Waste Characterization Study Curaçao

Transforming Waste to Value

Funded by the European Union
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Report:	**Waste Characterization Study Curaçao** **Transforming Waste to Value** • **Waste Generation Analysis (WGA)** • **Waste sampling and sorting** • **Waste drying** • **Survey of wastes not brought to landfill** • **Waste forecast** Main report
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Glossary

Asbestos	A naturally occurring mineral commonly found in buildings that is now recognized as hazardous due to its link to serious respiratory illnesses.
Ash	The inert residue left behind after the combustion of solid waste in waste-to-energy facilities, often containing minerals, metals, and other non-combustible materials.
Bulky waste	Waste consisting of large items, such as furniture, appliances, construction materials, and tires.
Bulky domestic waste	Bulky waste from households, such as furniture, appliances, or oversized objects.
Circular economy	The circular economy is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing, and recycling existing materials and products as long as possible.
CLEAR	Selikor's database with weighbridge-data
Commercial waste	Waste collected and disposed of by commercial transportation companies and other companies. This does not include waste from Selikor trucks, except for Selikor trucks servicing separate clients ("afzet"). Within Selikor a different definition is being used: waste collected for a fee.
Compost	Compost is organic waste that has decomposed by biodegradation under an aerobic atmosphere under controlled conditions. Compost is nutrient-rich fertilizer that also increases the organic content of soils. Sufficient organic content in soil improves fertility and avoids dehydration of the soil.
Construction and demolition waste (C&D)	Waste from construction, renovation, and demolition activities, including concrete, wood, metal, bricks, and other materials.
Domestic waste	Waste generated from households, including kitchen scraps, packaging, paper, plastics, and other items typically disposed of in residential trash bins.
E-Waste	Waste from electrical or electronic devices, such as computers, smartphones, tv's, and other electronic equipment, often containing hazardous materials and requiring specialized disposal methods.
Ferrous metals	Magnetic metals consisting mostly of steel, but in small quantities nickel and cobalt.
Fines	Small material fragments resulting from waste screening.
Garden waste	Organic materials such as grass clippings, leaves, branches, and plant trimmings generated from gardening and landscaping activities. Also referred to as green waste.
Grapple	A mechanical attachment mounted on specialized vehicles like waste collection trucks, featuring hydraulic hinged jaws or claws to lift large waste materials efficiently, including debris and scrap metal, aiding in the collection and transportation of bulky items.

Hazardous waste	Waste materials posing threats to public health or the environment due to toxicity, reactivity, or corrosivity, requiring special handling and disposal, such as chemicals, batteries, and medical waste.
High density polyethylene (HDPE)	A type of plastic variety frequently used in packaging and containers, known for its recyclability and ability to be reused multiple times. Examples: bottles, containers, pipes, and plastic lumber.
Incineration	Waste management process where solid waste is combusted at high temperatures, reducing its volume, and converting it into ash, gases, and heat.
Landfill	Designated site where waste is deposited.
Landfill gas	The gas flow generated in a landfill from the decomposition of organic waste. It consists of mostly composed of methane and carbon dioxide, with potential environmental and energy recovery implications.
Low-density polyethylene (LDPE)	A type of plastic known for its flexibility, toughness, and chemical resistance. It's commonly used in packaging films, plastic bags, squeeze bottles, and various other applications.
Leachate	Contaminated liquid formed as water percolates through waste material, containing dissolved and suspended pollutants.
Liner	A barrier for a landfill made of impermeable materials. It is installed at the base and sides of a landfill to prevent the leakage of leachate and landfill gas into surrounding soil and groundwater.
Liquid waste	Waste in a liquid state.
Medical waste	Waste originating from hospitals and healthcare facilities, containing infectious substances, human pathological waste, human blood products, and discarded sharps.
Mixed waste streams	Waste streams from the collections of various types of waste materials combined, often requiring specialized sorting and processing methods for proper disposal or recycling.
Multiple linear regression	A statistical technique used to analyze the relationship between two or more independent variables and a dependent variable.
National Development Plan 2015-2030	Outlines the strategic goals and priorities for Curaçao's socio-economic growth and development for 2015-2030.
Non-bulky waste	Waste materials that are not generally smaller than 40cm, most often offered in plastic waste bags, boxes and small containers (e.g. 240 l. containers).
Non-bulky commercial waste Selikor routes	Non-bulky waste collected by Selikor from businesses in specific routes on the island of Curaçao.
Non-bulky commercial waste from hotels	A waste category. Non-bulky waste collected from hotels.
Non-ferrous metals	Non-magnetic metals consisting mostly of aluminum, copper, zinc, stainless steel, and lead.
Other non-bulky commercial waste	A waste category. Bulky waste collected by private waste collection companies.

Other commercial bulky waste	A waste category. Non-bulky waste collected by private waste collection companies.
Organic waste	Biodegradable waste materials derived from plant or animal sources, including food scraps, yard trimmings, and other natural substances.
Polyethylene terephthalate (PET)	A type of plastic commonly used to make bottles for beverages and other liquid products, as well as for packaging various consumer goods.
Polypropylene (PP)	A type of plastic commonly used in packaging (margarine tubs and microwaveable meal trays), and textiles. They are identified by a number five inside a triangle on the packaging.
Polystyrene (PS)	A type of plastic used in products like foam packaging, disposable cups, and food containers. It's known for its lightweight and insulating properties.
Polyvinyl chloride (PVC)	A type of plastic widely used in construction, plumbing, and manufacturing for items like pipes, window frames, flooring, and packaging.
Polyurethane (PUR)	A type of plastic used in various applications such as foam insulation, furniture cushions, coatings, adhesives, and sealants due to its durability and flexibility.
Ramsar Convention	International treaty that aims to conserve and protect important wetlands around the world.
Recycling	The process of converting waste materials into reusable products to reduce the consumption of new raw materials, energy usage, and environmental impact.
Reuse	The reuse of a product multiple times without significant modification, either for the same purpose or for a different one.
Sanitary landfill	A site for the safe disposal of solid waste, where waste is compacted and buried in thin layers and covered with soil to reduce environmental pollution and health hazards.
Sewage sludge	Leftover solid, semisolid, or liquid waste from treating wastewater, usually containing organic matter, nutrients, and some pollutants. Also referred to as “biosolids”.
Solid waste	Any discarded material that is not in a liquid or gaseous state, such as household garbage, construction debris, or industrial waste.
Textiles	Materials made of fibers, like cotton or polyester, used for making clothes, towels, and other fabric products.
Waste	Materials and objects that are unwanted or no longer needed and are disposed of.
Waste category	A waste stream, defined by method of collection, e.g. domestic waste from Selikor’s vehicles. Waste categories do not overlap.
Waste-to-energy	A thermal waste treatment process that converts waste into energy to generate electricity or heat.
Weighbridge	Large scale used to weigh vehicles loaded as well as unloaded, to calculate disposal fees.

Abbreviations

ANN	Artificial neural networks
CBS	Central Bureau of Statistics
CRC	Curaçao Recycling Company
C&D	Construction and demolition
DOW	Dienst Openbare Werken
EEA	European Environment Agency
GDP	Gross domestic product
GHG	Green house gasses
HDPE	High density polyethylene
IMF	International Monetary Fund
INF	Infant mortality rate
LDPE	Low-density polyethylene
LHV	Lower heating value
MLR	Multiple linear regression
MSW	Municipal solid waste
PET	Polyethylene terephthalate
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl chloride
PUR	Polyurethane
SIDS	Small Island Developing States
SDG	Sustainable Development Goals
SWA-Tool	The European methodology for the analysis of solid waste
UOOW	Public Works - Uitvoeringsorganisatie Openbare Werken
WCS	Waste Characterization Study
WGA	Waste Generation Analysis
WtE	Waste-to-energy

Summary

Introduction

Currently, Curaçao generates approximately 210,000 metric tons[1] of solid waste per year. Most of the solid waste, approximately 130,000 tons, is disposed of at the Malpais Landfill. This landfill is owned by the Curaçao government and is managed by Selikor. Approximately 83,000 tons per year is not disposed of at the landfill but processed for recycling by other local waste management/recycling companies, or stored by Selikor for future recycling.

EcoVision, in cooperation with Royal HaskoningDHV and De Afvalspiegel from the Netherlands, prepared a Waste Characterization Study (WCS) to obtain detailed data on the volumes, composition & characterization of solid wastes generated in Curaçao. The overall objective to which this project contributes is:

To contribute to a reduction in the adverse ecological and social impacts of solid waste disposal on the island of Curaçao and to the transition to renewable energy.

Important components of the project are: a Waste Generation Analysis (WGA), a waste sampling and sorting campaign, determination of moisture content, a survey of wastes not brought to landfill and a waste forecast.

The study focused on 8 waste categories. Non-bulky wastes include domestic waste, hotel waste, waste from Selikor's commercial routes, other (non-bulky) commercial waste. Bulky wastes include domestic bulky waste, commercial bulky waste, construction and demolition waste (C&D waste) and garden waste. A waste category is a specific, recognizable (by transport) type of waste that does not overlap with any other category.

Waste Generation Analysis

During the 28 days of the Waste Generation Analysis (WGA), 6,687 vehicles stopped at the weighbridge at the Malpais Landfill. A total of 6,152 (92%) vehicles were registered and their drivers were interviewed by the team. This corresponds to 97 wt.% of all incoming waste.

Extrapolating the WGA data results in a total amount of waste landfilled of 129,170 tons per year.

Non-bulky domestic waste is the largest waste category (26%), followed by construction & demolition (C&D) waste (23%), bulky commercial waste (17%) and garden waste (11%). The WGA data reveal that C&D waste is much more prevalent than would be expected based on the CLEAR (weighbridge) data of 2022 (6% C&D waste in 2022). Although garden waste is a significant part of total waste, it is not

[1] In this report we refer to metric ton as ton (= 1,000 kg)

being registered separately by Selikor. 54% of the waste was labelled as bulky (> 40 cm) and 44% of the waste was labelled as non-bulky (< 40 cm). 2 wt% was a mix of bulky and non-bulky waste.

Sampling and sorting campaign

During the 8-week sampling and sorting campaign, 96 samples were taken for sorting from the 4 non-bulky waste categories and 143 entire truckloads of waste from bulky waste categories were sorted. The campaign showed that in non-bulky waste (including domestic waste), the fractions organic waste, paper/cardboard and plastics constitute 58% of all non-bulky waste. With respect to plastics in non-bulky wastes: LDPE was the largest plastic fraction for all waste categories, followed by PET, PP and HDPE.

Compared to other (non-bulky) waste categories, commercial waste from Selikor routes contains relatively large quantities of paper/cardboard (24.2 wt%). Hotel waste contains relatively large amounts of glass (18.1 wt%) and - compared to other waste categories - domestic waste contains significant amounts of textiles (9.3 wt%).

Bulky waste composition is highly variable over the 4 bulky waste categories. In domestic bulky waste and commercial bulky waste, wood is the dominant fraction by weight, in construction and demolition waste concrete stones and tiles are the dominant fraction, and in garden waste organic garden waste is the dominant fraction by weight.

Waste drying

The waste drying campaign showed that the fractions with the highest moisture content are organic kitchen food/waste (58 wt% moisture), sanitary waste (49 wt% moisture), and cardboard (30 wt% moisture). The calculated average moisture content of paper, textiles and plastics were 24, 23 and 13 wt%, respectively.

Wastes not brought to the landfill

The survey on wastes not brought to the landfill pointed out that 78,000 metric tons of waste on Curaçao is being brought to recycling companies (for local use and export)[2]. The bulk of this amount is metals and concrete. An amount of 5,600 metric tons is stored for future recycling, which is mainly concrete from C&D waste.

Plastic recycling by private companies on Curaçao is still relatively small (39 tons per year), but initiatives are forecast to increase this amount more than fourfold in the next few years. Paper and cardboard recycling amounts to 200 tons per year and recycling of aluminum cans to 4 tons per year.

The potential for recycling is much greater than what is currently realized. The amount of paper and cardboard in landfilled waste for instance is 10,000 tons per year, the amount of plastics is also 10,000

[2] This is excluding 30,000 ton of asphalt being recycled from the Asphalt Lake

tons per year and the amount of organic (kitchen/food) waste is 9,000 tons. These figures are "as received" and are significantly lower on a dry weight basis. On top of that, optimized collection systems rarely result in collection rates higher than 90%. They are usually much lower.

Waste to Energy

Waste-to-energy plants can operate if the Lower Heating Value (LHV) of the waste received is roughly between 6 MJ/kg and 14 MJ/kg. Approximately 106,000 tons of the 129,000 tons received at Malpais could be suitable as fuel for a WtE plant. The 23,000 tons not suitable for WtE consists mostly of the mineral fraction present in C&D waste. The average lower heating value for this 106,000 tons combustible waste is 7.6 MJ/kg as received. This LHV is relatively low, but not unfeasible for WtE. The amount of ash generated by a WtE plant will be approximately 22,200 tons per year (with average moisture). If no recycling of bottom ashes from WtE is implemented, WtE will still result in 22,200 tons/yr ashes that has to be landfilled in a sanitary landfill. Together with the 23,000 tons waste which cannot be incinerated, 45,000 tons landfill capacity will be required on an annual basis.

Waste forecast

After 23 years of a declining waste generation trend (approximately 1% per year), a period with increased waste production is forecasted, fueled by a growing economy over the next 5 years. After this period, waste generation may further increase or instead decrease, depending on economic scenarios. GDP development scenarios for the next 10 years suggest that total waste on Curaçao may grow by 26% (high growth scenario), 18% (medium growth scenario), 10% (limited growth scenario) or -2.5% (negative growth scenario).

Recommendations

For future analysis, it is recommended to introduce the 8 categories in the monitoring system at Selikor's weighbridge at the landfill. Special attention should be paid to construction & demolition waste, garden waste and the difference between bulky and non-bulky waste. To account for all seasons of the year, it is recommended to repeat the WGS during the dry season and high tourism season.

1 Introduction

1.1 Background

Currently, Curaçao generates approximately 213,000 metric tons[1] per year of solid waste. Most of the solid waste (approximately 130,000 tons) is disposed of at the Malpais Landfill. This landfill is owned by the Curaçao government and is managed by Selikor. Approximately 83,000 tons per year is not disposed of at the landfill but handled for recycling (or storage for future recycling) by other local waste management/recycling companies. Besides this, significant amounts of solid waste are dumped illegally at various locations on the island. On a small island such as Curaçao, where availability of space is limited, long-term reliance on landfilling as a disposal method for solid wastes is imprudent. The Malpais Landfill is a controlled, sanitary landfill. The landfill is not an engineered landfill with synthetic liners, leachate collection, and landfill-gas extraction. Contaminated leachates can potentially infiltrate into the groundwater and/or eventually into the ocean and/or the adjacent Malpais nature area, which is protected under the Ramsar Convention. Uncontrolled landfilling is internationally, and locally, no longer viewed as environmentally sustainable regarding the circular economy and scarcity of resources. As such, sustainable waste management practices, in terms of waste collecting, sorting, recycling, transporting, disposal, and waste-to-energy (WtE)/value are imperative.

The current waste management strategy in Curaçao is to keep the island clean and dispose of all waste at the only landfill. Recycling takes place but only voluntary by companies that see a positive business case for recycling. This approach results in a large loss of materials and organic nutrients that could have been recycled. This approach is not only used on Curaçao, but also on many other Caribbean Small Island Developing States (SIDS).

State-of-the-art waste management that results in more recycling, less landfilling and less environmental impact is needed for Curacao. The first step in assessing more possibilities for recycling and other modern waste processing methods, requires a mass balance for waste streams on Curaçao and the composition of mixed waste streams. This requires a waste characterization study for Curaçao.

EcoVision, in cooperation with Royal HaskoningDHV and De Afvalspiegel from the Netherlands, prepared a Waste Characterization Study (WCS) to obtain detailed data on the volumes, composition & characterization of solid wastes generated in Curaçao. This waste characterization study is in line with the Curaçao government's priorities and goals as stated in its National Development Plan 2015-2030, National Energy Policy, National Export Strategy, and the Doughnut Economy Compass strategy. Furthermore, it enriches the sustainability theme of Curaçao's National Plan and supports numerous Sustainable Development Goals (SDGs) (i.e., #7, 8, 9, 11, 14, 15).

[1] In this report we refer to metric ton as ton (= 1,000 kg)

1.2 Overall objective, project objectives and project output

The **overall objective** (impact) to which this project contributes is:

To contribute to a reduction in the adverse ecological and social impacts of solid waste disposal on the island of Curaçao and to the transition to renewable energy.

The specific **objective of this study** is as follows:

Creating a data set on waste volumes and compositions that will enable the Curaçao government to draft a sound and realistic national waste management plan that pursues the goals of a circular economy and provide data to (commercial) companies that enables them to define sound business cases for more recycling. This will therefore contribute to the formulation and implementation of circular and sustainable solid waste management strategies and for improved renewable energy in Curaçao.

1.3 Scope summary

The scope of work for this study can be summarized in the following activities:

1. waste generation analysis (WGA) at Malpais. For 1 month all incoming waste will be monitored for tonnage, origin, and type of waste.
2. sampling and sorting campaign. On at least 30 days the waste composition of incoming waste streams at the Malpais Landfill will be sampled and sorted.
3. determination of the moisture content. The dry matter content will be determined on sorted fractions in an oven at 105 ^{o}C.
4. analysis of waste not disposed of at the landfill (including recyclables).
5. waste forecast.

1.4 Selection of waste categories

The aim of sampling campaign was to sort at least 90 samples. These samples have been allocated proportionally to the following 8 waste categories:

1. domestic waste,
2. bulky domestic waste,
3. non-bulky commercial waste from Selikor routes,
4. non-bulky commercial waste from hotels,
5. other non-bulky commercial waste,
6. garden/yard waste;
7. construction & demolition waste;
8. other commercial bulky waste.

1.5 Expected outputs to be achieved by the contractor

The expected **output** to be achieved by the contractor is:

A Waste Characterization Study (WCS) to obtain detailed data on the volumes, composition & characterization of solid wastes generated in Curaçao.

EcoVision has produced the following documents:

- sampling plan,
- health and safety plan,
- work procedures, work schedule,
- project handbook,
- quarterly summary report,
- draft report of the WCS,
- final report of the WCS.

2 Methods

2.1 Pre-investigation

The European Methodology for the Analysis of Solid Waste (SWA-Tool) was used to carry out a pre-investigation before setting up a waste characterization campaign. This pre-investigation, carried out in September 2023, focused on the following subjects:

- general description of the area under investigation;
- waste management structure;
- waste supply to landfill 2018-2022;
- stratification for sampling.

In dialogue with the Contracting Authority, it was decided to not apply stratification with respect to:

- meteorological season;
- tourism season;
- average income of residential areas and;
- waste source (e.g. within commercial waste: restaurant waste, hotel waste, office waste, etc.).

2.2 Waste Generation Analysis (WGA)

General method

The WGA was carried out by two data collectors during the period of September 25 to November 3. During this period vehicles were registered at the weighbridge, from 07:00 to 18:00. Care was taken that all days of the week were included equally frequently in the investigation. Every weekday was monitored 4 times (4 complete weeks). This was especially important because substantial differences in waste supply exist between (some) days of the week.
During the investigation the target was to register every vehicle passing over the weighbridge. During the monitoring hours a few vehicles were left out primarily due to short bathroom breaks. Additionally, no vehicles were registered between 18:00 and 19:00. During this last opening hour very few vehicles arrive at the landfill.

The following information was recorded about the vehicle and its driver:

- license plate number;
- type of vehicle/transporter;
- bulkiness of waste;
- waste category;
- for commercial vehicles: origin of the waste load;
- comments.

This data was registered on paper sheets and added to the daily exported digital dataset afterwards. Selikor provided this daily data export. This way all relevant information was registered and linked to the registration number of each incoming vehicle.

2.3 Determining number of samples per waste category

The aim of number of samples to be taken in the waste sorting campaign was 90, to be distributed proportionally over the 8 waste categories according to weight per waste category. In the current data sets of Selikor (CLEAR), not all waste categories that need to be studied are included. Garden and hotel waste for example are not included and no distinction was made between bulky and non-bulky wastes. Therefore, the number of samples within each waste category was allocated proportionally using the tonnages in the 2022 CLEAR data, supplemented with required estimates on the missing data for waste categories and the bulkiness of waste (see Handbook paragraph 4.1.2 and 4.1.3).

The first 2 weeks of Waste Generation Analysis (WGA) data were essential to gain information on the actual quantities of waste in each waste category. With these quantities, new targets could be set for numbers of samples per waste category, based on 90 samples total and again based on proportionality to weight. These numbers were re-iterated after 4 complete weeks of WGA data (see table 2-1).

After one week of sampling and sorting, it became clear that more samples were realized than initially planned. This overperformance was mainly caused by the great commitment of the sorting team. In similar projects usually 20% or more of the sorting staff quit their jobs after a few days. To achieve the project targets the sorting team was slightly larger than necessary for the target. This was done in order to address inefficiency due to sorting staff possibly leaving and attracting new staff and instructing them. However, no workers left the project, their motivation remained strong. At the same time the project developed under relatively favorable conditions (only a few rainy days at the start of the wet season[1] and extreme heat). In practice, 3 non bulky samples could be sorted per day (expected: 2) and 4-5 bulky samples (expected: 2).

Based on a higher realized work pace than planned, we again set new targets for the number of samples per waste category. Initially, this was done proportionally to the weight of the eight waste categories. However, from week 6 onwards, with still 2 weeks to go in the sorting campaign, in dialogue with Selikor, we decided to allocate the remaining 50-60 samples to the smaller waste categories. At that stage, the approach of proportionality to weight could be abandoned because for the larger waste categories enough samples have already been realized. A larger number would have given only little added value in terms of more accuracy. This choice ensured sufficient samples per waste category and allowed for more representative data and more reliable conclusions for all waste categories.

[1] The month of September was relatively dry, while in the month of October 2.5 times more rain fell than the multi-year average (Meteo Curaçao)

Table 2-1 Number of samples targeted at start of project, after 2 and 4 full weeks of WGA, number of samples realized after 6 weeks of sorting and final target.

	Contract	Target 2 weeks WGA	Target 4 weeks WGA	Realized after 6 weeks	Final target (*)	Realized
Total samples	**90**	**90**	**90**	**183**	**239**	**239**
Total non-bulky	**53**	**47**	**41**	**72**	**96**	**96**
Total bulky	**37**	**43**	**49**	**111**	**143**	**143**
Domestic non-bulky	23	25	23	35	35	36
Bulky domestic	2	2	3	12	23	24
Selikor commercial routes	5	7	5	10	20	19
Non-bulky commercial	18	10	8	16	21	21
Bulky commercial	22	12	15	32	40	39
Hotel waste	7	5	5	11	20	20
Garden	9	11	10	25	30	30
Construction & demolition	4	18	21	42	50	50

(*) The final target was defined in the Quarterly report of November 11, 2023

From table 2-1 it can be concluded that the ratio of “bulky” samples to “non-bulky” samples changed significantly with progressing use of the WGA data.

2.4 Determination of waste composition

2.4.1 Standards

The following standards were used for the determination of the waste composition in this sampling and sorting campaign:

- Methodology for the Analysis of Solid Waste (SWA-Tool, European Commission, 2004); and
- Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste (ASTM, D5231).

The SWA-tool is written to be used for residual household waste (domestic waste) and residual co-collected commercial waste. The latter resembles domestic waste but can differ in amounts and composition, depending on the business category (SWA-tool, 2004). The SWA-tool and the ASTM standard are not written for bulky wastes, for which other sampling and sorting techniques are being proposed (see Chapter 3 and Annex 1).

2.4.2 Sampling of waste categories

The full sampling process is described in the sampling plan (see Handbook WCS, Annex 1). In the text below a summarized version of the text is given.

Non-bulky waste

Non-bulky waste was sampled from vehicle loads (one sample per vehicle) by the sampling team of three workers including a bobcat driver. After determining the required waste category, a vehicle with this waste category was randomly selected to discharge waste on the inspection floor, and relevant data was recorded such as vehicles' license plate number, waste origin, and sample number. The next step was to randomly fill four 240-liter containers with approximately 100 kg of waste. The sample was subsequently transported to the waste sorting location for non-bulky waste.

Bulky wastes

Bulky wastes were not sampled. The whole vehicle load was sorted.

2.4.3 Sorting of samples and vehicle loads

Sorting of non-bulky waste samples

Sorting of non-bulky waste was carried out by a team of five sorters and a data manager. Each working day three samples of approximately 100 kg were sorted. A sample consisting of four 240-liter containers was weighed and emptied on the sorting tables. The empty containers were subsequently weighed to determine the empty weight. Three categories of particle size distribution were used to describe the waste in each 240-liter container. The three categories were:

- fine (main part of waste is smaller than 4 cm.),
- average (main part of waste is between 4 and 40 cm.), and
- bulky (main part of waste is larger than 40 cm.).

The waste sample was then sorted into 26 fractions of which 9 consisted of plastics fractions (table 2-2). Starting with big items, all waste was sorted until particles of 13-40 mm were left on the table, these were weighed as "other materials/fines". Items consisting of two or more different materials were added to the fraction of the material with the largest weight fraction. Buckets and 240-liter containers used for the sorted waste were weighed by the data manager, both full and empty. All data was registered on pre-prepared paper sheets and entered in an MS Excel-spreadsheet the same day. All working procedures are included in the WCS-Handbook (Annex 1).

Every day six fractions were kept apart for drying, after sorting and weighing. Each day the first sample of day was used for this purpose. Procedures are specified in paragraph 2.4.

Table 2-2 shows the sorting fractions and examples for each sorting fraction. In bold are the six fractions that were dried during the project, the different plastic fractions were combined into one fraction for this drying method.

Table 2-2 Sorting fractions

Waste fraction	Examples
Paper	Office paper, paper bags
Cardboard/corrugated	Cardboard boxes, drink cartons
Plastics	
PET bottles	Soft drink bottles
PET	Food containers, cups
LDPE	Plastic bags, cling wrap
HDPE	Cleaning product bottles, food containers
PP	Cups, food containers
PS	Foam food containers, plastic cutlery
PVC	Plumbing pipes
PUR	Foam cushions, foam insulation
Other plastics	Packaging combining different types of plastics
Non-ferrous metals	Aluminum (beverage) cans
Ferrous metals	Food cans
Glass	Beer bottles
Organic garden/yard waste	Branches, leaves
Organic kitchen/food waste	Bread, fruit peels, coffee grounds
Wood	Pallet wood, board (thick branches and tree stems or trunks belong to garden/yard waste)
Durable goods	Brushes, toys
E-waste	Printers, headphones
Textiles	Clothes, shoes
Rubber	Gloves
Hazardous	Batteries, drugs
Sanitary waste	Tissues, pampers
Liquid waste	Full water bottles
Minerals	Stones
Other materials including fines	Small particles of mixed materials

Sorting of bulky waste vehicles loads

Bulky waste was sorted manually with a team of 3 workers including the bobcat driver. All fractions were separated by hand and by use of the bobcat. A maximum of 11 fractions for bulky waste was sorted (Table 2-3).

Table 2-3 Sorting fractions bulky wastes

Waste fraction	Examples
Paper & cardboard	Paper dossiers
Plastic film	Film used for wrapping pallets
Other plastic	Mixed plastic, PVC
Metals	Pipes, stoves
Garden & yard	Branches etc.
Wood	Construction wood, plywood
Durable goods, furniture, e-waste	Refrigerators, computers
Textiles	Clothing, carpets
Rubber	Tires
Concrete stones & tiles etc.	Blocks, concrete rubble
Other materials & fines	Small particles
Non bulky	Waste bags with domestic waste, waste smaller than 40cm

Sorting of bulky waste started with creating of piles for each sorting fraction on the inspection floor. Subsequently the weight of each pile was estimated. Weighing would be preferable, but the required large scale of Selikor was not available. Therefore, estimates were done using known bulk densities for each material/fraction. In case of unknown densities, a 240-liter, or 1100-liter container was filled and weighed at the weighbridge with the sorting fraction.
Within the durable goods category specifically, a variety of distinct objects could be identified such as electric waste (fridges, washing machines, ovens etc.), electronic waste (computers, tv's, phones), mattresses, sofas etc. The objects within this category were then also placed in separate piles and the total number of each item was noted. The conversion to weight per fraction was facilitated by preparing a list of objects with standardized weights (e.g., refrigerator small, medium, large, car tire, vehicle tire, single mattress, double mattress, children's mattress, furniture with mixed components, etc.).

In the case a bulky waste load consisted entirely of one fraction, the vehicle was not unloaded. The fraction was recorded, and the vehicle's load weight was recorded at the weighbridge. This was mostly the case for garden/yard waste or for Construction & Demolition (C&D) waste (e.g. only concrete).
For construction & demolition waste we took out all relevant components (fractions) except for concrete and stony material; the concrete and stony fraction is the remaining component, of which the weight was determined based on an estimate of the volume.

In case of heavy objects (> 150 kg) we used a combination of visual characterization and measurement of dimensions in combination with information on specific weight of the material.

Per day 4-5 samples were sorted by the bulky waste team. The data from these samples, recorded on paper, were entered in our pre-prepared MS Excel-spreadsheet the same day.

2.5 Drying of waste fractions

The standard *Solid recovered fuels - Determination of moisture content using the oven dry method - Part 1: Determination of total moisture by a reference method (CEN/TS 15414-1:2010)* was used to determine the moisture content of selected fractions This required the use of an oven. Samples for drying were taken proportionally from the non- bulky waste categories. A total of 30 waste samples divided over the following six fractions was collected:

1. paper (e.g. white office),
2. cardboard/corrugated,
3. plastic,
4. organic kitchen/food waste,
5. textiles (incl. leather),
6. sanitary waste.

For each fraction a representative sample (+/- 1-2 kg) was collected from the collection container. The particles were cut into smaller pieces. Prior to weighing the samples, the weight of the six empty trays was determined and noted on the form (see Annex 1). Subsequently, the six sorted fractions including the trays were weighed. After weighing, the fractions were placed in a fan-assisted oven at 105°C for 22 hours[1]. After the drying process each tray with the dried fraction was removed from the oven and the dried fractions were weighed in grams on a high accuracy scale.

The equation below shows how moisture content (as received) was calculated.

$$Moisture\ content\ in\ \% = \frac{weight\ sample_{as\ received} - weight\ sample_{dry}}{weight\ sample_{as\ received}}\ x\ 100\%$$

Moisture contents, as derived from the weighing measurements, are given in chapter 7.

2.6 Safety

Safety is extremely important during the waste characterization operation. Safety regulations from the Dutch company Afvalspiegel and the Selikor emergency plan (noodplan) were used to write a safety plan and to design an incident report form (see WCS-Handbook; Annex 1). These documents

[1] We aimed for 23 hours of drying, but in practice we needed 2 hours for cooling down and handling of the waste, on a daily basis.

were the guideline to ensure a safe working environment. During the first two weeks of work, safety regulations were evaluated on a day-to-day basis. After two weeks all staff were asked to take part in the evaluation and some adjustments were made to decrease heat discomfort. Adjustments included extra shade for the sampling team for bulky waste and an extra window to promote air circulation for the sorting team. No accidents happened during the entire operation.

2.7 Data management sampling and sorting

Data managers recorded all data in the sampling and sorting forms according the corresponding procedures (see WCS-Handbook; Annex 1). The data was entered the same day in the MS Excel-spreadsheet.

2.8 Wastes not brought to landfill

Companies processing waste streams which are not disposed of at the landfill Malpais have been contacted by EcoVision. Most of these companies have been visited at their location. Some companies have been contacted by phone or email.

The following questions were asked:

- Which waste streams do you recycle or export for recycling?
- Which waste streams do you produce (e.g. chicken farm)?
- What is the amount of these waste streams in tons per year and their characteristics?
- What opportunities do you see to improve your business?

2.9 Waste forecast

A short term (5 years) waste forecast was made for Municipal Solid Waste (MSW) and a (long term, (10 years) for total waste. The method used for MSW (by Beigl et al, 2004), is based on Multiple Linear Regression (MLR) and is considered more accurate than the forecast for total waste which is based on single regression.
For the MSW method several socio-economic parameters were collected for the period of 2011 to 2022, such as GDP, GDP per capita, inflation rate, population size and infant mortality. The formula by Beigl et al (2004) was used to calculate forecasted MSW.
For the forecast for total waste[1] a linear relationship was established between GDP per capita (independent variable) and waste production (dependent variable), which was then used for forecasting. Data from the longest possible time-period (2001-2023) were chosen. With the relationship established, forecasted real GDP-growth by IMF and the Curaçao and Sint Maarten Central Bank for the next 5 years were used to forecast total waste.
Chapter 11 provides more information on the chosen methods, formulas, and accuracy.

[1] In fact the following categories were combined: domestic, domestic bulky, commercial and construction and demolition waste. These categories represent >98 wt% of total waste on Curaçao

3 Results of the pre-investigation

3.1 General description of the area under investigation

The island of Curaçao is situated in the Caribbean Sea and has a size of 444 km^2.

Curaçao has a high population density of 335 per km^2 (CBS, 2022). Total population on January 1st, 2023, was 148.925 (CBS, 2023). According to the CBS website (https://www.cbs.cw/population) this number relates to the persons registered with the population register and reflects less the undocumented.

In 2011, CBS conducted a Census. The total number of private households counted in 2011 was 54.936, the total population size was 150.563 persons. According to Selikor, currently (2023) there are 67.923 household 240-liter containers (kliko's) in service. This is 25% more than the number of households 54,936 counted in 2011. While the population decreased slightly in the same period and households are becoming smaller, it seems likely that a substantial number of households have 2 (or more) 240-liter containers.

Figure 3-1 shows the numbers of households, each polygon representing a neighborhood.

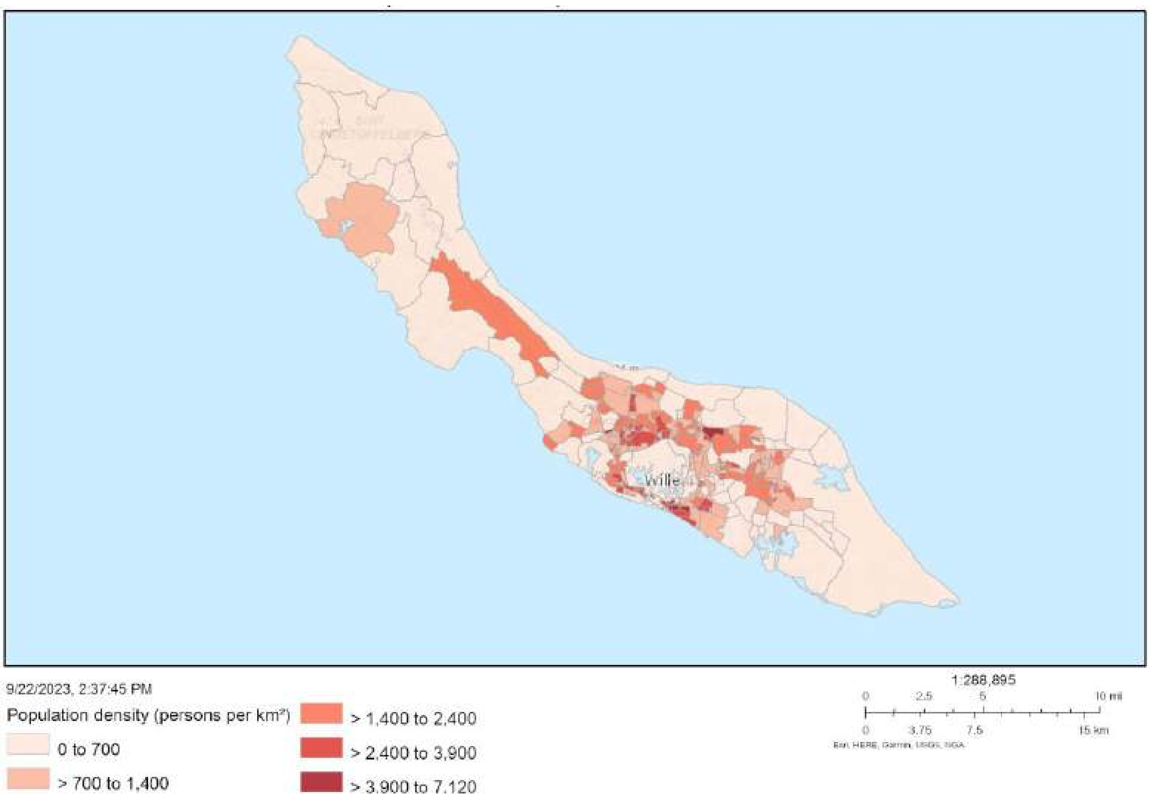

Figure 3-1 Number households per neighborhood during Census 2011. Each polygon represents a neighborhood. Total number of households: 54.936. Source: CBS Curaçao.

In 2011, the average monthly gross household income was ANG 5.332, varying from an average of ANG 2.899 in the neighborhood of Monte Carmelo to an average of ANG 13.487 in Rooi Catootje. Figure 3-2 shows mean incomes per neighborhood determined in the Census in 2011, each polygon representing a neighborhood.

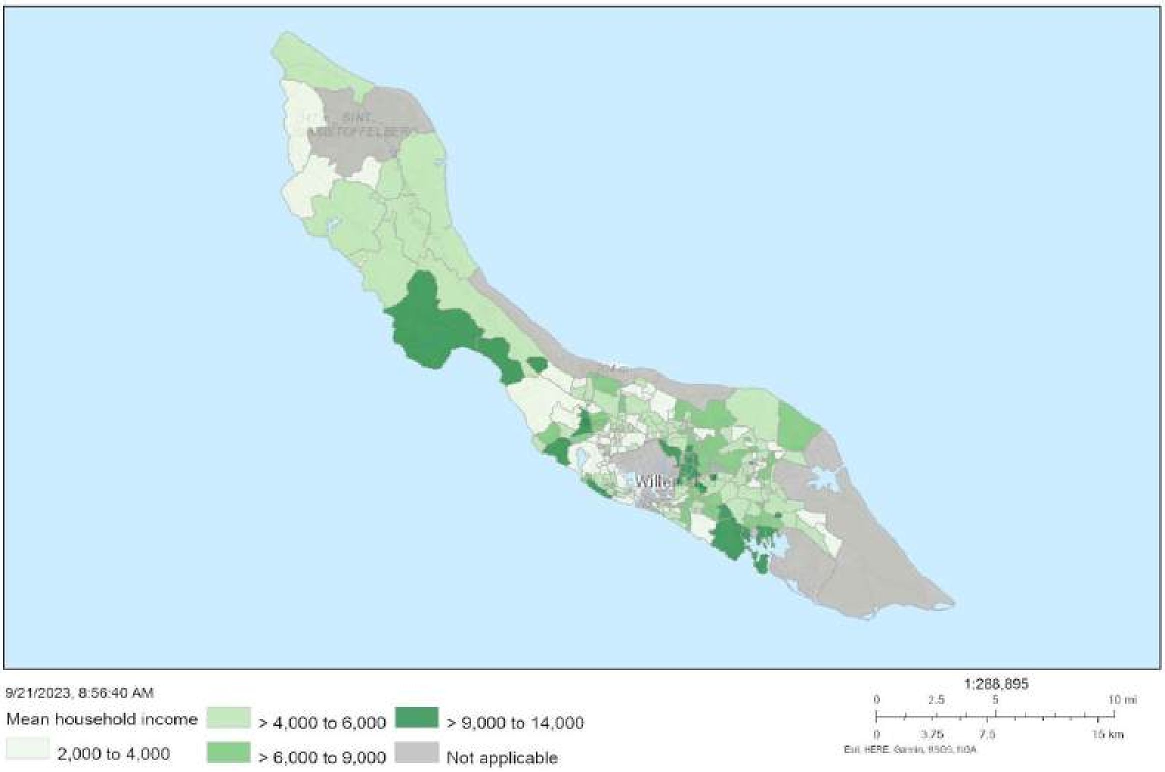

Figure 3-2 Mean household income per neighborhood in 2011, each polygon representing a neighborhood. Source: CBS Curaçao.

Annex 1 shows a table with information about income, population, and number of 240-liter containers (kliko's). The information is sorted for 3 income groups: high, middle, and low.

3.2 Waste management structure

3.2.1 Waste collection operators

The role being played by the main operators in waste collection differs depending on the type of waste. The text below shows an overview of the most important waste categories registered by Selikor (data 2022), These waste categories are domestic non-bulky waste, domestic bulky waste, commercial waste and construction & demolition waste. They comprise together 96.6 wt% of total waste (data from CLEAR, 2022).

Domestic waste (non-bulky)

The collection of non-bulky domestic waste is dominated by Selikor N.V. Selikor collects 99.4 wt% of all domestic non-bulky waste and transports it to the landfill. Selikor owns 22 collection vehicles that are used for this waste category (Technical Year Report Selikor, 2022).

Domestic bulky waste

Selikor is also an important player in the collection of domestic bulky waste. Selikor owns 2 collection vehicles with a grapple that are used for collection of bulky domestic waste. On the other hand, a large amount of this type of waste is also collected by private waste collection operators. This waste is not registered as “Domestic bulky waste” by Selikor, but as “Commercial waste”, because it is brought to the landfill by private waste collection companies.

The WGA provides insight into the origin of commercial waste, and hence the amount of bulky domestic waste brought in by private waste collection companies.

Commercial waste

Commercial waste is by far the largest waste category. In 2022 it was 86,754 tons (see section 2.3). Selikor is still an important player in the collection of commercial waste for both bulky and non-bulky waste, but most commercial waste is collected by private collection companies.

On Curaçao, approximately 5,000 private companies, both large and small, have delivered commercial waste to the landfill. The five waste collection companies collecting and transporting the most commercial waste -by weight- are:

- Dijk Transport, 15% of total weight
- Selikor N.V., 9% of total weight
- H&M Transport, 4% of total weight
- Ready to Go Transport and Services: 3% of total weight
- Wash on Wheels (W.O.W.): 3% of total weight.

(data CLEAR, 2022).

Construction & demolition waste

The total amount of C&D waste in 2022 was 6,320 tons. The two operators collecting most C&D waste -by weight- are:

- H&M Transport: 17% of total weight; and
- Curaflor Recycling N.V.: 6% of total weight.

3.2.2 Waste processing

Most waste on Curaçao is landfilled on the controlled, sanitary landfill. Of the total 132,131 tons of waste (excluding non-bulky domestic) brought to the landfill, 94,2 wt% was landfilled, 5.5 wt% was recycled or stored in the landfill area for future recycling, and 0.1 wt% was incinerated (CLEAR data, 2022).

3.3 Waste supply to landfill 2018-2022

Table 3-1 summarizes the registered mass of waste transported to the landfill for the main waste categories from 2018 to 2022.[1] Bulky domestic waste is not included in this overview because of discrepancies with the figures from the Technical Year Reports.

Table 3-1 Waste disposal at Malpais landfill according to CLEAR 2018-2022.

Category	2018 (tons)	2019 (tons)	2020 (tons)	2021 (tons)	2022 (tons)
Domestic waste	32,484	35,017	35,603	36,298	31,946
Commercial waste	94,781	81,517	69,173	75,379	86,754
Concrete/construction waste	13,964	7,207	5,757	6,368	6,320
Other	2,635	7,449	13,635	6,666	7,110
Total	143,864	131.186	124,169	124,713	132,131

From 2019 to 2021 (with a peak in 2020) so-called soils from the new Mangrove-park in Otrobanda were transported to the landfill: 5,762 tons in 2019; 46,730 tons in 2020 and 5,269 tons in 2021. This material was used for daily covering of the landfill and is not included in the total numbers of these years.

From 2018 to 2022, the average waste origin was 62% commercial waste, 27% domestic waste 27% and 6% construction & demolition waste (see figure 3-3).

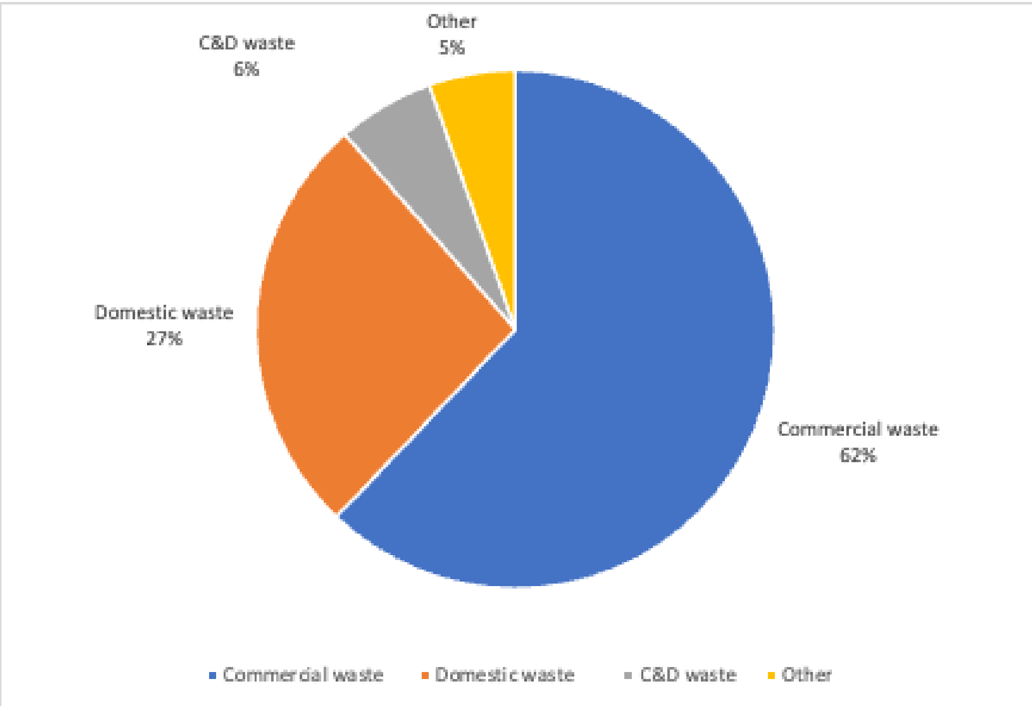

Figure 3-3 Main categories of waste landfilled in period 2018-2022.

[1] source CLEAR database

Over the last 5 years, domestic waste brought to the landfill was rather constant (average approximately 35,000 tons). On the other hand, the amount of commercial waste brought to the landfill significantly dropped during the covid years of 2020 and 2021. Since 2022, the numbers seem to be "normalized" at pre-covid values. Therefore, we choose to use the 2022 numbers for the definition of sample numbers (proportionally to weight of waste category).

3.4 Stratification

In dialogue with Selikor it has been decided that stratification of domestic waste will not occur. However, we do distinguish between "high income", "low income" and "middle income" areas on Curaçao. During sampling care was taken that the total number of samples for this waste category was evenly distributed over the 3 income strata.

Commercial waste was stratified as follows:

1. Commercial non-bulky, which was further stratified as:
    - Selikor routes;
    - Hotel waste;
    - Other commercial non-bulky;
2. Commercial bulky, which was further stratified as:
    - Garden and yard waste;
    - Other Commercial bulky.

The next paragraph describes the resulting 8 waste categories of which weights and compositions were investigated in this study.

3.5 Waste categories

In this WCS, a waste category is defined as a waste stream, defined by method of collection, e.g. domestic waste from Selikor's domestic waste vehicles, commercial waste from Selikor's collection routes, commercial waste from other vehicles. The categories do not overlap.

According to the selected stratification in section 3.4 the following waste categories of solid waste have been defined for this WCS:

"Non bulky" waste (regular waste):

a) Domestic/municipal waste;
b) Hotel and restaurant waste;
c) Commercial waste from Selikor routes;
d) Other commercial waste;

Bulky waste:

e) Bulky domestic waste;
f) Bulky commercial waste;
g) Garden/yard waste;
h) Construction & demolition waste;

Other categories:

i) Hazardous waste (including medical waste). This waste has not been sorted due to health and safety risks;
j) Tires.

The two “other” waste categories are minor categories and have not been sorted. Sorting hazardous waste is involves serious risk and tires consist of a single sorting fraction, rubber.

4 Results of the Waste Generation Analysis

4.1 General results

The data collection team completed the registration of 28 days. In this period 6,687 vehicles stopped at the weighbridge. In total 6,152 (92%) vehicles were registered and their drivers were interviewed by the team. The 92% corresponds to 97 wt.% of all incoming waste.

Commercial vehicles were most numerous with 82% and Selikor's vehicles were responsible for 15% of the transports. The average load from the commercial vehicles is much smaller and therefore the commercial vehicles were responsible for only 61 wt.% of the received waste. Selikor was responsible for 34 wt.% of the received waste.

Table 4-1 to 4-3 summarize the main results of the WGA. Detailed results per day of the week can be found in Annex 2.

Table 4-1 Overall results WGA.

WGA analysis	Unit	Total
Total number days in WGA	number	28
Total loads WGA	number	6,687
Average loads per day	number	239
Total weight landfilled	kg	9,910,837
Average load per vehicle	kg	1,482

Table 4-2 Number of vehicle loads and weight registered during WGA.

Registered in WGA	Unit	Total	Percentage total
Yes	number	6,157	92%
No	number	530	8%
Yes	kg	9,587,177	97%
No	kg	323,660	3%

Table 4-3 Number and type of vehicles registered and weight transported.

Type of vehicle	Unit	Total	Percentage total
Selikor "HV", "ROL", or "Bulky"	number	635	10%
Selikor commercial (afzet)	number	302	4.9%
Private person	number	198	3.2%
Commercial/company (*)	number	5,022	82%
Selikor "HV", "ROL", or "Bulky"	kg	3,233,620	34%
Selikor commercial (afzet)	kg	508,230	5%
Private person	kg	40,820	0.4%
Commercial/company (*)	kg	5,804,507	61%

(*) non-Selikor

4.2 Amounts of waste per waste category

Table 4-4 presents the amounts of waste brought to the landfill during the 28 days of the WGA, for the 8 waste categories investigated. Non-bulky domestic waste is the largest waste category (26%), followed by construction & demolition waste (23%), bulky commercial waste (17%) and garden waste (11%).

The current WGA data reveal that C&D waste is much more prevalent than would be expected based on the CLEAR data of 2022 (6% C&D waste in 2022). A possible explanation is that Selikors' classification of C&D waste is reserved for stony materials only and that mixed loads (concrete, wood, other) are being classified as "commercial waste". Garden waste was not separately specified in the data of 2022 but proves to be a significant part of the waste that was formerly classified as "commercial waste". Although the weight of garden waste is only 11%, due to its low density its share in transports is much higher.

Table 4-4 Amounts of waste per waste category (4 full weeks of WGA data).

Waste category		Total	Percentage total
Domestic waste non bulky	kg	2,450,840	26%
Bulky domestic	kg	285,720	3%
Selikor routes (commercial waste)	kg	528,310	6%
Non bulky commercial	kg	811,220	8%
Bulky commercial	kg	1,617,960	17%
Hotel waste	kg	559,380	6%
Garden	kg	1,088,220	11%
Construction, demolition	kg	2,242,387	23%
Total	kg	9,910,837	100%

In table 4-5 these figures are converted to quantities per year and small waste categories are added to the list.

Table 4-5 Amounts of waste per waste category (WGA data extrapolated for full year).

Waste category	Unit	Total	Percentage total
Domestic waste non bulky	tons	33,031	**26%**
Bulky domestic	tons	3,851	**3%**
Selikor routes (commercial waste)	tons	7,120	**6%**
Non bulky commercial	tons	10,585	**8%**
Bulky commercial	tons	20,790	**16%**
Hotel waste	tons	7,539	**6%**
Garden	tons	14,667	**11%**
Construction, demolition	tons	30,222	**23%**
Waste potentially containing asbestos	tons	361	**0.3%**
Rubber tires	tons	375	**0.3%**
Glass	tons	181	**0.1%**
Medical waste	tons	167	**0.1%**
Waste from cleaning public spaces	tons	280	**0.2%**
Total	tons	*129,170	**100%**

* This figure slightly differs from the 129.195 tons in table 9-1 due to rounding[1].

4.3 Bulkiness of waste

Table 4-6 presents the results of the WGA with respect to bulkiness of the waste. The data shows that in general, disposers bring more bulky wastes to the landfill than non-bulky wastes.

Table 4-6 Bulkiness of waste.

Bulkiness waste		Total	Percentage total
Bulky 100%	kg	5,142,557	54%
Mix	kg	223,430	2%
Non-bulky 100%	kg	4,213,820	44%

4.4 Origin of commercial waste

Table 4-7 presents for commercial waste the origin/type of disposer excluding all commercial Selikor transports. The data shows that the main origin of the waste being transported to the landfill by private (non-Selikor) commercial transporters is domestic. This is confirmed by the observed practice of vehicle drivers servicing domestic areas (commercially) while Selikor is providing these same

[1] This figure is in line with total waste landfilled during the last 5 years and reported in Selikor's Technical Reports (2019-2023: 129.705 ton averaged). The total amount in 2022 was 123.579 ton and in 2023 it was 114.978 ton.

services for free. Other important sources are construction & demolition projects (23.5%), gardening (11.3%) and shops, stores, supermarkets (7,9%).

Table 4-7 Origin of commercial waste (excluding all Selikor transports).

Origin, type of disposer commercial waste, excluding all Selikor transports	Unit	Total	Percentage total
Households	kg	3,187,310	33.4%
Construction, demolition	kg	2,247,317	23.5%
Gardening	kg	1,083,410	11.3%
Shops, supermarkets, malls	kg	751,360	7.9%
Mixed origin	kg	641,820	6.7%
Hotels and other tourist accommodations	kg	592,630	6.2%
Industry	kg	239,050	2.5%
Other commercial waste not in list	kg	170,690	1.8%
Vehicle maintenance	kg	156,340	1.6%
Restaurants and bars	kg	148,800	1.6%
Office and institutions incl. schools	kg	103,240	1.1%
Ships	kg	65,160	0.7%
Airport	kg	53,120	0.6%
Other medical e.g. pract., dentist, vet	kg	38,250	0.4%
Hospitals	kg	37,050	0.4%
Specified only as waste from companies	kg	25,250	0.3%
Unspecified by driver	kg	13,830	0.1%
Festivals	kg	260	0.0%

5 Results from sorting of non-bulky wastes

5.1 Sample size

A total number of 96 samples was taken from non-bulky waste, which was divided into 4 waste categories (see table 5-1). The domestic waste samples taken were equally divided over low, medium, and high-income neighborhoods as explained in paragraph 3.4.

Table 5-1 Number of samples non-bulky waste analyzed per waste category.

Waste category	Number of samples
Domestic-municipal waste	36
Hotel and restaurant waste	20
Commercial waste from Selikor routes	19
Other commercial waste	21
Total non-bulky waste	**96**

The preferred sample size was 100 kg. As a large scale was unavailable for use on the sampling floor the sampling team had to estimate the required weight. Therefore, sample sizes ranged between 76 kg and 120 kg. Figure 5-1 shows the weight distribution of the samples. The weight of 79 samples (82%) deviated less than 10% from the target weight of 100 kg. In total 14 samples (15%) weighed more than 10% too little and 3 samples (3%) weighed more than 10% too much. The sampling team estimated the weight of the sample to be 100 kg, when samples weighed more than 109 kg at the sorting station some waste was taken out to fall within the 91-109 kg range. This explains why there are more samples weighing less than 91 kg than there are samples weighing more than 109 kg, since at the sorting station no extra waste could be added to samples weighing less than 91 kg.

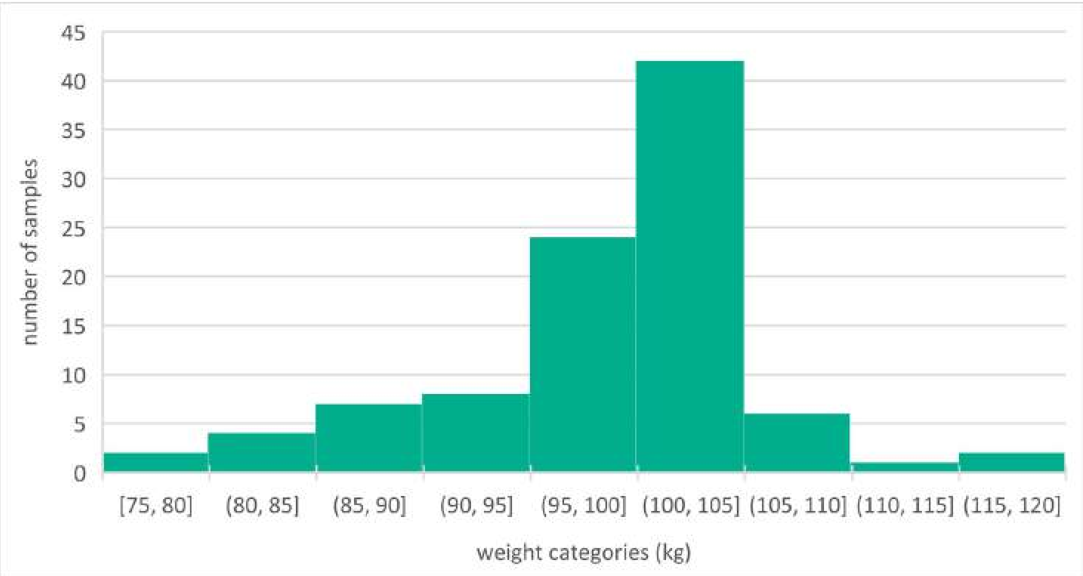

Figure 5-1 Weight distribution of the 96 samples taken.

The average sample weight was 98.7 kg and average weight of all sorted fractions was 97.5 kg, therefore the average weight loss during sorting was 1.3 kg (1.3%). Weight loss during sorting occurs for instance due to items falling off the sorting table, items being blown away by the wind, evaporation of moisture during sorting or liquids leaking off the table. As the day progresses temperature rises and the rate of evaporation increases. For this reason, a comparison was made between morning and afternoon samples. Morning samples were found to have a lower weight loss of 1.0% than afternoon samples with a 1.5% loss. It seems therefore likely that evaporation had an influence on the weight loss.

5.2 Particle size distribution

The particle size distribution of the majority of samples was classified as average (between 4 and 40 cm). In total 83 samples were classified as average. These 83 samples include 292 240-liter containers. Only 13 240-liter containers contained a deviating particle size distribution (table 5-2).

Table 5-2: Particle size distribution of the samples (number of samples)

Waste category	240-liter containers with		
	average particle size distribution	bulky particle size distribution	fine particle size distribution
Domestic-municipal waste	134	1	1
Hotel and restaurant waste	75		1
Commercial waste from Selikor routes	58	1	3
Other commercial waste	54	4	2

Containers classified as bulky often consisted of large amounts of large cardboard boxes and containers classified as fine often consisted of either garden waste like leaves or office waste with bags of shredded paper.

5.3 Waste composition overview, merged fractions

Figure 5-2 shows an overview of the waste composition for the four waste categories. For this overview some of the 26 waste fractions were grouped, these are: paper and cardboard, ferrous and non-ferrous metals, organic garden and kitchen waste and the different plastics fractions.

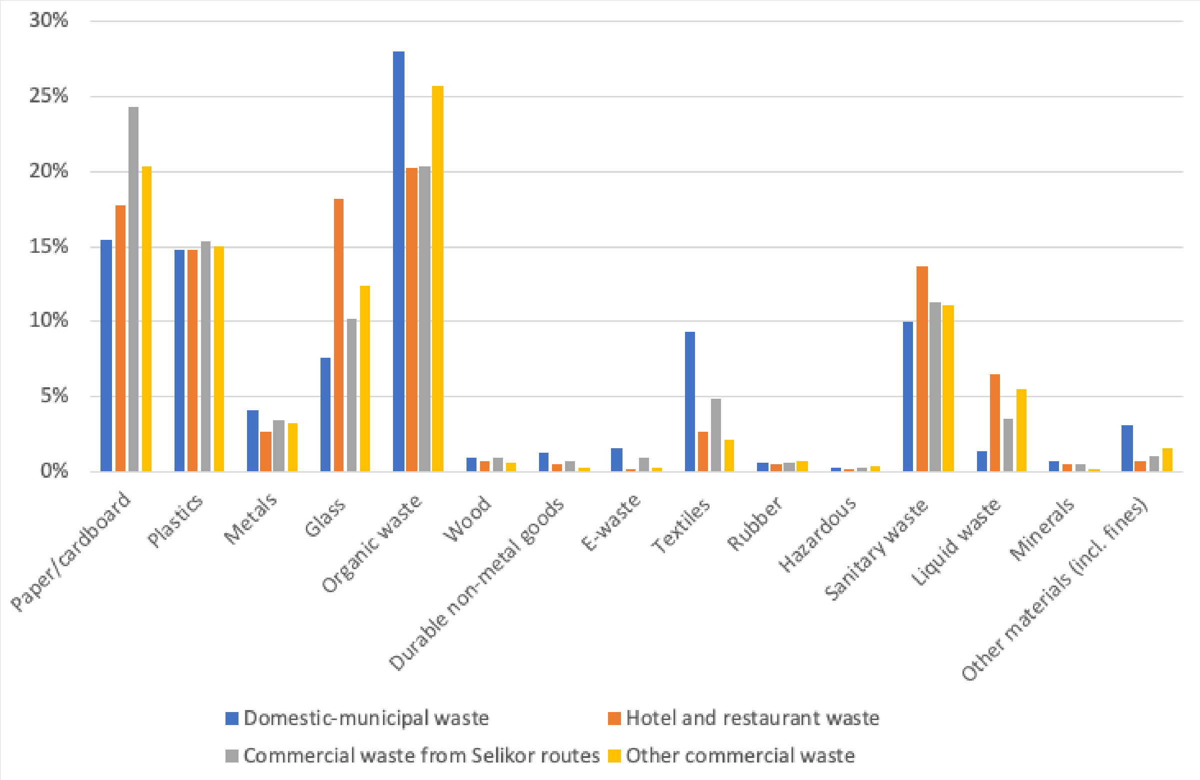

Figure 5-2 Summary of the waste composition for the four non-bulky waste categories.

Figure 5-2 shows that organic waste, paper/cardboard, plastics, glass, and sanitary waste (diapers etc.) are the largest fractions in non-bulky waste.

Fractions smaller than 1 wt.% of sample weight include wood, rubber, hazardous materials, and minerals. The three largest fractions, paper/cardboard, plastics, and organic waste, constitute 58% of all non-bulky waste.

5.3.1 Waste composition domestic municipal waste

Figure 5-3 shows the composition of domestic waste. The largest fraction with 28.0 wt.% was organic waste. One fraction that was larger in domestic waste than in the other waste categories was textiles with 9.3 wt. %. The following fractions in domestic waste were smaller than 1 wt.%: wood, rubber, hazardous materials, minerals, durable goods, and e-waste.

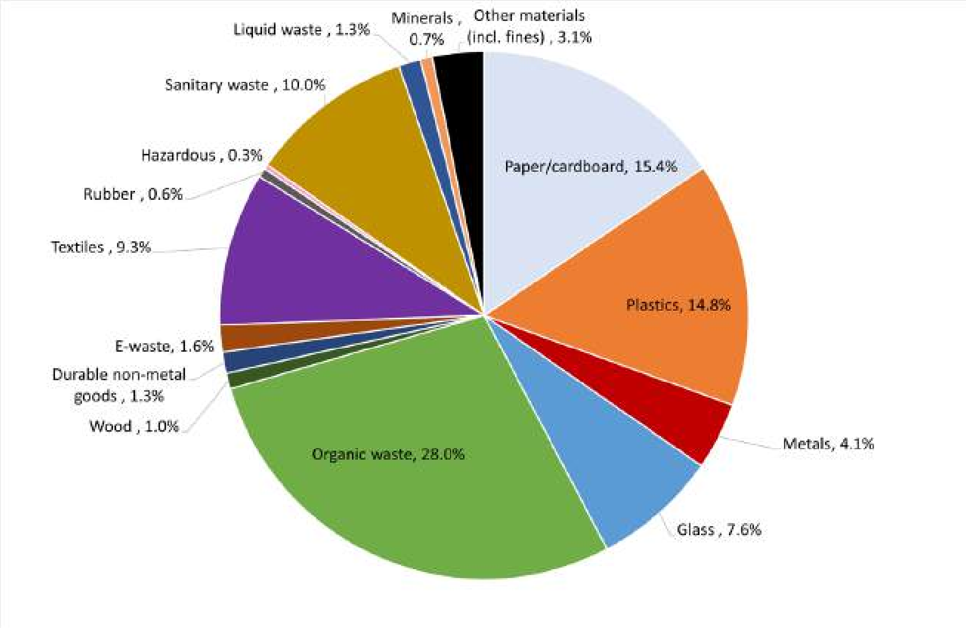

Figure 5-3 Waste composition domestic municipal waste

5.3.2 Waste composition commercial waste Selikor routes

Figure 5-4 shows the waste composition for the commercial waste from Selikor routes. The largest fraction was paper/cardboard (24.2 wt.%). This was the only waste category where paper/cardboard was the largest fraction. Other large fractions were organic waste (20.4 wt.%) and plastics (15.4 wt.%).

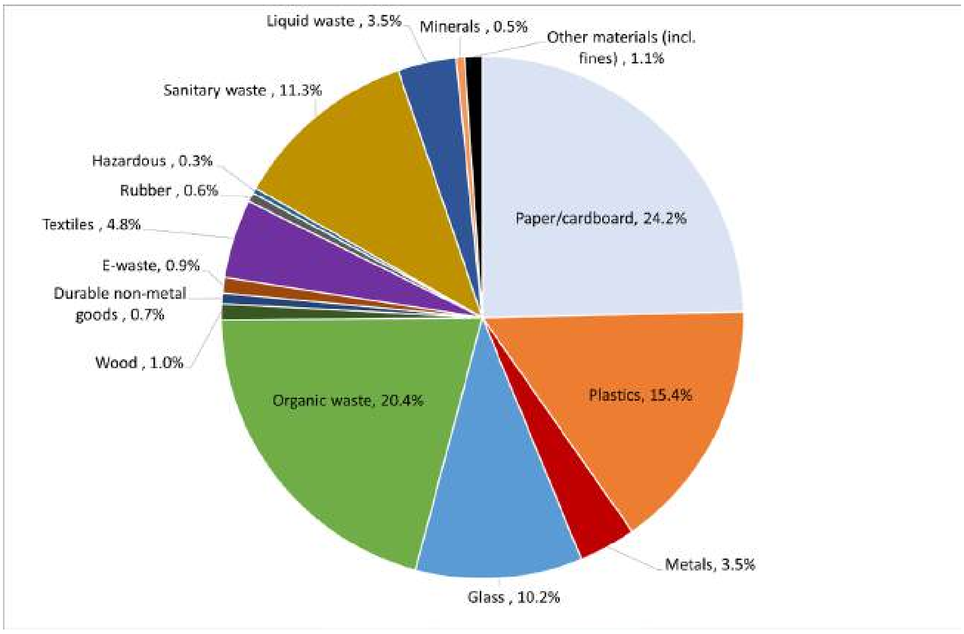

Figure 5-4 Waste composition commercial waste Selikor routes

5.3.3 Waste composition other commercial waste

Figure 5-5 shows the waste composition for commercial waste not brought in by Selikor. The largest fraction was organic waste with 25.7 wt.%. There are a few differences between commercial waste from Selikor routes and other commercial waste. Fractions that differed most were organic waste, paper/cardboard, glass, textiles, and liquid waste.

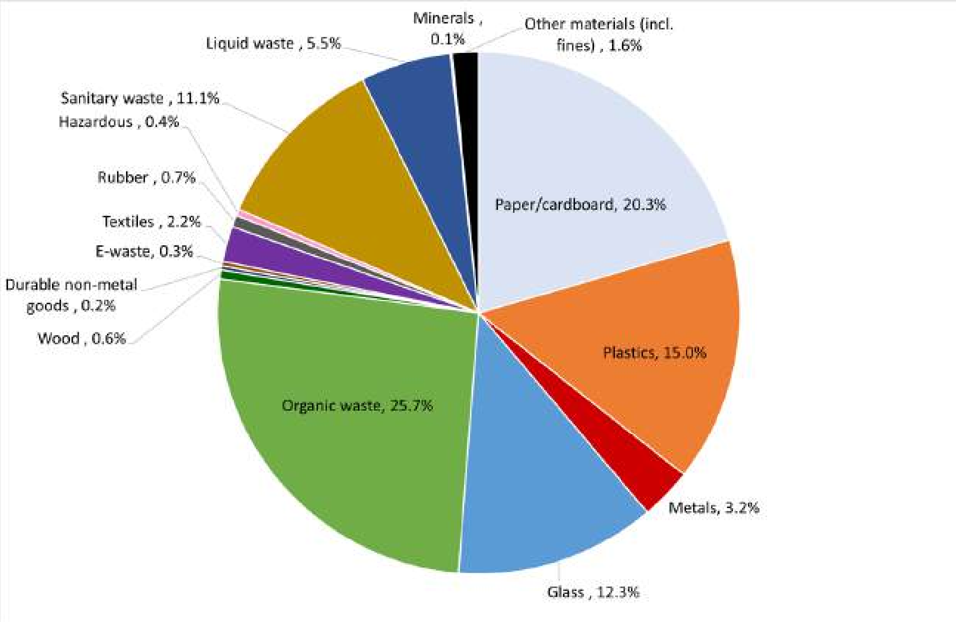

Figure 5-5 Waste composition other commercial waste

5.3.4 Waste composition hotel and restaurant waste

Figure 5-6 shows the waste composition of hotel and restaurant waste. Organic waste in this waste category was the largest fraction (20.3 wt.%). The fraction glass (18.1% wt.) was significantly larger in this waste category than in other categories.

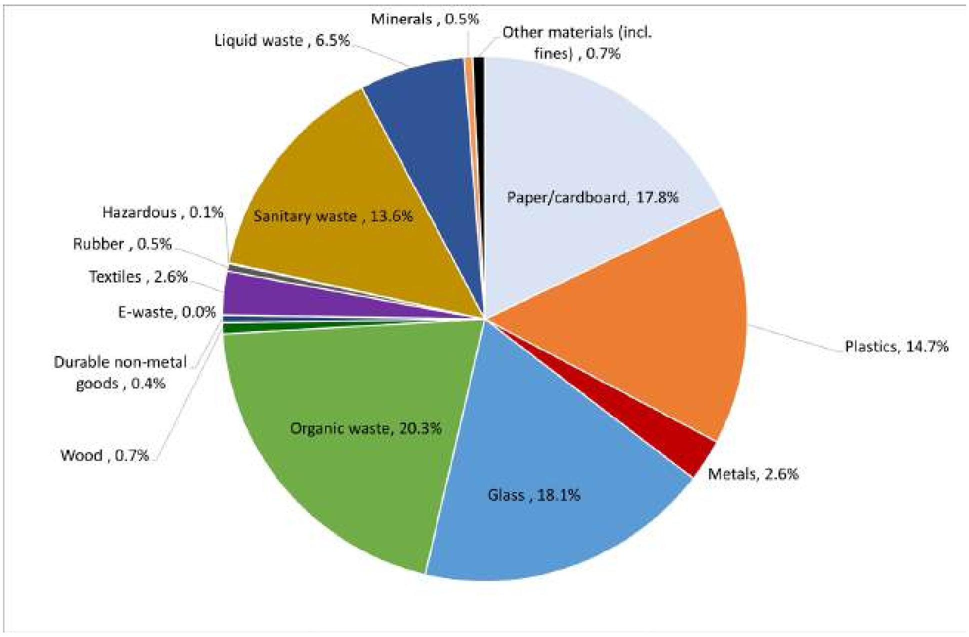

Figure 5-6 Waste composition hotel and restaurant waste

5.4 Composition and income of neighborhoods

As explained in paragraph 3.4 there was no stratification in the domestic-municipal waste samples, but a distinction was made between low, medium, and high-income neighborhoods. The samples were distributed evenly over the three strata with 12, 11, and 12 samples for respectively low, medium, and high-income areas. From one sample the origin was unknown. Overall, there were no significant differences in the waste composition of the different income areas, except for two waste fractions. These fractions were cardboard and organic garden/yard waste (table 5-3).

Table 5-3 Differences in waste composition for three income categories (2 waste fractions)

	Low income	Medium income	High income
Cardboard/corrugated	8.0 wt%	10.0 wt%	13.8 wt%
Organic garden/yard waste	19.0 wt%	13.2 wt%	12.0 wt%

The data suggest that high income households dispose of more cardboard than lower income households and at the same time less organic waste.

5.5 Waste composition, unmerged fractions

In the overview of figure 5-3 several waste fractions consisted of merged fractions. Although these merged fractions consist of similar types of waste, the recycling options might differ greatly. The waste composition of the unmerged fractions is shown in Table 5-4. The break-down of the paper-cardboard combination shows that cardboard was a bigger fraction than paper for all waste categories. Organic waste showed differences between garden and kitchen waste per waste category. For the domestic-municipal waste category, garden waste was the bigger fraction within the organic waste. For the other three waste categories kitchen waste was the bigger fraction and garden waste only accounted for a small portion. Metals also varied per waste category, with non-ferrous metals taking a bigger part in hotel and restaurant waste and commercial waste from Selikor routes and ferrous metal taking a bigger part in domestic-municipal waste and other commercial waste. The breakdown of the plastics is discussed in more detail in paragraph 5.5.

Table 5-4 Waste composition of the unmerged fractions (in wt%)

Waste sorted fraction	Domestic-municipal waste	Hotel and restaurant waste	Commercial waste from Selikor routes	Other commercial waste
Paper	4.87%	3.14%	10.80%	4.72%
Cardboard/corrugated	10.53%	14.63%	13.44%	15.61%
PET bottles	2.44%	3.18%	2.23%	1.55%
PET	0.71%	0.78%	0.92%	0.95%
LDPE	4.58%	6.97%	6.29%	6.64%
HDPE	1.59%	1.05%	1.03%	1.51%
PP	2.13%	1.49%	1.83%	1.78%
PS	1.32%	0.59%	1.33%	1.13%
PVC	0.09%	0.05%	0.05%	0.02%
PUR	0.03%	0.02%	0.03%	0.03%
Other plastics	1.94%	0.59%	1.67%	1.42%
Non-ferrous metals	1.33%	1.86%	2.05%	1.26%
Ferrous metals	2.76%	0.77%	1.42%	1.93%
Organic garden waste	15.21%	0.61%	7.85%	2.39%
Organic kitchen waste	12.75%	19.67%	12.52%	23.28%

5.6 Waste composition plastics

Figure 5-7 shows the breakdown of the different plastics fractions. LDPE was the largest fraction for all waste categories. The most frequent LDPE waste items found were garbage bags, these items typically weigh little, therefore the volume of this fraction is a substantial part of the complete sample. PET packaging and especially PET bottles were another substantial fraction. On the other hand, PUR and PVC were fractions that were hardly found in non-bulky waste. Waste items that consisted of a combination of plastic types or when the plastic type was unknown were added to the other plastics fraction.

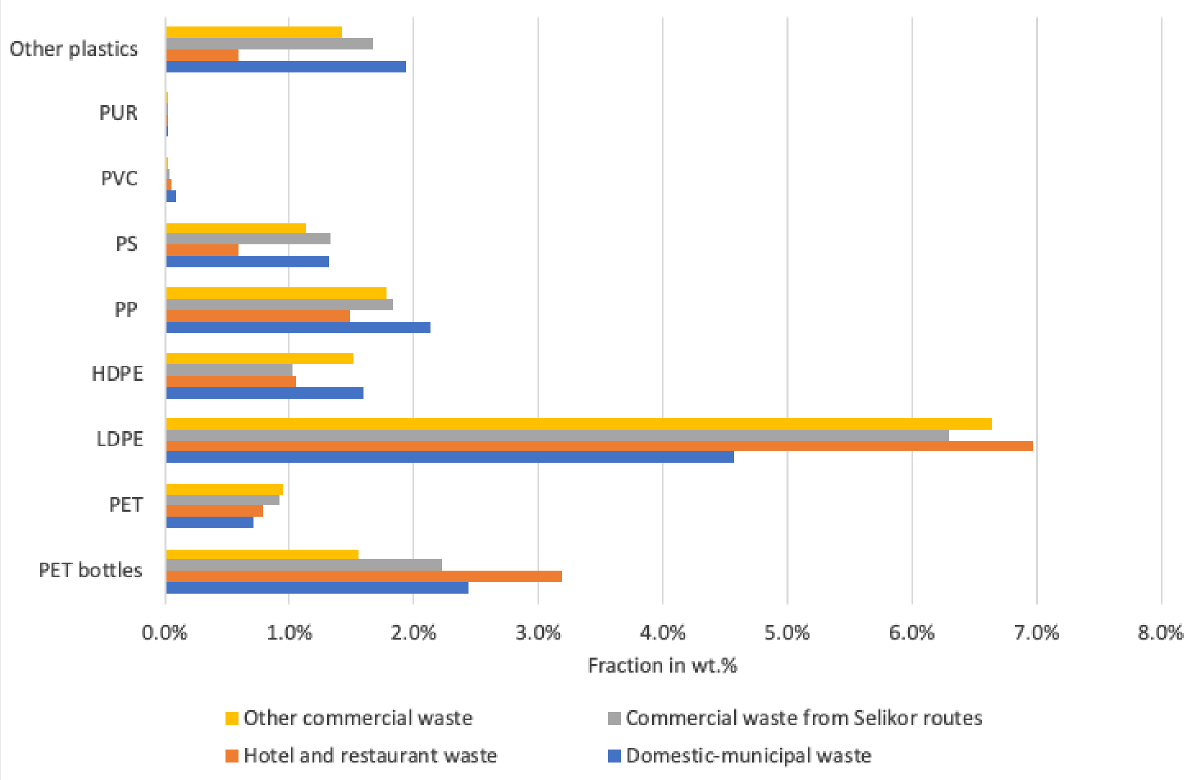

Figure 5-7 Breakdown of the plastics fractions for each waste category (in wt%).

6 Results from sorting of bulky wastes

6.1 Overview

Figure 6-1 shows an overview of the results from the sorting of the 143 bulky waste samples, after 8 weeks of sorting. The figure shows the relative presence of the sorting fractions per waste category (bulky domestic, bulky commercial, C&D and garden waste). Paragraph 6.2 to 6.5 and figures 6-2 to 6-5 present the same figures for each of these 4 waste categories.

Figure 6-1 clearly shows that -as could be expected- the fraction garden and yard waste is dominant in the waste category of garden waste. The same applies to the fraction concrete, stones, and tiles in the waste category C&D waste.

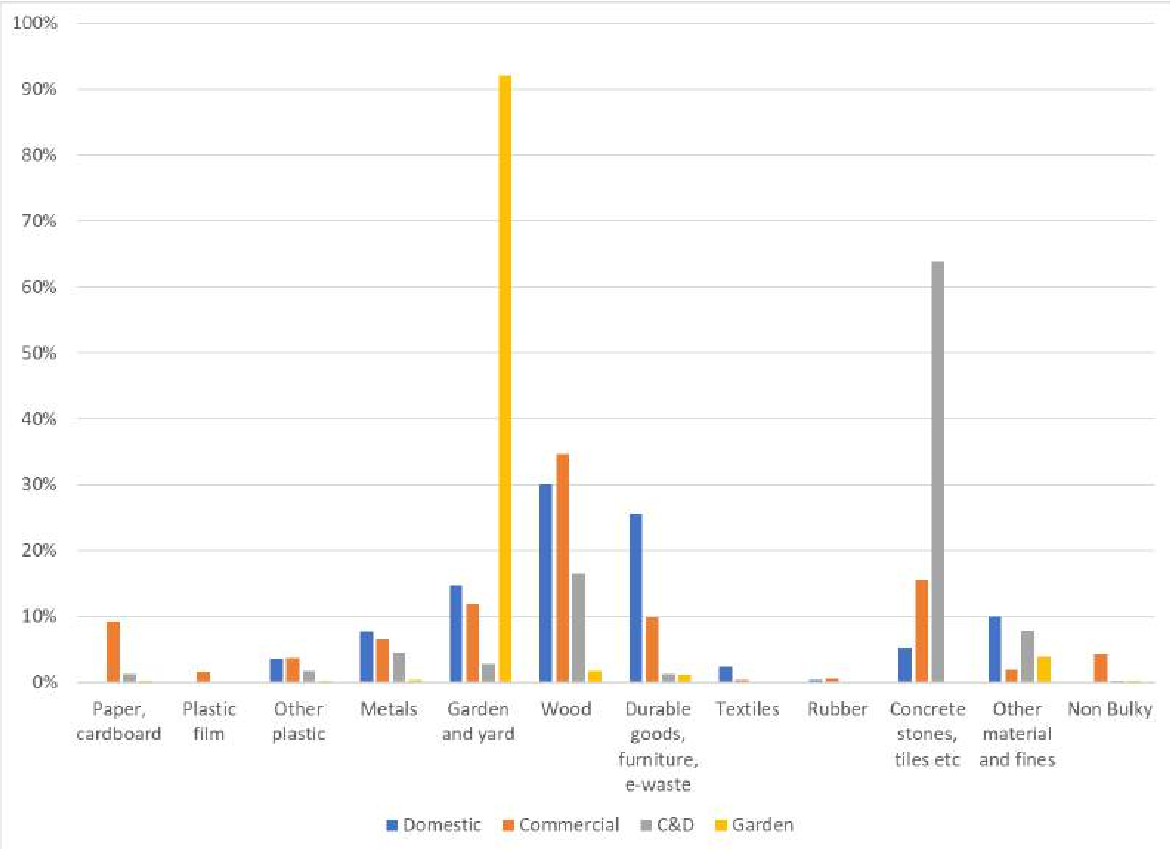

Figure 6-1 Waste composition (in wt%) of 4 bulky waste categories (n=143, for sample numbers per waste category see table 2-2).

6.2 Bulky domestic waste

Within the bulky domestic waste category (figure 6-2), 'wood' emerges as the predominant fraction in terms of weight, comprising 30.2wt%, succeeded by 'durable goods, furniture & e-waste' at 25.7wt%, and 'garden & yard' at 14.7wt%.

Additionally, the 'other materials and fines' fraction contributes to 10 wt% of the weight in the bulky domestic waste category, followed by 'metals' at 7.8 wt%, 'concrete stones & tiles' at 5.2 wt%, 'other plastics' at 3.6 wt%, and 'textiles' at 2.4 wt%. The residual fractions, including 'rubber', 'paper & cardboard', 'plastic film', and 'non-bulky' items, collectively contribute to less than 1 wt% of the total weight in the bulky domestic waste category.

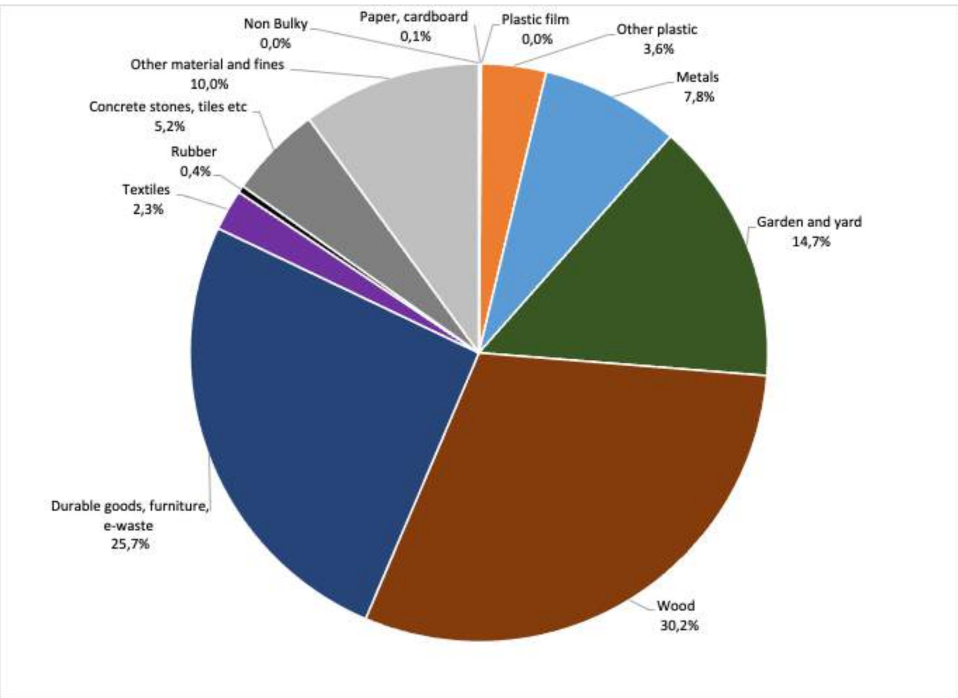

Figure 6-2 Waste composition of bulky domestic (n=24: , for sample numbers per waste category see table 2-2).

6.3 Commercial bulky waste

The fraction with the highest proportion by weight in the 39 samples of bulky commercial waste is 'wood', with 34.7 wt% (see figure 6-3). This fraction is followed by 'concrete stones & tiles' with 15.5 wt%, and 'garden & yard' with 11.9 wt%. Furthermore, the 'durable goods, furniture & e-waste' and 'paper & cardboard' fractions contribute 9.8 wt% and 9.3 wt%, respectively, to the weight in the bulky commercial waste category. This is followed by 'metals' at 6.5 wt%, 'non-bulky' at 4.2 wt%, 'other plastics' at 3.8 wt%, 'other materials and fines' at 1.9 wt%, and 'plastic film' at 1.6 wt%. The other fractions, including 'rubber' (0.6 wt%) and 'plastic film' (0.3 wt%), collectively represent less than 1 wt% of the total weight in the bulky commercial waste category.

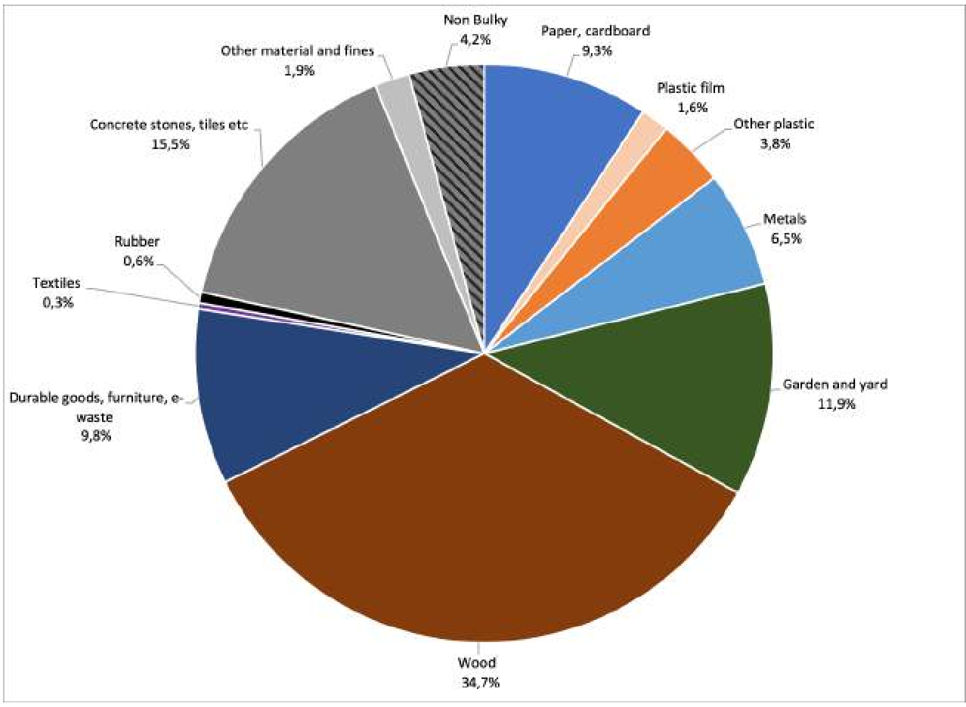

Figure 6-3 Waste composition of bulky commercial (n=39: , for sample numbers per waste category see table 2-2).

6.4 Construction & demolition waste

The fraction with the highest proportion by weight in the 50 samples of C&D waste is 'concrete stones & tiles', with 63.8 wt% (see figure 6-4). This fraction is followed by 'wood' at 16.5 wt%, and 'other materials & fine,' which includes sand, contributing 7.9 wt%. Subsequently, the 'metals' fraction accounts for 4.5 wt%, 'garden & yard' at 2.9 wt%, 'other plastic' at 1.7 wt%, and both 'paper & cardboard' and 'durable goods, furniture & e-waste' at 1.2 wt%. Lastly, the 'non-bulky' fraction represents 0.2 wt% of the total weight for the C&D waste category, while both 'rubber' and 'plastic film' each account for 0.1 wt%. 'textiles' did not contrubte to the total weight of the C&D waste category.

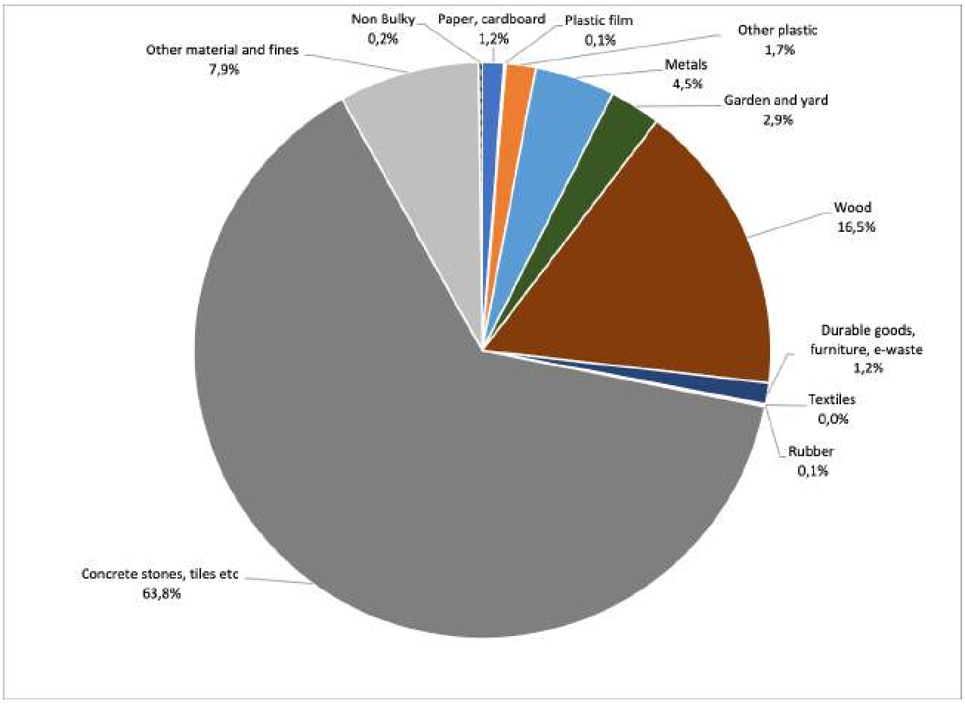

Figure 6-4 Waste composition of C&D (n=50, for sample numbers per waste category see table 2-2).

6.5 Garden waste

The fraction with the highest proportion by weight in the 30 samples of garden waste is unsurprisingly 'garden and yard waste', with 92.1 wt% (see figure 6-5). This fraction is followed by the 'other materials & fines' fraction accounted for 4 wt%, 'wood' for 1.8 wt%, and 'durable goods, furniture & e-waste' for 1.1 wt%. Finally, 'metals,' 'other plastic,' 'paper & cardboard,' and 'non-bulky' collectively contributed to less than 1 wt% of the total weight of the garden waste category, while the remaining fractions—'plastic film,' 'concrete stones & tiles,' textiles, and rubber—did not contribute to the overall weight of this bulky waste category.

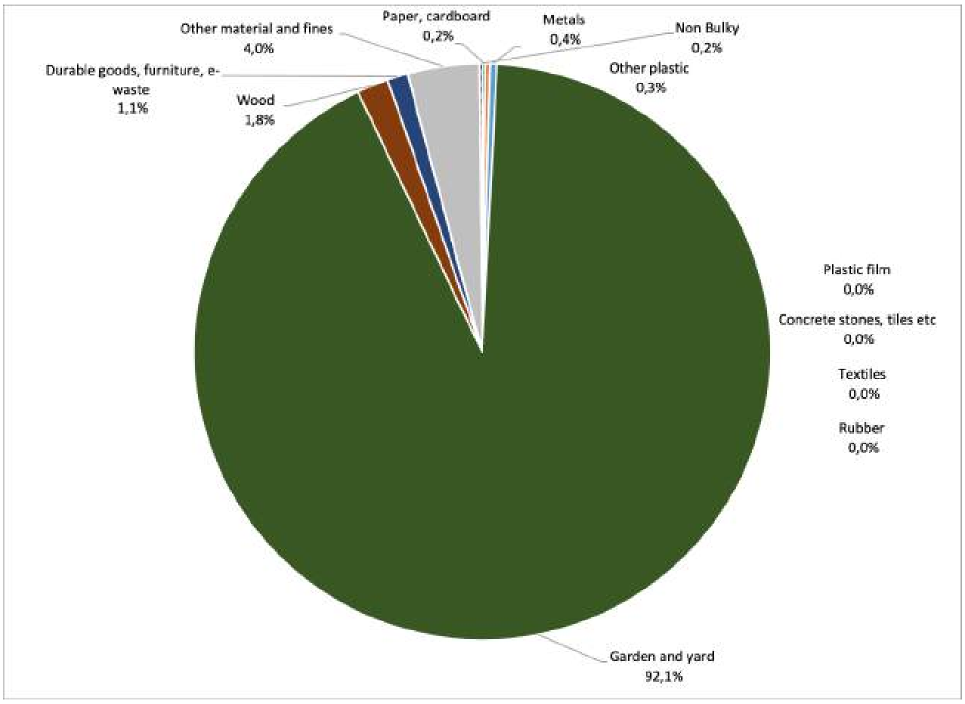

Figure 6-5 Waste composition of garden and yard (n=30: , for sample numbers per waste category see table 2-2).

7 Moisture content waste fractions

Moisture content of waste is important because of two reasons. Knowledge of moisture enables to calculate the true availability of recyclables such as paper and cardboard for recycling. Knowledge also affects the average lower heating value that governs the energy production in a WtE plant. Therefore, in this WCS the moisture content was determined for the six sorting fractions most affected by moisture. An unknown part of the moisture present in e.g. cardboard originates from organic waste in mixed waste categories.

Figure 7-1 shows the results of the average moisture content per fraction in weight percent. Based on the results, the fractions with the highest moisture content are organic kitchen food/waste (58 wt%), sanitary waste (49 wt%), and cardboard (30wt%). The calculated average moisture content of paper, textiles and plastics were 24, 23 and 13 wt%, respectively.

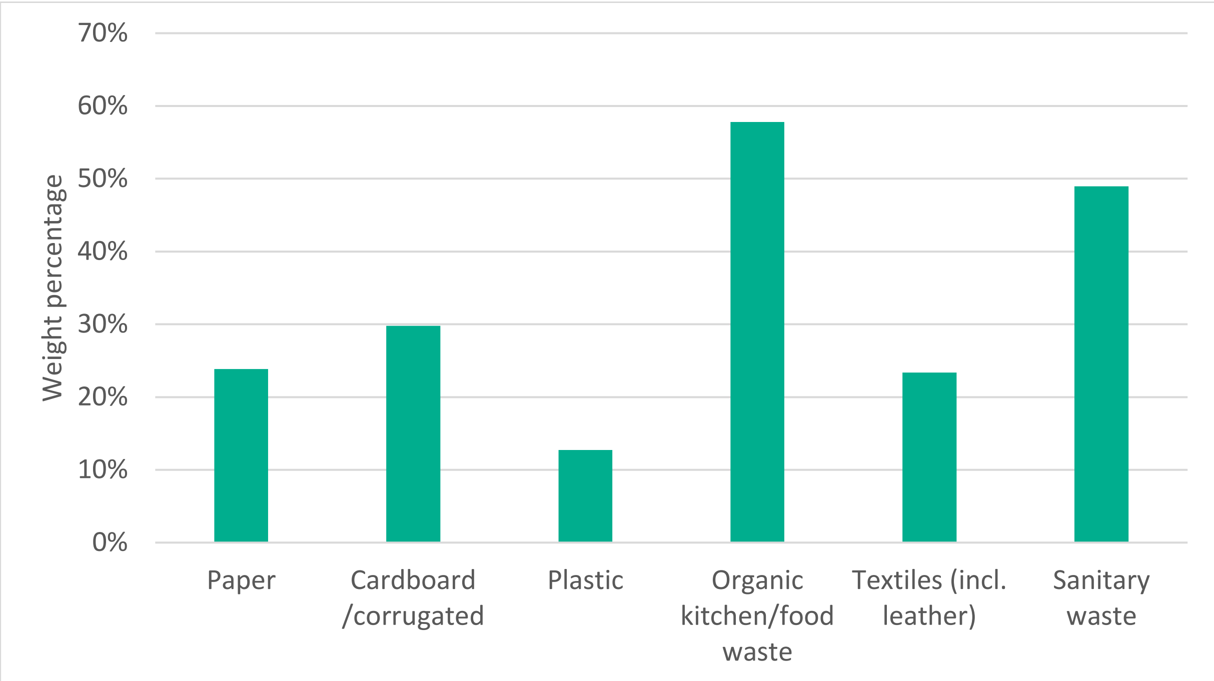

Figure 7-1 Moisture content of the 6 relevant fractions (30 samples, 180 dried fractions).

8 Wastes not brought to landfill

8.1 Introduction

Companies producing, collecting, exporting, or recycling waste streams which are not disposed of at the landfill are selected on basis of:

1. Companies known to EcoVision and Selikor;
2. Companies which operate for at least one year with some success;
3. Companies listed in the Waste Management Matrix from the Curaçao Business Platform for Sustainability;
4. Companies which are known not to be involved in illegal business. Companies which are involved in illegal activities are not likely to provide reliable data.

Most companies were reluctant to share their business data with EcoVision. Several of them complained about the lack of willingness of Selikor to work together with them. Additionally, the companies view Selikor as a potential competitor to whom they may lose business.
Results from the survey are grouped by waste stream type for the following type of waste:

1. Sewage sludge;
2. Chicken manure;
3. Construction & demolition waste mix;
4. Wood waste, re-using;
5. Concrete waste, used for recycling;
6. Concrete waste, used as filling material;
7. Concrete waste, stockpiled at Malpais;
8. Asphalt (Asphalt Lake);
9. Lead-acid batteries;
10. Metals (ferrous, non-ferrous);
11. Aluminum (cans);
12. PET / PP / HDPE / LDPE;
13. Paper;
14. Cardboard;
15. Cooking oil – biofuel;
16. Garden waste;
17. Glass.

Each waste stream is elaborated in the paragraphs below. Twenty-one companies/organizations were interviewed and/or visited. More detailed information on the individual waste stream processing companies is available in Annex 3.

8.2 Sewage sludge

It is estimated by UOOW that the sewage plants Klein Hofje, Klein Kwartier and the future sewage plant Tera Kora produce 800 m^3 (1,000 tons) dried sludge per year. The sludge is dried in the open air. During drying in the open air, the sludge will produce methane, a strong greenhouse gas and will produce a strong smell. After drying, the sludge will contain approximately 20 wt% water content. DOW analyses the dried sludge periodically on heavy metals.

The dried sludge is collected by a company for free. This company distributes the sludge to local farmers as fertilizer.
In many countries sewage sludge is not allowed to be used for agricultural purposes. In these countries three options are generally available:

1. Fuel production. The sewage sludge is dried in drying plants. The dried sludge enables the production of e.g. fuel pellets with a calorific value of approximately 14 MJ/kg as received. This makes it suitable for cement kilns and power stations as a secondary fuel.
2. Direct combustion in a sludge incinerator with (limited) energy recovery.
3. Landfilling. This is possible, but for sound landfill operation not desirable.

8.3 Chicken manure

It is estimated by the management of Moderno that the 2 large chicken farms “Moderno” and “Pita” produce 15 tons **wet** chicken manure per day. This is close to 5,500 tons manure per year. Moderno is obliged via their environmental permit (“hindervergunning”) to transport the manure from its premises to an area away from the residential area for further disposal. At this moment the manure is transported to a location where it can dry where no residential houses are nearby. During drying in the open air, the chicken manure will produce carbon dioxide (CO_2), methane (CH_4), ammonia (NH_3) and nitrous oxide (N_2O). Methane and nitrous oxide are both stronger greenhouse gasses than carbon dioxide. During drying, the manure produces a very strong smell.
It is estimated the dried manure contains 20 to 30 wt% water. The dried manure is collected by a company for free. This company distributes the chicken manure to local farmers as fertilizer.
Of all animal manures, chicken manure has the highest amount of nitrogen, phosphorus and potassium and is widely used as fertilizer in agriculture.

The wet chicken manure can also be used as input for a digester system producing biogas. In this way it will prevent the emission of methane and nitrous oxide into the atmosphere.

8.4 Construction & demolition waste

Construction & demolition waste (C&D waste) from construction or demolition sites is collected by several waste collection operators and is processed by 4 different companies: Heavy Mix, Mijnmaatschappij, Asphalt Lake Recovery and Living furniture.
Demolition waste can roughly be divided into the following components:

- Wood;
- Concrete (clean and very clean);
- Mix (roof tiles, PVC pipes, metals, etc.).

8.5 Mix

In many cases demolition waste is not sorted and cannot be recycled. This mixed demolition waste stream must be deposited on the landfill for a price per ton (30 ANG per ton).

Sorting the components when demolishing a building would greatly contribute to a higher volume of recycling and re-use (see "urban mining" concept of New Horizon, https://newhorizon.nl/urban-mining/).

8.6 Wood waste, re-using

Wood of good quality is often donated to employees of the demolition company (information from the company Heavy Mix) but most demolition wood, an estimated 95 wt%, will be deposited at the landfill (estimate from the company Living Green).

A small part of the demolition wood (especially from old historical buildings) is used by Living Green Furniture to produce custom-built furniture for the high-end furniture market. Living Green Furniture selects only certain quality wood for their furniture production. It is estimated that Living Green recycles 5 metric tons wood per year which is around 90 wt% of the total amount of demolition wood collected by Living Green Furniture. The remaining 10 wt% is deposited at the landfill. There is an ongoing dispute between Living Green and Selikor on depositing this 10 wt% for free instead of having to pay 30 Ang per ton.

8.7 Concrete waste, used for recycling

"Very Clean" concrete waste is recycled by the companies Mijnmaatschappij and Heavy Mix, and "Clean" concrete is used as filling material at the Asphalt Lake Recovery project or can be deposited at the Curaçao Recycling Company (CRC, a subsidiary of Selikor).

"Clean" concrete waste means concrete waste without contamination of wood, cables, plastics, or other demolition waste fractions, although some contamination is accepted. "Very clean" concrete waste may contain steel reinforcement but is not contaminated with plastic or wood.

Heavy Mix crushes the "very clean" concrete waste and uses it as material for foundations for roads and sports fields and re-uses the material in the production of their concrete blocks. Up to 30 wt% of the materials used for producing blocks can be of recycled origin. Heavy Mix recycles around 5,000 metric tons "clean" concrete per year and can expand this capacity.

Heavy Mix uses special heavy equipment to separate the steel enforcement from concrete. The steel is brought to Antillean Scrap for further sorting and exporting.

Mijnmaatschappij (a Janssen de Jong Caribbean company) also crushes "very clean" concrete and produces different types of recycled aggregates (sand, small stones, larger stones) which is sold as raw material to companies.

Up to 10,000 metric tons aggregates per year is exported to Bonaire, 1,500 metric tons is used locally on Curaçao. Contractors on Curaçao are more conservative than contractors on Bonaire: most of the Curaçao contractors want to use non-recycled raw material to prevent any risks, although Mijnmaatschappij guarantees the recycled aggregate meets all construction requirements.

Mijnmaatschappij can expand their concrete waste recycling operation.

These aggregates are not yet used by Beton Industrie Brievengat (another Janssen de Jong Caribbean company) in their production process such as Heavy Mix is currently doing.

8.8 Concrete waste, used as filling material

Large amounts of "clean" concrete and sand are now used by BuskaBaai, the company exploiting the asphalt lake, to fill up the dry part of the asphalt lake where asphalt is mined to produce bitumen (see section 8.10). In the future, filling up the wet part of the asphalt lake will probably require larger amounts of concrete and sand waste. BuskaBaai expects that another 7 to 10 years are needed to fill up the asphalt lake completely. To accomplish this goal, probably up to 500,000 metric tons of "clean filling material" should be deposited. The largest part of these 500,000 metric tons is needed to fill up the wet part of the asphalt lake.

BuskaBaai has built up a large stock of clean filling material during past years. BuskaBaai has no exact figures on this stored volume, but it is estimated by Asphalt Lake Recovery there is sufficient stock for the coming 5 years to replace asphalt mined at the dry part of the asphalt lake with this stock material. EcoVision estimates this stock to be 150,000 tons.

8.9 Concrete waste, stockpiled at Malpais

Clean concrete waste can also be deposited at the Landfill, at the Curaçao Recycling Company (CRC, a subsidiary of Selikor) for no fee and is stockpiled awaiting recycling. Clean waste asphalt can also be deposited at CRC (for a NAF 5/ton fee).

The yearly volume figures of deposited clean concrete waste registered at CRC shows a significant decline: in 2016 20,000 metric tons has been recorded while in 2023 only 5,100 metric tons has been deposited.

8.10 Asphalt (Asphalt Lake)

The asphalt lake located in the east part of Schottegat Bay, contains the heavy fraction of oil distillation, produced during the second world war by Shell to meet the urgent need for aircraft fuels. This heavy fraction, "asphalt" has been stored in this lake, partly on dry land, partly in water. For many years this asphalt has been recycled into heavy fuel for the refinery energy needs and for the international market.

A few years ago, after the shutdown of the refinery, the company Asphalt Lake Recovery (ALR) changed their process and started recycling the asphalt into bitumen instead of heavy fuel. The bitumen is exported to a specialized company outside Curaçao which processes the bitumen into different asphalt products.

There is still up to 300,000 tons of asphalt to be exploited, 100,000 metric tons from the dry part and 200,000 metric tons from the wet part of the asphalt lake. The exploitation of this material will probably take another 5 to 7 years. After mining the asphalt, the asphalt lake will be filled up with "clean" filling material (concrete rubble and sand) to make it suitable for industrial use.

Large amounts of heavy fuel are used to heat the asphalt in ovens to make it suitable for recycling. Part of the heavy fuel is collected on the island but it is mostly imported from other islands such as St Maarten and St Vincent.
During the process of heating and recycling, a fraction called "sediment" must be removed monthly from the ovens and is returned into the asphalt lake.
There is some consultation with the company Asfalt Centrale Curaçao (another subsidiary of Janssen de Jong Caribbean) to deliver bitumen as raw material for the local asphalt production on Curaçao but the economy of scale seems too low for a sound business case.

8.11 Lead-acid batteries

Most old lead-acid batteries on the island are collected by the companies ZAP batteries, NAPA, MAC and Curaçao Waste Management. Some scrap yards also accept lead-acid batteries. Most companies pay the customers a small fee to return their old batteries: 8 to 50 guilders per battery.

Most companies export the old batteries including the acid to specialized recycling plants abroad, which recover the lead from the batteries. ZAP batteries contracted Green Force to export its old lead acid batteries.

The companies interviewed are reluctant to share numbers on the amount of batteries exported with EcoVision and Selikor. EcoVision estimates that approximately 730 metric tons are exported to specialized battery recycling companies abroad. This estimate is based on information from NAPA and Curaçao Waste Management.

The sulfuric acid in the batteries can be an issue for transporting companies. Transporting companies may refuse to accept containers containing old batteries with sulfuric acid. When exporting lead batteries without sulfuric acid, certain battery recycling plants abroad demand an official government statement that the sulfuric acid has been removed in an environmentally sound way. One of the interviewed companies now stores the old batteries due to these restrictions. Through this assignment, this company has started the dialogue with Ministry of Environment again after 2 years.

8.12 Metals (ferrous and non-ferrous)

It was difficult to get access to the several scrap companies at Curaçao. Ecovision was not able to obtain data from all scrap companies. Via international trade websites[1], the export of scrap metal from Curaçao could be retrieved for 2021:

[1] https://oec.world/en/visualize/tree_map/hs02/export/cuw/all/show/2021
The Observatory of Economic Complexity (OEC) is an online data visualization and distribution platform focused on the geography and dynamics of economic activities

Table 8-1 Scrap metals exported by Curaçao (2021).

Type of metal scrap exported by Curaçao in 2021	Exported in tons
Scrap iron	21,128
Scrap copper	268
Scrap aluminum	1,637
Scrap lead	8
Scrap zinc	392
Total metal scrap:	23,433

Curaçao Waste Management indicated they process approximately 200 tons of non-ferrous metals per year, apart from e-waste and batteries from vehicles. It is assumed that this quantity is included in the quantities exported.

From Selikors database (CLEAR) it is known that yearly approximately 600-800 tons of material are collected by pickers on the landfill. This material consists predominantly of steel (observations EcoVision).

8.13 E-waste

Curaçao Waste Management is the only company on Curaçao that accepts e-waste. The company pays for the different items the accept, for instance ANG 2.00 per laptop. If necessary, they dismantle the wastes into its different components such as removal of circuit boards from computers and removal of copper from compressors. The waste is exported for recycling. In total Curaçao Waste Management processes approximately 600 tons of e-waste per year.

8.14 Aluminum (cans)

Several companies collect aluminum cans for export: Green Force, Green Phenix and Green&Clean. In addition, scrap companies also collect and export aluminum.

Since the baled aluminum can price on the scrap market is stable and relatively high[1], the companies can make some profit by exporting the aluminum cans. Companies are afraid Selikor will take away this profitable business and are therefore reluctant to give EcoVision/Selikor information on the volumes exported.

Only Green Force shared the quantity of exported bales of aluminum cans: 3 metric tons in 2023. Recently, Green Phenix asked Green Force to bale and export their collected cans. Green&Clean is a small player on the recycling market and stockpiles the collected cans.

[1] https://www.letsrecycle.com/prices/
letsrecycle.com is part of ROAR B2B Ltd, and is the UK's leading independent dedicated website for businesses, local authorities and community groups involved in recycling and waste management.

8.15 PET / PP / HDPE / LDPE

Collection operators

The following 3 operators collect PET, PP and/or HDPE:

- Green Force,
- Green Phenix and
- Green&Clean.

Green Force is by far the largest collector with 30 metric tons collected PET/PP/HDPE in 2023. Green Force bales the collected materials and exports the bales in containers to specialized recycling companies abroad. Green Force also collects LDPE (wrapping material) at large companies.

Green Phenix does not want to share turnover data with EcoVision. Green Phenix is sorting, cleaning, and shredding the collected plastics and uses this raw material for constructing products. Green Phenix does not export baled plastics to recycling companies abroad.

Green&Clean is a very small organization, mainly collecting PET/PP/HDPE at events. It has no data on the volumes and is still stockpiling the collected PET/PP/HDPE. Green&Clean probably collects less than 5% of the Green Force volume based on the information collected during the interview.

Plastic waste stream during processing

Green Force says they produce little waste during the collecting, sorting, and exporting process: less than 10 wt% of the total of collected plastics. There is no data to support this figure.
Green Phenix uses a less selective collecting process than Green Force and has a very selective sorting process, Consequently, a very high percentage of the collected plastics end up at the landfill. This is confirmed by Selikor statistics.

Prognosis

Green Force expects to be able to collect up to 90 tons per year by increasing the number of collection stations at supermarkets the coming years. Green Phenix has the ambition to collect 20 tons PET/PP/HDPE per year.

100% recycling

The company Limpi each year produces up to 4 metric tons of high-quality products made of recycled HDPE. Limpi does not collect actively HDPE: it receives HDPE from Green Force and receives HDPE from organizations and private persons. Limpi is very selective which HDPE (type and color) it accepts and uses to create their products. Consequently, Limpi hardly produces waste in their recycling process: failed products will be melted end re-used again. Limpi shared a lot of their knowledge with Green Phenix when Green Phenix was starting up.

FUSE Caribbean

At this moment FUSE Caribbean is starting up its operation on Curaçao, with Curacao Beverage Bottling Company (local producers of Coca Cola) and Kooyman hardware store as strategic partners. FUSE Caribbean has the ambition to produce construction material from a mixture of recycled plastic which will be marketed through Kooyman under the brand name EkoDuro.

FUSE started a dialogue with Living Green to have furniture constructed with the recycled plastic.

FUSE ambition is to process 150 metric tons end of life plastics per year. This seems ambitious since Green Force as the largest collector of plastics on the island only collects 30 metric tons per year. FUSE has contracted Green Force to supply 15 metric tons of shredded HDPE per year.

8.16 Paper

The following two companies are responsible for collection and export of most paper:

- Van Rumpt and;
- Paradise Recycling.

Paper is exported for recycling. In Curaçao two paper qualities are collected:

- office paper and
- newsprint (newspapers).

Van Rumpt only collects and exports (shredded) office paper, as part of their archive destruction business. Paradise Recycling collects and exports newsprint and office paper and works with printing company "De Stad" and newspaper "Extra". Van Rumpt did not want to share data on the volumes of exported paper per year. Therefore, EcoVision could only estimate the volume based on general information from Van Rumpt. It was estimated that Van Rumpt exports 50 metric tons of high-quality shredded office paper.

Paradise Recycling is also reluctant to share data but mentioned it exports 150 metric tons of office paper, newsprint, and cardboard per year. Paradise Recycling also exports shredded paper for the (small) local archive destruction company "Shred".

8.17 Cardboard

At this moment Paradise Recycling is the only active company collecting and exporting old cardboard. The fluctuating price of old cardboard on the market was the reason why companies such as Green Force and ATCO discontinued their cardboard collection and exporting activities.

Paradise recycling works together with Dijk Transport who has several cardboard compactors at large companies on the island. Paradise Recycling also operates a few compactors of their own like one compactor at Carrefour. Furthermore, Paradise Recycling collects cardboard at several large companies such as Firgos.

Paradise Recycling is reluctant to share data but mentioned it exports 150 metric tons of office paper, newsprint, and cardboard per year.

Prognosis

Paradise Recycling thinks the volume of cardboard collecting and exporting can greatly increase when companies better sort their waste streams. At this moment some of the cardboard bales are contaminated, are unsuitable for export and end up at the landfill.

This is a general concern of more local companies exporting waste streams to recycling companies abroad: they must deliver good quality, well sorted, and properly baled recycling material to make some profit in the low-margin business of recycling.

8.18 Cooking oil - Biofuel

The only active company on the island collecting cooking oil is Bio Fuel Caribbean (BFC) which is connected to Wasserij Korsou. BFC collects cooking oil mainly from restaurants. BFC collects 20,000 liter per year and exports this to a biofuel company abroad.

Prognosis

BFC expects that twice as much can be collected when the government starts an awareness campaign or start enforcing rules at restaurants (it is forbidden to drain cooking oil into the sewage system).

8.19 Garden waste

Large landscaping companies like Vitis and Vivian's Nursery use their garden waste as input for compost production and to produce mulch. The compost and mulch produced is for their own use only and totals a few tons per year (assumed 3 tons/year). Also, the numerous small horticultural businesses on the island produce compost mainly for their own use.

Several initiatives are in the process of starting a larger scale composting, mostly in combination with food waste:

- Soltuna plans to produce compost from their organic waste and sell this to the public;
- The project "Groen-Blauw-Curaçao" plans to start recycling of green waste and food waste from hotels, restaurants, and gardens into compost. Their target is to produce 21 tons of compost per year;
- Curvital/Tiarah den Doelder plans to setup a compost operation at Brievengat/Ronde Klip.

8.20 Glass

Selikor collects glass and stockpiles this at the landfill (181 tons/year). There is no processing of the stockpiled glass yet.

Selikor had numerous glass collection containers at gas stations but due to misuse of these containers (using it for other waste) almost all of these collection containers have been removed. One can only bring used glass to the Sta. Rosa gas station, landfill at Malpais or to the Selikor collection station at Koraal Specht.

8.21 Overview of companies and waste streams

The following table gives an overview of the most important waste streams which get recycled or exported and the corresponding companies collecting/producing these waste streams.

Table 8-2 Overview of wastes recycled on Curaçao in tons/year[1].

	Sewage sludge	Chicken Manure	C&D waste	Asphalt	Lead-Acid batteries	E-Waste	Aluminium	Plastics	Paper, Cardboard	Metal scrap
Sewage plants	1,000									
Moderno		3,500								
Pita		1,800								
Happy Chicken		200								
Heavy Mix			5,000							
Mijnmaatschappij			11,500							
Buskabaai			30,000							
CRC			5,100							
ALR				30,000						
ZAP					120					
NAPA					90					
MAC					120					
Cur. Waste Man.					400	600				
Green Force							3	30		
Green Phenix							1	4		
Limpi								4		
Green&Clean								1		
Paradise									150	
Van Rumpt									50	
Scrap yards[2]										23,400

Green	Data not provided by company. Estimation by EcoVision and other companies in the field
Yellow	Source: Data Observatory of Economic Complexity (OEC, 2023)
Light blue	Data provided by recycling company

[1] Small amounts of cooking oil (section 8.18), organic garden waste (section 8.19), and glass (section 8.20) not included

[2] Included in the 23,433 ton is 200 ton non-ferrous from Curaçao Waste Management

8.22 Potential future waste streams

Refinery waste

Prior to the shutdown in 2019, Refineria ISLA handled its waste by either disposing of it on its own premises or outsourcing the disposal to other companies. According to the 2018 annual Industrial Waste Generation Report of Refineria Isla, the average waste generation over the period 2016-2018 was 10,519 tons per year. Table 8-3 provides an overview of the types of industrial waste for these years.

Table 8-3 Industrial Waste generated at Refineria ISLA (2016-2018, source: RdK and Refineria ISLA).

Industrial Waste Type	Waste Disposal Method	Average (tons/year)
Asbestos containing material	Asbestos burying yard at RdK Yard	459.75
Oily sludges and oil contaminated soil	Oil contaminated ground (ISLA)	9,213.52
Ferrous and non-ferrous scrap material	Currecycles Metals N.V & Antillian scrap	379.1
Spent attapulgus clay	RdK yard	52.63
Vanadium ash	Export for metals reclamation	242.47
HF alky debris	Selikor	78.4
Concrete, bricks, etc. (**)	Selikor	93.57
Total		**10,519.44**

(*) Excluding waste from the CD-3 fire, which was a one-time event
(**) Concrete and bricks etc. have been brought to the landfill during the operations of the refinery.

Illegal dumping

Additionally, there is an estimated annual quantity of 10,000 tons of illegal dumping activities, as evaluated by EcoVision in the WMPP Phase 1 Design Feasibility Study (June 2011). This could potentially become a significant waste stream in the future, e.g. when measures will be implemented to reduce illegal dumping or when measures will be implemented to intensify cleaning of illegal dump locations.

9 Mass balance

9.1 General results

This chapter describes the mass balance for waste on Curaçao. The mass balance combines:

- the annual tonnage of the 8 waste categories investigated;
- the average composition of the 8 waste categories investigated;
- the annually collected tonnages of source separated recyclables.

At Malpais a diversity of (very) small waste categories are received. In the period 2021-2023 these waste categories covered only 2 wt% in total of received waste. Examples of these waste categories are vehicle loads dedicated to waste from illegal waste dumps, rubber tires, asphalt, animal carcasses, and hazardous waste including medical waste and waste potentially containing asbestos. During this WCS most of these waste transports were registered as one of the 8 categories, predominantly commercial waste.

The annual waste volume for Malpais for the mass balance of Curaçao has been calculated by multiplying the weight of daily averages of the 28-day WGA period by 365 (days).

Table 9-1 Mass balance waste on Curaçao per material in tons per year[1]

Waste composition as received (grouped)	Total waste received at Malpais	Total waste collected for recycling on Curaçao	Total waste stored at Selikor landfill for future recycling	Total waste collected on Curaçao
Paper/cardboard	12,804	200		13,004
Plastics	10,649	39		10,688
Metals	5,284	23,437		28,721
Glass	5,943		181	6,124
Organic waste	32,573	3		32,576
Wood	14,481			14,481
Durable non-metal goods	530			530
E-waste	640	600		1,240
Textiles	4,009			4,009
Rubber	516		375[2]	892
Hazardous	167	730[3]		897
Sanitary waste	6,349			6,349

[1] Excluding asphalt recycled from the Asphalt Lake
[2] Tires stored by Selikor at the landfill
[3] This hazardous waste includes lead acid batteries that are collected for recycling. See section 8.11.

Waste composition as received (grouped)	Total waste received at Malpais	Total waste collected for recycling on Curaçao	Total waste stored at Selikor landfill for future recycling	Total waste collected on Curaçao
Liquid waste	1,788			1,788
Minerals from construction and demolition waste	23,194	46,500	5,079[1]	74,773
Other materials (incl. fines)	9,775	6,475[2]		16,250
Sorting loss /evaporation	494			494
Total	129,196 (61 wt%)	77,984 (36 wt%)	5,656 (3 wt%)	212,815 (100 wt%)

Table 9-1 shows that 61 wt% of all collected waste in Curaçao is landfilled at Malpais. This means that 39 wt% is stored for recycling, recycled, or exported for recycling. Recycling is predominantly limited to metal recycling (23,437 tons) and recycling of concrete and other mineral construction materials. Metals are exported for recycling and concrete is recycled mostly for foundations and land reclamation.

Table 9-1 also shows which materials could additionally become available for sorting and recycling, but it also shows other opportunities. Most glass for example is from glass bottles. Replacing glass bottles with aluminum cans can easily bring down the waste volume that is landfilled by 5,000 tons. Plastics draw most attention when it comes to waste, but they are less than 10% of the weight.

Figure 9-1 shows a Sankey diagram for the mass balance for waste on Curaçao. From the figure and table 9-1 it can be observed that most of the waste not brought to the landfill ("recycling routes") is (mineral materials and metals). From other waste categories, which are brought to the landfill, recycling is minimal. The figure shows that garden waste (15,000 tons) and the mineral fraction of C&D (23,000 tons) are not being recycled, while they represent a large potential for recycling. Furthermore, a large potential for source separation is presented for metals in residual waste (5,200 tons), paper and cardboard (13,000 tons), and glass (6,000 tons).
Instead of collection recycling other options are available, e.g. replacement of glass bottles with cans (or plastic).

[1] The 5,079 ton stored minerals includes concrete and mineral debris from construction and demolition waste stored at CRC. See section 8.4.
[2] The 6,475 ton recycled other waste includes chicken manure and sewage sludge. See section 8.2 and 8.3.

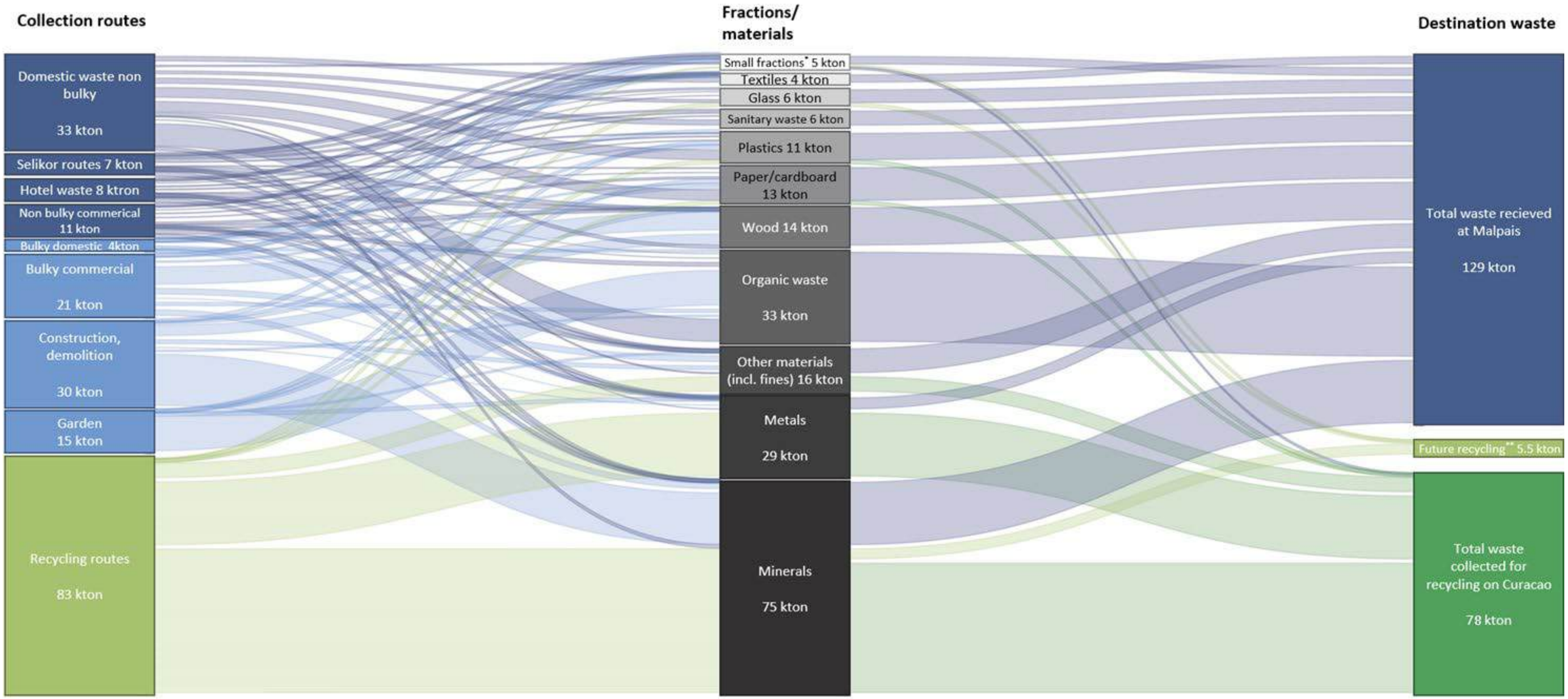

Figure 9-1 Mass balance waste on Curaçao

9.2 Feasible quantities for source separation for recycling

The mass balance gives an indication of what is present in the waste landfilled in Curaçao, however what is available for recycling is much less. The next two paragraphs describe two effects that reduce the available quantity for recyclables.

9.2.1 Impact of moisture content

The weight of the sorted fractions includes moisture. When separated at the source some fractions will be much dryer than if collected via mixed waste. Paper and cardboard have a very low moisture content when collected at households and companies. Table 9-2 shows the calculated dry available quantity of some recyclable materials that are currently landfilled.

Table 9-2 Impact of moisture content.

Fractions	Total waste as received at Malpais in tons/year	Total in tons/year dry
Paper/cardboard	10,379	7,474
Paper	3,132	2,385
Cardboard /corrugated	7,247	5,089
Plastic	10,649	9,296
Organic kitchen/food waste	9,133	3,854
Textiles (incl. leather)	4,009	3,071
Sanitary waste	6,349	3,240

From this table it becomes clear that the real (dry) weights are much lower than the amounts "as received".

9.2.2 Impact collection rate

The mass balance in table 9-1 gives an impression on what quantities could be collected for potential recyclables. For example, how much paper/cardboard would be available for recycling. It is important to acknowledge that these tonnages are the maximum feasible. Even if civilians would receive money for recyclable materials such as waste paper, collection rates will not be 100%. Optimally matured and functioning collection systems for easy to collect materials have maximum collection rates of 90%.[1]

[1] Recycling results Dutch EPR scheme for packaging waste

10 Fuel properties

10.1 Waste as fuel for energy

This chapter describes the key fuel properties for waste that is collected on Curaçao for disposal. If reuse and recycling are not feasible, waste, instead of ending up on the landfill, can be used as fuel to recover energy (Waste-to-Energy, WtE). In addition, emissions of the potent green house gas (GHG), methane, from the landfill would be avoided. There are two options to use waste as fuel:

- Incineration of (mixed) waste in a WtE plant. This involves incineration of the entire waste stream as it is collected;
- Using (specified) waste as solid recovered fuel in e.g. a cement kiln. The production of solid recovered fuels involves source separation or post-collection-sorting of high calorific materials such as paper/cardboard and plastics.

Determining whether these options are suitable is not part of this study, but such an analysis requires detailed insight in the lower heating value as received (LHV) and the ash content of the available waste.

Rubber and hazardous waste from all bulky waste categories are excluded from both the fuel properties and quantity for combustible waste calculation. Hazardous waste is not tolerated in a traditional WtE plant. Substantial rubber items such as rubber tires are also excluded, because a grate furnace is not suitable for the combustion of large rubber items. Additionally, mixed C&D will not be accepted in a grate furnace unless mineral materials and fine fractions are removed from the waste in a sorting facility. Nevertheless, the grate furnace is the technique that is capable of incinerating the largest variety of materials, and therefore, it diverts the largest fraction of combustible waste from landfilling. Other incineration techniques such as pyrolysis or gasification are suitable for processing of rubber tires, but other fractions with more weight will not be accepted in these facilities.

10.2 Lower heating value

The lower heating value (LHV) indicates how much energy can be generated by the incineration of specific types of waste. This study has determined the LHV for all investigated waste categories. Figure 10-1 shows the 'LHV as received' per waste category. Fractions that are not suitable for waste incineration such as mineral waste in construction & demolition waste and rubber tires are left out of the calculation. All fraction-specific LHVs are based on average values for these fractions in two undisclosed developing countries with a hot climate in both South America and Asia.

Organic waste reported in those studies is the organic fraction that mainly consists of organic kitchen waste, but excludes bulky garden waste which is generated in negligible amounts. In Curaçao on the other hand, fresh wood and other garden waste constitute a large part of organic waste (70-80%), and organic waste from households is present in significantly smaller amounts (20-30%). Therefore, for organic waste the Dutch LHV-value for waste from parks is used.[1]

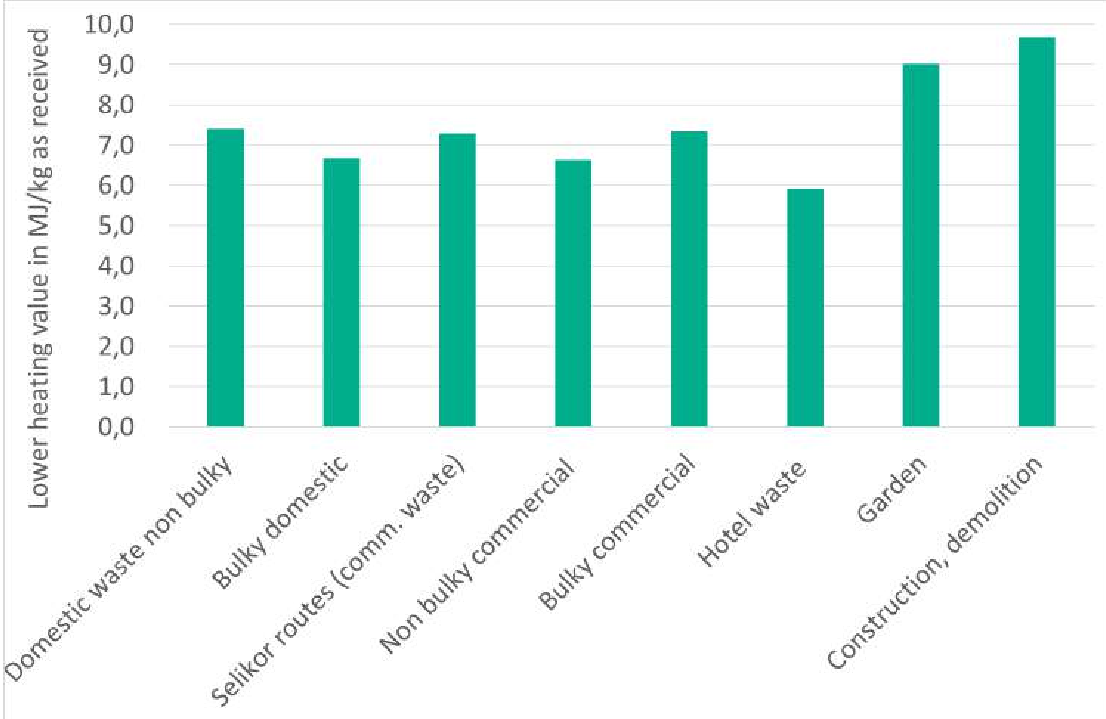

Figure 10-1 Lower heating value (MJ/kg) of waste as received, per waste category.

The LHV value is strongly influenced by choices in waste management. If kitchen (and garden) waste is to be separated at source the LHV of the residual waste will increase considerably. On the other hand, if source separation of paper and plastics is started, the LHV of the remaining waste will be reduced.

10.3 Ash content

The ash content indicates how much ashes will be generated by the incineration of specific types of waste. This study has determined the ash content for all investigated waste categories. Figure 10-2 shows the ash content per waste category. Fractions that are not suitable for waste incineration such as mineral waste in construction & demolition waste and rubber tires are left out of the required calculation for Figure 10-2. Analogous to the LHV-value for organic waste, we used the Dutch value for waste from parks for ash content.[2]

[1] Phyllis database => wood mixed (#900)
[2] Phyllis database => wood mixed (#900)

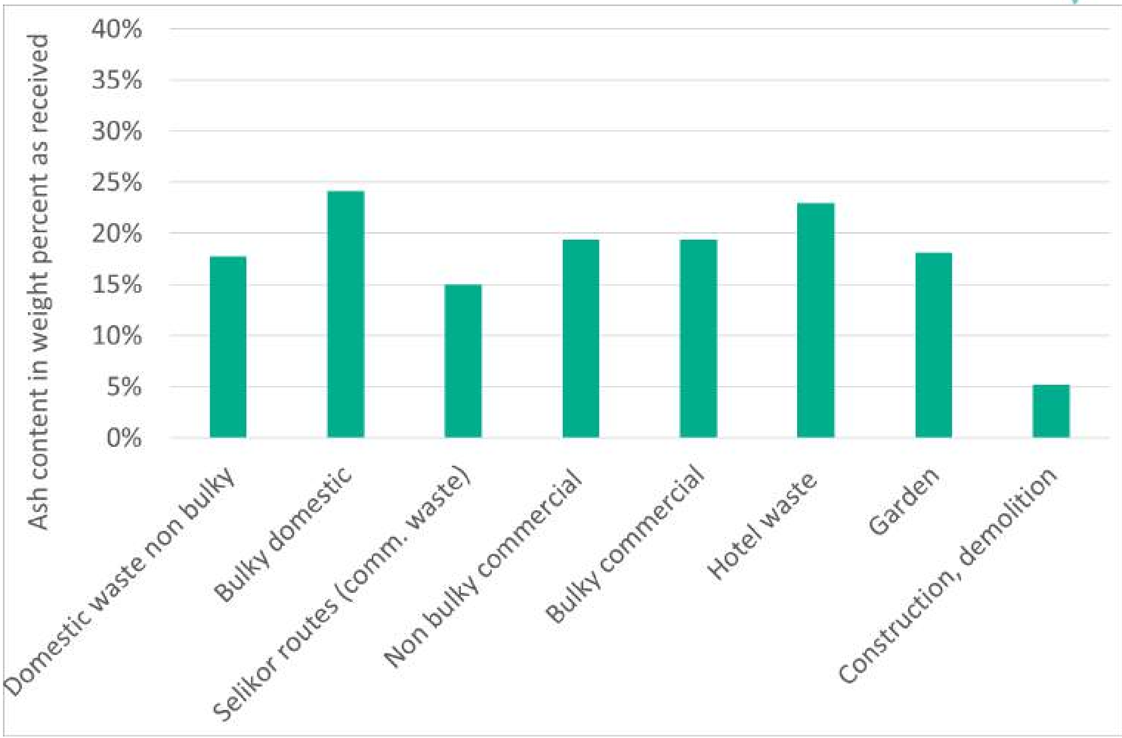

Figure 10-2 Ash content as received in weight percent per waste category.

The ash content is important to estimate because these ashes are highly alkaline and should either be landfilled in a sanitary landfill or be used as a resource to produce construction materials. If the ash comes into direct contact with (rain)water, it harms aquatic life. If recycling is not realized for the ashes landfill capacity is still required.

10.4 Suitability for waste-to-energy

Waste-to-energy plants can operate if the LHV of the waste is roughly between 6 MJ/kg and 14 MJ/kg as received. If the fractions that are not suitable for waste incineration are left out approximately 106,000 tons of the 129,000 tons received at Malpais could be suitable as fuel for a WtE plant. The 23,000 tons not suitable for WtE consists mostly of the mineral fraction present in C&D waste. The average lower heating value for this 106,000 tons combustible waste is 7,6 MJ/kg as received. This LHV is relatively low, but not unfeasible for WtE. The main reason for the relatively low LHV is that in Curaçao no source separation of organic waste takes place.

Figure 10-3 shows available quantity per waste category.

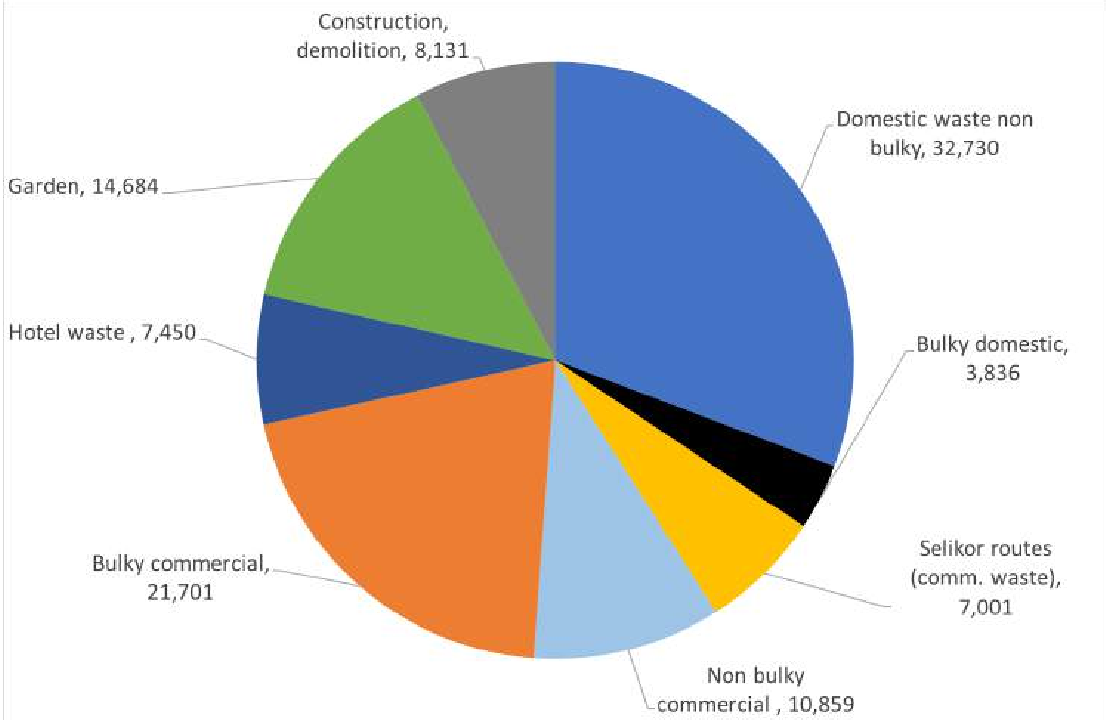

Figure 10-3 Weight (tons/year) per waste category potentially suitable for WtE.

Figure 10-4 shows how much ash will be generated per waste category for those waste categories suitable for WtE. The total expected weight is 18,800 tons/year dry ash and with its average moisture content[1] approximately 22,200 tons/year ash.

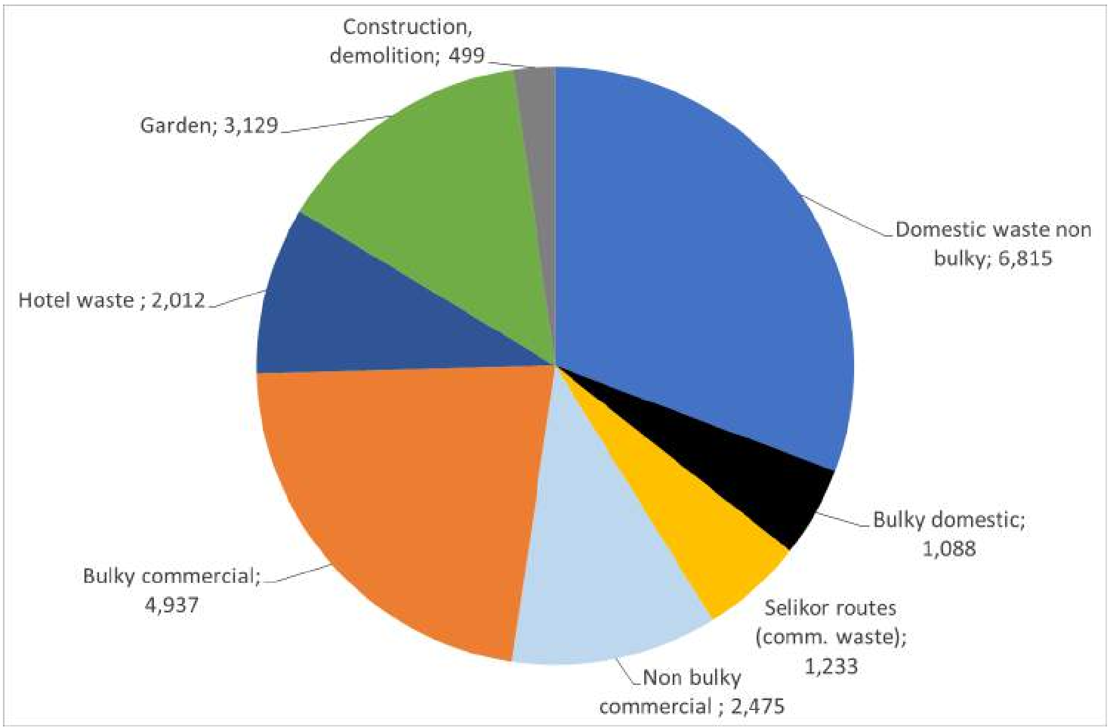

Figure 10-4 Ash (tons/year) generated by WtE per waste category.

[1] Ashes are usually cooled in water and therefore contain moisture.

If no recycling of bottom ashes from WtE is implemented, WtE will still result in 22,200 tons/year ashes having to be landfilled in a sanitary landfill. Together with the 23,000 tons waste which cannot be incinerated 45,000 tons landfill capacity will still be required on an annual basis.

11 Future waste generation

11.1 Introduction

Forecasting of waste generation, sometimes referred to as waste-prognosis, generally concerns the estimation of future development of waste generation. Inferring the future development of waste generation based on historical data is always a difficult—and often largely unsolvable—task (Šomplák et al., 2023). Other forecasting targets such as waste composition are rare.

If socio-economic or demographic parameters are to be used, it is imperative that such data are of sufficient quality. Forecasting models assume that the respective parameters will evolve in a similar way to their past development. The primary feature of a forecast is that no change in the current waste management conditions is expected. Longer-term forecasts are more indicative in terms of how the development of waste generation might manifest if nothing changes (e.g., without any changes being made to the waste management legislation (Šomplák et al., 2023)).

11.2 Waste generation on Curaçao in the past

A summary of the waste generation in past years can help understand how future waste generation may develop. Figure 11-1 shows the waste generation over the past 23 years, distinguishing domestic waste, bulky domestic waste, commercial waste, and construction & demolition waste. For the two largest waste categories, as well as for GDP per capita (at 1995 purchasing power parity) trend lines and their formulas have been added.

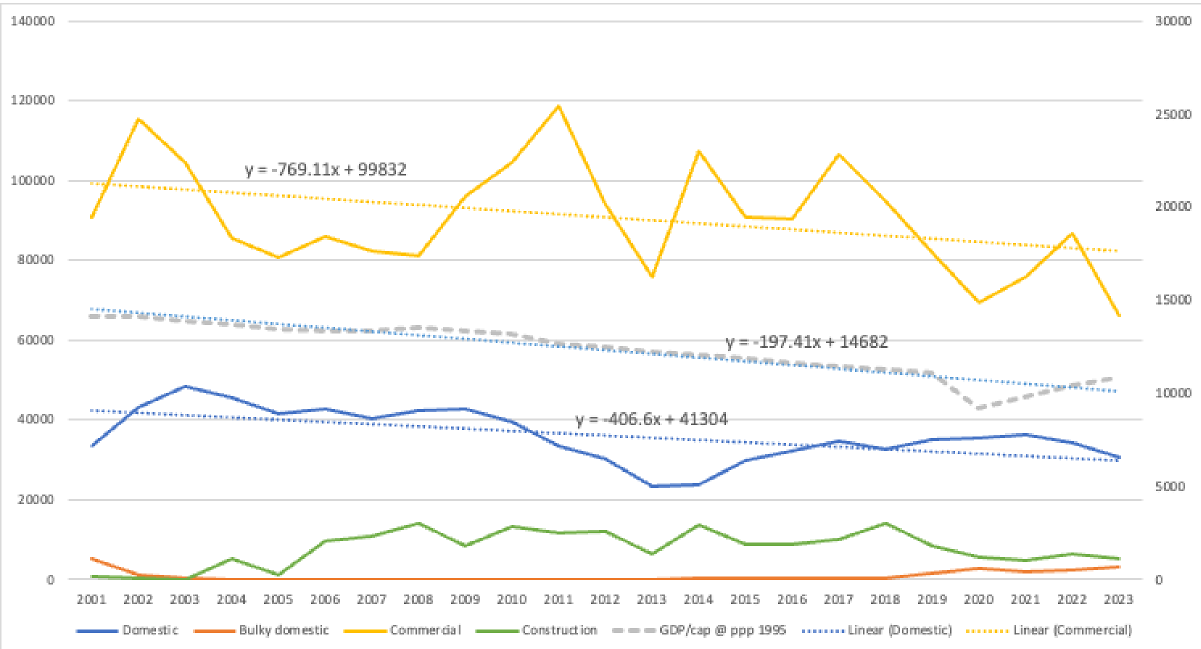

Figure 11-1 Historic data on waste generation (in tons/year) of commercial waste, domestic waste (non-bulky), construction & demolition waste, and domestic bulky waste. Trendlines and their formulas are included for the 2 largest waste categories and GDP/capita.

From figure 11-1 it can be observed that both the amounts of commercial waste and of (non-bulky) domestic waste decline over time (0.8% and 1.2% per year respectively). The general picture for C&D waste is different: from 2005 to 2013 there seems to be a steady supply of C&D waste (11,000 tons/year), which started declining after 2018 (to 6,000 tons/year). This decline may be related to the presence of another location where C&D waste can be brought: the ALR depot for clean C&D waste, for use in the Asphalt Lake of Buskabaai N.V.

11.3 Census-data based forecasting tool

For forecasting of waste generation by communities several methods exist. In a review by Šomplák et al. (2023) the most common method used by researchers was Multiple Linear Regression (MLR). In MLR, waste generation is estimated based on the available sociological, economic, demographic, and other data. In recent years, the use of artificial neural networks (ANN), which belongs to artificial intelligence methods, has become increasingly popular.

Den Boer et al. (2005) developed a software tool, the LCA-IWM Waste Prognostic Tool for waste generation by communities. This tool was used by Beigl et al. (2004) for forecasting waste generation in European Cities (Ghinea et al., 2016). The method is based on readily available socio-economic and demographic statistics, that can be forecasted with a relatively high accuracy and have a long forecasting horizon, such as GDP per capita, population size, infant mortality, and average household size.

While the gross domestic product and infant mortality rate were identified as significant parameters for high-income cities, the age structure, household size and two health indicators (i.e., infant mortality rate and life expectancy at birth) proved capable of explaining variations observed in medium income cities (Beigl et al., 2008). For cities with a medium to high income -higher than 11.400 USD per capita per year at 1995 purchasing power parities- future waste generation can be forecasted with the use of the former two parameters. Between 1999 and 2022 the GDP per capita on Curaçao, at 1995 purchasing power parities, averaged USD 12,400. Curaçao can be regarded as a community (city) with a relatively high income per capita.

For high income European cities, Beigl et al. (2004) found a linear relationship between municipal solid waste generation, GDP per capita and infant mortality, with the following formula producing the best fit:

$$\mathrm{MSW}_t = 276.5 + 0.016 \times \mathrm{GDP}_t - 126.5 \times \log(\mathrm{INF}_{urb}) \quad \text{formula 1}$$

Where:

MSW_t is the municipal solid waste generated per capita and year;

GDP_t is the national gross domestic product per capita at 1995 purchasing power parities;

INF_{urb} is the infant mortality rate per 1,000 births in the city (in this case Curaçao).

The model developed by Beigl et al. (2004) was validated by the researchers with a holdout sample[1] which included 59% of all cases. The out-of-sample error represents a median absolute percentage error of 8.0%, providing a useful model for waste management planning.

In this WGS, the formula above was used for hindcasting of waste generation on Curaçao and for forecasting the next 5 years (see figure 11-2 and 11-3). MSW_t (per capita) is multiplied by the population number to calculate the total MSW in a specific year.
Since the forecasting tool was developed for European cities, and not for small island developing states (SIDS) the results should be regarded with caution. Another aspect that should be regarded with caution is that the forecasting tool is developed solely for municipal solid waste (MSW), not for other types of waste (bulky wastes, C&D waste, etc.). MSW accounts for approximately one third of total waste generated on Curaçao.
In the prognostic tool developed by Den Boer et al. (2005), the definition of the European Environment Agency (EEA) was used for municipal (solid) waste. It is defined as garbage and rubbish which normally originates from houses and similar wastes. Similar wastes are wastes from commercial and institutional sources, such as offices and shops and are collected and disposed of in the same manner as household waste. This definition aligns with the definition of the European SWA-tool (2004), which excludes bulky wastes.

In line with this definition, we defined actual municipal waste as household waste + the non-bulky part of commercial waste. Since no historical data from Selikor on bulkiness of commercial wastes are present, the results of the WGS-2023 (see chapter 4 above) on bulkiness of waste were assumed to be valid for all years in the 2011-2022 period.
The values for actual waste (MSW) (CLEAR) and hindcasted waste are very similar, and the formula by Beigl et al. (2004) was deemed to be fit for forecasting the waste for the 5 years after 2023 (paragraph 11.5 and figure 11-3).

[1] A hold-out sample is a random sample from a data set that is withheld and not used in the model fitting process. After the model is fit to the main data (the "training" data), it is then applied to the hold-out sample. This gives an unbiased assessment of how well the model performs if applied to new data

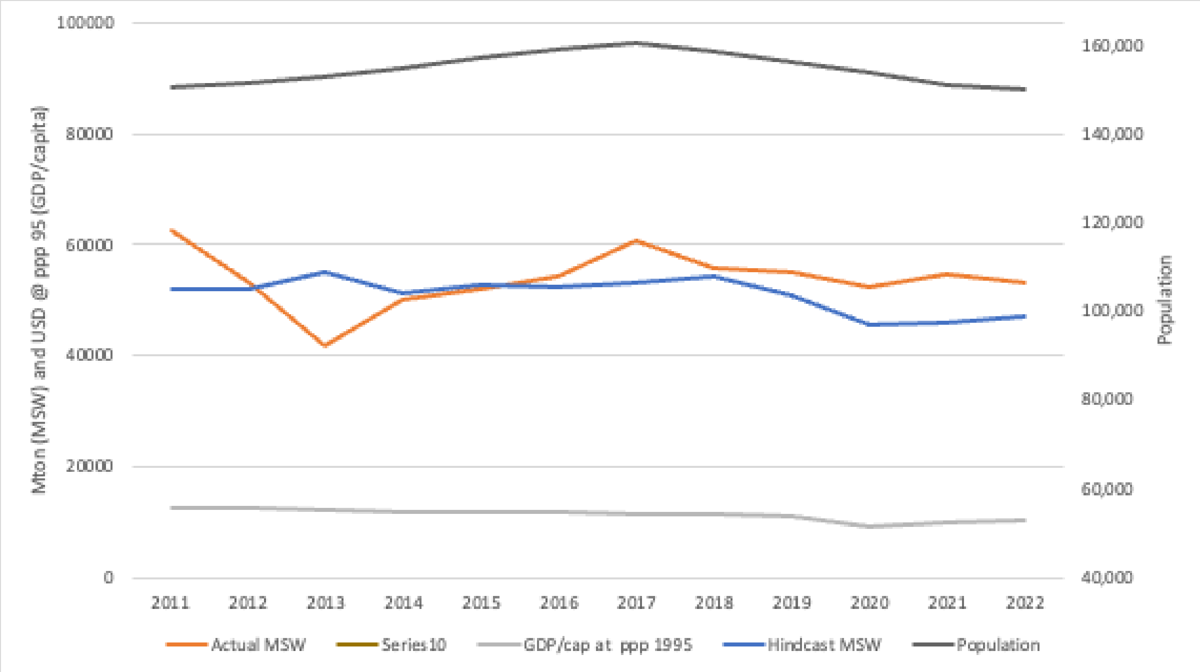

Figure 11-2 Actual MSW and hindcasted MSW, together with GDP per capita in 1995 purchasing power parity 1995 and population (source: Selikor CLEAR data, Central Bureau of Statistics Curaçao).

11.4 Curaçao economic outlook

On July 24, 2023, the Executive Board of the International Monetary Fund (IMF) concluded for Curaçao[1]:

After a robust recovery in 2022, estimated at 7.9 percent, output growth is expected to moderate. Further expansion of the hospitality sector would support GDP growth of 3 percent in 2023 and 2024. The economy is projected to recover to its pre-pandemic level by 2026, later than the Caribbean average, as the decline of real GDP in 2020 was deeper than in Curaçao's peers. The easing of oil and food prices, along with disinflation in major trading partners, is expected to reduce headline 12-month average inflation to 3.8 percent in 2023 and to the historical average in the medium term. Assuming that gains from a strong post-pandemic fiscal consolidation are preserved, public debt is projected to decline over the medium term.

In its Economic Bulletin of December 2023, the Central Bank of Curaçao and Sint-Maarten (CBCS) states:

According to the Bank's latest estimates, Curaçao's real GDP grew by 4.1% in 2023, representing an upward revision of 0.3 percentage point compared to the outlook presented in September 2023. The upward revision reflects a better-than-earlier expected performance of tourism – both stay-over and

[1] https://www.imf.org/en/News/Articles/2023/07/27/pr23279-imf-executive-board-concludes-2023-article-iv-consultation-with-Curacao-and-sint-maarten#:~:text=Curacao%20outlook.&text=Further%20expansion%20of%20the%20hospitality,deeper%20than%20in%20Curacao%27s%20peers

cruise – during the first nine months of 2023. In addition, stay-over tourism is expected to grow further into the fourth quarter of 2023 sustained by an increase in airlift.

According to the CBCS, Curaçao will reach the pre-pandemic level by 2024, which is earlier than previously expected.

Table 11-1 summarizes both actual and forecasted inflation and real GDP for Curaçao for the period of 2020 to 2027. In our calculations for 2028, the same figures as those of 2027 have been used.

Table 11-1 Actual and forecasted inflation and real GDP for Curaçao.
(2020-2027, source CBCS)

	Inflation	Real GDP growth
2020	2.2%	-18%
2021	3.8%	4.2%
2022	7.4%	7.9%
2023	3.3%	4.1%
2024	2.8%	4.4%
2025	2.8%	3.0%
2026	2.7%	2.2%
2027	2.4%	1.7%
2028	(2.4%)*	(1.7%)*

* Inflation and GDP growth in 2028 are extrapolated by EcoVision

Forecasted GDP changes may involve forecasted changes in population. For our calculations however, we assumed that population growth on Curaçao is zero and (real) GDP per capita multiplied by the population number equals the forecasted (real) GDP.

11.5 Waste generation forecast

Short term forecast MSW

The short-term forecast (5 years) is based on the formula presented by Beigl et al. (2004) and concerns "Municipal Waste" (household waste and similar waste (non-bulky). The result is presented in figure 11-3, in which the orange line represents actual waste (MSW) and the modelled forecast and the blue line represents modelled waste (MSW) and modelled forecast.

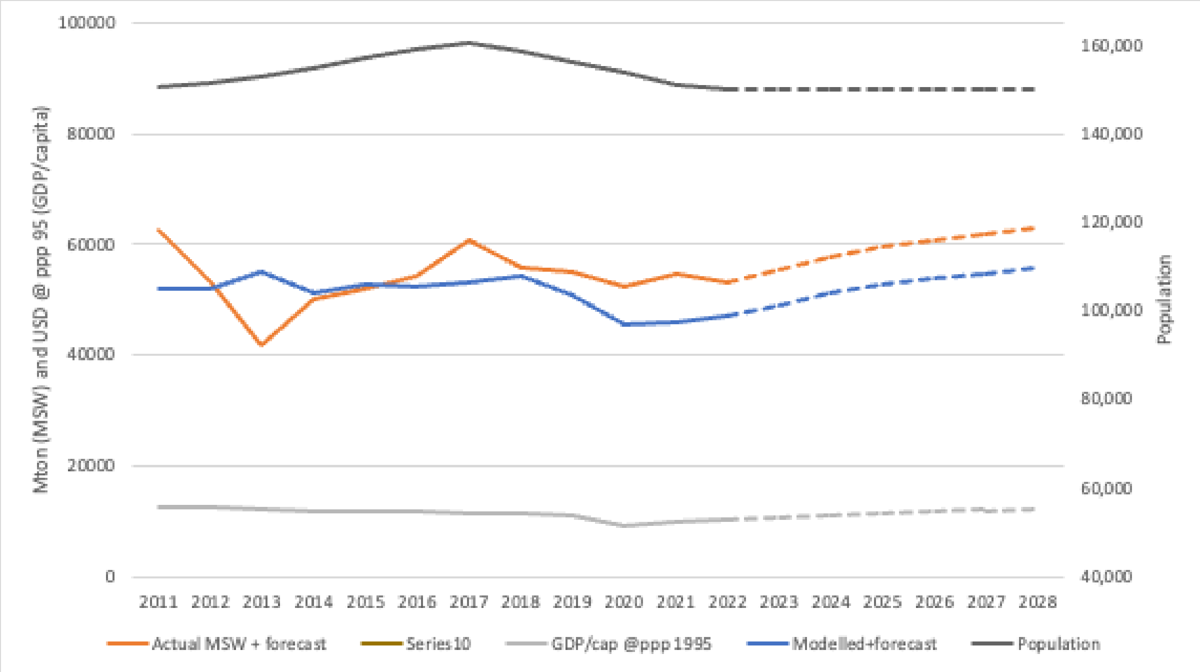

Figure 11-3 Short term forecast (5 years), based on Beigl et al. (2004).

Long term forecast total waste (2024-2033)

The Selikor data from 2001-2023 provide consistent information on quantities of 4 categories of waste: domestic waste (non-bulky), domestic waste bulky, commercial waste and construction & demolition waste (see paragraph 11.2). These 4 categories account for more than 98 wt% of total waste and are referred to as total waste in this paragraph. The data on total waste was combined with data on GDP per capita (at 1995 purchasing power parity) to carry out a linear regression analysis (Pearson correlation coefficient)[1]. The analysis points out that a significant medium positive relationship exists between GDP per capita (@ 1995 p.p.p.) and domestic non-bulky waste (formula 2). Additionally, a significant medium positive relationship exists between GDP per capita and total waste (formula 3). This relationship does not exist between GDP per capita and any other waste category than domestic waste.

GDP per capita (@ 1995 p.p.p.) and domestic (non-bulky waste): r(20) = .484, p = .022

$$\text{Relationship: } y = 2267\,x + 8343$$

GDP per capita (@ 1995 p.p.p.) and total waste: r(20)=.475, p=.026

$$\text{Relationship: } y = 5009\ x + 74891$$

Where y = waste quantity and x = GDP/cap (@ p.p.p. 1995)

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[1] According to De Boer et al, 2005 (volume 2.1, p. 47) using multiple linear regression is more advantageous than using single regressions. The use of multiple linear regression however is beyond the scope of this project

In the test two hypotheses are tested:

H_0: there is no relationship between GDP per capita and waste quantity;

H_1: the relationships described are true.

With $p < .022$ and $.026$ respectively, the chance of rejecting a correct H_0 is small. The smaller the p-value the more it supports H_1. See Annex 4A and B for the results of the statistical analysis.

Table 11-2 shows 4 GDP development scenarios for the next 10 years: high growth, medium growth, limited growth, and negative growth (continuation of historic negative trend (2001-2022)). In all 4 scenarios, the first 3 years are equal to the CBCS forecast and divert in subsequent years. Formula 3 is used for calculation of the forecasted total waste for the next 10 years. Figure 11-4 shows the results.

Table 11-2 Real GDP (per capita) scenarios

	High growth	Medium growth	Limited growth	Current trend after 2028
2024	4.4%	4.4%	4.4%	4.4%
2025	3.0%	3.0%	3.0%	3.0%
2026	2.2%	2.2%	2.2%	2.2%
2027	2%	1%	0%	-1.4%
2028	2%	1%	0%	-1.4%
2029	2%	1%	0%	-1.4%
2030	2%	1%	0%	-1.4%
2031	2%	1%	0%	-1.4%
2032	2%	1%	0%	-1.4%
2033	2%	1%	0%	-1.4%
Total period	+26%	+18%	+10%	-2.5%

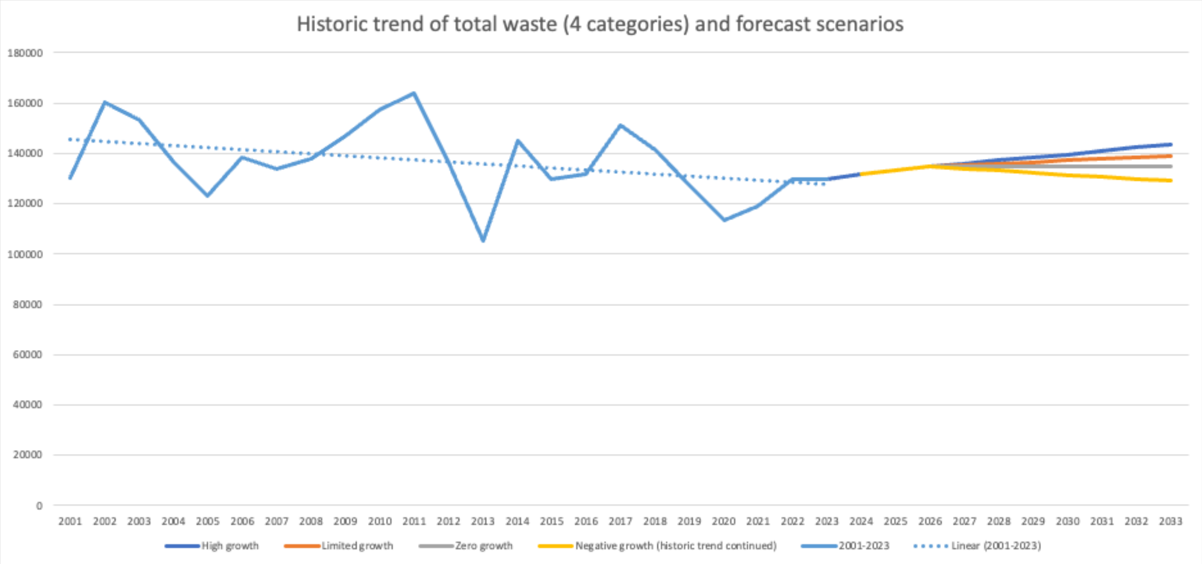

Figure 11-4 Long term forecast (2024-2033) for the total of 4 waste categories.

Note: when planning future waste processing options, a forecast as presented here alone is not sufficient. There is significant variation from the trend from year to year (and probably even more from month to month) and these fluctuations must be acknowledged and dealt with.

12 Conclusions and recommendations

12.1 Conclusions

Total waste

1. On Curaçao, 213,000 tons of waste is generated per year (wet weight). Of this waste, approximately 129,000 tons[1] is brought to landfill Malpais and 78,000 tons is brought to recycling companies (for export and local recycling). An amount of 5,600 tons is stored for future recycling.

2. The three largest waste categories brought to the landfill are: non-bulky domestic waste (or "garbage", 26 wt%), construction & demolition waste (23 wt%), and commercial bulky waste (17 wt%).

3. Smaller waste categories are: garden waste (11 wt%), non-bulky commercial waste (8 wt%), waste from Selikor commercial routes (6 wt%), hotel waste (6 wt%) and bulky domestic waste (3 wt%).

4. The main origin of the waste being transported to the landfill by private (non-Selikor) commercial transporters is households.

5. Most waste is bulky waste (54 wt%). Non-bulky waste is 44 wt% and 2 wt% is a mix between bulky and non-bulky.

Non-bulky wastes

6. Organic waste, paper/cardboard, plastics, glass, and sanitary waste (diapers etc.) are the largest fractions in the four non-bulky waste categories.

7. Fifty-eight percent (58 wt%) of all non-bulky waste consisted of the sum of the three biggest fractions: paper/cardboard, plastics, and organic waste.

8. About a quarter of all non-bulky waste is organic waste.

9. Compared to other waste categories, commercial waste from Selikor routes contains relatively large quantities of paper/cardboard; this was the largest fraction (24.2 wt%) in this waste category. Hotel waste contains relatively large amounts of glass (18.1 wt%) and -

[1] During the period of 2019-2022 approximately 133,000 ton was brought to landfill Malpais.

compared to other waste categories- domestic waste contains significant amounts of textiles (9.3 wt%).

Bulky wastes

10. The fraction garden (and yard waste) is vastly dominant in the waste category of garden waste. The same applies for the fraction concrete, stones, and tiles in the waste category construction & demolition waste.

11. The current WGA data reveals that construction & demolition waste is much more prevalent (23 wt% of total waste) than would be expected based on the CLEAR data of 2022 (6 wt% of total waste in 2022). A possible explanation is that Selikors' classification of C&D waste is reserved for pure stony materials and that mixed loads (concrete, wood, other) are being classified as "commercial waste". These mixed loads frequently include (much) more than 50 wt% stony materials.

12. Garden waste is not being registered separately at the gate of Selikor but proves to be a significant part of total waste (11 wt%). The density of this waste category is low, and its volume is much larger than 11%. It is currently being classified as "commercial waste". At the same time, this type of waste is the least contaminated with other waste streams and has a high potential for recycling.

Moisture content and fuel properties

13. Organic waste, sanitary waste and paper and cardboard are the waste fractions with highest moisture contents (58 wt%, 49 wt% and 30 wt% respectively).

14. Approximately 106,000 tons of the 129,000 tons received at Malpais could be suitable as fuel for a WtE plant. The 23,000 tons not suitable for WtE consists mostly of the mineral fraction present in C&D waste. The average lower heating value for this 106,000 tons combustible waste is 7.6 MJ/kg as received. This LHV is relatively low, but not unfeasible for WtE.

Waste forecast

15. After 23 years of a declining waste generation trend (approximately 1% per year), a period with increased waste production is forecasted, fueled by a growing economy over the next 5 years. After this period, waste generation may further increase or instead decrease, depending on economic scenarios.

Social aspects of waste generation

16. The WGS data suggest that high-income households dispose of more cardboard than lower income households and at the same time dispose of less organic waste.

12.2 Recommendations

1. For future analysis, it is recommended to introduce the 8 categories in the monitoring system at Selikor's weighbridge at the landfill. Special attention should be paid to construction & demolition waste, garden waste and the difference between bulky and non-bulky waste.

2. To facilitate this, it may be considered to install cameras on top of the weighbridge building to check for the type of waste and to organize training for weighbridge personnel.

3. To account for dryer periods and for changes in tourism related waste, carry out the same WGS for the dry season and high tourism season.

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TRANSFORMING WASTETOVALUE

Energized by Selikor and the Ministry of Health, Environment & Nature