AUGUST 2019

Reducing Greenhouse Gas Emissions through Inclusive Recycling

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GLOBAL ALLIANCE OF
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Abbreviations and Acronyms

BC	Black Carbon
GHG	Green House Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HDPE	High-density polyethylene
IPCC	Intergovernmental Panel on Climate Change
LDPE	Low-density polyethylene
MSW	Municipal Solid Waste
PET	Polyethylene terephthalate
PP	Polypropylene
PVC	Polyvinyl chloride
WIEGO	Women in Informal Employment: Globalizing and Organizing

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Introduction

1.1

Introduction to inclusive recycling

A large share of the world's waste is recycled and reused at the hands of waste pickers[1]. The few studies[2] that have attempted to document the climate impacts of waste pickers have shown them to make contributions to the reduction of greenhouse gases through their expansive and low-tech recycling and reuse practices. But as cities grow and government leaders face pressure to modernize waste management systems, preference is usually given to capital and carbon-intensive technologies, private waste management firms and technologies that displace waste pickers.

As a way of defending and improving their livelihoods, many waste pickers around the world have organized themselves into Membership-Based Organizations (MBOs). MBO's exist in different stages of organization- from the very nascent, to those with complex cooperative structures supported by national movements.   The goal of waste picker organizing is to increase the degree to which waste pickers are integrated into more formal waste management systems. Waste picker integration is context based, though key dimensions as defined by WIEGO's IEMS study[3] include:

1. Broad consultation and empowered participation: involvement of waste pickers' through their representatives as full partners in negotiation processes; participation framed as an ongoing process (via stakeholders' platforms);
2. Strengthening of the economic environment: payment for waste pickers' labour and/or compensation through subsidies; schemes for payment of environmental service rendered; 3. Access to finance: credit lines for equipment (scales, shredders, etc.), as well as micro-financing schemes;
3. Legal framework: proper contracts with payment for environmental service ("diversion rate") stipulated; laws and bylaws that recognize pickers as legitimate actors;
4. Work Conditions: provision of infrastructure for sorting/storage/ processing; capacity building; support given to MBOs so they can

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[1] Waste pickers collect household or commercial/industrial waste. They may collect from private waste bins or dumpsters, along streets and waterways or on dumps and landfills. Some rummage in search of necessities; others collect and sell recyclables to middlemen or businesses. Some work in recycling warehouses or recycling plants owned by their cooperatives or associations." Source: http://www.wiego.org/waste-pickers

[2] See: Vergara, Sintana et al. (2015). The Efficiency of Informality: Quantifying Greenhouse Gas Reductions from Informal Recycling in Bogotá, Colombia. Journal of Industrial Ecology. Volume20, Issue1. February 2016. Pages 107-119. Chintan. 2009. Cooling Agents: An Examination of the role of the Informal Recycling Sector in Mitigating Climate Change, New Delhi: Chintan.

[3] Dias, S. and Samson, M. (2016), 'Informal Economy Monitoring Study Sector Report: Waste Pickers', WIEGO IEMS Research Report, Manchester

enter new niches in the recycling chain; establishment of social protection schemes and proper programs to address specific risks (child labour; child care); upgrading plans to move from work in open dumps to safer schemes (such as inclusion in door-to-door domestic and/or segregated collection). Vehicles for collection; legal recognition (such as Organic Law); bylaws, decrees; compensation for environmental service rendered; payment for collection).

Waste picker integration may have one or all of these components in place, and where integration exists the system is described as “inclusive”, although the degree of inclusivity may vary from city to city. An “ideal type” of inclusive system will, from WIEGO’s ´perspective, be able to advance waste pickers in the recycling value chain, enabling added value to recyclable materials, processing of materials, self-management, decent work conditions and social protection.

Inclusive Recycling Systems are the product of considerable advocacy on the part of waste picker MBOs and their supporters. This methodology and its associated greenhouse gas emissions tool were formulated to enable Membership-Based Organizations (MBOs) of waste pickers and their allies to measure the greenhouse gas emissions that waste pickers already help prevent, and use those results to more effectively advocate for their inclusion into waste management systems. The hope is that this tool will also help demonstrate that integrating waste pickers into more formal systems enhances their ability to reduce GHG emissions when compared with more capital-intensive waste management providers. In this way, the tool can also be used to help waste picker organizations strategize their own inclusion in a more ecologically-attentive manner by enabling them to measure the difference in greenhouse gas emissions between different types of transportation, sorting technologies, and material preferences.

Waste picker MBOs and mechanization

Waste pickers MBOs tend to be rooted in an ethic of inclusion, demanding the maximization of labor and, therefore, the distribution of profits among as many people as possible. This has important implications for the mechanization of waste management. Increased integration of waste picker groups often, but not always, denotes increased mechanization of transportation, sorting, and processing of materials. While many waste picker groups aspire for more mechanized, and thus more carbon-intensive, systems as a means of increasing productivity and improving occupational health and safety, there is a limit to which most groups are willing to mechanize their work. This is because mechanized technologies pose barriers to participation and also reduce the need for human labor. Often, waste picker groups are willing to mechanize their work somewhat, but intentionally limit the degree of mechanization. For example, the waste picker cooperatives of Buenos Aires employ mechanical sorting, but are not interested in adopting more automated technologies, like optical sorting, because it would drastically reduce labor needs and thus limit inclusion for some waste pickers.

Limiting mechanization within waste picker MBOs stands in contrast to the ever-increasing mechanization and automation of private, profit-driven waste management firms, which operate with more capital for large investment and can increasingly save on labor costs through automation. While society tends to equate waste sector modernization with mechanization and automation, it is important to point out that increased mechanization need not be an infinite goal and that waste picker groups may, in fact, be more visionary in this regard than profit-driven waste management firms. Refraining from excessive mechanization not only helps maximize jobs, but can also prevent greenhouse gas emissions (Dias, 2016[4]; UNHabitat, 2010[5]). This methodology aspires to enable waste picker groups to put data to this assertion, and help ensure the survival and integration of waste picker groups around the world while meeting cities' strategic priorities for the environment.

1.2

Background on GHG emissions and mitigation in the waste sector

The waste sector is known to be a modest contributor to GHG emissions making up about 3 – 4% of global anthropogenic emissions, 43% of which being from solid waste disposal to land, 51% from wastewater handling, and waste incineration and other minor sources being the remainder[6] (IPCC 2014). Waste management interventions have an impact upstream and downstream in mitigation so the sector has the potential to mitigate about 15 to 20% of the emissions if we consider upstream and downstream impacts of waste management interventions[7].

45%[8] of the global emissions[9] arise from the way we make and use products and food. In a circular economy the value of materials and resources are retained in the economy for as long as possible[10], these emissions can be reduced by 20-30%[11].

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[4] Dias, Sonia Maria. 2016. Waste Pickers and Cities. In: Environment & Urbanization- International Institute for Environment and Development (IIED). 375 Vol 28(2): 375–390.

[5] Scheinberg, Anne & Wilson, David & Rodic-Wiersma, Ljiljana. (2010). Solid Waste Management in the World's Cities, UN-HABITAT.

[6] IPCC, 2014. Climate Change 2014: Mitigation of Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

[7] Global Waste Management Outlook, 2015

[8] IPCC 5th Assessment Report, Working Group III, Mitigation, page 399

[9] IPCC 5th Assessment Report, Working Group III, Mitigation; United States Environmental Protection Agency, Global greenhousegas emissions data, This 45% includes fossil fuels burned at facilities for energy

[10] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0614

[11] https://unfccc.int/sites/default/files/resource/tp02.pdf

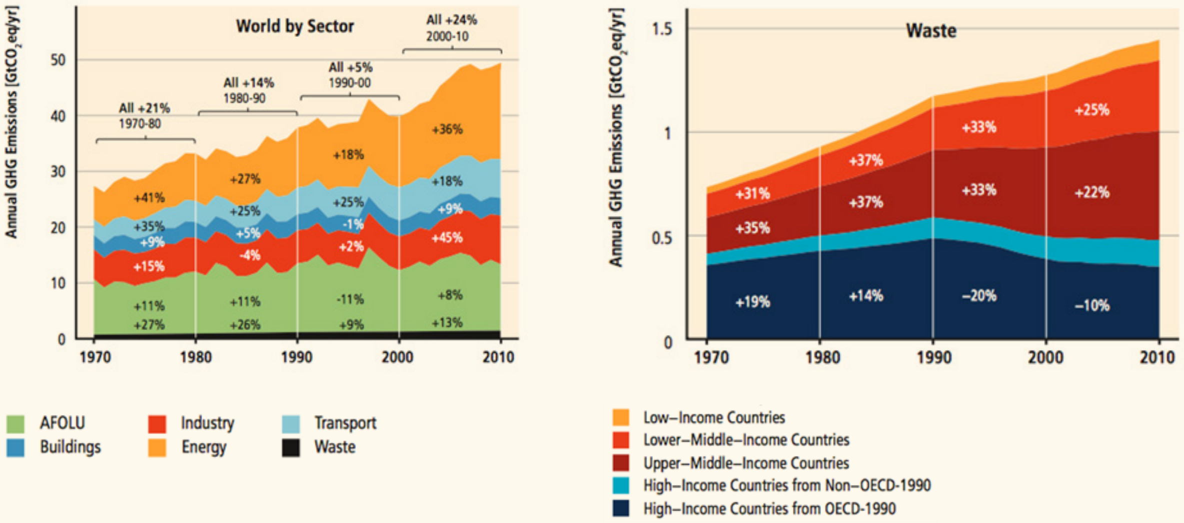


Figure 1 GHG emissions by sector (left) and development of GHG emissions in the waste sector (right)

Mitigation actions should follow efforts in line with the waste management hierarchy, prioritizing prevention, reuse, recycling (including composting) and energy recovery from waste. Inclusive recycling, repair and reuse are high up on the waste and resources management hierarchy and at the same time plays an important role in meeting climate targets.

1.3

Why this methodology?

The objective of the proposed methodology is to enable GHG assessment of inclusive recycling, paying close attention to the specificity of the activities in such recycling systems and relying on internationally recognized methodologies and research. The users of the methodology are:

- international NGOs or field practitioners working in inclusive recycling;
- governments and international organizations looking at enhancing inclusive recycling while maximizing mitigations impacts; and
- waste picker organization representatives.

Though the methodology comes with a user-friendly tool and instructions built into the tool, a basic set of skills and knowledge is needed and training may need to be conducted before using it. Understanding of waste management and the recycling chain, knowledge of the sources and sinks of GHG emissions in the waste sector and the circular economy and intermediate level excel skills are required.

The current paper goes through the steps of establishing the methodology:

- Establishing principles, the methodology adheres to;

- Reviewing existing GHG impact assessment methodologies and research, assess their suitability for the purpose of this methodology and select those that will be used and tailored for assessing impacts of inclusive recycling;
- Establish system boundary, including sources of emissions and sinks, scope of emissions and basket of gases; and
- Baseline setting, including a discussion on additionality and leakage.

Once these are established the method of calculation, input data, parameters and emission factors are explained for each source of emission or sink.

2

Methodological considerations

The emissions sources and sinks are identified taking into account typical waste picker activities and stating all assumptions clearly.

2.1

Principles

To ensure that the methodology represents a true and fair account of GHG emissions, it strives to abide by the GHG accounting principles of the GHG Protocol:

RELEVANCE

The methodology includes information to support the decision-making processes with regards to selecting and planning a mitigation pathway or accounting for the progress made by specific projects during implementation/ monitoring phase.

COMPLETENESS

The methodology strives to rely on complete, accurate and consistent waste data and associated GHG emissions accounting. Wherever completeness is not possible due to lack of data or other limitations, this is clearly stated in the methodology.

CONSISTENCY

Comparable data are needed to track emissions and recycling indicators over the project timeline. Consistency refers to well-established accounting approaches such as project boundaries and calculation methodologies, etc.

TRANSPARENCY

The information related to emissions and recycled quantities is reported in a transparent manner to facilitate replication and assessment. Clear supporting materials, sources and clearly stated assumptions are used so that all calculations are traceable.

ACCURACY

Data should be credible enough and uncertainties should be reduced as far as practical. The level of accuracy of data is established transparently, even in case of limitations.

Adhering to these principles allows for the GHG impact assessments using this methodology to be auditable. The level of uncertainty in GHG accounting in case of inclusive recycling is relatively high due to difficulty in collecting waste management data in general and especially in case of informal waste management sytems.

2.2

Inventory of existing methodologies

A number of existing methodologies for GHG impact assessment of waste management and activities connected to waste management sector have been identified and analysed. The tables below present a list of documents, guidelines, tools and training materials that were reviewed and this methodology draws upon.

Greenhouse gas accounting in the sector initially responded to the need for nations to measure global GHG emissions so that binding quotas for reduction could be assigned to countries in the framework of the Kyoto protocol. This is done based on the methodologies developed by the Intergovernmental Panel for Climate Change (IPCC). Following this, the international emission trading system set up in the same framework lead to the development of project based GHG emissions assessment. In parallel GHG Protocol has set the leadership in organizational GHG impact assessment referring to the same IPCC methodologies. Different planning and scenario assessment tools were also developed for the sector, none is however addressing inclusive recycling interventions in a comprehensive mannerIn waste management the sources of emissions are different in the different treatment and disposal pathways.

	Method or tool	Purpose and scope	Source
National GHG inventory			
1	2006 IPCC waste sector guidelines and 2019 refinements	Volume 5 of the 2006 IPCC guidelines for national GHG inventories is dedicated to the waste sector and includes the following specific chapters: solid waste disposal (and the IPCC waste model in excel format), biological treatment of solid waste, incineration and open burning of waste and wastewater treatment and discharge (and the 4 Waste excel tool which refers to emission from the latter 3 categories). This methodology is the basis of all subsequent methodologies developed for GHG accounting.	Intergovernmental Panel for Climate Change (IPCC), 2006, Guidelines for National Greenhouse Gas Inventories, Volume 5, Waste Riitta Pipatti (Finland) et al **ACCESSIBLE AT:** https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html

2	Good Practice Study on GHG-Inventories for the Waste Sector in Non-Annex I Countries	For the most part, this report extracts good practices and lessons learned of the inventories and reports under the UNFCCC of 16 countries as required by the IPCC guidelines. Information on how countries collect activity data, solve issues of extrapolation, avoid double counting can be sourced from this report.	Deutsche Gesellschaft fur Inertantionale Zusammenarbeit (GIZ, GmbH, on behalf of Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety of the Federal Republic of Germany, 2015, Berlin, Good Practice Study on GHG-Inventories for the Waste Sector in Non-Annex I Countries **AVAILABLE AT:** https://www.transparency-partnership.net/sites/default/files/u1998/giz_2015_good_practice_study_on_ghg-inventories_for_the_waste_sector_in_non-annex_i_countries_0.pdf
Project impact and carbon footprint of organizations and settlements			
3	Clean Development Mechanism methodologies	Used for projects emission accounting for projects developed with the aim to reduce emissions. These are rigorous methodologies that are used to issue and certify emission reduction that is traded on the emission trading market managed by the UNFCCC based on the Kyoto Protocol and subsequent international agreements. For example the methodology for earning credits from investing into a plastic recycling facility requires site-specific data on fuel and energy consumption of the planned recycling facility.	CDM methodologies are available at the UNFCCC website: https://cdm.unfccc.int/methodologies/index.html UNFCCC, Clean Development Mechanism, Small-scale Methodology, Recovery and recycling of Materials from solid waste, 2018 **AVAILABLE AT:** https://cdm.unfccc.int/filestorage/2/P/Y/2PYNW9CMSL14D8JH3BZAVF7QOKTE6G/EB100_repan07_AMS-III.AJ.pdf?t=S2d8cHVkaGhrfDA1vwEETt-moU1pdD6cC0oaH
4	GHG Protocol sector tool	Used by waste management operators to measure and monitor the impact of their activities. Process emissions are considered.	Members of the Companies for Environment Working Group: Seche Environment, Suez Environment, Veolia Environment on behalf of The GHG Protocol, 2013, Protocol for the quantification of greenhouse gas emissions from waste management activities and associated calculation tool **AVAILABLE AT:** https://ghgprotocol.org/sites/default/files/Waste%20Sector%20GHG%20Protocol_Version%205_October%202013_1_0.pdf
5	ICLEI Recycling and Composting Emissions Protocol	This tool is looking at emissions tracking at community level and is inclusive of upstream and downstream emissions.	ICLEI, Local Governments for Sustainability, 2013 David Allaway et al **AVAILABLE UPON REGISTRATION AT:** http://icleiusa.org/publications/recycling-composting-emissions-protocol/
6	Waste Reduction Model, WARM, US EPA	EPA created the Waste Reduction Model (WARM) to help solid waste planners and organizations track and voluntarily report greenhouse gas (GHG) emissions reductions, energy savings, and economic impacts from several different waste management practices. WARM calculates and totals these impacts from baseline and alternative waste management practices—source reduction, recycling, anaerobic digestion, combustion, composting and landfilling.	**ALL DOCUMENTATION AVAILABLE AT:** https://www.epa.gov/warm

7	LandGEM calculation tool	The model allows calculation of mitigation potential for methane recovery in landfills. The model is useful to estimate mitigation potential from CH4 recovery, default data for Latin American countries can be used in the IPCC model.	US EPA, 2005, Landfill Gas Emissions Model (LandGEM) Version 3.02 User manual available at: https://www3.epa.gov/ttncatc1/dir1/landgem-v302-guide.pdf **CALCULATION TOOL AVAILABLE FROM:** https://www.epa.gov/land-research/models-tools-and-databases-land-and-waste-management-research
GHG impact as criteria for scenario selection and planning			
8	GIZ/IFEU scenario assessment tool	This tool is designed for a quick comparison between baseline and three scenarios. The tool does not include transport sector impacts, but it includes abatement cost comparisons, so an additional helpful element next to GHG impact.	German Technical Cooperation (GTZ), Heidelberg Institute for Energy and Environment (IFEU), German Development Bank (KfW), 2009, Tool for Calculating GHG in Solid Waste Management **TOOL, USER MANUAL AND EXAMPLES AVAILABLE:** https://www.ifeu.de/en/project/tool-for-calculating-greenhouse-gases-ghg-in-solid-waste-management-swm/
9	CCAC waste sector tool	The tool is developed to broaden the source and type of emissions considered in the waste sector from the common practice including short-lived climate pollutants such as black carbon. The tool allows the user to undertake an assessment of the emissions from their current situation and identify suitable alternative solutions (up to 4 scenarios). Comparative analysis between different scenarios for the waste management sector can be conducted. The tool utilises country/regional specific data and default values.	CCAC Municipal Solid Waste Initiative and Institute for Global Environmental Strategies (IGES), 2018 Nirmala Menikpura, Premakumara Jagath Dickella Gamaralalage **AVAILABLE AT:** https://www.ccet.jp/publication/Emission_Quantification_Tool_CCAC-MSWI-IGES

Table 1 Sources relevant to assess the GHG impact of inclusive recycling

2.3

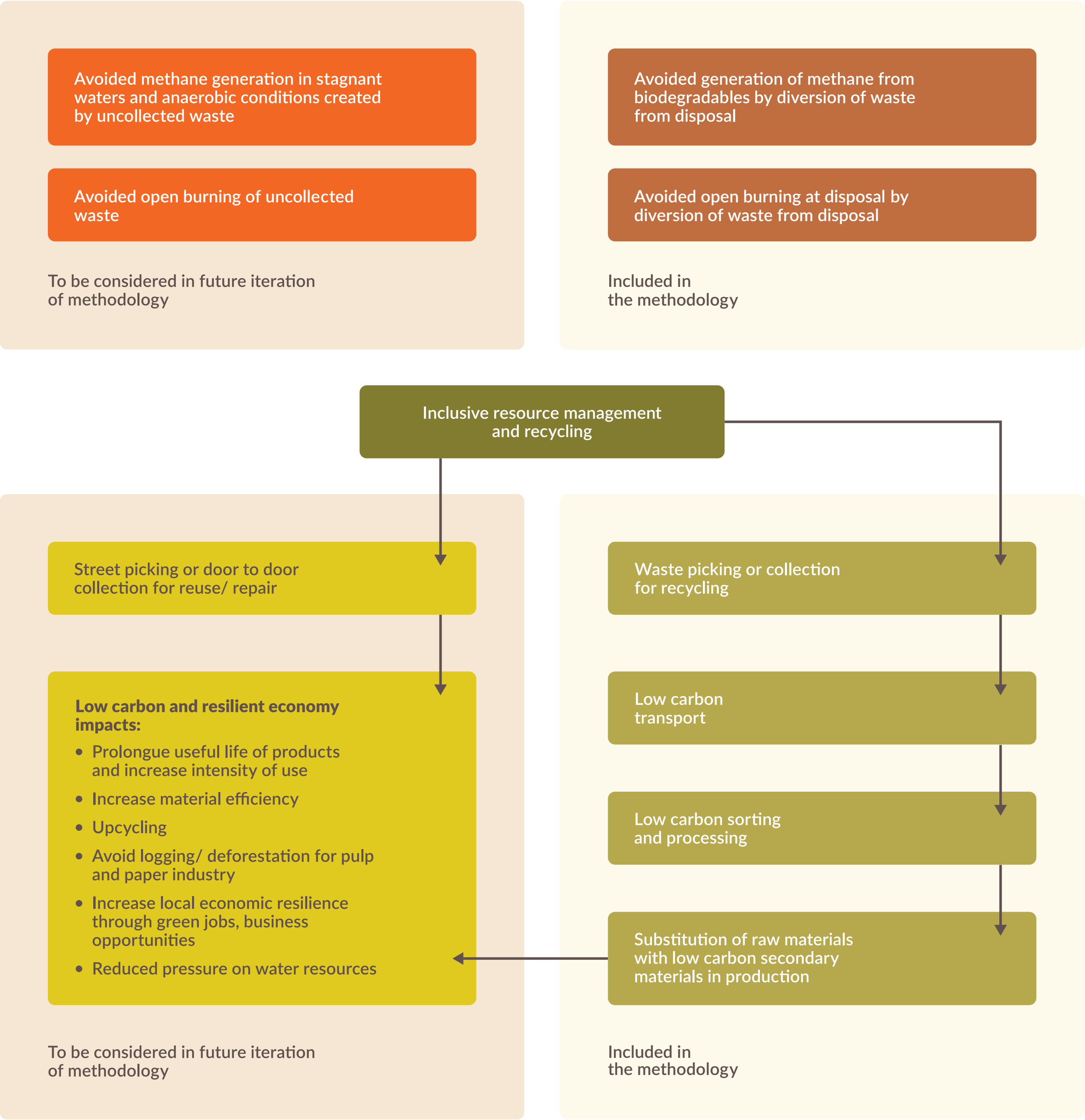
Sources GHG emissions

Most importantly in terms of emission sources we can speak of:

- Methane generation from biodegradation of the decomposable organic content of waste materials disposed. The biodegradation occurs over time and depends on the composition of waste, temperature and humidity and the aerobic or anaerobic conditions formed in the disposal site among other things;
- Black carbon emissions from open burning of waste are still commonly used to reduce the volume of uncollected waste or at the disposal site
- Greenhouse gases generated during the various types of treatment, either as process emissions (fugitive emissions) or from the consumption of energy.

In terms of mitigation of emissions, those are related to either to avoiding emissions by diversion of waste from disposal, inadequate or absent waste management system and to the climate benefits of inclusive resource management and recycling. The methodology is set up in a way to account for potential benefits or low carbon practices in the informal sector. The figure below depicts the sources of mitigation captured in the methodology and those to be addressed in the next iterations of the methodology.The following gives more explanation on the sources of mitigation considered in this methodology:

Figure 2 Climate benefits of inclusive resource management and recycling



- **Avoided emissions from disposal sites from biodegradation of the organic content of waste**

Through recycling of various waste streams certain streams with biodegradable content are diverted from the disposal site. Such material streams include paper and cardboard or may include wood products.

- **Avoided emissions from open burning of municipal solid waste at the disposal site**

Through the recycling of waste streams such as plastic, burning of such materials will be reduced at the disposal site, thus emissions associated with open burning of fossil fraction of municipal solid waste will be reduced. Not all disposal sites use open burning as a waste management practice and in some well-managed sites, fires don't occur at all, so the mitigation impact will depend on the specific disposal site.

- **Avoided emissions from transportation**

Emissions occur from collection and transport of waste. In inclusive recycling motorized transport may be replaced by manual transport or animal traction and in these cases mitigation will occur.

- **Avoided emissions due to substitution of virgin raw materials through recycling**

Extraction and production of virgin materials generally are more energy intense than secondary materials resulting from recycling. Recycling various metals reduces energy needs by an average of 90% as compared to extracting metals.

- **Avoided emissions due to energy use in sorting and processing facilities**

Inclusive recycling often uses less energy because of manual sorting practices as compared to mechanized or high tech sorting facilities.

2.4

Physical and operations boundary

Physical and operations boundary refer to the physical activities that are part of the inclusive recycling system that the GHG emissions impact assessment will include. These boundaries are best shown on a process flow that includes the mass balance of the entire waste management system.

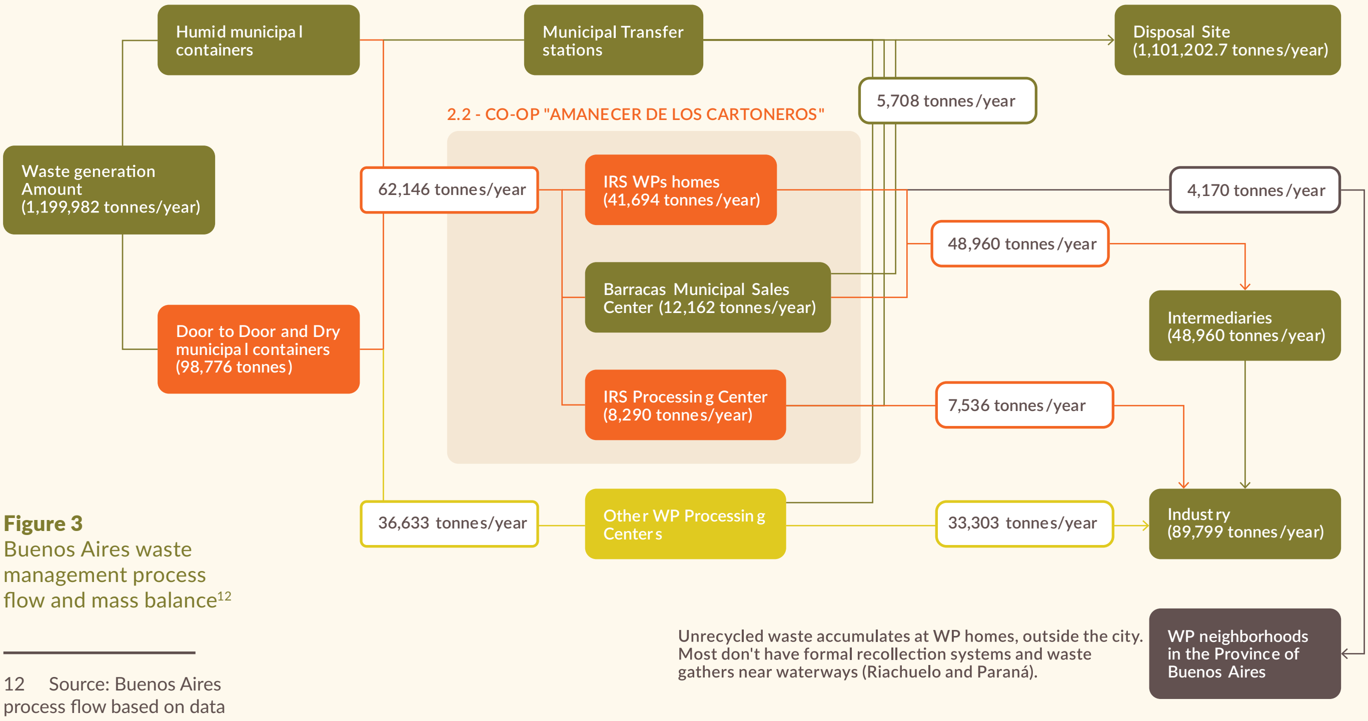
For the purposes of the generic calculation tool we have included activities related to collection, transport, sorting, processing and sale of recyclable materials. As an example of what a process flow and physical boundaries of enhanced recycling look like we have included the pilot testing of this tool carried out in Buenos Aires in the figure below. The physical and operations boundaries marked with the light pink background are considered part of the physical boundaries of the inclusive recycling system in Buenos Aires carried out by the waste picker cooperative "Co-op Amanecer de los Cartoneros". Formal sector activities are marked in blue boxes, waste pickers activities belonging to the Co-op studied are marked in red and other waste picker activities are marked in green.

As can be seen from the figure the following activities are included in the project/operation boundary:

- Door to door collection and collection from municipal containers for dry materials carried out by the waste pickers. The total tons of waste materials collected are 98,776 tonnes per year.
- Transportation of 62,146 tonnes of waste materials towards various activities in the recycling chain
- Materials processed, sorted, stored, sold at either Informal Recycling Sector Waste Pickers (IRS WP) homes, Barracas Municipal Sales centres or Informal Recycling Sector (IRS) Recycling Center also belong within the project boundary

Other waste picker activities marked in green were not included in the boundaries of the project. Though these are part of the inclusive recycling system, the focus of this particular project was on the operation boundaries of the cooperative "Co-op Amanecer de los Cartoneros".

The Municipal Sales Center, marked in blue, though not run by the Co-op is included in the boundary since much of the materials collected by waste pickers who are members of the cooperative are sold through these Centers.



Unrecycled waste accumulates at WP homes, outside the city. Most don't have formal recollection systems and waste gathers near waterways (Riachuelo and Paraná).

Figure 3
Buenos Aires waste management process flow and mass balance[12]

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[12] Source: Buenos Aires process flow based on data collected in the framework of WIEGO's "Reducing Waste in Coastal Cities" project in 2018

2.5

Basket of greenhouse gases and climate pollutants

The calculation tool and methodology focuses on the major sources of mitigation that result from inclusive recycling.

The greenhouse gases included and/or excluded from the project boundary are given in Table below. A more complete assessment of all included emission sources is presented in the next section.

Source of mitigation	Gas	Included/ Excluded	Methodology	Justification
Avoided emissions from disposal sites from biodegradation of the organic content of waste	CO2	Excluded	Not relevant	The CO2 emissions are of biogenic origin, either generated from the oxidation of the biomass in the waste or from the oxidation of methane and therefore not accounted for
	CH4	Included	IPCC waste model	This is a major source of GHG emissions in the waste sector
	N2O	Excluded	IPCC waste model	N2O emissions are small compared to CH4 emissions. Exclusion of this gas is a conservative approach, ensuring that any mitigation results are not overestimated in this category.
Avoided emissions from transportation	CO2	Included	2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2, Energy – Mobile combustion	This is a direct source of emission, and in case inclusive recycling is carried out manually or with animal traction, additional mitigation can be obtained when enhancing inclusive recycling.
Avoided emissions due to substitution of virgin raw materials through recycling	CO2	Included	GIZ/IFEU tool (2009); David A. Turner et al (2015) for emission factors	Avoided emissions are calculated in the same way in all scenario analysis tools, emission factors used vary. We use a combination of GIZ/IFEU (for mixed plastic waste) and the recent research work of David A. Turner at all for emission factors of specific materials
Avoided emissions due to energy use in sorting and processing facilities	CO2	Included	2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 3, Industrial Processes and Product Use, or other methodologies	Source of avoided emissions in the baseline due to less energy intensive sorting and pre-processing activities as compared to mechanical sorting.
Avoided emissions from open burning of municipal solid waste at the disposal site	CO2	Included	IPCC waste sector Chapter on Incineration and Open Burning	CO2 emissions from open burning of the fossil content of waste is calculated here.

	N2O	Included	IPCC waste sector Chapter on Incineration and Open Burning	N2O emissions occur at relatively low combustion temperatures. As open burning is not a controlled combustion process, such emissions occur. Default factors are used from the methodology for mixed municipal waste
	CH4	Included	IPCC waste sector Chapter on Incineration and Open Burning	CH4 emissions from open burning of waste, due to incomplete combustion, some biodegradation and methane emissions still occur.
	Black Carbon	Included	CCAC tool	The CCAC is a well-known international organization focused on mitigating short-lived carbon pollutants (SLCP), among these, black carbon. Emission factors for black carbon are taken from this methodology

3

Calculating GHG emissions

This section of the methodology explains in detail the calculations used for estimating emissions in each of the emission sources considered. These calculations are built in the excel calculation tool that performs these automatically based on input data on the activities.

3.1

Avoided emissions from disposal sites

The figure below depicts the categories of activities covered in the GHG inventory under the waste sector according to the IPCC methodology. The IPCC Guidelines include instructions on allocating different emissions to the different sectors (waste, transportation, industry). The guidelines can be downloaded from: https://www.ipcc-nggip.iges.or.jp/public/2006gl.

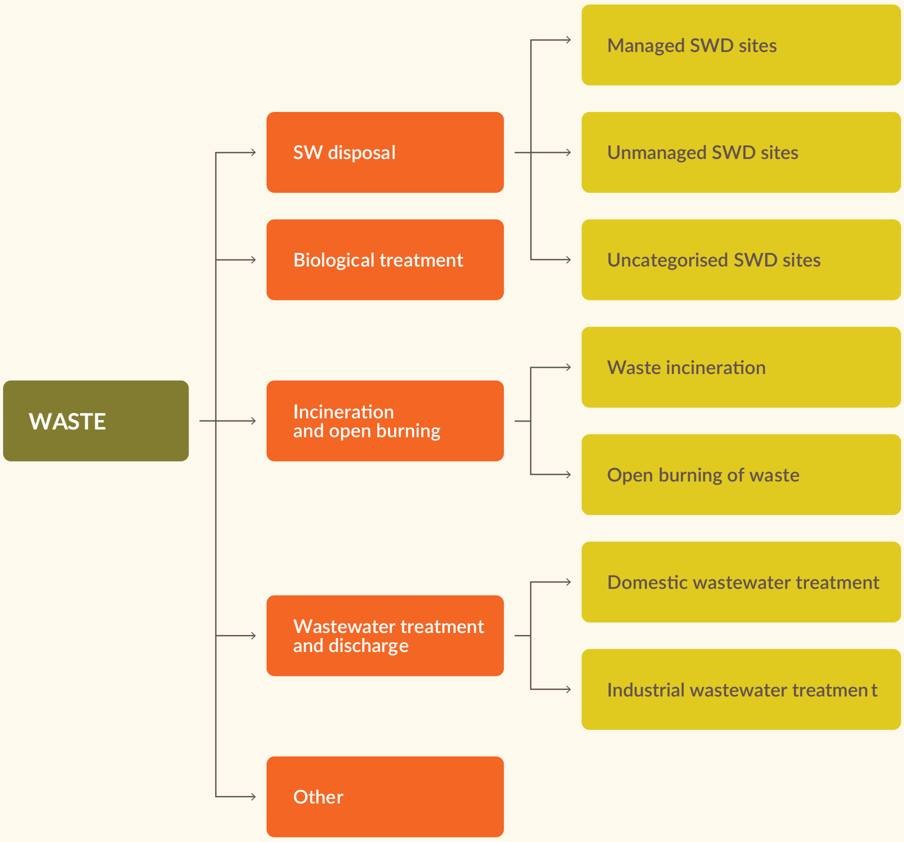

Figure 4
Sectors covered by guidelines[13]

The solid waste disposal category and the emissions associated with solid waste disposal. The main pathway for GHG emissions from disposal sites is methane generation through anaerobic digestion of biodegradables. This methane is oxidised in cover layers, released into atmosphere, or extracted for flaring or energy recovery.

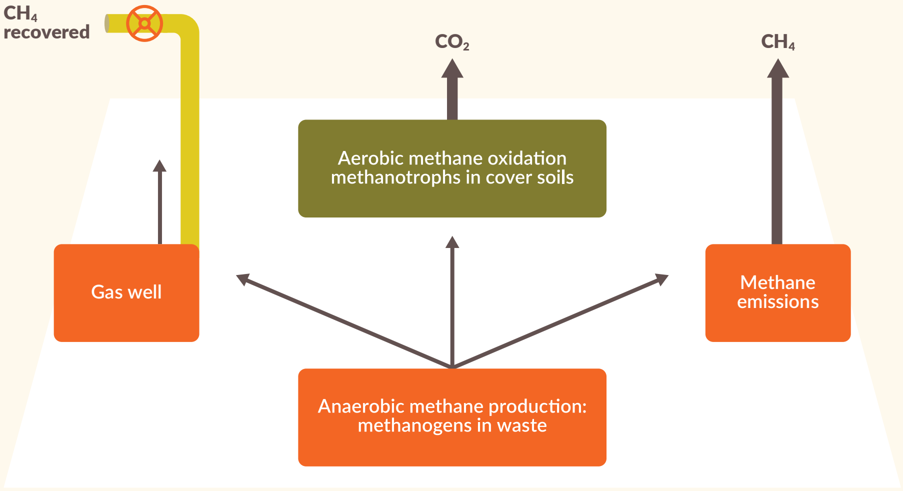

Figure 5
Pathways for GHG emissions from landfills[14] Country specific data need for

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[13] Source: RWA Group, adapted from 2006 IPCC Guidelines for National Greenhouse Gas Inventories, vol.5 Waste, Introduction.

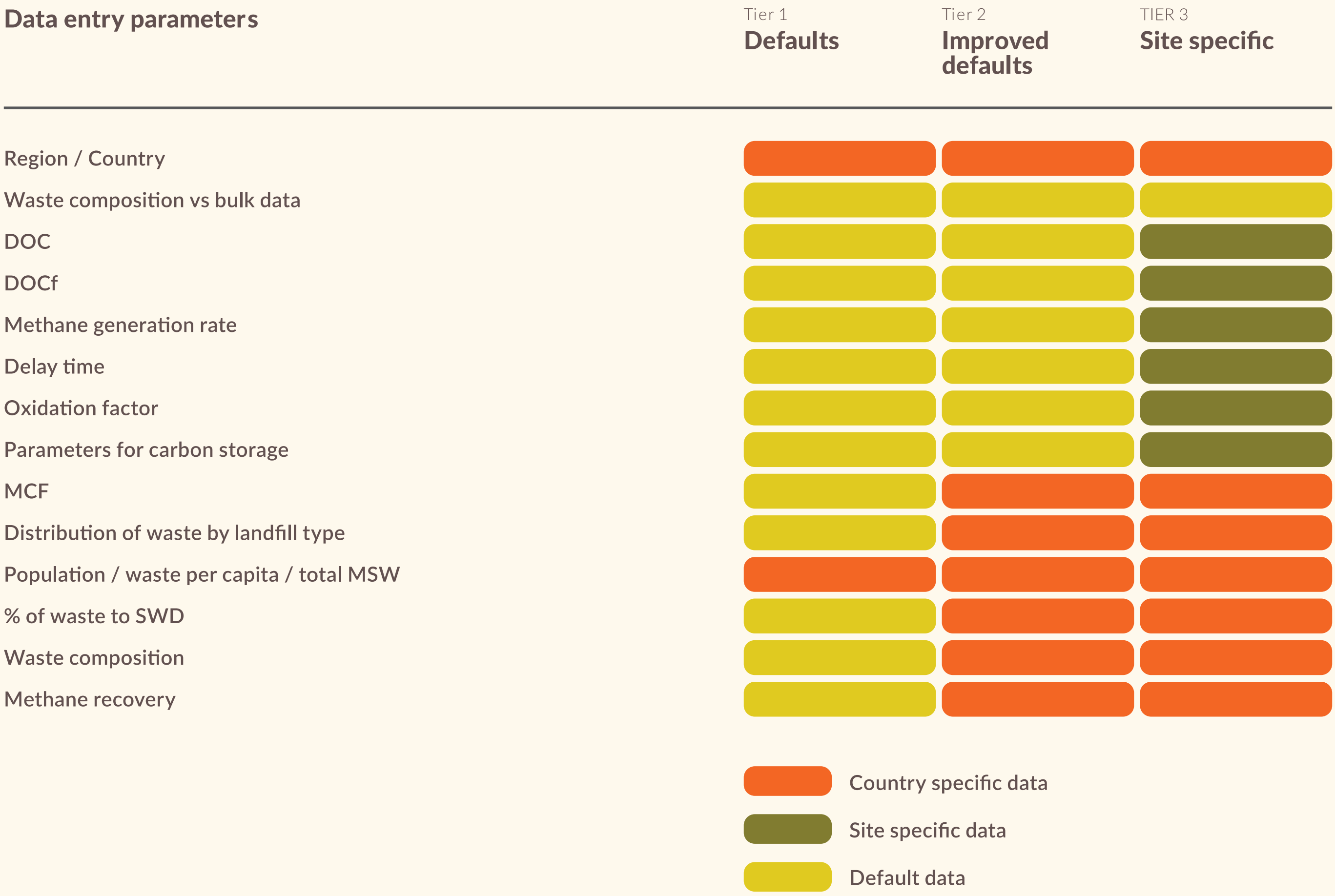
[14] IPCC, Jean Bogner, Chapter 10 Waste Management, Fourth Assessment Report

The CH4 emissions from disposal site are estimated, as any waste diverted from disposal site by the informal sector would reduce the amount of waste disposed and consequently the associated emissions are also reduced.

The IPPC waste model implements the First Order Decay method, as previously introduced, for estimating emissions from solid waste disposal sites. According to this method the rate of CH_4 generation depends on the amount of CO_2 remaining in the waste throughout the years it takes for the degradable organic fraction of the waste to slowly decay.

There are several ways in which the model can be used to calculate CH_4 emissions all being dependent on the tier used. Tier 1 method uses a set of default data for all the parameters feeding the model, therefore there is no need for any site/country specific activity data. Tier 2 consists in using site/country specific data instead of the default values thus allowing a more accurate calculation of the emissions. The use of a tier 3 method would consist in providing specific data for some of the parameters in the model. Nevertheless, in practice the use of complete tier 3 is difficult as it requires site-specific data obtained through measurements.

Figure 6
Country specific data need for the three tiers in the waste model[15]



Data entry parameters	Tier 1 **Defaults**	Tier 2 **Improved defaults**	TIER 3 **Site specific**
Region / Country	🟧	🟧	🟧
Waste composition vs bulk data	🟨	🟨	🟨
DOC	🟨	🟨	🟫
DOCf	🟨	🟨	🟫
Methane generation rate	🟨	🟨	🟫
Delay time	🟨	🟨	🟫
Oxidation factor	🟨	🟨	🟫
Parameters for carbon storage	🟨	🟨	🟫
MCF	🟨	🟧	🟧
Distribution of waste by landfill type	🟨	🟧	🟧
Population / waste per capita / total MSW	🟧	🟧	🟧
% of waste to SWD	🟨	🟧	🟧
Waste composition	🟨	🟧	🟧
Methane recovery	🟨	🟧	🟧

🟧 Country specific data
🟫 Site specific data
🟨 Default data

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[15] Source: RWA Group

The CH_4 is generated under anaerobic conditions as a result of degradation of organic material.

CH_4 emissions from SWDS

$$CH_4 \text{ Emissions} = [\sum_{x} (CH_4 generated_{x,T} - R_T)] * (1 - OX_T)$$

Where:

CH_4 Emissions = CH_4 emissions emitted in year T

T = year

x = waste category or type/material

R_T= recovered CH_4 in year, T

OX_T= oxidation factor in year T

Decomposable DOC from waste disposal data

The CH_4 generation potential can be estimated based on the amount of waste, composition and waste management practices at the disposal sites. The DDOCm is the fraction of the organic carbon deposited which will degrade under anaerobic conditions.

$$DDOCm = W \times DOC \times DOC_f \times MCF$$

Where:

DDOCm = mass of decomposable DOC deposited

W = mass of waste deposited

DOC = degradable organic content in the year of deposition

DOC_f = fraction of DOC that can decompose (fraction)

MCF = CH_4 correction factor for anaerobic decomposition in the year of deposition

Methane generation potential

$$L_0 = DDOCm \times F \times 16/12$$

Where:

L_0 = CH_4 generation potential

DDOCm = mass of decomposable DOC deposited

F = fraction of CH4 in generated landfill gas

16/12 = molecular weight ration CH_4/C

For calculation purposes the IPCC 1996 methodology is built into the model, assuming that all emissions related to waste diverted in a given year are avoided in that same year. This is a simplification used by many models looking at scenario assessment for mitigation projects due to the fact that historical data on disposal is not available.

3.2

Avoided emissions from transportation

Municipal waste collection is the responsibility of municipalities or local/regional governments. The service can be organized inside municipalities or the responsibility can be outsourced to private waste operators. Estimated emissions from waste collection can be calculated taking into account two sets of data: total fuel consumption at the operator or the distance travelled by vehicles.

CO2 emissions

Emissions of CO2 are best calculated on the basis of the amount and type of fuel combusted (taken to be equal to the fuel sold) and its carbon content. Depending on the data availability, either country specific carbon contents (tier 2) or default carbon contents (tier 1) can be used.

Tier 1

$$\text{Emissions} = \sum_a (\text{Fuel}_a \times \text{EF}_a)$$

Where:

Emission = Emissions of CO_2 (kg)

Fuel_a = fuel sold (TJ)

EF_a = emission factor (kg/TJ). This is equal to the carbon content of the fuel multiplied by 44/12.

a = type of fuel (e.g. petrol, diesel, natural gas, LPG etc)

The Tier 2 approach is similar to Tier 1 except that country-specific carbon content of the fuel consumed by the operator are used. The equation above still applies but the emission factor is based on the actual carbon content of fuels consumed.

For the purposes of the calculation model, the excel tool allows the user default data on typical motorized collection fuel consumptions in case this data is not available locally. This makes the use of the tool easier, as projects or organizations using the tool need to know data only on the activities of the project and the motorized transport being replaced by people or animal traction.

For electric vehicles, CO_2 emissions are calculated based on the amount of electricity consumption per 100 km and the country specific emission factor for the production of electricity.

Fuel Type	Default (kg/TJ)	Lower	Upper
Motor Gasoline	69300	67500	73000
Gas/ Diesel Oil	74100	72600	74800
Liquefied Petroleum Gases	63100	61600	65600
Kerosene	71900	70800	73700
Lubricants[b]	73300	71900	75200
Compressed Natural Gas	56100	54300	58300
Liquefied Natural Gas	56100	54300	58300

Source: Table 1.4 in the Introduction chapter of the Energy Volume.

Notes:
a Values represent 100 percent oxidation of the fuel carbon content.
b See Box 3.2.4. Lubricants in Mobile Combustion for guidance for uses of lubricants.

Table 4:

Road Transport Default CO_2 Emission Factors and Uncertainty Rangesa[a]

3.3

Avoided emissions due to substitution of virgin raw materials through recycling

Turning waste into a resource is one key to a circular economy. In case of re-manufacturing, reusing and recycling, we can move to a more circular economy where one's industry's waste becomes another's raw material and resources are used in an efficient and sustainable way. Inclusive recycling contributes to reducing greenhouse gas emissions indirectly through channelling materials to recycling, which would otherwise be extracted and processed. The table below presents the potential impact of recycling for various materials. The factors show the mitigation potential of each material recycled as compared to extraction and processing of new raw materials. These factors are calculated as a difference between the emissions occurred with the extraction, transportation and processing of virgin raw materials and the collection, sorting and recycling of secondary materials.

The emission factors are the result of analysing increasingly large datasets from pools of case studies. The emission factors will differ depending on both the energy intensity of the value chain of virgin raw material production and the energy intensity of recycling value chain in any given case study. Differences in the different case studies may come from distances in logistics, the types of fuel used for transport, the energy mix for electricity in the specific country and the related emission factor, the energy intensity of the extraction, processing and production lines and the specific technologies used, etc. However, these studies look at increasingly large pools of case studies and the data is sufficient to draw the overall conclusion with confidence that recycling is less energy intense than virgin raw material extraction and production.

We have chosen to use the most recent data available for emission factors from the research work of David A Turner at al, as this is relying on the vastest pool of case studies and is giving emission factors by a breakdown of materials. We also use the reference emission factor for mixed municipal waste from the work of GIZ/IFEU as this is an international reference that is widely used in countries outside the EU and the developed countries, accepted by the climate finance institutions.

Recycling is any reprocessing of waste material in a production process that diverts it from the waste stream, except reuse as fuel. For the purpose of the project, recycling is defined as any activity by which materials are diverted from waste stream into recycling value chains with the final intended destination of the material being a recycling processing plant and the final product as a secondary raw material.

Material/Source	AEA technology 2001	EPA 2006	ADEME 2007	Prognos 2008 for 2004	CE Delft 2007	BIR 2008	GIZ 2009	David A Turner 2015	Fraunhofer 2008 for 2007	Oko-Institut / IFEU 2010 for 2006	IFEU 2011, 2010 tools	ETC/SCP for EEA 2011
Paper and cardboard												
Paper	0,6			0,84	1,296	0,000	820	459				
Paper/cardboard								120	94	674	820	564
Corrugated Box		3,43										
Magazines		3,38										
Newspaper		3,08										
Office Paper		3,14										
Phonebook		2,93						117				
Textbook		3,43						117				
Mixed Paper Board		3,9										
Mixed Paper - Residential		3,9										
Cardboard packing			-0,22									
Graphic papers			0									
Special and hygiene papers			0,07									
Plastics												
PE			1,39									
PE/PP				0,16				1184	1194			
HDPE	0,491	1,53			1,098			1149				
LDPE		1,86						972				
PET	1,761	1,7	2,01	1,64	1,271			2192	2538			
PS				1,7								
PVC				0,74				1549				
Mixed Plastics		1,64					414	1024	416			
Glass												
GLASS	0,253	0,31	0,45	0,18	0,321		480	314	170	465	480	159
Ferrous metals												
FERROUS METALS	1,487		1,57			0,97						3220
Steel				1			2025					
Steel Cans		1,97						862				
Iron									856	945	2025	
Non-ferrous metals												
Aluminium	9,074		7,11	11,1		3,54	11100	8143	9872	9307	11100	
Aluminum Cans		14,96						8143				
Copper				1,18		0,81			3522			
Copper Wire		5,42	1,13									
Nickel						1,9						
Tin						2,15						
Zinc						1,8						
Lead			0,68			1,61						
Textiles												
Textiles	3,17			2,818	2,919		2818	3376			2818	1728
Rubber												
Tires		2,01						636				
Rubber				1,8								

Table 5:

Avoided emission factors for various materials, kg CO_2eq/tonne of waste

Thus the data needs for implementing for calculating emission mitigation in this category include:

Total quantity of waste captured by the inclusive recycling chain intended to be recycled

A breakdown of the above materials by streams is beneficial and can result in better estimations.

At the data collection phase it's not always possible to determine whether all material intended for a recycling destination will actually be recycled. For the purposes of this methodology we assume it will be.

Also for the purposes of this methodology recycling rate is not the relevant input data, rather the tons of materials recycled as a result of the intervention project, the enhanced inclusive recycling scenario. This is because we are not looking to calculate the mitigation achieved at the level of a settlement, but from the point of view or an organization or project that is enhancing inclusive recycling.

It should be noted that this methodology accounts only for materials recovered for recycling, despite that some materials are in fact reused instead of recycled. Material reuse avoids more greenhouse gas emissions than recycling, so counting reuse as recycling gives us a conservative estimate for amount of greenhouse gas emissions avoided. Eventually this methodology may be adapted to account for reuse separately from recycling.

3.4

Avoided emissions due to less energy intensive recycling value chain

Though not always the case, sorting activities in inclusive recycling are often less energy intensive as compared to the mechanical processes, or may be entirely manual. The emission factors presented in Table 6 above reflect the mitigation potential of recycling done through mechanical processes. By replacing mechanical processes with manual sorting, more mitigation opportunities can occur. As a result, the process emissions associated with waste sorting must be determined and accounted.

A methodology will be identified and selected once a clear definition of the current sorting and pre-processing activities will be provided during data collection activities. Based on the potential emissions sources, if any, the selection of an appropriate methodology will be conducted. The IPCC Industrial Processes and Product Use guidelines will be investigated as a potential methodology for assessing the avoided emissions of less energy intensive sorting and pre-processing.

In case no site specific data is available about the processing plant in the formal recycling system or a case study from nearby/ similar city or settlement, we suggest to leave out this section from the calculations.

3.5

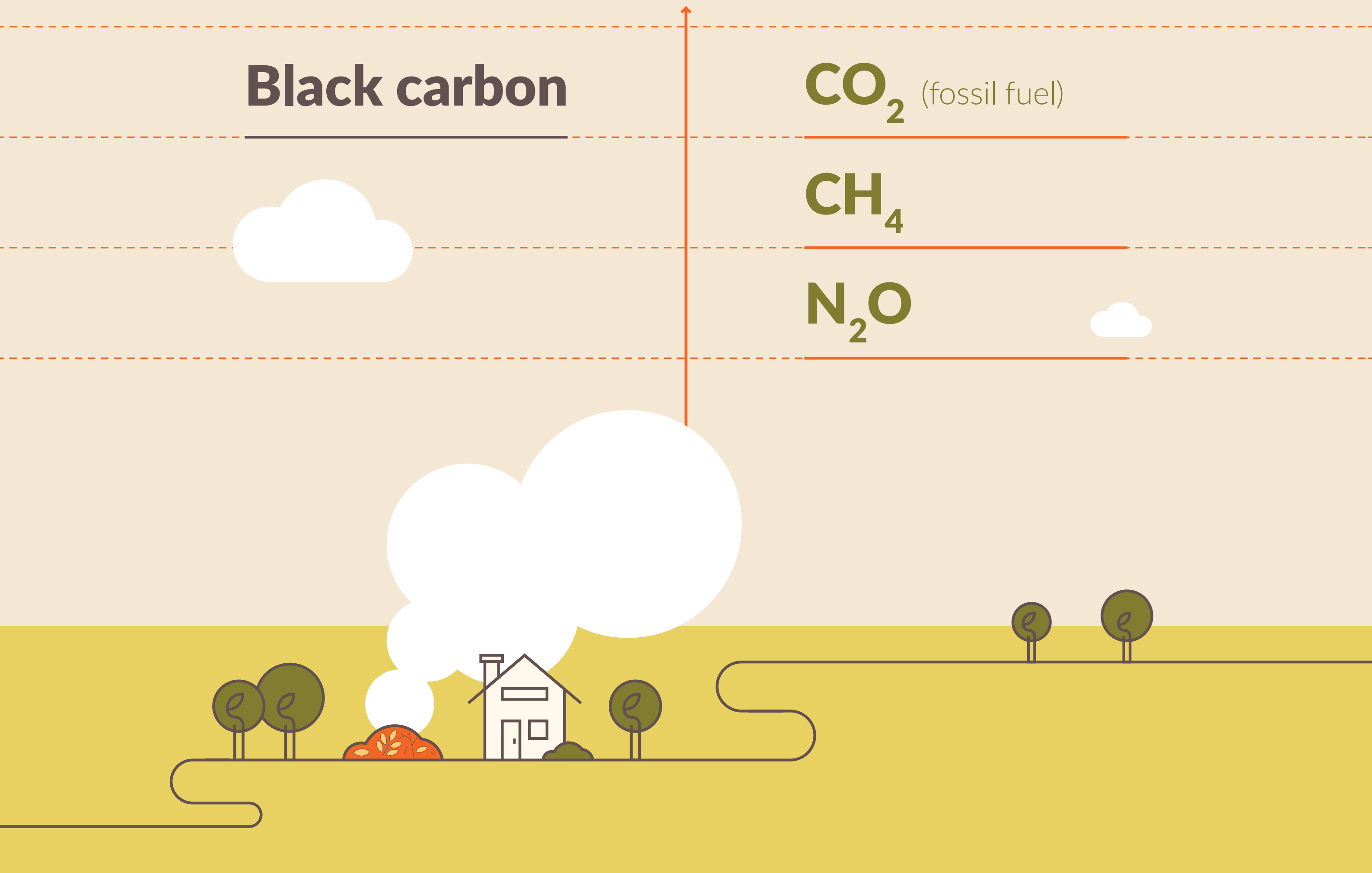
Avoided emissions from open burning

In line with 2006 IPCC Guidelines for National GHG Inventories, we define open burning as the combustion of unwanted materials such as paper, wood, plastics, textiles, rubber, waste oils and other debris in open dumps, where smoke and other emissions are released directly into the air without passing through a chimney or stack.

Open burning is a common practice in developing countries and is a source of greenhouse gas emissions. While monitoring and reducing the frequency of open burning should be a priority in terms of mitigating GHG emissions, it is in practice a difficult task because of the lack of data regarding the MSW that is openly burned and the frequency of the burning, as open burning can be both the result of intentional activity and the unintentional result of the improper management of the MSW.

Four types of emissions are generated as a result of the open-burning of MSW:CO2, CH4, N2O and Black Carbon. The emissions are calculated based on the quantity of MSW that is open-burned and the composition of the MSW, as detailed below.

Figure 7
GHG emissions from open burning[16]



CO2 emissions

In order estimate the amounts of GHG emissions resulting from open burning, it is good practice to calculate CO_2 emissions on the basis of waste types in the waste open burned, as shown in the Equation below:

$$CO_2 \text{ Emissions} = MSW * \sum_{J} (WF_J * dm_j * CF_j * FCF_j * OF_j) * 44/12$$

Where:

CO_2 Emissions = CO_2 emissions in inventory year, Gg/yr

MSWB = total amount of municipal solid waste as wet weight open-burned, Gg/yr

WF_j = fraction of waste type/material of component j in the MSW (as wet weight incinerated or open-burned)

dm_j = dry matter content in the component j of the MSW incinerated or open-burned, (fraction)

CF_j = fraction of carbon in the dry matter (i.e., carbon content) of component j

FCF_j = fraction of fossil carbon in the total carbon of component j

OF_j = oxidation factor, (fraction)

44/12 = conversion factor from C to CO_2

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[16] Source: RWA Group

With

$\sum_j WFj = 1$

j = component of the MSW open-burned such as paper/cardboard, textiles, food waste, wood, garden (yard) and park waste, disposable nappies, rubber and leather, plastics, metal, glass, other inert waste.

The values for Dry Matter Content, Total Carbon Content and Fossil Carbon Fractions for different MSW fraction are calculated based on the table below.[17]

The default oxidation factor in % of carbon input for open burning is suggested as 58. When waste is open-burned, refuse weight is reduced by approximately 49 to 67 percent (US-EPA, 1997, p.79).[18]

MSW component	Dry matter content in % of wet weight	Total carbon content in % of dry weight	Fossil carbon fraction in % of total carbon
Food / Organic Waste	40%	38%	-
Yard / Garden / Green Waste	40%	49%	0%
Wood	85%	50%	-
Paper & Cardboard	90%	46%	1%
Plastic	100%	75%	100%
Rubber/Leather	84%	67%	20%
Textiles	80%	50%	20%
Other	90%	3%	100%

CH4 emissions

The calculation of CH4 emissions is based on the amount of waste open-burned and on the related emission factor as shown in the equation below:

$$CH_4\ Emissions = \sum_{MSW} (IW_{MSW} * EF_{MSW}) * 10^{-6}$$

Where:

CH_4 Emissions = CH_4 emissions in inventory year, Gg/yr

IW_{MSW} = amount of MSW open-burned, Gg/yr

EF_{MSW} = aggregate CH_4 emission factor, kg CH_4/Gg of waste

10^{-6} = conversion factor from kilogram to gigagram

For open burning of waste, a CH4 emission factor of 6500 g / t MSW wet weight has been reported (EIIP, 2001).

The default emission factor for MSW open burning is considered **150 g N2O/t waste**, as accepted by the 2006 IPCC Guidelines.

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[17] Source: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_2_Ch2_Waste_Data.pdf

[18] Source: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_5_Ch5_IOB.pdf

N2O emissions

The calculation of N2O emissions is based on the waste input to the amount of waste open-burned and a default emission factor, as defined in the equation below:

$$N_2O \text{ Emissions} = \sum_{MSW} (IW_{MSW} * EF_{MSW}) * 10^{-6}$$

Where:

N_2O Emissions = N_2O emissions in inventory year, Gg/yr

IW_{MSW} = amount of open-burned MSW, Gg/yr

EF_{MSW} = N_2O emission factor (kg N_2O/Gg of waste) for MSW

10^{-6} = conversion factor from kilogram to gigagram

Black carbon

Black carbon (BC) is a potent climate-warming component of particulate matter formed by the incomplete combustion of fossil fuels, wood and other fuels. Black carbon is a short-lived climate pollutant with a lifetime of only days to weeks after release in the atmosphere. During this short period of time, black carbon can have significant direct and indirect impacts on the climate, glacial regions, agriculture and human health.[19]

BC emissions from open burning are estimated (Bond, 2013) **at 0.65 kg of BC/tonne** of open-burned waste, with BC presenting a global warming potential over 100-year time of **590** (IPCC,2013).

Estimating the amount of waste that is open burned

The equation below can be used to estimate the amounts of MSW openly burned:

$$MSW_B = P * P_{frac} * MSW_P * B_{frac} * 365 * 10^{-6}$$

Where:

MSW_B = Total amount of municipal solid waste open-burned, Gg/yr

P = population (capita)

P_{frac} = fraction of population burning waste, (fraction)

MSW_P = per capita waste generation, kg waste/capita/day

B_{frac} = fraction of the waste amount that is burned relative to the total amount of waste treated, (fraction)

365 = number of days by year

10^{-6} = conversion factor from kilogram to gigagram

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[19] https://ccacoalition.org/en/slcps/black-carbon

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Green Partners is a 100% privately owned and independent environmental consulting company. We provide consultancy services to governments, International Finance and Development Institutions and industry. Green Partners was founded in 2001 as a response to a growing market in environmental infrastructure development and compliance in Eastern Europe. We specialize in waste management, green energy, climate change mitigation and resilience and urban planning. We often assist clients to adhere to environmental and social safeguards.

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