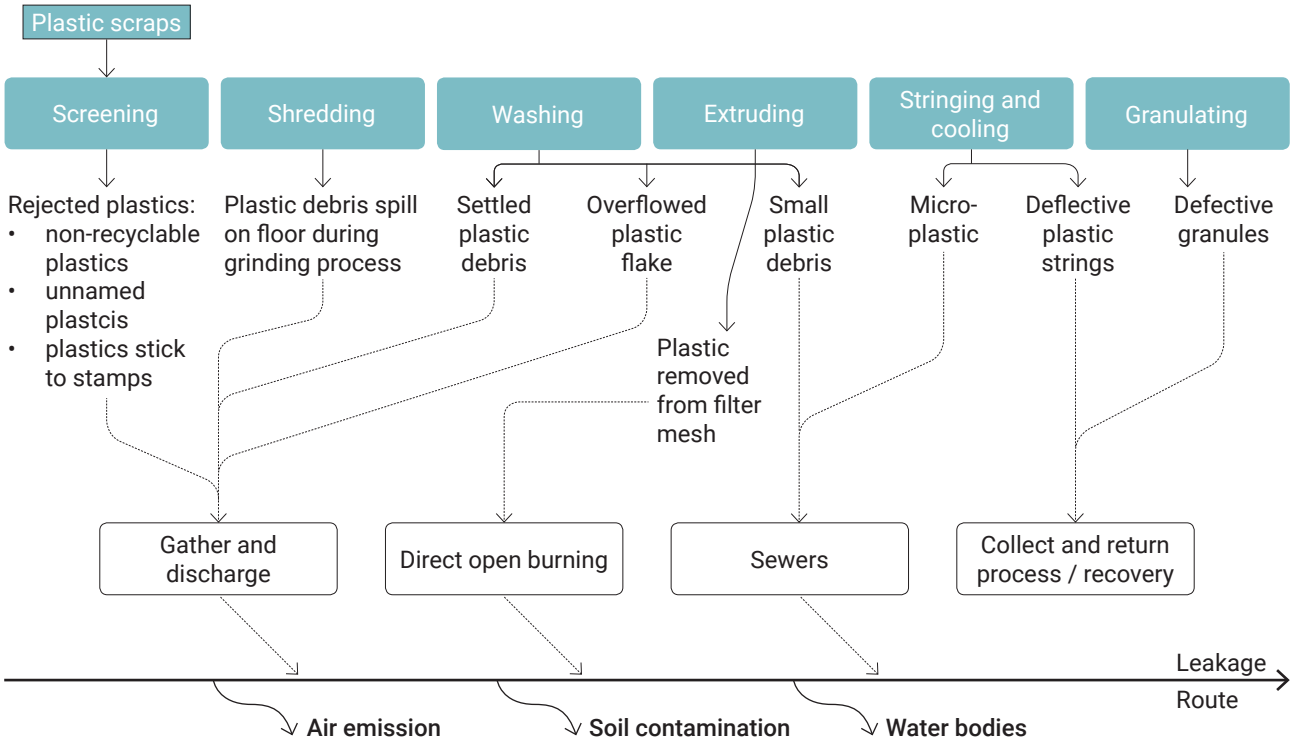
For many years, people in Commune C of Hanoi have had to live with environmental pollution caused by several plastic manufacturers (Figure 11). These spontaneous plastic production facilities have operated day and night for many years and have been carelessly releasing smoke and wastewater into the environment. This has caused noise, air, and serious water pollution that are harmful to human health. Production facilities buy cement bags at a purchase price of 1,000–1,200 VND/bag and then process cement bags and polyester sacks. In the sorting stage, the cement paper was preliminarily pressed into the paperboard, whereas the polyester sack was placed in a washing machine. Each facility must drill at least 1–2 wells to provide sufficient water for production. The workers then pump water directly into the rotating machine (loading the washing machine). Common output products were bundles of 100 washed sacks, and the volume of the dry finished product was 10 kg, costing approximately 125,000 VND.

3.3 Factors contributing to plastic recycling losses and leakage

In Hanoi, Vietnam, technological adoption in the recycling and waste management sector are at a low-grade of advancement. Waste management and sorting rely predominantly on manual labour from the informal sector, which collects, sorts, and transports recyclable feedstock down the value chain.

Figure 11. Photograph of the inside of a plastic recycling facility in Commune C

Figure 12. The pathway of plastic leakage to environment along the production processes



All recyclers (informal and formal) apply conventional mechanical recycling technologies. Furthermore, plastic processing facilities are poorly monitored and use outdated infrastructure, which can be a public health hazard for employees and nearby community members (Yeoh, 2020). Plastic waste related to manufacturing and recycling activities may leak into the environment due to the following factors.

Outdated and manual recycling machines and technologies result in low efficiency, leading to ineffective material conversion, a high rate of defective products, and increased emissions of gases and dust.

Existing recycling technologies in craft villages are traditional and obsolete; therefore, they generate large volumes of waste, including solid waste, in the form of discarded plastics, sediments, and other solid waste, wastewater, and energy loss. The scope of this section focuses on plastic waste leaks during recycling steps owing to technological factors in craft villages. In Hanoi's plastic craft recycling villages, wet technology is mainly applicable. In contrast, plastic scraps are mechanically recycled into plastic flakes (in the case of primary recycling), plastic granules, and recycled products (secondary recycling). Figure 12 shows the pathway of plastic leakage into the environment during production.

Detailed descriptions of these leakages are provided in Table 4.

Mismanaged discarded plastic wastes

Open burning at dumpsites, indiscriminate discharge of discarded plastic on roads, and vacant lots surrounding the living environment. There are no official data on illegal dumpsites in Hanoi; however, in practice, there are many small- and medium-sized dumpsites, especially along the rivers running around Hanoi.

Bad quality of input materials (low ratio of recyclable plastic scrap) in the plastic recycling industry

Plastic scrap was purchased domestically or imported and used as a material input for plastic recycling facilities. The rate of discard from plastic scrap classifications ranges from 1–25%, depending on the plastic quality and source.

Table 4. List of plastic leakage pathways during the plastic recycling processes

No.	Step	Current situation	Plastic losses and leakage pathway
1	Sorting	Manual sorting lacks specific guidelines for identifying categories for segregation.	Depending on material quality, 10-25% of plastics are rejected during sorting as they are unrecyclable, unwanted, or difficult to process. These rejected plastics are temporarily stored on-site until there is no more space, then illegally disposed of in vacant lands or open dumpsites through burning.Top of Form
2	Shredding	Insufficient lubrication maintenance results in increased noise levels. Lack of a cover causes plastic flakes to spill out.	The shredding machines in plastic craft villages, typically sourced from China or Taiwan, are antiquated and of low quality. Plastics are manually fed into the machines, resulting in material blockages. Additionally, the lack of covers on the shredding machines allows plastic debris and particles to escape into the ambient air.
3	Washing	The floating washer, constructed from cement with a flat bottom, complicates cleaning. The conveying blade fails to collect small materials entirely. There is excessive water spillage from the washing tank.	Uncollected plastic materials will then have discharged together with wastewater to the sewer system. The water spills out also bring plastic floating debris. Then, normally it will be pushed along with the water when cleaning the floor to drainage system
4	Extruding	Intermittent extruding, 2 or 3 steps High residues in metal sieves	Molded plastics with impurities on the filter sieve will be burned to recover the sieve for the next batch (Figure 12)
5	Stringing & cooling	High water consumption is observed in the process, where hot water from the string formation step is discharged directly into the environment without undergoing reuse or circulation	The immediate cooling of newly formed plastic strings with clean water may result in the release of nano/ micro-plastics into the cooling water. Subsequently, this cooling water containing plastic particles is discharged into the sewer.Top of Form
6	Granulating	A cutter located at outcome of plastic strings	Defective granules which have a different size compared to the standard size

Figure 13. Practical use of filter mesh at plastic recycling household in craft village

Burning to remove plastics on filter mesh

Figure 14. Disposals of rejected plastic on (a) roadside and (b) drainage channel

3.3.1 Systematic factors contributing to plastic loss and leakage

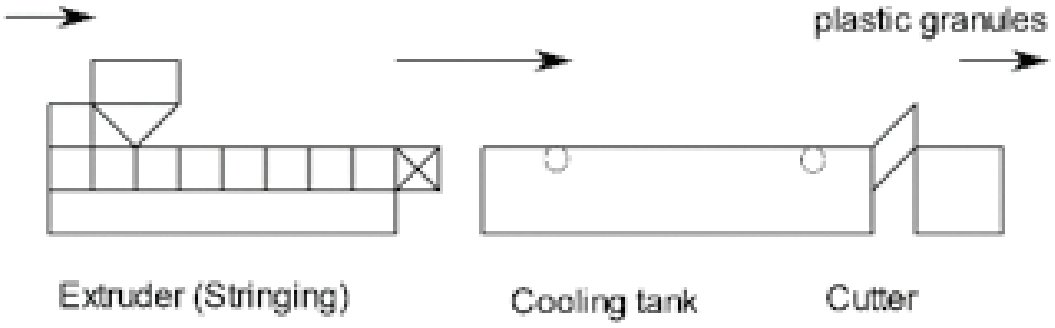
- Most informal recyclers are small- to medium-sized, scattered, and lack adequate infrastructure.
- Recycling activities often occur in sites without environmental or labour security standards.
- Waste collection, transportation, and disposal processes suffer from low quality and efficiency.
- Improving plastic waste management services can significantly reduce plastic waste leakage into the marine environment.
- Low-quality recyclables result from the absence of design-for-recycling standards.

The plastic material contamination rate can reach 30% of the feedstock, impacting the volume and price yields owing to inadequate source segregation and design-for-recycling flaws. Examples include PET, PP, and HDPE products with subpar recycling standards

3.4 Examples of applicable plastic recycling granulation technologies for craft villages in Hanoi

Three prevalent types of plastic recycling granulation technologies are currently available in the market and can be implemented in the craft villages of Hanoi[10]: Dry granulation technology, two-stage wet granulation technology, and three-stage wet granulation technology (Figures 15–17). Detail description of the mechanical recycling described in Annex 1.

Figure 15. Dry granulation technology diagram



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Hanoi, Vietnam

3.4.1 Dry granulation technology

The dry granulation technology (Figure 15) is applied when the input material is clean, dry, and does not contain impurities. The recycled plastic material is fed to the extruder to make plastic strings without a washing stage. The screw of the extruder is made of an anti-corrosive alloy which prevents the plastic liquid from sticking to the screw and barrel (with or without the air extraction system); the barrel is heated using a resistance heater or induction heating technology to melt the plastic. The plastic strings come out from the extruder and go through a water tank for cooling, and finally to the cutter to form plastic granules. This technology does not require significant equipment; therefore, the processes of installation, operation, and maintenance are very simple. This technology also does not consume much energy and releases little emissions, noise, and solid waste into the environment. Moreover, especially no wastewater is generated.[11]

3.4.2 Two-stage wet granulation technology

Two-stage wet granulation technology is applied when the material source (scrap plastic) is mixed with impurities, most of which can be easily removed during material segregation. The production process for two-level wet granulation technology is shown in Figure 16. This technology requires more equipment than the dry granulation technology requires. After sorting, the raw materials are placed in a shredder to reduce their size and then cleaned in a washing tank to remove all impurities. The pre-drying process is performed naturally or forced using a centrifugal water extractor. Finally, it is fed into a two-stage extruder, cut, and cooled to produce recycled plastic granules. This technology is more complex and costly than dry granulation technology is in terms of installation, operation, and maintenance. With an extra clean stage, this technology consumes more water and generates more wastewater, solid waste, emissions, and noise than dry granulation technology generates.

3.4.3 Three- stage wet granulation technology

The three-stage wet granulation technology is applied when the material source (scrap plastic) contains impurities that cannot be easily separated in the material segregation stage and are removed in the granulation stage.

In general, the process is the same as that of the two-stage wet granulation technology. However, three-stage wet granulation technology requires an additional extrusion stage to remove impurities that are unable to be removed in the material segregation

Figure 16. Recycling plastic production by using two-stage wet granulation technology[11]

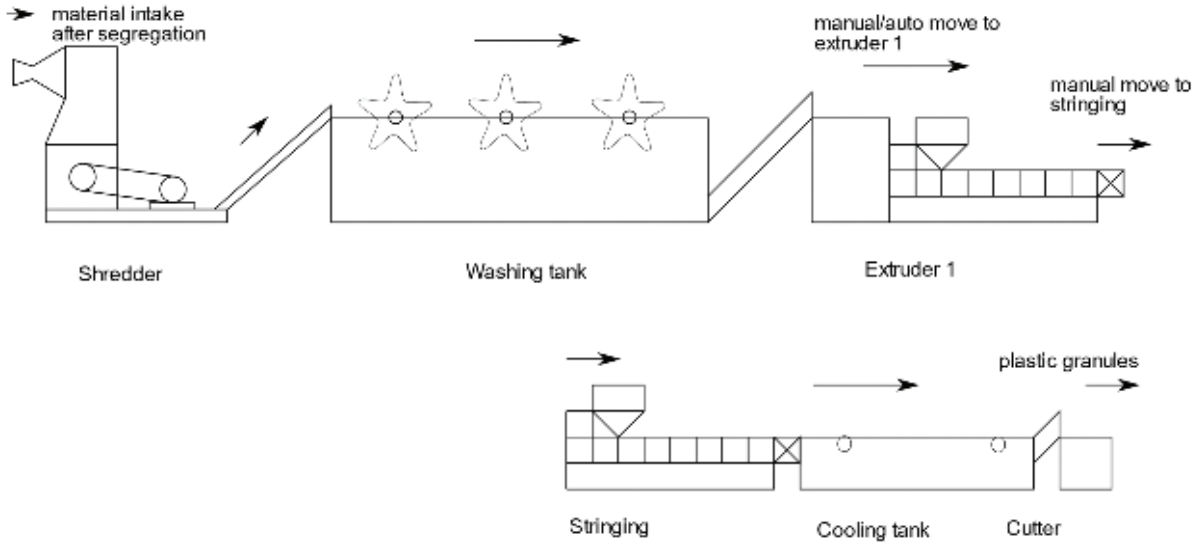

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Figure 17. Recycling plastic production by using two-stage wet granulation technology[12]

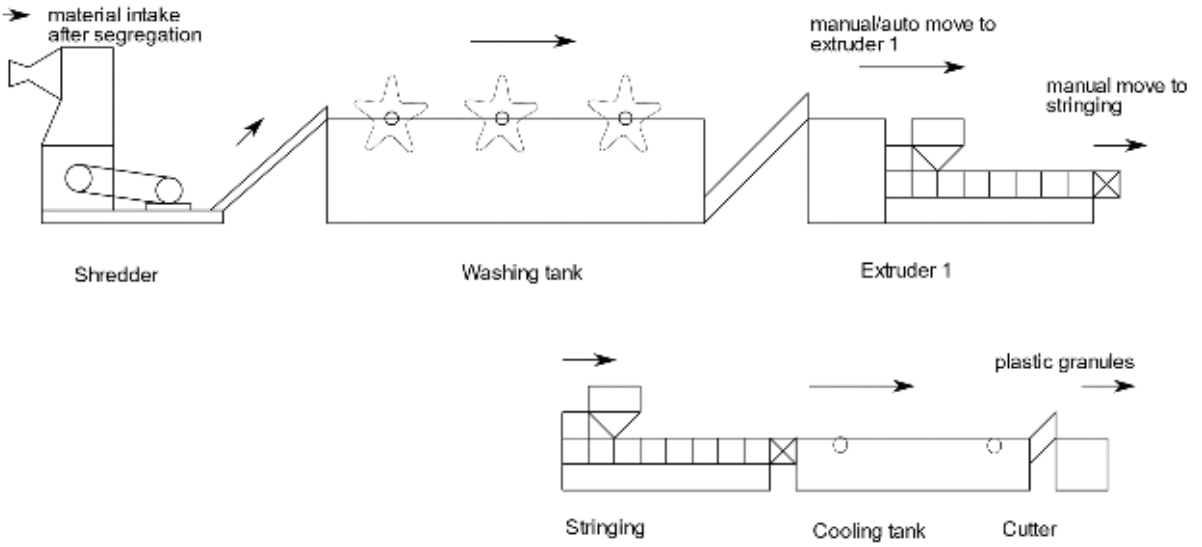
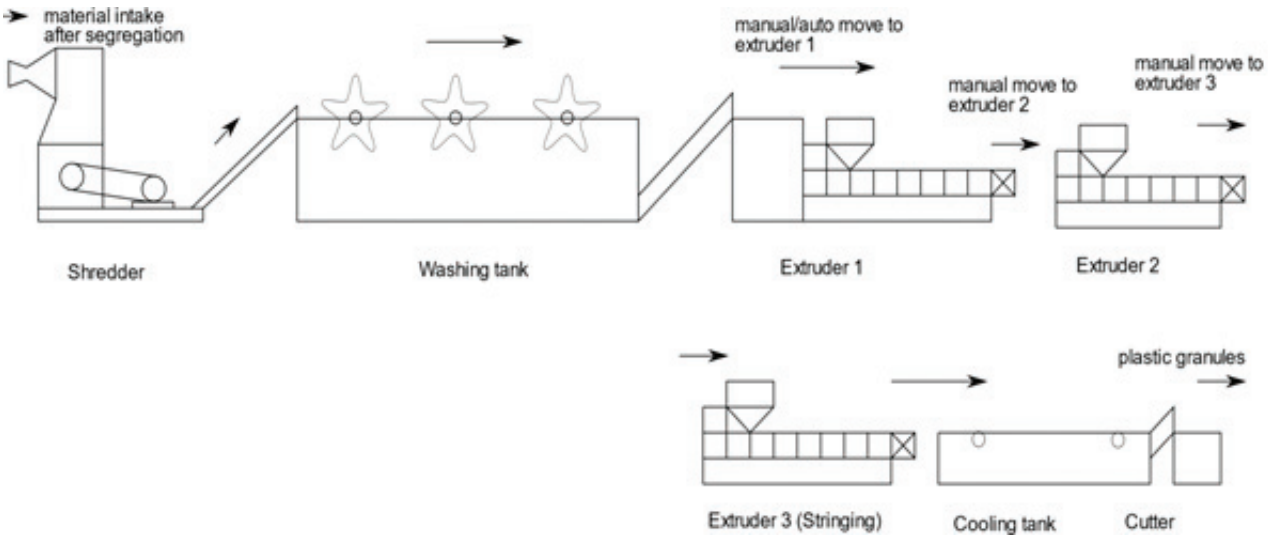


Figure 18. Recycling plastic production by using three-stage wet granulation technology[13]



stage, or because this stage is too complex and inefficient. This technology is more complex and costly than the two-grade wet granulation technology in terms of installing, operating, and maintaining machines and equipment, and it consumes more electricity than the three-stage wet granulation technology consumes because it requires an additional extruder. Hence, the system generate more solid waste, emissions, and noise that the other systems generate.

The assessment and selection of plastic recycling technologies were based on the following basic criteria:

- Relevance to local practical conditions (weight, composition, and properties of scrap plastics).
- Economic criteria: total initial investment, loss rate, product quality, manpower, price of material, electricity consumption, water consumption, and profit.
- Technical criteria: easy to install, maintain, replace, and operate.

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- Environmental criteria: generation of wastewater, emissions, solid waste, and noise.

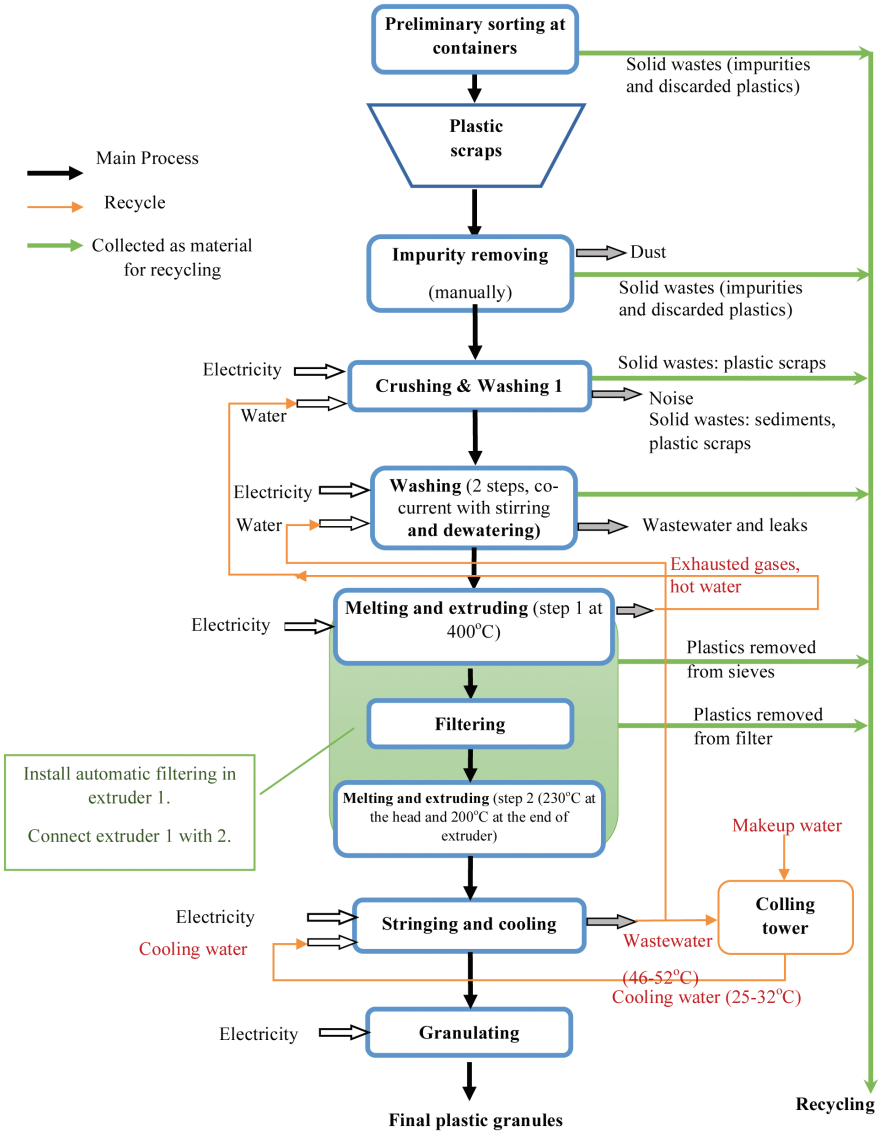
3.5 Best available technologies

The potential technologies for plastic waste management vary depending on many factors associated with the broad waste management system and the characteristics of plastic waste. This study focused on the best available technologies (BAT) for plastic waste recycling in Hanoi.

3.5.1 Mechanical recycling

Recyclable plastic waste and scraps in Hanoi are mechanically recycled by small- and medium-sized recycling facilities located in local craft villages. From a resource efficiency perspective, material recycling is an optimal method for managing and reclaiming plastic waste. Nonetheless, the effectiveness depends on criteria such as scale, input material quality, process quality, and purity. It is generally recommended that improved plastic material recycling be prioritised over landfill. Examples of BAT/best environmental practice (BEP) solutions

Figure 19. Diagram for major proposed BAT/BEP options for plastic recycling process

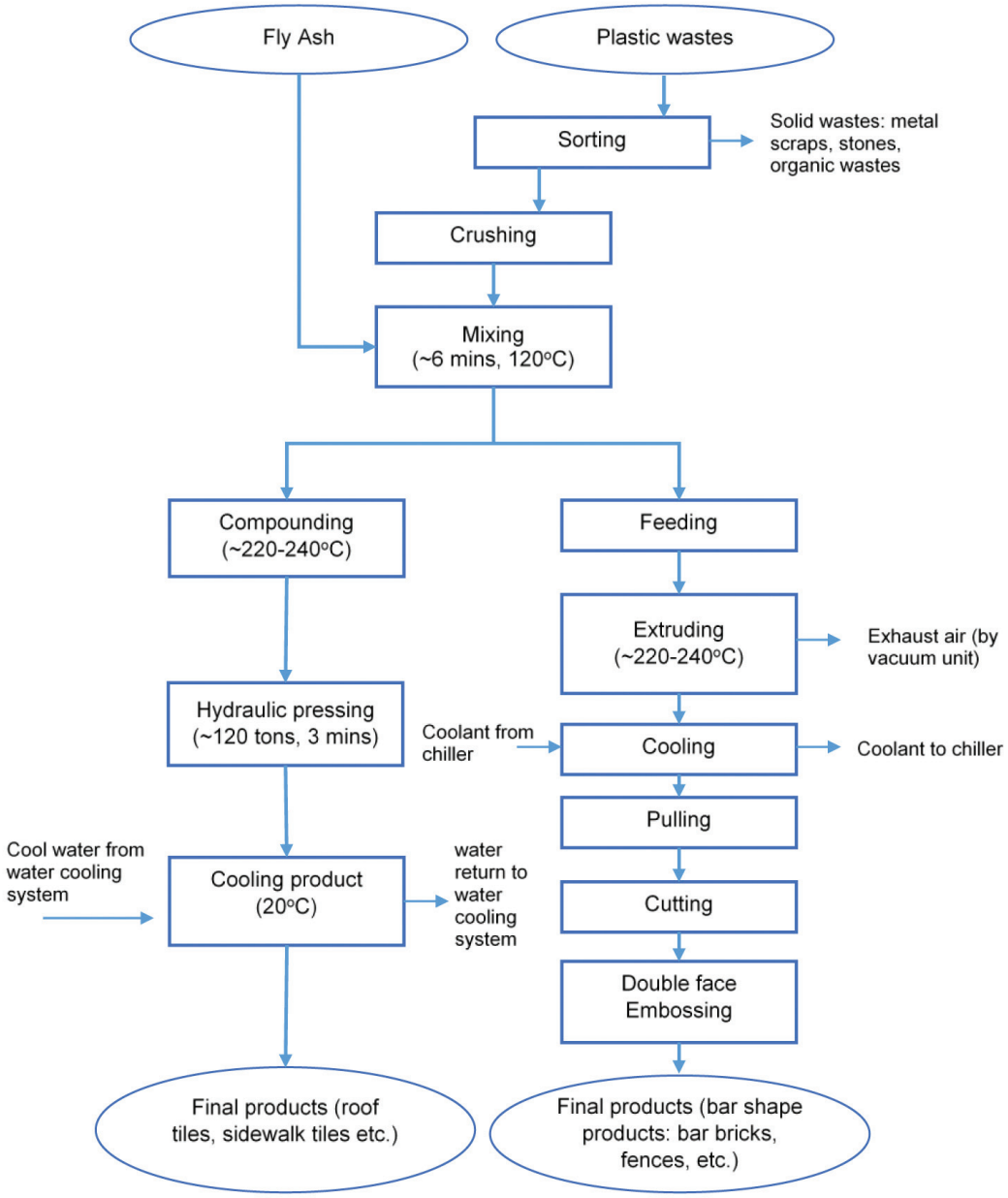


along with existing mechanical plastic recycling are presented in Figure 19.

3.5.2 Converting discarded plastics and wastes into construction materials

In principle, discarded plastics and waste can be recycled to manufacture various useful products, such as pallets, bricks, tiles, and road pavements. This solution is versatile, as it can accommodate different types of waste materials, such as plastics, sand, and wood, thereby reducing the need for extensive sorting. Moreover, this technology offers numerous advantages such as being sustainable, environmentally friendly, and circular. This process involves mixing discarded plastic and waste with additives and filling materials to form compounds. Depending on the desired product, the compound is processed using hydraulic pressing or extrusion machines to produce semi-finished goods that

Figure 20. Principle diagram of recycling process for discarded plastics and wastes from craft village[13]



13 UNIDO's project on BAT/BEP application for plastic recycling craft villages in Minh Khai and Phan Boi, Vietnam

undergo further post-processing steps to achieve the final product. An illustration of this is shown in figure 20.

The process of manufacturing recycled products from waste plastic is described as the following:

- Sorting: Plastic waste is manually sorted to eliminate metals, stones, and organic matter.
- Crushing or shredding: Input materials (plastic waste) are fed into a shredder to create small pieces to improve the efficiency of the mixing and extrusion processes.
- Mixing: After being shredded, waste plastic is added with fly ash at the ratio of 60% of plastic waste and 40% of fly ash and put into the mixer to mix well over a duration of approximately 6 min at a temperature of 120°.
- Extrusion or hydraulic pressing technologies can be applied depending on the characteristics and shape of the product. Extrusion technology is applied to simple bar-shaped products such as bar bricks and fences, whereas products with complex shapes, such as roof tiles and sidewalk tiles, are produced using hydraulic pressing technology with shaped moulds. The core processes of these two technologies include melting, moulding, and cooling.

From a perspective of resource efficiency - extracting the highest value out of plastic waste - material recycling is the most favorable option, followed by energy recovery and sanitary landfill. Any technological option for recovering value from plastic waste can only operate if synchronized with the collection system. In general, the higher the value of the recycling as output material, the higher the requirements on the input material. Certain key findings need to be taken into consideration when assessing the suitability for any technology to manage plastic waste in Hanoi:

Dependence on available input material: Whichever technology is applied should depend on the nature of the input material (i.e., the waste composition). The better the segregation, the more possibilities for subsequent treatment steps. Therefore, technologies directly rely on adequate practices of collection and separation.

Pre-treatment requirements: Due to the usual variety of waste composition, including a variety of different plastic fractions, certain treatment and pre-treatment steps need to be combined to realize an operationally and economically feasible model.

Minimum critical scale: All recycling processes are highly scale dependent (i.e., they need to be operated with a minimum input to have potential income exceeding the operational costs). This, again, refers to access of the correct input material and a more sophisticated mode of recycling.

Given the above-outlined challenges concerning technology uptake for plastic waste in city contexts, any action to mitigate the adverse effects of plastic waste requires concerted action across the waste value chain, beyond just technologies alone.

Chapter 4

Policy and Institutional Aspects

4.1 Legal and regulatory frameworks and subordinate laws

In Vietnam, foundational legal frameworks have been established to manage plastic waste within the broad context of municipal solid waste, although institutional arrangements sometimes exhibit regulatory overlaps and gaps. However, in recent years, the national government has intensified efforts to address plastic pollution by introducing various policies and regulations, particularly those focusing on plastic scrap import regulations and taxes, to discourage the use of nonbiodegradable plastic bags.

Vietnam's legislative landscape consists of three main levels: National Laws, regulatory instruments issued by the national government, and regulatory instruments issued by ministries and provincial governments. Annexure 1 provides an overview of key legal documents pertaining to plastic waste management and recycling. Hanoi aligns its plastic waste management and recycling efforts with the national legal and regulatory framework by integrating environmental pollution control activities related to plastic products into its environmental protection and solid waste management plans.

The city implemented a comprehensive plan, schedule, and strategy to combat environmental pollution in craft villages by 2025, with a vision extending to 2030. Hanoi aims to ensure that all officially recognised handicraft villages meet the environmental protection criteria by 2025. Moreover, beyond 2025, manufacturing facilities will be relocated from craft villages to concentrated industrial zones, clusters, and specific production areas. Strategic investments in essential infrastructure are targeted to support the functioning and growth of industrial clusters, with the primary goal of promoting adherence to the environmental protection standards outlined in the Environmental Protection Law. Hanoi also introduced various directives and decisions at the local level to enhance the management and recycling of plastic waste, with specific details provided in Table 5.

4.2 Institutional arrangements

- At both national and local levels, there is no central agency specifically responsible for managing plastic waste; instead, it is typically handled alongside other types of municipal solid waste. The governing framework at the national level assigns tasks and responsibilities to relevant ministries. The MONRE oversees these matters at the state level, whereas it transitions to the DONRE at the city level. At the district level, there is a unit with similar assignments, and at the ward level, an official is designated to address environmental issues.

Table 5. Hanois' regulations and policies on plastic waste management and recylcing

Regulations and policies	Description
Decision No. 609/QD-TTg on Approving the master plan on solid waste disposal of Hanoi capital to 2030 with vision to 2050 On 25-Apr-2014 considering the proposal of the chairperson of the Hanoi PPC and appraisal opinions of the Ministry of Construction	Hanoi city has planned for 17 domestic solid waste treatment (SWT) zones, including 8 upgraded/ expanded SWT zones and 9 new SWT zones. Presently, 6/17 SWT zones are out of services (full and closed); 3/17 zones are ineffective and no/stop serving; 2/17 zones are hanlding by PPC of districts and 4/17 have been approved for investment, but site clearance has not been completed. Therefore, mainly generated solid wastse presently are transferred and treated at 2 SWT zones, i.e. (i) Nam Son SWT zone in Soc Son district and (ii) Xuan Son SWT zone in Son Tay township.

Continued next page

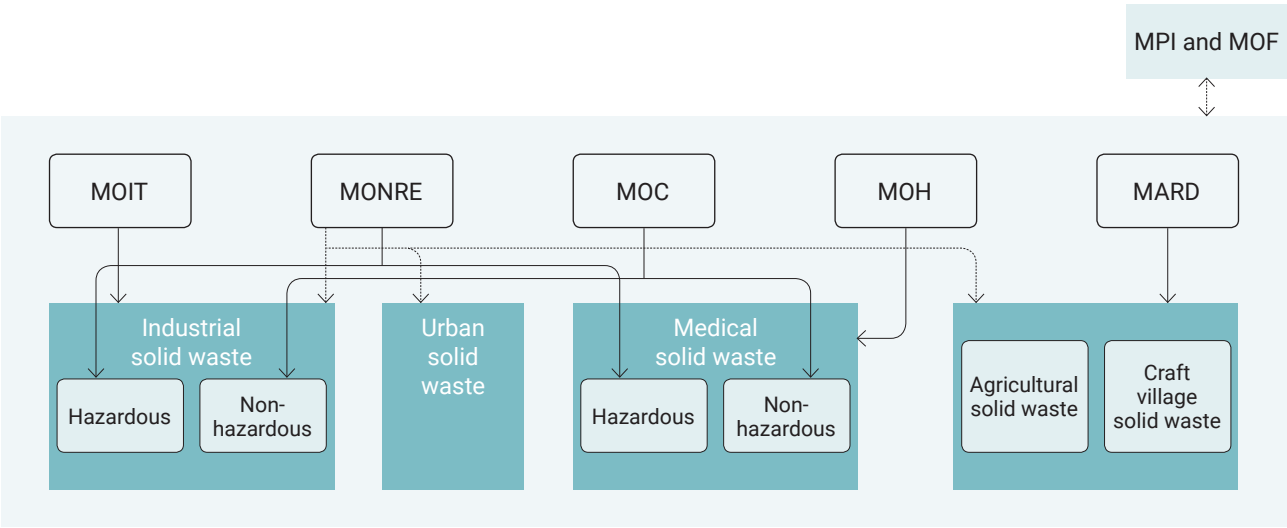
Table 5 continued

Regulations and policies	Description
Plan No. 206/KH-UBND on "Implementing Hanoi city's action plan on sustainable production and consumption by 2020", issued by Hanoi PPC on 31-Oct-2018	To requires the service, industrial and commercial businesses to implement waste reduction and recycling models in their operations
Plan No. 7255/KH-STNMT-SGDDT on the implementation of the program of collecting, sorting and recycling milk cartons at some schools in the city for the 2019-2020 school year with the theme: "One second of action - Protecting the environment" Issued on 05-Aug-2019	The Hanoi DONRE, Department of Education and Training, in collaboration with Tetra Park Vietnam JSC, Lagom Vietnam Co., Ltd., and NHC Social Enterprises collect, sort and recycle milk cartons, and plastic straws at 800 kindergartens and primary schools in over 16 districts and towns in Hanoi city such as Hoan Kien, Cau Giay, Dan Phuong, Chuong My, My Duc, Thanh Oai, Phuc Tho, Son Tay, Hoang Mai, Gia Lam, Me Linh, Dong Anh, Soc Son, Nam Tu Liem
Plan No. 232/KH-UBND on "Prevention and control of plastic waste and plastic bags until 2020, vision to 2025", issued by Hanoi PPC on 25-Oct-2019	To promote the collection and recycling of SUP waste and non-degradable plastic bags, departments and branches need to study the investment in points to collect plastic waste and non-biodegradable plastic bags from daily activities; develop a network of units that collect and recycle plastic waste from daily-life activities and connect with households, groups of individuals and units, creating a closed cycle to minimize a large amount of plastic waste generated; invest in a factory to recover and recycle plastic waste according to the circular cycle
Directive Document No. 4996/UBND-ĐT on the implementation of solutions to reduce plastic waste for state administrative agencies, socio-political organizations and non-business units under the city according to Directive No. 33/CT-TTg dated 20-Aug-2020 of the Prime Minister issued by Hanoi PPC, on 16-Oct-2020	State administrative agencies are exemplary, active and take the lead in reducing plastic waste; Minimize the use of SUP products; Do not use disposable banners, straws, bowls, plastic chopsticks... in the office and in conferences and seminars. All prioritize the selection of recycled products to reduce plastic waste.

- The MONRE is also responsible for managing hazardous waste and manages industrial and hospital waste, but also has indirect regulatory powers on domestic waste management in collaboration with the Ministry of Construction (MOC) and the management of agricultural waste in rural areas shared with the Ministry of Agriculture and Rural Development (MARD).
- The MARD is responsible for managing agricultural waste.
- The Ministry of Planning and Investment (MPI) and the Ministry of Finance (MOF) are not directly involved in the waste management system but plan and elaborate strategies related to waste treatment projects and control the public finances of the sector (Figure 20).
- Laws and regulations regarding the modalities of collaboration between various departments when they oversee the same type of waste appear vague.
- Task partitioning might be different between diverse administrative entities from central to local levels[14].
- The division of powers, resources, and responsibilities in the waste management area replicates from the central to local levels.

14 The legal framework on waste management states that the Ministry "guide," "collaborate," or "coordinates," bringing all entities listed by the law to discuss and find a consensus. For example, the Decree No 38/2015/NN-CP issued by the Government in 2015 related to waste and scraps management provides that the MONRE "collaborates" with the MOC to regulate the construction waste sorting and collection.

Figure 21. Diagram of solid waste (including plastic) management at national level in Vietnam[15]



Notes: ⟶ Direct interactions; ⇢ Indirect interactions; ⟷ Financial relations
MOIT: Ministry of Industry and Trade; MOC: Ministry of Construction; MOH: Ministry of Health; MOF: Ministry of Finance; MONRE: Ministry of Natural Resources and Environment; MARD: Ministry of Agriculture and Rural Development; MPI: Ministry of Planning and Investment
(*) Agricultural solid waste has not been clearly demarcated between MOC and MARD
(**) Craft village solid waste has not been clearly demarcated between MOIT, MOC and MARD

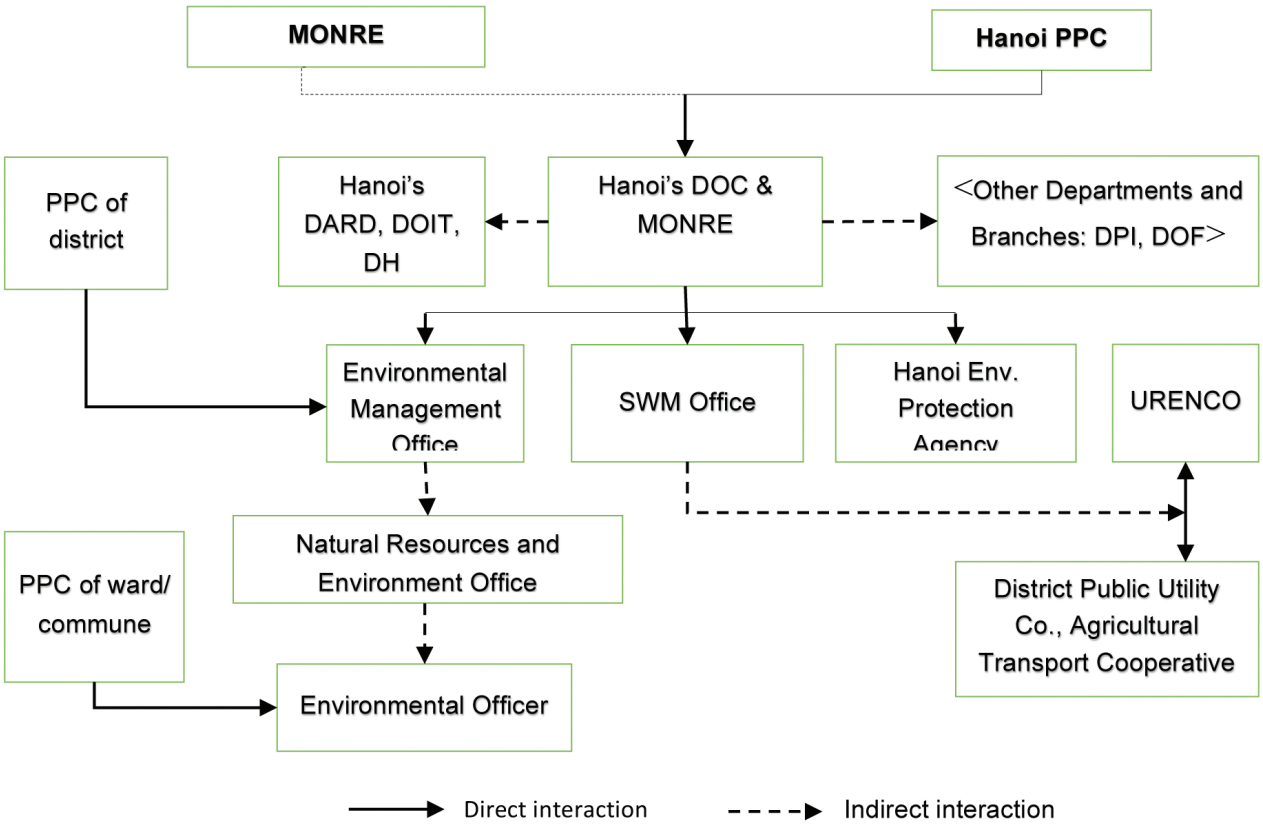
This figure illustrates the complexity of competence allocation between ministries. For instance, the MONRE manages industrial waste and hospital waste but also has indirect regulatory powers on domestic waste management in collaboration with the MOC and the management of agricultural waste in rural areas shared with the MARD. Regulatory laws regarding the forms of collaboration among various departments when they are in charge of the same type of waste remain vague. The legal framework on waste management states that the Ministry "guide", "collaborate", or "coordinates", bringing all entities listed by the law to discuss and find a consensus. For example, the Decree No 38/2015/NN-CP issued by the Government in 2015 related to waste and scrap management provides that the MONRE "collaborates" with the MOC to regulate the construction of waste sorting and collection, without precisely defining the task of the MONRE. Consequently, task partitioning might differ between diverse administrative entities, from the central to the local levels. The division of powers, resources, and responsibilities in the waste management area replicates from the central to local levels. For example, MONRE at the state level becomes DONRE at the city level. At the district level, a unit with similar assignments exists, and at the ward level, an official is responsible for environmental issues.

At the level of Hanoi city, the Hanoi PPC is the highest administrative body of the city and is responsible for implementing the legislation and regulations from the state level for solid waste management. It specifies the adaptation modalities for regulations issued at the national level. Every year, the Hanoi PPC draws up a report for the MONRE and MOC on waste treatment within Hanoi (Figure 21). Several departments within the PPC are responsible for waste management: some are directly in charge, such as the DONRE, Department of Construction (DOC), Department of Agriculture and Rural Development, and the Department of Health. Others are indirectly responsible, such as the Department of Planning and Investment and Department of Finance.

SWM, solid waste management; URENCO, Urban Environment Company; DONRE, Department of Natural Resources and Environment; DH, Department of Health; DARD, Department of Agriculture and Rural Development; DPI, Department of Planning and Investment; DOF, Department of Finance

15 MONRE, National environment report in 2011: Chuong 7 – Solid waste management

Figure 22. Schematic diagram of governing framework for (plastic) waste management in Hanoi city



Hanoi's waste management system differs significantly between the urban and suburban areas. Specifically, the DONRE manages domestic waste in 17 suburban districts, whereas the DOC oversees waste management in 12 urban districts and Son Tay Township. Suburban districts often face challenges in waste management, and sometimes rely on private companies for assistance if they have access to public funds. In cases where funds are lacking, open-air waste disposal sites are established at village entrances, leading to environmental pollution from untreated waste and leachate, which impacts air, soil, and water quality as well as community health.

At the district level, plastic waste management is overseen and reported on by the Environment and Natural Resources Office of the People's Committee of the district. Finally, at the ward level, which is the institutional level closest to citizens, environmental officers are responsible for addressing environmental issues.

Table 6. Key actors of (plastic) waste management in Hanoi city

No	Departments and branches	Assigned tasks and competences
	Hanoi PPC	Responsible for planning (long term plan/strategy for SWM, landfill, waste treatment facility, etc.) and monitoring SWM at city level Approve Environmental Impact Assessment reports for waste treatment facilities. Directing and coordinating activities; coordination between URENCO, DONRE (Waste Management Department) and public utilities Coordinate with DOC to review and select the SWT zones
	DOC	Advise the Hanoi PPC in order to apply the state's directive management of solid waste in collaboration with other services. Is responsible for the management of domestic waste in urban areas, industrial parks, economic zones, high-tech zones, construction waste and sludge
	DONRE	Runs state guidelines for environmental protection. Advise the Hanoi PPC in order to apply the state's directive management of solid waste in collaboration with other services. Manages domestic waste in rural areas, hazardous solid waste (in collaboration with DH and DOIT) and the craft villages (in collaboration with DARD)
	DARD	Oversees agricultural waste in collaboration with DONRE
	DH	Dictates regulations and manages the waste collection and storage inside health facilities
	DPI	Budget planning Advises and assists the Hanoi PPC concerning investment needs. Controls the implementation of the state budget given to the city. Ensures the conformity of the budget implementation with regulations and guidelines issued on waste management. Mobilizes national and foreign investors
	DOF	Implements the budget. Works with the DPI to ensure a balanced budget in waste management. Works with the DOC and the DONRE to supervise and inspect the use of revenues from waste management
	The Office of Environmental Police	Monitors compliance with laws and regulations on waste management Identifies and prevents violations in the management of solid waste in accordance with regulations
	URENCO	Under the management of DOC General responsible for collection, transportation, and treatment of mostly amount of solid waste generated over the city (mainly in urban districts and other suburban districts) Management of Nam Son SWT zone, Xuan Son SWT zone and a number of concentrated waste treatment zones of the city

Chapter 5

Conclusion and Recommendations

5.1 Conclusion

Plastic pollution and the leakage of pellets from recycling facilities, whether formal or informal, pose significant risks to both the environment and public health. The release of plastic waste and pellets can lead to ecosystem contamination, wildlife harm, and introduction of toxins into the food chain, thereby endangering human health through ingestion or exposure to harmful chemicals. This issue is exacerbated by inadequate waste management practices, outdated technology, and a lack of regulatory oversight, resulting in the release of pellets and plastic waste into the environment. Furthermore, plastic pollution and pellet leakage have far-reaching economic and social consequences, including a decline in tourism, diminished property values, and increased healthcare expenses, all of which affect community well-being and livelihood. Addressing these challenges requires a comprehensive approach, including stringent government regulations, industry standards for waste management, community participation in waste reduction efforts, and investment in innovative recycling technologies to mitigate harmful effects and foster a sustainable environment.

5.2 Good practices and methods for determining best fit solutions for various actors in value chain

From the present status of the plastic waste management and recycling industry, particularly in Hanoi City, good practices and solutions were identified and summarised for different key actors along the value chain, as shown in Table 7.

Table 7. List of identified good practices and solutions for key actors

Key actors	Good practices and solutions
1-Plastic scrap generators	
Domestic scrap: mainly from households, streets, public facilities (schools, hospitals, offices, hotels, etc.)	Strengthening organization and deployment of communication and education activities to raise awareness and encourage people taking acts to reduce and prevent plastic waste Effectively deploying and replicating the model of waste separation at source Raising collection/landfill fees to limit plastic waste disposal
Industrial actors: virgin/ recycling manufacturers	To strengthen strict control of production, business and service units that produce non-degradable plastic bags and disposable plastic products. Enterprises need to pay attention to environmental protection issues, use eco-friendly packaging products to replace plastic packaging products, improve production processes, innovate technology to save resources, prioritize the use of environmentally friendly raw materials. Establishing industry-specific collection/ recovery requirements for the end-use plastic packaging industry
Market side: traders	To implement solutions to limit plastic, change their perception to take action, actively reduce the amount of plastic waste released into the environment in trading and doing business. Applying biodegradable/ alternative environmentally friendly materials to replace nylon bags in markets and supermarkets. To increase taxes and fees on SUP products

Continued next page

Table 7 continued

Key actors	Good practices and solutions
Brands	Promoting PPP between brands such as Unilever, Nestlé…and state agencies in plastic waste management Enforcing EPR; encourage businesses that use a lot of plastic to commit to recycling/reusing their packaging materials
Imported scrap	Tightening regulations on restricting the import of plastic waste Completing the legal framework and issuing detailed guidelines to limit illegal imports
Collection	
URENCO; private companies	Increase the efficiency of collection network operation; closely coordinate with the private/ informal facilities to ensure thorough and timely collection of generated waste. Improve waste handling infrastructure, especially at the collection step, provide a system of recycling bins and synchronous management. Strengthen technical infrastructure management of gathering points, transfer stations, SWT facilities to minimize plastic waste leakages. To increase plastic recovery rates from municipal solid waste, fully exploit plastic scrap before transferring to landfill. Develop a roadmap to gradually increase the price of waste collection, transportation, and treatment services to gradually reduce the burden on the state budget
Waste pickers	Strengthening protective equipment for waste pickers Developing policies and mechanism to support and improve the effectiveness and role of this group
Junkshops, pretreatment facilities	Consolidate facilities and apply advanced technologies to increase operational efficiency: applying compressors to reduce the volume of waste plastic for ease and reduce transportation and logistics costs
Processing	
Producers in craft villages	Planning centralized recycling zones such as craft villages and plastic recycling industrial clusters far from residential areas, accompanied by environmental infrastructures. Promoting application of BAT/BEP solutions to improve product quality, resource saving and environmental protection. Providing policies and mechanism to support SMEs with preferential loans to invest in modern and advanced machineries
Recycling facilities	Setting technical standards, supporting the recycling of environmentally friendly plastic products, and promoting producers and importers' sense of responsibility Stronger preferential policies for businesses to invest in modern equipment and technology to recycle waste
Offtake	
Domestic manufacturer	Mechanisms and policies to support and give incentives to encourage manufacturing enterprises to prioritize using domestic raw materials, especially recycled plastics. Labeling recycled plastic products and encouraging use in public procurement; establishing a market for recycled products, communicating, and introducing products to consumers
Foreign buyers	Developing a transparent database of the plastic market to facilitate foreign investors and buyers

5.3 Policy and practice recommendations

By implementing these recommendations, stakeholders can work together to mitigate the adverse impacts of plastic pollution and pellet leakage from recycling factories and move towards a sustainable and environmentally friendly waste management system.

- **Strengthen regulatory frameworks:** Implementation and enforcement of stringent regulations governing waste management practices in informal and formal recycling factories.
- **Enhance monitoring and enforcement:** Increase oversight and surveillance of recycling facilities to ensure compliance with environmental regulations and standards.
- **Invest in technology and infrastructure:** Enhancing recycling technologies and infrastructure to reduce plastic pollution and pellet leakage. This includes investing to improve the recycling infrastructure for advanced sorting, shredding, and pelletising equipment. Further enhancement of equipment and personnel for collection and transportation and ensuring proper handling of non-recyclable and hazardous plastics are vital.
- **Promote training, education and awareness:** Educate stakeholders, including workers, local communities, and businesses on the importance of proper waste management practices and the dangers of plastic pollution.
- **Encourage collaboration and partnerships:** Foster collaboration between government agencies, recycling industry stakeholders, NGOs, and local communities to develop and implement effective solutions for preventing plastic pollution and pellet leakage.
- **Support research and innovation:** Invest in research and development to identify innovative solutions and technologies to reduce plastic pollution and pellet leakage in recycling factories.
- **Provide incentives for sustainability:** Offer financial incentives and support mechanisms to encourage recycling factories to adopt sustainable practices and technologies.
- **Foster circular economy initiatives:** Promote the transition towards a circular economy model in which plastics are reused, recycled, or repurposed to minimise waste generation and pollution.

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Annexes

Annex 1. Overview of key regulations for plastic waste management and recycling

Code	Legislation	Issue date; authority	Related content
Level 1: National law			
Law No. 72/2020/QH14	Law on Environmental Protection (LEP) (latest revision in 2020)	17-Nov-2020; By the National Assembly	The most relevant articles for plastic circulation in the LEP 2020 are: Articles 53, 54, 55 (Recycling Responsibility and EPR), Article 146 (Green Procurement); Articles 149, 150 (Green credits and green bonds), and Articles 75, 76, 77, 78, 79, 80 (Management of domestic solids). Under the LEP 2020, businesses can do EPR in one of three ways: (1) recycle on their own, (2) recycle through a third-party as Product Recycling Organization (PRO), and (3) contribute to Vietnam Environment Protection Fund (VEPF). The content on reducing, reusing, recycling and handling plastic waste, prevention of ocean plastic pollution has been specified.
Law No.57/2010/ QH12	Laws on Environmental Protection Tax	15-Nov-2010 By National Assembly	Taxable-plastic bag (is subjected to charge environmental protection fee) means bags; packages are made from polyethylene plastic film unit, its technical name is a porous plastic bag; Environmental protection tax for non-degradable plastic bags is VND 50,000/kg
Level 2: Regulatory instruments issued by the national government			
Decree 08/2022/ ND-CP	Elaboration of several articles of the law on environmental protection	10-Jan-2022	Stipulate roadmap to to restrict the production and import of SUP products, non-biodegradable plastic packaging and products and goods containing microplastics; Ensure that after 2025, do not circulate and use SUP products, difficult-to-biodegradable plastic packaging at commercial centers, supermarkets, hotels, tourist areas and so on.
Decision No. 889/QD-TTg	Approving national action program for sustainable production and consumption for 2021-2030	24-Jun-2020 By Prime Minister, Requested by MOIT	Incentive policies for production, distribution and consumption of ecofriendly packaging instead of non-biodegradable or SUP products; and regulations on green public procurement; targeting by 2025 is 85% and by 2030 is 100% of supermarkets and shopping malls use ecofriendly packaging products instead of single-use or non-biodegradable plastic packaging

Code	Legislation	Issue date; authority	Related content
Decision No. 2149/QD-TTg	Approving the National Strategy of Integrated SWM to 2025, vision to 2050	17-Dec-2009 By Prime Minister request by the MOC and MONRE	Sets out various targets for increasing rate of municipal waste collection, recycling, reduction rate in plastic bags in supermarkets, etc.
Decision No.491/ QD-TTg	on adjustments to National Strategy for general management of solid waste to 2025 with vision towards 2050	07-May-2018 Issued by Prime Minister Requested by MONRE and Ministry of Construction	Identified the specific requirement for domestic waste at urban area is to use 100% environmentally friendly plastic bags in shopping centers, supermarket instead of normal plastic bags and 90% of domestic waste in urban area is collected and treated properly, in which direct landfill is expected to be lower than 30% of amount of waste collected
Decision No. 1979/QD-TTg	On approval for SWM planning in Northern key economic region by 2030	14-Oct-2016 By Prime Minister Upon request by the MOC	Enhance solid waste (including plastic waste) management, prevent and reduce generated solid waste; prioritize to apply solid waste technologies such as recycle and reuse, minimize landfill method
Decision No. 1316/QD-TTg	Approving proposal for strengthening management of plastic waste in Vietnam	22-Jul-2021	Strengthening management of plastic waste from the central to local level, contributing to the successful implementation of the national strategy for comprehensive SWM by 2025, scheduled for 2050; Contributing to designing a circular economy model in Vietnam with the orientation towards reducing the use of non-biodegradable disposable plastic products and plastic bags; increasing the reuse, recycling and disposal of plastic waste
Decision No. 1746/QD-TTg	National Action Plan for Management of Marine Plastic Litter by 2030	04-Dec-2019 At the request of the MONRE	Effectively implement innovations and fulfill Vietnam's commitments to other countries regarding resolution for plastic litter, with a focus on marine plastic litter, to eliminate plastic litter from land-based and ocean-based sources, and strive to become a pioneering country in mitigation of marine plastic litter in the region
Decision No.582/ QD-TTg	To approve the project on enhancing the control of environmental pollution due to the use of non-biodegradable plastic bags by 2020	11-Apr-2013 Issued by Prime Minister Requested by MONRE	With general objectives are to gradually reduce the use of non-degradable plastic bags in daily life; Enhance the collection and recycling of dumped non-biodegradable plastic bags. The target is to reduce 65% of plastic bags in 2020 (in comparison to that in 2010)
Decision No. 687/QD-TTg	Approving the scheme for circular economy development in Vietnam	07-Jun-2022	Circular economy models assist development of green living, encourage waste segregation, and promote sustainable consumption. By 2025, reuse, recycle, and treat 85% of plastic wastes generated; reduce 50% of plastic wastes in ocean and at sea compared to prior period; gradually reduce production and use of non-biodegradable nylon bags and disposable plastic products

Code	Legislation	Issue date; authority	Related content
Decree No. 38/2015/ND-CP	Decree on Waste and Scrap Management	24-Apr-2015 At the proposal of the MONRE; Issue by the national government	Only organization or individuals directly using scraps as production raw materials and/or undertaking the entrusted import of scraps for organizations or individuals using imported scraps as production raw materials for recycling can import scraps
Directive No.27/ CT-TTg	A number of urgent solutions for enhancement of management of scrap import and use of imported scrap for production purpose	17-Sep-2018 Prime Minister	There is no permission for the import of plastic scraps only for preliminary processing
Directive No. 2227/VPCP-KTTH	Stipulates a ban on importing plastic scrap after 2024	21-Mar-2019 Vice Prime Minister	The plastics recycling industry will depend on domestic sources of plastic scrap, particularly after 2024 when the full ban is in place
Directive 33/CT-TTg	Regarding strengthening of management, reuse, recycling, disposal and reduction of plastic waste	20-Aug-2020 By Prime Minister	In order to continue to strengthen the efficiency of the management, reuse, recycle and dispose of used plastics, and reduce emission of plastic waste into the environment
Level 3: Regulatory instruments issued by ministries an provincial/ city governments			
Circular No.41/2015/TT-BTNMT	Circular on Environmental protection in import of scrap for use as raw production materials	09-Sep-2015 By MONRE	Regulated procedure and types of imported scrap. It includes requirements on checking, custom approval with papers, certificates on environmental protection that prolong the storage time at custom. The recent promulgation of Circular No. 03/2018/TT-BTNMT revising some item in Circular No. 41/2015/TT-BTNMT simplifies list of goods and checking procedures
Directive No. 08/ CT-BCT	Strengthening measures to reduce plastic waste in Industry and Trade sector;	15-Jul-2019	The Ministry of Industry and Trade requires the units under the Ministry and the Departments of Industry and Trade to strengthen measures to reduce plastic waste according to their functions, management scope and activities.
Official Dispatch No. 5539/ BTNMT-TCMT	Launching the movement “Against plastic waste”	10-Oct-2018	In order to propagate, mobilize and call on the community to change their behavior and habits of using SUP products and non-degradable plastic bags, contributing to reducing environmental pollution and protecting human health and ecosystem
Circular No.08/2018/TT-BTNMT	Promulgation of national technical regulations on environment	14-Sep-2018 By MONRE	Set the requirements on detailed contents of the contract on importing plastic scraps and compulsory commitments; types, pre-cleaning, classification and labeling of plastic scraps legitimate for being imported

Code	Legislation	Issue date; authority	Related content
Circular No.121/2008/TT-BTC	Guiding Incentive machanisms and financial support for Investment in SWM	12-Dec-2008 By the Ministry of Finance	Incentive mechanisms and financial supports applicable to domestic and foreign organizations and individuals investing in one of the following SWM activities: constructing solid waste disposal facilities, collecting and transporting solid wastes and cooperatives and households collecting, transporting and disposing solid wastes in rural residential areas and craft villages without solid waste collection and transportation services
Decision No.43/2007/QD-BYT	Promulgating the regulation on management of medical wastes	30-Nov-2007 By Ministry of Health	Regulates the list of medical wastes, which are allowed for collection for recycling. According to this, waste plastic bottles containing nonhazardous chemicals and other plastic containers not containing hazardous substances are considered recyclable plastic wastes
Circular No.07/2012/TT-BTNMT	Providing on criterion of, order of, procedures for recognition of environmentally friendly – nylon bags	04-Jul-2012 By MONRE	The environmentally friendly - nylon bags must satisfy technical characteristics (thickness, enable biology decompose); meet the permitted maximum content of heavy metals; obey fully provisions of law on environmental protection
Document No.8170/BTC-CST	On the exemption of import and export tax on plastics recycled from hazardous waste	15-Jun-2016 By Ministry of Finance	Plastic products recycled from scrap battery shells and other waste products produced and exported by Ngoc Thien Co., Ltd. are eligible for consideration for export tax exemption or reduction under the provisions of Clause 2, Article 44 of Decree No. 19/2015/ND-CP
Decision No.2992/QD-BCT	Master plan for plastic sector to 2020 with vision to 2025	17-Jun-2011 By Ministry of Industry and Trade	There is plan for increasing usage of waste material ratio in sectoral master plans: The plastic sector aims to treat plastic waste to materials in order to increase the ratio of domestic plastic materials
Circular No. 25/2009/BTNMT (QCVN 25:2009/TT-BTNMT)	National technical regulation on wastewater of the solid waste landfill sites	16-Nov-2009 By MONRE	Regulation of the maximum allowable concentration of pollutant parameters in wastewater of solid waste landfills when discharging into receiving sources
Circular No. 03/2016/TT-BTNMT (QCVN 61-MT:2016/BTNMT)	National technical regulation on domestic solid waste incinerator	10-Mar-2016 By MONRE	Stipulates the technical requirements for domestic solid waste incinerators and the maximum allowable values of pollution parameters in flue gas from domestic solid waste incinerators

Annex 2. Detail information about mechanical recycling

Extrusion: The input material can be presented in many forms (bottle, can, film…) and chemical types (PP, PE, PET…). Plastic waste items are shredded, washed and processed via melting and filtering into granules that can be used to produce new plastic items later on. As derived from post-consumer waste with poor pre-handling step, the granules are usually of low quality and high impurities, limiting their application for food grade material.

Injection molding/pressing: Plastic granules are used as an input material and can be derived from an initial extrusion recycling process. The particles are inserted into a cylinder where the material is fully melted, homogenized and filtered for impurities. The plastic is then either molded or pressed under pressure into a form which hardens as it cools. Depending on the quality of the input material and the applied pressure, a range of applications can be served with products from injection molding/pressing. These include pallets, pots for planting, barriers for agriculture or car bumpers.

Intrusion: The melted plastic material is inserted in forms and cools until it becomes hard. The resulting products include poles, boards, pillars for street signs, park benches, etc. Intrusion requires lower purity levels, enabling the processing of mixed or contaminated plastics commonly found in post-consumer waste streams. The products are usually of lower specific value and their characteristics are less versatile than injection molding. Therefore, extracting a relatively lower part of the input material value is a form of "down-cycling."

Sintering: A wide array of mixed and contaminated plastic waste can be used (e.g., melted and poured into square molds). It then goes through a heating process of several steps, pre-heating, melting and cooling. During the process, the pressure continuously increased. The end product is a board with a thickness of up to 60 mm, which can be used as construction material or for furniture.

Table below lists out the major BAT/BEP options for recycling process in the villages:

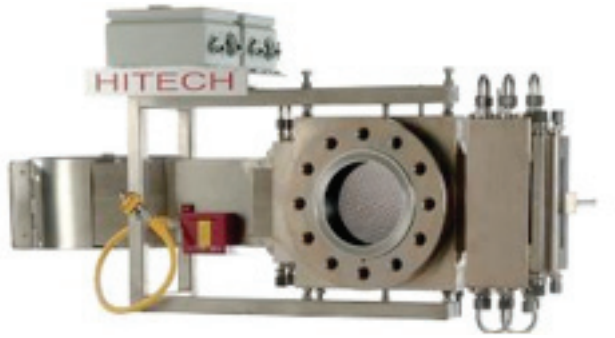
No	Step	Current situation	BAT/BEP options
1	Sorting	• Manual sorting: workers are sitting on improper posture causing back pain and low capacity	• Install a conveyer for sorting, moving material between steps: This helps to increase productivity up to 30% and reduce labor for carrying
		• There is no identification of plastic category for segregation	• Make a classification board to better identify different types of plastics, avoid mixing; • Sorting Guide by using sample picture

No	Step	Current situation	BAT/BEP options
2	Crushing + Washing 1	• Crushing/ shredding process generates noise	• Put rubber pieces under the machine, install noise reduction devices such as cover layers*
			• Regularly maintain the machines
		• Chemical detergent (dish washing liquid) was added by experience and discharged freely at the normal temperature	• Replace chemical detergent by bio detergent such as Bio-Taf, Golden Wing, etc. so that the final wastewater is much more environment friendly*
			• Calculate a suitable amount of detergent when add to water for washing to save water and detergent as well*
		• Screw in high-speed friction washer is short and slow with low washing efficiency	• Using more advance high-speed friction washer with special washing blades, high speed to increase the washing efficiency
3	Washing 2	• - Floating washer is made by cement and the bottom is flat, that make cleaning become harder	• - Using stainless steel to make washing tank instead of cement. The tank's bottom should be in trapezoid shape, this help to collect sediment and sludge from washing tank during operation time
		• - Small materials are not completely collected by conveying blade	• - Install a rotating net in the tank to collect the small material that is not collected by conveying blade
		• - A lot of water spills out of washing tank	• - Install mechanisms to prevent water spill out of washing tank, this helps to reduce water and material loss and increase efficiency of washing step
		• - The process releases lots of wastewater; salty wastewater is discharged without treatment and recirculate	• - Install tank to collect washing water for recirculating to reduce water consumption
			• - Install side drainage screw beside washing tank, it will help to remove sediment and sludge at the bottom of tanks without renew the water
			• - Calculate the suitable amount of salt when using for sink-float separation
4	Horizontal dewatering	• - Most of household don't have horizontal dewatering machine • - Water is removed by using the 1st extruding lead to high energy consumption and reduce the product quality due to thermal degradation •	• Using horizontal dewatering machine (screw and press machine) for drain-off water. After this process the humidity of material is reduced to 5~7%
			• Install drying pipe system to blow material through pipe system with hot air for drying material before moving them to extruding step. After drying, humidity of material is reduced to 3~5%
			• Increase the drain-off time*
5	Extruding	• - The extruders are not insulated, result in heat loss, and consume more power, and hot working condition for the worker	• Install insulation layer for the extruder
			• Adjusting the burner to suitable temperature for each type of plastic to prevent unnecessary heat loss
		• - High residue in metal sieves	• Install an automatically filter system to remove the dust, particle in the extruding process

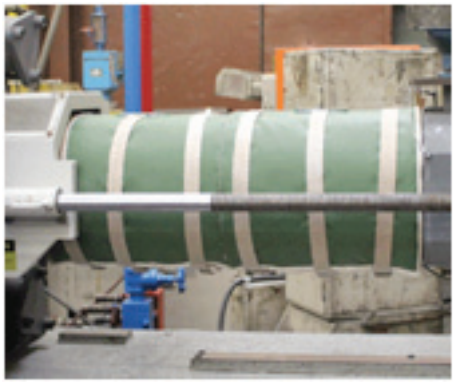
No	Step	Current situation	BAT/BEP options
6	Stringing	• -High water consumption, hot water from string step is released directly into environment without reuse or circulation	• - Recycle hot water from string step to increase the efficient of washing
			• - Recycle water by using cooling tower or extend and/or lengthen the cooling water bath
7	Cutting	• - High electricity consumption	• Using Good Housekeeping option for good management in workshop as: efficient lighting, capacitor, etc.
		• - Granules have different size versus standard size	• Install vibrator sieve for screening to segregate granules of uniform size, granules bigger and smaller than standard size are segregated for reprocessing
8	Packaging and storing	• - Manual package product by worker in bag for storing	• Use silo storage system with blowing fan to store granule product: • Granules are drier and cooler; • Easier for worker to package the products; • Improve efficiency of packaging
9	Residues	• - Open burn residues plastic and wastes from screening and extruding step • - Solid waste such as sand, small piece of plastic, etc. along with wastewater are discharged directly to the environment • - The large quantity of plastic discard in the village landfill	• Recycle the discarded plastic and waste to create new products such as plastic brick, tile, fence, pallet, etc.
			• Install stainless steel filter net along washing tank to remove small plastic pieces.
10	Others	• -Recycling hazardous plastic such as lubricant, chemical and pesticides bottles	• - Prohibit household from recycling these types of plastic
		• - Voltage drop and low power factor cause energy loss	• Equip the capacitor for the equipment, motor with low power factor*
			• Replace aluminum wire by copper one*
		• - Hot air in the workshop	• Install vacuum pump for suctioning hot air (from chimney of extruding nozzle) and water
		• - Toxic pollutant such as CO, CO_2, SO_2, emitted to the environment. • - Bad ventilation inside workshop	• Install gas capture device and air intake system for blow the fresh air into the working area
		• - The scrap material is stored outdoor cause unpleasant odor in hot weather	• Cover the storage area with wall, roof to limit the odor of the scrap and penetrate of dirty water to the land
		• - Risk of fire and explosion cause by the material, the electricity wires are mess up	• Apply good housekeeping, 5S in all the step of the production, equip fire protection equipment

(*): Solutions recommended for household to applied if applicable to improve their production

Sample BATs in plastic recycling sector

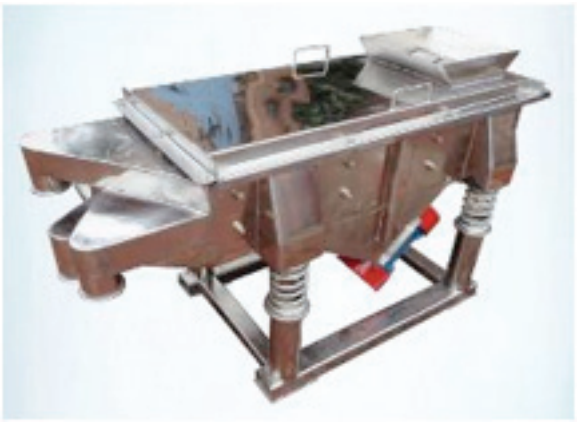


(a) Typical automatic filtering machine



(b) Insulation layer is installed on extruder

(c) Typical cooling tower



(d) Typical vibrator sieve