Technical Appendix - Brasil:

Methods for estimating community-scale sectoral data from national and regional statistics for the purpose greenhouse gas accounting and climate action planning

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Buildings and Stationary Energy Sector

This document details the calculation approaches and data sources for producing community-level activity data and emission factors for the buildings and stationary energy sector. This sector contains the following subsectors:

Buildings and Stationary Energy Sector	
Residential buildings	Not Currently Estimated
Commercial buildings	Estimated
Municipal buildings	Not Currently Estimated
Industry	Not Currently Estimated
Agriculture, forestry and fisheries	Not Currently Estimated
Fugitive emissions	Not Currently Estimated

Commercial Buildings

Subsector Summary:

The commercial buildings subsector encompasses all GHG emitting activities from energy use in commercial buildings, including heating, cooling, and lighting. The two primary categories of GHG emitting activities within the subsector are: scope 1 emissions from fuel combustion associated with commercial buildings within the community boundary and scope 2 emissions from consumption of grid-supplied electricity.

Inclusions:

For Brasil, based on data availability and country-specific relevance, estimates for the following activity data points are produced:

- **Natural gas**, **liquefied petroleum gas**, and **biomass** used by households, based on annual fuel consumption by commercial customers at a national level.
- **Grid-supplied electricity** used by households, based on annual electricity consumption by commercial customers at a national level.

Exclusions:

Due to lack of data availability or occurrence in-country, estimates for the following activity data points are not produced:

- **Off-highway motor gasoline** consumption, e.g. for use in landscaping equipment
- **District heating, cooling,** or other non-electricity grid-supplied energy

Activity Data Coverage:

The specific data points and energy sources covered by the methodology are outlined in the table below.

Fuels/Energy Source	GHGDP Definition	Units	Scope
Natural Gas	Natural gas consumption within a community boundary for a single year for all commercial buildings	m^3	Scope 1
Liquefied petroleum gas	All liquefied petroleum gas consumption within a community boundary for a single year for all commercial buildings	m^3	Scope 1
Biomass	All biomass consumption within a community boundary for a single year for all commercial buildings	Tonnes	Scope 1

Grid Electricity	Grid-supplied electricity consumption within community boundary for a single year for all commercial buildings	kWh	Scope 2

Calculation Methodologies:

Scope 1: Natural Gas

Methodology Notes

Commercial building LPG consumption is taken from Brasil's National Energy Balance data located at the Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa (SEEG) 2018 database and data from the Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (ANP, 2016) on commercial business customer consumption, at a national level, for the year 2015 in cubic meters (m^3). Initial input data is then allocated to communities based on the **proportion of employees** in the community relative to the national totals.

Total counts of employees, by community are sourced from the Instituto Brasileiro de Geografia e Estatística's (IBGE)2010 Census and the Confederação Nacional da Indústria (CNI) portal. Furthermore, the national building Natural Gas consumption is **scaled by the percentage of employees in each community to estimate the building natural gas consumption by each community.**

Equation 1

The following equation is utilized to estimate commercial sector natural gas consumption.

$$\text{Community-scale commercial consumption} = \text{aggregate national NG consumption}_{\text{commercial}} \times \left(\frac{\text{sector employees}_{\text{community}}}{\text{sector employees}_{\text{state}}}\right)$$

Equation Data Elements

Data element	Description	Source	Units
Community-scale commercial consumption	Natural gas consumption within community boundary for a single year for all commercial buildings	Equation 1	m^3
Aggregate NG national consumption	Amount of NG fuel distributed to commercial customers within entire country in 2015	ANP (2016) SEEG (2018)	m^3

$\text{sector employees}_{\text{community}}$	Estimated number of commercial sector employees for the community in 2015	IGBE (2010) CNI (2016)	Employees
$\text{sector employees}_{state}$	Estimated number of commercial sector employees within the state in 2015	IGBE (2010) CNI (2016)	Employees

Methodology Assumptions and Potential Improvement

General assumptions and limitations

- The distribution of commercial sector natural gas consumption within a state is proportionally related to the distribution of commercial establishments and employees.
- All natural gas sold to commercial customers is consumed within the year it is delivered
- Finally, weights used in the current iteration partially do not take account of differences in the building context of each community in terms of the size of establishments. Additional weighting and calibration are necessary, however, in order to account for differences in per-employee intensities not just based on establishment sizes, but by different categories of commercial enterprises such as finance, education, and retail trade. Future iterations will incorporate these additional into final estimates.

Scope 1: Liquefied Petroleum Gas

Methodology Notes

Commercial building LPG consumption is taken from Brasil's National Energy Balance data located at the Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa (SEEG) 2018 database and data from the Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (ANP, 2016) on commercial business customer consumption, at a national level, for the year 2015 in cubic meters (M^3). Initial input data is then allocated to communities based on the **proportion of employees** in the community relative to the national totals.

Total counts of employees, by community are sourced from the Instituto Brasileiro de Geografia e Estatística's (IBGE)2010 Census and the Confederação Nacional da Indústria (CNI) portal. Furthermore, the national building LPG consumption is **scaled by the percentage of employees in each community to estimate the building natural gas consumption by each community.**

Equation 2

The below equation represents the calculation method utilized to estimate commercial sector LPG consumption.

$$\text{Community-scale commercial consumption} = \text{aggregate national LPG consumption}_{\text{commercial}} \times \left(\frac{\text{sector employees}_{\text{community}}}{\text{sector employees}_{\text{state}}}\right)$$

Equation Data Elements

Data element	Description	Source	Units
Community-scale commercial consumption	LPG consumption within community boundary for a single year for all commercial buildings	Equation 2	m^3
Aggregate LPG national consumption	Amount of LPG fuel distributed to commercial customers within entire country in 2015	ANP (2016) SEEG (2018)	m^3
$\text{sector employees}_{\text{community}}$	Estimated number of commercial sector employees for the community in 2015	IGBE (2010) CNI (2016)	Employees
$\text{sector employees}_{state}$	Estimated number of commercial sector employees within the state in 2015	IGBE (2010) CNI (2016)	Employees

Methodology Assumptions and Potential Improvement

General assumptions and limitations

- The distribution of commercial sector LPG consumption within a state is proportionally related to the distribution of commercial establishments and employees.
- All LPG sold to commercial customers is consumed within the year it is delivered
- Finally, weights used in the current iteration partially do not take account of differences in the building context of each community in terms of the size of establishments. Additional weighting and calibration are necessary, however, in order to account for differences in per-employee intensities not just based on establishment sizes, but by different categories of commercial enterprises such as finance, education, and retail trade. Future iterations will incorporate these additional into final estimates.

Scope 1: Biomass (Firewood)

Methodology Notes

Commercial building Biomass consumption is taken from Brasil's National Energy Balance data located at the Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa (SEEG) 2018 database and data from the Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (ANP, 2016) on commercial business customer consumption, at a national level, for the year 2015 in tonnes. Initial input data is then allocated to communities based on the **proportion of employees** in the community relative to the national totals.

Total counts of employees, by community are sourced from the Instituto Brasileiro de Geografia e Estatística's (IBGE)2010 Census and the Confederação Nacional da Indústria (CNI) portal. Furthermore, the national building Biomass consumption is **scaled by the percentage of employees in each community to estimate the building natural gas consumption by each community.**

Equation 3

The below equation represents the calculation method utilized to estimate commercial sector biomass consumption.

$$\text{Community-scale commercial consumption} = \text{aggregate national Biomass consumption}_{\text{commercial}} \times \left(\frac{\text{sector employees}_{\text{community}}}{\text{sector employees}_{\text{state}}}\right)$$

Equation Data Elements

Data element	Description	Source	Units
Community-scale commercial consumption	Biomass consumption within community boundary for a single year for all commercial buildings	Equation 3	m^3
Aggregate Biomass national consumption	Amount of Biomass fuel distributed to commercial customers within entire country in 2015	ANP (2016) SEEG (2018)	m^3
$\text{sector employees}_{\text{community}}$	Estimated number of commercial sector employees for the community in 2015	IGBE (2010) CNI (2016)	Employees
$\text{sector employees}_{state}$	Estimated number of commercial sector employees within the state in 2015	IGBE (2010) CNI (2016)	Employees

Methodology Assumptions and Potential Improvement

General assumptions and limitations

- The distribution of commercial sector biomass consumption within a state is proportionally related to the distribution of commercial establishments and employees.
- All Biomass sold to commercial customers is consumed within the year it is delivered
- Finally, weights used in the current iteration partially do not take account of differences in the building context of each community in terms of the size of establishments. Additional weighting and calibration are necessary, however, in order to account for differences in per-employee intensities not just based on establishment sizes, but by different categories of commercial

enterprises such as finance, education, and retail trade. Future iterations will incorporate these additional into final estimates.

Scope 2: Electricity

Commercial building Electricity consumption is taken from Brasil's National Energy Balance data located at the Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa (SEEG) 2018 database and data from the Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (ANP, 2016) on commercial business customer consumption, at a national level, for the year 2015 in kWh. Initial input data is then allocated to communities based on the **proportion of employees** in the community relative to the national totals.

Total counts of employees, by community are sourced from the Instituto Brasileiro de Geografia e Estatística's (IBGE)2010 Census and the Confederação Nacional da Indústria (CNI) portal. Furthermore, the national building Electricity consumption is **scaled by the percentage of employees in each community to estimate the building natural gas consumption by each community.**

Equation 4

The below equation represents the calculation method utilized to estimate commercial sector electricity consumption.

$$\text{Community-scale commercial consumption} = \text{aggregate national electricity consumption}_{\text{commercial}} \times \left(\frac{\text{sector employees}_{\text{community}}}{\text{sector employees}_{\text{state}}}\right)$$

Equation Data Elements

Data element	Description	Source	Units
Community-scale commercial consumption	Electricity consumption within community boundary for a single year for all commercial buildings	Equation 4	m^3
Aggregate Electricity national consumption	Amount of Electricity fuel distributed to commercial customers within entire country in 2015	ANP (2016) SEEG (2018)	m^3
$\text{sector employees}_{\text{community}}$	Estimated number of commercial sector employees for the community in 2015	IGBE (2010) CNI (2016)	Employees
$\text{sector employees}_{state}$	Estimated number of commercial sector employees within the state in 2015	IGBE (2010) CNI (2016)	Employees

Methodology Assumptions and Potential Improvement

General assumptions and limitations

- The distribution of commercial sector electricity consumption within a state is proportionally related to the distribution of commercial establishments and employees.
- All electricity sold to commercial customers is consumed within the year it is delivered
- Finally, weights used in the current iteration partially do not take account of differences in the building context of each community in terms of the size of establishments. Additional weighting and calibration are necessary, however, in order to account for differences in per-employee intensities not just based on establishment sizes, but by different categories of commercial enterprises such as finance, education, and retail trade. Future iterations will incorporate these additional into final estimates.

Emission Factors:

The following table provides IPCC (2006) emission factor values for the list of fuels used in the buildings and stationary sector methodology for Brasil. All fuel and grid-based electricity utilized by commercial consumers are considered to have the same emission conversion factors despite the state each community is located. As a result, there is no need to adapt the emission factors produced by the IPCC 2006.

Fuel type	Carbon Dioxide (CO2) kg/GJ	Methane (CH4) kg/GJ	Nitrous Oxide (N2O) kg/GJ	Heating Value Mass GJ/ton	Heating Value Liquid Volume GJ/liter	Heating Value Gaseous Volume GJ/m3
Fossil						
Natural Gas	56.1	0.001	0.0001			0.039
Liquified Petroleum Gas (LPG)	63.1	0.001	0.0001			
Non-fossil						
Solid biomass	100	0.03	0.04			

References:

Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (ANP, 2016) Available at http://www.anp.gov.br/dados-estatisticos/vendas-anuais-de-etanol-hidratado-e-derivados-de-petroleo-por-municipio

This report provides estimates for fuel price, sales and volume of fuel consumed by city for the year 2015.

Confederação Nacional da Indústria (CNI) (2016). Available at http://perfildaindustria.portaldaindustria.com.br/

Websites provides state level industrial employee datasets in Brasil.

IBGE., Instituto Brasileiro de Geografia, Estatística (2010). Available at https://cidades.ibge.gov.br/

Website reports statistics and census information on population and other demographics in Brasilian cities.

IPCC (2006). IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2: Energy. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Available at https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html

Provides default emission factor values for a range of fuel types.

Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa (SEEG, 2016). Available at https://seeg.eco.br/tabela-geral-de-emissoes/

This database provides information in fuel sales for the year 2015.

Transportation and Mobile Energy Sector

This document details the calculation approaches and data sources for producing community-level activity data and emission factors for the transportation and mobile energy sector in Brasil. This sector contains the following subsectors:

Transportation and Mobile Energy Sector	
On-road	Estimated
Rail	Not Estimated
Waterborne navigation	Not Estimated
Aviation	Not Estimated
Off-road	Not Estimated

On-Road

Subsector Summary

GHG emissions within the On-Road subsector result from the consumption of fuel for on-road vehicles such as passenger cars, light trucks, motorcycles, microbuses, buses, single-unit trucks, and combination trucks within a community boundary. The GHG emitting activity we focus on in this subsector is fuel consumption (scope 1) from fuels such as hydrous ethanol, gasoline, and diesel oil.

Inclusions

For Brasil, based on available data and method, activity data produced includes:

- **Gasoline** and **diesel fuel** consumption for all private and commercial vehicles within a community boundary.
- **Hydrous ethanol** consumption by all vehicles within a community boundary.

Exclusions

Due to lack of data, this methodology does not include:

- Fuel consumption by all **publicly owned vehicles**.
- **The vehicle kilometers traveled** by all on-road vehicles
- **Grid electricity consumed** for on-road vehicles used within the community boundary (scope 2). This is instead included in the Stationary Energy sector.

Activity Data Coverage

Table 1 shows the emissions sources covered by this methodology.

Table 1 – Allocated activity data, units, and emission sources

Emissions Source	Definition	Units	Scope
Private and commercial all vehicles (gasoline)	The amount of gasoline consumed for a single year by all private and commercial vehicles in a community boundary	Liters	Scope 1
Private and commercial all vehicles (diesel)	The amount of diesel consumed for a single year by all private and commercial vehicles in a community boundary	Liters	Scope 1
Private and commercial all vehicles (ethanol)	The amount of ethanol consumed for a single year by all private and commercial vehicles in a community boundary	Liters	Scope 1

Fuel Consumption

The input data from the Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (ANP) provides values for the volume of gasoline, diesel, and hydrous ethanol sold within each city, hence no city specific disaggregation was needed from a national to a city-specific level.

Vehicle Registrations

The list of vehicle registrations provided by the IBGE (Brazilian Institute of Geography and Statistics) – DENATRAM provides community specific contextual data with which the city fuel consumed can be disaggregated to the city and vehicle level, with the use of appropriate weighting factors.

Weighting Factors

This method uses city-level values for fuel use by the on-road transport sector and incorporates weighting factors, which help control for unexpected variation in fuel use across vehicle types in various city types. According to IBGE vehicles tend to fall into one of the following category types and uses either gasoline, diesel or hydrous ethanol for fuel:

- Passenger Cars
- Light duty vehicles
- Heavy duty vehicles
- Buses
- Motorcycles

These vehicle types, and the associated fuel use, are then compared against the national average fuel use and the results are then integrated into one combined calculation methodology.

Calculation Methodologies:

Scope 1: Gasoline

The equation 1 represents the calculation method utilized to estimate gasoline consumption per vehicle within a city boundary

Equation 1

$$\text{Community gasoline consumption}_{\text{vehicle type}} = \text{Community gasoline consumption} * \text{GFP}_{\text{vehicle type}} * \frac{\text{Community VC}_{\text{vehicle type}}}{\text{Community VC}}$$

Table 2: Equation Data Elements (Gasoline Fuel)

Data element	Description	Source	Units
$\text{Community gasoline consumption}_{\text{vehicle type}}$	Consumption of gasoline within the community boundary, by vehicle type	Equation 1	Liters
$\text{Community VC}_{\text{vehicle type}}$	The count of all vehicles registered within the community, by vehicle type	IBGE, 2016	vehicles

$GFP_{\text{vehicle type}}$	The proportion of each vehicle type that uses gasoline[1]	MMA, 2011	%
Community VC	The total count of all vehicles registered within the community	IBGE, 2016	vehicles

Scope 1: Diesel Oil

Equation 2 represents the calculation method utilized to estimate diesel consumption per vehicle within a city boundary.

Equation 2

$$\text{Community diesel consumption}_{\text{vehicle type}} = \text{Community diesel consumption} * GFP_{\text{vehicle type}} * \frac{\text{Community VC}_{\text{vehicle type}}}{\text{Community VC}}$$

Table 3: Equation Data Elements (Diesel Fuel)

Data element	Description	Source	Units
$\text{Community diesel consumption}_{\text{vehicle type}}$	Consumption of diesel within the community boundary, by vehicle type	Equation 2	Liters
$\text{Community VC}_{\text{vehicle type}}$	The count of all vehicles registered within the community, by vehicle type	IBGE, 2016	vehicles
$GFP_{\text{vehicle type}}$	The proportion of each vehicle type that uses diesel[2]	MMA, 2011	%

[1] Information is obtained from the Ministry of the Environment in 2011. Of the vehicle categories present in Brasil, the percentage of those that use gasoline are incorporated into our calculation and then applied to other municipalities in Brasil.

[2] Information is obtained from the Ministry of the Environment in 2011. Of the vehicle categories present in Brasil, the percentage of those that use diesel are incorporated into our calculation and then applied to other municipalities in Brasil.

Community VC	The total count of all vehicles registered within the community	IBGE, 2016	vehicles

Scope 1: Hydrous Ethanol

The below equation represents the calculation method utilized to estimate ethanol consumption per vehicle within a city boundary

Equation 3

$$\text{Community ethanol consumption}_{\text{vehicle type}} = \text{Community ethanol consumption} * \text{GFP}_{\text{vehicle type}} * \frac{\text{Community VC}_{\text{vehicle type}}}{\text{Community VC}}$$

Table 4: Equation Data Elements (Hydrous Ethanol Fuel)

Data element	Description	Source	Units
$\text{Community Ethanol consumption}_{\text{vehicle type}}$	Consumption of ethanol within the community boundary, by vehicle type	Equation 3	Liters
$\text{Community VC}_{\text{vehicle type}}$	The count of all vehicles registered within the community, by vehicle type	IBGE, 2016	vehicles
$\text{GFP}_{\text{vehicle type}}$	The proportion of each vehicle type that uses ethanol[3]	MMA, 2011	%
Community VC	The total count of all vehicles registered within the community	IBGE, 2016	vehicles

Methodological and Data Assumptions & Limitations

This methodology assumes that:

- All vehicles use some combination of diesel, gasoline, and hydrous ethanol.

[3] Information is obtained from the Ministry of the Environment in 2011. Of the vehicle categories present in Brasil, the percentage of those that use ethanol are incorporated into our calculation and then applied to other municipalities in Brasil.

Emission Factors

This methodology uses emission factors from the IPCC *Guidelines for National Greenhouse Gas Inventories Volume 2: Energy* (IPCC, 2006). These are globally recognized default emission factor values. All passenger vehicle fuels are considered to have the same emission conversion factors despite the state the fuels are sold. As a result, there is no need to adapt the emission factors produced by the IPCC 2006.

Table 2 shows the fuels used in Brasil and their corresponding emission factor values.

Table 2 – IPCC Emission Factors for Fuels

Fuel type	**Carbon Dioxide (CO2) kg/GJ**	**Methane (CH4) kg/GJ**	**Nitrous Oxide (N2O) kg/GJ**
Fossil			
Gasoline	69.3	0.12	0.002
Liquified Petroleum Gas (LPG)	63.1	0.001	0.0001
Ethanol	64.9	0.001	0.0001

References:

Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (ANP, 2016) Available at http://www.anp.gov.br/dados-estatisticos/vendas-anuais-de-etanol-hidratado-e-derivados-de-petroleo-por-municipio

This report provides estimates for fuel volume sold and consumed by city for the year 2016.

Companhia Ambiental Do Estado De São Paulo (CETESB, 2016) Emissões veiculares no estado de São Paulo 2015." Available at: https://cetesb.sp.gov.br/veicular/wp-content/uploads/sites/6/2017/11/EMISS%C3%95ES-VEICULARES_09_nov.pdf

Report provides information on fuel efficiency of various vehicle types by fuel type

Balanço Energético Nacional (2018). Available at http://epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-303/topico-419/BEN2018__Int.pdf

This database provides information in fuel sales for the year 2016.

IBGE., Instituto Brasileiro de Geografia, Estatística (2010). Available at https://cidades.ibge.gov.br/

Website reports statistics and census information on vehicle registrations in Brasilian cities.

IPCC (2006). IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2: Energy. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Available at https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html

Provides default emission factor values for a range of fuel types.

Waste Sector

This document details the calculation approaches and data sources for producing community-level activity data and emission factors for the waste sector. This sector contains the following subsectors:

Waste Sector	
Solid waste	Estimated
Biological waste	Not currently estimated
Incinerated and burned waste	Not currently estimated
Wastewater	Not currently estimated

Solid Waste

Subsector Overview

This section covers the activity data and emission factors needed for communities in Brasil to estimate emissions from the disposal of municipal solid waste (MSW). While other gases are also emitted through the collecting, sorting, and transporting of solid waste to treatment facilities—namely biogenic carbon dioxide, non-methane volatile organic compounds, and nitrous oxide—this methodology focuses on estimating values related to MSW treated at landfill facilities or open dumps only. If desired, communities may consult international resources such as the IPCC guidelines for national reporting or local guidance documents, if available, to estimate non-methane GHG emissions from solid waste disposal. Hence, emissions under this sub-sector are influenced by the following five factors:

1) The mass of community-generated waste disposed in landfills or open dumps;
2) The methane generation potential
3) The methane correction factors; influenced by waste composition
4) The oxidation factors
5) The amount of methane recovered (for facilities with existing technology to do so).

Methane (CH_4) is the main gas emitted during the MSW treatment processes. The following section discusses methods for estimating the mass of waste, methane correction factor, oxidation factor and methane recovery fraction—where applicable—at a community level. All of these variables impact the final total of methane emissions reported in Brasil.

Inclusions

For Brasil, based on available data, our methodology provides estimates on:

- Community-specific **mass of waste landfilled at managed landfill facilities** based on national data allocated proportionally with population.
- Community-specific **mass of waste landfilled at unmanaged/open dumping facilities** based on national data allocated proportionally with population.
- **Methane Correction Factor** based on historical landfill management characteristics such as managed, unmanaged deep, unmanaged shallow, and uncategorized landfills.
- **Methane Generation Potential (L_0)** based on degradable organic carbon, landfill management type and fraction of methane in landfill gas nationally.
- **Oxidation Factors (OX)** based on waste disposal management practice.

Exclusions

Due to the unavailability of data, the data provided excludes:

- Community-specific **mass of industrial, sludge, clinical, and fossil liquid waste.**
- **Landfill methane recovery fraction** at landfill facilities with recovery systems in place.
- The combustion, or flaring, of landfill gas for non-energy purposes[4]
- The combustion of solid waste for non-energy purposes[5]

Activity Data Coverage

Nationally reported data on mass of waste sent to various landfill treatment facilities is available for Brasil. As a result, this MSW section provides final estimations which fall under Scope 3 emissions.

Table 1: Activity data, units, and scope covered under solid waste disposal

Activity Data	Definition	Units	Gases Reported	Emissions Scope
Mass of Waste	The mass of waste disposed at unmanaged, managed, and uncategorized landfills and open dumps within a community boundary, regardless of where the waste was generated.	Tonnes	CH_4	Scope 3

Allocation Methodology

Activity Data – Mass of Waste (Landfills)

The community-specific mass of waste sent to sanitary landfills is obtained from the Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais (ABRELPE) from their 2016 report *Panorama dos Resíduos Sólidos no Brasil.* This report provides data on state-specific mass of waste treated at sanitary landfills which is used to disaggregate and provide estimates for a community-specific level using a population-based approach. Datasets provided by the 2010 Brazilian Institute of Geography and Statistics are used to divide the number of persons living within the community boundary by the total Brasilian population reported in a calendar year in that specific state per the following equation:

Equation 1

$$\text{Landfilled MSW}_{community} = \text{Landfilled MSW}_{State}\ X\ \frac{\text{Community Population}}{\text{State Population}}$$

Table 2: Data elements and sources

[4] While the flaring of landfill gas is typically reported under the waste sector, to burning of landfill gas for energy purposes is reported under the stationary energy sector

[5] Similar to above, the burning of waste for non-energy purposes falls under the waste sector, whereas any waste burned for energy (e.g. heat or electricity generation) falls under the stationary energy sector

Data Element	Definition	Units	Data Source
Landfilled $MSW_{community}$	Mass of community -generated organic waste landfilled	Tonnes	Equation 1
Landfilled MSW_{state}	Mass of state generated organic waste landfilled	Tonnes	ABRELPE, 2016
Community Population	Total number of residents living within community boundary	People	IBGE Censo, 2010
State Population	Total number of persons living in the State	People	IBGE Censo, 2010

Activity Data – Mass of waste (Open-dumping)

Υνμαναγεδ σηαλλοω λανδφιλλ σιτεσ λεσσ τηαν 5μ δεεπ αρε αλσο χομμονλψ ρεφερρεδ το ασ οπεν δυμπσ. Λικε τηε Σανιταρψ Λανδφιλλσ, τηε χομμυνιτψ–σπεχιφιχ μασσ οφ ωαστε σεντ το οπεν δυμπ λανδφιλλσ ισ οβταινεδ φρομ τηε Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais (ΑΒΡΕΛΠΕ) φρομ τηειρ 2016 ρεπορτ *Panorama dos Resíduos Sólidos no Brasil*. Τηισ ρεπορτ προϖιδεσ δατα ον στατε–σπεχιφιχ μασσ οφ ωαστε τρεατεδ ατ οπεν δυμπ λανδφιλλσ ωηιχη ισ υσεδ το δισαγγρεγατε ανδ προϖιδε εστιματεσ φορ α χομμυνιτψ–σπεχιφιχ λεϖελ υσινγ α ποπυλατιον–βασεδ αππροαχη. Τηισ μετηοδολογψ χαλχυλατεσ τηε χομμυνιτψ–σπεχιφιχ μασσ οφ ωαστε οπεν–δυμπεδ ιν Βρασιλ υσινγ εθυατιον 2 βελοω:

Equation 2

$$\text{Open dumped MSW}_{community} = \text{Open dumped MSW}_{state} * \frac{\text{Community Population}}{\text{StatePopulation}}$$

Table 3: Data elements and sources

Data Element	Definition	Units	Data Source
Open dumped $MSW_{community}$	Mass of community -generated organic waste open dumped	Tonnes	Equation 2
Open dumped MSW_{State}	Mass of state generated organic waste open dumped	Tonnes	ABRELPE, 2016
Community Population	Total number of residents living within community boundary	People	IBGE Censo, 2010
State Population	Total number of persons living in the State	People	IBGE Censo, 2010

Activity Data – Methane Correction Factor (MCF)

Since CH_4 generation rates are dependent on landfill management practices, this methodology uses the IPCC (2006) default landfill management types to determine an appropriate community-specific methane correction factor. Brasil waste is diverted to two different disposal sites managed, unmanaged shallow. The IPCC (2006) unitless MCF values of 1.0 and 0.4 respectively are used

Activity Data –Methane Recovered

Μετηανε ρεχοωερεδ ωασ νοτ ρεπορτεδ ανδ τηυσ νοτ φαχτορεδ ιν φορ τηε χασε οφ Βρασ ιλ.

Emission Factors

Under this method the solid waste disposal emission factor (EF) is a combination of two factors, the methane generation potential (L_0) and the oxidation factor (OX). In the absence of data on facility-specific emission factors, this methodology relies on the default factor for OX derived from IPCC (2006).

Equation 3

$$EF = L_o * (1 - OX)$$

Table 4: Data elements and sources

Data Element	Definition	Units	Data Source
L_O	Methane Generation Potential – the amount of methane generated per tonne of waste	Tonnes CH_4/tonne waste	Equation 4
OX	Oxidation factor (Methane Oxidized in top layer)	Unitless	IPCC (2006)

Oxidation Factor (OX)

The oxidation factor—the percentage of carbon that is oxidized during decomposition—is another EF value utilized in the estimation of methane from landfilled/or open-dumped MSW. Since Brasilian landfills are either managed or unmanaged shallow, both managed and unmanaged oxidation values are used in this methodology.

Methane Generation Potential (L_0)

Methane generation potential (L0) is itself a combination of several components: The Methane Correction Factor (MCF); Degradable Organic Carbon (DOC), weighted by waste stream type (discussed below); the fraction of waste degraded anaerobically (DOCf); the fraction of landfill gas that is methane (F); and the methane to carbon ratio. In the absence of facility-specific

data, each of these values is derived from IPCC 2006 list of default values. Hence, τηισ μετηοδολογψ χαλχυλατεσ τηε μετηανε γενερατιον ποτεντιαλ οφ λανδφιλλεδ ωαστε ιν τηε Βρασιλ υσινγ εθυατιον 4 βελοω:

Equation 4

$$L_0 = MCF * DOC * DOC_F * F * {}^{16}/_{12}$$

Table 5: Data elements and sources

Data Element	Definition	Units	Data Source
MCF	Methane Correction Factor (based on management type) – part of the landfilled materials that is left to degrade anaerobically.	Unitless	IPCC (2006)
DOC	Degradable organic carbon – the portion of the waste stream that can decompose under aerobic conditions. This is estimated using the mass of waste under each waste stream and the IPCC designated DOC fractions.	Tonnes C/tonne waste	Calculated
DOC_F	The fraction of DOC ultimately degraded anaerobically	Unitless	IPCC (2006)
F	The fraction of methane in landfill gas	Unitless	IPCC (2006)
${}^{16}/_{12}$	Methane to carbon ratio	Unitless	IPCC (2006)

Degradable Organic Carbon (DOC)

Degradable Organic Carbon represents the amount of organic carbon in the waste that can be degraded. The final DOC value **(0.234)** is estimated by using the fraction of the total mass of the waste and apportioning it with the DOC fractions. Equation 5 below provides the IPCC designated DOC fractions.

Equation 5

$$DOC = (0.15 * A) + (0.2 * B) + (0.4 * C) + (0.43 * D) + (0.24 * E) + (0.15 * F)$$

Table 5: Data elements and definitions

Metric	Definition
A	Mass of food waste
B	Mass of garden and plant debris

C	Mass of paper
D	Mass of wood
E	Mass of textiles
F	Mass of Industrial waste

The IPCC also provides the regional MSW composition data for South America which were assumed to reflect the waste characteristics in Brasil. Relative shares of each waste type within the total landfilled waste stream are combined with the national DOC value of 0.234.

Additionally, emissions are produced from industrial wastes, which have their unique set of DOC values. However, in the absence of data for this category, this methodology omits community-specific activity data or emission factors for industrial waste.

General Assumptions & Limitations

Mass of Waste

- We only attempt to estimate scope 3 emissions, and do not attempt to estimate scope 3 emissions from the activities of the residents within the community boundary.
- IPCC values for waste composition is representative of Brasil's waste which is applied to each city.

Emission Factors

- The IPCC (2006) *IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5: Waste, Chapter 3: Solid Waste Disposal* provides national waste composition estimates for Brasil. In the absence of national or community-specific datasets on industrial, clinical, sludge, and fossil liquid waste this methodology is unable to determine a community-specific DOC estimate for these waste streams.

Methane Correction Factor

- All landfilled and controlled landfill sites are assumed to fall under the managed anaerobic IPCC landfill characteristic and were therefore assigned an MCF of 1.0.
- All unmanaged shallow (open dumps) are assumed to fall under the unmanaged IPCC landfill characteristic and were therefore assigned an MCF of 0.4

Methane Recovery

- ABRELPE (2016) does not provide information for methane recovered, therefore our method does not estimate it.

References:

Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais (ABRELPE, 2016). Panorama dos resíduos sólidos no Brasil 2016. São Paulo. Available at http://www.abrelpe.org.br/panorama_edicoes.cfm

Provides national municipal solid waste mass values as well as estimates for kg of waste per capita sent to disposal sites.

IBGE., Instituto Brasileiro de Geografia, Estatística (2010). Available at https://cidades.ibge.gov.br/

Website reports statistics and census information on population and other demographics in Brasilian cities.

IPCC (1996). IPCC Guidelines for National Greenhouse Gas Inventories. Volume. 1: Greenhouse gas inventory reporting instructions. Volume. 2: Greenhouse gas inventory workbook. Volume 3: Greenhouse gas inventory reference manual. Available at http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.html

Provides a method for estimating methane emissions from MSW using the methane commitment estimate model.

IPCC. (2000). Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Chapter 5: Waste. Available at https://www.ipcc-nggip.iges.or.jp/public/gp/english/5_Waste.pdf

Includes an updated method for estimating methane emissions from MSW using the methane commitment estimate model.

IPCC (2006). IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5: Waste, Chapter 3: Solid Waste Disposal, The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

Provides default values for the fraction of degradable organic content present in waste stream.