Green Technology Application for the Development of Low Carbon Cities (GTALCC)

City-wide GHG accounting

22 March 2021

Module E: Waste

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- Waste calculators 05
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Materials

CIRIS

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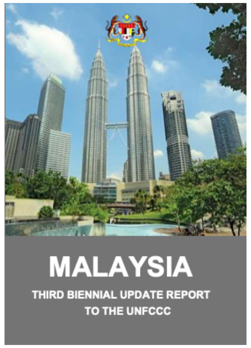

GTALCC GHG Accounting - Participant handbook

Exercises	
Module B	Calculating GHG emissions
	Reviewing an inventory
Module C	Stationary energy
Module D	Transportation
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Checklist

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Module E

Waste

01

Overview

Requirements

BASIC	Cities shall report all GHG emissions from disposal or treatment of waste generated within the city boundary, whether treated inside or outside the city boundary.
BASIC+	Not applicable
Territorial	Emissions from waste imported from outside the city but treated inside the city shall be excluded from BASIC/BASIC+ totals. These emissions shall still be reported in total scope 1 emissions.

Categorising emissions

Scope 1	Scope 2	Scope 3
Emissions from waste treated inside the city	**Not applicable**	**Emissions from waste generated by the city but treated outside the city**
This includes all GHG emissions from treatment and disposal of waste within the city boundary regardless whether the waste is generated within or outside the city boundary. Only GHG emissions from waste generated by the city shall be reported under BASIC / BASIC+. GHG emissions from imported waste shall be reported as scope 1, but not added to BASIC / BASIC+ totals.	All emissions from the use of grid-supplied electricity in waste treatment facilities within the city boundary shall be reported under scope 2 in Stationary Energy, commercial and institutional buildings and facilities (I.2.2)	This includes all GHG emissions from treatment of waste generated by the city but treated at a facility outside the city boundary.

Boundaries for imported / exported waste

A = waste generated outside of the city boundary and treated within the boundary

B = waste generated and treated within the city boundary

C = waste generated inside the city boundary and treated outside of the boundary

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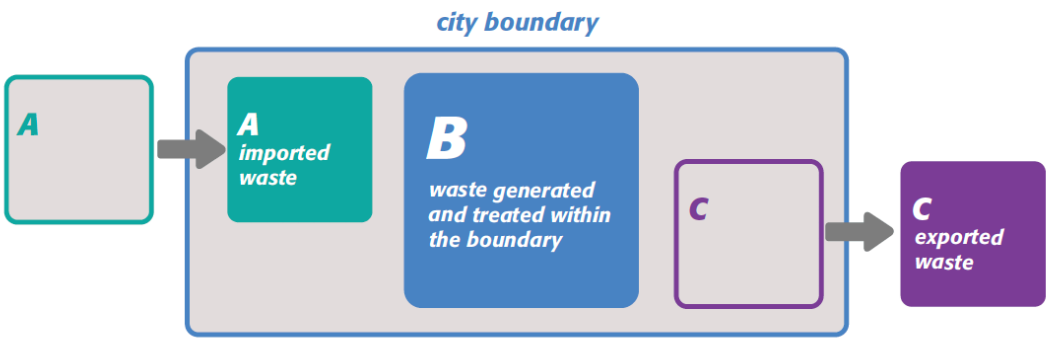
Scope 1 emissions = **A+B** (all emissions generated within the city boundary)

Scope 3 emissions = **C**

BASIC = **B+C** (all emissions resulting from waste generated by the city)



Sub-sectors

Sub-sector		Definition
III.1	Solid waste	Solid waste disposal in landfills or dump sites, including disposal in an unmanaged site, disposal in a managed dump or disposal in a sanitary landfill
III.2	Biological treatment	Composting and anaerobic digestion of organic waste, such as food waste, garden and park waste, sludge, and other organic waste sources
III.3	Incineration and open burning	Incineration is a controlled, industrial process of buring waste, often with energy recovery. By contrast, open burning is an uncontrolled, often illicit process
III.4	Wastewater	Municipal and industrial wastewater, and can be treated aerobically (in presence of oxygen) or anaerobically (in absence of oxygen)

Overview waste (GPC)

Waste sub-sectors	Scope 1	Scope 2	Scope 3
Solid waste generated **in** the city and disposed in **landfills**	III.1.1		III.1.2
Solid waste generated **outside** the city and disposed in **landfills**	III.1.3		
Solid waste generated **in** the city that is **biologically treated**	III.2.1		III.3.2
Solid waste generated **outside** the city that is **biologically treated**	III.2.3		
Solid waste generated **in** the city that is **incinerated**	III.3.1		III.5.2
Solid waste generated **outside** the city that is **incinerated**	III.3.3		
Wastewater generated **in** the city	III.4.1		III.4.2
Wastewater generated **outside** the city	III.4.3		

Waste types

Waste type	Description
Muncipal solid waste (MSW)	MSW is generally defined as waste collected by municipalities or other local authorities. MSW typically includes: food waste, garden and park waste, paper and cardboard, wood, textiles, disposable diapers, rubber and leather, plastics, metal, glass, and other materials (e.g. dirt, dust, soil, electronic waste).
Sludge	In some cities, domestic wastewater sludge is reported as MSW, and industrial wastewater treatment sludge in industrial waste. Other cities may consider all sludge as industrial waste.
Industrial waste	Industrial waste generation and composition vary depending on the type of industry and processes / technologies used and how the waste is classified by country. Sometimes includes as MSW.
Clinical waste	These wastes cover a range of materials including plastic syringes, animal tissues, bandages and cloths. Some countries choose to include these items under MSW. Clinical waste is usually incinerated,
Hazardous waste	Waste oil, waste solvents, ash, cinder, and other wastes with hazardous properties — such as flammability, explosiveness, causticity, and toxicity — are included in hazardous waste. Hazardous wastes are generally collected, treated and disposed of separately from non-hazardous MSW and industrial waste streams.

Quantifying waste emissions

Step	Description
Determine the quantity (mass) of waste generated by the city and how and where it is treated	For all disposal and treatment types, cities should identify the quantity of waste generated in the analysis year. In the absence of local or country-specific data on waste generation and disposal, the 2006 IPCC Guidelines provide national default values for waste generation rates based upon a tonnes/capita/year basis and default breakdowns of fraction of waste disposed in landfills, incinerated, and composted.
Determining solid waste composition and degradable organic content (DOC)	The preferred method to determine the composition of the solid waste stream is to undertake a solid waste composition study, using survey data and a systematic approach to analyze the waste stream and determine the waste source (paper, wood, textiles, garden waste, etc.). In the absence of a comprehensive waste composition study, IPCC Guidelines provide sample regional and country-specific data to determine waste composition and carbon factors.
Determine the emission factor	
Multiply quantity of waste disposed by relevant emission factors	

Exercise: Waste

A = waste generated outside of the city boundary and treated within the boundary

B = waste generated and treated within the city boundary

C = waste generated inside the city boundary and treated outside of the boundary

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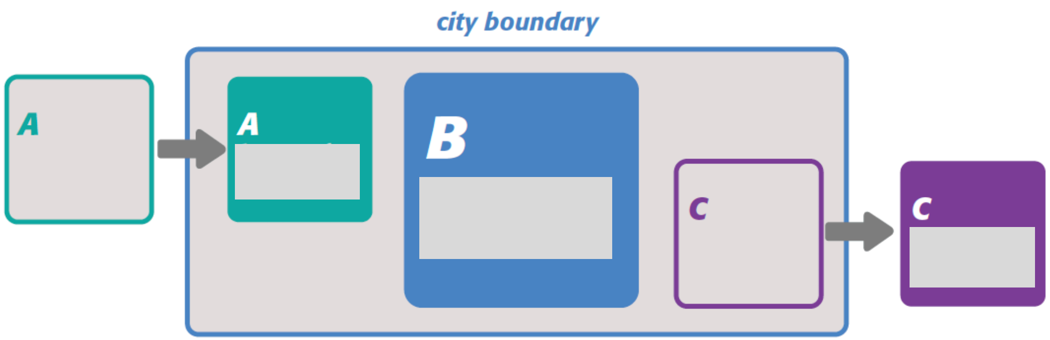
Scope 1 emissions = **A+B** (all emissions generated within the city boundary)

Scope 3 emissions = **C**

BASIC = **B+C** (all emissions resulting from waste generated by the city)



Exercise: Waste

Activity	Sub-sector
Household waste burned in an open dump	III.3
Paper recycling	-
Composting of garden waste	III.2
Food waste disposed in a managed dump	III.1
Household waste burned with energy recovery	(Stationary energy)
Food waste flushed down the toiler	III.4
Clinical waste burned without energy recovery	III.3
Electronic waste sent to landfill	III.1

Module E

Waste

02

Biogenic carbon

$CO_2(b)$

$$CO_2 \neq CO_2(b)$$

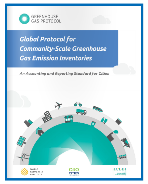
CO_2 emissions from combustion of materials of biogenic origin (e.g. biomass, biofuel, landfill gas etc.) shall be reported separately from fossil carbon and are not counted in total emissions.

Biogenic emissions – $CO_2(b)$ – are those that result from the combustion of biomass materials that naturally sequester CO_2, including materials used to make biofuels (e.g. crops, vegetable oils, or animal fats).

CO_2(b)

For the purposes of national level GHG inventories, land-use activities are recorded as both sinks and sources of CO_2 emissions.

Reporting emissions from combusting these biogenic fuels would result in double counting on a national level.



CO_2(b) should be reported to show they have been accounted for and are not included in total emissions

Reporting of CO_2(b) is optional

Module E

Waste

03

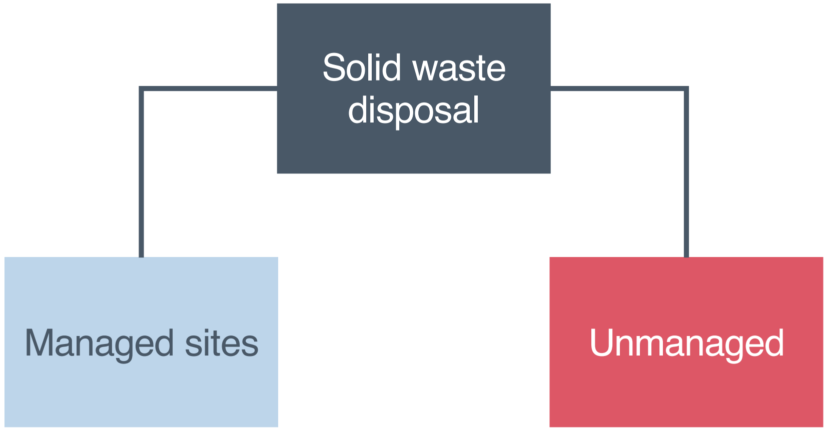
Treatment types

Solid waste disposal

Solid waste may be disposed of at:

- **Managed sites**: sanitary landfill and managed dumps
- **Unmanaged disposal sites**: open dumps, including above-ground piles, holes in the ground, and dumping into natural features, such as ravines

Cities should first calculate emissions from managed disposal sites, and separately calculate and document emissions from unmanaged disposal sites.

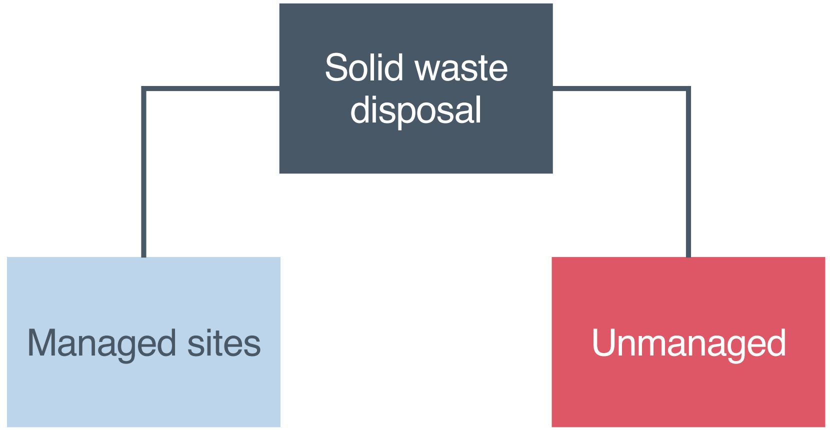


Solid waste disposal

Activity data on quantities of waste generated and disposed at managed sites can be calculated based on records from waste collection services and weigh-ins at the landfill.

Waste disposed at unmanaged sites (e.g. open dumps) can be estimated by subtracting the amount of waste disposed at managed sites from the total waste generated.

Total waste generated can be calculated by multiplying the per capita waste generation rate (tonnes/capita/yr) by the population (capita).



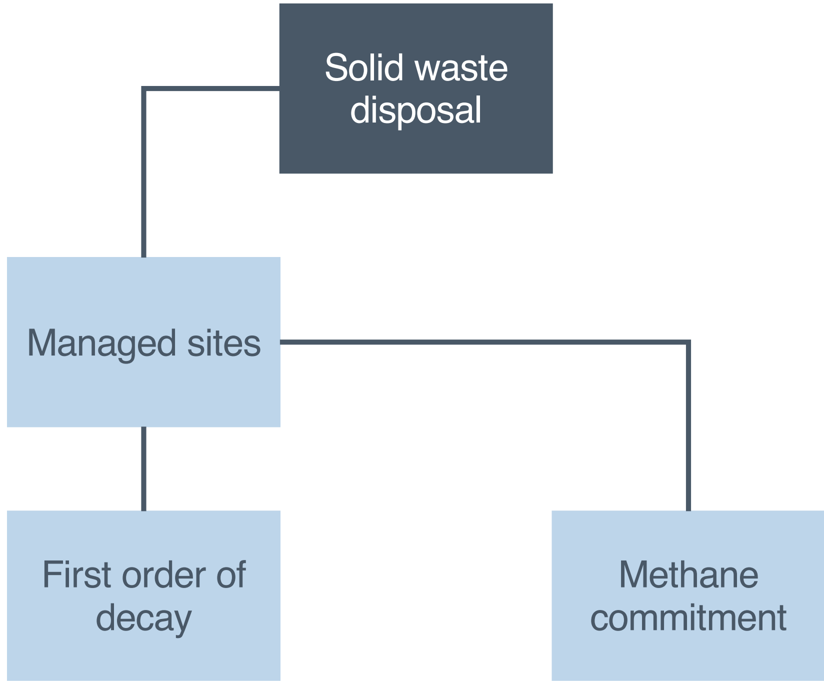
Managed sites (landfill)

Methane (CH_4) emissions from landfills continue several decades (or sometimes even centuries) after waste disposal.

Waste disposed in a given year thereby contributes to GHG emissions in that year and in subsequent years.

Likewise, methane emissions released from a landfill in any given year include emissions from waste disposed that year, as well as from waste disposed in prior years.

The GPC (and CRF) provides **two commonly accepted methods** for calculating emissions from managed sites



First order of decay (FOD) model

First order of decay (FOD) model counts **GHGs actually emitted from landfill sites during inventory year**, regardless of when the waste was disposed.

The FOD model assumes that the degradable organic component (DOC) in waste decays slowly over a few decades, during which CH_4 and CO_2 are released.

If conditions are constant, the rate of CH_4 production depends solely on the amount of carbon remaining in the waste, which gradually declines as it decays / is consumed by bacteria.

CH_4 emissions =

$$\{ \textstyle\sum_x [MSW_x \times L_0(x) \times ((1 - e^{-k}) \times e^{-k(t-x)})] - R(t)\} \times (1 - OX)$$

Description			**Value**
CH_4 emissions	=	Total CH_4 emissions in tonnes	Computed
x	=	Landfill opening year or earliest year of historical data available	User input
t	=	Inventory year	User input
MSW_x	=	Total municipal solid waste disposed at SWDS in year x in tonnes	User input
R	=	Methane collected and removed (ton) in inventory year	User input
L_0	=	Methane generation potential	Consult equation 8.4
k	=	Methane generation rate constant, which is related to the time taken for the DOC in waste to decay to half its initial mass (the "half-life")	User Input or consult default value in table 3.4 of 2006 IPCC guidelines, vol. 3: waste, chapter 3: solid waste disposal, p. 3.17
OX	=	Oxidation factor	0.1 for well-managed landfills; 0 for unmanaged landfills

Source: IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (2000)

Complex model so cities are recommended to use the IPCC Waste Model. Will need:

- Total waste in place
- Years of operation
- Population data over time

Methane commitment (MC) model

Methane commitment (MC) model assigns landfill emissions based on waste disposed in a given year.

The MC model takes a lifecycle and mass-balance approach and estimates future landfill emissions based on the **mass of waste disposed during the inventory year**, regardless of when the emissions actually occur (a portion of emissions are released every year after the waste is disposed).

For most cities, the MC method will consistently overstate GHG emissions by assuming that all DOC disposed in a given year will decay and produce methane immediately.

$$CH_4 \text{ emissions} = MSW_X \times L_0 \times (1-f_{rec}) \times (1-OX)$$

Description			Value
CH_4 emissions	=	Total CH_4 emissions in metric tonnes	Computed
MSW_X	=	Mass of solid waste sent to landfill in inventory year, measured in metric tonnes	User input
L_0	=	Methane generation potential	Equation 8.4 Methane generation potential
f_{rec}	=	Fraction of methane recovered at the landfill (flared or energy recovery)	User input
OX	=	Oxidation factor	0.1 for well-managed landfills; 0 for unmanaged landfills

Source: Adapted from *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*

$$L_0 = MCF \times DOC \times DOC_F \times F \times 16/12$$

Description			Value
L_0	=	Methane generation potential	Computed
MCF	=	Methane correction factor based on type of landfill site for the year of deposition (managed, unmanaged, etc., fraction)	Managed = 1.0 Unmanaged (≥5 m deep) = 0.8 Unmanaged (<5 m deep) = 0.4 Uncategorized = 0.6
DOC	=	Degradable organic carbon in year of deposition, fraction (tonnes C/tonnes waste)	Equation 8.1
DOC_F	=	Fraction of DOC that is ultimately degraded (reflects the fact that some organic carbon does not degrade)	Assumed equal to 0.6
F	=	Fraction of methane in landfill gas	Default range 0.4-0.6 (usually taken to be 0.5)
16/12	=	Stoichiometric ratio between methane and carbon	

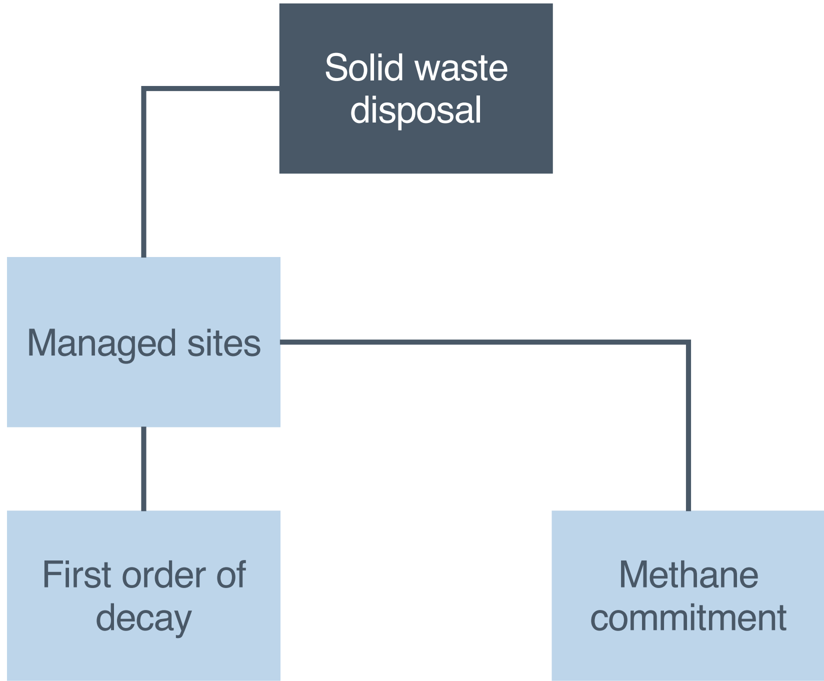
Source: *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (2000)

Managed sites (landfill)

The FOD model provides a more accurate estimate of annual emissions— and is recommended in IPCC Guidelines—but it requires historical waste disposal information that might not be readily available.

The GPC, however, recommends the MD model.

Which model does your city use?



Comparing MD and FOD models

User Consideration	Methane commitment (MC)	First Order of Decay (FOD)
Simplicity of implementation, data requirements	**Advantage:** Based on quantity of waste disposed during inventory year, requiring no knowledge of prior disposal.	**Disadvantage:** Based on quantity of waste disposed during inventory year as well as existing waste in landfill(s). Requires historic waste disposal information.
Consistency with annualized emissions inventories	**Disadvantage:** Does not represent GHG emissions during inventory year. Rolls together current and future emissions and treats them as equal. Inconsistent with other emissions in the inventory.	**Advantage:** Represents GHG emissions during the inventory year, consistent with other emissions in the inventory.
Decision-making for future waste management practices	**Disadvantage:** May lead to overestimation of emission reduction potential.	**Advantage:** Spreads benefits of avoided landfill disposal over upcoming years.
Credit for source reduction/recycling	**Advantage:** Accounts for emissions affected by source reduction, reuse, and recycling.	**Disadvantage:** For materials with significant landfill impacts, FOD not as immediately sensitive to source reduction, reuse, and recycling efforts.
Credit for engineering controls, heat/power generation	**Disadvantage:** Doesn't count current emissions from historic waste in landfills, thus downplaying opportunities to reduce those emissions via engineering controls.	**Advantage:** Suitable for approximating amount of landfill gas available for flaring, heat recovery, or power generation projects.
Credit for avoided landfill disposal	**Disadvantage:** Overstates short-term benefits of avoided landfill disposal.	**Advantage:** Spreads benefits of avoided landfill disposal over upcoming years, minimizing overestimation of emission reduction potential.
Accuracy	**Disadvantage:** Requires predicting future gas collection efficiency and modeling parameters over the life of future emissions.	**Advantage:** More accurate reflects total emissions occurring in the inventory year.

Biological treatment

The biological treatment of waste refers to **composting** and **anaerobic digestion** of organic waste, such as food waste, garden and park waste, sludge, and other organic waste sources. Biological treatment of solid waste reduces overall waste volume for final disposal (in landfill or incineration) and reduces the toxicity of the waste.

Data on composting and anaerobic treatment should be collected separately, in order to use different sets of emission factors.

Where there is gas recovery from anaerobic digestion, cities should subtract recovered gas amount from total estimated CH_4 to determine net CH_4 from anaerobic digestion.

Equation 8.5 Direct emissions from biologically treated solid waste

CH_4 Emissions =

$$(\Sigma_i (m_i \times F\_CH4_i) \times 10^{-3} - R)$$

N_2O Emissions =

$$(\Sigma_i (m_i \times EF\_N2O_i) \times 10^{-3})$$

Description			Value
CH_4 emissions	=	Total CH_4 emissions in tonnes	Computed
N_2O emissions	=	Total N_2O emissions in tonnes	Computed
m	=	Mass of organic waste treated by biological treatment type i, kg	User input
EF_ CH4	=	CH_4 emissions factor based upon treatment type, i	User input or default value from table 8.3 Biological treatment emission factor
EF_ N2O	=	N_2O emissions factor based upon treatment type, i	User input or default value User input or default value from table 8.3 Biological treatment emission factor
i	=	Treatment type: composting or anaerobic digestion	User input
R	=	Total tonnes of CH_4 recovered in the inventory year, if gas recovery system is in place	User input, measured at recovery point

Source: *2006 IPCC Guidelines for National Greenhouse Gas Inventories,* Volume 5, Chapter 4: Biological Treatment of Solid Waste

Table 8.3 Biological treatment emission factors

Treatment type	CH_4 Emissions Factors (g CH_4/ kg waste)		N_2O Emissions Factors (g N_2O /kg waste)	
	Dry waste	Wet waste	Dry waste	Wet waste
Composting	10	4	0.6	0.3
Anaerobic digestion at biogas facilities	2	1	N/A	N/A

Source: *2006 IPCC Guidelines for National Greenhouse Gas Inventories,* Volume 5, Chapter 4: Biological Treatment of Solid Waste

Incineration and open burning

Incineration is a controlled, industrial process, often with energy recovery where inputs and emissions can be measured, and data is often available.

By contrast, open burning is an uncontrolled, often illicit process with different emissions and can typically only be estimated based on collection rates.

CO_2 emissions associated with incineration facilities can be estimated based on the mass of waste incinerated at the facility, the total carbon content in the waste, and the fraction of carbon in the solid waste of fossil origin. CH_4 and N_2O, are more dependent on technology and conditions during the incineration process.

To calculate emissions from waste incineration, cities must identify:

- Quantity (mass) of total solid waste generated in the city that is incinerated
- % of waste generated in the city that is incinerated in (III.3.1) and outside the city (III.3.2)
- Quantity of total solid waste generated by other communities and incinerated in the city (III.3.3)
- Type of technology and conditions used in the incineration process(es)
- "Energy transformation efficiency" (applies to incineration with energy recovery)

Incineration and open burning

Equation 8.6 **Non-biogenic CO_2 emissions from the incineration of waste**

$$CO_2 \text{ Emissions} = m \times \sum_i (WF_i \times dm_i \times CF_i \times FCF_i \times OF_i) \times (44/12)$$

Description			Value
CO_2 emissions	=	Total CO_2 emissions from incineration of solid waste in tonnes	Computed
m	=	Mass of waste incinerated, in tonnes	User input
WF_i	=	Fraction of waste consisting of type i matter	User input[54]
dm_i	=	Dry matter content in the type i matter	User input (default values provided in Table 8.4 below)
CF_i	=	Fraction of carbon in the dry matter of type i matter	
FCF_i	=	Fraction of fossil carbon in the total carbon component of type i matter	
OF_i	=	Oxidation fraction or factor	
i	=	Matter type of the Solid Waste incinerated such as paper/cardboard, textile, food waste, etc.	

Note: $\sum_i WF_i = 1$

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories

Equation 8.7 **CH_4 emissions from the incineration of waste**

$$CH_4 \text{ Emissions} = \sum (IW_i \times EF_i) \times 10^{-6}$$

Description			Value
CH_4 Emissions	=	CH_4 emissions in inventory year, tonnes	Computed
IW_i	=	Amount of solid waste of type i incinerated or open-burned, tonnes	User Input
EF_i	=	Aggregate CH_4 emission factor, g CH_4/ton of waste type i	User Input (default values provided in Table 8.5 below)
10^{-6}	=	Converting factor from gCH_4 to t CH_4	
i	=	Category or type of waste incinerated/open-burned, specified as follows: MSW municipal solid waste, ISW: industrial solid waste, HW: hazardous waste, CW: clinical waste, SS: sewage sludge, others (that must be specified)	User input

Equation 8.8 **N_2O emissions from the incineration of waste**

$$N_2O \text{ Emissions} = \sum (IW_i \times EF_i) \times 10^{-6}$$

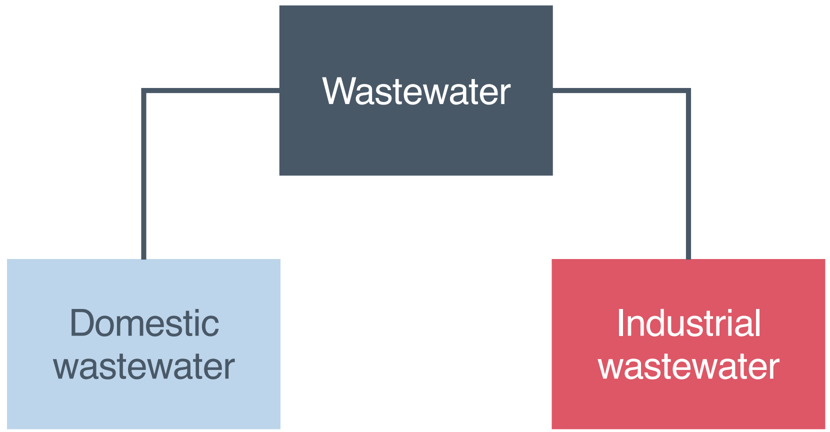
Description			Value
N_2O Emissions	=	N_2O emissions in inventory year, in tonnes	Computed
IW_i	=	Amount of solid waste of type i incinerated or open-burned, in tonnes	User Input
EF_i	=	Aggregate N_2O emission factor, g CH_4/ton of waste type i	User Input (default values provided in Table 8.6 below)
i	=	Category or type of waste incinerated/open-burned, specified as follows: MSW: municipal solid waste, ISW: industrial solid waste, HW: hazardous waste, CW: clinical waste, SS: sewage sludge, others (that must be specified)	User input

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, chapter 5: Incineration and Open Burning of Waste

Wastewater

Municipal wastewater can be treated **aerobically** (in presence of oxygen) or **anaerobically** (in absence of oxygen).

- When wastewater is treated anaerobically, **methane (CH_4)** is produced
- Both types of treatment also generate **nitrous oxide (N_2O)** through the nitrification and denitrification of sewage nitrogen. Some nitrogen can also be removed as sludge
- **CO_2** from wastewater treatment is considered to be of biogenic origin and reported outside the scopes (ie CO_2(b))



Methane from wastewater treatment

In order to quantify the CH_4 emissions from both industrial and domestic wastewater treatment, cities will need to know:

- Quantity of wastewater generated.
- How wastewater and sewage are treated
- Wastewater's source and organic content. This can be estimated based on population of the cities served and the city's composition in the case of domestic wastewater, or the city's industrial sector in the case of industrial wastewater.
- % of wastewater treated from other cities at facilities located within the city's boundaries (this can be estimated based upon other cities' population served)

Equation 8.9 **CH_4 generation from wastewater treatment**

$$CH_4 \text{ emissions} = \sum_i [(TOW_i - S_i)\, EF_i - R_i] \times 10^{-3}$$

Description			Value
CH_4 emissions	=	Total CH_4 emissions in metric tonnes	Computed
TOW_i	=	Organic content in the wastewater **For domestic wastewater:** total organics in wastewater in inventory year, kg BOD/yr[Note 1] **For industrial wastewater:** total organically degradable material in wastewater from industry i in inventory year, kg COD/yr	Equation 8.10
EF_i	=	Emission factor kg CH_4 per kg BOD or kg CH_4 per kg COD[Note 2]	Equation 8.10
S_i	=	Organic component removed as sludge in inventory year, kg COD/yr or kg BOD/yr	User input
R_i	=	Amount of CH_4 recovered in inventory year, kg CH_4/yr	User input
i	=	Type of wastewater **For domestic wastewater:** income group for each wastewater treatment and handling system **For industrial wastewater:** total organically degradable material in wastewater from industry i in inventory year, kg COD/yr	Equation 8.10

Note 1: Biochemical Oxygen Demand (BOD): The BOD concentration indicates only the amount of carbon that is aerobically biodegradable. The standard measurement for BOD is a 5-day test, denoted as BOD_5. The term "BOD" in this chapter refers to BOD_5.
Note 2: Chemical Oxygen Demand (COD): COD measures the total material available for chemical oxidation (both biodegradable and non-biodegradable).
Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, chapter 6: Wastewater Treatment and Discharge

Equation 8.10 **Organic content and emission factors in domestic wastewater**[55]

$$TOW_i = P \times BOD \times I \times 365$$

$$EF_j = B_o \times MCF_j \times U_i \times T_{i,j}$$

Description			Value
TOW_i	=	For domestic wastewater: total organics in wastewater in inventory year, kg BOD/yr	Computed
P		City's population in inventory year (person)	User input[56]
BOD	=	City-specific per capita BOD in inventory year, g/person/day	User input
I	=	Correction factor for additional industrial BOD discharged into sewers	In the absence of expert judgment, a city may apply default value 1.25 for collected wastewater, and 1.00 for uncollected.[57]
EF_i	=	Emission factor for each treatment and handling system	Computed
B_o	=	Maximum CH_4 producing capacity	User input or default value: • 0.6 kg CH_4/kg BOD • 0.25 kg CH_4/kg COD
MCF_j	=	Methane correction factor (fraction)	User input[58]
U_i	=	Fraction of population in income group i in inventory year	User input[59]
$T_{i,j}$	=	Degree of utilization (ratio) of treatment/discharge pathway or system, j, for each income group fraction i in inventory year	

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, chapter 6: Wastewater Treatment and Discharge

Nitrous oxide from wastewater treatment

Nitrous oxide (N_2O) emissions can occur as direct emissions from treatment plants or as indirect emissions from wastewater after disposal of effluent into waterways, lakes or seas.

- **Direct emissions** from nitrification and denitrification at wastewater treatment plants are considered as a minor source and not quantified here
- Therefore, the GPC addresses **indirect N_2O emissions** from wastewater treatment effluent that is discharged into aquatic environments

Equation 8.11 Indirect N_2O emissions from wastewater effluent

$$N_2O \text{ emissions} = [(P \times Protein \times F_{NPR} \times F_{NON-CON} \times F_{IND-COM}) - N_{SLUDGE}] \times EF_{EFFLUENT} \times 44/28 \times 10^{-3}$$

Description			Value
N_2O emissions	=	Total N_2O emissions in tonnes	Computed
P	=	Total population served by the water treatment plant	User input
Protein	=	Annual per capita protein consumption, kg/person/yr	User input
$F_{NON-CON}$	=	Factor to adjust for non-consumed protein	1.1 for countries with no garbage disposals, 1.4 for countries with garbage disposals
F_{NPR}	=	Fraction of nitrogen in protein	0.16, kg N/kg protein
$F_{IND-COM}$	=	Factor for industrial and commercial co-discharged protein into the sewer system	1.25
N_{SLUDGE}	=	Nitrogen removed with sludge, kg N/yr	User input or default value: 0
$EF_{EFFLUENT}$	=	Emission factor for N_2O emissions from discharged to wastewater in kg N_2O-N per kg N_2O	0.005
44/ 28	=	The conversion of kg N_2O-N into kg N_2O	

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, chapter 6: Wastewater Treatment and Discharge

Wastewater (III.4)

Cape Town

Equations 8.9, 8.10 and 8.11 in GPC using default factors from national inventory report

Rio de Janerio

Activity data from wastewater management companies combined with IPCC emission factors

Oslo

Emissions data from Statistics Norway based on nitrogen removal at specific treatment plants

Module E

Waste

04

Energy or Waste

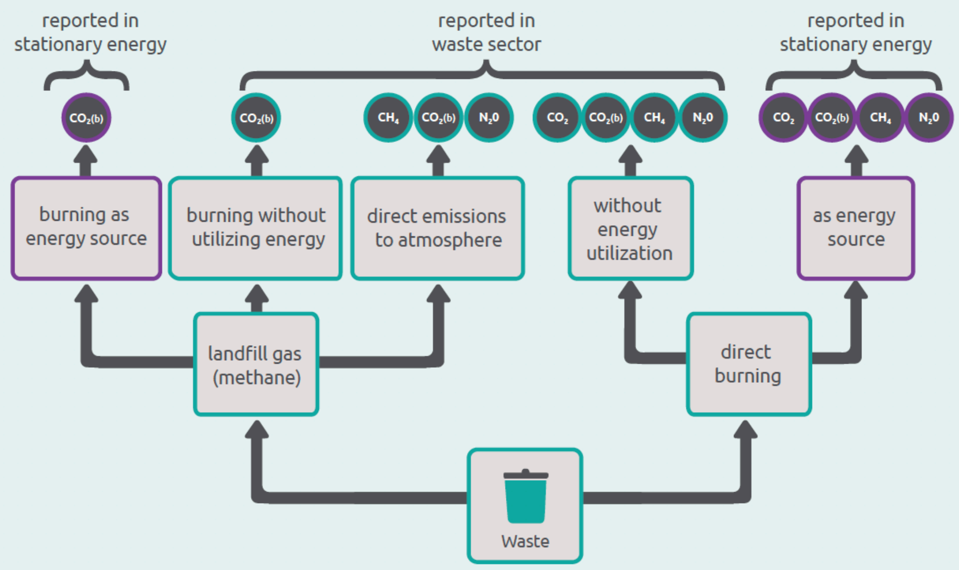
Energy or Waste?

If **methane** is recovered from solid waste or wastewater treatment facilities and used as energy sources, those GHG emissions shall be reported under **Stationary energy**.

Emissions from waste incineration without **energy** recovery are reported under the **Waste** sector, while emissions from incineration with energy recovery are reported in **Stationary energy**, both with a distinction between fossil and biogenic carbon dioxide (CO_2(b)) emissions.

Box 8.1 Waste and stationary energy emissions

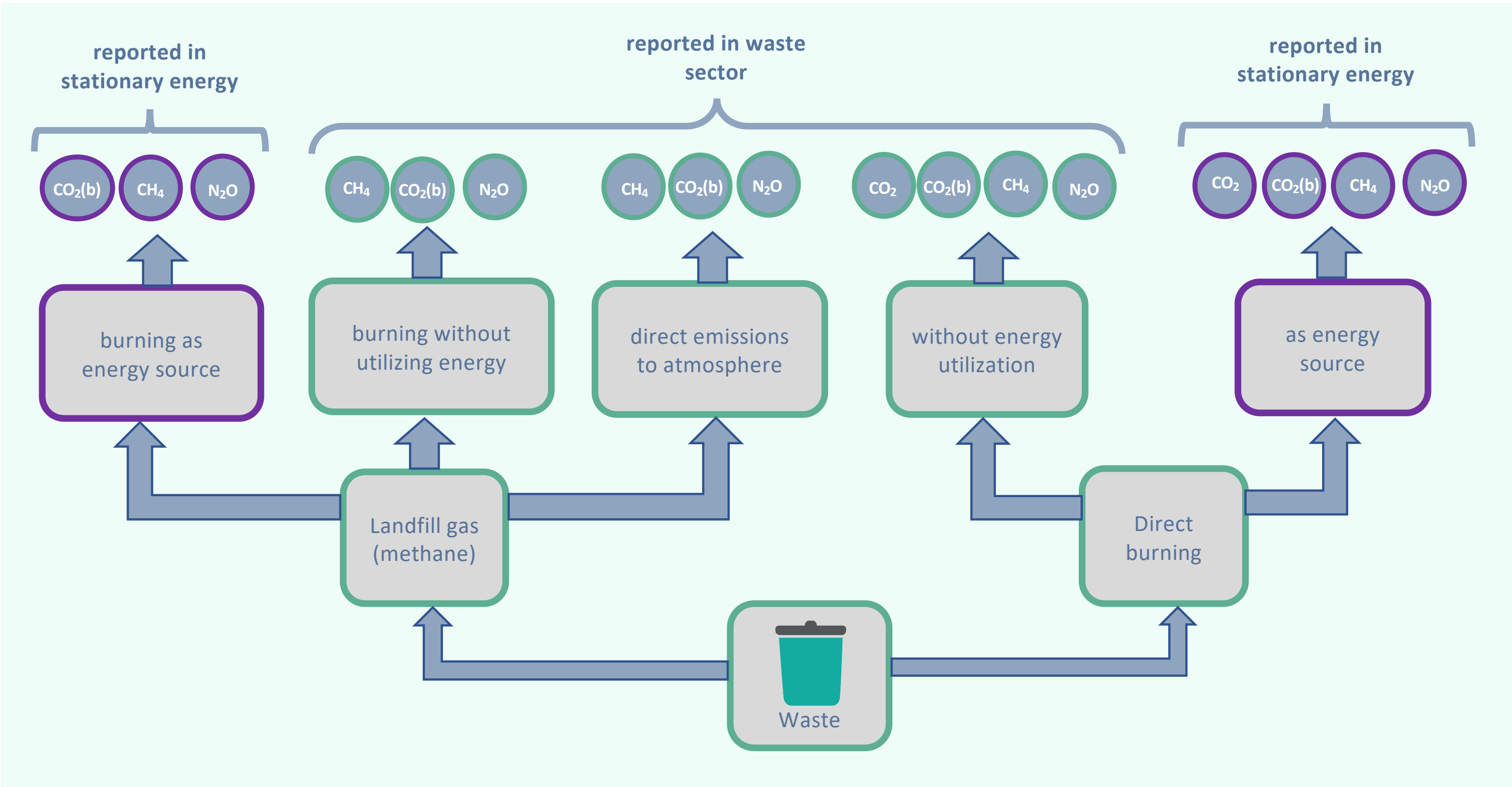
As described in Chapter 6, *Stationary Energy* (Table 6.7), if methane is recovered from solid waste or wastewater treatment facilities as energy sources, those GHG emissions shall be reported under *Stationary Energy*. Emissions from waste incineration without energy recovery are reported under the *Waste* sector, while emissions from incineration with energy recovery are reported in *Stationary Energy*, both with a distinction between fossil and biogenic carbon dioxide (CO_2(b)) emissions. See below for an illustrated explanation of these differences.



Energy or Waste?

Activity	Purpose	CO_2	CH_4 and N_2O
Landfill gas combustion	As part of waste disposal process	Report biogenic CO_2 emissions under Waste sector (separately from any fossil CO_2 emissions)	Report emissions under Waste sector
	Energy generation	Report biogenic CO_2 under Stationary Energy sector (separately from any fossil CO_2 emissions)	Report emissions under Stationary Energy sector
Waste incineration	Waste disposal (no energy recovery)	Report CO_2 emissions under Waste sector (with biogenic CO_2 reported separately from any fossil CO_2 emissions)	Report emissions as Waste sector
	Energy generation	Report CO_2 emissions under Stationary Energy sector (with biogenic CO_2 reported separately from any fossil CO_2 emissions)	Report emissions under Stationary Energy sector
Biomass incineration	Waste disposal	Report biogenic CO_2 emissions under Waste sector (separately from any fossil CO_2 emissions)	Report emissions under Waste sector
	Energy generation	Report biogenic CO_2 emissions under Stationary Energy sector (separately from any fossil CO_2 emissions)	Report emissions under Stationary Energy sector

Energy or Waste?



Exercise: Energy or Waste

Activity	Sector
Landfill gas used to generate electricity	Stationary energy
Open burning of waste	Waste
Atmospheric releases of landfill gas	Waste
Biogas from anaerobic digestion of waste used in vehicle fleet	Transportation
Flaring of landfill gas	Waste
Incineration of waste with energy recovery	Stationary energy
Electricity used in recycling depot	Stationary energy

Module E

Waste

05

Waste calculators

Waste calculators

CIRIS	Introduction	Set-up	Inventory	Calculators	Results	Notes
	Fugitive emissions	Solid waste disposal	Biological treatment	Incineration	Wastewater	

Waste calculators

Key features
Based on IPCC 2006 Guidelines for National Greenhouse Gas Inventories
Designed to be used with minimum user-input
City information tab must be completed
All red cells in calculator tabs must be filled in
Grey cells contain formulas and default values
White cells allow users to override default value
All formulas are set out in boxes
All data used is referenced in data tables

Waste calculators

CIRIS	Introduction	Set-up	Inventory	Calculators	Results	Notes
	City information	Data sources	Emission factors	IPPU Emission factors		

City information	Details
A. INVENTORY BOUNDARY	
City	
Country	
Population	
C. INVENRTORY INFORMATION	
Global warming potential	

Solid waste disposal

Methane commitment model only

Methane (CH_4) generated in landfill

= Mass of solid waste sent to landfill * Methane generation potential (L_0)

Methane (CH_4) generation potential

= L_0* degradable organic carbon (DOC) * Fraction of DOC that is degraded (DOC_F) * Fraction of methane in landfill gas (F) * 16/12 (molecular weight ratio of CH_4 and C)

Corrections if collection efficiency < 100%

Exercise: Solid waste disposal

City information	Details
Region	Asia
Sub-region	South-Eastern Asia
Total waste deposited in landfill	1.000 metric tonnes
Landfill gas collection efficiency	75% (intermediate soil cover and active gas collection)
% of landfill gas used as energy	0%
Management of landfill	Managed
	368 tCO_2e (5AR; Population = 1,000,000)

Biological treatment

Methane (CH_4) emissions

= Mass of organic waste per treatment type (composting or anaerobic digestion) * Emission factor for treatment type – Amount of methane recovered (assume 0)

Nitrous oxide (N_2O) emissions

= Mass of organic waste per treatment type (composting or anaerobic digestion) * Emission factor for treatment type

Exercise: Biological treatment

City information	Details
Total organic waste treated biologically	1,000 metric tonnes
Type of waste (wet or dry)	Wet waste (most commonly used for waste)
Treatment type (must add to 100%)	Composting (75%)
	Anaerobic digestion (25%)
	137 tCO_2e (5AR; Population = 1,000,000)

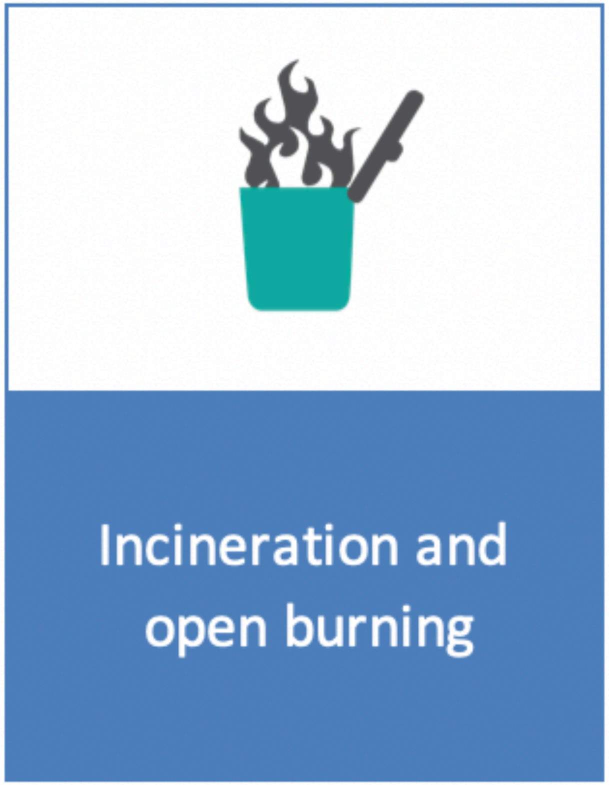
Incineration and open burning

CO_2 = Mass of waste incinerated * [Fraction of waste * Dry matter content * Fraction of carbon in dry matter * Fraction of fossil carbon in total carbon component * oxidation factor * 44/12 (molecular weight ratio of and CO_2 and carbon)]

CH_4 = Mass of waste incinerated * Emission factor

N_2O = Mass of waste incinerated * Emission factor

For each waste type



Exercise: Incineration

City information	Details
Region	Asia
Sub-region	South-Eastern Asia
Management	Incineration
Total waste sent for incineration	1,000,000 metric tonnes
% waste containing type i matter (must add to 100%)	Food waste (50%); Paper (20%); Wood (5%); Garden waste (10%); Plastics (15%)
CH_4: Type of incineration / Technology	Batch type incineration / Stoker
N_2O: Type of waste / Type of technology / Weight basis	MSW / Batch type incinerators / Wet weight
	460,887 tCO_2e (5AR; Population = 1,000,000)

Wastewater

Methane (CH_4) emissions

= (Organic content of wastewater – Organic component removed as sludge) * Emission factor – Amount of CH_4 recovered

Organic content of wastewater

= Population * City-specific per capita biochemical oxygen demand

Emission factor

= Maximum CH4 producing capacity * Methane correction factor * Fraction of population in different income groups * % utilization of treatment type per income group

Wastewater

Nitrous oxide (N_2O) emissions

= N_2O emission from wastewater effluent + N_2O emissions from centralized treatment processes

N_2O from wastewater effluent

= [(Population * protein consumption * Fraction of nitrogen in protein * Fraction of non-consumed protein added to wastewater * Fraction of industrial and commercial co-discharged protein) – Nitrogen removed with sludge - N_2O emissions from centralized wastewater treatment processes] * Emission factor * 44/28 (conversion of N_2O-N into N_2O)

N_2O emissions from centralized treatment processes

= Population * Degree of utilization of modern wastewater treatment plants * Fraction of industrial and commercial co-discharged protein * Emission factor

Exercise: Wastewater (dom-com)

City information	Details
Proxy region	Asia_MiddleEast_LatinAmerica
Proxy country for wastewater treatment	Indonesia
Proxy country for protein consumption	Malaysia
Garbage disposal	No garbage disposals
Climate (wet/dry)	Wet
	171,132 tCO_2e (5AR; Population = 1,000,000)

Module E

Waste

06

Practical

Practical

Practical

	Task	
1	Identify all different types of waste generated across your city from residential (municipal), commercial and industrial sources. List them in Table 1	20m
2	Where does your city's waste go? Identify all waste treatment facilities within your city boundary, and any out of boundary waste treatment facilities used by your city. Complete Table 2	
3	Estimate GHG emissions for all sub-sectors using (a) the CIRIS calculators and (b) by scaling down national waste data from BUR3	40m
4	Record your data in Table 3, clearly documenting methodologies and data sources used. For now, assume all your city's waste is treated outside of your city boundary. Where no GHG emissions occur or are deemed insignificant, use "NO". For scope 3 sources, use "NE".	HW
5	Consolidate the above information into Table 4 and identify what activity data and emission factors you will need to estimate GHG emissions for Waste, and where you will source this from, including (a) quantity of waste generated by waste type, (b) quantity and location of waste treated by treatment type	

Practical

	Task	
1	Identify all different types of waste generated across your city from residential (municipal), commercial and industrial sources. List them in Table 1	20m
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Workbook

GTALCC GHG Accounting - Participant handbook

Exercises	
Module B	Calculating GHG emissions
	Reviewing an inventory
Module C	Stationary energy
Module D	Transportation
Module E	Waste
Module F	IPPU and AFOLU

Tables	
Table 1	GHG emission sources
Table 2	Fuel types
Table 3	GPC
Table 4	Action plan

Reference
GPC
GWP
Notation keys
Checklist

Table 1: Waste types

Sub-sector	Waste types
Residential (municipal)	
Commercial	
Industrial	

Checklist: Waste types

Waste types			Treatment types
All waste	All organic waste	Paper / cardboard	Landfill sites
Municipal solid waste	Food waste	Wood	Unmanaged waste disposal
Sludge	Garden and park waste	Textiles	Composting
Industrial waste	Sludge	Nappies	Anaerobic digestion
Clinical		Rubber / leather	Open burning
Hazardous		Plastics	Incineration with energy recovery
Construction		Metal	Incineration without energy recovery
		Glass	All wastewater
		Other	Domestic wastewater
			Industrial wastewater

Practical

	Task	
1	Identify all different types of waste generated across your city from residential (municipal), commercial and industrial sources. List them in Table 1	20m
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Table 2: Waste treatment facilities

Sub-sector		In boundary	Out of boundary
III.1	Solid waste		
III.2	Biological treatment		
III.3	Incineration and open burning		
III.4	Wastewater		

Practical

	Task	
1	Identify all different types of waste generated across your city from residential (municipal), commercial and industrial sources. List them in Table 1	20m
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Calculations

Estimate GHG emissions for all sub-sectors using:

(a) the CIRIS calculators

(b) by scaling down national waste data from BUR3

In Module B, we already estimated GHG emissions for all waste sub-sectors using the proxy city approach (Kuala Lumpur)

We'll then compare the different results, discuss any differences and choose a preferred method to use for now

Recommended waste sector methodologies:

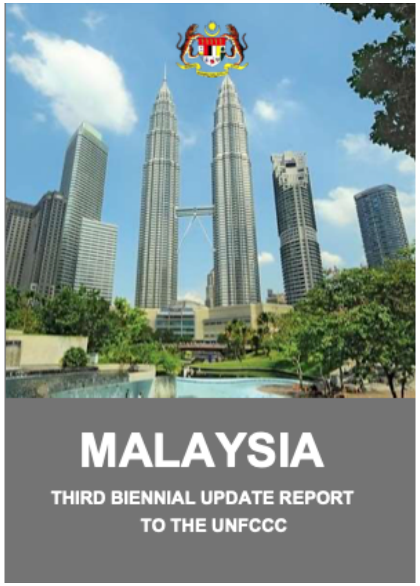
Use local activity data and emission factors

Use a proxy city

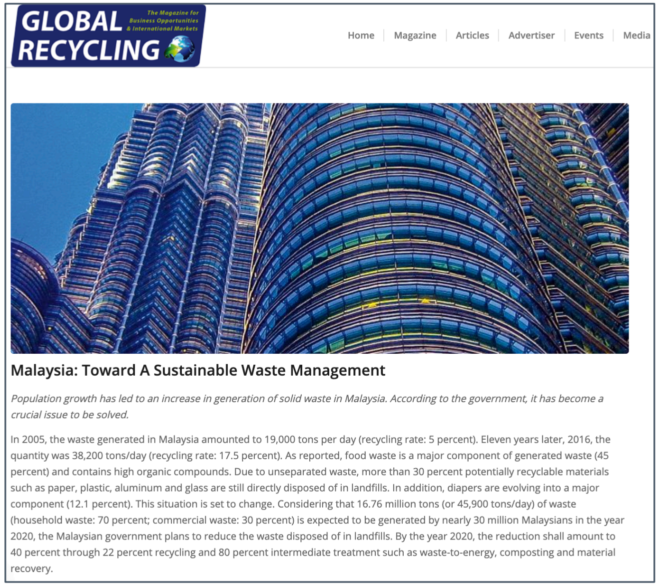
Scale down from national

Use CIRIS calculators

Data sources



Source: BUR3



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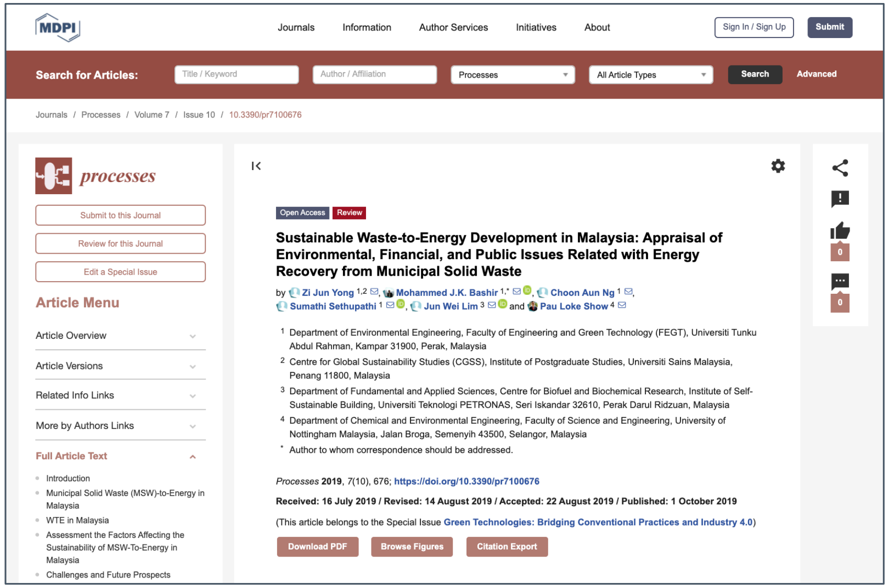
Malaysia: Toward A Sustainable Waste Management

Population growth has led to an increase in generation of solid waste in Malaysia. According to the government, it has become a crucial issue to be solved.

In 2005, the waste generated in Malaysia amounted to 19,000 tons per day (recycling rate: 5 percent). Eleven years later, 2016, the quantity was 38,200 tons/day (recycling rate: 17.5 percent). As reported, food waste is a major component of generated waste (45 percent) and contains high organic compounds. Due to unseparated waste, more than 30 percent potentially recyclable materials such as paper, plastic, aluminum and glass are still directly disposed of in landfills. In addition, diapers are evolving into a major component (12.1 percent). This situation is set to change. Considering that 16.76 million tons (or 45,900 tons/day) of waste (household waste: 70 percent; commercial waste: 30 percent) is expected to be generated by nearly 30 million Malaysians in the year 2020, the Malaysian government plans to reduce the waste disposed of in landfills. By the year 2020, the reduction shall amount to 40 percent through 22 percent recycling and 80 percent intermediate treatment such as waste-to-energy, composting and material recovery.

Source: https://global-recycling.info/archives/1451



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  - Assessment the Factors Affecting the Sustainability of MSW-To-Energy in Malaysia
  - Challenges and Future Prospects

Open Access | Review

Sustainable Waste-to-Energy Development in Malaysia: Appraisal of Environmental, Financial, and Public Issues Related with Energy Recovery from Municipal Solid Waste

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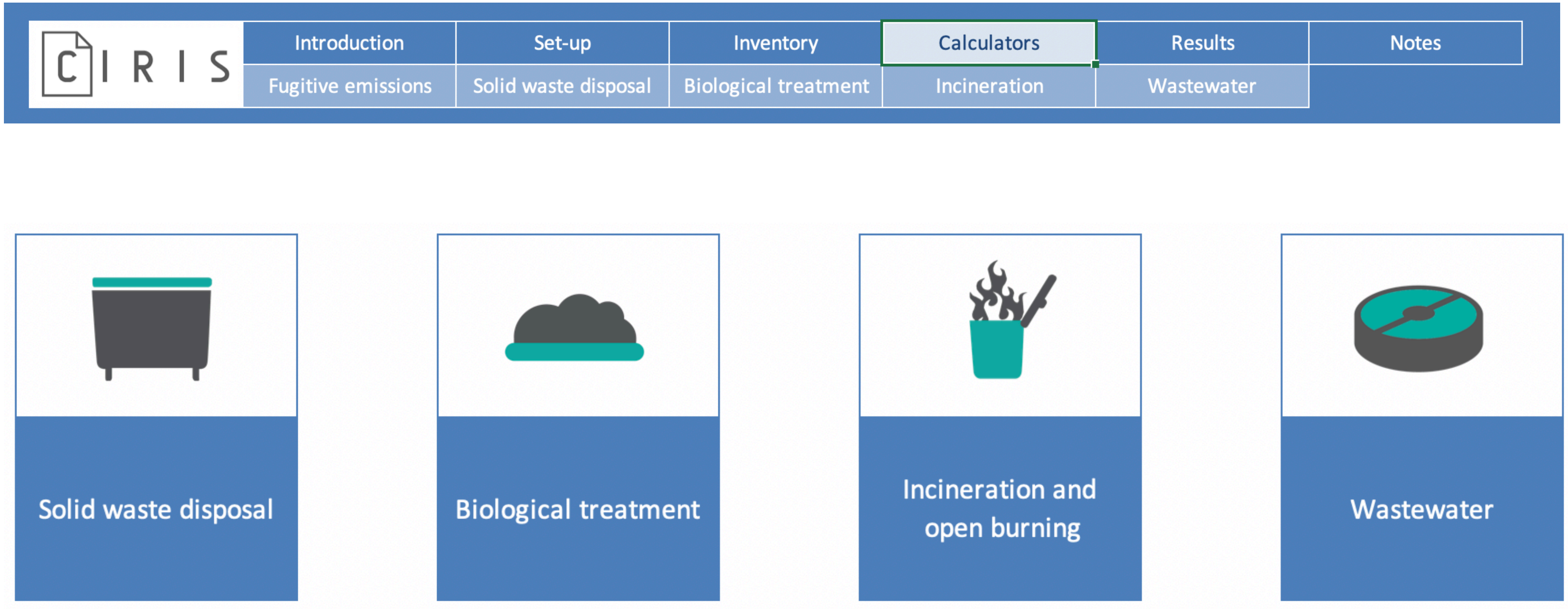
Source: https://www.mdpi.com/2227-9717/7/10/676/htm

Note: Population for Malaysia in 2017 = 31,600,000

(a) Waste calculators



Workbook

GTALCC GHG Accounting - Participant handbook

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GWP
Notation keys
Checklist

Solid waste disposal

Solid waste disposal	
Region	Asia
Sub-region	South-Eastern Asia
Total waste deposited in landfill	Assume 38,200 metric tonnes per day, of which 17.5% is recycled. 89% of the remaining waste is sent to landfill. Scale according to your city's share of the national population
Landfill gas collection efficiency	0%. Assume most do not have active gas collection
% of landfill gas used as energy	0%. If assuming collection = 0, then this will be 0 as well
Management of landfill	No further information so assumed Uncategorised (MCF = 0.6)

In 2005, the waste generated in Malaysia amounted to 19,000 tons per day (recycling rate: 5 percent). Eleven years later, 2016, the quantity was 38,200 tons/day (recycling rate: 17.5 percent). As reported, food waste is a major component of generated waste (45 percent) and contains high organic compounds. Due to unseparated waste, more than 30 percent potentially recyclable materials such as paper, plastic, aluminum and glass are still directly disposed of in landfills. In addition, diapers are evolving into a major component (12.1 percent). This situation is set to change. Considering that 16.76 million tons (or 45,900 tons/day) of waste (household waste: 70 percent; commercial waste: 30 percent) is expected to be generated by nearly 30 million Malaysians in the year 2020, the Malaysian government plans to reduce the waste disposed of in landfills. By the year 2020, the reduction shall amount to 40 percent through 22 percent recycling and 80 percent intermediate treatment such as waste-to-energy, composting and material recovery.

Source: https://global-recycling.info/archives/1451

As Malaysia is a fast-developing country, its prospects of sustainable energy generation are at the center of debate. Malaysian municipal solid waste (MSW) is projected to have a 3-5% increase in annual generation rate at the same time an increase of 4-8% for electricity demand. In Malaysia, most of the landfills are open dumpsite and 89% of the collected MSW end up in landfills. Furthermore, huge attention is being focused on converting MSW into energy due to the enormous amount of daily MSW being generated. Sanitary landfill to capture methane from waste landfill gas (LFG) and incineration in a combined heat and power plant (CHP) are common MSW-to-energy technologies in Malaysia. MSW in Malaysia contains 45% organic fraction thus landfill contributes as a potential LFG source. Waste-to-energy (WTE) technologies in treating MSW potentially provide an attractive economic investment since its

A total of 89% of the Malaysian MSW generated directly enter into landfills with minimal treatment, where only 1% of the total incoming MSW receive proper treatment [1]. In Malaysia, 50% of landfills are open dumping sites; 30% use-controlled tipping; 12% are controlled landfills with daily cover; 5% are sanitary landfills without leachate treatment facility; and the other 5% are sanitary landfills with leachate treatment. Within the coming 10 years (by 2030), over 80% of the Malaysian open dumping landfill sites are to be shut down due to reaching full capacity. The major MSW fractions generated in Malaysia are 45% organic material, 13% plastics, 12% diapers, 9% paper, 3% glass, 3% metal and others [1,5]. **Figure 3** shows the composition of solid waste in Malaysia. It can be concluded that organic waste represents the largest portion of the total solid waste produced by Malaysians therefore making landfills a potential

Source: https://www.mdpi.com/2227-9717/7/10/676/htm

Solid waste disposal

Solid waste disposal	
Region	Asia
Sub-region	South-Eastern Asia
Total waste deposited in landfill	Assume 38,200 metric tonnes per day, of which 17.5% is recycled. 89% of the remaining waste is sent to landfill. Scale according to your city's share of the national population
Landfill gas collection efficiency	0%. Assume most do not have active gas collection
% of landfill gas used as energy	0%. If assuming collection = 0, then this will be 0 as well
Management of landfill	No further information so assumed Uncategorised (MCF = 0.6)

17.5 % recycled

Scale

$$= 38\,200 * 0.825 * 365 * 0.89 * (\text{your city population} / 31\,600\,000)$$

Per day

Remaining 89% sent to landfill

Biological treatment

Biological treatment	
Total organic waste treated biologically	2.49 Gg of waste in Malaysia is treated biologically (=2,490 tonnes). Scale according to your city's share of the national population
Type of waste (wet or dry)	Wet waste
Treatment type	No data found so assume 50/50 split between composting and anaerobic digestion

Table B10a: Waste Background Table for GHG Inventory Year 2016 – CO_2, CH_4, N_2O Emissions

Categories	Type of Activity Data	Unit	Emissions Factor CO_2 (Gg/unit activity data)	Emissions Factor CH_4 (Gg/unit activity data)	Emissions Factor N_2O (Gg/unit activity data)	Emissions CO_2 (Gg)	Emissions CH_4 (Gg)	Emissions N_2O (Gg)
4A Solid Waste Disposal							448.57	NA, NO
4A1 Managed Waste Disposal Sites	675.52	Gg		1.00	NA		22.43	NA
4A2 Unmanaged Waste Disposal Sites	12,834.93	Gg		0.80	NA		426.14	NA
4A3 Uncategorised Waste Disposal Sites	NO	Gg		0.60	NO		NO	NO
4B Biological Treatment of Solid Waste	2.49	Gg		4.00	0.24		0.01	0.00
4C Incineration and Open Burning of Waste						31.06	0.08	0.01
4C1 Waste Incineration	60.21	Gg				30.36	-	0.01
Hazardous Waste	43.92	Gg	0.48	0	0.00	21.04	-	0.00
Clinical Waste	16.29	Gg	0.57	0	0.00	9.32	-	0.00
Fossil Liquid Waste	0.00	Gg	2.93	NA	NA	0.01	NA	NA
4C2 Open Burning of Waste	11.85	Gg	0.06	0.01	0.00	0.70	0.08	0.00
4D Wastewater Treatment and Discharge							621.44	1.26
4D1 Domestic Wastewater Treatment and Discharge							64.33	1.26
CH_4 Emissions	502,972,650.00	kg					64.33	
Centralized Aerobic Treatment Plant	318,661,340.24	kg		0			0.00	
Septic Tank	86,714,496.75	kg		0.00			24.97	
Latrine 3 (Pour Flush)	97,596,813.01	kg		0.00			39.35	
Sea, River and Lake Discharge	0.00	kg		0.00			0.00	
N_2O Emissions	160,566,584.64	kg			0.00			1.26
4D2 Industrial Wastewater Treatment and Discharge							557.12	NA
CH_4 Emissions	3,229,744,342.75	kg					557.12	
Palm Oil Mill Effluent	2,799,644,962.00	kg		0.00			550.66	
Natural Rubber (SMR/Latex)	21,228,927.75	kg		0.00			4.25	
Pulp and Paper	319,770,000.00	kg		0.00			1.10	
Petroleum Refineries	14,726.00	kg		0.00			0.00	
Meat & Poultry	89,085,727.00	kg		0.00			1.11	
N_2O Emissions	NA	kg			NA			NA
4E Other (please specify)	NO	NO	NO	NO	NO	NO	NO	NO

Source: BUR3

Incineration

Incineration	
Region	Asia
Sub-region	South-Eastern Asia
Management	Incineration
Total waste sent for incineration	Assume national incineration capacity of 210 tonnes MSW per day
% waste containing type i matter	Food waste (45%) Paper (10%) Nappies (12%) Plastics (10%) Metal (5%) Glass (5%) Other (13%)
CH_4: Type of incineration / Technology	Assume: Continuous incineration / Stoker
N2O: Type of waste / Type of technology / Weight basis	Assume: MSW / Batch type incinerators / Wet weight

Table 3. The summary of the five incineration plants which are funded by the Ministry of Local Government and Housing (MHLG) in Malaysia [28].

Location	Capacity (MSW tones/day)	Electricity Generation	Current Status	Year of Completion
Pulau-Pangkor	20	Nil	Active	2009
Pulau-Tioman	15	Nil	Closed	2010
Pulau-Langkawi	100	1 MW	Active	2010
Cameron Highlands	15	Nil	Active	2010
Labuan	60	Nil	Active	2010

A total of 89% of the Malaysian MSW generated directly enter into landfills with minimal treatment, where only 1% of the total incoming MSW receive proper treatment [1]. In Malaysia, 50% of landfills are open dumping sites; 30% use-controlled tipping; 12% are controlled landfills with daily cover; 5% are sanitary landfills without leachate treatment facility; and the other 5% are sanitary landfills with leachate treatment. Within the coming 10 years (by 2030), over 80% of the Malaysian open dumping landfill sites are to be shut down due to reaching full capacity. The major MSW fractions generated in Malaysia are 45% organic material, 13% plastics, 12% diapers, 9% paper, 3% glass, 3% metal and others [1,5]. Figure 3 shows the composition of solid waste in Malaysia. It can be concluded that organic waste represents the largest portion of the total solid waste produced by Malaysians therefore making landfills a potential source of landfill gas (LFG) [6]. Nevertheless, decommissioning a landfill involves the process of obtaining other lands and is an environmentally challenging process. This will make land scarcer in the future. Employing MSW to energy can solve two problems at once, namely the demand for more energy and the continuous increase in MSW generation. Hence, waste is no longer an undesired product from the society but a new resource by treating non-recyclables and non-reusables from MSW to generate a substantial amount of energy for urban use while preserving scarce lands [7].

Source: https://www.mdpi.com/2227-9717/7/10/676/htm

Wastewater

Wastewater	
Proxy region	Asia_MiddleEast_LatinA merica
Proxy country for wastewater treatment	Indonesia
Proxy country for protein consumption	Malaysia
Garbage disposal	No garbage disposals
% urban high income	80%
% urban low income	20%
Climate (wet/dry)	Wet
Industrial wastewater	Assume no industrial wastewater

(b) Scale down using national data

Scale down national GHG emissions data from BUR3 for all four GPC sub-sectors using population as a scaling factor:

- Solid Waste Disposal
- Biological treatment of Solid Waste
- Incineration and Open Burning of Waste
- Domestic Wastewater Treatment and Discharge

$$\text{Scaling factor} = \frac{\text{Your population}}{\text{Malaysia population}}$$

Note: Population for Malaysia in 2017 = 31,600,000

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Table 2.5: Approach 1 Key Category Analysis of Greenhouse Gas Emissions for 2016, without Land Use, Land-Use Change and Forestry Emission

Sector	IPCC Category Code	IPCC Category Name	Gas	2016 estimate (Gg CO_2 eq)	Level Assessment (%)	Cumulative (%)
Energy	1.A.1	Energy Industries - Solid Fuels	CO_2	68,189.15	21.52%	21.52%
Energy	1.A.3.b	Road Transportation	CO_2	55,188.34	17.42%	38.94%
Energy	1.A.1	Energy Industries - Gaseous Fuels	CO_2	52,070.82	16.43%	55.38%
Energy	1.B.2.b	Fugitive Emissions from Fuels - Natural Gas	CH_4	24,446.89	7.72%	63.09%
Waste	4.D.2	Industrial Wastewater Treatment and Discharge	CH_4	13,927.93	4.40%	67.49%
Waste	4.A	Solid Waste Disposal	CH_4	11,214.23	3.54%	71.03%
Energy	1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	CO_2	10,896.28	3.44%	74.47%
Energy	1.A.1	Energy Industries - Liquid Fuels	CO_2	10,663.81	3.37%	77.83%
IPPU	2.A.1	Cement Production	CO_2	9,125.90	2.88%	80.71%
Energy	1.A.2	Manufacturing Industries and Construction - Solid Fuels	CO_2	6,795.19	2.14%	82.86%
Energy	1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CO_2	6,164.27	1.95%	84.80%
Energy	1.A.3.d	Transport - Water-borne Navigation - Liquid Fuels	CO_2	5,505.04	1.74%	86.54%
Energy	1.A.4	Other Sectors - Liquid Fuels	CO_2	5,260.26	1.66%	88.20%
IPPU	2.A.4	Other Process Uses of Carbonates -	CO_2	4,184.05	1.32%	89.52%

Sector	IPCC Category Code	IPCC Category Name	Gas	2016 estimate (Gg CO_2 eq)	Level Assessment (%)	Cumulative (%)
		Limestone and Dolomite				
AFOLU-Agriculture	3.C.4	Direct N_2O Emissions from Managed Soils	N_2O	4,052.61	1.28%	90.80%
IPPU	2.B.8	Petrochemical and Carbon Black Production	CO_2	3,583.40	1.13%	91.93%
AFOLU-Agriculture	3.C.7	Rice Cultivations	CH_4	2,265.20	0.71%	92.65%
IPPU	2.C.3	Aluminium Production	PFC-14	2,246.56	0.71%	93.36%
Energy	1.B.2.a	Fugitive Emissions from Fuel - Oil	CO_2	1,846.14	0.58%	93.94%
Waste	4.D.1	Domestic Wastewater Treatment and Discharge	CH_4	1,608.12	0.51%	94.45%
IPPU	2.C.1	Iron and Steel Production	CO_2	1,384.51	0.44%	94.88%
AFOLU-Agriculture	3.A.1	Enteric Fermentation	CH_4	1,370.44	0.43%	95.31%

Note: Population for Malaysia in 2017 = 31,600,000

Note: all emissions in CO_2e: CO_2e = CO_2e * scaling factor

Source: BUR3

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Table B6: Waste Sectoral Table for GHG Inventory Year 2016

Categories	CO_2	CH_4	N_2O	NO_x	CO	NMVOCs	SO_2
	(Gg)						
4 WASTE	31.06	1,070.10	1.27	0.00	0.00	NA, NE	0.00
4A Solid Waste Disposal		448.57	NA	NA	NA	NA	NA
4A1 Managed Waste Disposal Sites		22.43	NA	NA	NA	NA	NA
4A2 Unmanaged Waste Disposal Sites		426.14	NA	NA	NA	NA	NA
4A3 Uncategorised Waste Disposal Sites		NO	NO	NO	NO	NO	NO
4B Biological Treatment of Solid Waste		0.01	0.00	NA	NA	NA	NA
4C Incineration and Open Burning of Waste	31.06	0.08	0.01	0.00	0.00	NE	0.00
4C1 Waste Incineration	30.36	0.00	0.01	0.00	0.00	NE	0.00
4C2 Open Burning of Waste	0.70	0.08	0.00	0.00	0.00	NE	0.00
4D Wastewater Treatment and Discharge		621.44	1.26	NA	NA	NA	NA
4D1 Domestic Wastewater Treatment and Discharge		64.32	1.26	NA	NA	NA	NA
4D2 Industrial Wastewater Treatment and Discharge		557.12	NA	NA	NA	NA	NA
4E Other (please specify)	NO	NO	NO	NO	NO	NO	NO

Note: Population for Malaysia in 2017 = 31,600,000

Note: all emissions in GHG. CH_4 and N_2O will need converting using GWP: $CO_2e = CO_2 + (CH_4 * 25) + (N_2O * 298) *$ scaling factor

Source: BUR3

Use a proxy city ✓

CITY	INVENTORY YEAR	POPULATION	GDP (MILLION USD)	AREA (KM2)
Kuala Lumpur (Malaysia)	2017	1,793,000	52,097	243

	Scope 1	Scope 2	Scope 3
Kuala Lumpur	**15,548,891**	**8,969,058**	**576,105**
Stationary	**1,472,306**	**8,882,384**	**0**
Residential buildings	182,833	2,365,581	0
Commercial and institutional building and facilities	174,796	5,857,396	0
Manufacturing industries and construction	1,031,904	659,407	0
Energy industries	0	0	0
Agriculture, forestry and fishing activities	0	0	0
Non-specified sources	0	0	0
Fugitive emissions from mining, processing, storage and transportation of coal	0	0	0
Fugitive emissions from oil and natural gas systems	82,773	0	0
Transport	**13,875,481**	**86,674**	**0**
On-road transportation	13,875,481	0	0
Railways	0	86,674	0
Waterborne navigation	0	0	0
Aviation	0	0	0
Off-road transportation	0	0	0
Waste	**201,104**	**0**	**576,105**
Solid waste disposal	0	0	572,481
Biological treatment of waste	0	0	1,355
Incineration and open burning	0	0	2,269
Wastewater treatment and discharge	201,104	0	0

City waste calculations

Let's look at the results

- Different methodologies and data sources yield different results
- Big difference for biological treatment. Why?
- Can use different methodologies and data sources for validation
- Next: break emissions down by scope

Results for a city with 1,000,000 residents

	CIRIS calculators	Scale national data	Use proxy city
Landfill			
Biological treatment			
Incineration			
Wastewater			

Practical

	Task	
1	Identify all different types of waste generated across your city from residential (municipal), commercial and industrial sources. List them in Table 1	20m
2	Where does your city's waste go? Identify all waste treatment facilities within your city boundary, and any out of boundary waste treatment facilities used by your city. Complete Table 2	
3	Estimate GHG emissions for all sub-sectors using (a) the CIRIS calculators and (b) by scaling down national waste data from BUR3	40m
4	Record your data in Table 3, clearly documenting methodologies and data sources used. For now, assume all your city's waste is treated outside of your city boundary. Where no GHG emissions occur or are deemed insignificant, use "NO". For scope 3 sources, use "NE".	HW
5	Consolidate the above information into Table 4 and identify what activity data and emission factors you will need to estimate GHG emissions for Waste, and where you will source this from, including (a) quantity of waste generated by waste type, (b) quantity and location of waste treated by treatment type	

Table 3: GPC table

Sub-sector		Scope 1	Scope 2	Scope 3
III.1	Solid waste generated in the city and disposed in landfills			
	Solid waste generated outside the city and disposed in landfills			
III.2	Solid waste generated in the city that is biologically treated			
	Solid waste generated outside the city that is biologically treated			
III.3	Solid waste generated in the city that is incinerated			
	Solid waste generated outside the city that is incinerated			
III.4	Wastewater generated in the city			
	Wastewater generated outside the city			

Practical

	Task	
1	Identify all different types of waste generated across your city from residential (municipal), commercial and industrial sources. List them in Table 1	20m
2	Where does your city's waste go? Identify all waste treatment facilities within your city boundary, and any out of boundary waste treatment facilities used by your city. Complete Table 2	
3	Estimate GHG emissions for all sub-sectors using (a) the CIRIS calculators and (b) by scaling down national waste data from BUR3	40m
4	Record your data in Table 3, clearly documenting methodologies and data sources used. For now, assume all your city's waste is treated outside of your city boundary. Where no GHG emissions occur or are deemed insignificant, use "NO". For scope 3 sources, use "NE".	HW
5	Consolidate the above information into Table 4 and identify what activity data and emission factors you will need to estimate GHG emissions for Waste, and where you will source this from, including (a) quantity of waste generated by waste type, (b) quantity and location of waste treated by treatment type	

Table 4: Action plan

GPC	Data	Where from?	Action	Lead
Solid waste				
Biological treatment				
Incineration and open burning				
Wastewater				

The end

Next time: IPPU and AFOLU