

Zero Waste Design

for High-Density Cities

New York City, Hong Kong and Singapore



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Zero Waste Design Guidelines

The Zero Waste Design Guidelines were developed in New York City to address the crucial role that design of the built environment plays in achieving circular material loops. Since their launch in Oct 2017, they have been disseminated and implemented widely and the Center for Zero Waste Design was set up to broaden their reach.

The guideline is an interdisciplinary effort of experts in waste management and the design and development of buildings and cities. It required extensive collaboration, workshopping and on-the-ground field research with more than 40 building site visits and conversations with building porters and supers. The aim was to develop practical recommendations but also provide inspiration for improving the quality of life in the built environment, with a basis of understanding that the design of our buildings and city is crucial in reaching zero waste goals.

Although the guideline's design and development are based in NYC, its' many strategies are adaptable and can be accommodated to the conditions and requirements of the cities. The strategies are compiled as a tool for those responsible for planning, constructing and managing buildings, streets and neighborhoods.

Infographics illustrate maintenance operations, regulations and other relevant considerations in spatial terms. Best practice strategies offer recommendations that are illustrated by case studies from NYC and many other cities. Additionally, an interactive Waste Calculator tool approximates how much waste an individual building must plan for, under a variety of potential operating scenarios.

The Guidelines are best used as part of an integrative design process involving the entire team—clients, designers, contractors, operators—in setting goals and designing a system that maximizes the potential of achieving the city's zero waste objectives.

This report starts the process of adapting the Guidelines to Hong Kong and Singapore's local context. New building typologies have been added, and the most relevant best practice strategies identified.

Project Description

Hong Kong, Singapore, and New York City are all high-density cities, with goals to reduce waste and increase circular material flows. While their urban context, infrastructure, and policies differ, they all have similar challenges including:

- a lack of space, especially in older neighborhoods, for waste infrastructure and collection, and a high cost of development floor area
- a multi-cultural population producing large volumes of packaging and food waste from take-outs.
- many high-rise multifamily buildings, often with trash chutes but no space for recycling or organics collection.

They all have similar goals including:

- focusing on reducing food waste, single-use packaging, and electronic waste
- investigating whether volume-based charging can work
- increasing diversion and reducing contamination of recyclable and compostable materials
- looking at ways to process and productively reuse food and horticultural waste
- looking at the circularity of building materials
- seeing how zero waste goals can tie in with city sustainability and livability goals

Architects and urban designers have a key role to play here in ensuring that buildings and the urban realm are designed to help achieve these goals, as this report will outline.

Project Team

Center for Zero Waste Design (CfZWD), New York City, believes that waste is a design flaw. We work with cities to implement design strategies within buildings and the urban realm to facilitate circular material loops and achieve zero waste goals.

Business Environment Council (BEC), Hong Kong, is a non-profit organisation established by the Hong Kong business sector to advocate for clean technologies, waste-reducing strategies, improve corporate environmental and social responsibility through providing advisory, research and assessment services.

Renegii Asia, a Singapore-based urban systems and management advisory reimagining Asian cities as sustainable, regenerative ecosystems, with a platform Circular Cities Asia.

American Institute of Architects New York Chapter (AIA NY), works with the Center for Architecture in New York City to advocate for the relevance of architecture and design in the midst of a powerful and ever-changing city. We embrace values that support civic engagement, equity, environment sustainability, resiliency, new technologies, and excellent design that inspires.



This project is supported by the Design Trust Feature Grant from the Hong Kong Design Trust. Design Trust provides funding support to the project only and does not otherwise take part in the project. Any opinions, findings, conclusions or recommendations expressed in these materials/events (or by members of the project team) are those of the project organizers only and do not reflect the views of Design Trust.

Project Activities

Originally this project included a visit to Hong Kong and Singapore, with research and panel discussions and workshops in each city. Because of the COVID pandemic, this was not possible, and the research and panels were conducted virtually.

Research Phase

The team had conversations with architects, engineers, developers and waste advocates, consultants and equipment manufacturers in both HK and SG, researched local rules, codes, and programs on waste, and waste reduction guides and plans including:

Hong Kong

- Hong Kong Blueprint for Sustainable Use of Resources 2013-2022
- A Food Waste & Yard Waste Plan for Hong Kong 2014-2022
- Waste Blueprint for Hong Kong 2035

Singapore

- 3R Guidebook for Hotels
- 3R Guidebook for Food Retail Establishments
- Food Waste Minimisation Guidebook for Food Retail Establishments
- Solid Waste Management Technology Roadmap
- Sustainable Singapore Blueprint, 2015
- Zero Waste Masterplan Singapore



Roundtables and Panel Discussions

November 5th, 2020, Hong Kong Roundtable on Zero Waste Design

Hosted by BEC, this event included a presentation on the ZWDG by Clare Miflin, CfZWD, and a moderated conversation by Simon Ng, Director Policy & Research, BEC, with participants from the AEC community including:

- Ronald Lu & Partners
- Ove Arup & Partners HK Ltd
- Swire Properties Ltd
- Sun Hung Kai Properties Ltd
- Gammon Construction Ltd

December 8th, 2020, Designing Buildings for a Zero Waste Hong Kong

Hosted by BEC, this webinar was a panel discussion moderated by Simon Ng and included a keynote from Clare Miflin and speakers:

- Amie Lai, Senior Sustainable Development Manager, Swire Properties
- Cary Chan Executive Director, Hong Kong Green Building Council
- Fiona Sykes Associate, Arup
- Jackie Luk, Associate Principal, Kohn Pederson Fox (Hong Kong)
- M.K. Leung, Director of Sustainable Design, Ronald Lu & Partners

December 2nd, 2020, Singapore Roundtable on Zero Waste Design

Roundtable consultation hosted by Renergii, with a presentation on the ZWDG by Clare Miflin, CfZWD and a discussion with representatives from the design community including:

- WOHA
- Biomimicry Singapore Network

April 21st, 2021, Designing Buildings for a Zero Waste Singapore

Webinar presentation from Clare Miflin, CfZWD with a discussion moderated by Shiva Susarla from Renergii.

April 4th, 2021, Designing Zero Waste Food Places

Hosted by Shiva Susarla, Renergii and Simon Ng, BEC, this discussion was moderated by Clare Miflin, CfZWD and included panelists:

- Christina Grace, CEO Foodprint Group
- Hakan Akgun, VP of Engineering, Sustainability & Security, Rosewood Hotel Group
- Kuan Chee Yung, Managing Director, CPG Signature

JOIN OUR EVENT

DESIGNING ZERO WASTE FOOD PLACES

APRIL 23 2021 9AM-10.15AM GMT+8

Organised by:

- BUSINESS ENVIRONMENT COUNCIL 商界環保協會
- IRCULARITIES ASIA
- Center for Zero Waste Design
- renergii
- BIOMIMICRY Singapore Network
- foodprint group

Supported by:

- DESIGNTRUST 信託設計大使 AN INITIATIVE OF THE HONG KONG MANAGERS OF DESIGN

This event is part of Zero Waste Design Guidelines for High Density Cities: Hong Kong, Singapore and New York City, which is supported by a Hong Kong Design Trust Seed Grant

INTRODUCER	INTRODUCER	PANELIST	PANELIST	PANELIST	MODERATOR
					
Shiva Susarla Managing Director RENERGII	Simon Ng Director, Policy & Research Business Environment Council	Hakan Akgun Vice President of Engineering, Sustainability and Security Rosewood Hotel Group	Christina Grace CEO Foodprint Group	Kuan Chee Yung Managing Director CPG Signature	Clare Miflin Architect & Founder Center for Zero Waste Design

Roundtables and Panel Discussions: What We Heard

Engagement of architects

- Designing for zero waste is not considered by most architects, nor requested by developers. Reference materials and successful case studies would be helpful.

“Architects need to work creatively to tackle the waste issue. It should be a design motivator and part of the building concept”

Lack of motivation for developers

- Space is expensive in all three cities, and developers need to maximize rentable floor area. Providing enough space in new buildings for effective waste separation and storage is a challenge, and additional gross (zoning) floor area concessions would help.
- Most developers aren't using green building rating systems unless they are required to or they give additional floor area. While there are some incentives and requirements in HK and SG, the rating systems don't give many credits for reducing waste. Land purchase agreements could also mandate design for waste separation.

“We need more GFA concessions so we can allocate more space for waste equipment without giving up lettable floor area. BEAM Plus Gold rating gives 10% extra floor area, we could look at incorporating more waste-related credits.”

Lack of motivation of occupants

- While building owners may set up systems to separate and store recycling, there are challenges to ensure that tenants reduce procurement of single-use items, correctly segregate waste and that property management has effective waste management procedures.

“Swire Properties adopted several zero-waste design measures. New building designs make use of third party waste audits to better design spaces for anticipated waste. Sustainable fit-out and green kitchen guidelines are provided for tenants, and we are sourcing smart technology to help tenants understand waste generation.”

- Need to weigh the convenience of waste rooms on every story with easier management of a large central waste room for trash and multiple recycling streams, where all are equally convenient.
- There are credibility issues on downstream recycling, where occupants don't believe materials are actually being recycled.

“Many people don't believe in recycling, thinking that after it is collected it all gets tossed together again. There is a lot of misinformation and persistent myths out there.”

- Adopting Municipal Solid Waste Charging would help, but there has been opposition, and policy proposals have not passed.

Recycling Collection and Infrastructure

- In Hong Kong, the collection of recycling is very inefficient, as it is not done by the government, but has to be arranged privately. Traditionally many collections were done by small recycling businesses, but as the value of recyclable materials has dropped, there are fewer businesses collecting fewer materials.
- In Hong Kong, there are many social enterprises that can be engaged to reduce waste, especially in the hospitality industry.
- In Singapore, there are some requirements for pneumatics, and this helps with the efficiency of waste management, but it is still difficult to determine if food waste should go in pneumatics, and there needs to be more data and incentives to design larger systems.

Food Service and Waste

- Food packaging, especially from take-out, is a huge challenge. Many people don't cook at home, and there is so much styrofoam, bags and packaging material. And compostable packaging is often not getting composted.
- Pests and odors are a big problem with storing food waste in the climate in HK and SG.

“Figuring out solutions for food waste is very complicated, there are so many issues and different types of equipment. How prevalent is food donation? Should food waste storage be refrigerated? What makes the best compost?”

- In Singapore, there is support and incentives for greenery on buildings, and the use of compost from horticultural waste. Could this be developed to include the use of compost from food waste, and could it be integrated into urban agriculture initiatives?

District Scale Solutions

- In Singapore, most new development is at a neighborhood scale, so there are many opportunities for district-scale material loops and distributed infrastructure.

Construction Materials

- In HK offices typically have to be delivered as a shell at the end of tenancy, which results in lots of furniture and interior finish waste.
- Building Information Modeling (BIM) is very important to reduce waste from errors, also need to look at strategies like reusable formwork, modular construction, and reuse of scaffolds. The consideration of the durability of materials, finishes and the designing of dematerializing buildings are important as well.
- In Singapore all buildings are modeled in Revit, so have a BIM model, which can be used to develop a material passport. Prefabricated construction, also prevalent in Singapore, helps in designing for disassembly and in developing accurate material passports.

New York City Context



Urban Form and Waste Collection

New York City, located at the southern tip of the State of New York, has a landmass of 305 square miles (790 square km)¹. The city has one of the highest population densities in the US with a total of 8.7 million people, and an average density of 27,000 people per square mile (70,000 per square km)², though this varies greatly across the 5 boroughs, with an average density of 8,000 people per square mile³ in Staten Island and up to 69,000 people per square mile³ in Manhattan. Like Hong Kong and Singapore, limited land space and a high population density have led the city to reclaim land and continually revise its zoning rules to increase density.

The city was laid out on a continuous street grid, with few back alleys, to



SoHo shopping area



Brooklyn row houses



5th Avenue Manhattan

Sources:

1. <https://www1.nyc.gov/site/planning/planning-level/nyc-population/population-facts.page>
2. <https://worldpopulationreview.com/states/new-york-population>
3. https://en.wikipedia.org/wiki/Demographics_of_New_York_City

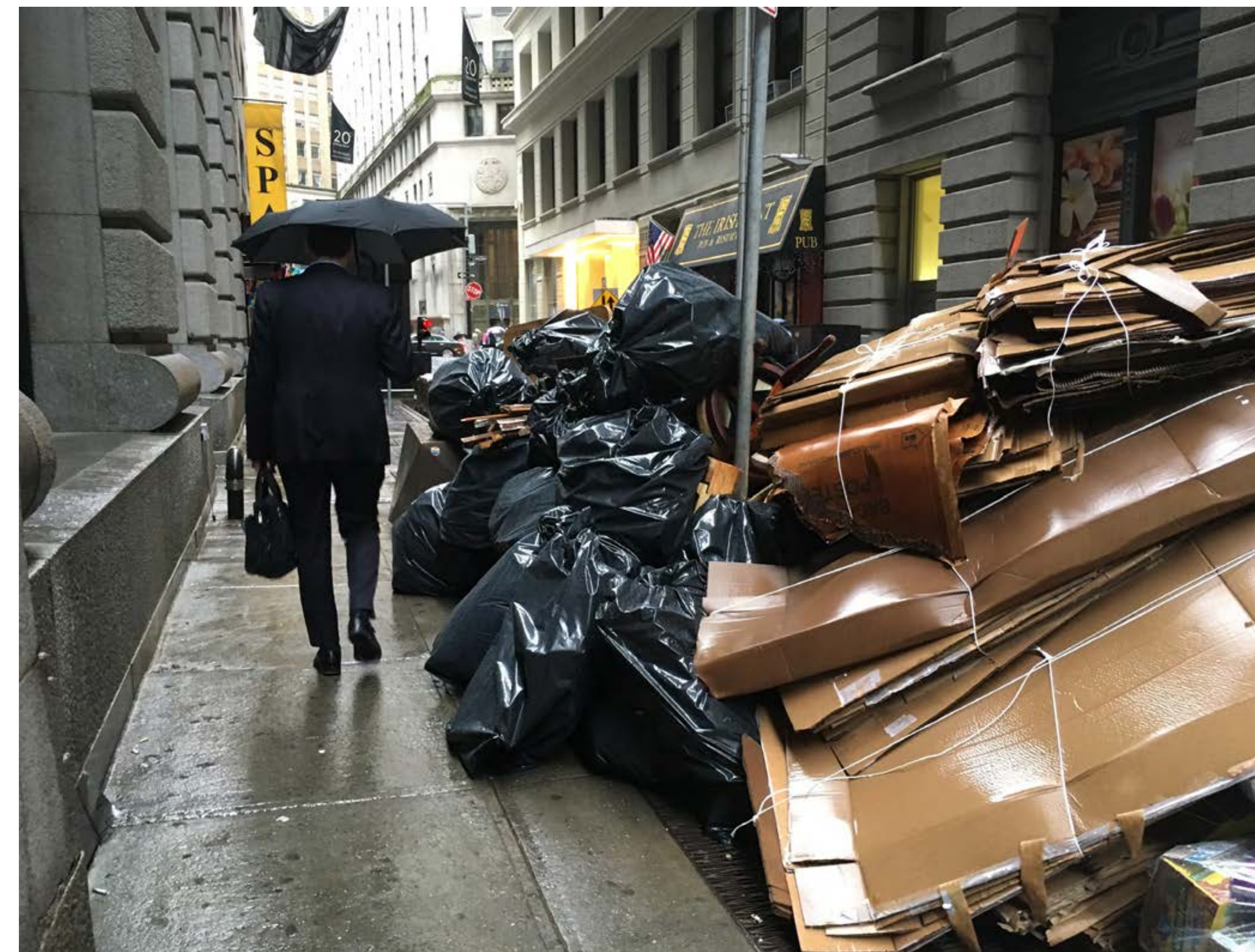
maximize the amount of real estate available for development. Most of the city has a continuous street wall, so waste is typically brought out of the front of the building, set out in bags on the sidewalk, and collected from the street. The Department of Sanitation (DSNY) collects waste from residences and some institutions, but commercial entities need to hire private carters. DSNY picks up waste in bags or small bins which need to be under 50lbs in weight as they are hand lifted into the back of the trucks. DSNY will also pick up large roll-on roll-off (RoRo) containers, but the headroom and area required are high, and there are no incentives or requirements to use them. For new buildings, DSNY no longer picks up the midsize 1-3 CY (660-2400 liter containers), which leaves most developers little choice but to stack bags on the sidewalk. Private haulers typically use semi-automated trucks and pick up bags, wheeled bins and 1-2 CY containers as well as RoRos for large buildings. The city is developing a zoned system for private waste haulers to reduce truck miles and incentivize waste reduction and diversion.



A RoRo container in the Stuy Town housing development. Current requirements for headroom are much higher than this installation



Sanitation workers collecting trash bags by hand on a busy street



Trash bags and cardboard set out on the sidewalk in Lower Manhattan

The city's housing stock ranges from 1-3 family homes, to highly serviced doorman buildings with service corridors, to high rise residential towers. For much of the city 2-6 story row houses predominate, with ground-floor retail on the main avenues. These buildings typically have bins or waste enclosures in the front yard or on the sidewalk, but there are conflicts when there is retail and sidewalk dining. In higher density areas there are high rise commercial and residential buildings, often with retail on the ground floor. Some mid-century housing was developed in housing estates, and this is the primary building type for NYC public housing by NYCHA, where there are often central shared roll-on roll-off (RoRo) compactor containers for trash. See also the [Stuy Town case study](#). Roosevelt Island, a planned community of 14,000, was the US's first use of a pneumatic system for trash, but otherwise, they are not common in the city. See [case study](#).



A brownstone building with waste and recycling bins set out front



Near the Financial District in Tribeca, Manhattan



Apartment blocks in The Bronx



Single home in Ozone Park, Queens



Residential apartments above ground floor retail

Waste Streams and Plans

In 2001, the city closed its last landfill, Fresh Kills, which at its peak received 29,000 tons a day⁴ and was the world's largest. Since then waste is transported to landfills and incinerators, many of which are hundreds of miles away. This disposal costs the city upwards of \$350 million a year. The methane released by the decomposition of the organic waste in the landfill contributes about 4% of NYC's greenhouse gas emissions. There are equity issues too, with waste infrastructure concentrated in a few neighborhoods, contributing to bad air quality and elevated asthma rates.

These factors prompted the city to include a goal of zero waste by 2030 within its sustainability plan issued in 2015 "One New York: The Plan for a Strong and Just City," which added to the vision set by the 2007 PlaNYC. Key initiatives for residential waste included a Save as You Throw program, which the plan stated could reduce generation by 30%, as well as diverting additional materials - organics, textiles and electronic waste. For commercial waste, the goals included food-waste reduction and diversion, including mandatory separation for large generators, aligning the commercial and residential rules, and increasing data-reporting requirements. In 2019 the city issued and updated OneNYC 2050 with a focus on goals for 2050, and it seems unlikely they will meet the 2030 zero-waste goal⁵.

DSNY collects ±12,500 tons a day of waste, and about the same amount is collected from commercial businesses, though there is fewer data available. Construction and demolition waste is not measured by the state, not the city. It is mandatory in all buildings - residential, institutional and commercial - to separate recycling. This must be dual-stream - paper & cardboard and

metal, glass, plastic & cartons - if picked up by DSNY, though these can be combined into a single recycling stream for commercial pickup.

Even so, the city's diversion rate is around 20% with only about 50% of recycling separated within buildings, see diagram on [page 14](#). And although NYC has expanded its organics collection program to 2 million residents, only a small fraction of the city's organic waste is diverted.

Organic waste—food scraps, food-soiled paper and yard waste—composes almost one-third of the residential waste stream. NYC has been expanding its curbside organics collection program, with plans to make it citywide and mandatory, though it was suspended during Covid and the budget crisis. It is now restarting as an opt-in program in certain



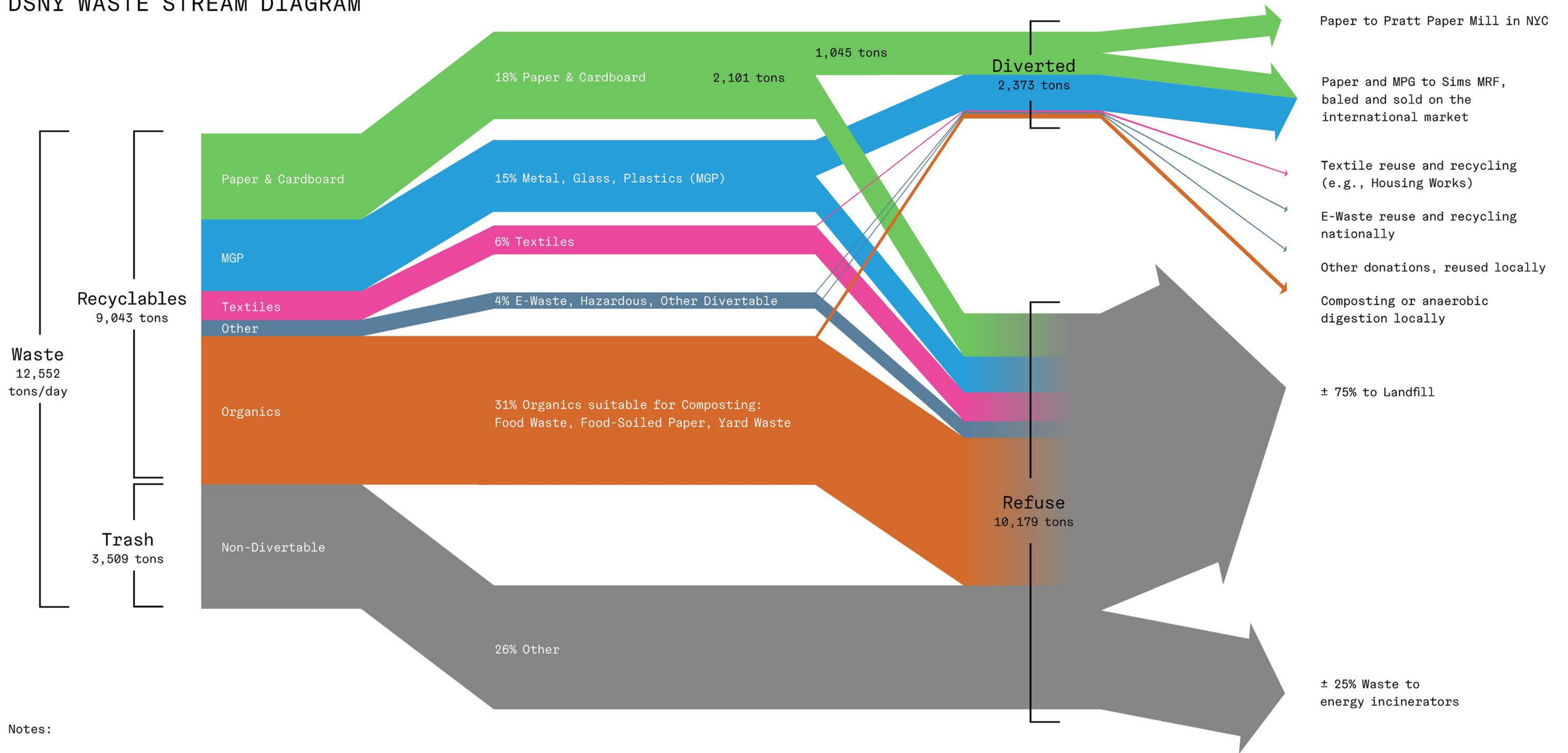
OneNYC 2050 - New York City's strategic development plan focusing on sustainability, equity and resiliency.

Sources:

4. <https://www.nycgovparks.org/park-features/freshkills-park/about-the-site5>

5. <https://www.wastedive.com/news/2030-zero-waste-goal-new-york-city/544155/>

DSNY WASTE STREAM DIAGRAM



Notes:

Capture rate is the proportion of recyclables that get diverted, and is measured per waste stream—e.g., for Paper & Cardboard = 1,045/2,101 = 50%

Diversion rate is the proportion of the total waste stream that is diverted from disposal = 2,373/12,552 = 19%

Refuse is defined as the waste stream that gets disposed (ie sent to landfill or waste to energy incinerators)

neighborhoods. The city supplies 13 or 21-gallon brown bins and collects them curbside weekly. There is also an extensive community composting program, where residents drop off food scraps in farmers markets or alongside community gardens and transit hubs, to be composted by non-profits within the city, see [case study](#).

DSNY's refashionNYC program, a partnership with the non-profit Housing Works, provides and services textile bins. Buildings of ten or more units can apply for these bins, which are often kept in laundry rooms or other communal areas; Housing Works empties them when they're full, and sells much of the clothing in its stores. Another collaboration with a nonprofit provides e-waste pickup to buildings of ten or more units. Citywide drop-off events, alongside a few permanent locations, allow the disposal of electronics and other hazardous household waste such as chemicals and household drugs. Bulk waste can be set out by residents for trash or recycling pick-up, though larger items require a collection request to be made.

DSNY took part in the development of the ZWDG, alongside the Departments of Transportation and City Planning. They recognize that designing buildings to accommodate initiatives such as Save-As-You-Throw or mandatory organics separation, will be critical to their success. They have now begun the cross-agency collaboration required to change city policies and collection methods, and are starting pilot programs such as shared containerized drop-offs. The scaling up and success of these efforts will be critical to change the ubiquitous presence of trash on NYC sidewalks, which has a marked effect on the quality of urban life. As the city's density increases and many begin to rethink the use of public space post-Covid⁶, the system becomes less and less tenable.



DSNY organics collection bins alongside public trash and recycling litter bins



Organics drop-off at Grand Army Plaza farmer's market in Crown Heights

Sources:
6. <https://nyc25x25.org>

BUILDING CONTEXT

NYC - TYPICAL EXISTING RESIDENTIAL BUILDING

1

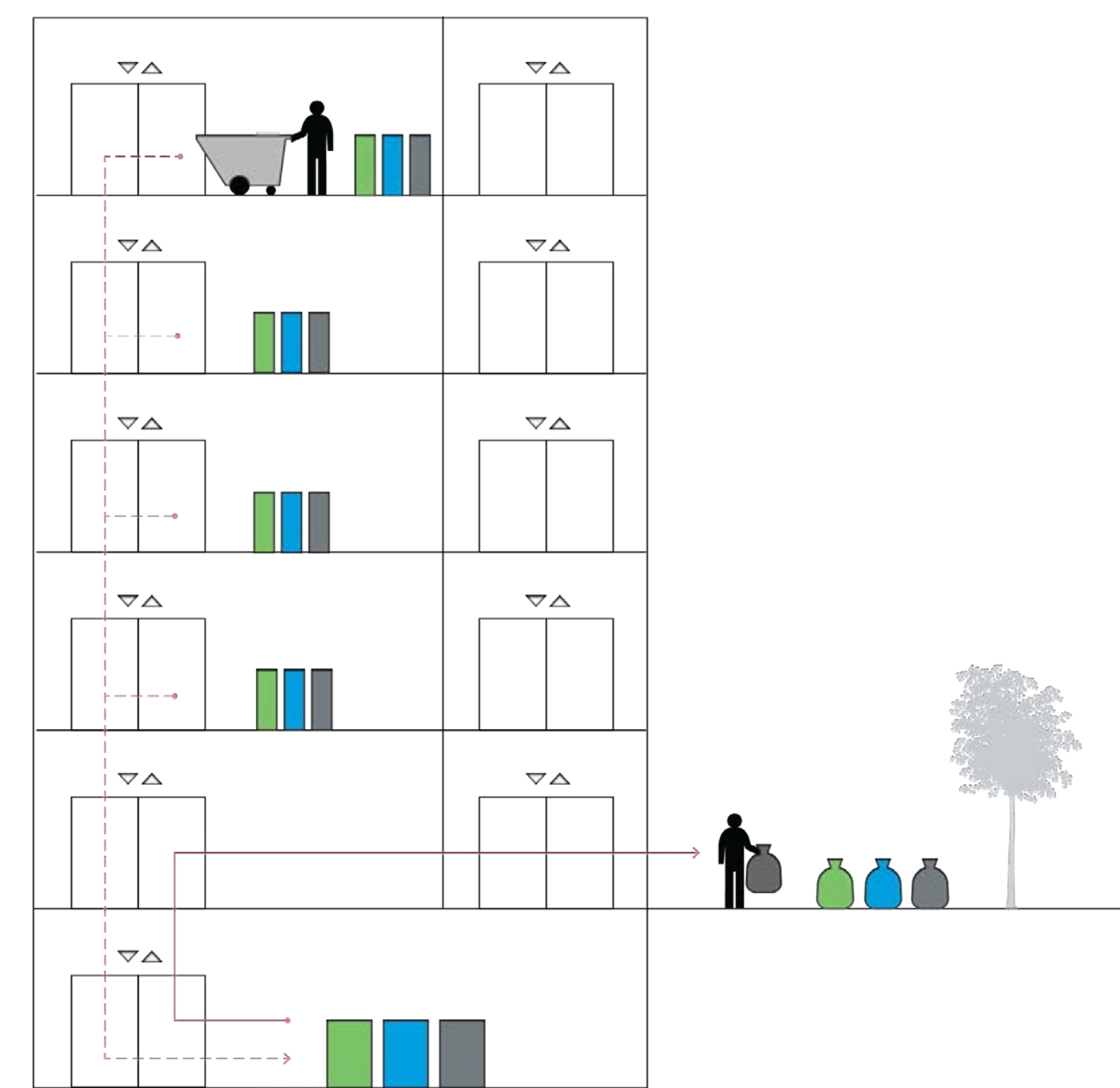


CENTRAL LOCATION

In NYC, smaller residential buildings, typically up to 6 stories and often without an elevator, have no waste rooms, and residents bring waste to enclosures on the street, or to a central area in the cellar.

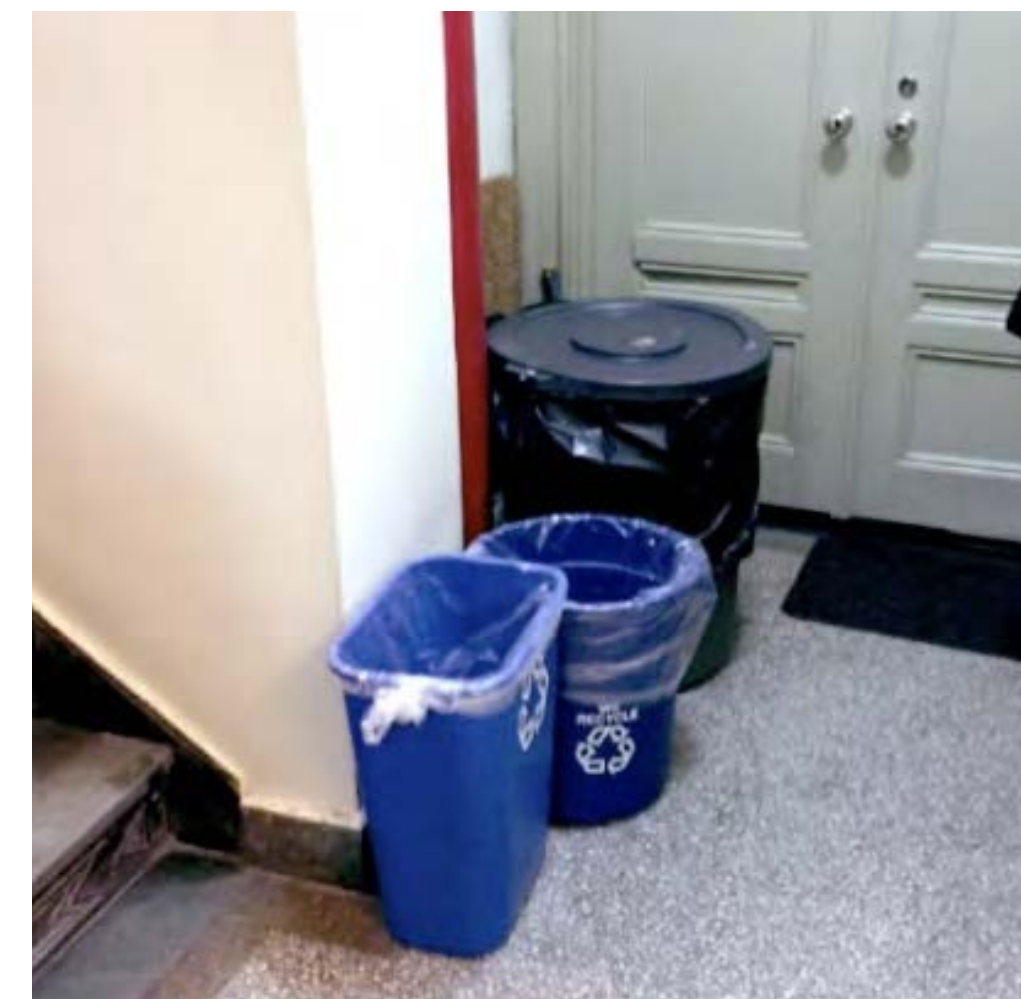


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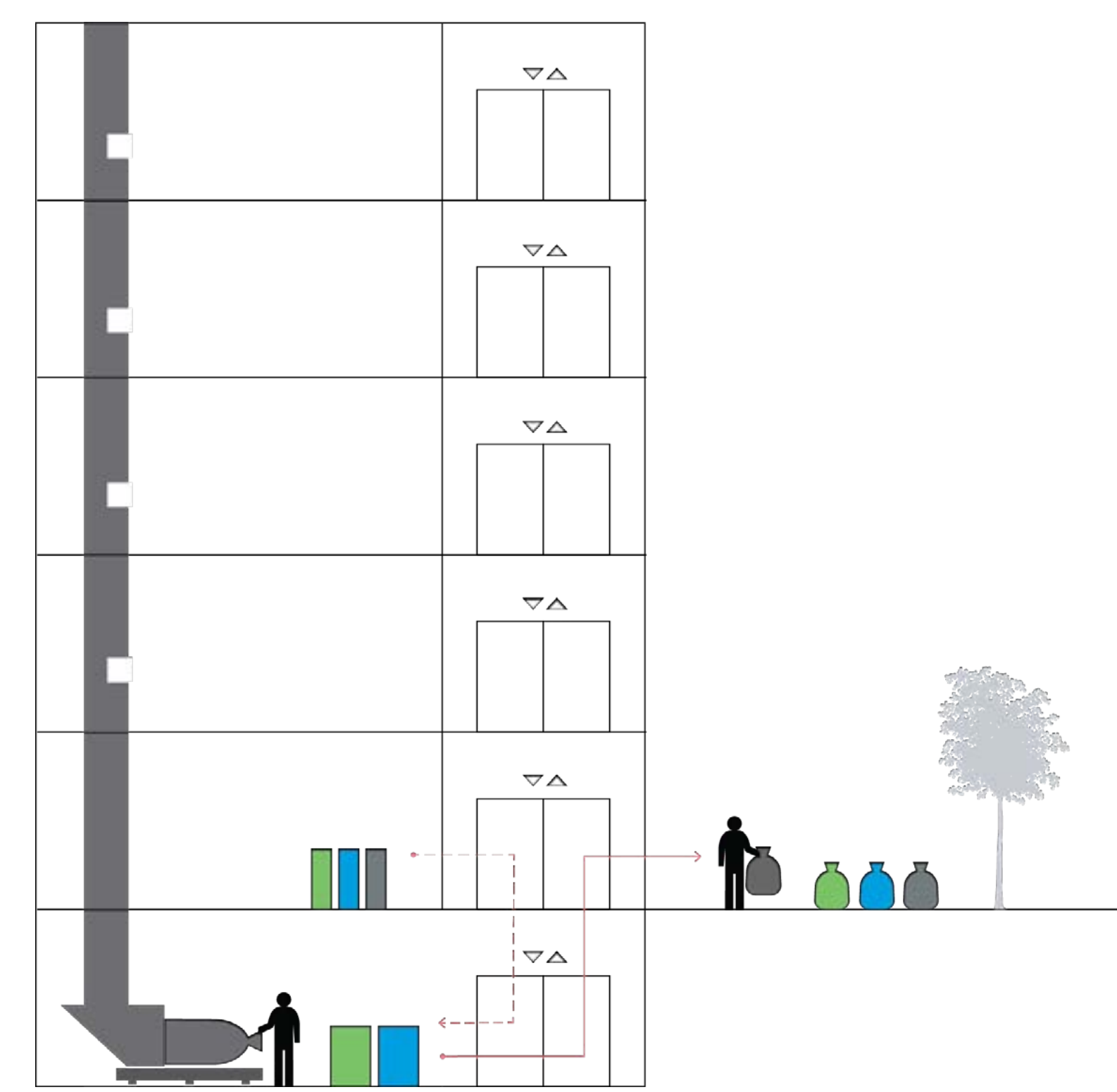


SERVICE CORRIDOR

Some buildings with service corridors and stairwells collect waste from the service door of each apartment.



3

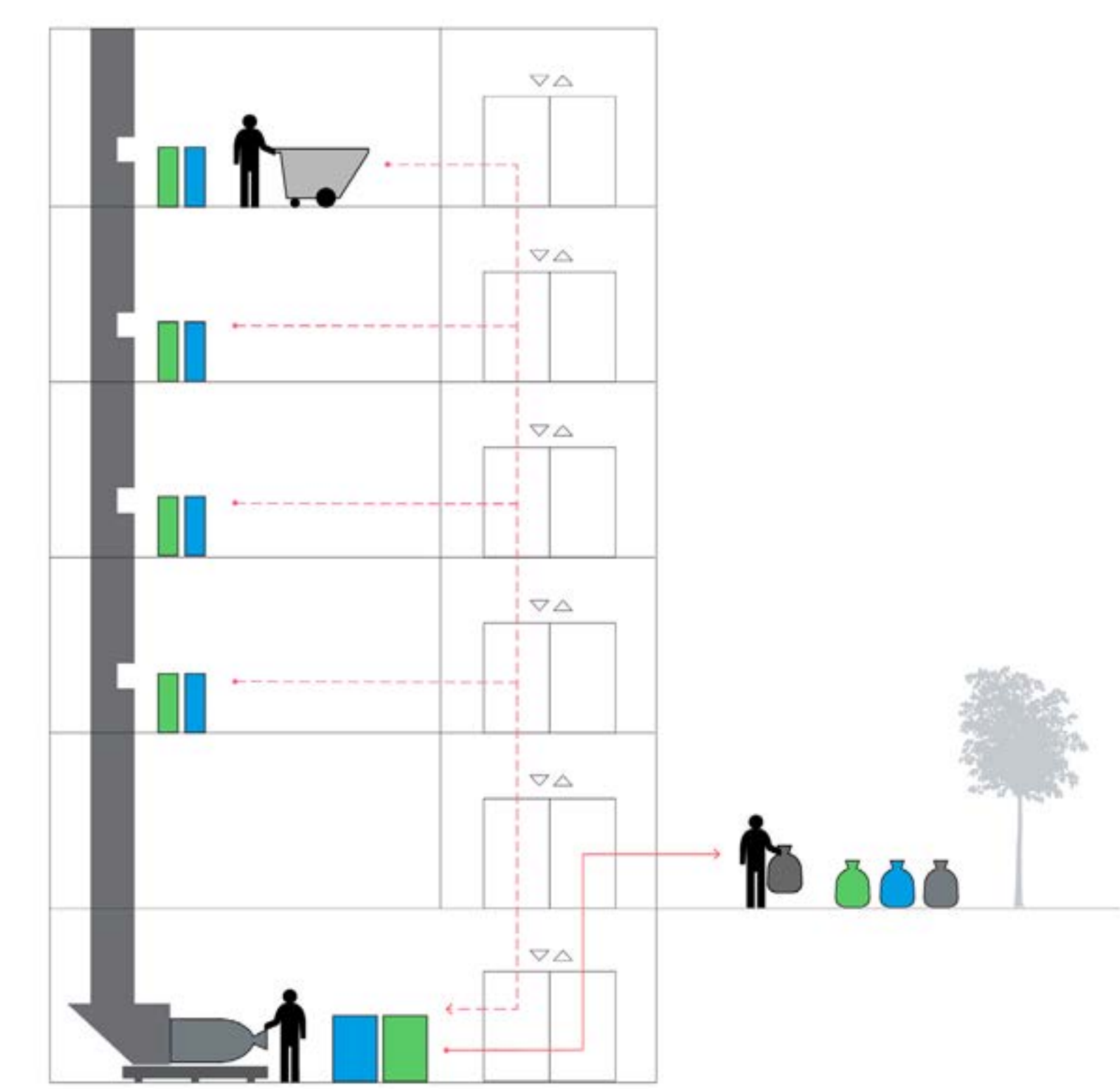


CORRIDOR TRASH CHUTE WITH CENTRAL RECYCLING

In larger buildings, there is typically a chute for trash, and there may be central recycling.



4



REFUSE ROOM WITH TRASH CHUTE AND BINS

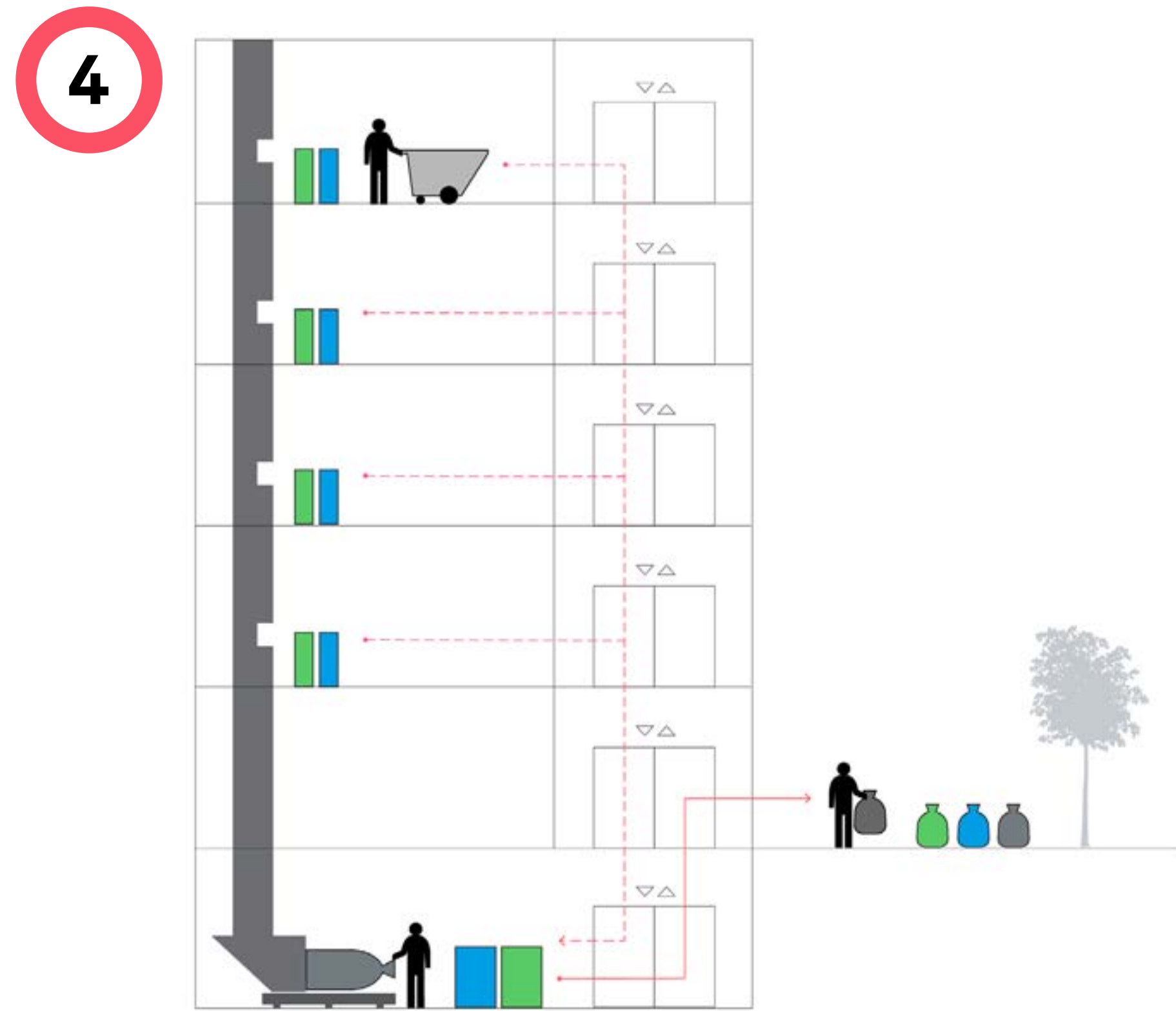
Many buildings have small refuse rooms on every story with bins for recycling and a trash chute.



Collection Rules: DSNY collect 32-gallon bags or 32-gallon bins of recycling and 44-gallon bags or 44-gallon bins of trash. All must weigh under 50 lbs (22.7 kg).



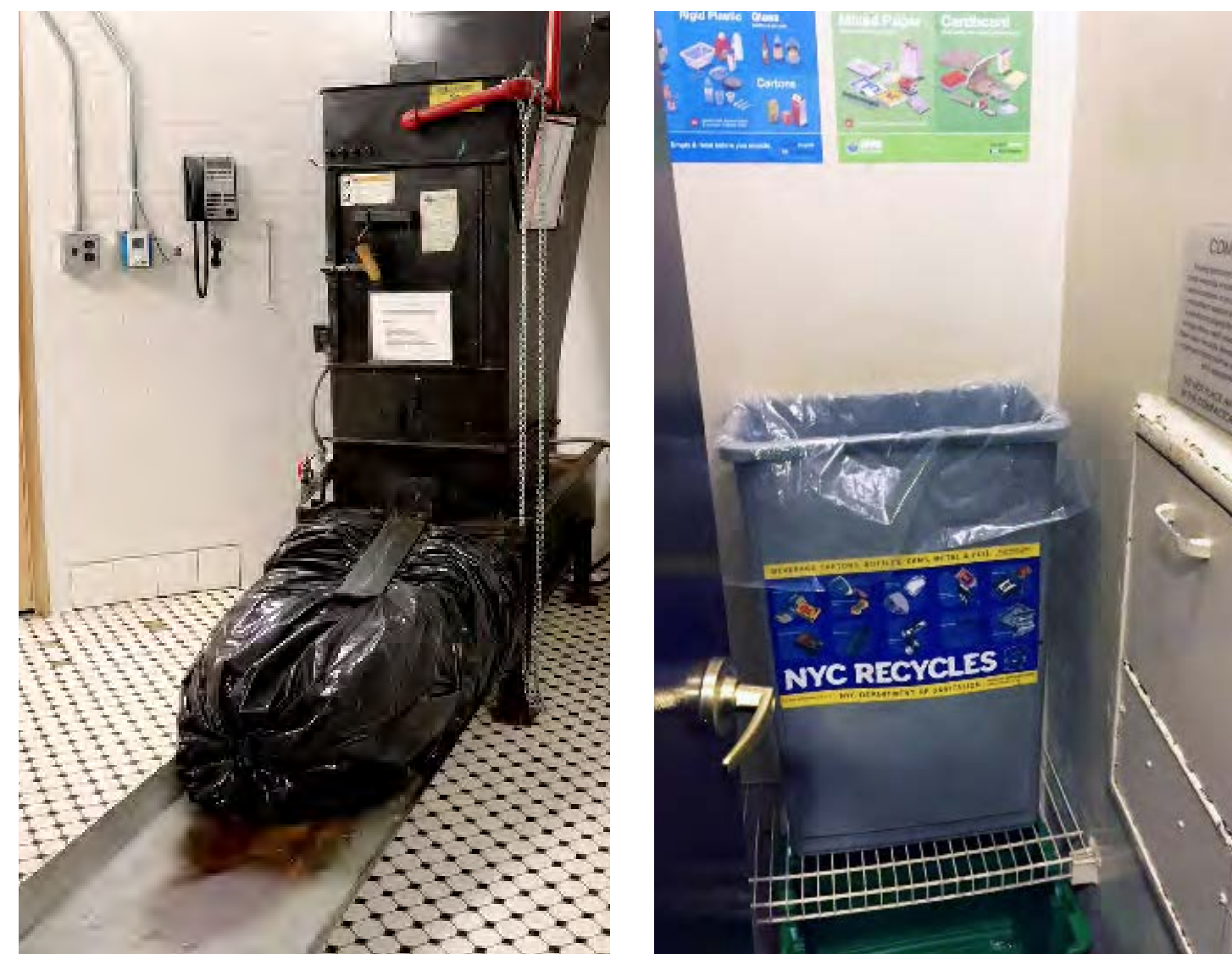
Refuse	by municipality 2-3x/week
Recycling	by municipality 1x/week (paper and MGP collected separately, sometimes in dual body truck)
Organic Waste	by municipality in some areas 1x/week (may increase in future)



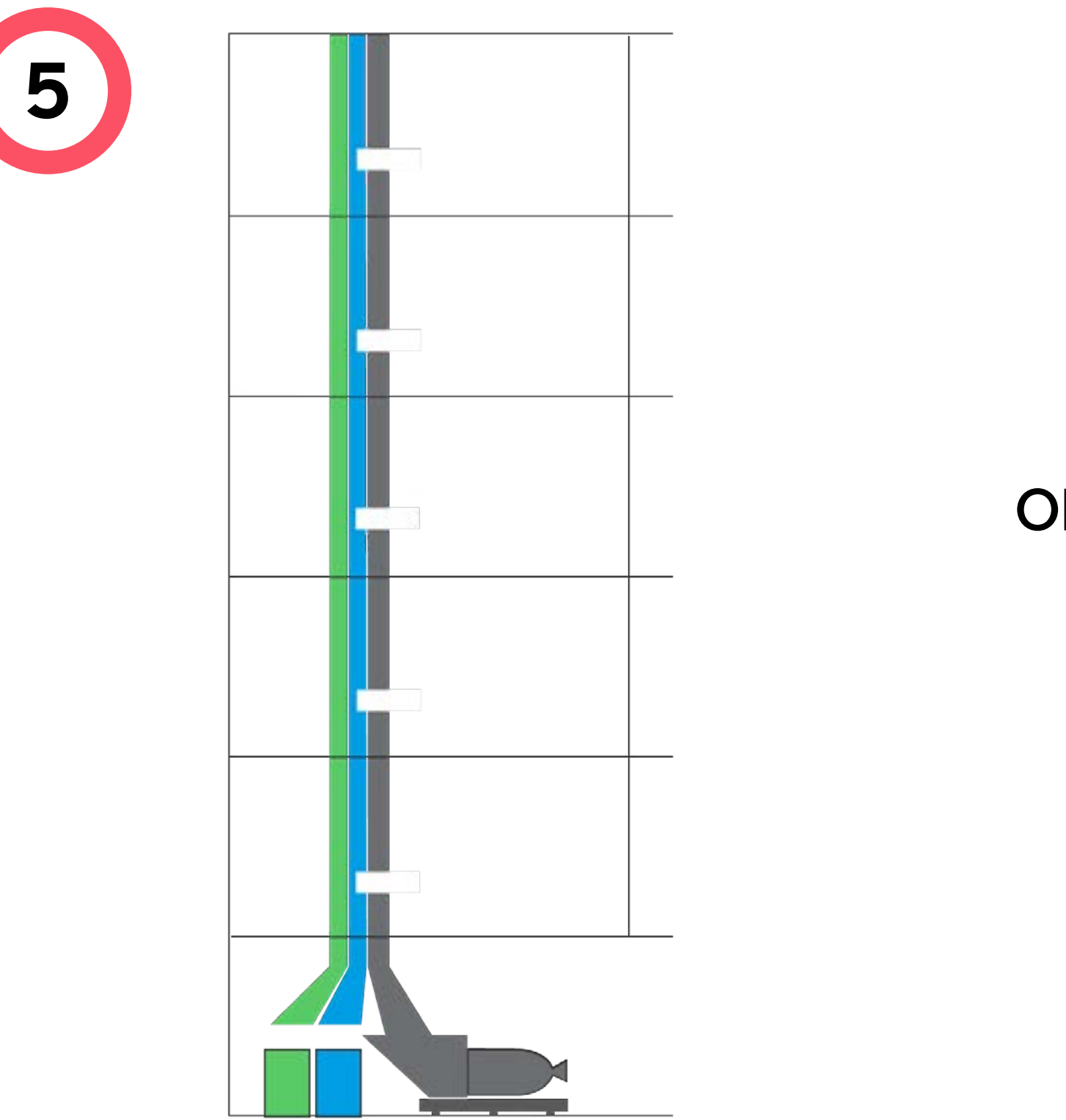
REFUSE ROOM WITH TRASH CHUTE AND RECYCLING BINS

For most new residential multifamily buildings code requires a refuse chute, within a refuse room with additional space to store recycling or provision for recycling to go down a chute.

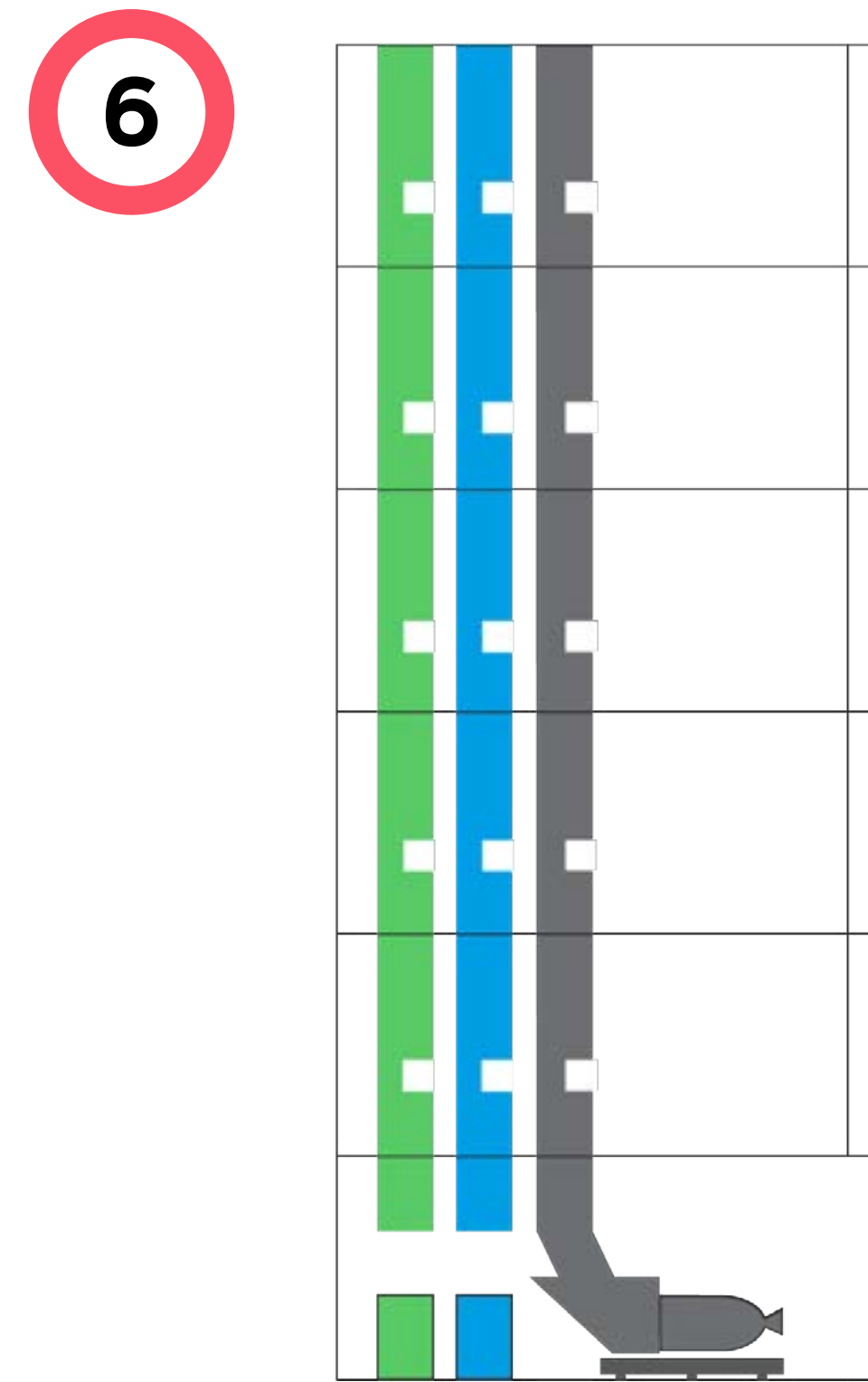
The chute feeds into a compactor with a plastic tube that is tied into bags. These are typically stored with the recycling bags in a storage room in the cellar.



OR



OR



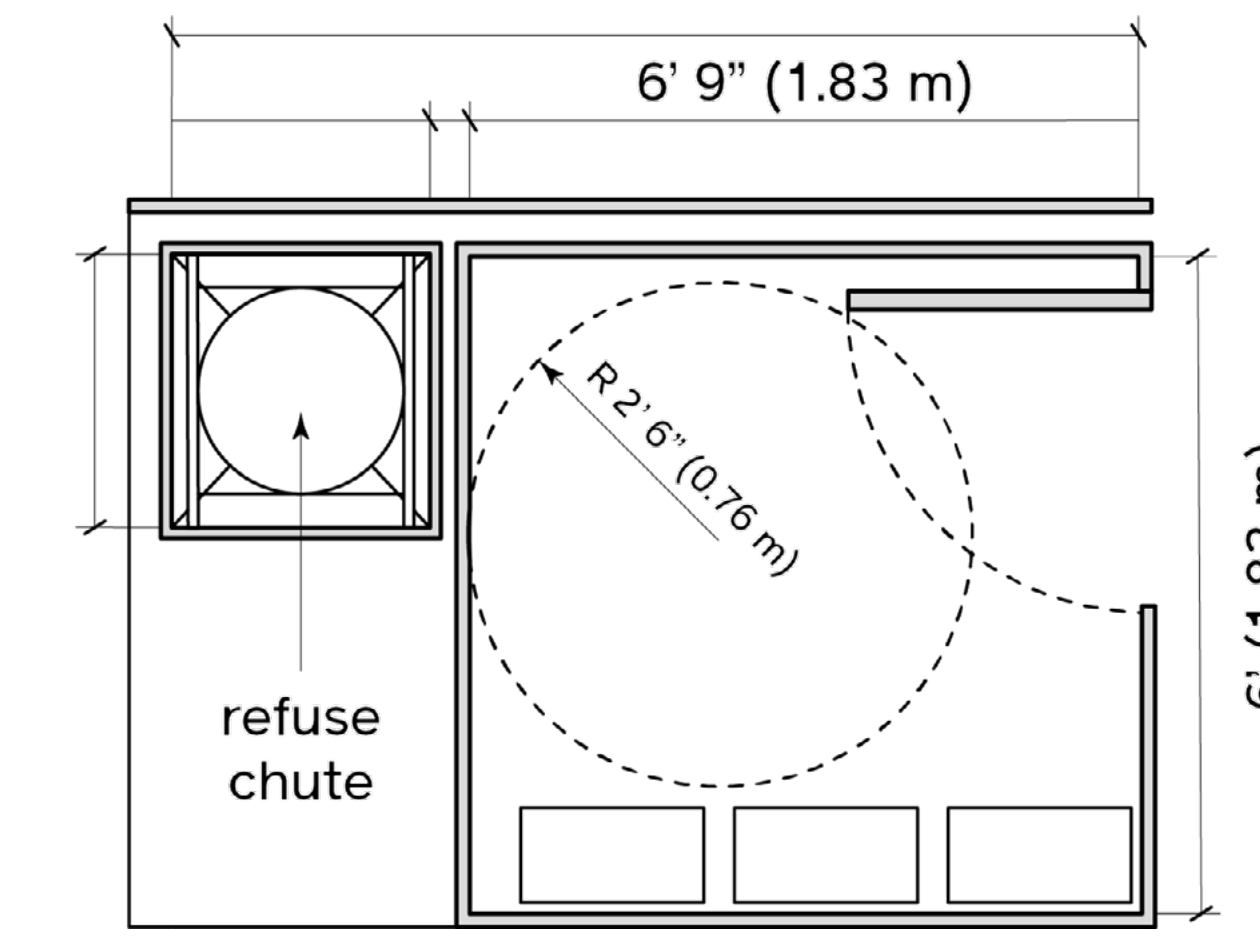
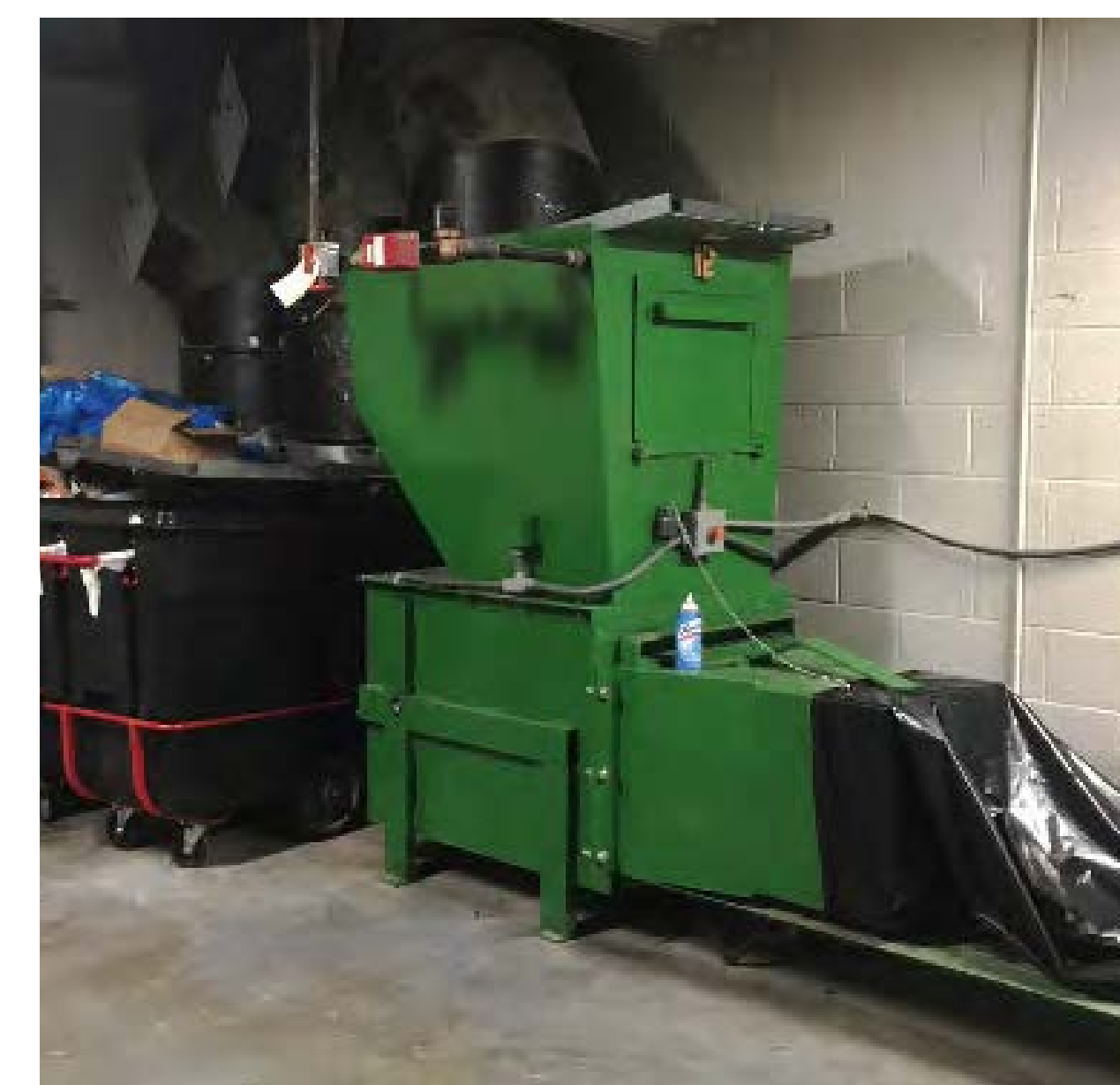
SINGLE CHUTE WITH SORTER

There may be a single chute with a sorter function to divert the recycling into different bins, and the trash into a compactor, at the bottom.

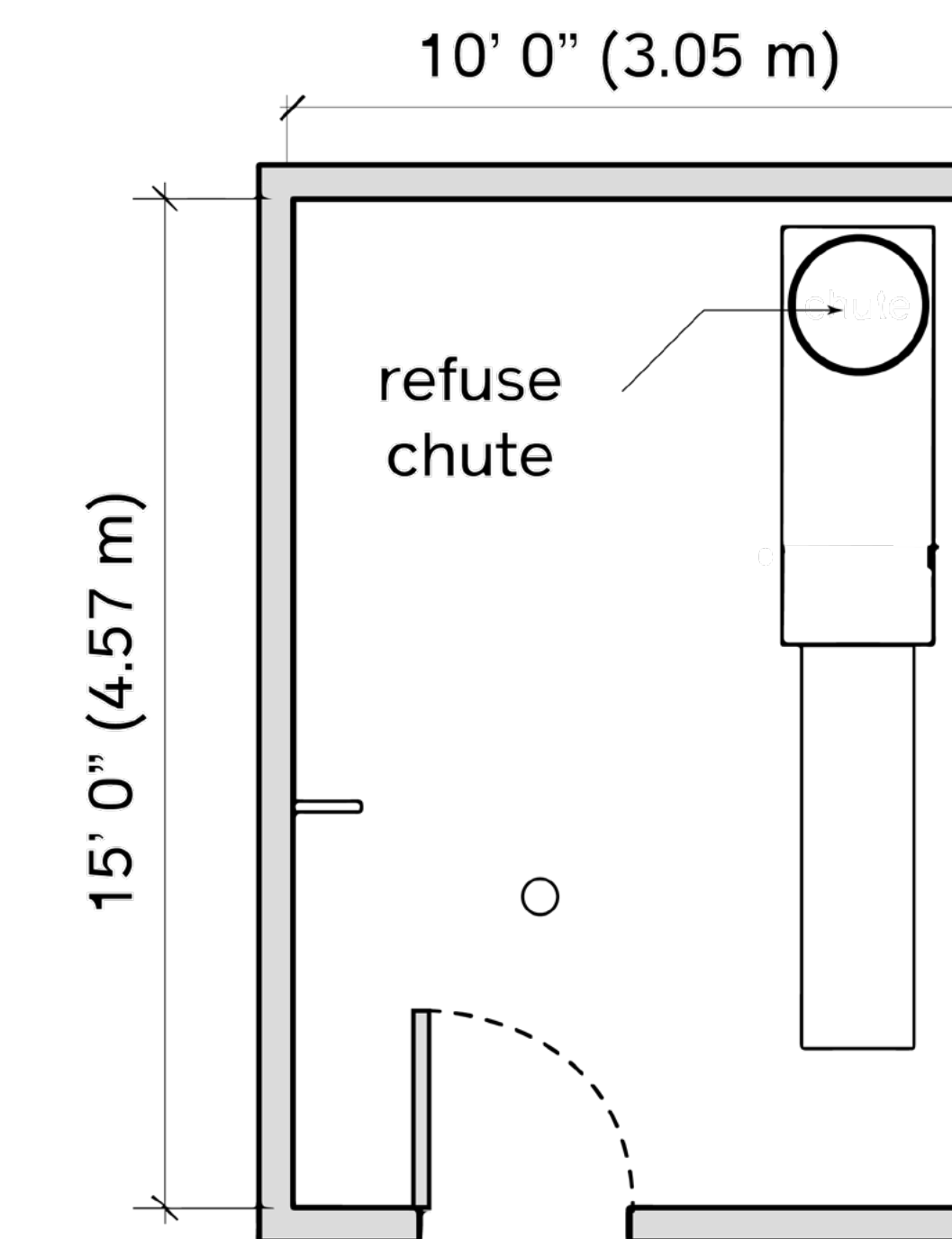


MULTIPLE CHUTES

Multiple chutes may be used for trash and the two recycling streams. Chutes are typically not used for organic waste because the bins that DSNY use are too small to put at the bottom of a chute, and organics are messy to transfer.



Scale 1/2" to 1'0"
Typical Refuse Room

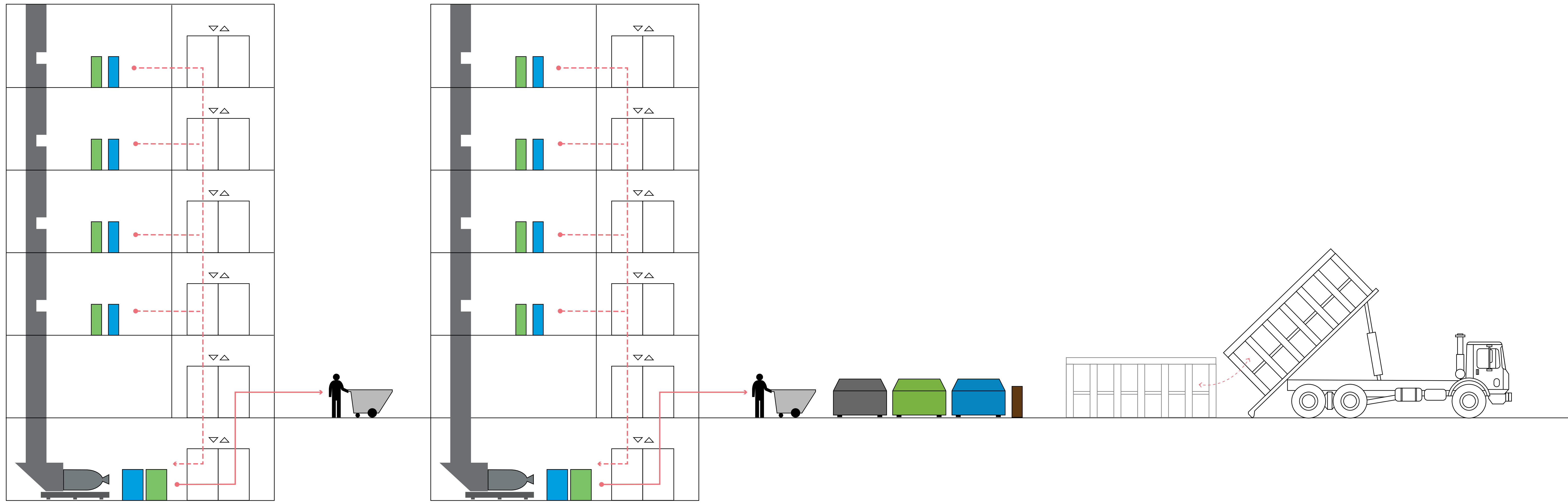


Scale 1/4" to 1'0"
Waste Storage Room

CODE REQUIREMENTS

- Trash chute and refuse room required in buildings ≥ 5 stories and ≥ 9 units.
- Ventilation and 5 SF (0.5m²) of storage are required in the refuse room for recycling unless a recycling chute or chute sorter is provided.
- The room is typically ≥ 40 SF (3.7m²) with required space allowances for ADA access.
- Waste storage room: rat-proof and fireproof with ventilation, floor drain, and water hose connection.
- Trash compactor required in buildings ≥ 4 stories and ≥ 12 units.
- Storage of 1 SF/unit up to 350 SF required to buildings with compactors (else 1.5 SF SF/unit).

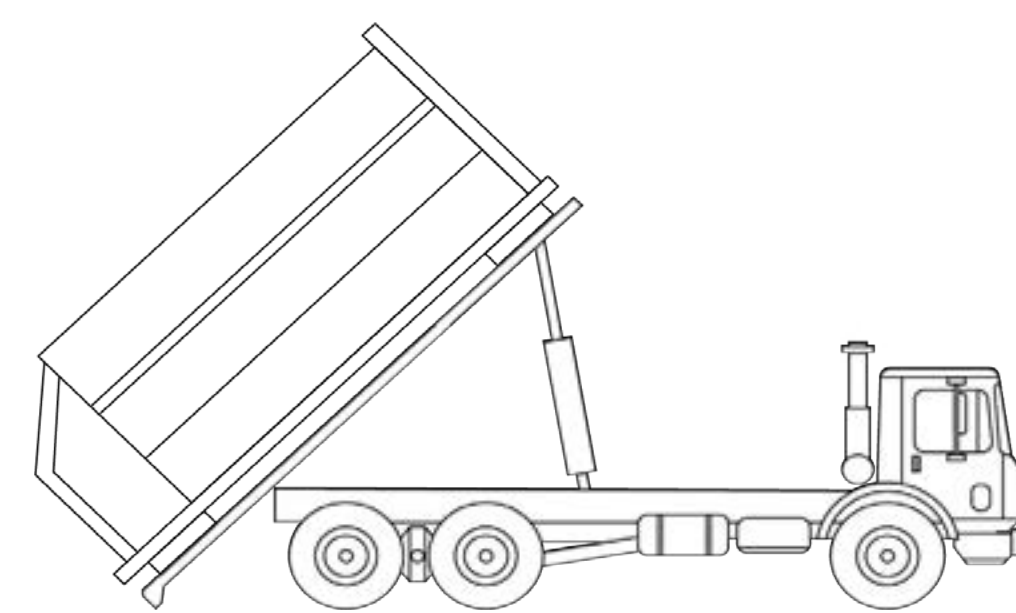
NYC - LARGE NEW RESIDENTIAL DEVELOPMENT WITH CONTAINERIZED WASTE



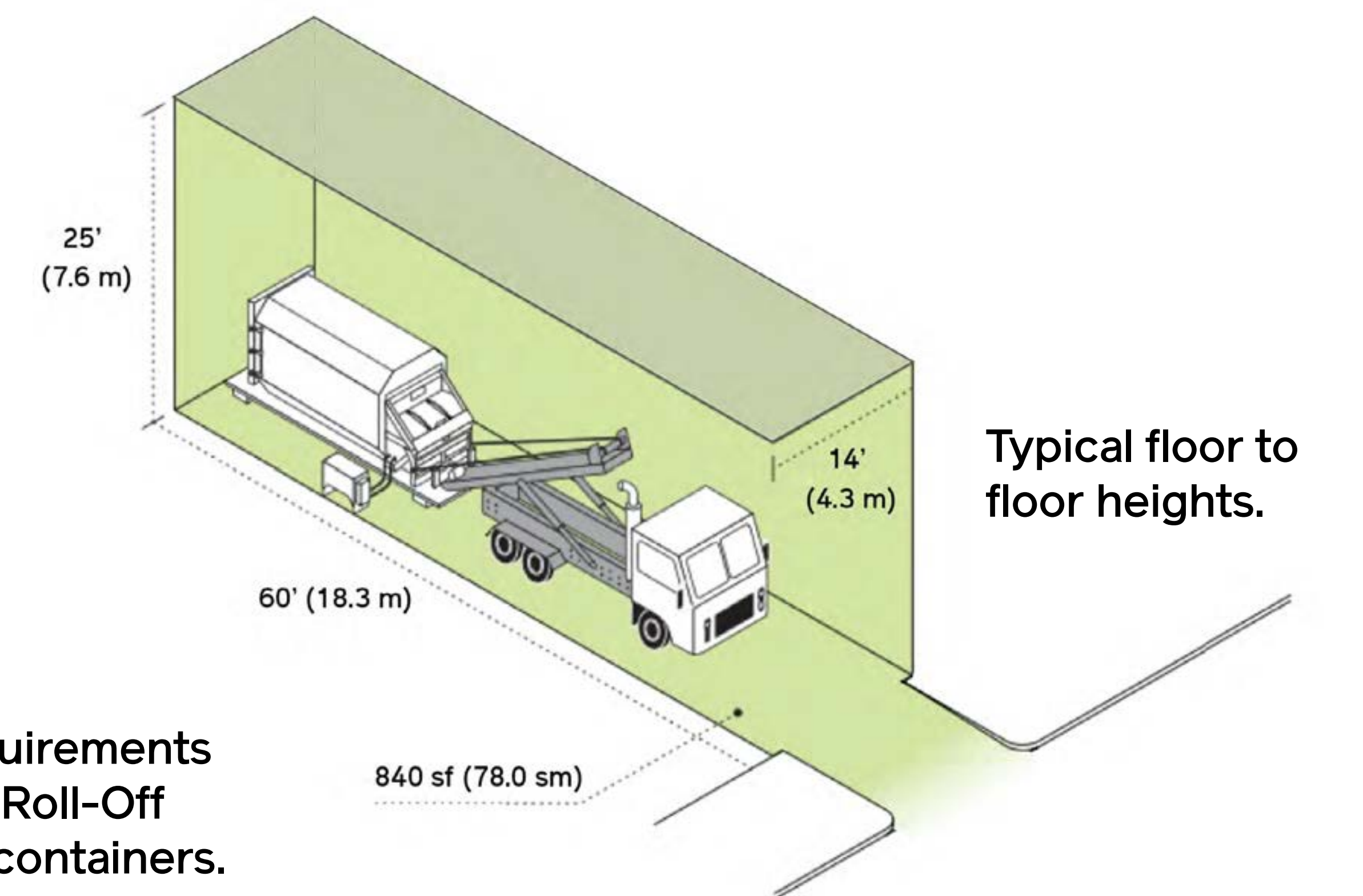
In NYC, there are no requirements to centralize waste in housing developments, although DSNY encourages the use of Roll-on, Roll-off (RoRo) compactor containers for developments with over 300 residential units.

Tower-in-the-park housing developments, such as those by the New York City Housing Authority (NYCHA), often have central waste yards with RoRo containers, but RoRos are typically not used in new developments, because of the floor area and headroom required.

DSNY collect RoRos of waste on demand, usually when the containers are 80% full.



Trash	35 cubic yard (cy) compactor container
Cardboard and Paper	35 cy compactor container
Metals, Plastic, and Glass	35 cy open-top container
Bulk	35 cy open-top container



Current requirements for Roll-On, Roll-Off compactor containers.

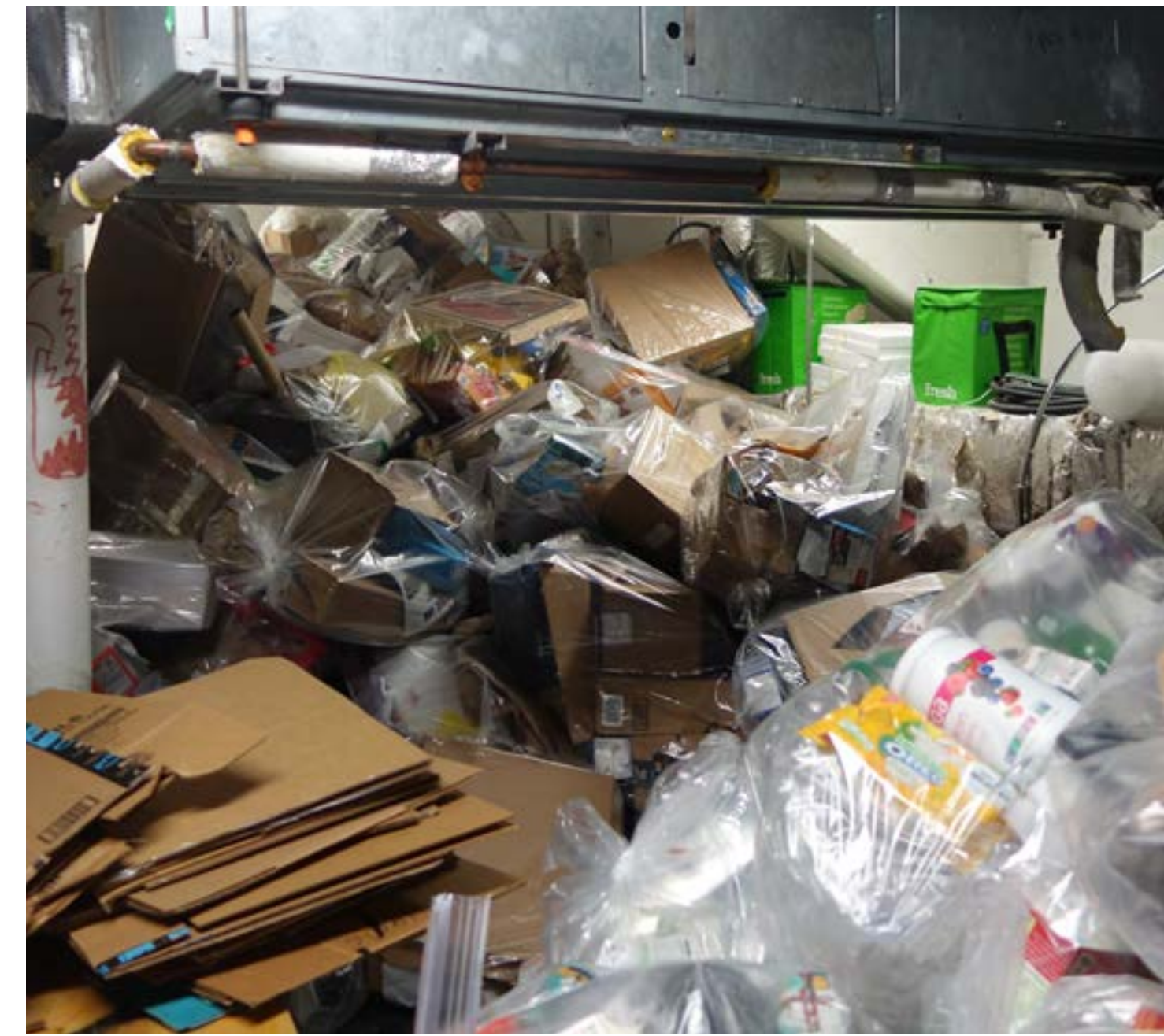
Recycling bins in refuse rooms on each story



Organics bins may be in refuse rooms or central location



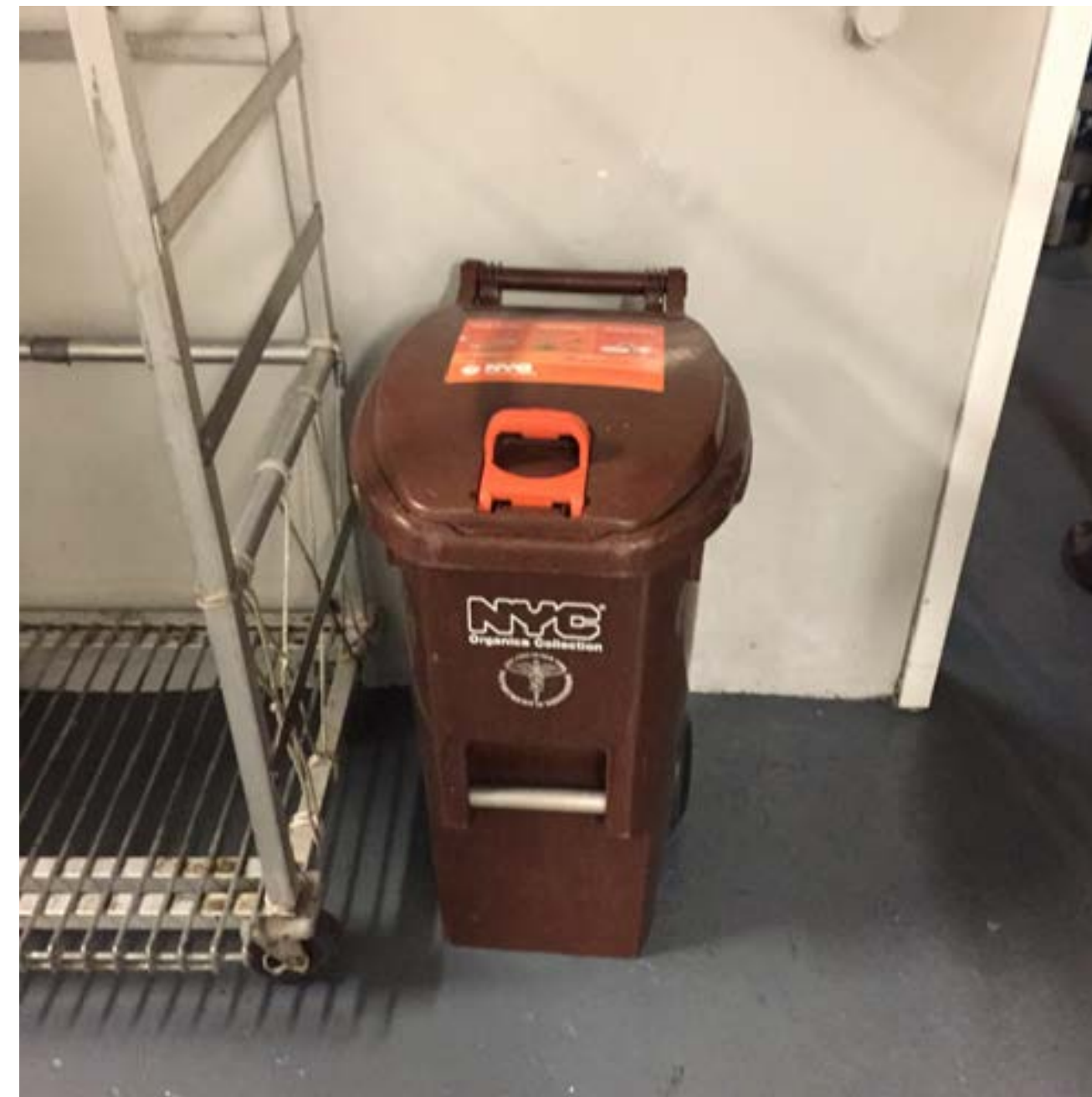
Cardboard boxes in bags and hand-baled



Bags set out on sidewalk



DSNY hauling



Equal convenience disposal for recycling and trash but not organics

Waste rooms on every story are convenient for residents but require high levels of labor to service the recycling bins. There is often insufficient space, ventilation or labor to add organics bins in each waste room.

Insufficient central storage space

Insufficient space is required by the building code for waste storage rooms, especially for recycling which is only collected once per week.

Trash bags set out on the sidewalk

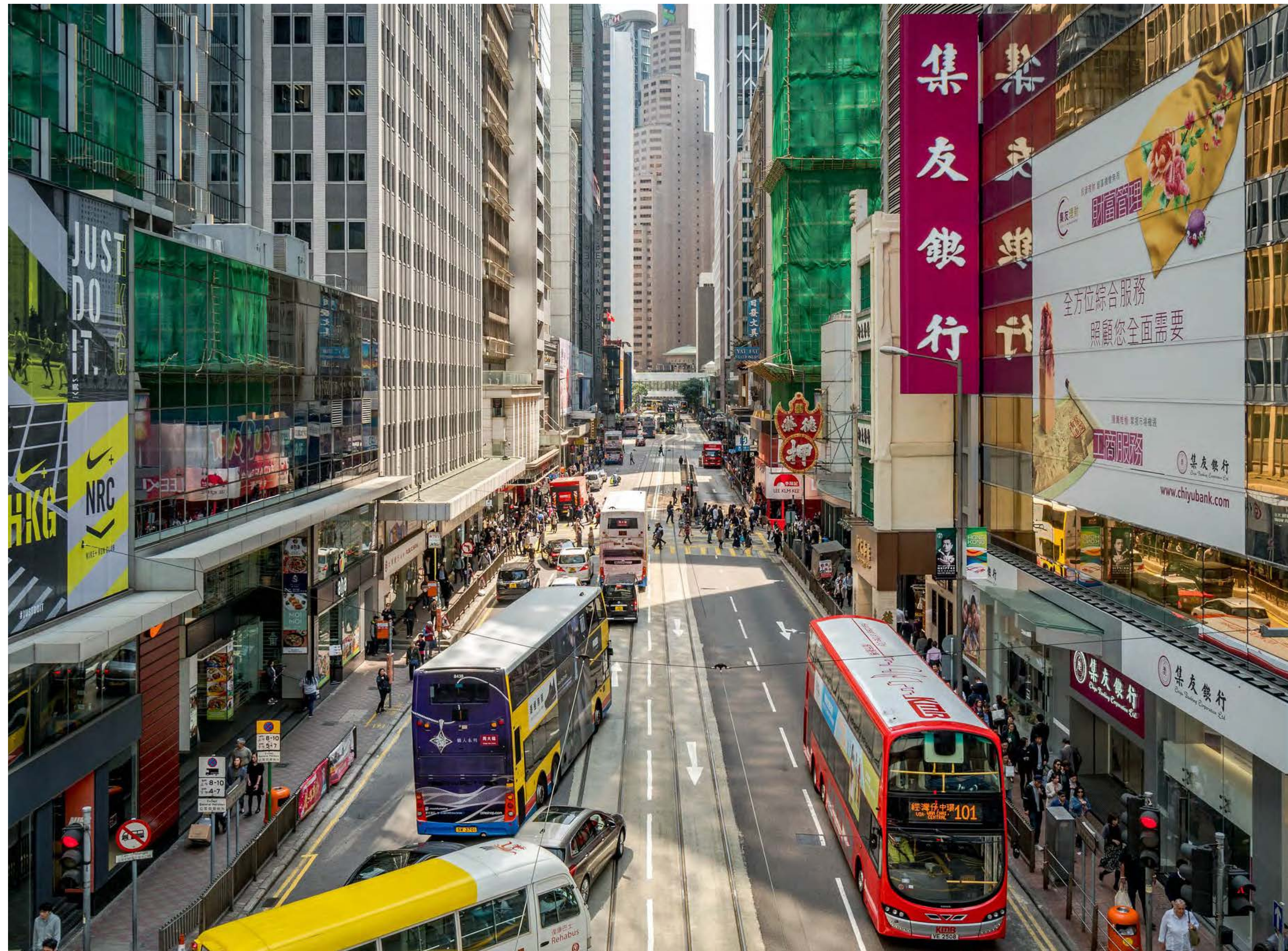
Bags of trash and recycling are set out for collection on sidewalks. The bag piles can be tall and block pedestrians and may sit there from 4 pm until they are picked up the next morning. Bags attract rats, cause litter and odors, and leak garbage juice. Hauling bags by hand into the back of trucks is unpleasant and causes injuries to DSNY workers.

Hong Kong Context



Urban Form and Waste Collection

Hong Kong's topography, history and zoning rules have led to a diverse urban form. With a landmass of 1106 square kilometers, it is one of the densest cities with 7.56 million people and a population density of 7,100 people per km². Yet density varies from low-density outlying villages with around 1000 people / km², such as Islands District, to high-density districts such as Kwun Tong, with a population density of 52,000 people / km².¹



Des Voeux Road in Central, Hong Kong.



Older districts with single block buildings.



Streets of outlying islands.

1. <https://www.worldometers.info/world-population/china-hong-kong-sar-population/>

Most people (88%) live in multifamily homes over 10 stories, primarily in housing estates with multiple towers managed by a property management organization (PMO).² The PMO collects refuse, and may also collect recycling, from each building and stores it in a central refuse storage area. The municipality, Food & Environmental Hygiene Department (FEHD), picks up the refuse from 660 liter wheeled containers daily, or RoRo containers may be used. Automated pneumatic refuse collection systems have been used in new public housing developments over 2,400 units since 2001.

There is no municipal collection of recycling, and its separation is encouraged but not mandatory. For recycling pick up the PMO has to contract with private haulers, and there are also many options for residents to drop off recycling themselves. Residents pay for waste collection through either property management organisation and indirectly through taxes.



Interior of refuse collection point.



Above: A residential estate with a refuse collection point.



Below: A refuse collection point integrated with public toilets and vertical greenery.

Older districts have many “single block buildings” with a continuous street wall, retail at grade and residential or commercial uses above. The ground floor retail may spill into the street with markets and food stalls. In these neighborhoods refuse is taken to the closest Refuse Collection Point (RCP), which is managed by FEHD. Private garbage collectors also pick up refuse from individual buildings and take it to the RCPs. Recycling may be taken to recycling stores or green stations. In outlying villages and suburban areas refuse is taken to bin sites or RCPs operated by FEHD.²

Private Waste Collectors (PWCs) also collect about 15% of residential waste from buildings and estates where FEHD doesn’t offer collection because of access or schedule issues. These PWCs mix residential and commercial waste in the same truck.

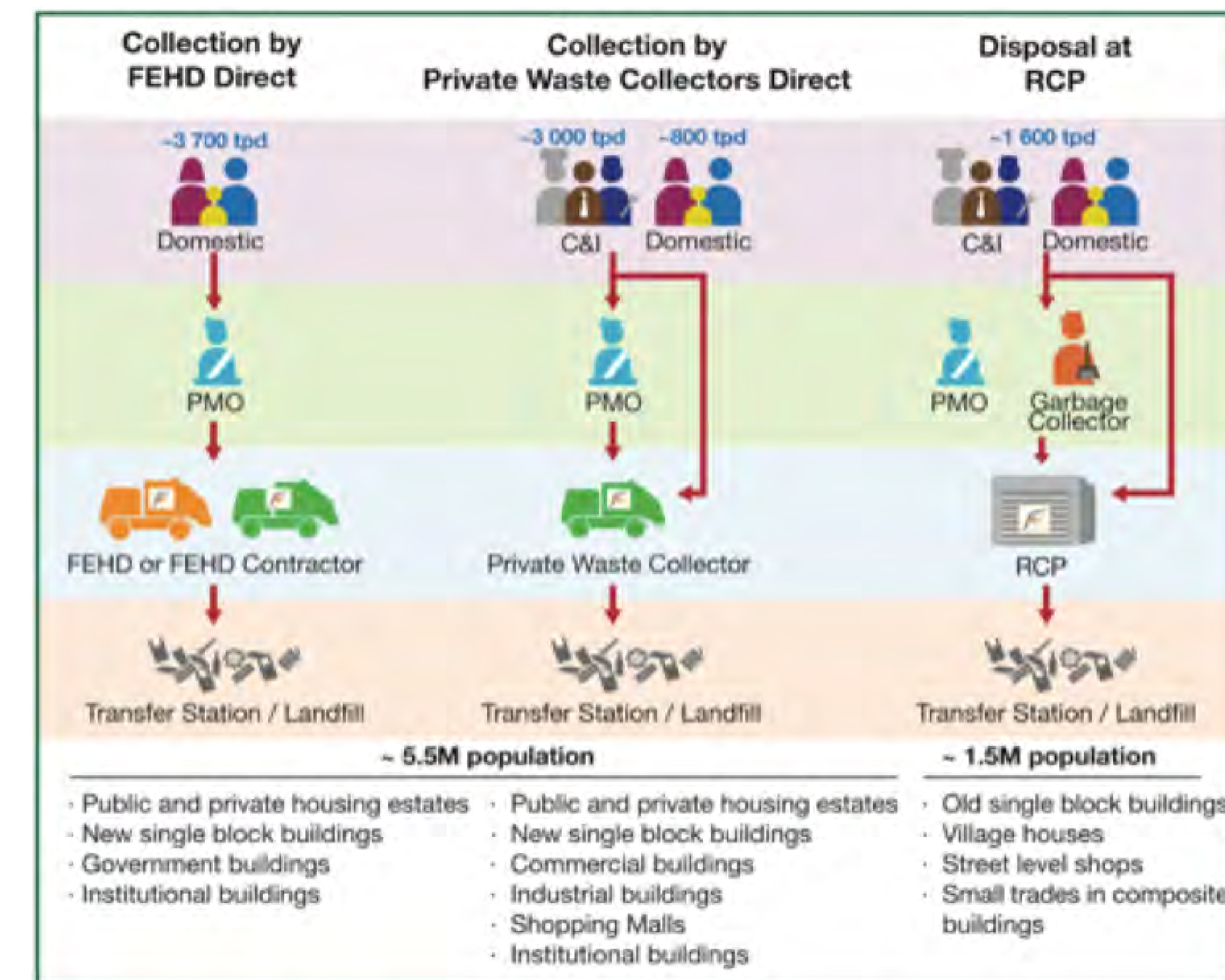
Larger commercial buildings and shopping malls typically have central refuse (and recycling and sometimes food waste also) storage and collection, and the PMO contracts private waste collectors to pick up refuse, and often recycling too, for the whole building.



A refuse collection point in remote village area.

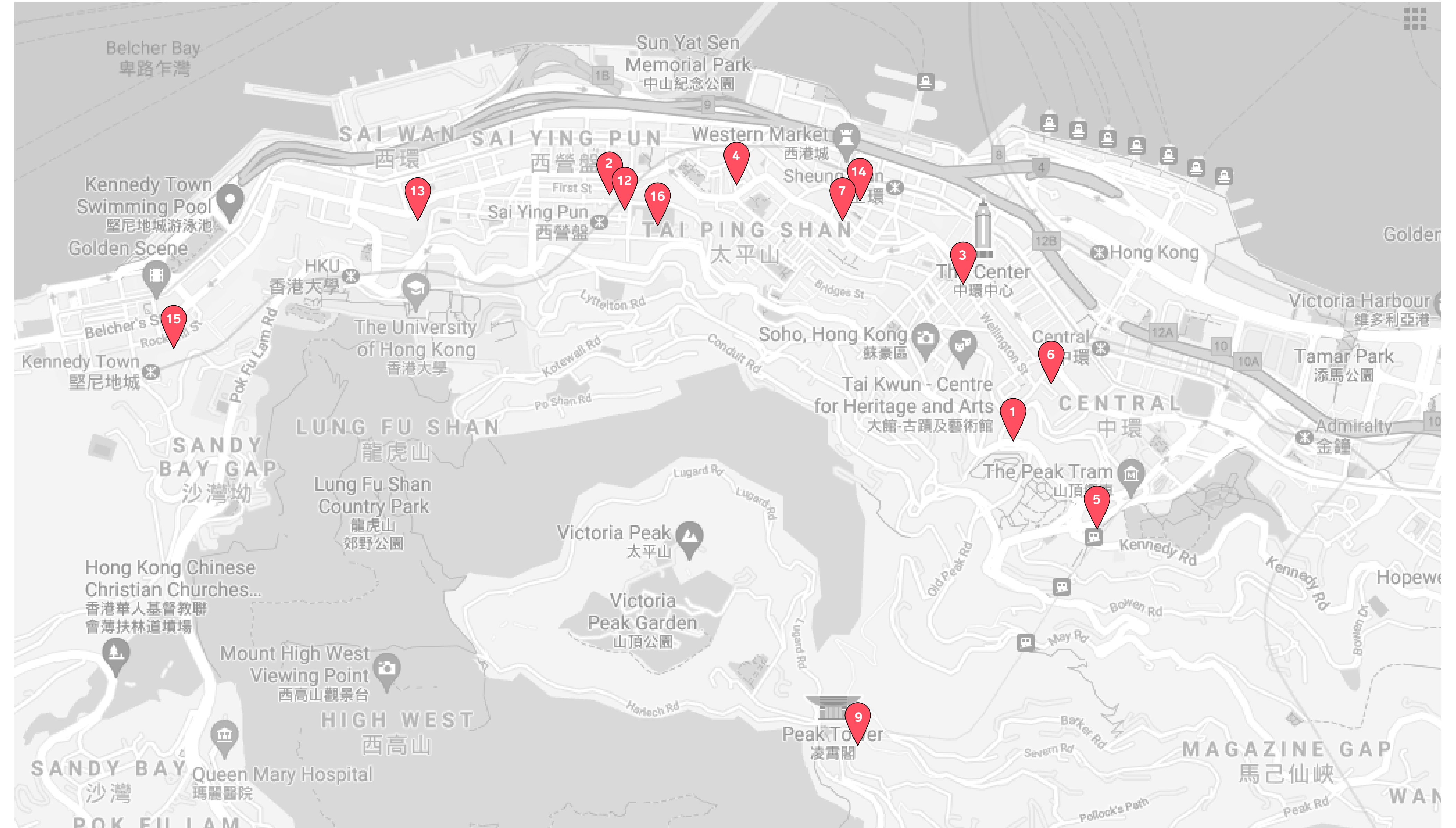


Single building blocks with shops on ground floor.



The FEHD and private waste collection processes.

FEHD has a total of 163 permanent off-street public refuse collection points (RCPs), 10 temporary RCPs; 868 village-type RCPs/RCPs with temporary structures; and about 1,900 bin sites. Some new RCPs have turntables to rotate trucks to save space. Refuse collection vehicles of the Department and its cleaning contractors will collect household refuse at least once a day at public refuse collection points which are generally in operation from 7:00 a.m. to 3:30 p.m. For those in busy areas, the operation hours are extended to 11:30 pm or may even be 24 hours.²



Above: Gage Street refuse collection point.

Below: Cleaner pushing trash cart into refuse collection point.



Above: Refuse collection points located across Hong Kong Island.

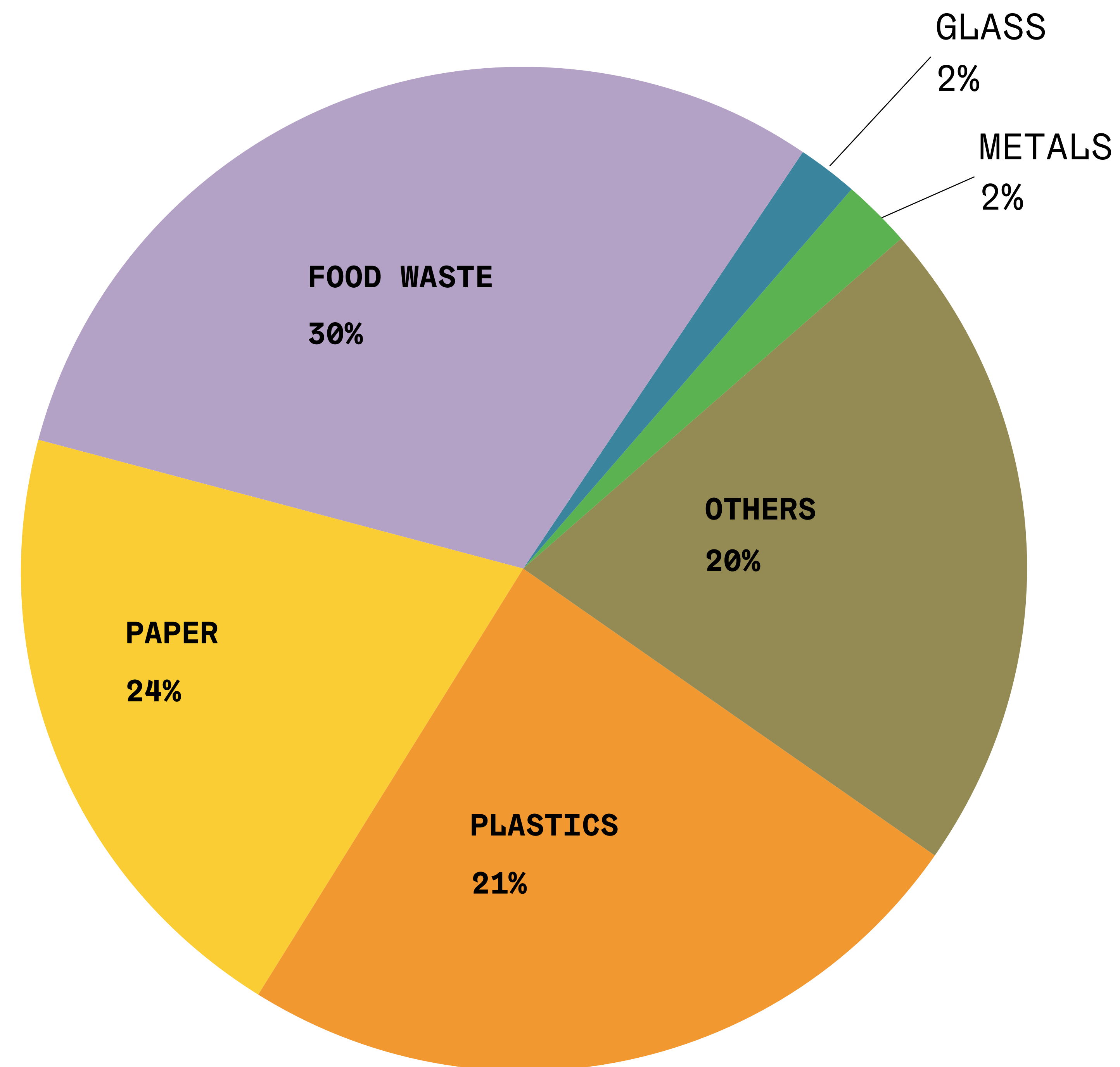
Below: Waste collection truck heading out of Cross Lane refuse collection point.

2. MSW_con_doc_full_eng.pdf

Waste Streams and Plans

Much of the recycling in Hong Kong has historically been carried out by informal recyclers. For decades, informal recycling has been an important source of financial income for many low-income individuals, who can often be seen collecting and pushing piles of cardboard and paper materials around on carts. Most of these collectors work alone and sell collected recyclables to small informal “recycling shops”.

COMPOSITION OF MSW DISPOSED OF AT LANDFILLS IN 2019



TOTAL DISPOSED QUANTITY: 4.04 MILLION TONNES



Collectors sorting through glass and plastics and putting them in collection bins.



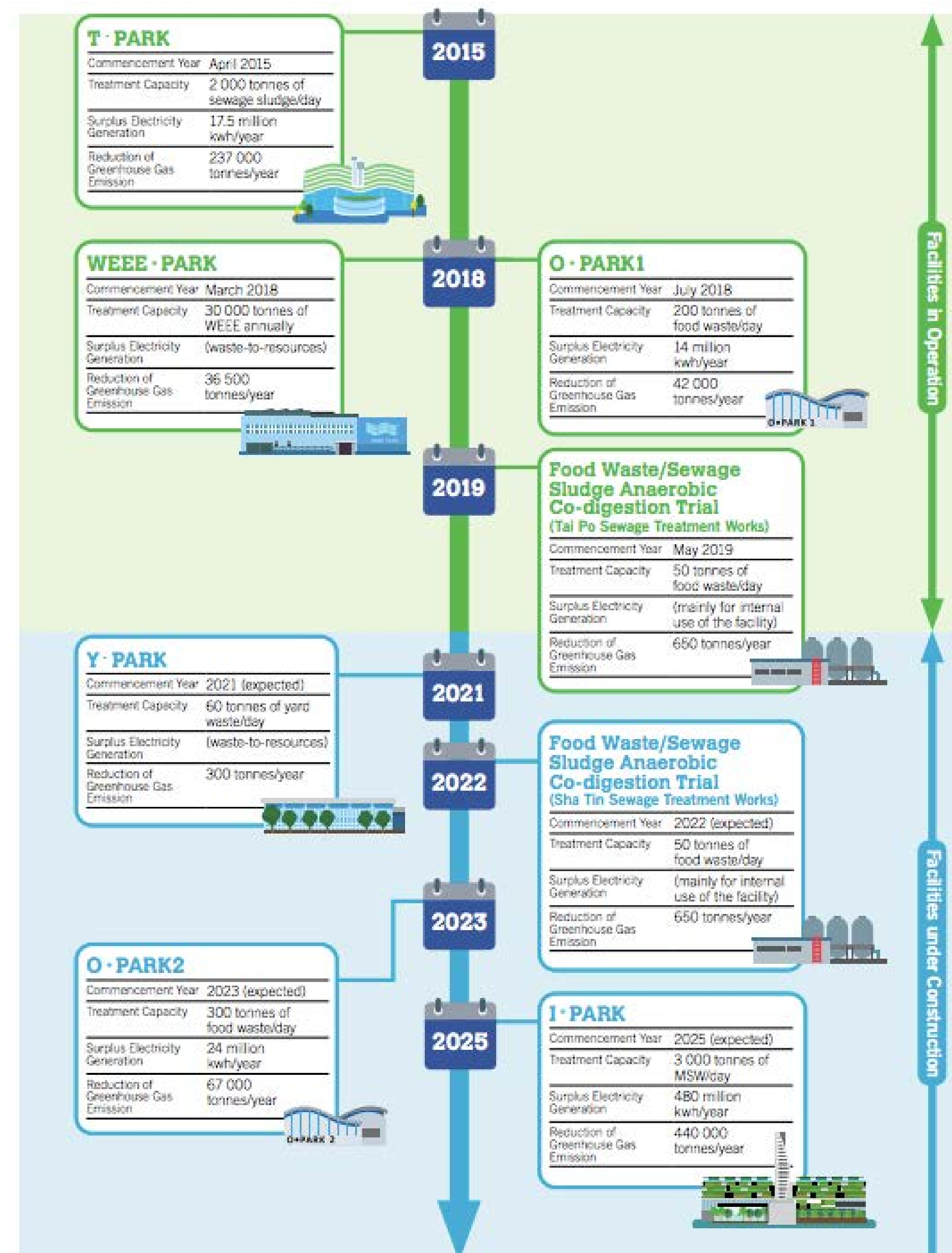
Informal recycler pulling a cardboard pile.



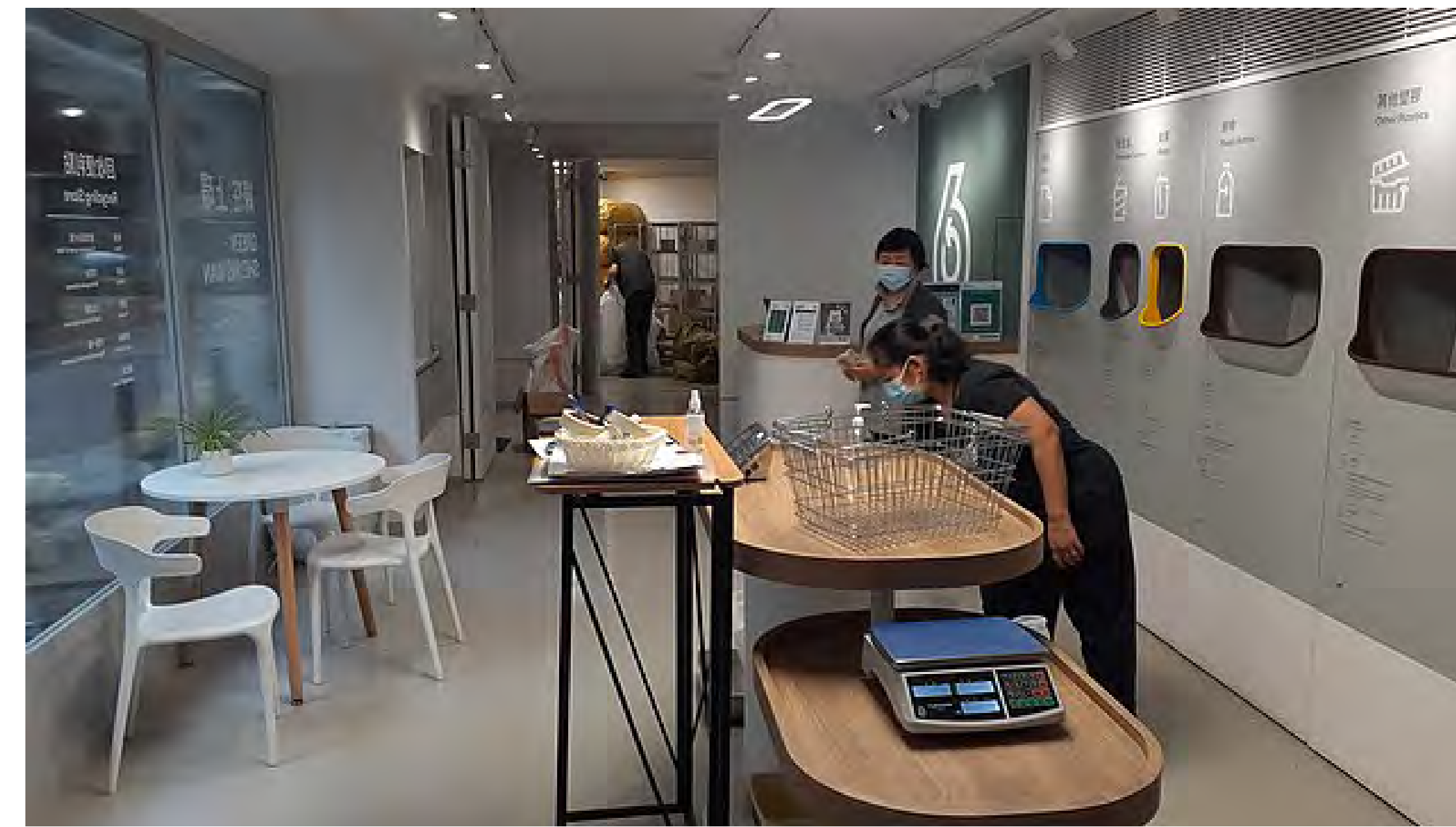
An informal recycling store with recyclers sorting and grouping low-value recyclable materials.

Hong Kong issued its Blueprint for Sustainable Use of Resources 2012-2022 in May 2013. It focused on policies to reduce waste, mobilize the community and invest in infrastructure. It recognizes that the value of some recyclables, such as metals, paper and electronic waste, led to them being diverted reasonably efficiently by informal and private waste collection industries, but there was little diversion of lower value recyclables such as plastic, glass and food waste. It proposed policies including a municipal solid waste charging scheme, also known as Pay-As-You-Throw (PAYT), and producer responsibility schemes, to improve the commercial viability of recyclables. It also included direct support for increased diversion of food waste and recyclables, through education, supplying bins, equipment grants, pilots and the development of local green stations. In 2005 a Construction Waste Disposal Charging Scheme was introduced, and there are plans to develop a construction waste sorting facility.

One key driver for the plan was the fact that HK was rapidly running out of landfill capacity. The plan includes the development of waste infrastructure to process recyclables, food waste, sewage sludge, as well as an EcoPark to provide affordable space for the recycling industry. The EcoPark has a site area of 200,000m² with twelve different sections treating and processing different waste such as food waste, cooking oil, metals, wood, electronic equipment (WEEE), batteries, and construction and demolition materials.³



The Waste Blueprint of Hong Kong 2035, issued in 2021, increases support for recycling, due to the declining market for many recyclables. The plan expands the supply of free bins for common interior and exterior areas of residential, commercial and industrial sectors. It also supports a community recycling network, comprising of recycling spots, vehicles, stores and stations, which are operated in conjunction with non-governmental organizations.. Since the 2018 municipal waste charging PAYT legislation did not pass, the Blueprint recognizes that it is all the more important to implement its other plans to meet the city's waste goals.³



Images of recycling network facilities - clockwise from above:

1. Interior of a recycling store - allows residents to drop off clean and sorted recyclables.
2. Inside of a recyclables collection compartment.
3. A smart recycling vehicle that travels to residential estates.
4. The exterior of a green recycling station located in Sha Tin.



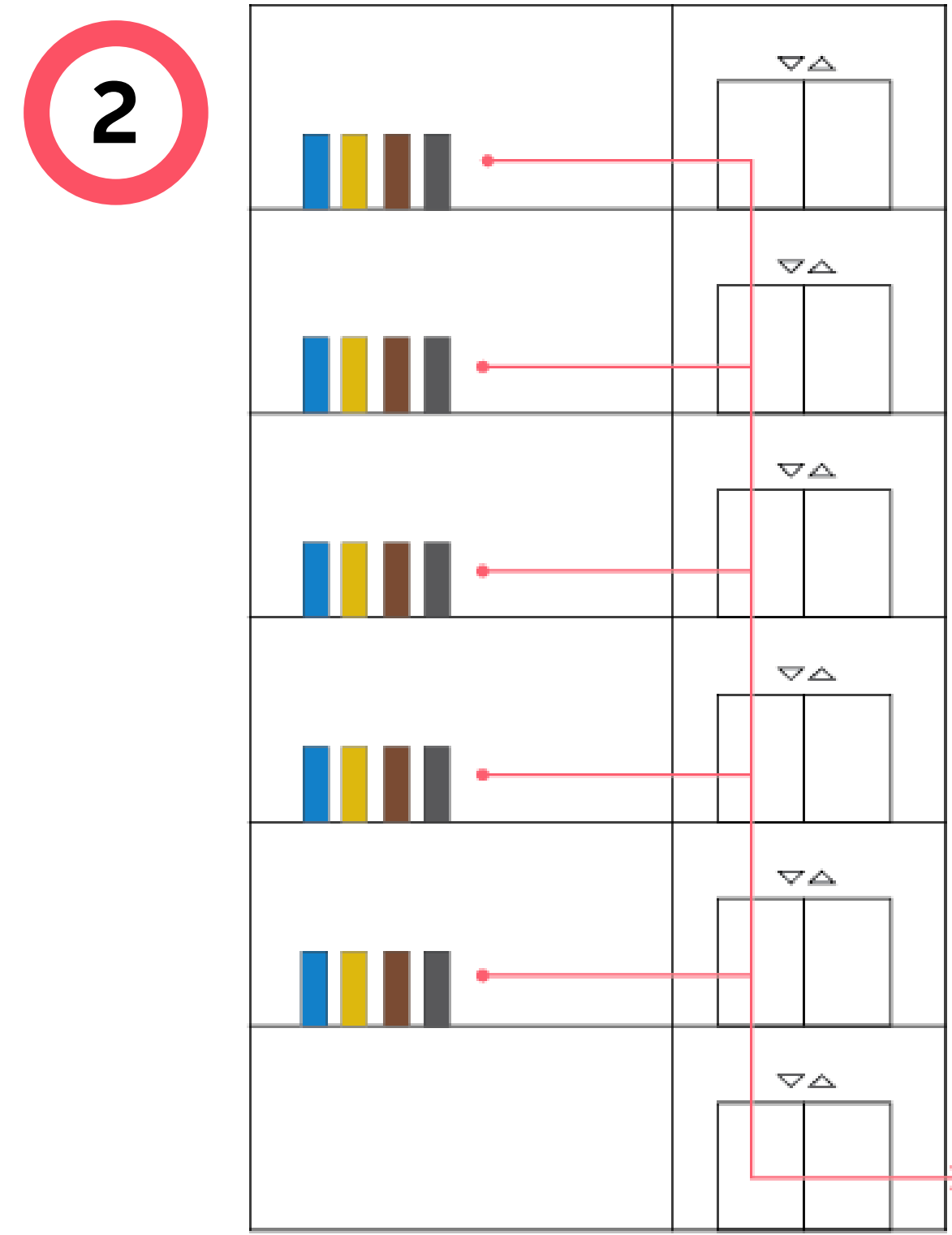
One of the recycling spots by a residential estate.



3. Waste Blueprint of Hong Kong 2035.pdf

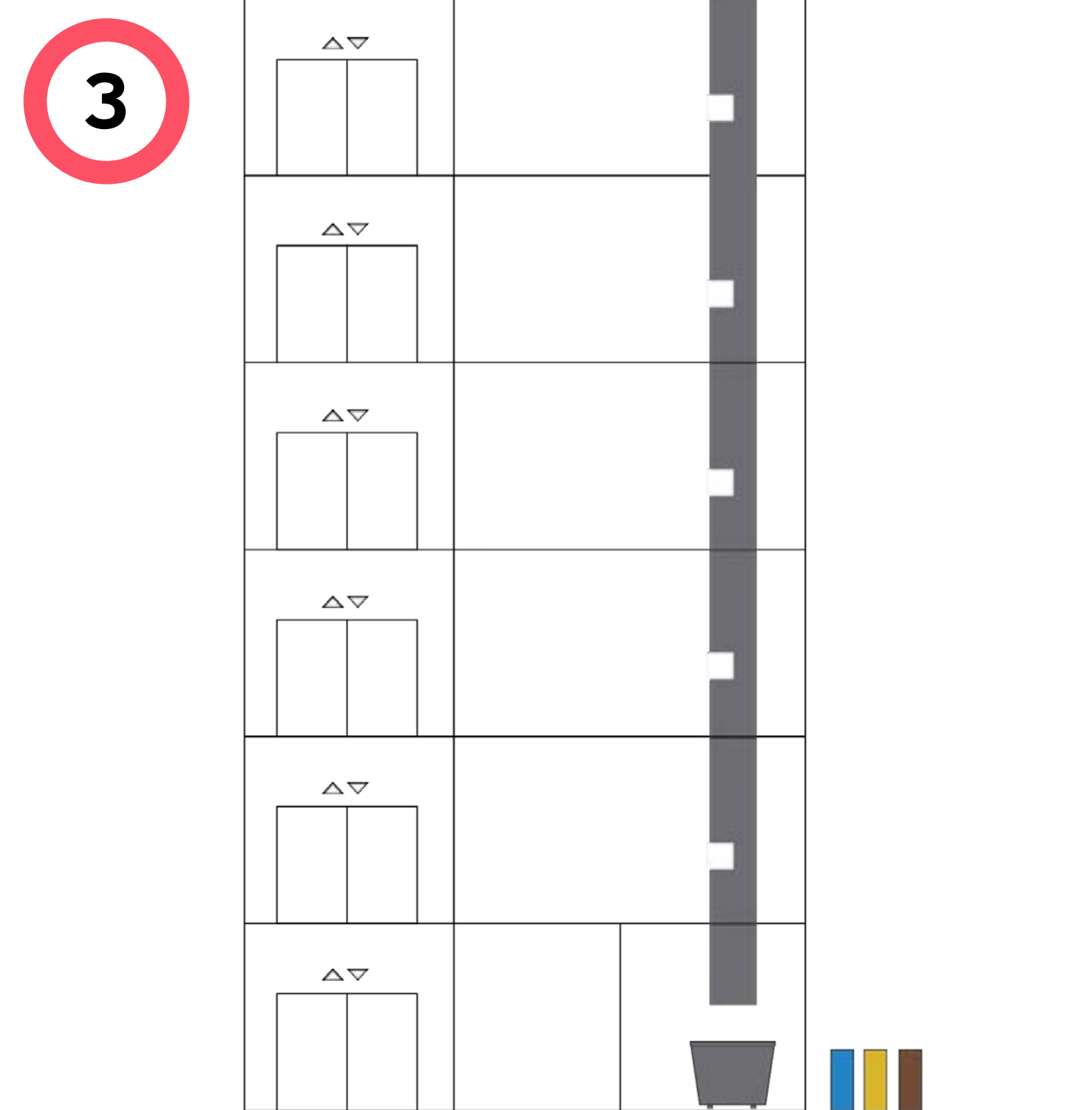
BUILDING CONTEXT

HK - TYPICAL EXISTING RESIDENTIAL BUILDING



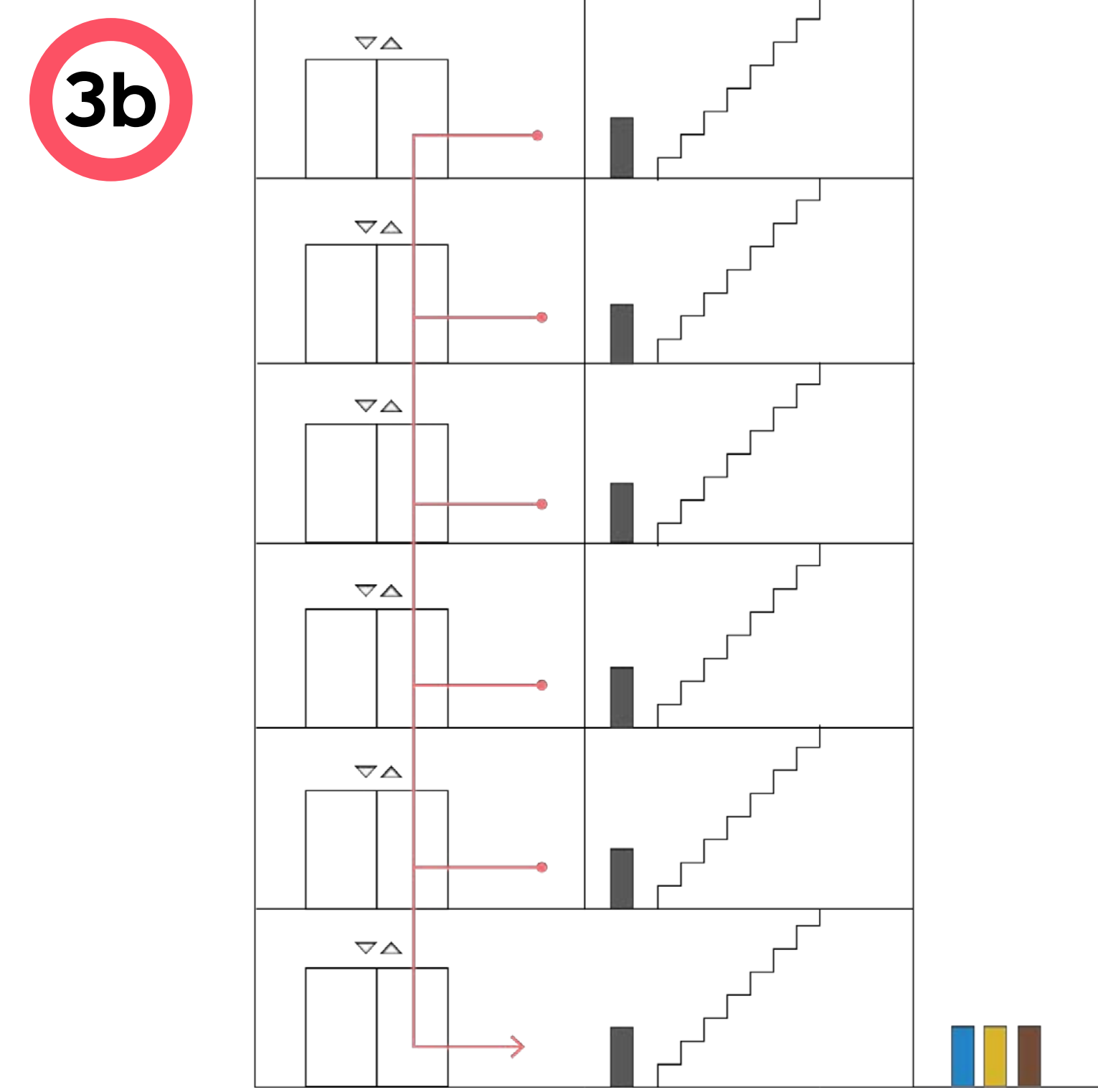
BINS IN SERVICE CORRIDOR

Bins for trash and recycling are wedged in existing service spaces, such as the stairwell, service lift lobby, or cleaning supply room.



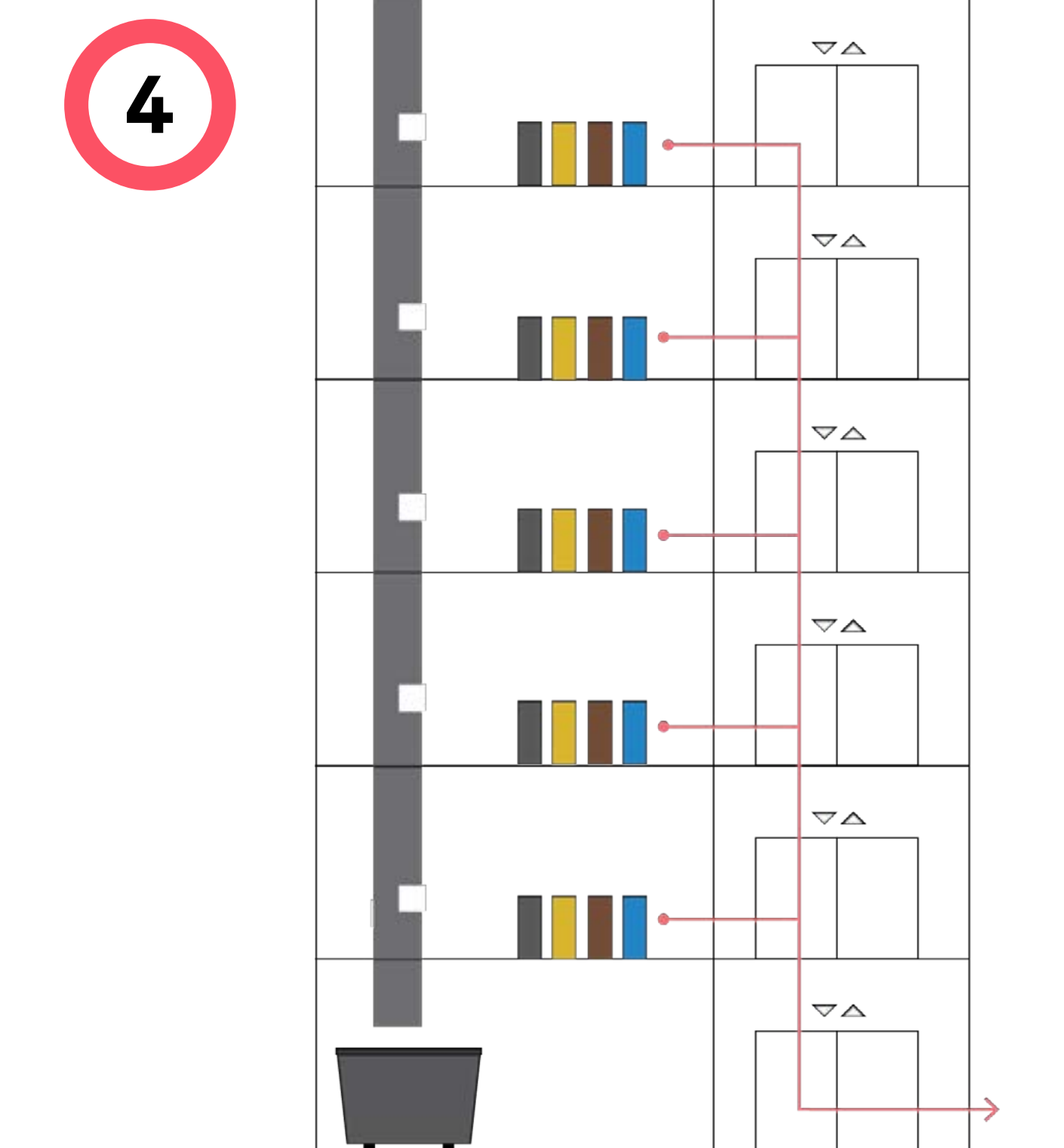
CHUTE WITH CENTRAL RECYCLING

In larger buildings, there is typically a chute for trash, and there may be central recycling.



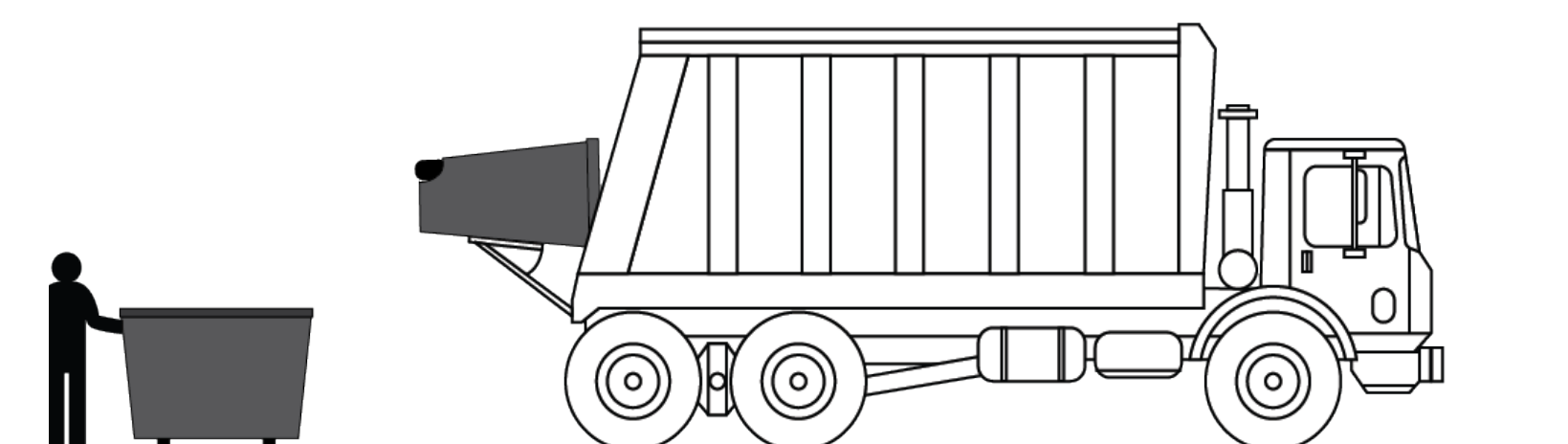
TRASH BINS WITH CENTRAL RECYCLING

In HK, smaller residential buildings, typically up to 6 stories and often without an elevator, have no waste rooms, and residents bring waste to enclosures on the street, or to a central area in the cellar.



REFUSE ROOM WITH CHUTE AND BINS

In other large buildings, bins reside in the small unventilated rooms on each story.



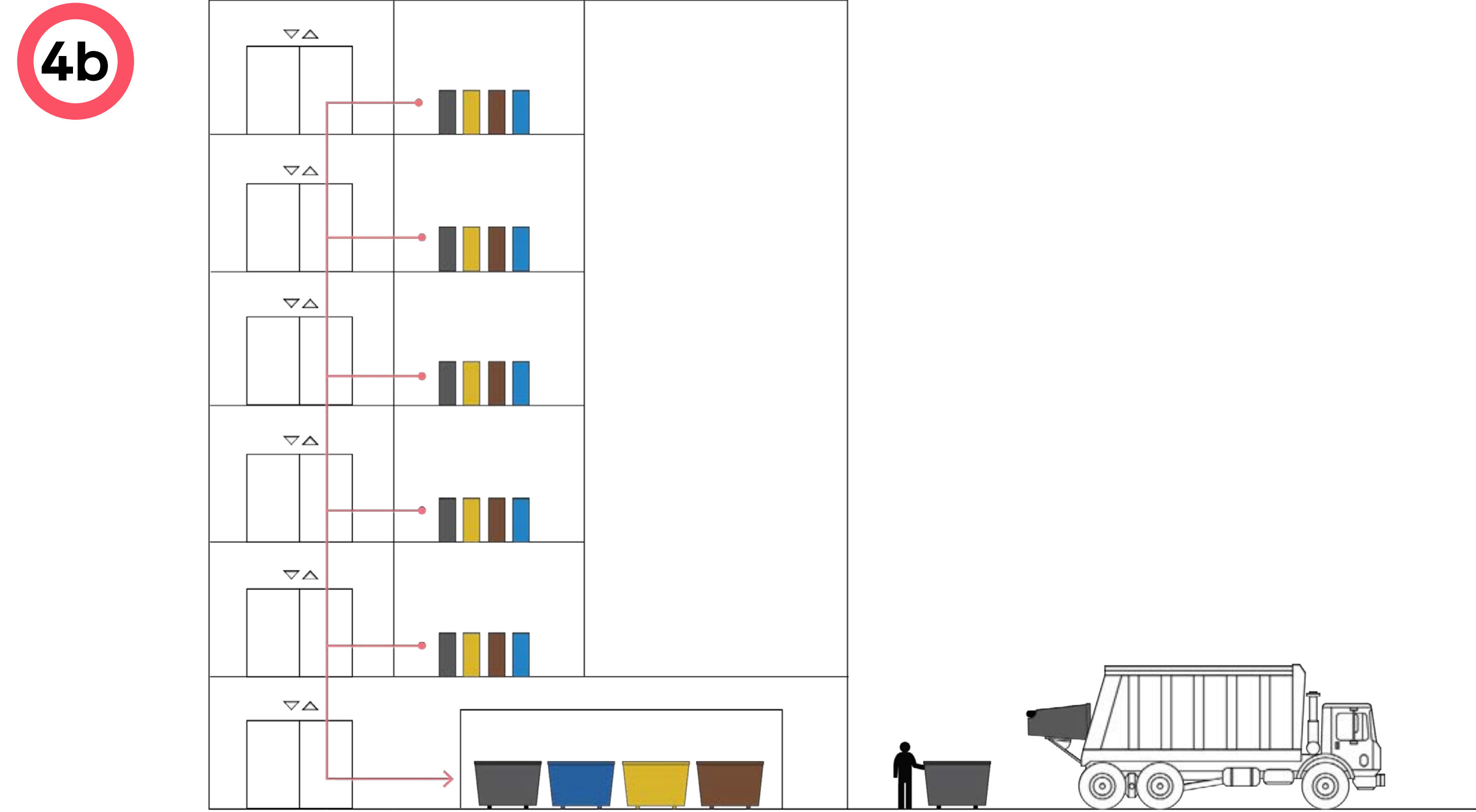
Collection Schedule

Refuse	by municipality 7x/week
Recycling	by private waste collectors, frequency varies with agreement
Organic Waste	no municipal collection, some options for drop-off



REFUSE ROOM WITH TRASH CHUTE AND RECYCLING BINS

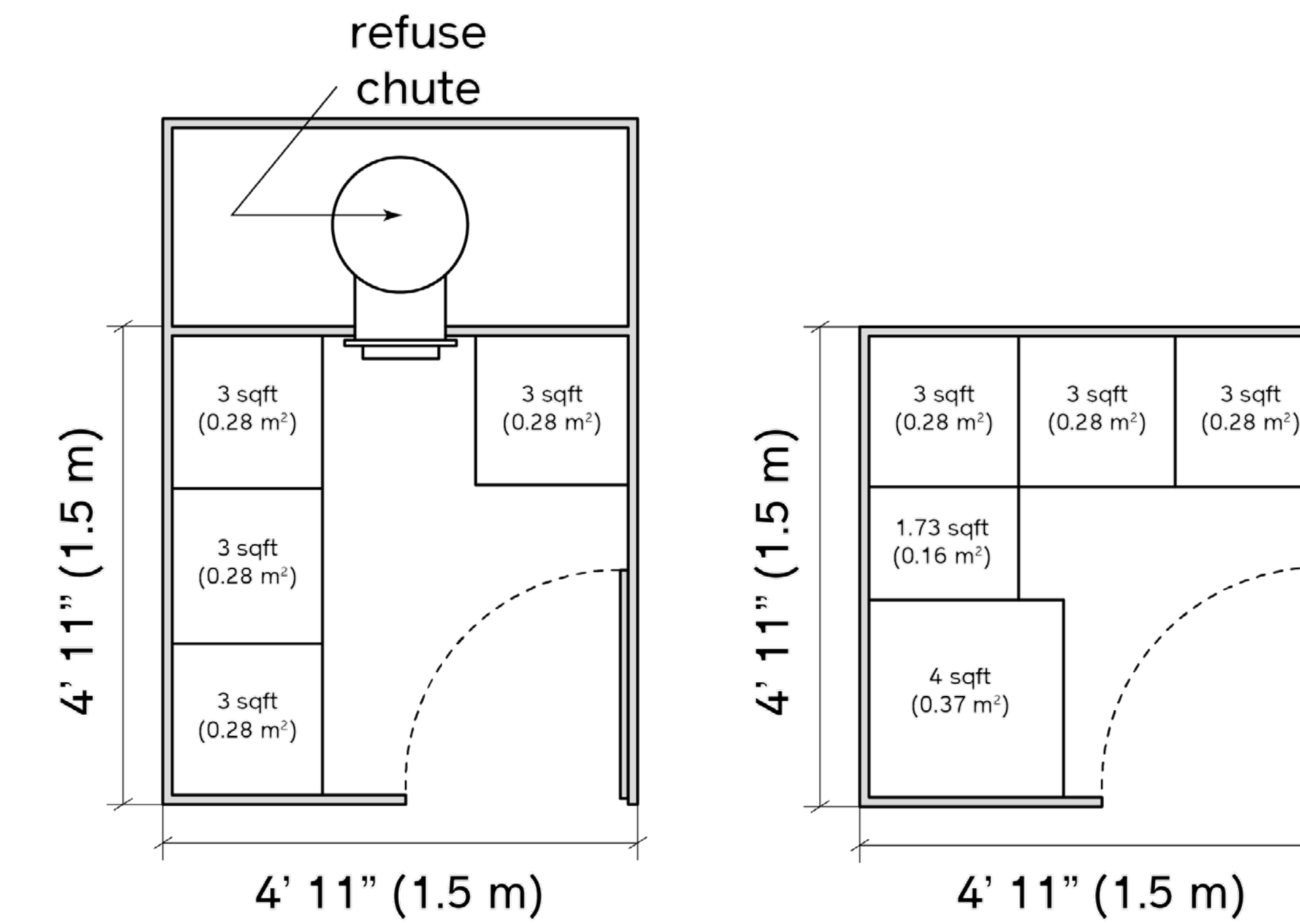
In new residential buildings, refuse and material recovery room with space for recycling bins is required on every story. A chute is optional. The refuse rooms are service by cleaning staff who take waste to a central storage area, either within the building, or the development.



REFUSE ROOM WITH TRASH AND RECYCLING BINS

The central storage area is required to have a door directly to the exterior, so is typically on the ground floor. 660 liter bins are typically used and taken directly out to the truck for pick up daily. Recycling has to be contracted to a private hauler, though indoor or exterior bins are provided by the government's Environmental Campaign Committee (ECC).

CODE REQUIREMENTS



Scale 1/2" to 1'0"

SAMPLE LAYOUT PLAN FOR REFUSE STORAGE AND MATERIAL RECOVERY ROOM

- Refuse storage room and material recovery chamber, with 1.25m doors direct to the exterior, ventilation, water supply, floor drain, durable surfaces. Area - is usable floor space / 347. If over 13,200 m2 usable floor space needs to have vehicle access.
- Refuse storage room and material recovery room on every story for most new residential buildings. 1.5m x 1.5m minimum (2.25m2 minimum), needs mech. ventilation.
- Chute is optional if the provided room needs an opening to the exterior. The chute may open into a compactor and 660 liter container, which reduces the volume by half.



DEVELOPMENT WITH CENTRAL
REFUSE COLLECTION

Central refuse collection point may have wheeled containers, typically 660 liters, or roll-off containers. In public housing with trash generation over 5 tons/day roll-off compactor containers for trash are typically used.

HK - CHALLENGES AND IMPACT OF RESIDENTIAL WASTE COLLECTION

Trash bins squeezed into exit stairwells



Refuse collection point



Separate central recycling area outside of building



Food waste collection



Food waste processing



Lack of space for bins; disposing of recycling and organics is typically much less convenient than trash

A lack of space for waste bins is a common issue in Hong Kong's residential buildings. When small bins are squeezed in stairwells or lobbies it requires a great amount of labor, as operation staff need to clear the room a few times a day to avoid the waste from piling up. Often recycling has to be deposited at centrally located bins, and no organics bins are provided. However for new buildings there are requirements for recycling bins and trash in a ventilated material recovery room on each story, which could accommodate organics bin also.

Food waste recycling scheme in housing estates

In 2011, the Environment and Conservation Fund (ECF) launched a pilot food waste recycling programme in housing estates to encourage food waste segregation and recycling. But the programme halted after a year due to low participation rates in many of the housing estates. Some of the feedback from residents included; not being aware of the programme; a lack of convenience and incentive; and odorous issues with the food waste processing machines.

Singapore Context



Urban Form and Waste Collection

Singapore is a city and nation, situated on one main island and many satellite islands, with a total land area of 720 square kilometres, around 25% of which is manmade by land reclamation. It has a multicultural population of 5.9 million, with four official languages. Singapore's overall population density is $\pm 8,200$ people per square kilometer. Despite such limitations, through strong urban planning, Singapore has been able to effectively develop a city that doesn't compromise liveability.¹

The limitations of land space have led Singapore to incentivize innovative, green strategies in their urban, infrastructure developments. The goal is to maximise spaces with green structures and increase the liveability of the city where parks, rivers, rooftop gardens, tree-lined roads, vertical



Singapore city center



Above: The ParkRoyal on Pickering Hotel's vertical gardens and green walls.

Below: Oasis Terrace's vertical gardens and green walls.



1. <https://www.worldometers.info/world-population/singapore-population/>

greenery are interspersed throughout the densely packed city. In order to encourage this greenery provision in Singapore, the National Parks Board has introduced the Skyrise Greenery Incentive Scheme (SGIS) to help fund greenery, and there are also Landscaping for Urban Spaces and Highrises (LUSH) requirements and development incentives for new residential and commercial developments.

The most common type of housing in Singapore is the high-rise apartment building. About 80% of the population live in public housing developed by the Housing Development Board (HDB). There are approximately 10,000 HDB blocks across Singapore, and most of the buildings are 10 to 40 storeys high. Housing is typically developed within self-sustaining satellite neighborhoods with schools, supermarkets, malls, food halls and healthcare facilities etc, to provide the common needs of residents within the area. On the ground floor of the HDB blocks, an open space (also known as a void deck) is commonly built-in that allows for resident's leisurely uses and communal gatherings.²

Historic neighborhoods have been substantially redeveloped, and there are not many areas left with traditional shop-houses, which have ground-level shops and residential apartments above. Downtown Singapore is largely commercial, but the Urban Redevelopment Authority plans to introduce residents and transform the area into mixed-use neighborhoods.

Most HDB blocks have a central refuse collection point within the development, where refuse is stored in 660 liter containers, dust drums or roll-off compactor containers. Refuse is typically collected daily, as the warm, humid climate leads putrescible waste to decompose rapidly.



Kampung Admiralty, HPD's first integrated mixed-use public development.



Amoy Street with traditional shop-houses.



Recycling initiative occurring on the ground floor of a HDB.

2. <https://www.bloomberg.com/news/articles/2020-07-08/behind-the-design-of-singapore-s-low-cost-housing>

Waste collection is set up with a zoned franchise system for public waste collection (PWC) for domestic and trade premises, and currently, 3 companies serve the 6 zones. Through the National Recycling Programme, PWC's are required to provide single-stream recycling bins and collection services to all HDB estates, private landed properties and condominiums, and is typically collected 3x/week from 660 liter bins put in a common area of the estate, or 1x/week from larger bins. Residents pay for waste collection through a fixed fee, which varies between different service providers in different areas.³

There are also general waste collectors (GWCs) which primarily serve commercial and industrial premises, and also handle other types of waste including construction debris, e-waste, organic waste, and used cooking oil. GWC's are charged for disposal of refuse at the National Environment Agency (NEA) facilities per volume but typically charge commercial customers a fixed fee.

Waste Streams and Plans

Singapore generates 7,695,000 tonnes of waste per year. Diversion rates vary widely by the stream, from just 4% for plastics and 17% for food waste to 99% for construction debris, most of which is ground up and used in land reclamation projects. Singapore also has a Demolition Protocol which requires reusable parts of a building, like piping and wiring, to be separated prior to demolition.

It is not mandatory for Singaporeans to separate recycling at home or at work, and there is still a strong informal economy of waste collectors,



An automated side-loader recycling truck can lift larger 1200 and 2400 liter recycling bins.



Loading a 660 liter recycling bin into a rear loading recycling truck.

3. <https://www.cnbc.com/2016/11/14/singapore-government-focuses-on-recycling-but-residents-fail-to-play-their-part.html>

called Karang-Guni, who go door to door and pay residents for items such as newspapers, textiles or electronic waste. Informal recycling is also done by individuals who go through bins to pick out newspapers, carton boxes and drink cans and sell the recyclables to a waste recycling company. In 2016, the National Recycling Programme started requiring PWCs to provide recycling bins and collection services to HDB estates, private properties, apartments and condominiums that are part of the public waste collection scheme. The programme collected just 2% of the total waste generated by households, whereas the informal recycling sector collected almost 9 times more.⁴

Singapore issued a Zero Waste Masterplan in 2021 which updated the Sustainability Blueprint of 2015. The Masterplan focuses on helping Singapore overcome the three challenges of Climate, Resource and Economic Resilience, helping Singapore develop climate, resource and economic resilience, and extending the life of the Semakau landfill, which is set to run out of space by 2035 at the current disposal rates. Singapore sends 7,600 tonnes of solid waste a day to five Waste to Energy Incineration plants, which provide up to 3% of the island's electricity needs, and the ash is sent to the 350-acre Semakau offshore landfill, which was constructed between two small islands.⁵

PWCs are required to have a Materials Recovery Facility (MRF), where recycling is sorted into different waste streams, baled and sent to local and overseas recycling plants. Some food waste is processed by anaerobic digestion with sewage sludge at wastewater treatment plants. A pilot mechanical biological treatment facility for separating recyclable materials

National Recycling Programme

The infographic is divided into four quadrants:

- Recycling in HDB estates:**
 - Recycling bins:** 1 recycling bin (660L) for every HDB block; Minimum collection of 3X / week.
 - Recycling bags:** Fortnightly door-to-door collection (discontinued).
- Recycling in Landed Estates:**
 - Recycling bins:** 1 recycling bin (120L) / landed house; Weekly collection.
 - Garden waste collection:** (Leaves, small branches).
- Incentive schemes:** Cash for Trash, GRIN programme.
- Commingled recycling system:** (Visualized with a house icon).



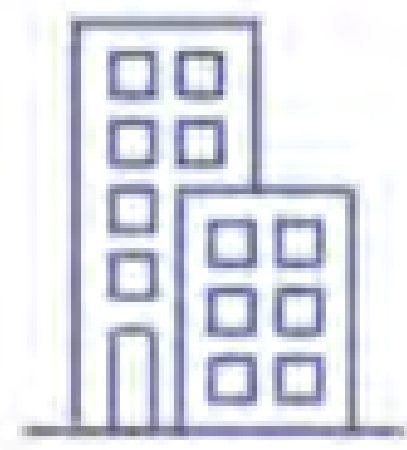
Above: National Recycling Programme requirements and incentives.

Below: Informal cardboard and paper collector.

4. <https://www.channelnewsasia.com/news/commentary/singapore-recycling-rag-a-bone-karang-guni-climate-change-11491692>
 5. <https://www.nea.gov.sg/our-services/waste-management>

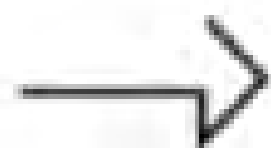
SINGAPORE'S WASTE FLOWS (2018)

DOMESTIC



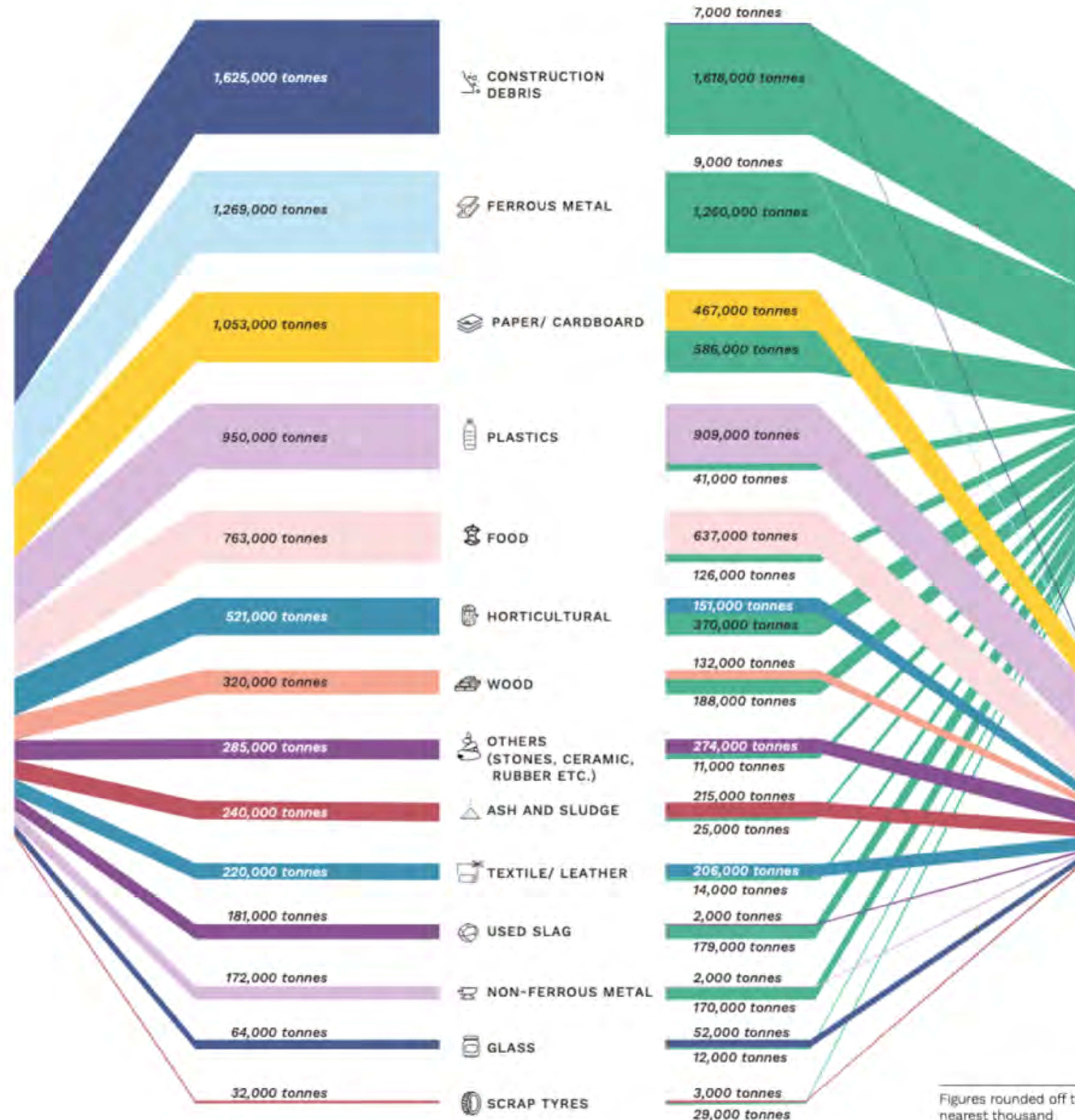
TOTAL WASTE GENERATED

+



7,695,000 TONNES

NON-DOMESTIC



TOTAL WASTE RECYCLED
4,629,000
tonnes



TOTAL WASTE DISPOSED OF
2,838,000
tonnes
228,000
tonnes

Figures rounded off to nearest thousand.

like plastics and metals from waste is also being piloted. A multistory recycling facility is being built which will house recyclers handling metals, e-waste, paper and plastics and encourage synergies between them.

The Masterplan's goals include reducing domestic MSW sent to landfills by 30% by 2030 (with 2018 as a baseline) and achieving a 70% overall recycling rate by 2030, with a non-domestic recycling rate of 81% and a 30% domestic waste recycling rate. The plan focuses on reducing and diverting food waste, packaging and electronic waste. In 2019, around 30% of the domestic waste stream consisted of plastic, 19% was cardboard and paper, and 20% was food waste, all recyclable materials with low diversion rates in Singapore.⁶

Furthermore, there are several initiatives focused on reducing waste related to the design of buildings and the city. One of them is the requirement of large commercial waste generators, such as hotels or malls, to report their refuse and recycling generation data, typically through truck weighing systems, and submit a waste reduction plan.

Through this effort, the NEA reports that recycling rates have increased from around 6% to 7.4% for hotels, and 11.4% for malls. Another is the requirement that on-site food waste equipment has to be provided in large foodservice establishments. And new hawker centers are not allowed to use disposable dishware for dine-in service, nor are new stallholders at existing hawker centers.

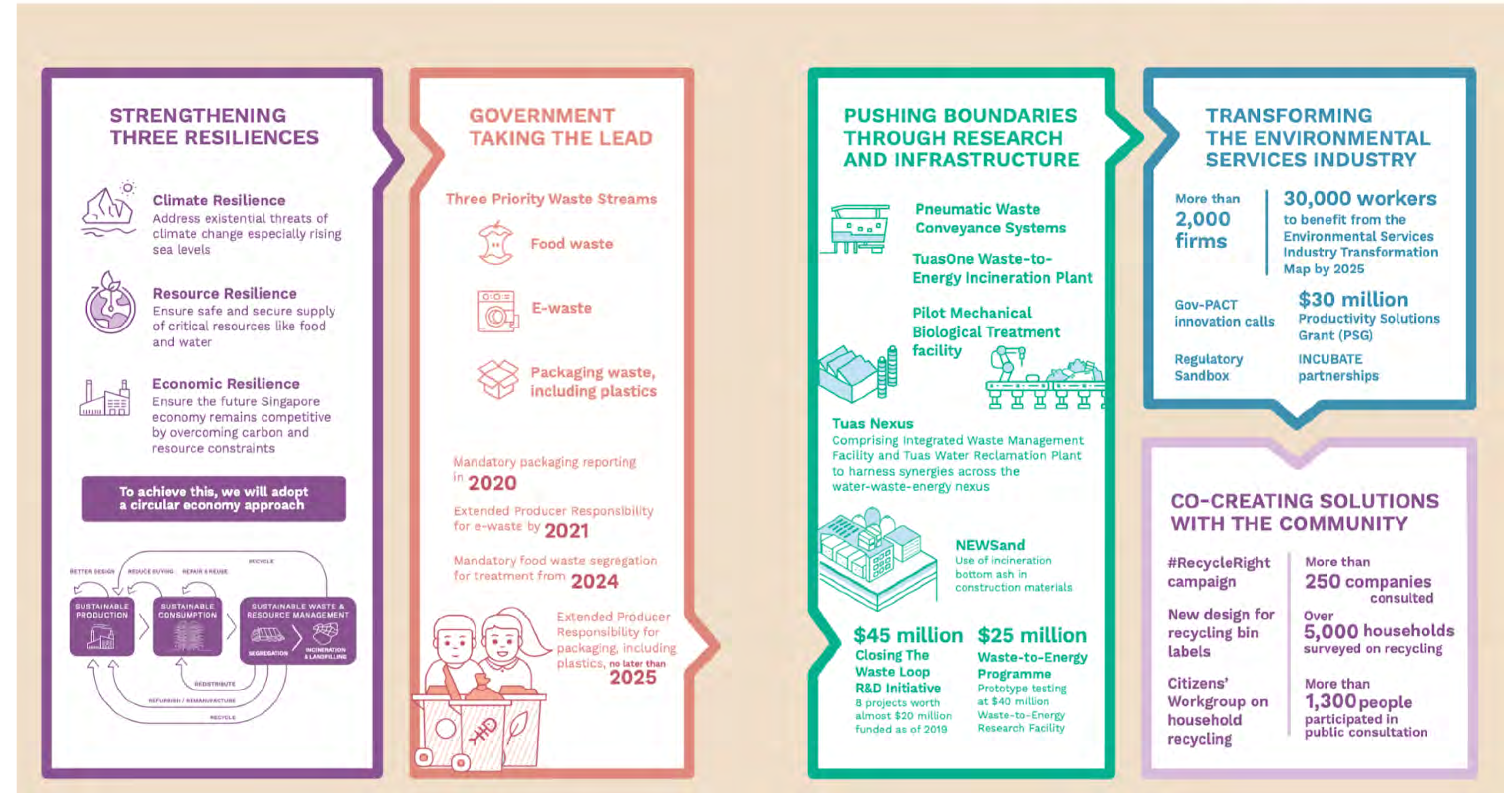
To promote reuse and donation, some hawker centers have allocated spaces for repair businesses, and are studying other ways of making

Zero Waste Masterplan

to Achieve a Sustainable, Resource-Efficient and Climate-Resilient Singapore

Our Targets

- 1 Extend Semakau Landfill's lifespan **beyond 2035**
- 2 Reduce amount of **waste sent to landfill per capita per day by 30%** by 2030
- 3 By 2030, achieve a **70% overall recycling rate**:
81% non-domestic recycling rate
30% domestic recycling rate



6. Zero Waste Masterplan in 2021.pdf

donation more convenient for Singaporeans. As well as a Renew program for electronic waste with collection bins across the island in community clubs, schools, shopping malls etc. There are also the Residents Network Resource Centers, which lend residents tools and goods (drills, ladders, trolleys etc) that they do not own.

Measures to make recycling more convenient are being taken, such as making it mandatory for all new non-landed private residential developments over 4 stories to have dual chutes for trash and recycling, in an attempt to reduce contamination of recycling - currently, 40% of the waste in the NRP recycling bins is contaminants, and only 60% of households regularly recycle at home.

Starting in 2018, Singapore requires that buildings of 500 and more apartments must have a pneumatic waste conveyance system (PWCS) waste collection system built-in. In addition, HDB initiated a Greenprint scheme to develop more sustainable public housing, where 38 residential blocks in Yuhua will be installing the PWCSs.⁷



Above: Pneumatic Waste Conveyance System (PWCS) collection bins at a residential development in the SSTECC.

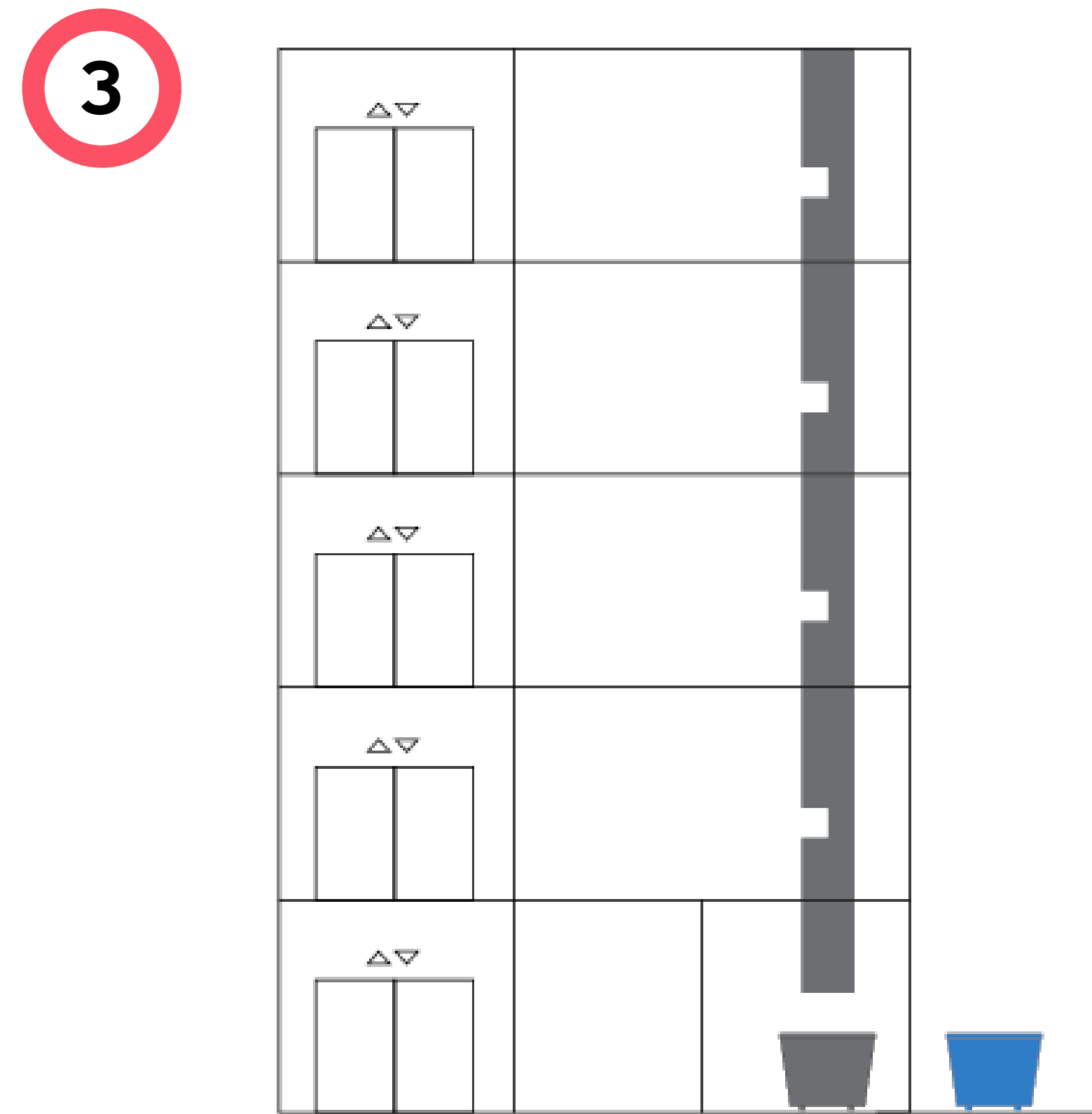


Below: Dust screw-bins located below buildings at Arena Green Condo.

7. <https://www.straitstimes.com/politics/parliament-dual-waste-chutes-for-new-private-flats-to-spur-on-recycling>

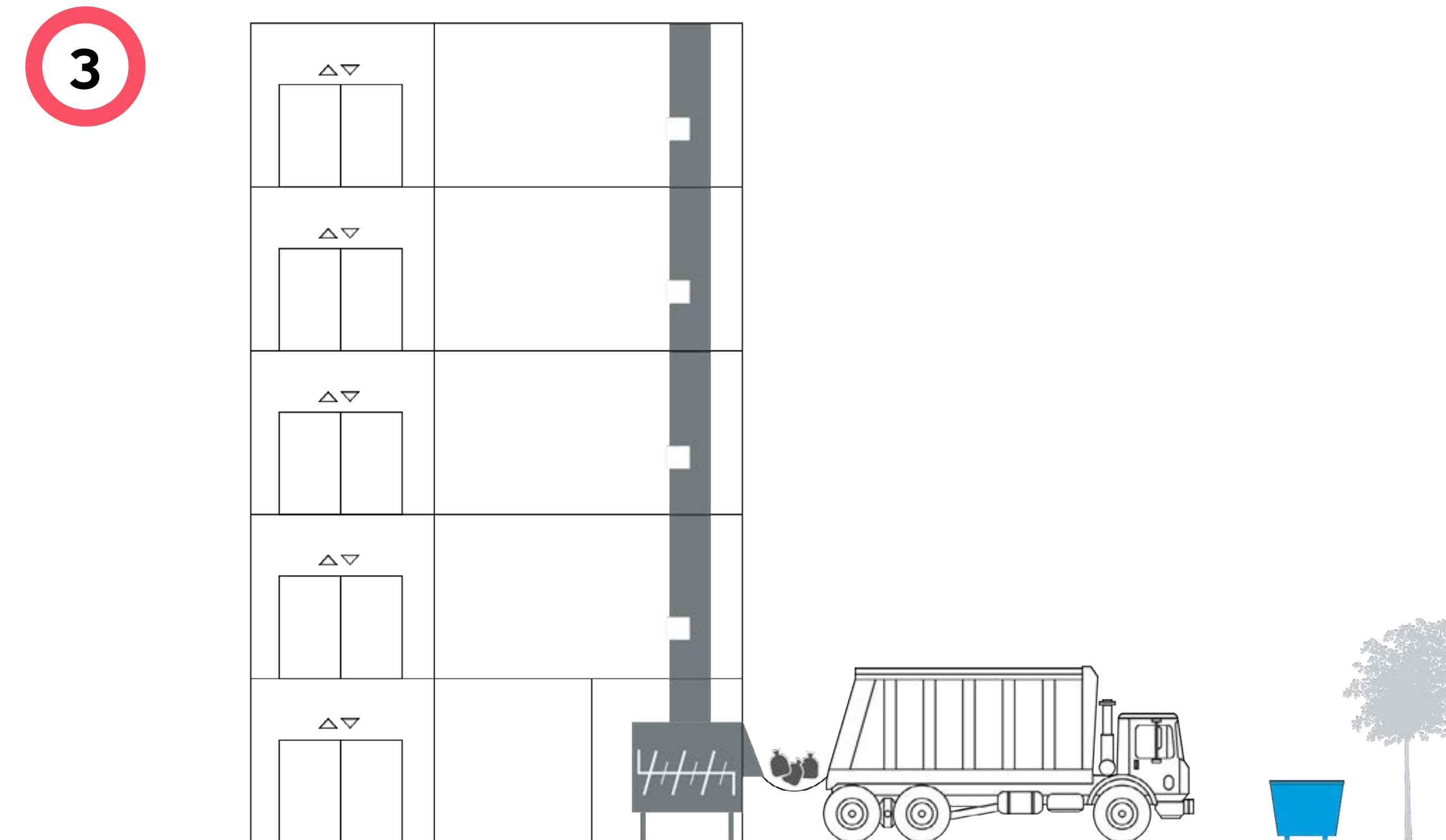
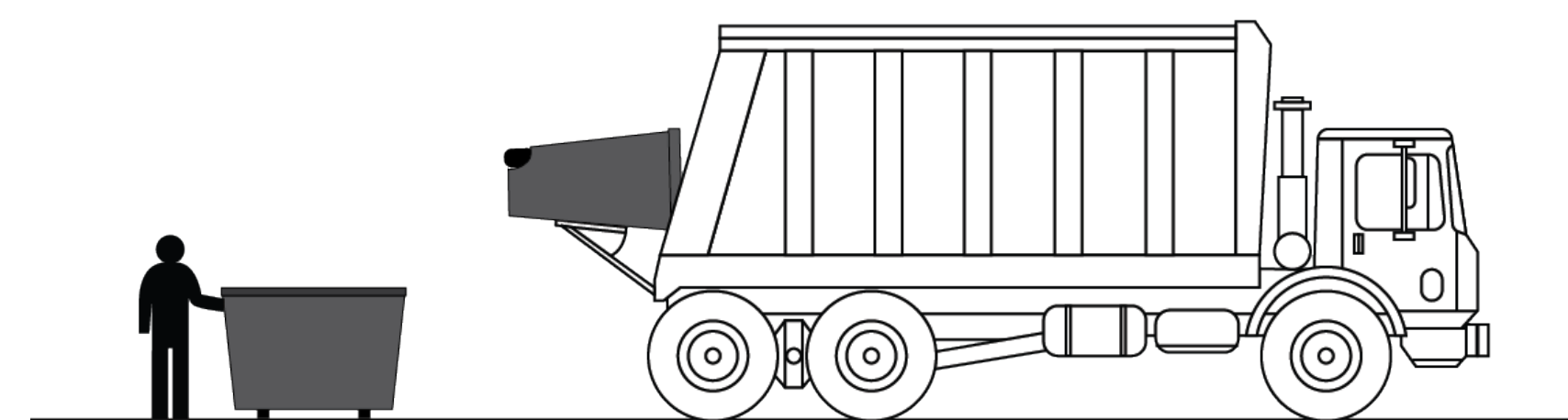
BUILDING CONTEXT

SG - TYPICAL EXISTING RESIDENTIAL BUILDING



CHUTE WITH CENTRAL RECYCLING: WHEELED BIN

Under the National Recycling Program, HDB estates and private properties serviced by Public Waste Collectors (PWC) have central recycling bins for mixed recycling. Flats built before 1989 use the individual Refuse Collection System (IRCS) for waste disposal. Residents will dispose of their waste through hoppers in the kitchen, the apartment, or elevator landing, and the waste goes down the chute into a collection bin at the bottom. The waste is then manually collected and stored at the bin center before being removed by the National Environment Agency's (NEA) Public Waste Collectors.



CHUTE WITH CENTRAL RECYCLING: DUST SCREW

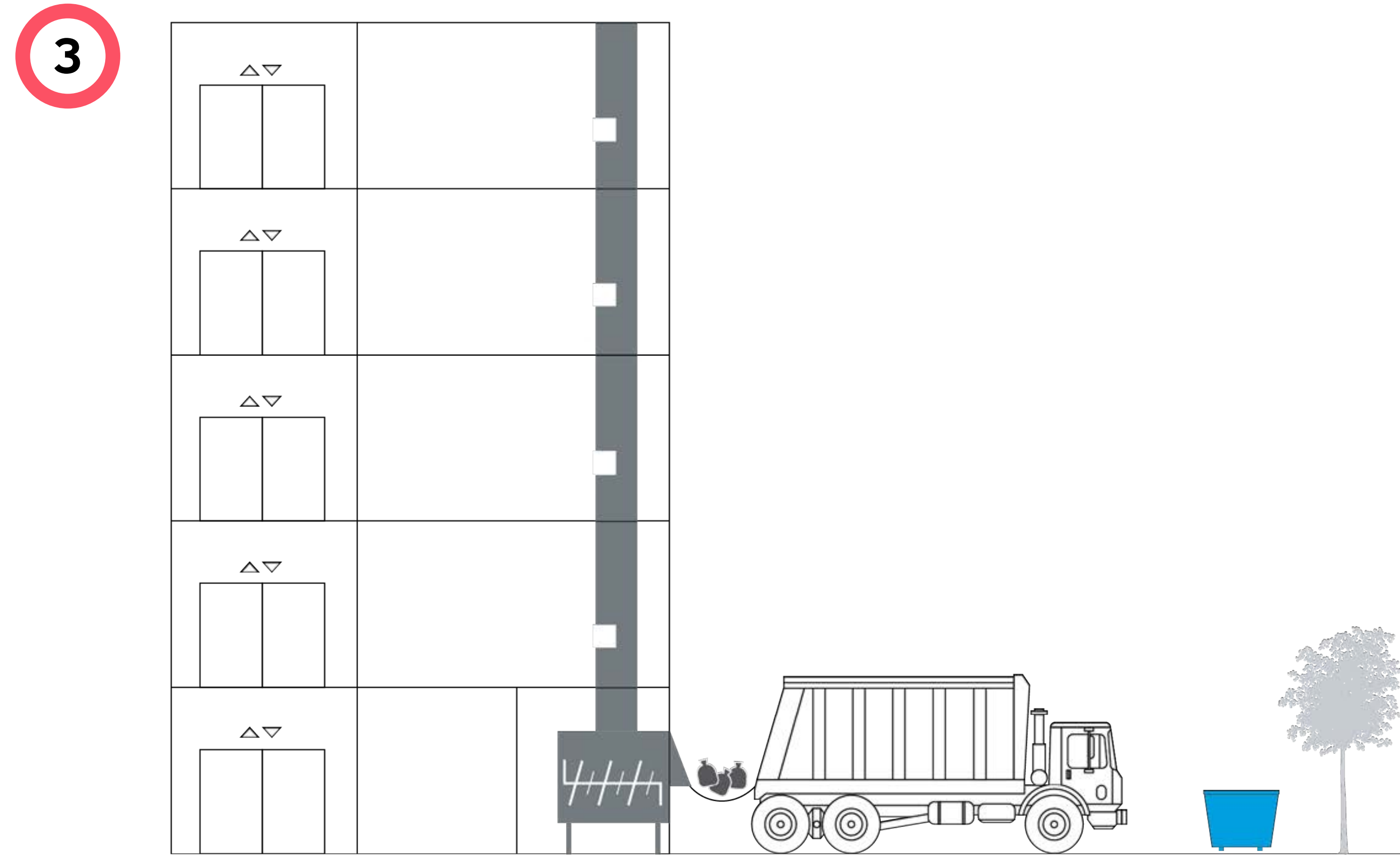
Flats constructed after 1990 were fitted with a dust screw unit at the bottom, in replacement of the individual-unit hoppers.

Collection Schedule

Refuse	daily
Recycling	3x/week if in 660l bin, 1x/week if in 1200/2400l side loader bin
Organic Waste	garden waste collected from landed properties 1x/week

SG - TYPICAL NEW RESIDENTIAL BUILDING

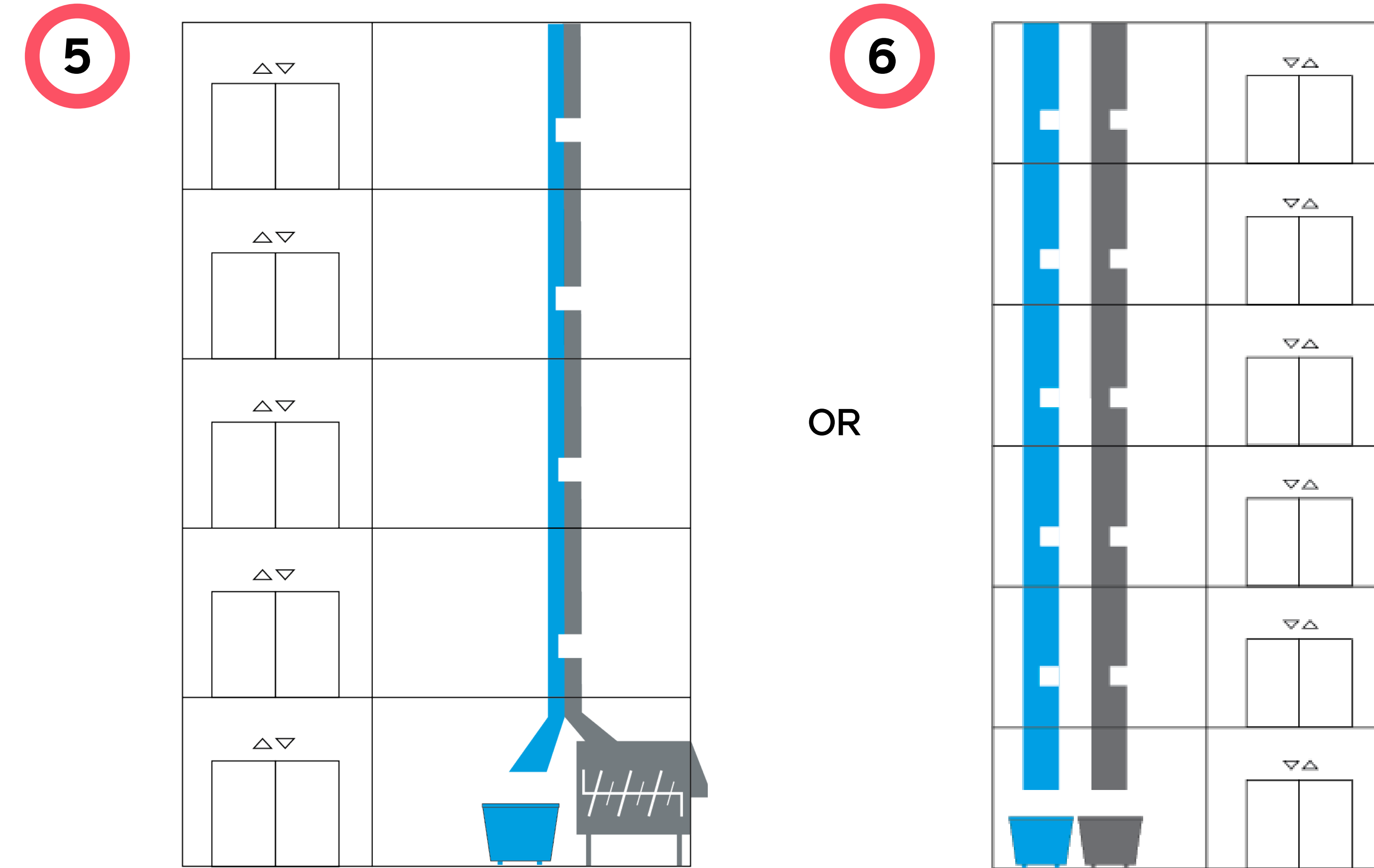
PUBLIC HDB ESTATE



CHUTE WITH CENTRAL RECYCLING

- Under the National Recycling Program, HDB estates have recycling bins for mixed recycling (1 per block).

PRIVATE RESIDENTIAL BUILDINGS

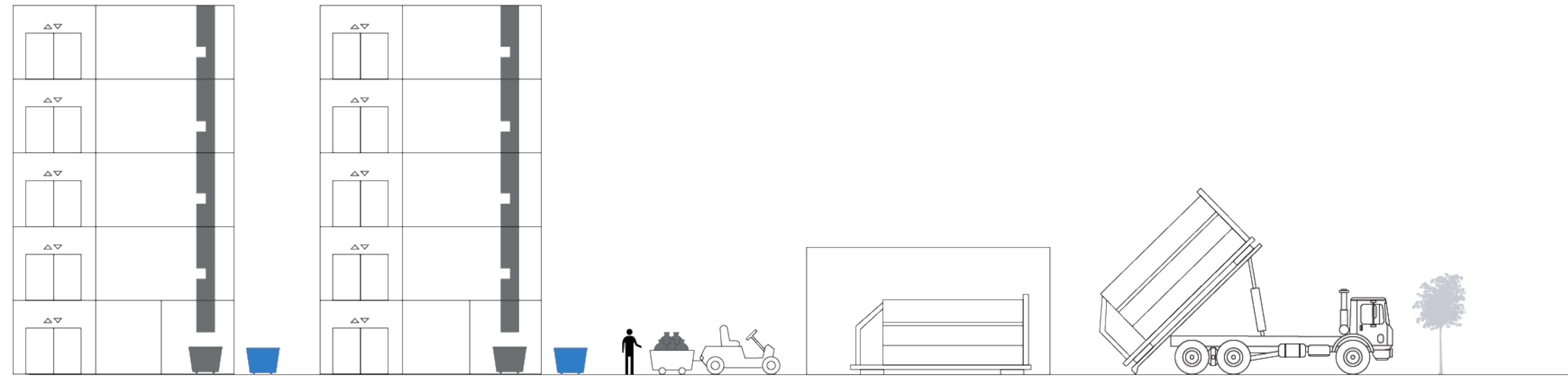


SINGLE CHUTE WITH SORTER

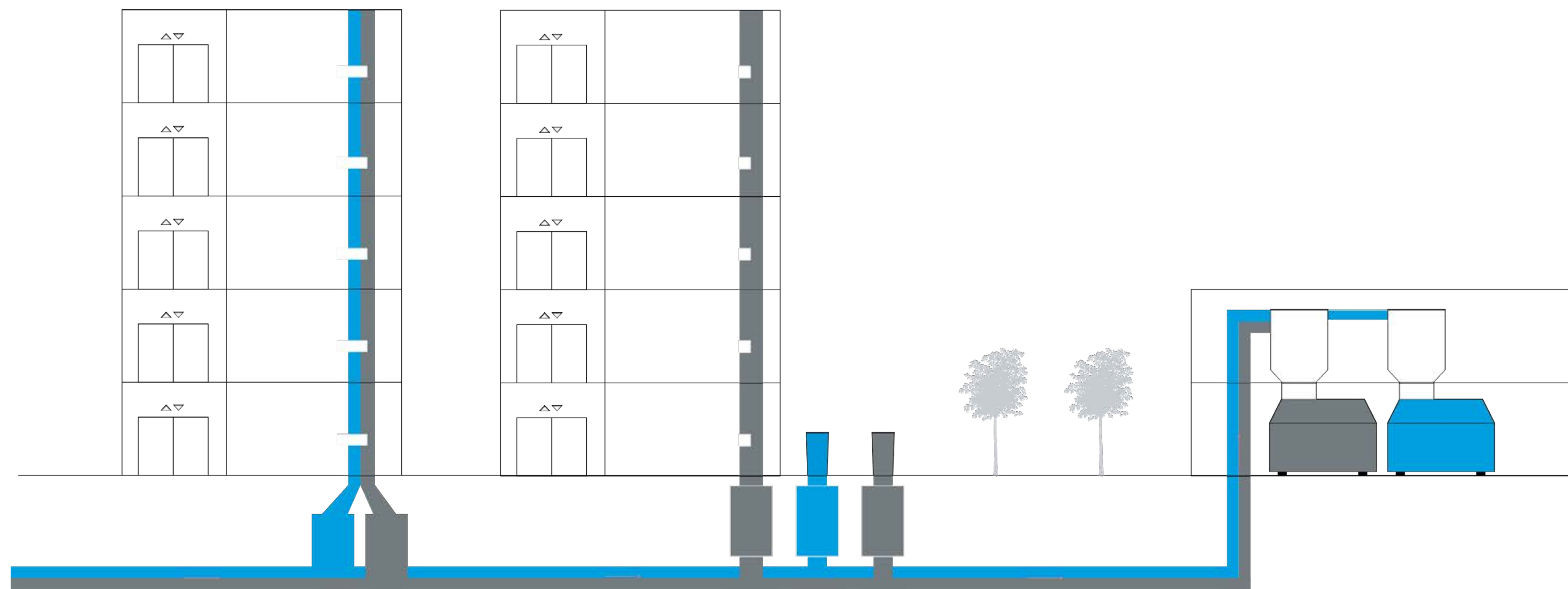
MULTIPLE CHUTES

- New strata-titled residential properties > 4 stories are required to have a recycling chute or chute sorter.
- Refuse chute required > 4 stories

SG - TYPICAL NEW RESIDENTIAL DEVELOPMENT



HDB ESTATE OR STRATA-TITLED UNDER 500 UNITS

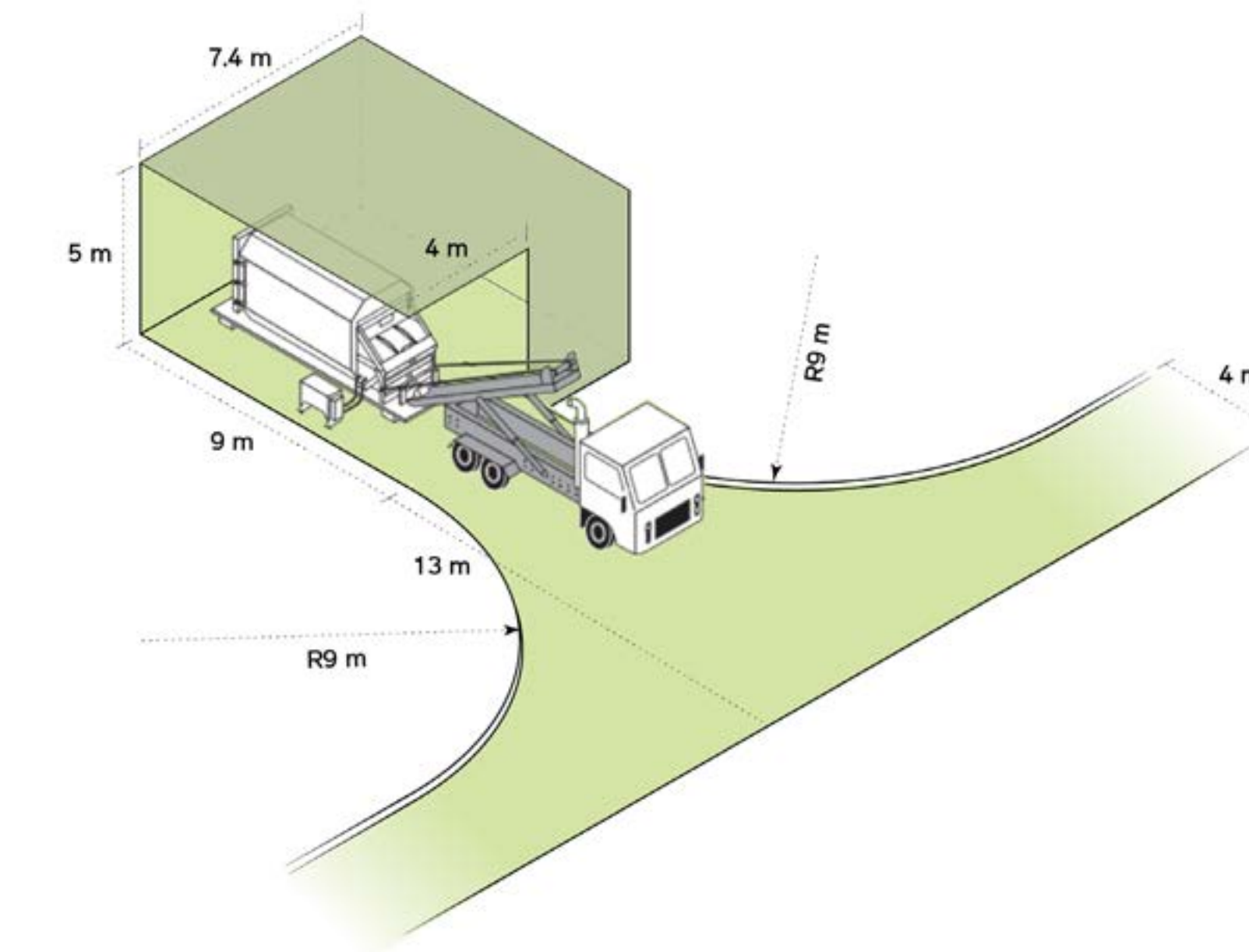


STRATA-TITLED ESTATE OVER 500 UNITS

CODE REQUIREMENTS

- If the refuse output exceeds 1,000 liters per day (typically 50 units) and the project adopts a refuse chute chamber, then a bin center will also be needed. The bin center needs to be accessible to collection vehicle and include space for 2 days worth of refuse storage, a water source, floor drain, pest proof, 1m clear access walkway.
- If over 4000 liters/day (200 units) need a roll-on roll-off compactor/ container, dust screw compactor or a rotary drum system. Needs a 4m x 5m high access door and 13m setback.

TYPICAL LAYOUT OF BIN CENTER



- All new strata-titled properties with 500 or more residential dwelling units shall be provided with a Pneumatic Waste Conveyance System (PWCS).
- A PWCS bin center shall be provided for stationary systems, with capacity for at least 2 days of refuse output and 2 days of recyclables output.
- For vacuum truck systems an intermediate storage area for >2 days of refuse output shall be provided, and follow the requirements for a Refuse Bin Center.

Recycling bin with high contamination



Single refuse chute



Waste collection from chute chamber



Disposal of recycling and organics is typically much less convenient than trash

Disposal of trash, recycling and organic waste is typically not equally convenient. Most older high-rise buildings have built-in single trash chutes that are accessible either in each unit (usually in the kitchen), or on every level (a shared facility), and recycling is usually located in a centralized area on the ground floor. The new code for private strata-titled buildings does require equally convenient trash and recycling if above 4 stories. Although food waste is an issue of increasing concern, there is still typically no provision for residential organics solutions for residential organics separation and collection.

High contamination rates in single-stream recycling

Around 40% of the materials collected in recycling bins are not suitable for recycling. The high contamination is most likely due to the fact that the recycling bin is the only available bin in outdoor areas. If a trash bin was put alongside, contamination would likely decrease.

Low recycling rates

Since trash is typically much more convenient to dispose of than recycling, and there is no financial incentive to recycle or penalty for not recycling, there are low diversion rates. There's also a common misconception that all recyclable materials are being mixed together which discourages residents to sort and separate their waste. In addition, people are cooking less at home and ordering take-out food more, which increases the use of single-use takeaway food containers, cutlery and packages, and non-recyclable styrofoam. An NUS study found that every household generated an extra 1,334 tonnes of plastic waste from food deliveries.¹

1. <https://www.todayonline.com/singapore/singapore-households-generated-additional-1334-tonnes-plastic-waste-during-circuit-breaker>

Regulations and Green Building Rating Systems

COMPARISON OF BUILDING DEVELOPMENT REGULATIONS FOR WASTE MANAGEMENT

		NYC	HK	SG
Regulations referred to <i>(All information below is summarized and should consult actual codes)</i>	<ul style="list-style-type: none"> • Building Codes • Zoning Ordinances 	<ul style="list-style-type: none"> • New York City 2014 Building Code, BC 1213 - applies to new buildings • New York City Zoning Resolution, updated May 2021 	Building (Refuse Storage and Material Recovery Chambers and Refuse Chutes) Regulations, Cap. 123H updated 9.2.2012	Code of Practice on Environmental Health (COPEH) 2017
Refuse Rooms in Residential Buildings	<ul style="list-style-type: none"> • Is a refuse room required on every story? • Is a refuse chute required? • Is provision for recycling required? 	<ul style="list-style-type: none"> • A refuse chute and refuse room required on every story in residential buildings ≥ 5 stories and ≥ 9 units • 5SF area for recycling required, or else chutes for the two mandatory recycling streams 	<ul style="list-style-type: none"> • A refuse storage and material recovery room required for most residential buildings, but a chute is optional. • The size of the refuse room is to designed to be large enough to fit recycling bins 	<ul style="list-style-type: none"> • A refuse chute is required for residential buildings >4 stories. • Strata-titled properties with residential units >4 stories with a refuse chute are required to have a recycling chute alongside.
	Do the refuse rooms count as zoning/gross floor area?	There are floor area deductions of 12sf / refuse room for "quality housing" only. But refuse rooms are larger because of required ADA (American Disabilities Act) access requirements.	Refuse storage and material recovery rooms are not counted as floor area	Refuse chutes are not counted as floor area
Central Storage Areas for Refuse	Requirements: <ul style="list-style-type: none"> • Size of storage area • Any compaction of waste? • Access for collection? • Hygiene? 	<ul style="list-style-type: none"> • 1SF / dwelling unit of storage required with a compactor, or 1.5SF without. • Refuse compactor is required in buildings ≥ 4 stories and ≥ 12 units • No access requirements, typically located in cellar where floor area is uncounted • Water source, floor drain, mechanical ventilation and rat-proof room required. 		Where daily refuse output is over 4,000 liters, a RoRo compactor / container, dust screw compactor or rotary drum system has to be provided.
	Required central storage area for waste for a building with 1,000 m ² (10,700 SF) residential area and 100 dwelling units	<ul style="list-style-type: none"> • 9.3m² storage required • 100 x 1SF = 100SF = 9.3m² • Note collection is 2 or 3x/ week 	2.8m ² storage required 1,000 m ² usable floor area/347 Daily collection of waste	<ul style="list-style-type: none"> • 8.6m² storage required • 20 liters / unit / day, 2 days storage required = 4,000 liters / 660 liter bin = 6 bins. Footprint of bins (1.37x0.8) = 6.66 m² plus 30% extra for recycling.
	Required central storage area for waste for a development with 10,000m ² (100,700 SF) and 1000 dwelling units in 4 buildings of 250 units each	<ul style="list-style-type: none"> • 23.2m² x 4 = 92.9m² storage required • 250 x 1SF = 250SF = 23.2m² per building, and typically provided for each building separately, though a central roll off container for trash is recommended by DSNY for developments over 300 units. 	28m ² storage required	<ul style="list-style-type: none"> • 86m² required • If a Strata-titled property (over 500 units) requires dual chute pneumatic system to central area.
	Floor Area Deductions for central storage area?	No floor area deductions given, typically provided in cellar (where floor area is uncounted)	Floor area deductions given, but often insufficient. Door to exterior required, so typically situated on ground floor.	Refuse chambers are not counted as floor area (couldn't see any deductions for central bin rooms)
Commercial Building Requirements	<ul style="list-style-type: none"> • Is storage required? • Is there a requirement to calculate refuse output for different occupancies? • Is recycling required? 	<ul style="list-style-type: none"> • No requirements for storage by building code • No requirement to calculate refuse output, except for large developments per CEQR. • Labeled bins and separate collection for refuse and recycling is required by city (DSNY) 	<ul style="list-style-type: none"> • No requirements for recycling • Central storage area requirements by building code 	<ul style="list-style-type: none"> • Central storage area requirements by building code • Refuse output is calculated for different occupancies. • Recyclables is counted as 30% extra.
Common Green Building Standards		<ul style="list-style-type: none"> • Enterprise Green Communities, mandatory for 'affordable housing' • LEED - common voluntary standard also mandatory for buildings developed with city funding 	<ul style="list-style-type: none"> • BEAM Plus, see website and LEED are the most commonly used programs in Hong Kong. • BEAM Plus gives incentives for floor area 	<ul style="list-style-type: none"> • Building Control (Environmental Sustainability) Regulations 2008, see website, requires a minimum Green Mark score for all buildings over 2,000m², and GM is required for some development areas. High GM scores also give floor area incentives. • While Green Mark is the most common program, LEED is also used in Singapore.

GREEN BUILDING STANDARDS

	DAILY WASTE STREAMS	CONSTRUCTION & DEMOLITION WASTE	CIRCULARITY
LEED New Construction v4.1 Prerequisites	Requires space is allocated for storage and collection of recyclables	Requires a construction waste management plan with 5 materials identified for diversion, separation and diversion strategies and targeted diversion rates.	
LEED New Construction v4.1 Credits		Credit for better C&D Waste Management - Reaching higher specified diversion rates for a number of streams Credit for life cycle impact reduction - Adaptive reuse of historic or abandoned or blighted building, or reuse of building and salvaged material on-site, or LCA of a new building	3 Credits for Building Product Disclosure and Optimization to reduce life cycle impacts, also incentivizes recycled and recyclable healthy circular materials.
Enterprise Green Communities Criteria 2020, with NYC Overlay	6.11 Recycling Storage For projects with municipal recycling infrastructure and/or haulers, provide separate bins for the collection of trash and recycling for each dwelling unit and all shared community rooms. OR For projects without that infrastructure, advocate to the local waste hauler or municipality for regular collection of recyclables.	6.10 Construction Waste Management Develop and implement a waste management plan that reduces non-hazardous construction and demolition waste through recycling, salvaging, or diversion strategies. Projects are encouraged to use DSNY's donateNYC for unwanted but usable building materials.	6.2 Recycled Content and Ingredient Transparency Use building products that feature, and disclose, their recycled content. The building product must make up 75% by weight or cost of a project category for the project and be composed of at least 25% postconsumer recycled content.
Green Mark v.4.1 Residential and Non-Residential (where only applicable for one is noted)	RB 3-4 Environmental Management Practice Provision for collection and storage of recyclable waste (at each block for residential buildings) RB 4-3 Waste Disposal (residential only) Locating refuse chutes or waste disposal at open ventilation areas like service balconies or common corridors to minimize airborne contaminants. RB 5-1 Green Features and Innovations Pneumatic waste collection system Dual chute system	RB 3-1 Sustainable Construction Use of Sustainable and Recycled Materials - 10% cement replacement with industrial byproducts (slag / silica fume /flyash) and recycled concrete aggregates from approved sources RB 3-2 Sustainable Products Promote use of non-structural and architectural products certified by local certification body. RB 3-4 Environmental Management Practice Monitoring of construction waste RB 5-1 Green Features and Innovations Calculation of Carbon footprint or concrete usage Conservation of existing building structure	RB 3-3 Greenery Provision Green Plot Ratio - calculated through the 3D volume covered by plants using leaf area index. Use of compost from horticulture waste
BEAM Plus, V2.0	4.3 Waste Reduction, MW 12 Enhanced Waste Handling Facilities 1 Credit for provision of facilities for collection, sorting, storage and disposal of standard recycling streams (listed in MW 1) 1 Additional Credit for additional facilities for recyclables in addition to those described in MW 1 1 Bonus Credit for providing at least one set of waste treatment equipment 1 Bonus Credit for provide alternative means of waste collection systems	4.3 Selection of Materials, MW 10 Life Cycle Assessment 1 Credit for demonstrating the embodied energy in the major elements of the building structure of the building has been studied and optimised through a Life Cycle Assessment	4.1 Use of Materials, MW 1 Building Re-Use 1 Credit for the reuse of 25% or more (by surface area) of superstructure elements and enclosure materials 2 Credits for 40%

Zero Waste Design Strategies

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- 59 Design for Urban Biocycles
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Plan for the Movement and Storage of Waste

Buildings need to be planned with sufficient space to store all waste streams so that staff can manage waste in a hygienic and efficient way. Providing equipment to reduce the volume of waste makes waste easier to move, store and collect.

In high-density cities floor area is expensive, and developers are reluctant to add space beyond that required by regulations. We heard that in all three cities the storage area required was not enough for good management of multiple waste streams, and that little incentive was given to provide more area or equipment to reduce the volume of waste.

Determine waste streams and quantities, provide adequate storage space and efficient routes

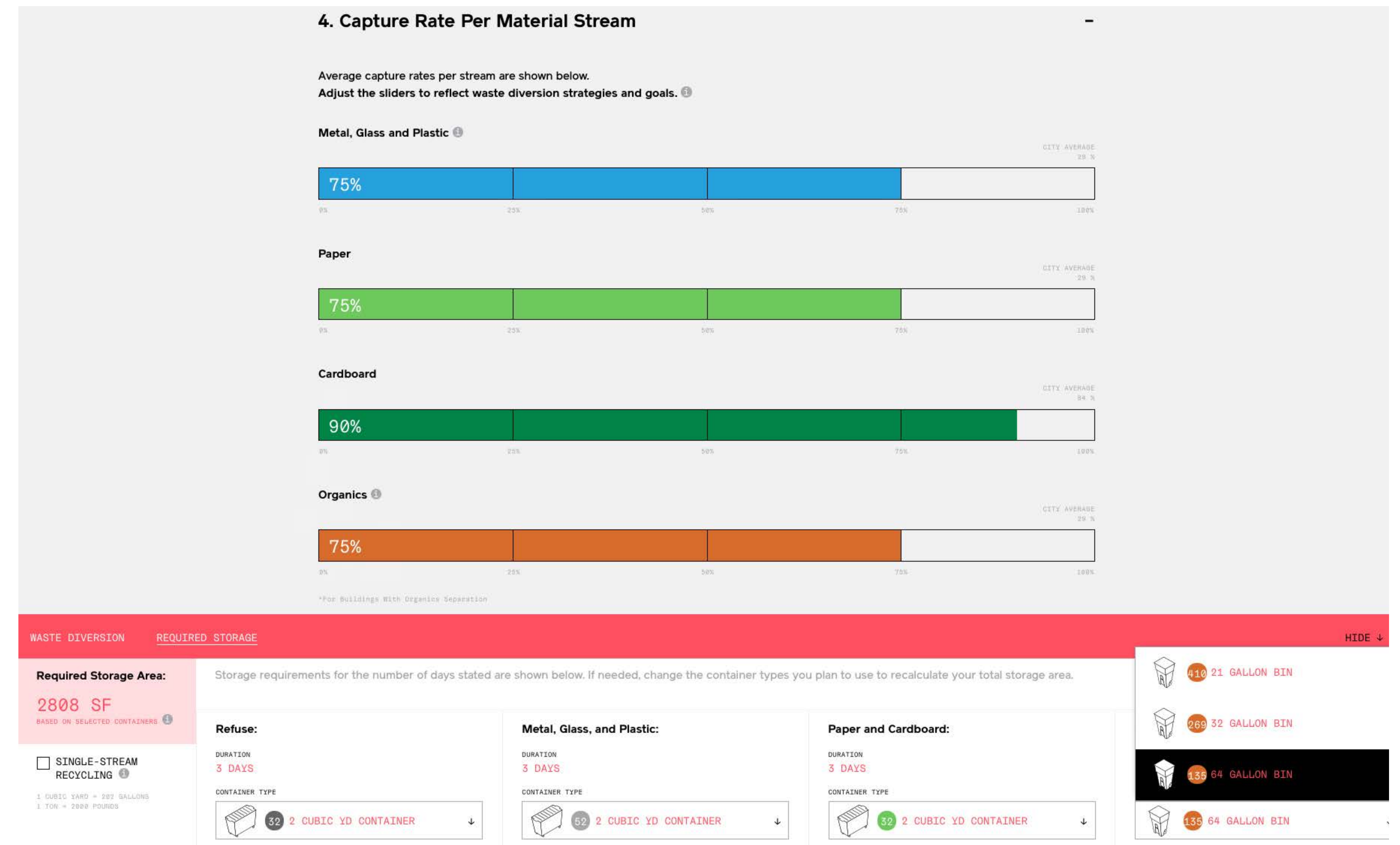
Building regulations typically have storage requirements for trash but assume little for separating recycling or organic waste. To reach zero waste, buildings need to be planned for the storage of all recyclable waste streams.

Provide sufficient storage space for all waste streams, preferably a central shared space to allow the provision of shared equipment and a means to track waste by tenant or department, so incentives for better waste management can be given.

Design to make it easy and efficient for staff to transport and move the waste from bins to the collection location.

Develop a calculator to accurately forecast storage space needs

For NYC we developed an online waste calculator tool that allows designers to determine the storage areas required by adjusting occupancy, waste reduction, capture rates, container type and use of volume reduction equipment.



Online Waste Calculator for NYC showing sliders to adjust capture rates.

Incentivize or require sufficient storage area

One way to incentivize sufficient space is to ensure that it does not count as zoning / gross floor area.

- In HK floor area within required waste storage rooms does not count as gross floor area, though they are typically too small.
- In NYC waste storage rooms cannot be deducted from the zoning floor area so they are typically put in the cellar, but this makes it more difficult to use containers instead of bags. There are also no area requirements for commercial buildings.

Provide equipment to reduce the volume of waste

Compactors and balers can reduce the volume of trash, cardboard and other materials. Food waste is mostly water. Equipment can reduce the volume and weight by up to 90% and reduce odors, making it less appealing to pests and easier to manage.

Incentivize or require equipment to reduce the volume of waste.

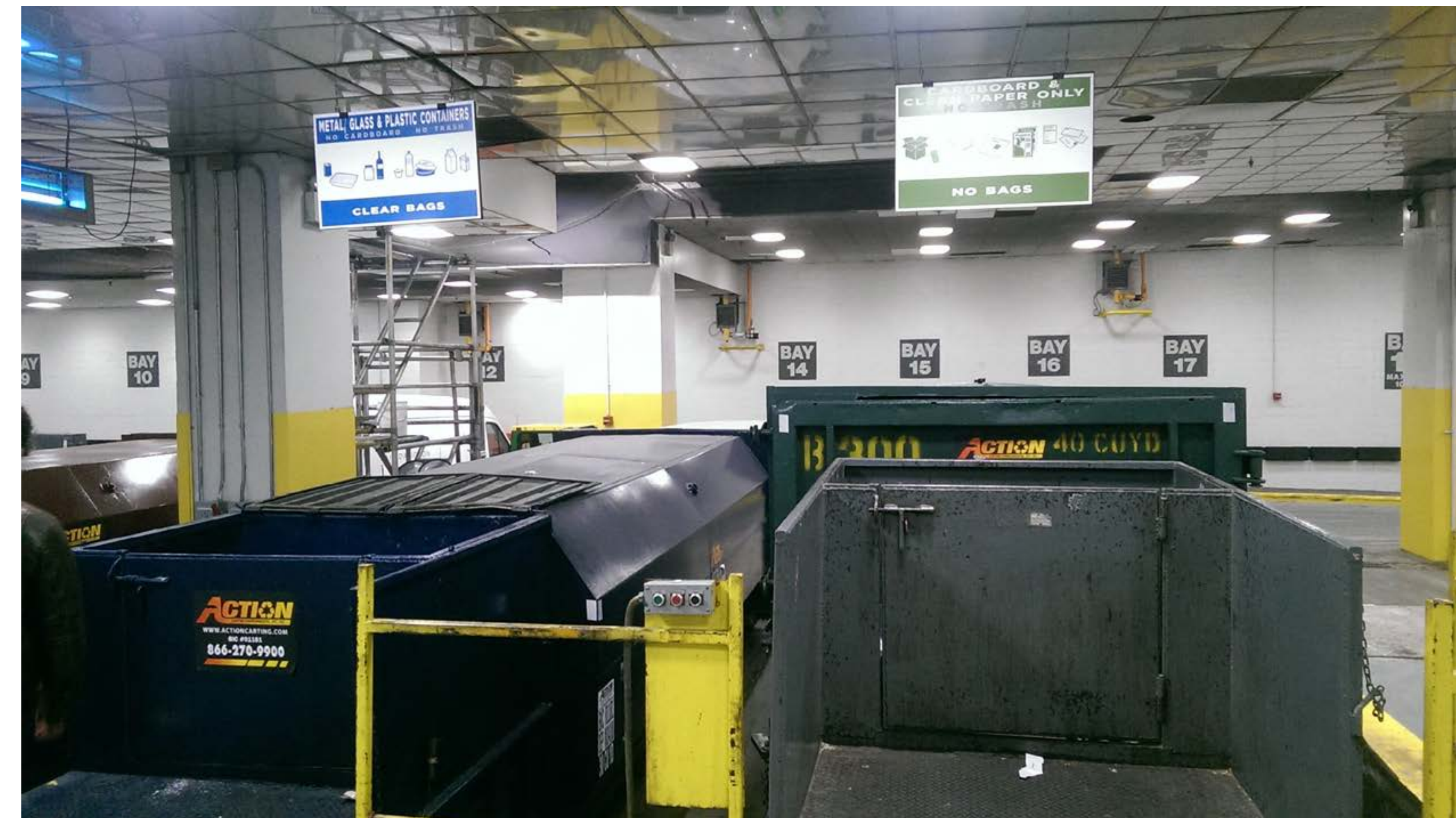
- In SG floor areas must be provided for food waste equipment in commercial and industrial buildings that produce a lot of food waste. In future years the equipment will also be required.
- In NYC the storage area for trash is reduced in residential buildings if a compactor is used. This should be applied to other equipment to compact recycling or treat organic waste, to encourage the provision of equipment.



Rendisk Food Waste Dewaterer.



Bramidan B3 Cardboard baler.



Cardboard and recycling compactors at Time Warner Center, NYC.

See the [Zero Waste Design Guidelines](#) best practice strategies 2.01 to 2.07 for more information.

Design to Reduce, Separate and Track Waste

Design strategies can reduce the amount of waste produced, and make it easier to separate recyclable and compostable waste materials.

Design can also make it easier to track waste, enforce waste separation rules, and make sure incentives work. NYC is developing financial incentives - volume-based pricing with lower rates for organics and recycling - for the commercial sector and considering whether a residential system, called Save-As-You-Throw, could be developed to motivate residents. For financial incentives to succeed buildings need to be designed to make it easy for waste to be separated correctly, and for incentives to be passed through to the waste generators.

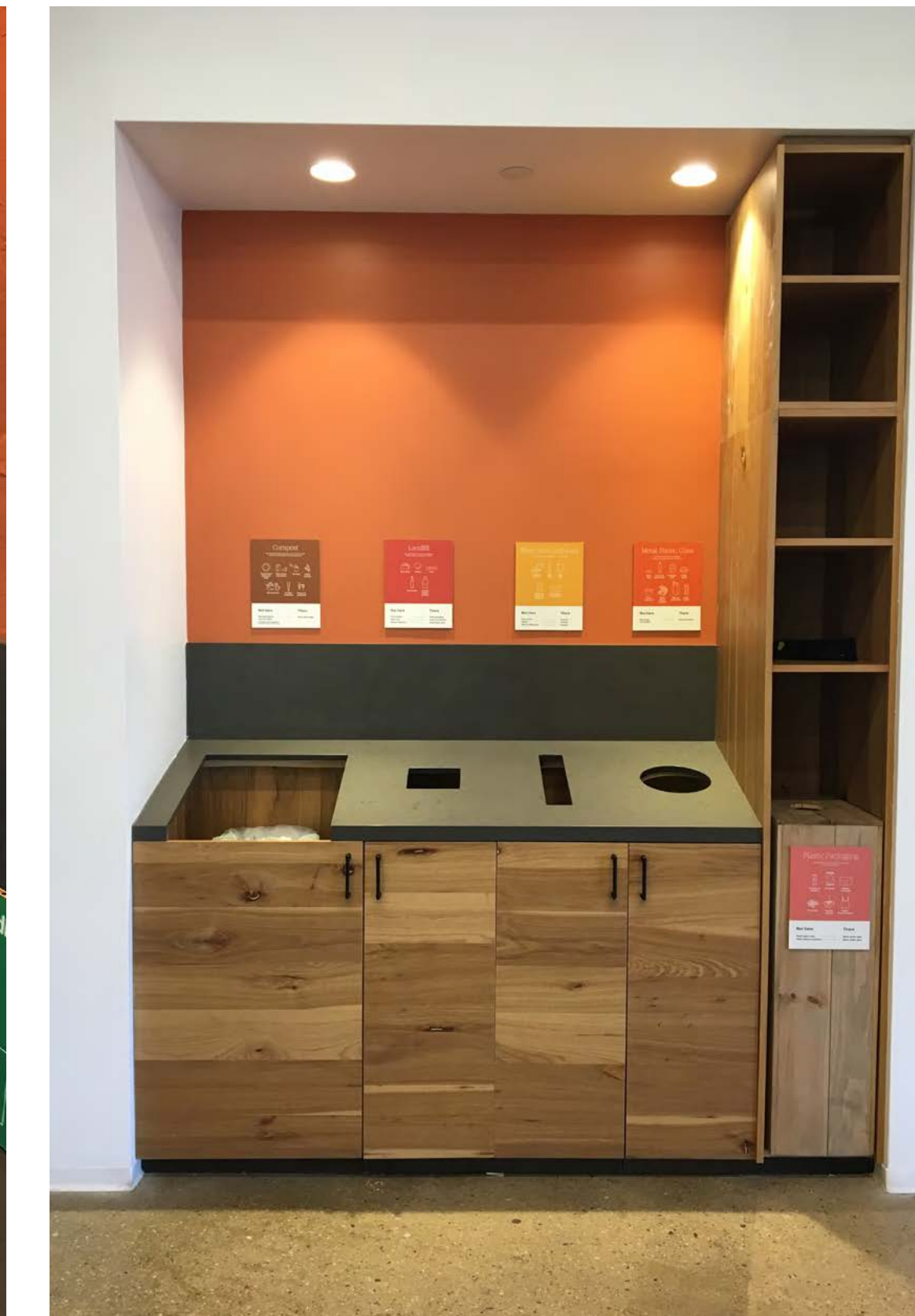
Designing waste disposal locations so it is equally convenient to put something in the recycling or food waste bin as the trash bin, means people are more likely to separate waste correctly. For example, offices should have centralized waste stations for all daily waste streams rather than providing a desk bin for trash and central bins for recycling.

Signage should be clear and consistent throughout the building, with visual cues such as colors and shaped openings for different waste types at all bins and storage locations.

Provide Equal Convenience Disposal, with Clear Visual Cues and Signage

Metering and charging for water and electricity usage is a proven method to reduce use, and the same is true for waste, it is just much more difficult to measure accurately. Volume-based charging is a powerful motivator to reduce waste and is most effective when the

incentive goes directly to the waste generator, which requires a method to track waste generation. Feedback can also be used to educate occupants, such as by displaying waste data at the point of waste disposal. See [Etsy case study](#).



Left: At Etsy, a zero waste TRUE certified office space, the central waste stations provide equal convenience disposal, with clear visual cues and signage, and feedback to let employees know how much waste was diverted the previous week.

Provide central waste rooms rather than refuse rooms on every floor in residential buildings

Cities that are successful at food waste separation generally do not require refuse rooms on every story, or trash chutes, but instead, require residents to bring waste of all types to a central location, so it is equally convenient for all waste streams. This also makes it easier to implement volume-based charging through the use of a bag or weight-based systems and allows the collection of more waste streams.

- Although the building codes in New York City, Hong Kong and Singapore have measures to incentivize co-location of recycling and trash on every story of a residential building, they do not address equal convenience for food waste. Changing the code to allow central waste rooms and no chutes would make it easier to successfully implement volume-based charging and food waste separation, though it would require modification of building regulations in all three cities.
- In Seoul, a city that recycles 95% of its food waste, the building codes were changed in 1991 to eliminate refuse chutes, and existing buildings were encouraged to close chutes. Then from 1995, a volume-based charging was implemented, which is fairly easy to enforce as there is only one waste area per building to monitor. See [Seoul case study](#).

Make sure that whenever there are recycling bins, there are trash bins alongside.

Whether in the kitchen or on the street place a trash bin alongside any recycling or food waste bins. If not contamination rates will be higher. In Singapore, recycling bins are provided on the ground floor of housing blocks, typically with no trash bin alongside. People who need to dispose of trash, maybe from a party, take out or picnic, use the bin for any type of waste, and they are typically 40% contaminated materials. Providing a similar clearly labelled trash bin alongside should greatly reduce contamination.



Food waste caddy and under counter bins for trash and recycling provide equal convenience disposal in kitchens.



Equal convenience for food waste, recycling and trash via a chute in a waste room on every story of a NYC luxury building is convenient for residents.



Residents bring waste down to the building lobby area and pneumatic tubes transport waste directly to the centralized containers in Paris, France.

Design shared waste storage rooms in commercial buildings, and incorporate methods for tracking, so incentives can be passed back to tenants.

Some commercial building owners require every container of waste that a tenant brings to the central area to be weighed and tracked, see [theMART](#) case study.

- Singapore requires tracking and reporting of trash and recycling quantities for large commercial waste generators, which is normally done through truck-based scales. Developing procedures to track waste by tenant or generator allows more accurate tracking and financial incentives can be applied to change waste behavior.



This is done by ensuring the cleaning staff use a hamper with scales and a tablet to record waste streams.



Anti-clockwise from bottom left:

1. A NYC food scrap drop-off sites with a trash bin alongside the food waste bins.
2. SG public recycling bin has clear visual cues, but a trash bin alongside should reduce contamination.
3. Recycling bins in SG HDB estates are typically located alone in common areas, and are 40% full of non-recyclable materials.

Design to Reduce Single-Use Packaging and Disposable Materials

Providing dishwashers for reusable food serviceware or space to store reusable delivery crates or beer kegs, is essential to allow buildings to be operated in a way that can eliminate all waste, and offers the greatest savings.

Provide dishwashing facilities and drinks fountains in foodservice spaces to facilitate the use of reusable service ware.

Single-use food and drink packaging and serviceware is a large part of the municipal waste stream, and the main cause of plastic pollution worldwide. Reusable dishes, cups and cutlery have fewer environmental impacts after 2-122 uses, see [Reuse Wins](#) report by Upstream. Providing dishwashers onsite allows sanitary and convenient reuse.

- In Singapore new hawker centers (food halls) and new hawker stalls at existing centers are required to use reusable dishware. In Berkeley CA, all dine-in service at restaurants have to use reusable dishware. HK and NYC could require similar provisions.
- In Hong Kong, the [Drink Without Waste](#) initiative led to the provision of 300 mineralized water vending machines across Hong Kong, and the [Water for Free](#) initiative promotes the use of public water fountains, with an app showing the location of 1500 fountains across the city. The provision of public water fountains could be expanded in all three cities.

Design to Reduce Wasted Food

Reducing wasted food has the largest economic benefits for foodservice businesses and environmental benefits for cities. Designing kitchens to allow tracking of food to be thrown away allows chefs to modify procurement and menus. Buffets and food displays can be designed to reduce waste at end of food service. Designing refrigerated space for food donations allows edible food to be eaten. See [Eataly case study](#).

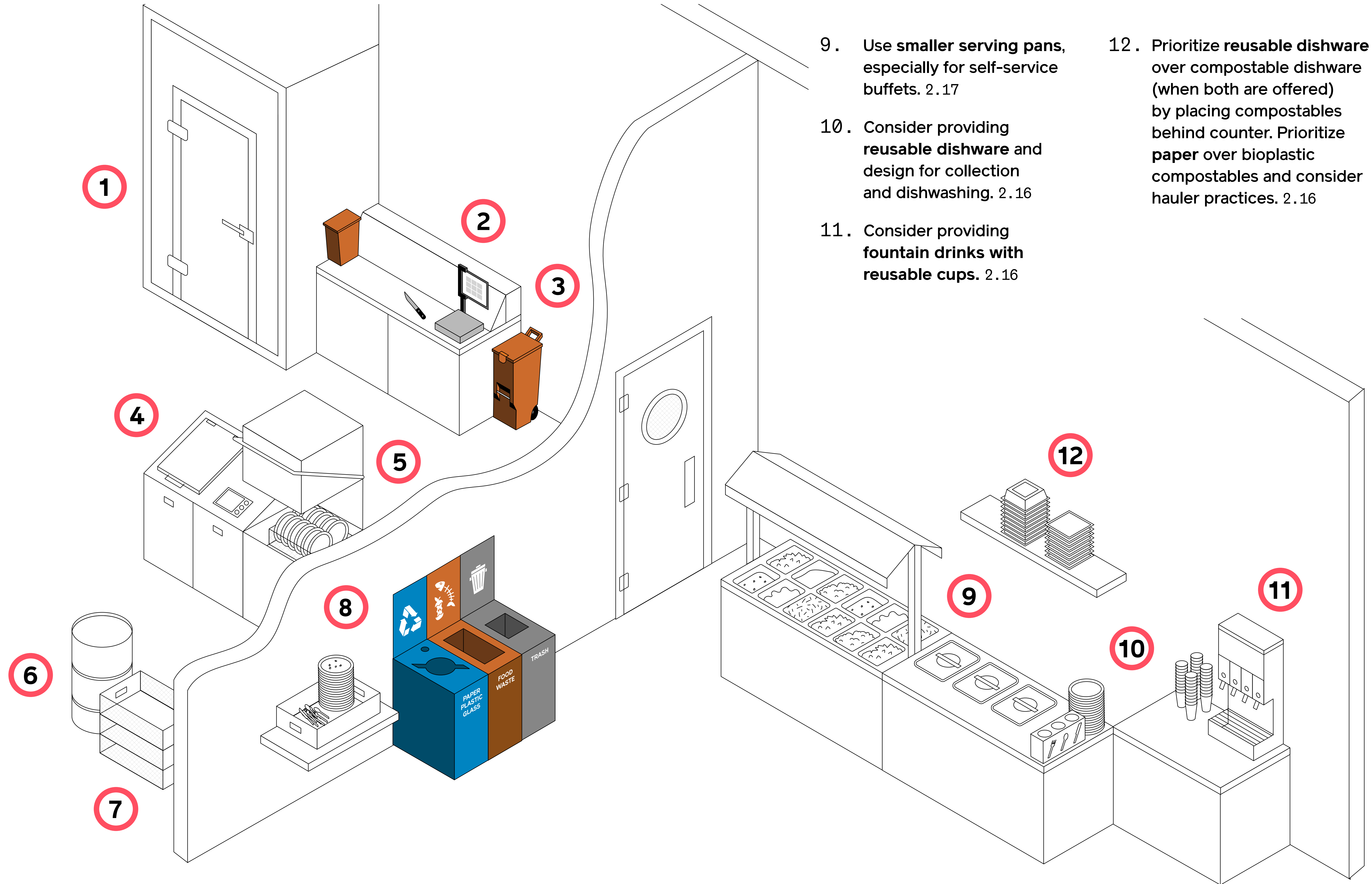


Above: Bonaqua water vending stations through Hong Kong dispense hot and cold and mineralized water.

Below: NYC public park with water fountain.

FOOD SERVICE DESIGN CONSIDERATIONS

1. Refrigerator includes **storage for food donations**. Locate food donation storage for convenient collection. 2.18
2. Provide **food waste tracking system with scale**. 2.17
3. Organic waste collection in kitchen: replace refuse bins with **small organics totes**, and **countertop organics caddies**. 2.09
4. For volume reduction, consider **food waste pretreatment equipment**.
5. Provide **dishwashers** and consider path from dish room to dining area. For larger operations consider dish carousels. 2.16
6. Accommodate **cooking oil collection and storage**. 2.14
7. Delivery considerations: Where possible receive deliveries in **reusable crates** that the vendor collects. 2.06
8. Design **customer recycling stations** with clear visual cues and signage to accommodate all waste generated, including liquids. 2.10



9. Use **smaller serving pans**, especially for self-service buffets. 2.17
10. Consider providing **reusable dishware** and design for collection and dishwashing. 2.16
11. Consider providing **fountain drinks with reusable cups**. 2.16
12. Prioritize **reusable dishware** over compostable dishware (when both are offered) by placing compostables behind counter. Prioritize **paper** over bioplastic compostables and consider hauler practices. 2.16

See the [Zero Waste Design Guidelines](#) best practice strategies 2.03, 2.04. 2.05 to 2.06, 2.08, 2.10 2.15 to 2.16 for more information.

Design for Waste in the Urban Realm

In NYC, waste is very visible in the urban realm, with bags of trash and recycling often stacked high on sidewalks, impeding passage, attracting vermin and leaking litter. In Hong Kong and Singapore, waste is collected from containers, not bags, and has much less presence, even in the older and downtown neighborhoods which have continuous streetwalls like most of NYC.

Designing aggregated collection into the urban realm allows convenient drop off for more waste streams, and automated pneumatic waste systems can reduce the presence of waste further. Together with low impact vehicles for last-mile delivery, these measures can help create green and walkable neighborhoods with permeable pavements, improved air quality and better street safety.

Design for neighborhood scale collection

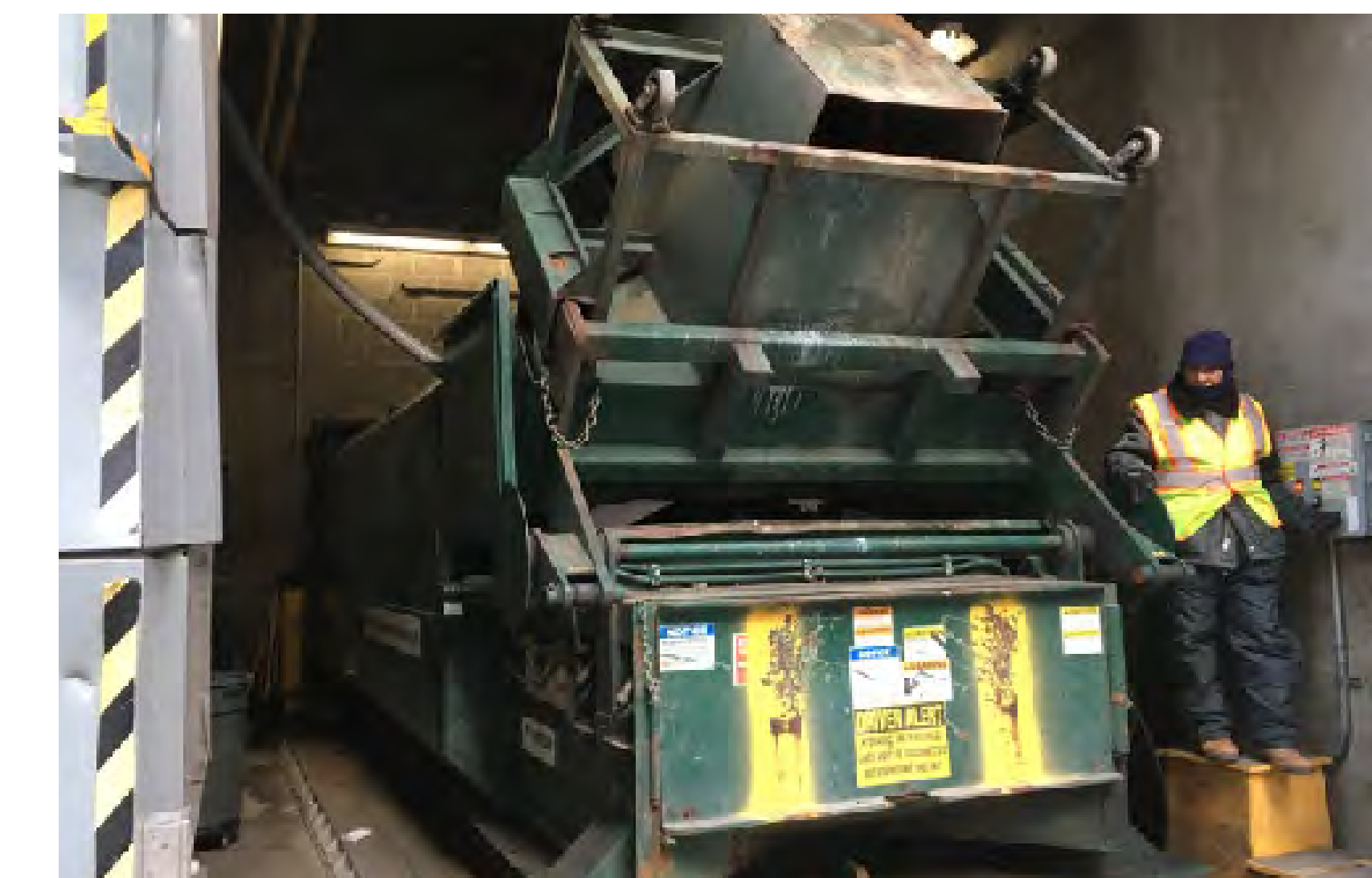
Anytime waste and recyclables can be aggregated between buildings via pushcarts, small electric vehicles or pneumatic tubes, truck miles are avoided, along with the attendant economic, environmental and public health costs.

Include shared waste facilities in new buildings to serve the neighborhood.

- In Hong Kong, the planning guidelines state that “Due to the difficulties in finding suitable sites for Refuse Collection Points, especially in the built-up areas, they should be incorporated in large-scale developments

and redevelopments of both public and private sectors, wherever possible.” There is already a network of refuse collection points that serve built-up areas and remote villages, see Hong Kong context section. They could be designed to serve recycling and organic waste as well as refuse.

- In Battery Park City, NYC, bags of trash on the sidewalks led to a rat problem, leading them to incentivize new buildings to include shared RoRo compactors for trash that serves multiple buildings in the neighborhood. Three shared facilities were developed which serve all buildings in the area. See [case study](#). Zoning rules in NYC could be changed to allow shared waste facilities in all neighborhoods, and their development could be incentivized.



Building staff transporting waste down the street, loading tilt truck into tipper, BPCA staff emptying tilt truck into compactor.

Require Pneumatic Waste Conveyance Systems to serve trash, recycling and food waste in larger new developments, consider retrofitting into existing neighborhoods and estates.

When planning for pneumatic systems, make sure they are designed for recycling and food waste streams, or the potential to add them in the future. Ensure that inputs for trash, recycling and food waste are located alongside each other for equal convenience disposal.

- In Singapore, new strata-titled developments over 500 units are required to use pneumatic systems for trash and recycling. In Hong Kong large public housing developments use pneumatic systems for projects over 2400 units. In NYC, Roosevelt Island, a planned community of 14,000 residents, has used a pneumatic system for trash since its completion in 1975, [see case study](#).
- In Singapore, a residential development of 38 resident blocks in Yuhua was retrofitted with a pneumatic system for recycling and trash going to a centralized bin center with RoRo compactor containers. [See link](#). HDB estimate that this will reduce manpower needs by about 70%, and provide a cleaner and greener environment.
- In Vitry-sur-Seine, France, a pneumatic system for trash and recycling, with the potential of adding organic waste, was retrofitted into a neighborhood as part of an urban renewal project, [see case study](#).
- In NYC a proposal to put a 1.5-mile long pneumatic tube below existing linear infrastructure - the raised rail line that is now the High Line park - is being studied, [see case study](#).



Centralised pneumatic waste bin center with roll-on roll-off containers.



Pneumatic waste input points integrated into street wall, France.



Pneumatic waste conveyance system at Yuhua.

Design drop-off locations for all waste streams within the public realm.

Access to efficient collection and recycling can be considered a public amenity, improving the quality of life in a neighborhood. Well designed drop-off collection points on street corners and public plazas can address inadequate storage in individual buildings, and provide access to convenient disposal for more waste streams. Increasing the degree of social interaction around waste management activities - and peer awareness of behavior - can lead to a higher degree of waste separation and less contamination of recycling.

Provide convenient permanent or temporary drop-off locations for multiple waste streams in public space

- In Hong Kong many options for dropping off recycling are available as part of EPD's Community Recycling Network, comprising permanent recycling stations and stores, as well as temporary recycling spots. The EPD engages nonprofit organizations to operate Recycling Stations (formerly Community Green Stations) and work with local property management organizations. The recycling spots are set up near single block and 3-nil buildings (ones without property managers), for residents to drop off waste themselves. They accept common recyclables as well as lamps, batteries and some electrical waste. [See EPD link and article](#), and [Eastern Community Recycling Station case study page 70](#).
- District scale waste facilities for specific streams can also be designed into buildings. In Menilmontant, Paris, a new building was designed to include a staffed recycling center, as well as a hub for aggregating truckloads of bulk materials from municipal collection routes. [See case study](#).



Clock-wise top left:

1. Store front of a recycling center in Sai Ying Pun.
2. Staff member sorting through the collected recyclables.
3. The collected recyclables from the front-of-store taken to the back.
4. People carrying bags of recyclables to the center.

See the [Zero Waste Design Guidelines best practice strategies 2.03, 2.04, 2.07, 2.09 to 2.25](#) for more information.

Support the Sharing and Circular Economy

The programming of buildings and neighborhoods plays a key role in enabling the sharing and circular economy.

Optimize asset utilization through programming

A key strategy of the circular economy is collaborative consumption, which prioritizes usage over ownership by sharing, swapping or renting products and services. The efficient use of assets results in reduced consumption and slows down material flows, ultimately resulting in fewer, more durable products and buildings, and less waste.

Program flexible and shared spaces in buildings, within mixed-use neighborhoods

Smart planning can reduce built area, furniture and equipment to optimize the use of every space and piece of equipment. Consider whether spaces can be multifunctional or flexible so they can be used consistently all day long. Studies show that the average office is used 35%–40% of working hours. Unassigned desks reduce the number required and allow the provision of a variety of workspaces and flexibility for employees. Shared live and shared workspaces offer additional flexibility for changing household or organization size, as well as sharing of dining and conference rooms. Spaces can also be designed to be shared at a neighborhood scale, and mixed-use neighborhoods enable this further.

- In NYC, The Center for an Urban Future’s report *Reenvisioning Branch Libraries* explored the variety

of functions libraries could serve for the surrounding community in the hours they are not open as libraries. Also in NYC, Kettlespace is a co-working company that collaborates with restaurants that open in the evenings only, offering freelancers fast wifi, coffee and snacks and a workspace.

- In Singapore, WOHA’s Skyville @ Dawson is a large residential complex programmed to have many shared public, external, shared spaces interwoven through the towers from the ground to the roof. Each home is part of a Sky Village of 80 homes sharing a sheltered community garden terrace designed to foster interaction and be part of daily life. The ground floor includes community living rooms, childcare, play and retail spaces flanking a public park. Apartments are column and beam-free, allowing for the flexibility to make changes as household size and lifestyle (eg. live-work) change over time. [See link.](#)



Skyville @ Dawson by WOHA

- In Hong Kong, One Bite Design has started the “Generative Utilization & Transformation of Spaces” aka GUTS platform to promote better use of underutilized resources in the city. [See link.](#)

Support neighborhood-scale libraries, repair and reuse centers.

Providing or subsidizing space for non-profits and social enterprises within the collaborative economy helps a city reach zero waste.

Designing a network of drop-off points for neighborhood or city-wide reusables networks makes them as convenient as single-use items. Food deliveries often come with single-use ice packs and packaging. Could they instead deliver to a refrigerated room in a development, which would also be a place to drop back the reusable packaging?

- In Singapore, a Resident’s Network’s of Resource centers have shared good libraries with ladders, cooler boxes, folding tables, trolleys and other commonly used items. There are also fixing repair sessions in the void decks of some developments like Tampines Bay. The NEA is looking at how to make donations more convenient through a network of donation stations.

Design collection points for reusables into buildings and neighborhoods.

- Reusable cup and to-go containers often have drop-off containers in the urban realm, such as Durham’s Green to-go program, or London’s CupClub. These could be better designed into the urban realm, and part of the public waste bin station.

See the [Zero Waste Design Guidelines](#) best practice strategies 2.07, 2.08, 2.09, 2.11, 2.12, 2.15 to 2.18 for more information.



Fixing event



Toronto’s Library of Things and Makerspace



Resource Center in Singapore



CupClub reusable cup drop off in Kings Cross Station, London



Reusable take out container collection point in Durham, NC

Urban Biocycles - Productive Reuse of Food and Horticultural Waste

Globally, soil stores more carbon than the atmosphere and all the plant biomass combined. As the Ellen MacArthur paper, [Urban Biocycles](#), points out, cities aggregate food from farmlands, and almost none of the nutrients or materials are looped back into the biosphere, so farmlands are becoming degraded and rely increasingly on synthetic fertilizers made from fossil fuels.

Then, in cities themselves, food waste is the most problematic part of the waste stream - it decomposes, smells bad, attracts pests, is heavy to transport, and gives off methane in landfills - yet it is also the part with the most potential to improve the city and engage residents through participation in sustainable activities such as composting, stewardship of green spaces and urban agriculture. Compost can also retain 6 times its volume of stormwater, helping filter and reduce flooding and increase the cooling effect of vegetation.

How can cities be designed to effectively separate food waste to support urban greening, carbon reduction and regional food systems?

Separate discarded food for use at the highest value

After measures have been taken to reduce wasted food, buildings should be designed to facilitate food donation, with sufficient refrigerators and storage space. In buildings with multiple food service tenants, it typically makes sense to centralize food donations storage in an area easily accessible for pick up by donation organizations. Commercial food waste

from kitchens can be used for higher-value products such as animal or fish feed. Waste oils are good for biofuels. Food manufacturers should assess their food discards, and determine the highest value reuse - see [ReFED Solution Provider Directory](#) for upcycling solutions such as Ground Upcycling who grow mushrooms on spent coffee grinds, or ReGrained, which make flour from spent brewing grains.



Above: Kampung Admiralty by WOHA

Below: Khoo Tech Puat Hospital, by CPG Consultants, Singapore. For every m² of land taken up 3m² of greenery was designed into the building, used for healing gardens and urban agriculture with community volunteers

Develop infrastructure and policy to encourage food donations and support ecosystems of food businesses

- Hong Kong EPD has developed EcoPark, to support recycling businesses with affordable long-term leases. Current tenants include businesses that turn food waste into animal feed and waste cooking oil into energy. Proximity allows the reuse of waste products from one food business to be used by another.
- In NYC, during the COVID pandemic, community fridges have been set up in the public realm, and are managed through volunteer efforts. In NYS a new Excess Food Law grocery stores are now required to donate excess food. Can a network of community fridges be designed into streetscapes?
- The Peninsula food business incubator space in NYC is being designed to support the reuse of food discards between tenants as well as a food donations program and food waste processing equipment that turns excess food waste into organic fertilizer for use in local community gardens.

Require food waste separation and support provision of food waste equipment for large generators

- In Singapore space for food waste equipment has to be provided in new commercial and industrial premises expected to generate large amounts of food waste, and from 2024 the equipment needs to be provided. There are grants to help fund.
- In NYC large food waste generators are required to separate food waste, and there are grants for equipment from NYS.



Community refrigerators in NYC



Above: South China Reborn food waste to animal feed facility in Hong Kong's ecopark

Right: Oasis Hotel by WOHA



- In HK a pilot project installed food waste equipment in residential buildings, but their use has tailed off. What incentives or improvements could lead to the continual use of food waste equipment in residential complexes?

Design composting into green spaces, so food and horticultural waste can regenerate urban soils.

Wherever there is greenery there is horticultural waste. This should be combined with food waste and made into compost for use in regenerating local soils. The balance of food to horticultural waste and the amount of compost applied needs to be matched to the vegetation type. Procedures need to be in place to ensure that food waste is correctly segregated, and in-vessel composting equipment can ensure that pests are not an issue.

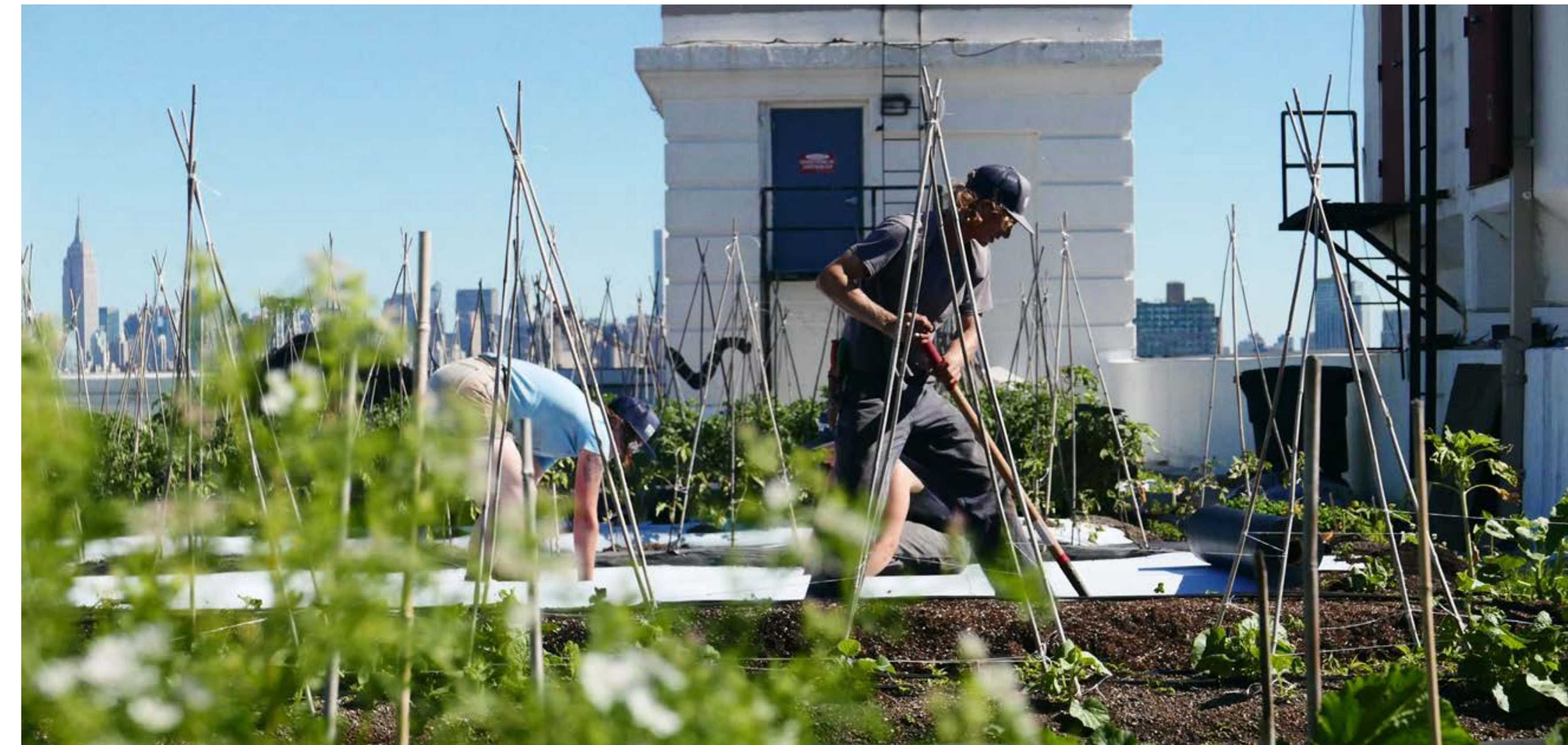
Require and support urban greening

- Singapore’s Landscaping for Urban Spaces and High Rises (LUSH) program is a combination of incentives and requirements to replace horizontal with vertical greenery and has led to extensive urban greening to increase the quality of life, air quality and urban cooling in Singapore.
- In NYC, the million tree initiative includes requirements for new developments to plant street trees, and new NYC developments need to install green or solar roofs.

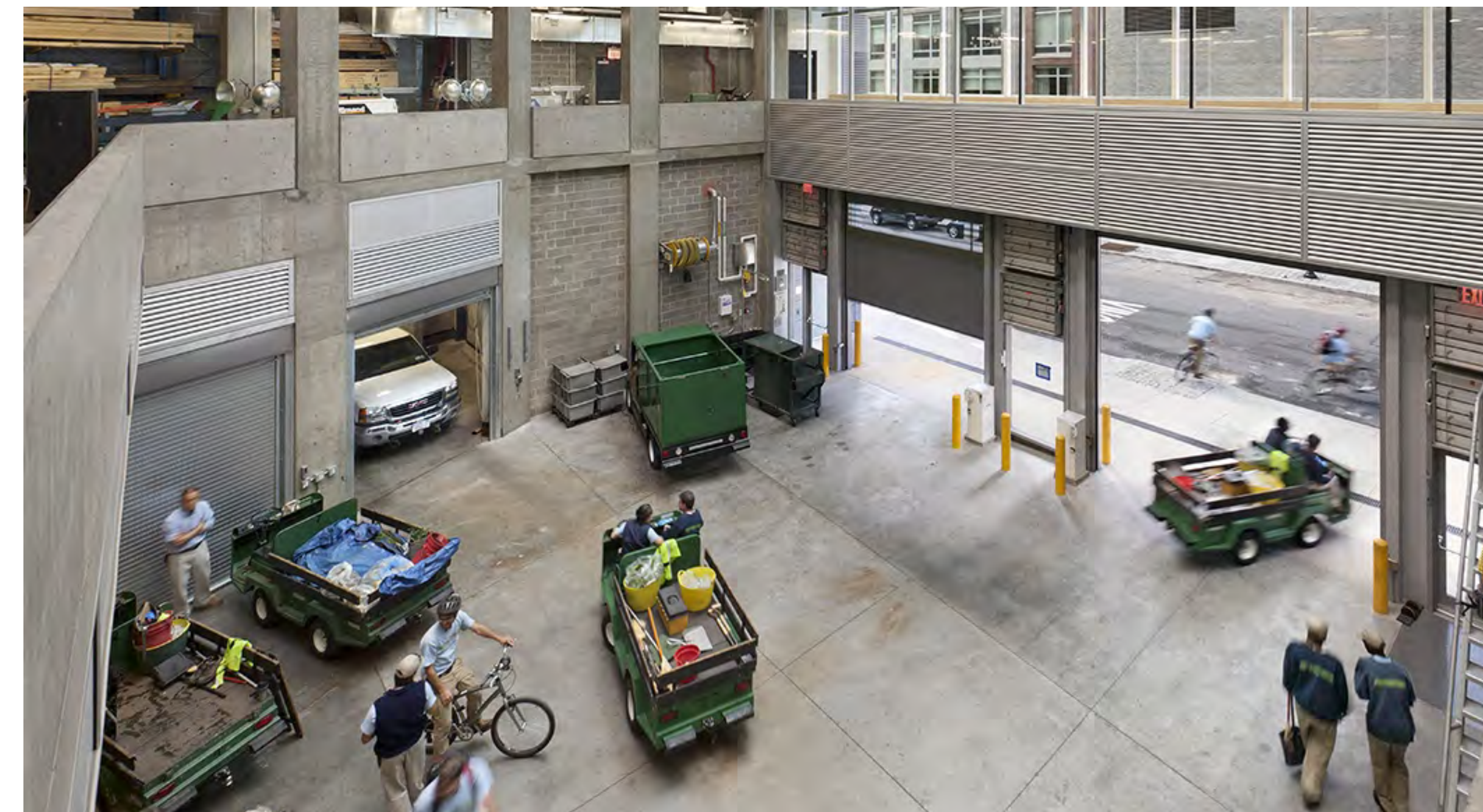
Increase demand for compost by requiring compost for greenery provision

- In Singapore’s Green Mark program there are credits for using compost from horticultural waste. Could this be extended to include extra credits for compost that uses food waste too?

- In NYC many parks include composting systems that combine food and horticultural waste, see Domino case study on page 68. Also, public housing projects (NYCHA), have outdoor 3-bin composting systems for food waste that generate compost for onsite farms, employ and train youth, and reward residents with free fresh produce. See link.



Brooklyn Grange, NYC rooftop farm.



Battery Park City Maintenance Facility includes an in-vessel composter that takes food waste and horticultural waste and uses the compost and compost tee to rejuvenate the soils of the parks.

See the Zero Waste Design Guidelines best practice strategies 2.07, 2.16, 2.17, 2.23 to 2.24 for more information.

Circular Building Materials

Reducing and diverting construction and demolition waste is just one part of developing a circular economy of building materials.

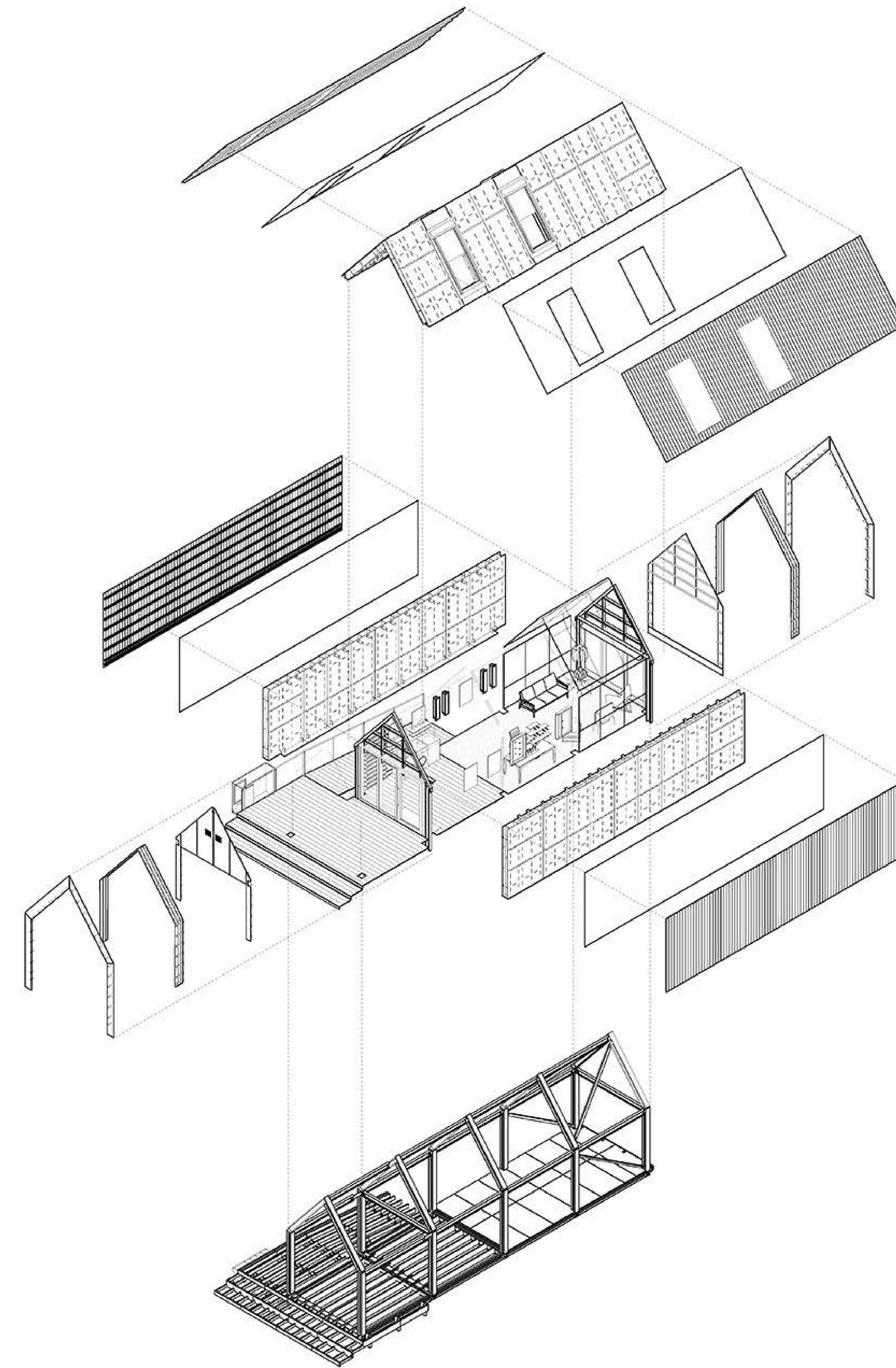
Designs should also incorporate salvaged and reusable products, and recycled and recyclable healthy materials. And buildings need to be designed so that they can be disassembled and their components reused or recycled. This is called “design for disassembly” or “reversible design”. These measures help reduce embodied carbon and support healthy material choices.

Design buildings as material banks (BAMB)

Designing so that the materials in a building retain their value, rather than becoming waste during demolition, is the concept behind BAMB. To retain value, we need to know what the materials are, and we need to be able to disassemble the building to recover the materials. Material passports are databases of all the materials in a building and are typically developed with a BIM model. Reversible building design focuses on ensuring that buildings can be disassembled and components reused. Making sure a building is designed to be durable and easily maintainable is also key.

Integrate material passports and BIM models

Singapore has an advanced building construction sector - buildings are designed with a BIM model for review by the building authorities, and many use prefabricated and modular construction. This gives Singapore a good opportunity to be a leader in the development of buildings designed with BAMB and material passport concepts.



The circular building by Arup Associates was designed to circular economy principles.

Design for slippage, and consider the product as service models

The many layers of a building have different life-spans. Shearing Layers, a concept coined by British architect Frank Duffy, lists them in order of decreasing life-span: Site, Structure, Skin, Services, Space Plan (interior partitions, finishes) and Stuff (furniture). Design for “slippage” so disassembly and removal of short life-span layers can occur without disturbing longer life-span layers. For shorter life-span layers consider products as service models, where the manufacturer leases the product and takes it back at end of life, or take-back models. These models are becoming increasingly available for furnishings, carpeting, lighting and even facades.

Design for circular building materials

Specify products with third-party certification labels

True circular building materials should have 100% recycled content and be able to be recycled themselves at the end of life, without down-cycling. There are not many materials that fulfil these criteria, but choosing materials with cradle-to-cradle certification, and Health and Environmental Product Declarations (HPD and EPDs) is the start of the process, as it encourages transparency and stimulates innovation.

Consider local waste material reuse possibilities

- In NYC, Building Product Ecosystems has led a collaborative which piloted and developed an ASTM standard for the use of glass pozzolan as a cement replacement, lowering the GWP of concrete through using



Lighting in Schiphol Airport is provided by Philips as a service.

post-consumer waste glass. See [link](#) and Ellen MacArthur paper. They also have a collaborative working on circular gypsum board, as if gypsum board scraps are separated on-site they can be perpetually recycled into new gypsum board, rather than disintegrating as they would in a C&D facility. See [link](#).

Construction and Demolition Waste Management

Require pre-demolition audits to identify salvageable and recyclable materials, as well as construction waste management plans.

- In Singapore, a demolition protocol, see [link](#), requires contractors to do a pre-demolition audit, and gives procedures for sequential demolition and on-site separation of construction waste, to maximize the diversion of waste materials for beneficial reuse or recycling. This leads to a 99% diversion rate of construction and demolition materials, with a high diversion of metals, concrete, bricks, and wood. A lot of concrete is crushed for use as recycled concrete aggregate.
- Construction management plans can also include measures to reduce waste from the construction process such as reusable concrete formwork, take-back for surplus materials, just-in-time ordering, allowing offcuts to be reused and other lean construction strategies.



Pilot pour using concrete containing glass pozzolan as a cement replacement, Halletts Point NYC.

See the [Zero Waste Design Guidelines](#) best practice strategies 2.25, 2.26, 2.27, 2.28, 2.29, 2.30, 2.31, 2.32, 2.33 to 2.34 for more information.

Case Studies

66 Food Waste Recycling in Seoul, South Korea

69 Domino Park, New York City

71 Eastern Community Recycling Station, Hong Kong

73 Our Tampines Hub: Hawker Center, Singapore

Food Waste Recycling in Seoul, Korea

Type

- Volume based charging and food waste collection in apartment buildings

Best Practice Strategy

- 2.08 Provide Equal Convenience Disposal
- 2.11 Provide opportunities for feedback
- 2.17 Reduce food waste generation
- 2.19 Design to incorporate financial incentives such as SAYT (residential)
- 2.23 Organic waste pretreatment (residential)

Background

In the 1990s South Korea made extensive efforts to reduce the amount of waste going to landfills and to improve waste management and public hygiene. Municipalities started collecting recycling and the government started looking at introducing a pay-as-you-throw system to increase recycling collection and reduce generation of trash. Pilot projects were done in several neighborhoods, which showed an average 40% reduction in waste and 100% increase in recycling collection.¹

Previously, a fixed rate via taxes or monthly fee was charged for municipal solid waste. In 1995 the introduction of the volume-based charging scheme nationwide required non-commercial, commercial



Above: Central refuse, recyclables and food waste collection area.

Left: Workers collecting food waste from the RFID bins.

entities and individuals to pay for the amount of waste they generate. Disposing of food waste costs a resident about half as much as trash, and recyclables are collected free of charge. These measures led to an increase in Korea's waste diversion rate for household solid waste rose from 24% in 1995 to 62% in 2017. Waste generation also decreased from 1.3kg/capita/day in 1994 to around 1.0kg/capita/day since 2012.²

The government also considered the fact that large apartment buildings typically used garbage chutes to convey garbage to the cellar where it was stored. They decided that this was not sanitary nor helpful for achieving their waste goals. So in 1991 they changed the building codes and refuse chutes were no longer allowed in new buildings, and existing buildings were encouraged to close chutes.³ The use of central waste areas instead makes it equally convenient to dispose of many different waste types, and allows for easier oversight to ensure residents separate correctly. It also allowed for easier implementation of “pay-as-you-throw” volume-based charging schemes. Korea typically collects at least 5 types of recycling (plastic, paper, glass bottles, vinyl and aluminum cans) as well as trash, food waste, e-waste and bulk waste, and having a large central room or outdoor area makes this much easier.

In 2005 a law was passed prohibiting the landfilling of food waste, and Korea introduced further policies and equipment which have reduced the generation of food waste. Now only 3-5% of food waste ends up in landfills. These included prioritizing methods which charge the individual over those which charge the building for the total amount of food waste within communal bins. These include 3 methods, based on designated bags, tags or use of an RFID food waste bin.

For the bag method, individuals and small-sized commercial entities are required to purchase pre-paid bags for food waste, in 1.5 to 10-litre sizes. For the tag system a prepaid waste slip has to be attached to a designated food waste bin. For apartment buildings, Radio Frequency Identification (RFID) bins incentivize households to reduce the amount of waste they put in communal bins, without the use of designated plastic bags. Each resident has an individual identification card that they use to operate the RFID bin. They tap the card on the screen, and if there is space the lid opens and they can dispose of their food. The screen displays how full each bin is. Each household receives a monthly food waste disposal bill. The RFID bin system has been shown to reduce food waste generation by 30% compared to communal food waste bins.⁴

Food waste treatment process - ① Disposal of food waste

✔ General customer disposes of garbage using either a designated envelope, a designated container with a payment receipt (chip) attached, or a weighing device (RFID).



✔ Producers of large amounts of waste either dispose of their own waste or entrust the disposal of waste to a disposer authorized by the local government.

1. https://seoulsolution.kr/sites/default/files/policy/2%EA%B6%8C_Environment_Pay%20as%20you%20throw%20system%20of%20Seoul.pdf
 2. <https://publications.iadb.org/publications/english/document/South-Koreas-Experience-with-Smart-Infrastructure-Services-Integrated-Solid-Waste-Management.pdf>
 3. https://s-space.snu.ac.kr/bitstream/10371/90501/1/4_Strategies_for_Developing_Responsive_Solid_Waste_Management_in_Seoul_City__Institutional_Arrangement.pdf
 4. <https://www.youtube.com/watch?v=VgUYTgwPKn8>

Seoul, a city of 25 million residents, which is twice as densely populated as NYC, is also promoting the use of food waste equipment to dehydrate and biologically break down the waste, reducing the volume by 80- 85%. Incentives of 35-65% of the equipment cost is given to large apartment buildings, and it is recommended that they are installed in all new large apartment buildings. This reduces pollution from collection vehicles and is necessary because of the difficulties in establishing food waste infrastructure in Seoul. Some buildings use the fertilizer in their gardens, and there has been an urban farming boom in the country, as city governments often fund 80-100% of the initial installation fees.⁵

Most districts have a designated hauler for collecting food waste, but alternative licensed recycling businesses or those using the food waste for livestock feed or compost may be used. Food waste is typically collected by 1 or 5 ton trucks although 11 ton trucks may be used if the facilities are located far away. Most food waste is converted to fertilizer or animal feed, and anaerobic digestion is also used to produce biogas or bio-oil.

Challenges & Opportunities

The RFID bins have been generally effective in collecting food waste, but there is still some confusion about how to use them, and frustration when the bins break and are down for maintenance. Although many residents say that the new food waste collection system can be inconvenient, they do agree that it has helped them become more environmentally conscious and reduce the amount of food they purchase. It has also led some to seek solutions to reduce the weight of their food waste, by manually draining and squeezing out liquids, or buying household-sized units to squeeze out

water and dry the food waste. The promotion of community urban farms has helped provide a local use for some fertilizer generated in buildings, but Korea has had challenges finding markets for the product. This could change as the price of fossil-fuel based fertilizer continues to rise, especially if Korea is able to produce a consistent quality product which it can sell to agricultural customers.



Above: Rooftop community garden in Seodaemun-gu.

Left: A food waste dehydrator.

5. https://www.koreatimes.co.kr/www/nation/2018/10/281_256714.html

Domino Park, New York City

Type

- On-site composting of food and horticultural waste

Best Practice Strategies

- 3.07 Staffed organics drop-off and processing on-site
- 3.09 Incorporate community into collection operations

Summary

Domino Park is a 5-acre park along the Brooklyn waterfront, designed by James Corner Field Operations in collaboration with Two Trees Management Company. The Williamsburg neighborhood of Brooklyn historically offered very little public access to the waterfront and is comparatively underserved by park space. Two Trees prioritized public access and enjoyment of the waterfront, and offer volunteer programs, workshops and tours to engage the community. The compost program gives the community access to food scrap drop-off and provides surplus compost for local community gardens and residents. They aim to be a leader in composting, showcasing a closed-loop organic waste system on the site.

Two Trees started collecting food scraps in 2018 from local restaurants and coffee shops as part of a sustainable initiative to divert organic waste from the landfill and to convert it into a soil enhancing compost for use in the park. Horticultural waste from the park - trimmings from trees and shrubs and fall leaves - are combined with food waste, which



Domino Park waterfront.



8' x 20' Shipping Container with Composter

Outline of 5 acre Domino Park in red



Residential drop-off into 20 gallon buckets.

produces high quality compost faster than using horticultural waste alone. There are 3.5 acres of planting beds, native plants and trees. Domino Park staff called “park ambassadors” manage the park and the composting system.

After COVID caused local restaurants to close and NYC’s curbside organics collection to be put on hold, Domino Park started accepting residential food scraps from across the neighborhood, with two 2-hour staffed drop off windows per week. An average of 80-120 participants come and drop-off around 5-10 lbs of waste each. The initiative is run by the horticultural director, who along with an assistant, each spend an average of 2 hours a day on the operation. Tasks include manning the drop-off, adding the food waste and wood chips, using the pulper, washing the buckets, weighing the waste, monitoring the equipment, and sifting the compost for use on site. They also make compost tea from soaking the compost and straining it, for use on the planting beds. They normally have sufficient landscape waste within the park, but occasionally need to source additional wood chips, which they get locally for free from Greenwood Cemetery.

Domino chose the Rocket in-vessel composter because it allows continuous feed, produces finished compost, is known to be robust, and has a local distributor. They set it up within an 8’ x 20’ reused shipping container, so it can be relocated as needed during the ongoing development of the site. They insulated the container and added wood panels, lighting, a utility sink and plumbing hookups which also allows them to dispose of greywater from the pulper.

Food waste is added to the Rocket up to 5 times a day, along with wood chips or other horticultural waste in a 2:1 ratio by volume of food waste: wood chips. This mixture is then processed in the Rocket for 2 weeks with close monitoring of the temperature through the readout. Ideally the output is cured for around 30 days before sifting for use on site. They have a waste pulper which they use when they have a lot of waste, as it increases the capacity of the Rocket threefold. They also made a 4 bin compost system with an air blower, which works like an aerated static pile, that they can use when they have additional material.

Contamination with non-compostable materials is minimal as Domino staff supervise drop-off and answer any questions people have. They monitor output and have adjusted which waste they accept to reduce problems. Currently they don’t accept meat, dairy, fish, compostable products or citrus as they were taking too long to break down. They also don’t accept sauces which were causing excess moisture and often contain oils which inhibit microbes. They are now experimenting with accepting some compostable products.



In-vessel composter.



Pulper, utility sink, and hot water heater.



Compost is collected into large bags.

Eastern Community Recycling Station, Hong Kong

Type

- Neighborhood-scale recycling center in public realm

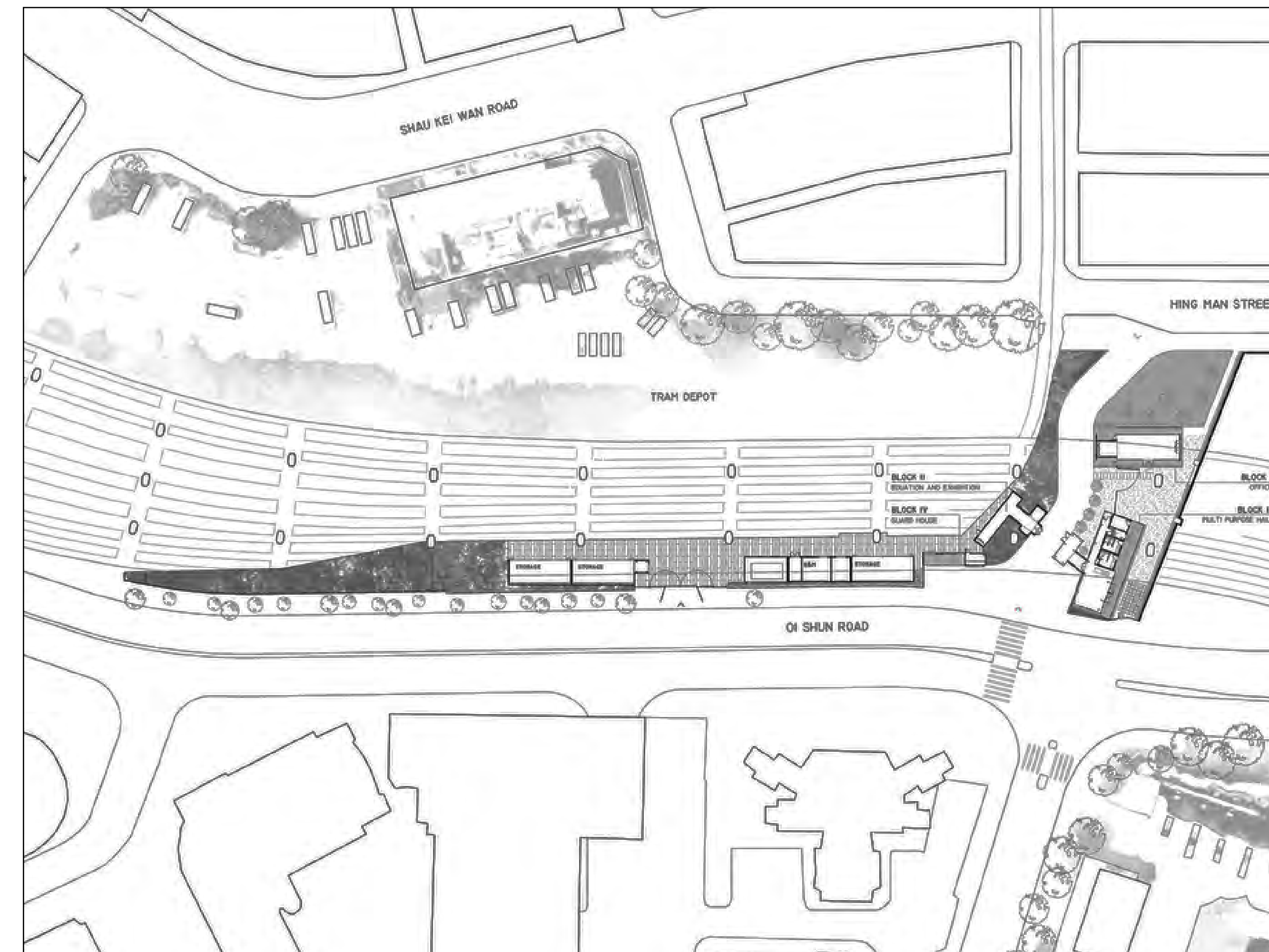
Best Practice Strategy

- 3.07 Staffed organics drop-off
- 3.09 Incorporate community into collection operations

Summary

With the aim of increasing district participation in waste reduction and recycling, the Environmental Protection Department (EPD) developed a community recycling network of Recycling Stations, Recycling Stores and Recycling Spots that is part of the GREEN@Community program, to promote zero waste initiatives and encourage green living. Currently, there are nine operating Recycling Stations and one hundred and thirty public collection points for glass bottles, electronic and electrical equipment, fluorescent lamps/tubes, rechargeable batteries as well as common recyclables such as plastics, paper and metals. Furthermore, collection vehicles are deployed to collect recyclables in the districts.

The Eastern Community Recycling Station (formerly known as Community Green Station) has been in operation since 2015. Besides functioning as a recycling collection point, it also includes an education center, office, a landscaped area, and a multi-purpose room for exhibitions, activities, and programs that promotes waste reduction and green living. The collected



Above: People dropping off their recyclables at the collection spot in the station.

Below: The Recycling Station is made up of several blocks where it serves as a collection spot and for public recreational use.

recyclables are sorted at a work area, delivered to qualified downstream recyclers for treatment and then converted into renewed resources.

The station was formerly a temporary parking lot, where it makes use of a flyover and surrounding greeneries to provide shade, as well as the design of overhanging roofs and vertical greening to block direct sunlight in order to minimise heat retention inside the facility. Most of the station's structures consist of reused materials, using modular containers as the foundation of the facility, which are fitted with floor-to-ceiling glass panels to let in natural sunlight. To encourage and attract community use, the site has open and semi-open spaces that consist of various gathering spaces and gardens, and also acts as a connector of the surrounding old and new communities and neighborhoods.

The main purpose of the station is to increase district recycling, amplify green initiatives and waste reduction education and experiment with incentivized approaches. The more recyclables a person brings, the more “green points” they get and with the points, they can exchange for gifts, or join a station's activity or program for free. It also offers convenient logistical support for recyclables collection and is part of a district network of residential, organizational and public recycling collection points.

Challenges/Opportunities

A study was conducted on the effectiveness of the Eastern Community Green Station through two questionnaire studies. Respondents were generally satisfied with the station's facilities, but there are also areas that require growth and development. The main challenges identified were the accessibility of the collection sites and the community's engagement with

the education programs and activities. Many respondents were relatively unsatisfied with the waste recycling services at the station where some commented that the recycling facilities were placed in hidden, hard-to-find areas and instructions were not clear. And the participation rate for the educational programs and activities were relatively low, indicating that more promotion was needed.

The station has the opportunity to expand the types of recyclables being collected, where food and organic waste should potentially be considered. With the EPD's several organic resource recovery schemes going underway, there is an even bigger need to have an established collection system for food waste.



Left: Recyclables collection machines. People can collect “Green Points” when they drop off their recyclables.

Our Tampines Hub Hawker Center, Singapore

Type

- Food hall with reusable serviceware and food waste equipment

Best Practice Strategies

- 2.02 Plan a route
- 2.03 Design storage space
- 2.05 Consider staff procedures
- 2.04 Plan for collection
- 2.09 Provide equal convenience disposal (commercial)
- 2.10 Provide clear visual cues and signage
- 2.12 Develop awareness and education programs
- 2.16 Reduce materials consumption
- 2.24 Organic waste pretreatment (commercial)

Summary

Our Tampines Hub (OTH), is a mixed-use facility serving the new eco-focused neighborhood of Tampines, with over 250,000 residents. With a supermarket, 30 eateries and a 24-hour hawker center with 42 stalls and 800 seats, it generates a significant amount of food waste.

Every day 1.4 tonnes (1.6 tons) of food waste, including expired foods from the supermarket and leftovers from the eateries and hawker center, are taken to



“Our Tampines Hub” hawker center eateries and dining area that provides seating and reusable eating utensils.

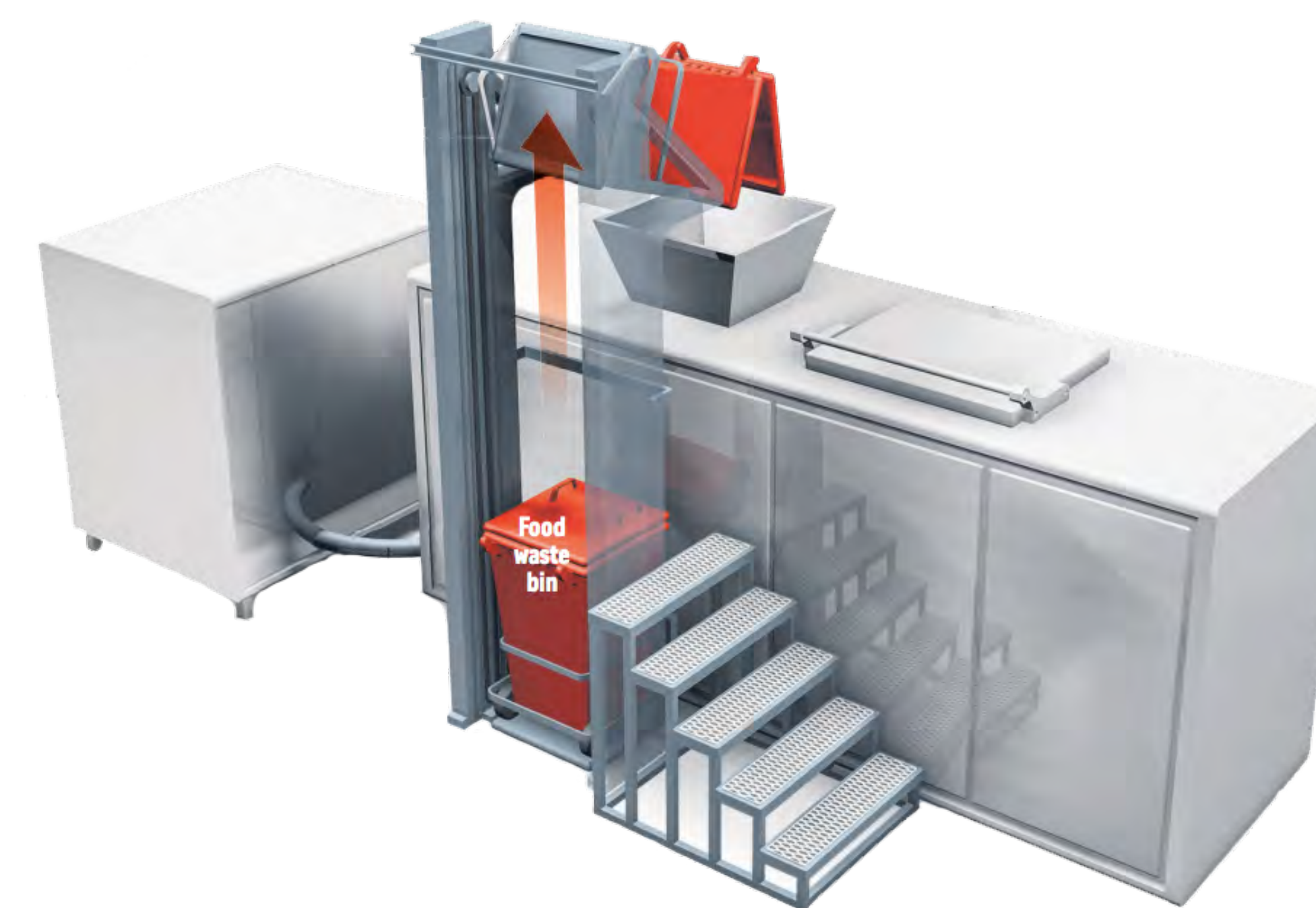
two food waste digesters in the OTH basement. These comprise a grinder, grease separator, microbial treatment and a filtration system that separates the output into fertiliser, liquid nutrients and non-potable water. The fertiliser and liquid nutrients are used in OTH's eco-community garden located on the roof and are also distributed to residents and schools monthly. The eco-community garden grows a variety of edible fruits and vegetables, and frequently hosts educational and engagement events where participants can harvest the produce and cook at their Wellness Center.

The hawker center uses reusable plates, cups, and utensils, which patrons bring them back to the collection area on a tray. Workers at these areas separate food scraps into collection bins and sort items for washing. Twice a day, the bins get wheeled to the food waste recycling room in the basement, where a bin lift makes it easy to empty them into the digester. All food and beverage tenants within the Hub have to undergo comprehensive training on food waste separation, and waste separation requirements are incorporated into their tenancy agreements.

The National Environment Agency (NEA) supported the program and has helped to evaluate and improve outcomes. In 2019, the NEA proposed a pilot scheme of installing an automated food waste collection conveyance system at OTH. With this system in place, the food stallholders and table-cleaners won't have to manually transfer the food waste bins to the digester, increasing hygiene, convenience and efficiency. The People's Association, the local government agency for community development, runs programmes to engage and educate the community through learning tours and volunteer opportunities.

Challenges

Challenges include preventing contamination of the food waste by sugar cane stalks, hard shells, coffee powder and non-organic items such as plastic packaging that cannot be processed by the digesters. After 4 years of operation, OTH aims to increase their zero waste efforts through further educational initiatives. More focus could also be placed on food waste prevention strategies and educating people on their habits and attitudes around food waste, as preventing waste is always environmentally better than recycling it.



Above: Reusable serveware and utensil return point at the hawker center.

Below: Digester used for processing food scraps (located in the basement of the hawker center).

Next Steps

- 76 Develop Zero Waste Design Guidelines for Hong Kong and Singapore
- 77 Get Architects, Landscape and Urban Designers Involved Creatively

Develop Zero Waste Design Guidelines for Hong Kong and Singapore

This document represents an overview of what guidelines for each city could contain - to really develop useful guidelines for different building types, I would recommend a process similar to the one that generated the ZWDG in NYC was followed.

Convene workshops with government agencies and designers

Multi-disciplinary workshops with city agencies, architects, urban designers and developers could be held to discuss and adopt the best practice strategies recommended in this report, and see how to best move forward with implementation within the city.



Designers and officials discuss designing for multifamily residences at a workshop.

Visit buildings to understand local challenges and solutions

A local team should research the context further, by visiting buildings and interviewing waste management staff and property managers to understand local barriers and identify successful solutions which can be developed as local case studies. Meeting with governmental entities working on waste reduction policies in each city, and understanding how to best support their goals is also key.



A visit to a building's trash room.



Participants share strategies in the zero-waste design challenge for professionals.

Adapt the waste calculator for local context

The ZWDG [online calculator](#) uses typical data, containers and equipment used in NYC and the USA. It should be adapted for Hong Kong and Singapore, and a district or development scale calculator could also be developed.

Get Architects, Landscape and Urban Designers Involved Creatively

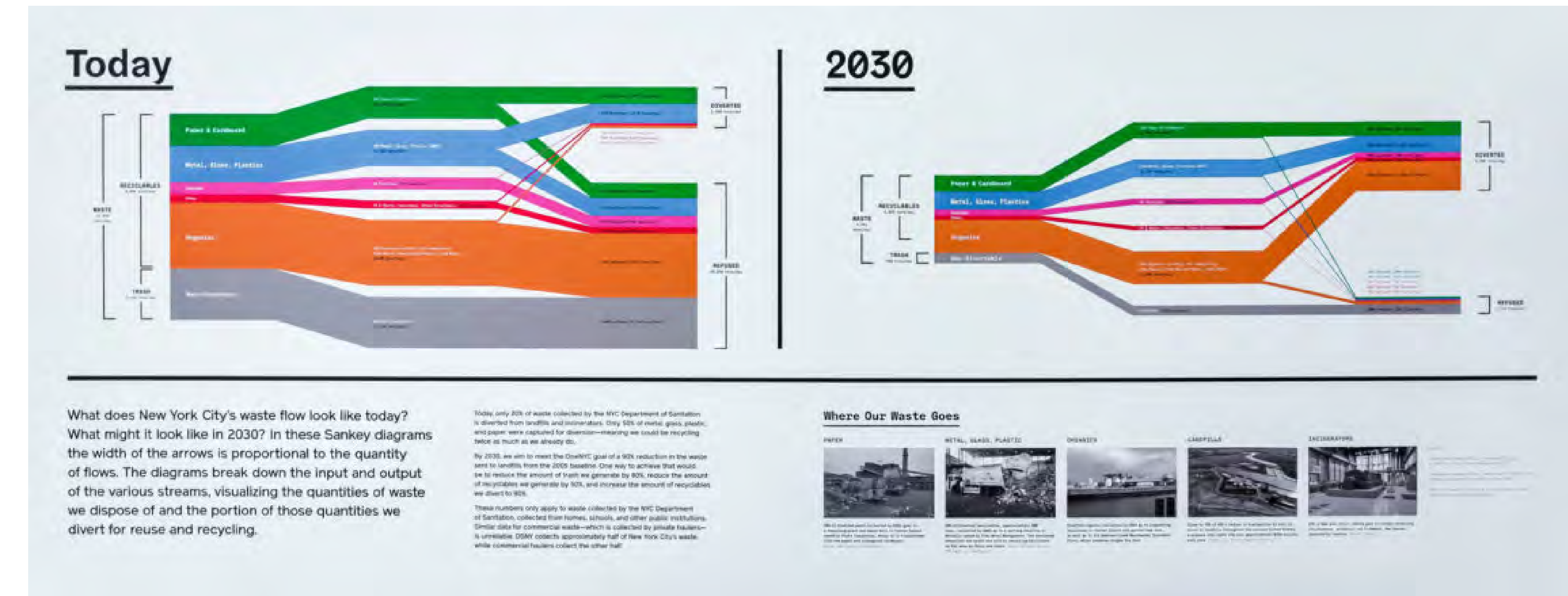
Designers love solving challenges in creative ways. Having the Guidelines be developed through the American Institute of Architects (AIA) was key to getting designers, developers and city agencies involved.

Hold a Zero Waste Challenge for designers

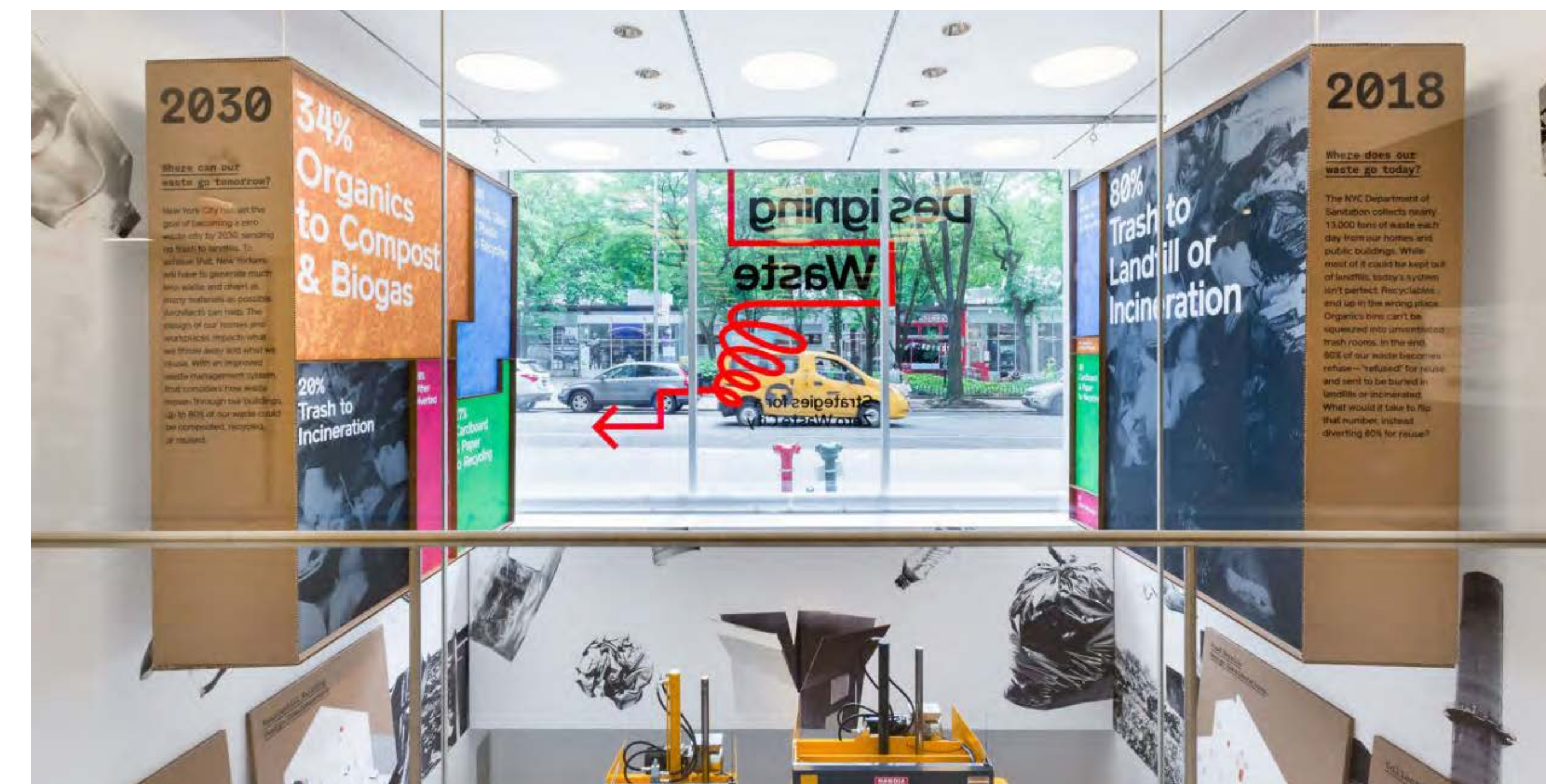
In NYC the AIA New York had a zero waste challenge for design offices, so architects could apply the best practice strategies to their own offices and measure results through waste audits at beginning and end. There was recognition of best performance through an awards ceremony for waste reduction, diversion and innovative strategies. [See link.](#)

Develop an Exhibition

In NYC we also had an exhibition in the Center for Architecture, called [Designing Waste](#), with seminars and associated education for students and professionals. This could include the display of local case studies or the display of a design ideas competition for a circular neighborhood.



Sankey diagrams depicting NYC waste streams, today and in 2030.



NYC's Designing Waste Exhibition, running July to September 2018.

Appendix

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35 bottom: flickr, Kai Hendry; 36 top: HDB recyclables collection diagram; 36 bottom: Wikimedia, Ccefalon (CEphoto, Uwe Aranas); 37 SG “Zero Waste Master Plan” (pgs 90-91); 38 SG “Zero Waste Master Plan” (pgs 88-89); 39 top: SG “Zero Waste Master Plan” (pg 87); 39 bottom: Zenith Engineering (Dust Screws); 43 top left: Straits Times, Jonathan Choo; 43 bottom left: Zero Waste Sg; 43 center: Zenith; 43 top right: SG Mediacorp; 43 bottom right: SG NEA; 48 top left: Rendisk; 48 top right: REC, Bramidan Baler; 49 Etsy office; 50 top row: The Container Store, Simple Human, Kitchen Compost Caddy; 50 bottom right: pneumatic inlets, France; 51 top left: Zero Waste SG; 51 top right: SG Mothership; 52 top: Swire Pacific; 52 bottom: Wikimedia, RoySmith; 55 top left: Straits Time, Lim YaoHui; 55 bottom: SG HDB; 56 top: Nathalie Kientz Ibanez for Green Queen Media; 57 WOHA; 58 top left: ZaoBao; 58 top right: Library of Things and Makerspace; 58 center right: SG Resource Center; 58 bottom left: Cup Club; 58 bottom right: Green-To-Go, Return Stations; 59 top: WOHA; 59 bottom: NParks; 60 right: 100pss; 60 top left: Barrio Fridge; 60 bottom left: South China Reborn; 61 top: Brooklyn Grange Rooftop Farm; 61 bottom: Dattner Architects; 62 Arup Associates; 63 Signify; 64 Building Product Ecosystems; 65 SHoP Architects PC; 66 top: jnuri.net; 66 bottom: Adrev Publishing; 67 PPT_NY_SEOUL; 68 top: Seodaemun-gu Office; 69 top: Barrett Doherty; bottom left & right: Two Trees Management 70 all images: Two Trees Management; 71 all images: ArchSD; 72 Google Review, Ah Man; 73 SGCLC case study; 74 top: SGCLC case study; 74 bottom: Sunday Times graphics; 75 all images: CfZWD; 76 all images: CfZWD;

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