BUSINESS ENVIRONMENT COUNCIL
商界環保協會

Materials Recovery Facilities ("MRFs"):

Exploring Recyclables Sorting Options in Hong Kong

May 2023

Executive Summary

Current state of waste management

- Waste management progress is made on the 'Reduce' and 'Recycle' aspect, namely with upcoming legislation on single-use plastics ban and PRS on beverage containers.
- However, both upstream and downstream recycling infrastructure is insufficient to accommodate for the projected increase of recyclables recovery volume based on the 2035 target.

Business case for MRF in HK

- MRFs operation can improve the quality (i.e., decreased contamination) and increase the volume of processed recyclables. Naturally, the larger the waste volume that is sorted by such waste facilities, the greater the economies of scale.
- MRFs operation have the potential to foster automation, innovation, and reindustrialisation in Hong Kong, as well as upskilling the population.

Establishing MRF in HK

- To maintain a multi-stream recyclables format, there are voices to call for decentralised and smaller-scale MRFs. The compact nature of equipment would allow flexibility in site location, fitting in urban dead-spaces such as under flyovers.
- The city needs to be open and anticipatory of the establishment of a larger scale MRF when the volume of recyclables reaches a critical point in the future

Recommendations for Government

- To bring greater efficiency to the recycling system, the Government's intervention would be necessary to either subsidise or fully fund the set-up and operations of MRFs.
- To incentivise the recycling industry to establish MRFs in Hong Kong, the Government could explore the feasibility of utilising closed landfill sites for the purpose of waste management activities.

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1 Introduction

1.1 Project Background, Objective and Activities

Project Background

Hong Kong has long been facing its waste crisis with a growing waste disposal rate and a consistently low resource recovery rate. In February 2021, the Hong Kong Government ('Government' hereof) announced the Waste Blueprint for Hong Kong 2035, setting a medium-term target to *reduce the per capita municipal solid waste ("MSW") disposal by 40-45%* and *increase the recovery rate to about 55%.* Food waste, plastic, and paper are consistently among the three most commonly disposed of waste types in landfills. However, they have inherent value and can generate even higher returns. For example, collecting half of the food waste in Hong Kong and sending to them to treatment facilities and transform to energy could potentially support the electricity needs of around 27,000 households. The Organic Resources Recovery Centre (O•PARK) 1, with a 200-tonne daily treatment capacity, can transform food waste into 14 million kilowatt hours of electricity surplus per year. Transforming half of the waste paper into pulp for export, the total value could be nearly HK$1.8 billion annually. Turning a quarter of the waste plastics into high-quality recycled plastic pellets, could potentially generate up to HK$1 billion per annum[1]. Upcoming policy measures, such as the MSW charging scheme and regulation of disposable plastic tableware and other plastic products, will have a significant impact on reducing MSW disposal. While this could drive up recovery rate to a certain extent, there is still room for improvement to accelerate waste recovery.

The pandemic has no doubt put pressure on the ability to make progress in increasing recovery rate, given that new streams of wastes namely face masks and testing kits are non-recyclable, and prevention measures at restaurants and public have also caused a substantial increase of takeaway waste. However, the underlying cause of a low recovery and recycling rate is the lack of effective and accessible recycling and collection infrastructure in Hong Kong. Most local recycling facilities operate on a small scale and rely mainly on manual sorting at source (Green@ Community, 3 colour-bin at shopping malls or residential buildings) or along conveyer belts (waste sorting and recycling centres). Such facilities could be considered Small Material Recovery Facilities ("SMRFs"). Establishing larger scale Material Recovery Facilities ("MRFs") would potentially improve

the efficiency of recyclables sorting and the quality of the output, which in turn would benefit the wider recycling eco-system. The topic of MRFs is also discussed by multiple industry experts and has gained wider attention in recent years. For example, relevant context was featured at the 2022 ReThink Conference, during a session titled "MRFing and SMRFing: Getting Recycling Right in Hong Kong"[2].

Project Objective

Business Environment Council supports Hong Kong's transition from linear to circular economy through engagement with member communities via the Circular Economy Advisory Group and research projects. In October 2022, BEC published the report on "Zero Waste Design for Buildings in Hong Kong (Link)" which provides recommendations to optimise the **upstream** collection of recyclables in residential and commercial buildings.

This research aims to explore the feasibility of using MRFs for **downstream** recyclables separation, by (i) identifying and summarising current waste separation practices and challenges in Hong Kong; (ii) comparing the recycling performance and effectiveness of different recycling systems adopted overseas, in particular on multi-stream collection; and (iii) recommendations for developing MRFs in Hong Kong. BEC hopes that this research can provide insights for local stakeholders, as well as other highly dense metropolitan areas with high waste disposal levels.

Project Activities

BEC Policy and Research Team conducted desktop research, stakeholder interviews and consultations with the Circular Economy Advisory Group to generate insights for this report.

1.2 Background of MRFs

This section is to provide an overview on the concept and functions of MRFs. Readers that are familiar with the concept may skip to section 1.2 in this report, which elaborates on the view of MRFs necessity, currently a missing piece of infrastructure in Hong Kong.

The definition of MRFs is facilities with manual or automated sorting mechanisms which aims *to* **maximise recyclables recovery rates and reduce contamination rates**. The mechanisms used vary depending on the target recyclable. For example, jet streams

could be used for separating plastic films, magnet could be used to extract aluminium and non-ferrous metals, and infrared sensing could be used for differentiating different types of plastics. Appendix A provides a visualisation of MRFs operation. Naturally, the larger the waste volume that is sorted by such waste facilities, the greater the economies of scale – this will be a critical consideration when assessing the feasibility of setting up and operating MRFs in Hong Kong.

Based on their input material, MRFs could be categorised into three separate categories: Dirty Material Recovery Facilities ("DMRFs"), Clean MRFs, and Material-specific Clean MRFs. In general, the MRFs operation separates the input stream into the desired recyclables output which will be further processed, and the general waste will be sent to a landfill or incinerated. The respective material inputs are listed in the table below.

Table 1: Types of MRF

Types of MRF	Material Input
Dirty MRFs	Input is a mix of general waste and recyclables
Clean MRFs	Input excludes general waste, and is a mix of different recyclables
Material-specific Clean MRFs	Input is only one type of recyclable. Examples include the recycling plant for waste plastic at New Life Plastics located in EcoPark.

Figure 1: BEC's Circular Economy Advisory Group Site Visit to New Life Plastics on 9th September 2022, a recycling plant for waste plastic that processes PET & HDPE plastics

DMRFs:

DMRFs are specialised facilities that process solid waste, including contaminated or hazardous materials, in order to recover materials and reduce the amount of waste sent to landfills or incinerators.

The input for DMRFs includes any waste and recyclable materials that contain contaminants and need to be cleaned and processed to recover valuable resources or dispose of the material properly. Typically, the material is extracted from mixed MSW streams.

The process of DMRFs typically involves several stages. First, the materials are sorted from mixed waste and separated into different categories, such as metals, plastics, and glass. Next, the materials are cleaned and processed to remove any contaminants or hazardous materials. This may involve using various techniques, such as shredding, crushing, or melting the materials.

Once the materials have been cleaned and processed, they can be sold to manufacturers who use them as raw materials in the production of new products. However, recyclables from DMRFs usually tends to be of poor quality and lower value.

In addition to recovering materials, DMRFs also play an important role in reducing the amount of waste that ends up in landfills or incinerators. By diverting materials from landfills and recycling them instead, DMRFs help to conserve valuable landfill space and reduce the environmental impact of waste disposal.

Clean MRFs:

Clean MRFs are recycling facilities that processes recyclables gathered from residential, commercial, and industrial sources. The input for clean MRFs are all recyclable materials that collected in the same bin or container without any need for sorting.

Clean MRFs utilise mechanisms which vary depending on the target recyclable. For example, jet streams could be used for separating plastic films, magnet could be used to extract aluminium and non-ferrous metals, and infrared sensing could be used for

differentiating different types of plastics. Different types of recyclables such as paper, cardboard, plastics, glass, and metals are then baled and sold to manufacturers who use them to make new products. The quality of recyclables processed in clean MRFs are relatively better quality and higher value.

Clean MRFs have become increasingly popular in recent years due to the convenience. Clean MRFs also make recycling easier for general public by assigning the sorting responsibility to the recycling facility. Hence, recycling process is simpler and more appeal to wider audience, thus streamlining the recycling process for public and reducing the amount of waste that ends up in landfills or incinerators. In addition, they help to conserve natural resources and reduce carbon emissions.

However, it is important to note that while clean MRFs recycling is convenient, it can lead to contamination of the recyclable materials. Contamination occurs when non-recyclable items are mixed in with the recyclables, such as plastic bags, food waste, or hazardous materials. To minimise contamination, it is important for public to properly dispose of their waste and follow the guidelines provided by their local recycling program. They should also make efforts to reduce their waste and recycle only the materials that are accepted by their local clean MRFs.

Material-specific Clean MRFs:

Material-specific Clean MRFs are recycling facilities that are similar to Clean MRFs, which only process recyclables gathered from residential, commercial, and industrial sources. However, the input for Material-specific clean MRFs consists of specific materials collected in multiple bins or containers and sorted at the source. The practice could be similar to the current recycling system in Hong Kong.

Material-specific Clean MRFs use mechanisms to sort the residual waste from the recyclables collected from specific recycling bins. This results in less contamination at the source and higher financial value of collected materials. The technical and financial barriers for Material-specific Clean MRFs are lower than for traditional Clean MRFs.
However, it is important to note that the public bears the burden of sorting between materials. Some people are less willing to take extra steps to sort materials for recycling.

Collection rates for recyclables driven by such system may therefore be lower compared to Clean MRFs.

2 Current Market Gaps and Need for MRFs in Hong Kong

To provide an objective and holistic view on whether Hong Kong needs MRFs, the factors below should be considered:

1) Current state of waste management infrastructure or initiatives in Hong Kong (existing and under planning) along the waste management hierarchy
2) Waste Composition
   a) Proportion of waste generated in the domestic versus commercial sectors, given that the two have different collection mechanisms for recyclables
   b) Which type of recyclables currently has the lowest recovery rate (due to inherent low value of the material, or insufficient infrastructure to support its recovery)
3) Effectiveness of the recycling ecosystem in Hong Kong and abroad

The following sub-sections will identify the market gaps on each factor and provide a rationale on why there is a need for MRFs in Hong Kong.

2.1 Current State of Waste Management Infrastructure or Initiatives:

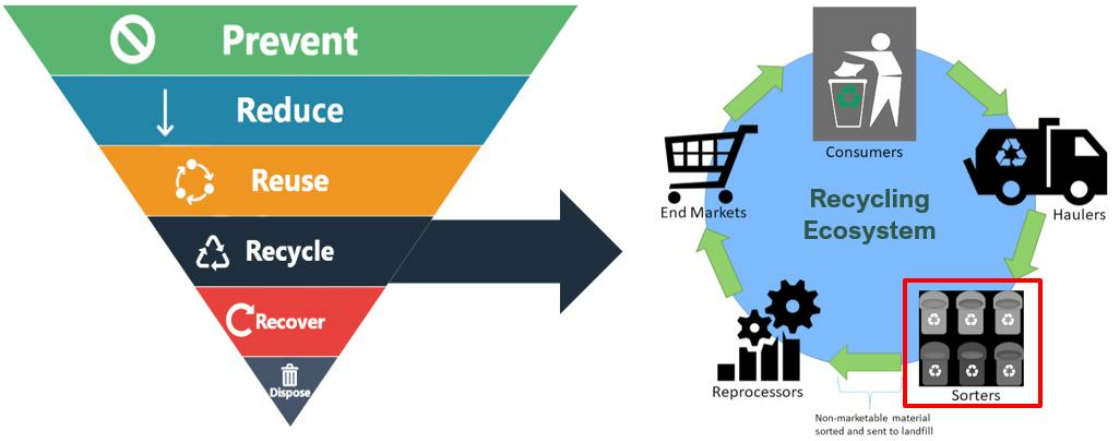


Figure 2: Diagram illustrating that MRFs fit within the 'Sorting' procedure in the recycling ecosystem, which fits into the recycling aspect in the waste management hierarchy, (Source of two diagrams in Endnote)

It is generally accepted that initiatives higher up in the waste hierarchy should be prioritised as they would be most efficient in reducing waste at source. However, the precondition is that all other initiatives and infrastructure is sufficiently robust to handle the waste stream that filters down the hierarchy. To investigate the robustness of the waste management system in Hong Kong as a whole, the table below lists out initiatives that are currently led or funded by the government.

Table 2: Waste Management Initiatives in Hong Kong (Existing and Under-planning)

Waste Hierarchy	Corresponding Initiatives in Hong Kong (Existing and under planning as of Dec 2022)
Prevent	• Regulation of disposable plastic tableware and other plastic products (legislation under planning, Phase 1: 4th quarter of 2023, Phase 2: 2025)
Reduce	• Municipal solid waste charging (legislation passed, expected to come in effect in 2023) • Increase of Plastic bag levy
Reuse	• Reusable Food Packaging Pilot (Initiative led by Foodpanda, funded by World Wide Fund for Nature ("WWF") and Environment and Conservation Fund)
Recycle	• Major housing estates and single-block buildings to collect, separate and pass recyclables to recyclers for processing (announced in 2022 Policy Address, legislation under planning) • Green@Community Collection Stores and Pilot Programme on Smart Recycling System around various districts (As of Dec 2022, Environmental Protection Department ("EPD") has set up 43 Green@Community collection stores and more than 120 makeshift recycling stops at regular locations.) • Producer Responsibility Scheme ("PRS") for all beverage containers (glass in May 2023, legislation under planning for plastic beverage container and cartons) • New PRS under review (electric vehicle batteries, lead-acid batteries and vehicle tyres) • Plastic Recycling Pilot Scheme, Reverse Vending Machines • WEEE Treatment and Recycling Facility • Yard Waste Recycling Centre ("Y•Park")
Recover	• Food waste collection bins (on-going pilots) • Three incinerators under construction and planning: 1) I•PARK 1 in Shek Kwu Chau (2025) 2) I•PARK 2 in Tsang Tsui, Tuen Mun (announced in 2022 Policy Address) 3) I•PARK 3, EPD is commencing a territory-wide site search study *The inefficiencies of incineration as a 'energy resource' should not be overlooked, and the method should be mostly considered as a last-resort recovery method

	• O•PARK 1, Sludge Treatment Facility ("T•PARK")
Dispose	• Landfill extensions are under planning

Overall, the Government has made progress in recent years to improve the various aspects along the waste hierarchy. Legislations that focus on **preventing** and **reducing** waste (such as the municipal waste charging scheme and single-use plastics ban) now have more solid implementation dates and plans. This is critical, given that waste plastics account for 21% of municipal solid waste disposed in landfills in 2021[3].

Next in the hierarchy is the **reuse** aspect. The Government is currently reliant on funding pilots or market initiatives for progress in this aspect. For example, Foodpanda's reusable food packaging pilot with WWF was funded by the Government through the Environment and Conservation Fund. But the Government has not yet considered more direct involvement, such as pushing for legislation that encourages and enables reuse. One example of this is the 'Right to Repair' legislation, which is passed in the European Union in February of 2021[4] and mandates that manufacturers make spare parts available to third-party repairers for up to ten years. Given that the Hong Kong consumer products market is mostly imports, initiatives that encourage reuse is harder to pursue compared to places that are less import reliant.

Recycling is arguably the most complex aspect within the Waste Hierarchy, consisting of **collection, sorting** and **processing** procedures for both domestic and commercial streams. The diagram in Appendix B provides an overview on the flow of recyclables along the procedures and the parties that are involved in each procedure. While the diagram was mapped for plastics recyclables, most streams (except the RVMs stream) are also applicable to metal and paper recyclables.

A recent development regarding the **collection** of recyclables is that EPD has confirmed that it has begun phasing out roadside three-coloured bins[5]. This decision is motivated by three factors: i) the on-going mistrust in such system; ii) a high contamination rate; and iii) the tendency for the bins to overflow, affecting the tidiness and hygiene of the station. As of mid-December, the department had removed 500 out of 700 recycling bins in urban

areas, and it would keep 1,100 in rural and fringe areas. The intended effect is that the domestic recyclables (including recyclables from pedestrians) will now be directed to the Green@Community stores, where collection will be monitored and orchestrated by the staffs, and in effect, minimising potential contamination and ensuring quality.

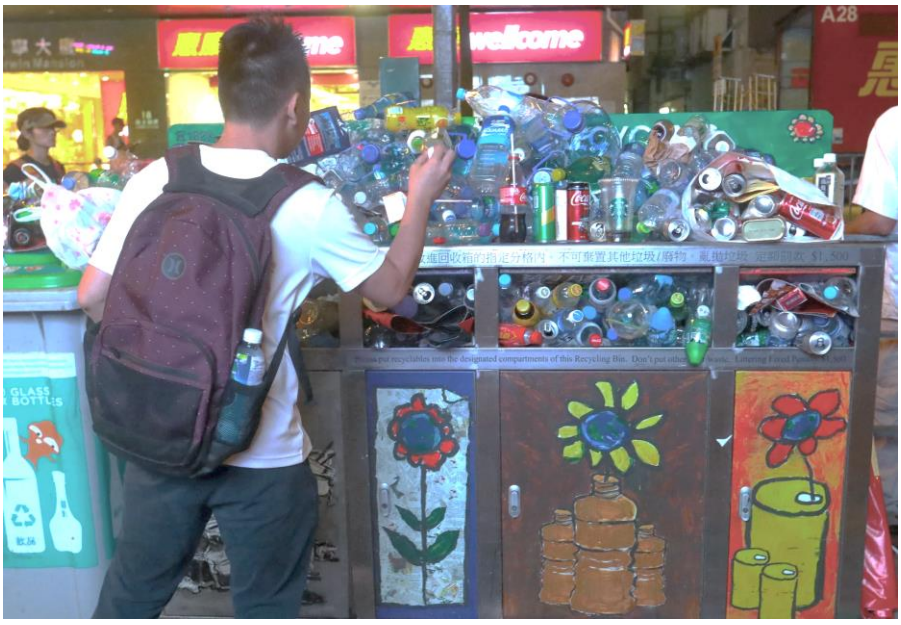


Figure 3: Roadside three-coloured bins to be phased out (Picture source: SCMP)

The above developments point to a need for a more efficient and convenient recyclables collection and sorting system. In order for recyclables to be processed into the end-product and generate value, there needs to be sufficient granularity in the sorting. For example, plastics need to be further separated into Type 1 (PET) and Type 2 (HDPE) plastics as a minimum. More advanced separation of materials (label, cap of bottles) will also occur in either sorting or processing facilities further downstream. Sorting also removes any contaminated recyclables which will impair the quality of the end-product. For example, bottle labels made from PVC are considered as contaminant in Hong Kong's mechanical recycling pathway and must be removed in a mechanical process.

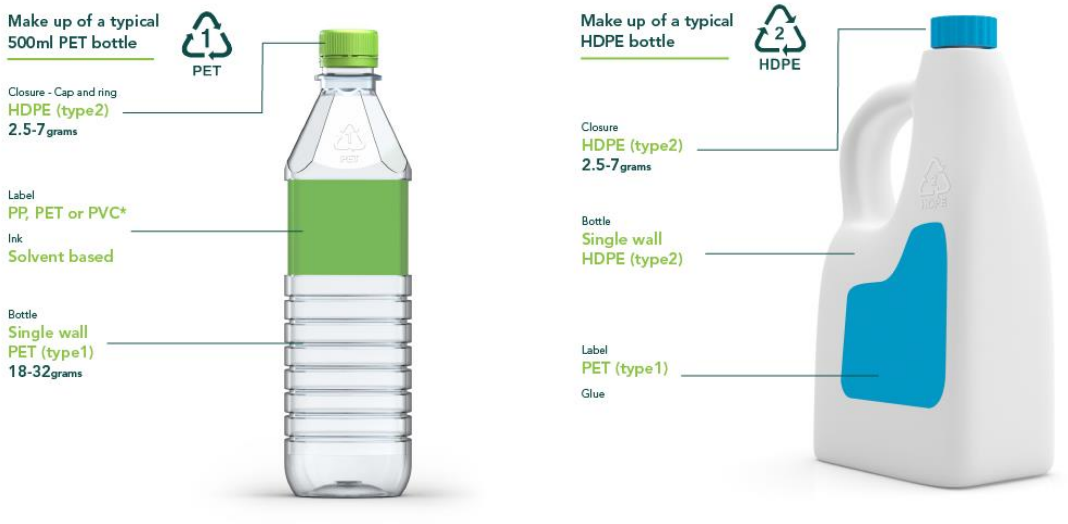


Figure 4: The material makeup of the different components within Type 1 (PET) and Type 2 (HDPE) plastic bottles (Source from New Life Plastics Website)

It is therefore important to note that a significant amount of sorting is required to be carried out on recyclable streams before they can meet the stringent requirements of processing. The method of sorting varies between recycling contractors. Larger contractors may be able to adopt more mechanised and automated sorting facilities, for example, Baguio adopts Near-Infrared technology to one of its plastic-specific MRF which automates and accelerates the sorting procedure. However, other operators of smaller scale might still rely on manual sorting by staff. Such a type of manual sorting comes with many disadvantages: i) it is staff-intensive, ii) nature of work is low-skilled, iii) there is significant occupational hazard associated with this nature of work, for example if staffs are not provided with sufficiently protective gloves, injuries could occur during sorting by hand. The key is that the sorting equipment available in the market have reached sufficient maturity, offering cost-competitiveness as compared to manual labour, the compactness of the equipment is also a benefit in the context of Hong Kong. More considerations on the feasibility, location, and logistics of installing such MRFs equipment will be discussed later in the report.

Figure 5: Left: Manual sorting facilities are still common across HK (Source: SCMP)
Figure 6: Right: Example of a compact and automised sorting equipment (Source: Van Dyk Recycling Solutions)

Key recommendation

A manual and decentralised system causes inefficiencies, and therefore, the main argument of this report is a small number of automated and centralised MRFs could be considered as an alternative option that could bring benefit to operators and the wider community.

Lastly, on the aspects of **recovery** and disposal, the Government has announced the expansion of the North East New Territories Landfill to provide an additional capacity of 21 million cubic metres, almost doubling its existing capacity; and the proposal of a second incinerator [6]. However, incineration is a less-than-ideal means for energy generation for the following reasons:

1) Waste incineration is not itself a source of renewable energy, given that most products that becomes waste are sourced from finite resources
2) Incinerators become a long-term financial burden for the government, and a constant waste-stream is needed to maintain operational cost of the facility, which at certain extent opposes the rationale to reduce waste
3) Incinerating rather than recycling materials strips the economic potential of building up a circular eco-system

This report would like to emphasise that waste incineration should be the last resort of waste treatment, coming after recycling as burning recyclables only contribute to a small proportion of power need, as compared against the material values of the recyclables.

2.2 Waste Composition (Domestic vs Commercial/Industrial, Types of Materials)

Table 3: Composition of MSW disposed at Landfills in 2021 (Source: Endnote 4)

Composition of MSW disposed at Landfills in 2021 (tonnes per day)						
Material	**Domestic**	**%**	**Commercial and Industrial**	**%**	**Total**	**Total %**
Glass	129	2%	91	2%	220	2%
Metals	120	2%	141	3%	261	2%
Paper	1,321	19%	913	21%	2,234	20%
Plastics	1,342	19%	989	23%	2,331	21%
Putrescibles (e.g., Food Waste)	2,510	36%	1,166	27%	3,676	32%
Textiles	252	4%	152	3%	404	4%
Wood	51	1%	211	5%	262	2%
Household Hazardous Wastes	92	1%	51	1%	143	1%
Others	1,177	17%	650	15%	1,827	16%
Total	**6,992**	**100%**	**4,365**	**100%**	**11,357**	**100%**
Domestic and C&I % to MSW Total	**6,992**	**62%**	**4,365**	**38%**	**11,357**	**100%**

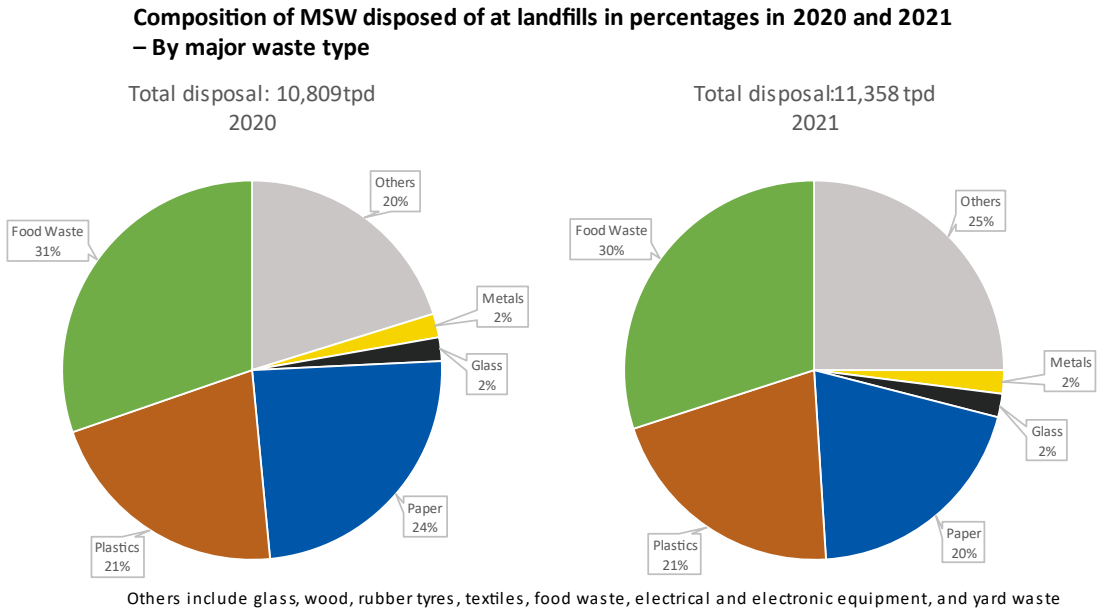


Figure 7: Composition of MSW disposed of at landfills in percentages in 2020 and 2021

The table and figure above provide the following key observations:

1) Domestic waste makes up of the majority of MSW at 62%, compared to commercial and industrial waste at 38%.
2) Food waste, plastic, and paper are always among the top three types of waste disposed of in landfills, accounting for more than 70% of MSW.
3) Food waste accounts for 32% of MSW, with domestic stream making up a larger portion.
4) The volume of paper and plastics MSW to landfill is significantly higher than other recyclables such as glass and metals

The first observation supports the latest proposal by Chief Executive John Lee Ka-chiu in his first Policy Address[7]. The Government will begin to explore legislation for mandatory recycling at housing estates of more than 1,000 families and single buildings with 100 households or above before 2024. The implementation if successful will push up the volume of recyclables collected and the recovery rate in the domestic MSW stream.

The second observation points out that establishing a robust food waste recovery system would be one of the key strategies that need to work in tandem with the upcoming policies and the possibility to establish MRFs. This is because food waste is a major contaminant to recyclables, particularly to paper. And without the separation of food waste as a first step, recyclables will be susceptible to contamination, even with the establishment of a MRF further downstream. Currently, food waste bins are being piloted in housing estates but recent malfunctions call for optimisation to both the hardware and software before it can be widely adopted.

The third observation is largely due to the low value of paper and plastics as compared to other recyclables such as metal. This makes it harder for recyclers to profit from recycling these two materials and reduces their incentives to do so. Moreover, plastic should be treated differently from other organic waste due to its non-biodegradable nature, which results in the magnitude and scale of plastic pollution across the world. MRFs operation could potentially lead to a larger volume of paper and plastics being processed and recycled, enabling more economic incentives for market players on such material streams.

Case Study and Key recommendation[8910]

Regarding the Commercial and Industrial MSW stream, a key difference to note is that property management companies must pay waste management companies to collect both its general waste and recyclables in commercial buildings, whereas for residential buildings, this operation is covered by the Government. The incentives for both commercial and residential buildings to recycle remain insufficient. One of the property management companies in BEC Circular Economy Advisory Group has shared that after performing internal financial analysis, the cost of sending plastic recyclables to landfills and paying the gate charge, is roughly the same as the cost of hiring a plastic recycler to collect and send the plastic for processing. In the upcoming MSW charging scheme, Commercial and Industry ("C&I") sectors will be charged HK$395 per tonne, at four urban refuse transfer stations (Island West, Island East, West Kowloon and Shatin) and the North West New Territories Transfer Station, and HK$365 per tonne at other refuse transfer stations and landfills, respectively. The gate fee remains relatively low compared to other countries, On the other hand, to minimise the amount of MSW sent to landfills and increase incentives for recycling, there is a landfill tax in the United Kingdom which is constantly increasing. In 2020, it costs around HK$1100 (£116) per tonne to dispose waste to landfills including landfill tax while it only costs around HK$400 (£43) per tonne to send recyclables to MRFs. The latest landfill tax rose from HK$890 (£94.15) per tonne in 2020 to HK$932 (£98.60) per tonne in 2022.

An underlying reason for this phenomenon is that recycling operations, particularly for plastic is not profitable for recyclers. And hence, if there could be optimisations in their operations, such as for MRFs to improve the quality and quantity of recyclables, recyclers could potentially make significant cost-savings, and this cost-saving could be passed onto their customers as a lower cost for recycling. Therefore, if the Government were to investigate policies that increase the recyclables recovery rate for commercial buildings, they would look beyond solely subsidising the cost, but ways to facilitate a more efficient and economically-viable downstream treatment process – where MRFs have the potential to contribute.

2.3 Effectiveness of the Recycling Ecosystem in Hong Kong and Abroad

During BEC's Circular Economy Advisory Group's site visit to New Life Plastics, the first local recycling plant to produce food-grade plastic bottles, the operator noted that the plastic recycling plant is currently not operating at full capacity. In fact, this has been the trend for most plastic operators in Hong Kong even prior to the pandemic. However, for recycling plants to run on an **economically viable scale**, there needs to be a sufficient level of input recyclables (rationale: high fixed cost of operating equipment and hiring staff, low marginal cost of additional unit of recyclables processed). This causes the irrational phenomenon for local recyclers to import waste to operate plants, even if there are large amounts of recyclables disposed locally which are going to landfills, or even exported.

This practice is partially limited by the introduction of regulations limiting transboundary movement of wastes. The shock to the recycling eco-system from Mainland China's ban on importing unprocessed plastic waste is furthered by the amendment to the Basel Convention, which also applies to neighbouring countries starting from 2021. The local recycling industry needs time to adjust and adapt to such changes affecting the global trade market. And naturally, MRFs will be an obvious solution to facilitate the retention of local recyclables to be processed at maximum capacity without reliance on export or import. Below is a diagram that illustrates the mechanism of this phenomenon.

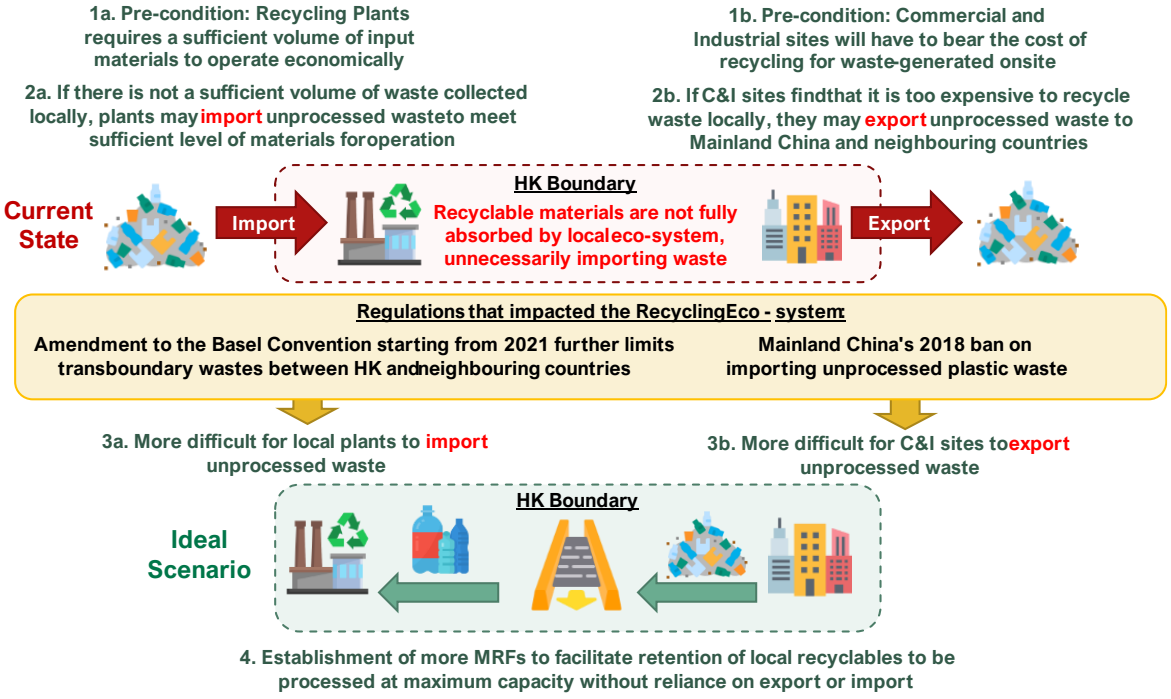


Figure 8: Current Recycling Eco-system and potential for MRFs to improve efficiency (Figure generated for this report)

Another consideration is that local recyclers are greatly impacted by 1) the market price of the processed recyclable (e.g., plastic pellets) and 2) the market price of virgin plastic pellets, which is a competitive product of processed recyclable (in the case without any government mandate on restricting its use). The underlying factor which influences the price of virgin plastic pellets is the price of oil/petroleum, the raw material of which is it derived from. Global demand and supply of oil is subjected to geopolitical events and hence it is prone to drastic fluctuations. In October 2019, the cost of virgin plastic became cheaper than its recycled counterpart by US$72 (HK$558) per tonne [11]for the first time, following a historic drop in the price of oil. This causes recycled plastic pellets to lose competitiveness, and plastic recyclers to struggle to stay in business. In contrast, the oil sanctions on Russia in 2022 has pushed up the prices of oil to the extent which is felt through an increase in electricity tariffs in Hong Kong, with the overall effect on recyclers still unclear. The need for the local government to impose price regulations on such materials to secure the recycling industry will be explored in the recommendations section of this report.

Figure 9: Left: Different grades of plastic recyclables separated by New Life Plastics Facility, with food-grade plastics having the highest value but hardest to derive due to stringent requirements and quality of incoming plastic waste stream. Other recycled plastics have wide application such as in the apparel industry. (Photo from site visit)
Figure 10: Right: Oil and gas companies are diversifying their businesses away from crude oil and natural gas to the production of virgin plastics. Relatively, its production faces a lot less scrutiny despite sharing the same depleting raw material and adverse effects[12].

3 International Examples

3.1 Example of Material-specific Clean MRFs from South Korea [13141516]

Ambitious waste management policies, downstream processing as joint effort by private companies and government

South Korea has one of the more advanced waste management systems in the world. In 2017, South Korea's waste recycling rate was 86% and each Korean citizen generated 1.02 kg of household waste per day, one third of the amount in 1991. South Korea has introduced different waste management policies to reduce waste generation and protect the environment. Separate disposal of recyclable waste and the Volume-Based Waste Fee (VBWF) system are two of the country's most effective waste management policies dated. South Korea's Extended Producer Responsibility (EPR) scheme also obliges product manufacturers to collect and recycle waste from their products.

To encourage the involvement of residents, informative notices and letters were sent to all companies and entertainment-related business places within each district boundary. It is compulsory for residents and commercial companies to collect and separate recyclables in South Korea. Recyclables include paper, glass, plastic, iron scraps, styrofoam, milk cartons, fluorescent lamp, and plastic bags. Local governments and private haulers are responsible for the recyclable collection and separation. Private companies and collectors are responsible for the purchase and treatment of valuable recyclables, while the local government will handle the remainder for the final treatment. Such ecosystem of recycling contributes to the success of a high recycling rate in South Korea. Below table indicates the types of recyclable categories in South Korea.

In Hwaseong, Gyeonggi-do, there is a plastic waste recycling facility with the functions to plastic sorting and production of high-quality recycled plastic. The recycling facility produces r-PP pellets through the process of sorting, crushing, cleaning, and pelletising and manufacturing compounds from pellets. The recycling facility recycled PP pellets and PP compound of more than 20,000 and 34,000 tons per year. The PP pellet could be used in different business sectors such as packaging (films, bottles), textiles (industrial fibre, fine denier fibre), agriculture (pipes), home and appliances (furniture), automotive (interior), industrial and logistics (buckets) and building and construction (spacers).

Apart from plastic waste recycling, there are other recycling facilities that process different materials. For example, paper recycling facilities sort newsprint, printing paper, cardboard, and other materials to produce newspapers, office papers, commercial catalogues, and textbooks. In aluminium recycling facilities, magnets are used to extract aluminium and other non-ferrous metals. After shredding, cleaning, and melting, alloys are created and transported to manufacturing plants to be made into new products.

Table 4: List of Recyclable Waste in South Korea[17]

Categories	Items
1. Paper	• Newspaper
	• Book, note, paper bag, calendar, packaging paper
	• Paper cup, Paper pack
	• Box (snacks, packaging, others)
2. Cans	• Steel can, aluminium can (drink, food)
	• Other cans (butane gas, pesticide container)
3. Bottles	• Drinking water bottle, the other bottles
4. Metal	• Scrap iron (engineering utensil, wire, nail, iron board, etc)
	• Nonferrous metal (nickel silver, styrene, electric wire)
5. Plastic	
- Extended polystyrene	• Fruit box, etc
- PETE (1)	• Drink bottle (coke, soda, juice), water bottle
- HDPE (2)	• Water bottle, shampoo and detergent container, white rice wine bottle
- LDPE (4)	• Milk bottle, rice wine bottle
- PP (5)	• Boxes (beer, coke, soju), garbage can, dustpan, water gourd dipper
- PS (6)	• Yogurt bottle, shawa bottle
6. Textiles	• Cotton
	• Other clothes
7. Waste from farming village	• Pesticide bottle
	• Waste vinyl for farming
8. Others	• Recyclable items depend upon regional circumstances

3.2 Example of Clean MRFs from East London, United Kingdom[1819]

MRF as a means to maintain high recovery rate and safeguard quality

The Greater London Authority has its vision to turn London into a zero-waste city in which no biodegradable or recyclable waste will be sent to landfill by 2026 and recycle near two-third of London's municipal waste by 2030. To achieve this vision, waste in London is processed through innovative channels to maximise recycling, including MRFs and subsequent energy recovery facilities.

Bywaters (Leyton) Limited owns and operates Lea Riverside Clean MRF to accept the broadest range of recyclables from both the municipal and commercial sectors in London. The MRF processed more than 80 000 tonnes of recyclables annually with two daily shifts. Mixed recycling offers an option to recycle various materials, including paper, cardboard, plastic containers and films, ferrous and non-ferrous metal, and glass, without segregating them at source. After collection, mixed recycling is mechanically sorted into materials that can be recycled. The recovery rate of MRF reached 96-98 per cent after upgrading the sorting line. The MRF helps safeguard the quality of the recyclables to satisfy the market requirements and fetches higher price.

Figure 11: Picture of sorting line at Lea Riverside MRF

4 Recommendations for MRFs

The previous sections illustrated the current state and challenges in the recycling eco-system in Hong Kong and presented MRFs as a potential solution for increasing the volume and quality of the recyclables. The following section aims to provide recommendations for MRFs that could be transforming or integrated into existing system and are feasible in the short-term. Recommendations that would disrupt and diverge from the existing system but has the potential to achieve greater efficiency will also be explored in a hypothetical manner.

4.1 Government Intervention for Setting-up MRFs

While the recycling industry is decentralised in general, with more than 800 recycling companies[20] registered with EPD, there are only a few key players which make up a sizeable portion of the market. None of these recyclers currently operate on a scale large enough to justify for the need to establish a large-scale MRFs. If the Government was to adopt a market-driven approach and leave it for recyclers to decide on the necessity of MRFs in their own accord, there may not be many incentives to do so.

However, if the Government also believes that MRFs of such a scale would bring greater efficiency to the recycling industry and wider economy, intervention would be necessary. A certain level of disruption to the recycling industry is inevitable in this case, with recyclables absorbed and sorted by bigger players, while smaller recyclers may be driven out of business. This also leads to the consideration of the ownership of MRFs. **The Government can choose to either subsidise or fully fund the set-up and operations of MRFs.** The latter arrangement would be similar to that of the Refuse Transfer Stations, O•Park, T•Park and WEEE facility (ALBA being the operator).

Initial fiscal injection has the potential to optimise logistics, sorting and facilities, which in turn increase quality and volume of processed recyclables, and eventually allow for eco-system to be robust enough to be self-sufficient. **Financial analysis would be the key tool to help the Government determine the appropriate mechanism and amount of the financial injection. Also, the Government needs to carry out cost-benefit analysis between continuing to expand landfills versus establishing MRFs to realise its value. A gradual**

transition from refuse transfer stations to adopting MRFs could take place, with residual waste from MRFs sent to incinerators to recover energy instead of landfilling. Given the complex nature of these financial analysis (for example, a cost-benefit analysis requires net present value, discount rate and their assumptions), the Government should employ external parties and experts to conduct such financial analysis where appropriate.

4.2 Specifications of MRF Set-Up

The specifications of MRF set up, including the type of MRF, number, and concentration of the MRF facility will be assessed in this sub-section under two scenarios, drawing insights from stakeholder interviews.

Table 5: Two proposed Scenarios of MRF Set-up

	Scenario 1	Scenario 2
Type of MRF	Material-specific Clean MRF, with recyclables coming from Green@Community e.g., Recycling Stations, stores and spots, and smart recycling system	Clean MRF, with a mix of different recyclables, e.g. case study in United Kingdom
Number and Concentration of MRF facility	Several decentralised smaller MRF facilities, located close to refuse sorting rooms, and shared between districts depending on recyclable volume	Centralised larger MRF facilities, 1-2 MRFs, located next to landfill or incinerator plants

In Scenario 1, assuming that the current recyclable collection and sorting system will be maintained, the type of MRF that would be compatible would be the Material-specific Clean MRF. Under this scenario, a more decentralised MRF system with smaller facilities would be appropriate. This is because the sorting requirements are less complex when the input is just one recyclable material, with the main purpose as removing any contaminants. This will allow for more lightweight MRF technologies and equipment (as mentioned in Section 2.1 in this report) to be used, and in turn, allow these facilities to be less intensive and fit into space-restrictive urban areas. One stakeholder has proposed that a feasible concentration of these MRF facilities could be at 7-8 stations across Hong Kong, with some being shared between districts, depending on the waste volume generated in each. Another stakeholder has also expressed that such facilities could be

accommodated in 'dead-space' across the city, such as bases of the flyover columns as long as they are accessible by trucks. Different to general waste stream, the odour coming from a recyclables stream would be relatively less, and hence there are more flexibility in its location. The matter of location of MRFs will be more closely examined in the next subsection.

In Scenario 2, a single-stream recyclables collection is hypothesised. This is based on one stakeholder's view that the logistics associated with single-stream collection would be more streamlined and space-efficient. Such a proposal has some basis for consideration in Hong Kong, given that for a lot of residential or commercial buildings struggle to find space that could accommodate all three coloured bins, in a location that is still convenient for citizens. More analysis on this upstream waste collection could be found in BEC's report on "Zero Waste Design for Buildings in Hong Kong (Link)". If Hong Kong transforms to such a single-stream collection system, Clean MRFs would be the appropriate option, requiring 1-2 facilities across the city, and operating at a larger scale. The advantage of such MRFs would be that volume of the incoming recyclables stream should enable the facility to run at a scale that is economical. And processed recyclables could be transported or export in a centralised manner to processors downstream.

Overall, both scenarios have their strengths and weaknesses to consider in Hong Kong. Scenario 1 would be a good fit for the current waste management system in Hong Kong, as the collection and sorting system has been developed over the decades. However, it is difficult to further increase the recovery rate in the long run due to its limitations, as it requires more efforts and disciplines from businesses and citizens.

Although Scenario 2 requires a fundamental transformation of the waste management system, it has the potential to leapfrog the recovery rate in Hong Kong, as this can address situations when sorting at source are challenging. This scenario has become increasingly popular worldwide in recent years due to its convenience. It makes recycling easier for the public by assigning sorting responsibility to the recycling facility. This approach could potentially increase the volume of recyclables collected from households and the recovery rate of recyclables in Hong Kong.

In any case it is important that the Government should consider banning recyclables from being sent to landfills with penalty mechanism (beyond or in complement with the MSW charging scheme) to boost recyclable collection and subsequent recycling.

The Government should also work closely with the recyclers to understand their needs and also internally with the Planning Department and other Bureaux / Departments (B/Ds) to best situate such MRF facilities. More considerations on urban planning will be discussed in the following sub-section.

4.3 Strategic Urban Planning and Effective Land Use

According to the Asian Development Bank, when locating MRFs, accessibility, land use, and geology need to be considered. MRFs should be sited in flat and stable areas that are close to existing roads, but traffic flow due to the movement of waste collection trucks should also be considered. These facilities must be located close to or within urban areas that maximise the collection of recyclables. MRFs should also be considered for locations in the industrial zone or close to landfills to facilitate the efficient movement of recyclables and wastes.

One of the biggest challenges faced by recycling or waste management companies is the lack of space for operating recycling facilities. Waste management policies should work in conjunction with strategic urban planning and effective land use. The figure below summarizes the barriers that the recycling industry may face.

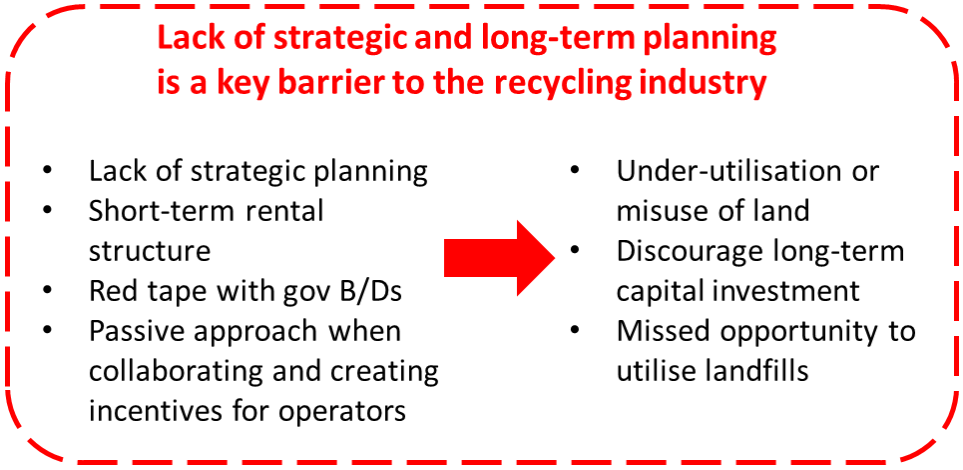


Figure 12: Key barrier to the waste management industry

The points above are not new and not unique to the recycling Industry. The recycling industry faces a two-fold challenge when trying to establish a facility of any scale. First, the relevant government bureau(x) or department(s) would have to permit the land for usage; and second, the recycling industry would have to compete for its usage against many other industries or purposes that are seen as a priority by the Government. There is some encouraging progress, for example with some areas under flyovers being utilised as Green@Community mobile stations. The initiatives would be useful for recycling collection, however, it could not be a long-term recycling facility.

Figure 13: Top left and right: Under-utilised urban spaces that are used as parking space or left empty. Botton left and right: Progress seen in urban space utilisation for waste management or recreational purposes (Pictures from Carparkhero[21], HK01[22], Sham Shui Po Recycling Station[23], Energizing Kowloon East Office[24])

As mentioned in the sub-section above, setting up MRFs of smaller scale would have the potential to utilise such urban spaces, which would enable sorting close to source. However, if setting up MRFs of larger scale would also one day come to picture, then more strategic and future-looking planning would be needed. Two stakeholders have interesting proposals for sites which would be appropriate for larger scale MRFs:

Vertical Space in Industrial Buildings

Singapore shares the same compact nature with Hong Kong, and hence, their first multi-story recycling facility, Kranji Green, presents as a valuable case study for Hong Kong. The recycling facility is also strategically located next to two factories processing timber and metal: recyclables from production would immediately be sent for recycling with minimal logistical needs, and three facilities have shared services onsite which maximises synergy. The figure below shows the specifications of the building interior, including floor loading and ceiling height:

Figure 14: Kranji Green Interior Specifications Requirements[25], layout of the multi-story recycling facility in Appendix D.

In the context of Hong Kong, many areas with existing industrial buildings have the potential to accommodate similar scale of MRFs that could serve the area. In particular, such options should be explored in new development areas that are with new roads (e.g. Hung Shui Kiu, artificial islands in the central waters). Sites in Kwun Tong may absorb a lot of the residential as well as commercial recyclables, but logistics may present problematic challenges.

Saturated Landfill Sites

Below is an extract taken from EPD's site detailing closed landfill sites in Hong Kong:
"*There are 13 closed landfills in Hong Kong that collectively occupy a total area of about 300 hectares. They take up enough space to accommodate 15 urban parks of the size*

of Victoria Park. These closed landfills need to be restored to minimise their potential adverse impacts on the environment and to render them safe for beneficial use."

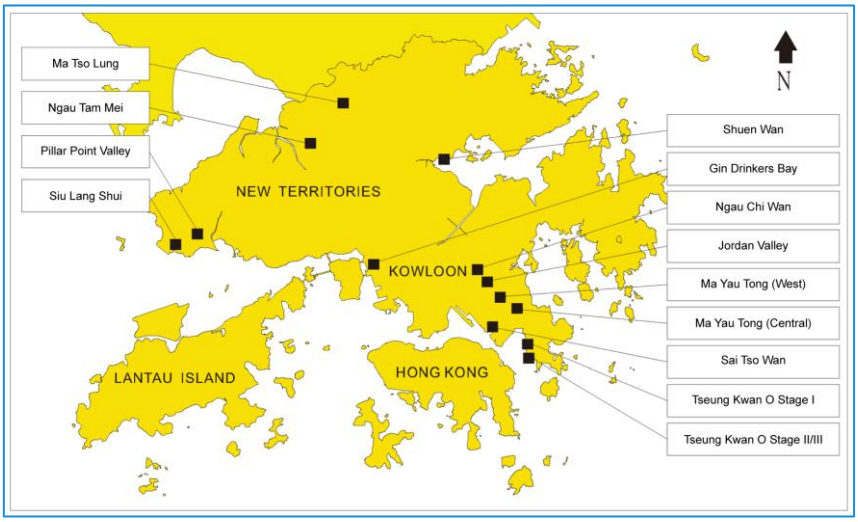


Figure 15: Location of 13 Closed Landfill Sites in Hong Kong[26]

Currently, these sites are (or are planned for) recreational uses such as parks or golf courses. There has always been reluctance for residential property to be built on top of saturated landfill sites, mainly due to the concerns of the release of methane gases, settlement and construction impacts. The stakeholder that was interviewed believes that this is why landfill sites would be ideal to be returned for the purpose of waste management activities, given that the site has passed safety assessment (e.g., on sinkage rates). Moreover, the stakeholder points out that a typical MRF facilities could likely be accommodated in a one-story building, and hence, would not create a large load that compromises the site. Such a facility is present in Santa Barbara, US, where a large scale MRF facility is built on an active landfill site.

Figure 16: The Tajiguas Landfill in Santa Barbara is adding a MRF and anaerobic digestion for organics, which is expected to extend landfill life by about a decade[27].

In Hong Kong, landfill sites and other waste infrastructure are owned by the Government while multi-year operational rights are granted to waste management companies. While building MRFs on saturated landfill sites represents new opportunities for recycling companies, they are relatively passive under the current system, the Government holds the power on deciding MRFs feasibility, design, site selection, tendering details, etc. In the future, the Government should further consult with companies with MRFs operating experience to understand the business case of MRFs.

4.4 Increasing Incentives for Commercial Sector to Recycle

As discussed in the previous section, one issue with Hong Kong's waste management hierarchy is the low gate fees (or landfill tax) for commercial and industrial (C&I) sectors to dispose of municipal solid waste (MSW) at landfills, compared to overseas examples. This has resulted in some C&I companies choosing to dispose of recyclables at landfills instead of recycling them. In the United Kingdom, the landfill tax is reviewed regularly and increases annually, from HK$781.3 (£80) per tonne in 2014 to HK$932 (£98.60) per tonne in 2022. Therefore, the cost of sending recyclables to MRFs is undoubtedly lower than disposing of MSW at landfills, which costs around 45% of the landfill tax (HK$420, £43). It is clear that C&I sectors are more willing to recycle.

A low landfill tax can have a significant negative impact on the environment. When landfill taxes are set too low, it can encourage companies to dispose of their waste in landfills, which can lead to an increase in the volume of waste sent to landfills. This can be particularly problematic when it comes to recyclable materials. When recyclable materials are disposed of in landfills, they take up valuable space. Furthermore, when recyclable materials are not properly recycled, it can lead to resource depletion and contribute to climate change. For example, if a plastic bottle is not recycled, it may end up in a landfill where it will take hundreds of years to decompose. During decomposition, plastic can release harmful chemicals into the environment.

To address these issues, the Government could consider increasing gate fees considerably for C&I sectors to dispose of MSW at landfills. This would incentivise companies to recycle more and reduce the amount of waste sent to landfills. Additionally, the Government could explore other measures such as providing tax incentives for companies that recycle and investing in recycling infrastructure to make it easier for

companies to recycle. Furthermore, the Government should introduce regulations to ban recyclables sending to landfills or incinerators, which ensure all recyclable materials are recycled and minimise waste of finite resources. By taking these steps, the city can work towards a more sustainable recycling system that benefits both the environment and the economy.

4.5 Establishing a Robust Eco-system for Processed Recyclables

For MRFs operations to become economically viable and self-sufficient in the long-term without relying on financial injections, there needs to be a robust eco-system for processed recyclables, given that the price of the processed recyclables is the main source of income for recyclers.

Recently, manufacturers are sourcing more recycled materials in their production as a means to achieve a circular economy. A notable example of initiatives is the upcycling of recycled plastic by 'EcoBricks'. **The Government should embrace such initiatives that make use of recycled materials in their businesses, like the case of using recycled plastic as fabric material in the apparel industry.**

5 Figure 17: EcoBricks upcycles recycled plastic and locally manufactures them into building bricks, contributing to the prevalent issue of reducing embodied carbon in the local construction industry (Source: EcoBricks Website[28])

However, the capacity for the local manufacturing industry in Hong Kong to absorb processed recyclables is still low, and it is not economical to export processed recyclables when most countries also have their own processed recyclables stream. Another challenge is that the price of processed recyclables is subjected to price fluctuations based on market needs. Considering these factors, **this report recommends the following actions from the Government:**

1) Promote and prioritise circular business models that source processed recyclables;
2) Enforce legislative measures (e.g. eco-procurement) to support the market competitiveness of processed recyclables against the virgin materials; and
3) Encourage also the use of local over imported processed recyclables for local manufacturing whenever possible.

Figure 18: Proposed funding streams for establishing MRF operation and promoting a more robust recyclables eco-system (Figure generated for this report)

The Government cannot hastily withdraw financial support before a robust eco-system is established and has proven to be sustainable. This is demonstrated by the 'Neighbourhood Bottle Reward Scheme' conducted by Drink Without Waste, which is a 10-month pilot scheme to subsidise the recycling of plastic bottles. As observed in the study report[29] (Table 9, page 47), the volume of plastic beverage bottles dropped quickly and significantly right after the cessation of the subsidy. This suggests that the recycling industry has not had time to develop and diversify an income stream that leverages the recycled plastic.

6 Conclusion

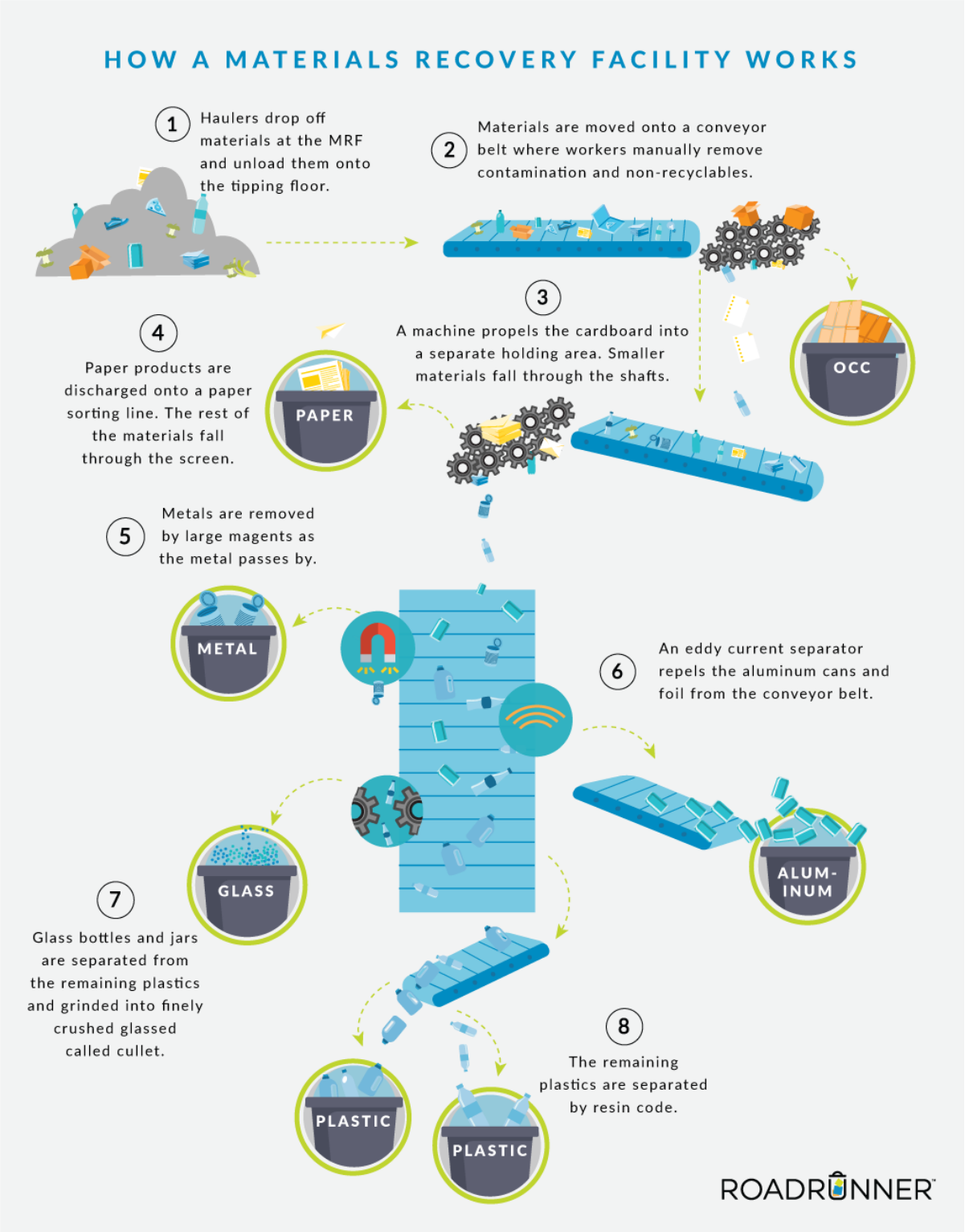
To recap this report, there is no doubt that the waste management in Hong Kong is undergoing substantial changes, with MSW charging scheme and upcoming legislation on single-use plastic ban, and producer responsibility scheme on beverage cartons. The changes also present a timely opportunity to examine whether the establishment of MRF is feasible and have the potential to propel and maximise the benefits from other initiatives.

More efforts are needed to change the Government and citizens' mindset to see waste management as profit-generating operation and green growth engine for Hong Kong, and understand the equal importance to other utilities and services within a city such as electricity and water. Only when waste management moves up in policy priority will there be a possibility of exploring the establishment of advanced MRFs. In the future, the Government should leverage industry know-hows from operators/recyclers and construct MRFs that fits in with the existing properties and constraints of the recycling eco-system. The Government also needs to work internally to remove any barriers that prevent the waste/recycling industry from utilising available land and ensure that mechanisms are in place to support long-term growth (such as long-term rental agreements).

Another factor that cannot be disregarded is the importance of product design and business models that enable circularity. This would require efforts from both the Government and private sector. For MRFs operation, an action point from companies would be to tweak their products so that the materials used are homogenous, and without materials that are considered a contaminant in the local recycling pathway. Business models would be harder to alter given that Hong Kong is still dependent on import/export markets and are subjected to market fluctuations. If the Government were to maintain a market-led approach without price control, then softer solutions such as subsidy schemes would be one of the options build robustness in the eco-system and improve self-sufficiency of the recycling industry in the long-term.

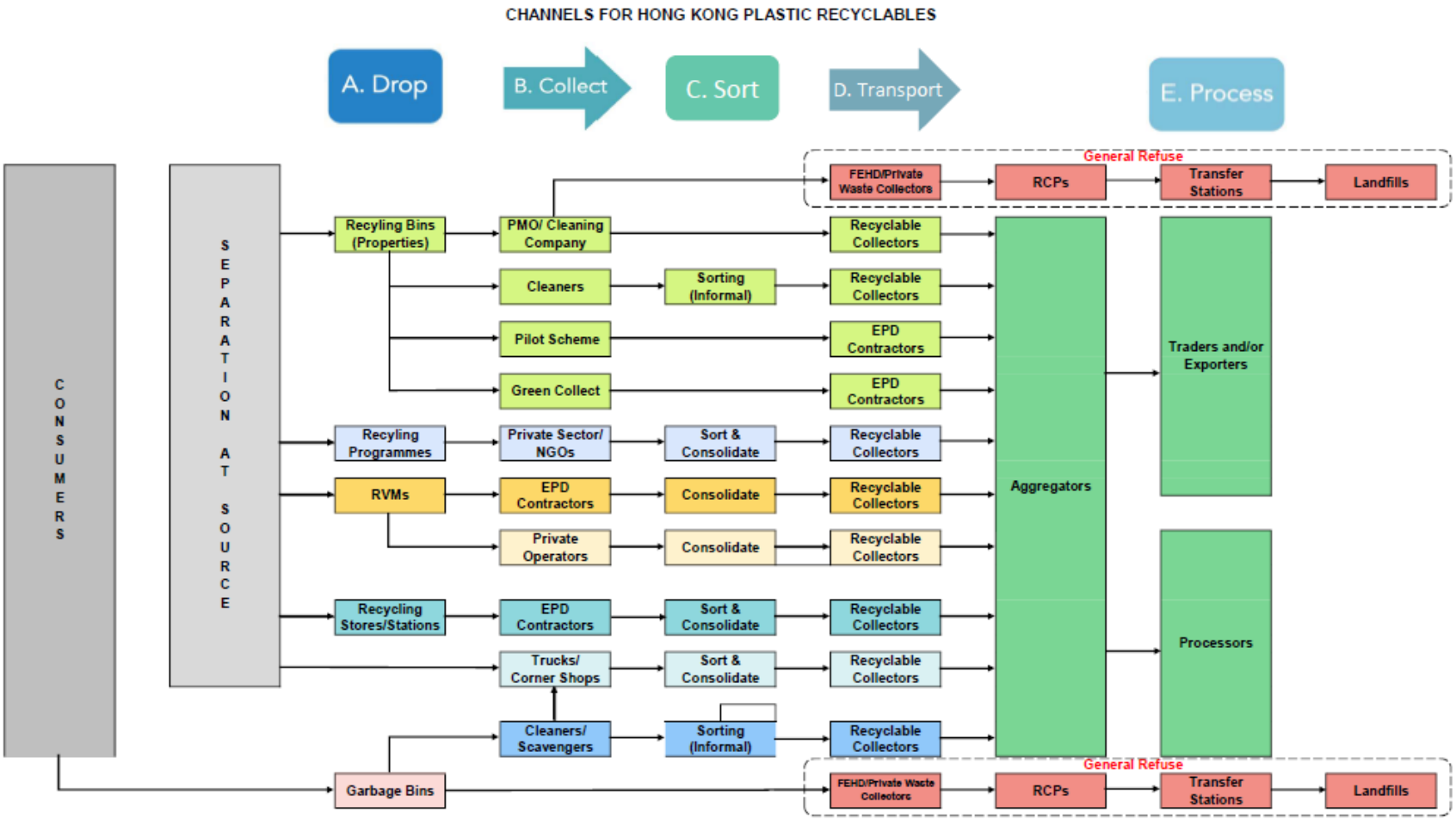
Appendix A

Mechanism of a Non-material specific Clean MRF (Separating paper, metals, glass and plastic). Source: Road Runner, Smarter Recycling blog (Oct 2019) Available from: Link



Appendix B

Mapping of the channels for plastic recyclables in Hong Kong (Source: Drink Without Waste)



Appendix C

Asian Development Bank: Material Recovery Facility Toolkit (2013) Publication Link

Example of a Financial Analysis of a Materials Recovery Facility

Table 8 Sample Financial Analysis of a Materials Recovery Facility

	Population	100,000							
	Kg/capita	0.6							
	Waste generated	60	tons						
	Collection efficiency	70%	Fraction of waste collected						
	Waste collected	42	tons	Recovery	50%	Fraction			
	Waste Components		tons	Recycled	Price P/Ton	Revenue P			
	Paper and carton	6.2%	2.604	1.302	3,000	3,906			
	Aluminum can	2.1%	0.882	0.441	60,000	26,460			
	Metals	5.3%	2.226	1.113	5,000	5,565			
	Plastic bottle	3.1%	1.302	0.651	20,000	13,020	P Million	P Million	
	Food waste	32.7%	13.734			48,951	17.867	7	10.867
	Other organics	21.4%	8.988			Total/day	Sale/year	O&M	Net revenue
	Other inorganics	28.9%	12.138						
	Special waste	0.3%	0.126						
	Total	100.0%	42						
	Investment	Equity	Debt	Interest	Income	Dividend	Repayment		
	68.5	30%	70%	8%		15%			
Year 0	68.500	20.550	47.950	3.836	7.031	3.083	3.949		
Year 1	64.551	20.550	44.001	3.520	7.347	3.083	4.265		
Year 2	60.287	20.550	39.737	3.179	7.688	3.083	4.606		
Year 3	55.681	20.550	35.131	2.810	8.057	3.083	4.974		
Year 4	50.707	20.550	30.157	2.413	8.455	3.083	5.372		
Year 5	45.335	20.550	24.785	1.983	8.884	3.083	5.802		
Year 6	39.533	20.550	18.983	1.519	9.348	3.083	6.266		
Year 7	33.267	20.550	12.717	1.017	9.850	3.083	6.767		
Year 8	26.500	20.550	5.950	0.476	10.391	3.083	7.309	Cost recovery in 8 years	
Year 9	19.191	20.550	-1.359	-0.109	10.976	3.083	7.893		

kg = kilogram, O&M = operation and maintenance.
Calculations at constant prices and constant input.
Source: Authors.

Appendix D

Layout of the Kranji Green Multi-Story Recycling Facility in Singapore adapted from JTC Corporation. Source: JTC Corporation (link)

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Interviewees

(by company name, listed alphabetically)

ALBA Group Asia

Arup

Drink Without Waste

New Life Plastics Ltd

BEC Staff

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Business Environment Council Limited ('BEC') is an independent, charitable membership organisation, established by the business sector in Hong Kong. Since its establishment in 1992, BEC has been at the forefront of promoting environmental excellence by advocating the uptake of clean technologies and practices which reduce waste, conserve resources, prevent pollution and improve corporate environmental and social responsibility. BEC offers sustainable solutions and professional services covering advisory, research, assessment, training and award programs for government, business and the community, thus enabling environmental protection and contributing to the transition to a net-zero economy.

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