- Protocol - - for the quantification - - of greenhouse - - gas emissions - - from waste management - - activities -

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entreprises pour l'environnement

- Acknowledgments and Contact -

This Protocol was developed by the Entreprises pour l'Environnement Working Group composed of the following companies:

Seche Environnement

Suez Environnement

Veolia Environnement

This is the fifth version of the Protocol.
It takes into account modifications identified by the EpE Working Group as well as changes related to comments provided by the World Resource Institute (WRI), following their review.

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- The International Solid Waste Association (ISWA) - Working Group on Waste Management and Climate Change
- the French Federation of Waste Management Services (FNADE),
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- the Dutch Waste Management Association (DWMA), and
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- the International Solid Waste Association (ISWA),
- the European Federation of Waste Management and Environmental Service (FEAD),
- the French Federation of Waste Management Services (FNADE),
- the Environmental Services Association (ESA) in the United Kingdom,
- the Spanish Association of Hazardous Waste Managers (ASEGRE),
- the Dutch Waste Management Association (DWMA) and
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EpE is the French partner of the World Business Council for Sustainable Development (WBCSD). The WBCSD is a CEO-led, global association of some 200 companies dealing exclusively with business and sustainable development.

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- Foreword -

Six years have passed since the Waste Sector Protocol was published for the first time in 2006. Today, global warming and climate change remain amongst the most significant environmental issues facing our planet. In 2006, the Kyoto Protocol had just been ratified and the European Emissions Trading Scheme (EU-ETS) had been recently launched, giving strong signals of the world's willingness to create the appropriate structures that would contribute to reducing the global greenhouse gases (GHG) emissions.

Unfortunately, the current global overview is much less optimistic. The last Conferences of the Parties (COP) and Earth Summit conferences have not delivered clear and ambitious targets and incentives to scale-up the implementation of low-carbon solutions to limit global temperature rise to 2 degrees centigrade. GHG emissions on a global level are far from decreasing or even stabilising. Total GHG emissions for 2010 and then for 2011 have been respectively identified as the highest ever.

Despite the uncertainty of the on-going international climate negotiations, many governments have taken steps to reduce GHG emissions through policy measures that include the introduction of emission trading schemes, voluntary programmes, carbon or energy taxes, and regulations on GHG monitoring and reporting.
There are increasing demands or expectations for businesses and communities to report their greenhouse gas emissions on a regular basis.

Sectorial protocols such as this Waste Sector Protocol are therefore very useful in such cases and contribute to the elaboration of complete GHG emissions accounting and reporting processes.

The Protocol itself has evolved with time, going through 4 version updates. The different versions correspond to evolutions initiated by the original Working Group but also to the suggestions and feedback provided by several waste associations that have reviewed and commented on the Protocol. As a result, several worldwide associations have validated and used the Protocol for their own greenhouse gas inventories.
Through these evolutions, the Protocol has been supported by the International Solid Waste Association (ISWA), the European Federation of Waste Management and Environmental Service (FEAD), the French Federation of Waste Management Services (FNADE), the Environmental Services Association (ESA) in the UK, the Confederation of European Waste to Energy Plants (CEWEP), the Dutch Waste Management Association (DWMA), and the Spanish Association of Hazardous Waste Managers (ASEGRE). It is the intent of the EpE Working Group to continue to promote its use internationally.

-> "Built on the GHG Protocol" label

In the perspective of continuous improvement of this document, and in order to meet the general expectations of users, the Working Group has decided to initiate a new revision of the Protocol.
Unlike the previous versions, it is not only based on a peer review but on a review conducted by the World Resources Institute (WRI). The objective is to have version 5 labelled "built on the GHG Protocol". This new label was initiated jointly by the WRI and the World Business Council on Sustainable Development (WBCSD). It is a way for the GHG Protocol to recognize those sector guidance documents, product rules, and calculation tools that have been developed in conformance with the GHG Protocol Corporate Standard. With such label, users should feel confident that the document or tool they are using is in conformance with the GHG Protocol Standards.

To obtain the label, the Protocol has been revised and two significant topics have been included.
• First, the emissions of biogenic CO_2 were added to the calculation tool. Even though these emissions are not included within the scope of direct and indirect emissions, they have to be calculated and reported separately in the tool.
• The second significant evolution is the completeness of emissions sources, requiring that all sources of emissions of all 6 of the identified Kyoto GHG's are considered. The threshold of 'significance' that was used to justify the exclusion of some sources is no longer applicable. The user is therefore in charge of including or not sources that he/she considers as not significant and should provide the adequate evidences / justifications.

-> The reference tool for the waste sector

With such label, the Waste Sector Protocol reinforces its desire to be the reference tool for the waste sector by ensuring its users of a total and transparent coherence and conformity with the GHG Protocol Corporate Standard's requirements.
The Protocol is exclusively dedicated to annual GHG reporting. It aims at being a supportive tool for waste managers or practitioners to prepare their GHG emissions inventory.
Based on such inventory, action plans and emission reduction objectives can be established. The present document along with the Excel emissions calculation worksheet constitutes the Waste Sector specific Protocol.

Protocol's Objectives and Principles

- 1.1. Objectives -

This document is intended to provide a credible approach to quantify, report and verify greenhouse gases (GHG) direct & indirect emissions of waste management actors. The purpose of this Waste Sector Protocol is to establish best practice across the waste sector for the implementation of a coherent and homogeneous annual GHG emissions reporting.

The reported data should be consistent with the guidance outlined in this document. Any deviation from these guidelines should be described fully in the report supporting the GHG emissions inventory.

This Protocol was built on the Greenhouse Gas Protocol – A Corporate Accounting and Reporting Standard – Revised edition, elaborated by the WBCSD and the WRI. A full review of the Protocol was undertaken by the WRI to ensure its compatibility with the requirements of the GHG Protocol. The Protocol is also compatible with the ISO standards related to GHG emissions inventory.

This Protocol is a dynamic document: it may be modified according to new knowledge and/ or improved calculation and measurement techniques.

- 1.2. Principles -

In line with the GHG Protocol Corporate Standard, this Protocol is based on the principles of relevance, completeness, consistency, transparency and accuracy. GHG reports should be based on the best available data at the time of publication. For more information on these principles, please refer to Chapter 1 of the Corporate Accounting and Reporting Standard of the GHG Protocol.

- 1.3. Definitions -

-> Entity

An entity is a group, a company, a subsidiary, a local authority or a site performing a GHG emissions inventory.
Any entity which performs its inventory according to this Protocol should apply the steps and meet the requirements described hereinafter.

-> Direct Emissions

Direct GHG emissions occur from process or equipments owned or controlled by the entity.
Example: emissions from combustion installations, landfills (fugitive emissions), company-owned vehicles, etc.
In accordance with the GHG Protocol, direct emissions are also known as 'Scope 1' emissions.
Direct emissions of biogenic carbon, resulting from biomass burning or decomposition, shall not be included in direct emissions but reported separately (see section 4.7).
It must be underlined that the term "direct GHG emissions" applies to the source type of emissions.

-> Indirect Emissions

Indirect GHG emissions are emissions that are consequences of the activities of the entity but that physically occur at sites or during operations owned or controlled by another organization than the reporting entity. In accordance with the GHG Protocol, indirect emissions can be distinguished into two categories known as scope 2 and scope 3 emissions.
Indirect emissions resulting from imports of electricity, heat or steam not self-produced have to be accounted for as scope 2 emissions.
Example: electricity purchased from the grid.
All other indirect emissions correspond to scope 3 emissions.
Example: waste transported in vehicles not owned (or not controlled) by the entity.
It must be underlined that the term "indirect GHG emissions" applies to the source type of emissions, i.e. it does not mean emissions of indirect greenhouse gases but emissions from indirect source types.

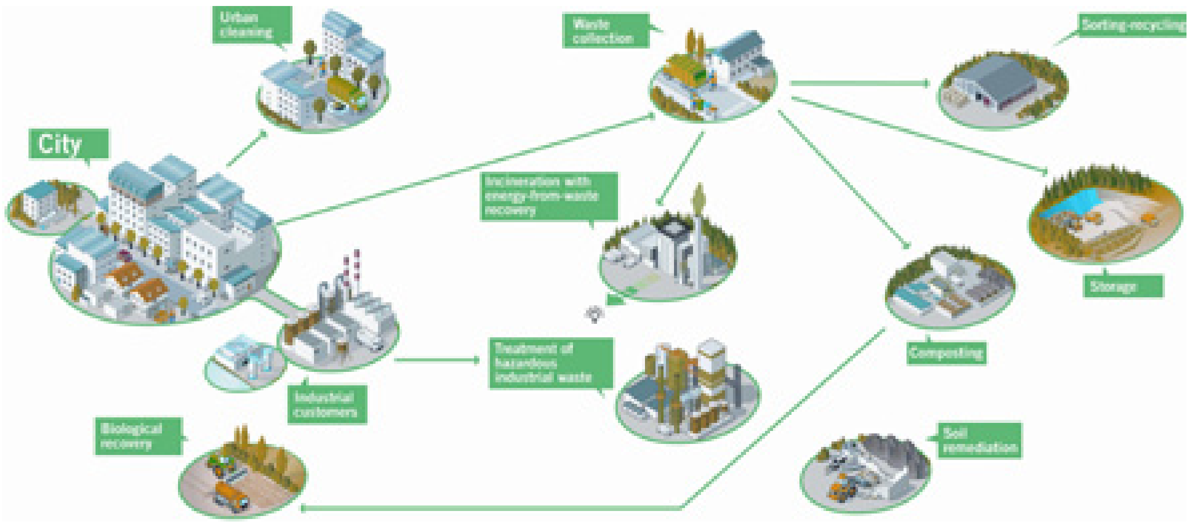
-> Avoided emissions

Certain waste treatment activities generate energy (electricity & heat) as a by-product and/or contribute to the re-use of materials or fuels.
Energy and material recovery can contribute to avoid GHG emissions compared to a baseline scenario.
Avoided emissions are not included in or deducted from direct and indirect emissions and should be reported separately.
For further details please see section 4.5.

Waste Management Sector

- 2.1. Waste Management Activities -

The various steps of the waste management are briefly presented below.



-> Collection and transportation

Collection is the first step of the waste management. It aims at gathering waste before transfert, sorting, treatment or recovery for instance.
Collection can be done door-to-door, using dedicated vehicles, or after preliminary voluntary drop-off in specific containers (packaging, paper, and glass).

-> Transfer

Waste that is collected from communities, individuals or companies can be directly transported to a treatment or material recovery facility or be firstly consolidated in a transfer center in order to optimise its transport to a treatment or material recovery facility.

-> Mechanical pre-treatment

Waste can undergo several methods of mechanical pre-treatment to facilitate its recovery or recycling.
For example, West Electrical and Electronic Equipment (WEEE) can be dismantled.

-> Sorting, recycling and material recovery

Waste can be sorted to separate the different materials fractions. Recyclable materials are then recycled by introducing them in the production cycle as a partial or total substitution (paper, glass, steel, etc.). Solid Recovered Fuels (SRF) can be produced and then used in substitution of conventional fossil fuels.

-> Physico-chemical treatment

It consists of mechanical, physical or chemical treatment of hazardous waste in dedicated installations. Alternative fuels can be produced.

-> Biological treatment (composting, anaerobic digestion)

These processes can be applied to agro-food industry waste, green waste, biowaste as well as sewage sludge. The composting process consists in organic matter aerobic degradation and stabilisation. It enables the production of organic amendment (compost) that can be used in agriculture, as a source of organic matter to improve certain low quality soils, e.g. in the restoration of brown field sites, or for landfill cap restoration. Anaerobic digestion consists of controlled anaerobic fermentation of organic waste in a digester, producing biogas which is mainly composed of methane. Produced biogas is captured and combusted in flares or recovered to produce thermal and / or electric energy.

-> Landfilling

Landfilling refers to the more modern sites where waste is placed in lined disposal areas which are environmentally isolated, and where waste is naturally degraded. Within best practices, emissions produced by decaying waste (gas and leachate) are recovered through drainage systems and treated. The amount and quality of these emissions are variable in time and depend on the composition of the stored waste. Organic waste decomposition produces landfill gas (comprised of methane and carbon dioxide in nearly the same amounts). The captured landfill gas is either combusted in flares or recovered to produce thermal and/or electric energy.

-> Thermal Treatment

Incineration is a treatment process applicable to hazardous and non-hazardous waste (municipal solid waste, industrial waste and sometimes sewage sludge). Waste is degraded through thermal treatment in incinerators. Incinerators are equipped with energy recovery systems, enabling electricity and / or heat generation. Furthermore, solid residues from combustion (bottom ash) are recovered and scrap metal can be recycled. Other thermal treatment exist such as pyrolysis or gasification.

-> Mechanical biological treatment (MBT)

MBT is an intermediate treatment step between waste collection and the subsequent treatment steps (landfill, thermal treatment, agronomic reuse, recycling or any other existing form of treatment). It is mainly used to treat municipal solid waste with an adequate biodegradable content to feed the biological step. In some cases, commercial and industrial waste or biowaste can also feed the plant. The configuration of the MBT process can vary, including more or less steps. The process can start with the mechanical step and then a biological step or the other way round, depending on the target of the plant: compost production, SRF production, energy production from biogas and/or stabilised product.

- 2.2. Specificities of Waste Sector's GHG Emissions -

The primary objective of the waste sector is to collect, treat and recover, as efficiently as possible, residues from human activities to limit their impacts on the environment.
Material and energy recovery have become crucial aspects for the sector so as to enable considering waste as a resource.

-> An uncommon position

The main specificity of companies in this sector lies in their original position: they generate environmental impacts that they are not the cause of, since they are not responsible for the very creation of the waste treated. In this context, the determination of the scope of responsibility for the impacts caused is crucial. GHG emissions generated whether during the transportation phase (collection, transport) or treatment phase consist in direct emissions (scope 1) for the waste sector companies however they constitute indirect emissions for waste producers (scope 3).

-> Emissions monitoring and uncertainties

In general, the waste sector is under strict monitoring regulations in terms of environmental impacts. As a result, treatment facility emissions and discharges are reported as accurately as possible by the operators. However, GHG emissions monitoring can present important uncertainties, because of several factors:

- Firstly, an important number of waste treatment activities incorporate complex processes (for instance biological) for which it is difficult to reach the same accuracy as in the other industrial activities' emissions to quantify GHG emissions,
- Finally, the composition of treated wastes is often very heterogeneous. In cases where a statistical approach / default values (national or IPCC) are used, it introduces important but unavoidable bias.

-> Avoided emissions

The waste sector is not only responsible for GHG emissions but also contributes to avoid GHG emissions. The waste sector aims at ensuring a maximum quantity of treated waste is recovered - either through material recovery (reuse, recycling, composting…), or as energy (electricity and/or heat produced out of biogas, incinerator, etc.). Material and energy recovery, when they occur, may result in an environmental benefit accounted for as avoided emissions.

Energy can be generated as a co-product by waste treatment facilities. If this electricity is sold to the grid, it is considered to contribute to avoid the emission of GHG that would have occurred if an equivalent amount of electricity had to be produced by power plants connected to the grid.

Materials sorted and recycled can be reprocessed and sold on the market as secondary materials.

The difference between emissions of GHG to produce equivalent (in quantity and quality) amounts of materials from raw virgin materials and from recycled ones enables the calculation of avoided emissions.

The consumption of these electricity and recycled materials results in a decrease of consumers' scope 2 and scope 3 emissions. However, these benefits cannot be translated in waste treatment players' carbon footprint directly, but are evaluated and reported separately as avoided emissions. Avoided emissions are reported for information purposes only.

As a result, this Protocol provides a methodology to evaluate avoided emissions and to report them in a separate memo item.

It should be noted that avoided emission should not be deducted from direct and indirect emissions.

-> Biogenic CO_2 emissions

GHG quantification and reporting is part of a process intending to evaluate the contribution of human activities to climate change. Nevertheless, climate change is a natural phenomenon to which the short cycle of carbon has always contributed. As such, the Intergovernmental Panel on Climate Change (IPCC) recommends for the Waste Sector that "Carbon dioxide from the combustion or decay of short-lived biogenic material removed from where it was grown is reported as zero"[1].
These emissions are reported in the AFOLU sector (Agriculture, Forestry and Other Land Use) to avoid double counting.

Yet, the GHG Protocol Corporate Standard requires the quantification and reporting of these biogenic emissions in a separate memo item.

This Protocol follows the Corporate Standard's guidelines and therefore provides a methodology for accounting and reporting of biogenic carbon dioxide emissions emitted by waste sector activities. These emissions are given for information purposes only. See section 4.7.

1. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol. 1, General Guidance and Reporting, p.6

Inventory Boundaries

- 3.1. Organizational boundaries -

Definition: [2] In setting organizational boundaries, an entity selects an approach for consolidating GHG emissions and then consistently applies the selected approach to define those businesses and operations that constitute the entity for the purpose of accounting and reporting GHG emissions.

-> "Equity share" and "control" approaches

The GhG Protocol's Corporate Accounting and Reporting Standard defines three approaches for setting organizational boundaries: the equity share, the financial control and the operational control approaches.[3]

- Under the "equity share approach", a company accounts for GHG emissions from operations according to its share of equity in the operation.
- Under the "control" approach, a company accounts for 100 percent of the GHG emissions from operation over which it has control, either "financial" or "operational".

The core business of the waste management sector is to operate sites, whether it is to collect, transfer, sort, treat and/or recover waste. It can operate its own sites or do it on behalf of municipalities and companies. In both cases, it is its responsibility to ensure that waste management is performed the most suitable way, to identify actions for improvement and to implement them, or at least, to inform and encourage their implementation.

As explained above, the "operational control" is a boundary approach that takes into account GHG emissions from source types under operational control.

In this Protocol, it is considered that an entity could exercise dominant influence over one source type if one of the following conditions is fulfilled:

- It holds a majority of the voting rights in the reporting entity,
- It holds the operating permit delivered by the administration,
- It has been delegated the operations of the considered installation,
- It has the power to impose its Health, Safety and Environmental (HSE) procedures at the considered site(s),
- It has been delegated the authority to make economic decisions concerning the technical operation of the considered installation,
- by virtue of the terms and conditions contained in the contract governing the operation of the source type.

2. Source: Chapter 3 of the GhG Protocol's Corporate Standard
3. Please refer to the Chapter 3 of the GhG Protocol's Corporate Standard for more information on these approaches.

The "operational control" approach thus appears as the most suitable for the GHG reporting of waste management operators.
This is the approach adopted in this Protocol, slightly enlarged in order to include the cases of delegation of services.

-> Specific cases: delegation, sub-contracting and financial control

It has to be highlighted that an entity that has operational control does not necessarily have the power to take all decisions concerning source types. In case of significant investments for example, approval from all of the partners that have a financial share will be required. In case of delegation of services, investments will depend on the decision of the municipality or company which delegates.

The operational control approach also applies in the case of sub-contractors of the entity. Therefore, GHG emissions from the sub-contractors will be included in the entity's direct emissions reporting if it maintains operational control over the activities it has assigned them, i.e. if it has the authority to make decisions over operational procedures generating these emissions. If the entity does not keep operational control over the delegated activities, corresponding GHG emissions should be integrated into the indirect emissions (scope 3). In all cases, the entity will have to coordinate with its sub-contractor to make sure that the data reported as direct emissions for one and as indirect emissions for the other in their respective inventories are consistent.

For some source types, an entity could have financial control shared with other entities, but not have direct operational control. In this case, in this Protocol, it is considered, that this entity has anyway an operational control, even if weak and indirect: since the entity intends to gain economic benefits from these activities, it has to endorse also their emissions and report them. The entity has the responsibility to refer to contractual agreements to establish which partner has the authority to introduce and implement operational procedures and to remind its role.

Consistency of GHG emissions consolidation will be reached only if all organizational levels follow the same approach. The « operational control » approach must therefore be implemented at all organizational levels.

- 3.2. Operational boundaries -

Definition 4.: In setting operational boundaries, an entity identifies emissions associated with its operation, categorizes them as direct (scope 1) and indirect emissions (scopes 2 & 3), and chooses the scope of accounting and reporting for indirect emissions.

-> Gases covered and units

The reporting unit used in the Protocol is metric tonnes of GHG. The consolidation unit is metric tonnes (CO_2). Results in GHG other than CO_2 are converted to CO_2e data using the Global Warming Potential (GWP) values provided by the IPCC (See section 4.4).

The seven GHG to be reported are:
- carbon dioxide (CO_2),
- methane (CH_4),
- nitrous oxide (N_2O),
- sulphur hexafluoride (SF_6),
- hydrofluorocarbons (HFCs),
- perfluorocarbons (PFCs)
- nitrogen triflouride (NF_3)

Nevertheless, waste management activities are mostly accountable for emissions of methane, carbon dioxide and nitrous oxide.

-> Scopes covered

In line with the GHG Protocol Corporate Standard, this Protocol enables the quantification and reporting of scope 1 and scope 2 emissions.

Guidance is also provided to estimate avoided emissions as well as for biogenic and sequestered carbon emissions.

As for now, it is not mandatory to report scope 3 emissions. In order to obtain a GHG emissions inventory as complete as possible, entities may also wish to report these other indirect GHG emissions. If so, they should refer to the new standard for developing and reporting inventories of scope 3 sources developed by the GHG Protocol (see http://www.ghgprotocol.org/standards/scope-3-standard).

4. Source: Chapter 4 of the GHG Protocol's Corporate Standard

Definition: A source type is a process or equipment which releases direct and indirect GHG emissions into the atmosphere. Source types are characterized by an identical calculation methodology.

-> Identifying the Source Type List

The user must list, every year, the source types it is taking into account to calculate its annual inventory emissions.
The entity should keep a written record of the decisions taken during the identification of the source type list.
To determine its source type list, the entity must identify all sources over which it has operational control. This list must be as exhaustive, complete and accurate as possible.

In the Excel Tool, a dedicated sheet entitled "Source Type List" helps the user to identify the emission sources that should be included in its reporting perimeter.
It is based on the following table which summarizes the main direct & indirect source types met in waste management activities. For information purposes, avoided emissions and biogenic carbon dioxide sources have been identified and listed separately.

All these different source types include both point source emissions (stacks, flares, etc.) and diffuse emissions sources (landfills).

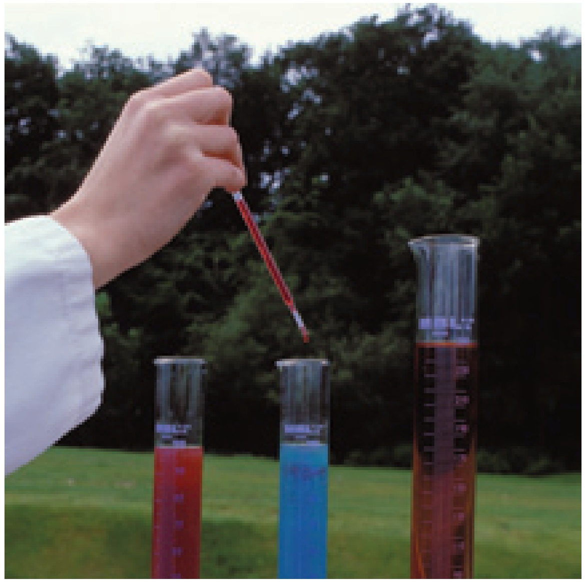
Table 1 -> Synthesis of main direct & indirect source types met in waste management activities

Activity	Direct Emissions Sources	Indirect Emissions Sources	Avoided Emissions Sources	Biogenic CO_2 Emissions Sources
Collection & Transportation	-> CO_2 from fuel consumption -> HFC from A/C leakages	-> CO_2 from electric vehicles -> CO_2 from outsourced transport	N.A.	-> CO_2 from consumption of biomass energy (biofuels, bioliquids, solid biomass, biogases)
Transfer	-> CO_2 from fuel consumption	-> CO_2 from purchased electricity consumption	N.A.	-> CO_2 from consumption of biomass energy (biofuels, bioliquids, solid biomass, biogases)
Mechanical Pre-treatment (dismantling)	-> CO_2 from fuel consumption	-> CO_2 from purchased electricity consumption	N.A.	-> CO_2 from consumption of biomass energy (biofuels, bioliquids, solid biomass, biogases)
Sorting, Recycling & Recovering	-> CO_2 from fuel consumption -> HFC emissions from WEEE dismantling	-> CO_2 from purchased electricity consumption	-> Potential avoided GHG emissions corresponding to the difference between virgin raw material production emissions and material recovery emissions -> Potential avoided GHG emissions corresponding to the difference between burning fossil fuel and solid recovered fuels (SRF)	-> CO_2 from consumption of biomass energy (biofuels, bioliquids, solid biomass, biogases)
Physico-chemical waste treatment	-> CO_2 from fuel consumption	-> CO_2 from purchased electricity consumption	-> Potential avoided GHG emissions corresponding to the difference between burning fossil fuel and alternative fuels	-> CO_2 from consumption of biomass energy (biofuels, bioliquids, solid biomass, biogases)
Biological Treatment (composting)	-> CO_2 from fuel consumption -> Process emissions (CH_4 and N_2O)	-> CO_2 from purchased electricity consumption	-> Potential avoided GHG emissions corresponding to the difference between use of chemical fertilizer and compost spreading	-> CO_2 from consumption of biomass energy (biofuels, bioliquids, solid biomass, biogases) -> CO_2 process emissions

Table 1 (continued)

Activity	Direct Emissions Sources	Indirect Emissions Sources	Avoided Emissions Sources	Biogenic CO_2 Emissions Sources
Biological Treatment (Anaerobic Digestion)	-> CO_2 from fuel consumption -> Process emissions (CH_4 and N_2O)	-> CO_2 from purchased electricity consumption	-> Potential avoided GHG emissions corresponding to the difference between biogas recovery emissions (as power, heat and/or fuel) and substituted energy production emissions	-> CO_2 from consumption of biomass energy (biofuels, bioliquids, solid biomass, biogases) -> CO_2 process emissions -> CO_2 from biogas combustion
Landfill	-> CO_2 from fuel consumption -> Diffuse CH_4 emissions -> CH_4 from incomplete landfill gas combustion	-> CO_2 from purchased electricity consumption	-> Potential avoided GHG emissions corresponding to the difference between landfill gas recovery emissions (as power, heat and/or fuel) and substituted energy production emissions	-> CO_2 from consumption of biomass energy (biofuels, bioliquids, solid biomass, biogases) -> Diffuse CO_2 & oxidised CH_4 emissions -> CO_2 from landfill gas combustion process
Thermal treatment	-> CO_2 from fuel consumption -> N_2O process emissions -> CO_2 process emissions (only the fossil carbon share of the waste)	-> CO_2 from purchased electricity consumption	-> Potential avoided GHG emissions corresponding to the difference between energy from thermal treatment processes recovery (as power and/or heat) emissions and substituted energy production emissions. -> Potential avoided GHG emissions corresponding to the difference between virgin raw material production emissions and material recovery emissions (e.g. slag, scrap, metals and bottom ashes)	-> CO_2 from consumption of biomass energy (biofuels, bioliquids, solid biomass, biogases) -> CO_2 process emissions (the biogenic carbone share of the waste)
Mechanical Biological Treatment (MBT)	-> CO_2 from fuel consumption -> Process emissions (CH_4, N_2O)	-> CO_2 from purchased electricity consumption	-> Potential avoided GHG emissions corresponding to the difference between biogas recovery emissions (as power, heat and/or fuel) and substituted energy production emissions -> Potential avoided GHG emissions corresponding to the difference between virgin raw material production emissions and material recovery emissions (compost production, alternative fuels, material recovery...)	-> CO_2 from consumption of biomass energy (biofuels, bioliquids, solid biomass, biogases) -> CO_2 process emissions

- 3.3. Exclusions -



Under the definition of the completeness principle given by the GHG Protocol, every source type that is in the chosen perimeter must be included in the inventory.
It is considered better to include all sources even though with high uncertainty factors if they can be estimated.

Nevertheless, based on experience of waste management practices, it is clear that some sources of emissions may not be significant compared to overall emissions and could therefore be excluded without prejudice to the report. The entity can also encounter obstacles in the quantification of some sources types because of a lack of knowledge.

Quantifications have been undertaken by members of the Working Group in charge of this Protocol to assess whether or not some sources could be excluded. The emissions for these sources have been compared to other total emissions of the same treatment process or activity.
Diffuse emissions of HFC gases from air conditioning (A/C) mobile & fix devices have been quantified using conservative assumptions. Even though these gases GWP is very high, these sources represented only minor contribution to the sites / activities overall emissions.

Veolia Environment and SITA Experiences

Estimations were made thanks to the "screening method" proposed by the HFC/ PFC Protocol[5] and using the most conservative assumptions proposed.

Veolia Environment estimated that HFC diffuse emissions from mobile A/C devices did not represent more than 0.80% of a truck's emissions due to fuel consumption during a year.

SITA calculated leakages for buildings, using conservative average annual gas recharge quantities. HFC diffuse emissions represent 0.2% (collection); 0.9% (sorting facility); 1.5% (landfill) of these facilities' total direct emissions.

Therefore, these sources are not considered to be significant for waste treatment activities and it may seem legitimate to consider as complete a GHG report that would not include one or all of these sources. Yet, the insignificance of these emissions can vary from one activity / site to another one. Users are therefore asked to carefully check whether the devices (age, size, refrigerant gas) used on the perimeter of their report is comparable or not.

The Excel tool of this Protocol compiles all GHG emission sources identified up to date to enable the user to inventory, as exhaustively as possible, the source types it is concerned by.
However, the user is responsible for the completeness of its GHG report.
In case a source of emission is not proposed in this Protocol, the user can still calculate and add the GHG emissions by using the space left available in the tool at the bottom of each tab.

In the case where access to information data is obstructed for any reason, it is highly recommended to refer to the GHG Protocol Corporate Standard[6] to set up processes and cross checks that will allow collection of detailed information relevant for future GHG emissions quantification reports.
Any excluded source should be properly explained and justified.
A minimum threshold cannot be defined to exclude some sources.

5. Calculating HFC and PFC Emissions from the Manufacturing, Installation, Operation and Disposal of Refrigeration & Air-conditioning Equipment (Version 1.0), January 2005, http://www.ghgprotocol.org/calculation-tools/refrigeration
6. GHG Protocol, Chapter 7, Managing Inventory Quality

- 3.4. Adjustments -

-> Adjustments to the Source Type List

Changes may relate to the entity's group structure or to its operations e.g. through the acquisition or divestiture of subsidiaries or assets. It follows that the source types in the source type list may not be fixed over time.
Each time an entity changes its structure or operations, adjustments must be made to the source type list and corresponding annual emissions calculations.
Any adjustment to the source type list must be completed by the end of the same year in which the structural or operational change occurred.

-> Adjustments for loss of operational control

An entity can divest operational control over source types within its source type list through:

- a de-merger or divestiture,
- outsourcing one or several activities,
- a re-organization of operational control (change of contractor …),
- termination of an activity (source type).

Should an entity divest operational control over source types within its source type list, that entity will be required to adjust its source type list and annual GHG emissions. In case of closure of a source type, GHG annual emissions will be taken into account until the final closing. The method to take into account structural changes must be explained.

-> Adjustments for taking over operational control

An entity can acquire operational control over source types outside of its source type list through:

- a merger,
- an acquisition,
- internalization of an activity,
- a re-organization of operational control (contractor's change …),
- opening a new source type.

Should an entity acquire operational control over source types outside of its source type list, that entity will be required to make an adjustment to its source type list and to its annual GHG emissions. In case of start up of a new activity, GHG emissions will be taken into account from the start date. The method to take structural changes into account must be explained.

4 Emissions calculations

- 4.1. Reporting Period and data -

The purpose of this section is to outline a common approach and methodology for quantifying GHG emissions, using the Excel calculation tool associated to this Protocol.

-> Reporting Period

This Protocol is designed for preparing a GHG inventory on the basis of activity data cumulated over a given period of time, typically one year.

-> Activity data

To calculate GHG emissions, the user has to identify and collect activity data which are representative data of an activity taking place during a given period of time (typically the reporting period). Data are linked to the activity such as collected, treated, sorted or recycled waste tonnage; but also quantities / volumes of fuel combusted or of electricity purchased. These activity data are determined by the emission source type and can be influenced according to the emission factors' unit available (m^3 rather than tonnes for instance). The entity is free to select activity data as long as its choices are justified.

The Excel calculation tool indicates the activity data that the user should collect for each source type.

- 4.2. Methodologies used -

-> Calculation and/or measurements

Different levels of accuracy can be achieved depending on the type of methodology used to assess GHG emissions:

- either calculation (use of activity data and standard emission factors),
- or measurements (periodic or continuous),
- or a combination of both.

This Protocol does not recommend one methodology more than the other because it is extremely dependant on the source type. It is thus of the responsibility of the user to identify the most accurate methodology for each of the source types of its inventory. The chosen method will depend on the significance of the source type and the uncertainties associated with the available methods of assessment.

When measurements are involved, there can be accuracy differences between alternative measurement techniques.
In case of continuous measurement for instance, there might be several sampling protocols applicable to perform a representative sampling for analysis.
Likewise, when calculations are involved, for a same source type, several emission factors from different bibliographic sources can be used.

For example, regulatory measurements of CO_2 emissions of stacks can be used by the site manager in case of GHG emissions due to hazardous waste incineration, as long as it can be justified that this method is more accurate than a calculation method using activity data and an emission factor.
In this case, the proper functioning of the emissions analyser should be verified, a preventive maintenance program should be implemented to avoid any deviation in the operation of the measuring device and maintenance record should be archived.
Moreover, the user must avoid double counting. Stack measurements apply to all of the incinerated carbon (waste as well as additional fuels).
It is therefore not necessary to do a separated and dedicated calculation for the emissions due to additional fuels.

The Excel calculation tool gives the possibility to use either a measurement or a calculation approach to quantify emissions from each kind of source type.
As previously explained, when calculations are involved, there can be several emission factors for the same source type.
The tool proposes default emissions factors, sometimes several for the same source type, with information on their perimeter so the user can select the most adequate factor for its defined case.

-> Reference Documents

This Protocol is built on the GHG Protocol, i.e. it is compliant with all requirements of the Corporate Standard.
It also refers to several external tools and models, such as: the Transport Protocol (EpE/ ADEME), GHG emissions generation from landfill sites models (ADEME, LandGEM, GasSIM, IPCC Tier II), the HFC Tool of the GHG Protocol… Detailed references are given for the sources of default values, emission factors and calculation methodologies within the Excel calculation tool (step by step).

- 4.3. Calculation Tool -

-> This tool is made of several spreadsheets:

- Source Type List:
  establishment of list of the source types included in the reporting perimeter
- Transport:
  calculation of emissions due to waste collection and transport.
  This table is based on the emissions calculation sheet for GHG emissions from transport published by EpE and focuses on relevant transport activities in waste management.
- Sorting - Transfer - Recycling:
  calculation of emissions due to transfer and sorting facilities
- Anaerobic digestion:
  calculation of emissions due to anaerobic digestion of waste
- Composting:
  calculation of emissions due to composting process
- SRF:
  calculation of emissions due to Solid Recovered Fuels preparation
- MBT:
  calculation of emissions due to Mechanical-Biological treatments
- Landfills:
  sheet presenting the recommendations and requirements concerning emissions calculation from landfills.
  Four theoretical methane production and emission models are presented (methane production calculation equation, major parameters…)
- Thermal treatment:
  calculation of emissions due to waste thermal treatment (all types)
- Avoided:
  calculation of potential avoided emissions through waste recovery following the principles presented in the present Protocol
- Source Type List with Results:
  sheet detailing the direct/indirect, biogenic and avoided emissions results associated with the activities covered by the inventory
- Synthesis:
  sheet summarizing the results of the inventory
- Factors:
  sheet summarising the recommended emission factors to be used for the reporting
- Recycling Factors:
  Recommended factors for avoided emissions potentially associated with material recovery

-> The user has different types of data entry fields:

- Fields where the user has to enter site specific values (for instance, activity data, such as incinerated waste tonnage)
- Fields where default values are presented (emission factors). Default values refer to nationally or internationally accepted values, when they are available. Sources are presented within the table. The user can adapt these default values to give the most accurate vision of its site situation. However, in this case, selected values will have to be documented and justified.

By filling in the calculation table, the user will see notes that indicate how to fill in the tool, precautions to take and some recommendations mentioned in this Protocol.

- 4.4. Global Warming Potentials -

The Global Warming Potentials (GWP) used in the Excel calculation tool are those proposed in the 4th IPCC report[7].
These GWPs are not those which have been integrated in the Kyoto Protocol framework and its associated project mechanisms.

It was chosen to move to the most recent GWP values available since the first commitment period of the Kyoto Protocol ends at the end of 2012 and that 2nd IPCC assessment values are only imposed until that time.
If users wish to use the GWP values imposed in the framework of the Kyoto Protocol, they should change the values in the "Factors" tab of the Excel tool, give the reference associated and justify this choice.

Table 2 -> Global Warming Potentials used in this Protocol

Gas	GWP
CO_2	1
CH_4	25
N_2O	298
SF_6	22 800
HFC	from 124 to 14 800 depending on the substance
PCF	from 7 390 to 12 200 depending on the substance
NF_3	17 200

7. Source: IPCC Fourth Assessment Report: Climate Change 2007, Climate Change 2007: Working Group I: The Physical Science Basis, 2.10.2 Direct Global Warming Potentials

- 4.5. Avoided emissions Calculation -

Avoided emissions are expected either from energy or from material recovery. Since they are outside the control of the Waste Sector, it is highly difficult to verify that they really occur. It depends on the behaviour of the consumers and also on the aftereffect of the introduction to the market of these energy and materials from waste. In fact, avoided emissions are therefore expected avoided emissions.

-> Energy recovery

Energy recovery consists in electric and thermal energy production from waste thermal treatment, landfill gas and biogas resulting from anaerobic digestion.

Avoided emissions correspond to the GHG emissions that would have occurred to produce an equivalent quantity of energy to what is dispatched to the grid / customer. They are calculated based on the carbon weight of the energy substituted.
It is considered that the electricity, steam or heat dispatched to the grid / network would have been produced by the grid-connected power sources, which constitute the national energy mix. Energy from waste treatment facilities is generated on a continuous basis and avoided emissions are calculated with emission factors adapted to local context.
Avoided emissions associated with energy production are only quantified for the energy effectively sold to the grid and used onsite for purposes other than that energy production, as can be seen on the diagram below:

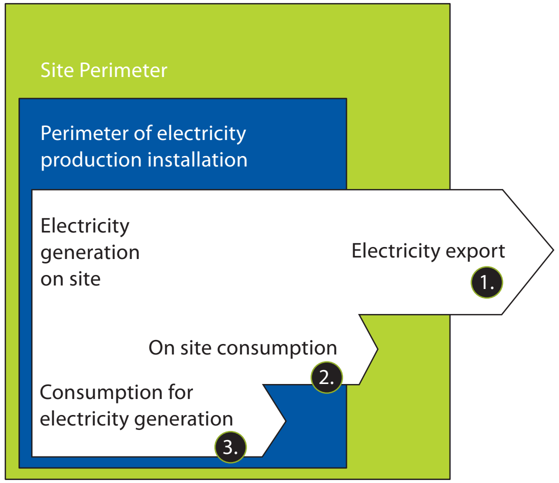


Figure 1 -> Consumption sources of energy produced by waste treatement activities

Avoided emissions can be quantified for the energy sent to sources of consumption 1 and 2. However, auto consumption dedicated to energy generation (sources of consumption 3) cannot be taken into account for avoided emissions quantification since, in the absence of the project, there would not be energy consumption.

-> Material recovery

Material recovery consists in recycling and reprocessing of waste fractions in substitution to an equivalent quantity of materials which would have been produced out of raw virgin materials.
The most common fractions are:

- Paper/Cardboard
- Glass
- Steel
- Aluminium
- Plastics
- Bottom ashes
- Scrap metal
- Substitute fuels (either Solid Recovered Fuels from non-hazardous waste or alternative fuels from hazardous waste)
- Slag

Avoided emissions associated with material recovery are calculated using a Life Cycle Analysis (LCA) approach.
The studies compare the global emissions generated to produce a given material using virgin raw materials / primary materials and the global emissions generated to collect, treat, re-process and manufacture recyclable materials into secondary materials with approximately the same quality and properties as the original material.
The emission factors for avoided emissions result in the difference between the global emissions of these two approaches.

For substitute fuels, avoided emissions correspond to the difference between GHG emissions associated with the combustion of the waste-origin alternative fuel and GHG emissions that would have occurred during the combustion of the substituted conventional fossil combustible (taking into account the same energy content).

Several studies exist and provide factors for the avoided emissions related to the recovery of different fractions (plastics, paper, metal…). In the Excel tool associated with this Protocol, we decided to provide emission factors resulting from six major studies:

- Waste management options and climate change, AEA Technology, study for the DG Environnement, 2001
- Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks, 3rd edition, US EPA, 2006
- Etude technico-économique sur le bilan des filières de recyclage, ADEME/ Ecobilan, 2007
- Resource savings and CO_2 reduction potential in waste management in Europe and the possible contribution to the CO_2 reduction target in 2020. Prognos. October 2008
- CO_2 kentallen afvalscheiding. JHB Benner et al. CE Delft, September 2007
- Report on the Environmental Benefits of Recycling -Bureau of International Recycling (BIR), October 2008.

The users will have to choose between these six databases according to their geographical context.
If the users want to use values other than those cited in the "Recycling factors" sheet, they should document them and give the references of the LCA study at the origin of the values used.

**As mentioned in section 2.2, waste treatment players cannot claim ownership upon avoided emissions.
These emissions are reported for information purposes only and therefore, cannot be deducted from direct or indirect emissions.**

It has to be noticed that, in its Corporate Accounting and Reporting Standard, the GHG Protocol only requires that avoided emissions be reported separately from the scopes. Otherwise, it does not currently provide any specific guidance on quantifying and reporting avoided emissions.

- 4.6. Specific case of landfill diffuse emissions modelling -

Accounting for methane captured in landfills can be done using flowmeters placed on the landfill gas collection system and composition analysis.
However, field conditions make diffuse emissions accounting difficult.

-> A diversity of existing models

To date, the most common approach has been to use landfill gas production models to estimate the diffuse emission.
The use of models is required to estimate diffuse emissions in this Protocol.
Annex 1 presents a comparative study of the existing models.

Among the diversity of existing models, only the models using first order equations can take into account the various factors affecting landfill gas production today.
The entity should therefore use these models, and ban the use of models using "0" order equations (or using standard emission factors). The various existing models were created to describe specific conditions and provide standard factors for waste that can be adapted. Each of them have their pros and cons and the corresponding numerical results can vary widely. Each model requires time to understand its specificity and functionality.

Today, because of the very nature of the modelling exercise, no model is recommended over another, as long as it uses first order equations.

It is advised to resort to the model accepted by local authorities for regulatory declarations. If there is no locally accepted model, the entity should use a model that is published, accepted and available in scientific and technical literature (the calculation tool associated with this Protocol lists the preferred models), and the parameters of the model should be adapted to reflect site specific conditions. The choice of the model as well as the parameter adaptation should be documented and justified.
The chosen model will have to consider the waste composition.

Because of the necessary adaptation of the model's parameters, the reporting entity should make sure that the same model is used every year, except if it justifies the use of another model that allows better representation of the landfill conditions.

-> The importance of input data

Good use of a landfill's emissions estimation model requires a real competence (essentially because of the great sensitivity to the input data). The accuracy of the results also highly depends on the knowledge of the landfill to be modelled (biogenic carbon content, waste age, landfill gas capture rate), as much as on cultural criteria (food, waste sorting practices).
It is important that the site operational staff work in close collaboration with the user of the model.
The entity should provide pertinent data for input parameters and perform a consistency check on the calculated data, even by conducting a calculation using data provided by the Operation Managers. The use of these models implies a high level of uncertainty that is difficult to assess.

- 4.7. Other specific cases -

-> Electricity transport and distribution

Related GHG emissions are reported by the electricity producer (scope 1). The electricity consumer reports GHG emissions corresponding to the electricity quantity displayed on the electricity meter (scope 2).

Remark: Concern is often expressed that accounting for indirect emissions will lead to double counting when two different reporting entities include the same emissions in their respective inventories. Double counting should be avoided. Entities must therefore clearly identify direct and indirect emissions in their reporting.

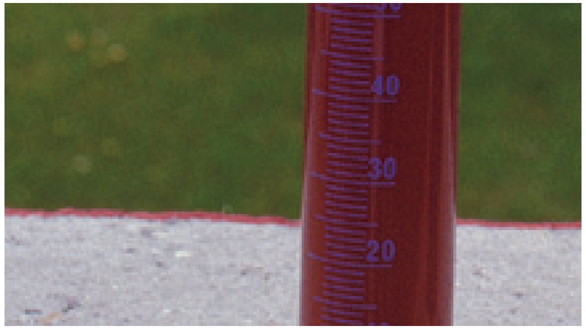
-> Sequestrated carbon

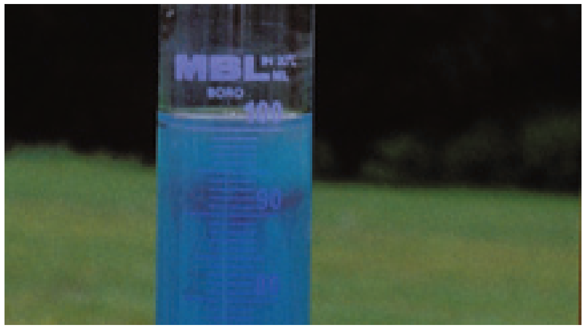
Since the accounting of sequestrated carbon in GHG inventory is complex, the Annex 2 of this Protocol is dedicated to this subject. The user is called to refer to this Annex for more information. It has to be noticed that the sequestrated carbon, if accounted, must be reported as a memo item, for information only, and separately from direct (scope 1) et indirect (scope 2) emissions, as well as from biogenic CO_2 emissions and avoided emissions.

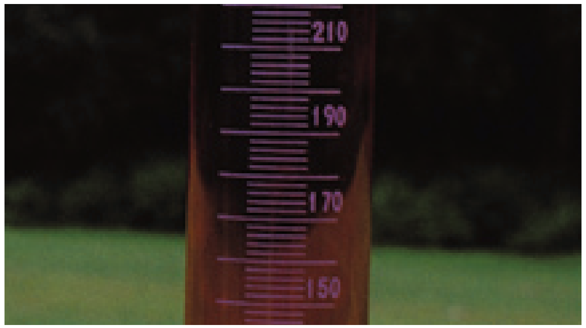
-> Biogas combustion in flare

When the specifications of the manufacturer are met, the efficiency of the flare is close to 100%. Yet, it may not always be 100% and drop by a few %. A generic approach was undertaken to show that these emissions are not significant between 99% and 100%. To best reflect each specific situation faced, no default value is given in the Protocol or in the excel tool. The value should be determined by the user.

A value set between 95% and 100% is estimated to correspond to most situations for properly operated flares. As for any value in the Protocol, the user is encouraged to properly document and justify the figures chosen.







-> Biomass emissions calculation

The short cycle of carbon

The short cycle of carbon consists in different stages; CO_2 in the atmosphere is captured by plants during photosynthesis and turned into carbon, stored in plants tissue. Biomass is considered to be a “carbon pool” before it releases the carbon back into the atmosphere when it is burnt or decaying. This sequestered carbon remains for a more or less long time in the pools, influencing the total CO_2 concentration in the atmosphere.

It is considered that in a balance system, the short carbon cycle is equal to zero with equivalent amounts of CO_2 captured and released. Biologically sequestered carbon can be released from these pools when biomass is burnt or decaying.

Reporting of Biogenic CO_2 emissions

International conventions[8] agree that carbon dioxide from biomass should not be accounted for in waste management section of National GHG inventories but under the specific category of Agriculture, Forestry and Other Land Use.

Therefore, the Protocol provides a methodology for quantifying and reporting these biogenic emissions in a separate memo item. This is in line with the GHG Protocol requirements and with the IPCC recommendations for National Inventories.

8. See for example: 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 1 – "Introduction": "Carbon dioxide from the combustion or decay of short-lived biogenic material removed from where it was grown is reported as zero in the Energy, IPPU and Waste Sectors (for example CO_2 emissions from biofuels, and CO_2 emissions from biogenic material in Solid Waste Disposal Sites." Volume 5 - "Waste": "CO_2 is also produced in SWDS, wastewater treatment and burning of non-fossil waste, but this CO_2 is of biogenic origin and is therefore not included as a reporting item in this sector"

Biogenic CO2 emissions from the waste sector are provided for information only and should not be added or deducted to direct or indirect emissions.

Emissions sources

The sources of biogenic CO_2 emissions identified for waste treatment activities are the following:

- Waste incineration of biodegradable fractions
- Biomass energy (biofuels, bioliquids, solid biomass, biogases) combustion.
- Diffuse CO_2 emissions from landfill sites
- Oxidised fraction of diffuse methane emissions from landfill sites
- Biogas combustion emissions
- Anaerobic digestion direct CO_2 emissions through leakages
- Composting CO_2 process emissions
- Refuse derived fuels incinerated (share of biogenic carbon)

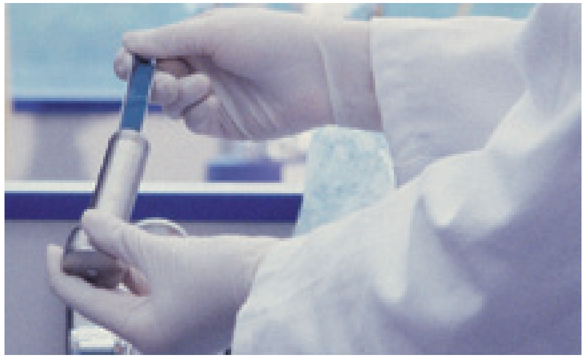
For each source, at least one quantification approach is proposed in the Excel calculation tool.
Default emission factors from the literature and from other protocols are proposed.

It has to be highlighted that relevant emission factors and activity data to calculate biogenic emissions are not always easily available, especially for biological treatment alternatives. These emissions depend of a number of parameters and complex phenomena that make the elaboration of emission factors uneasy. The Protocol proposes default accounting methods and emission factors in the calculation Excel tool. Other emission factors and default values can be used but must be clearly documented and justified.

- 4.8. Base Year and Historic Emissions Recalculations -

-> Base Year

The base year is usually the first year for which a GHG report is available. It is use as a reference year from which further annual GHG reports are compared to. In order to ensure coherency and comparison between different annual reports, the boundary of the report should be consistent. Yet, as explained in section 3.4, such boundary may evolve with time, resulting from acquisition, outsourcing, etc. of some or all activities. If so, the historical emissions should be adjusted according to rules defined previously and based on the following requirements.



-> Historic Emissions Recalculations

Historic emissions are modified in the following cases:

- Change in the sources types list (mergers, acquisitions, transfers, outsourcing or insourcing of sources types),
- Emissions quantification method change,
- Error detection in emissions quantification.

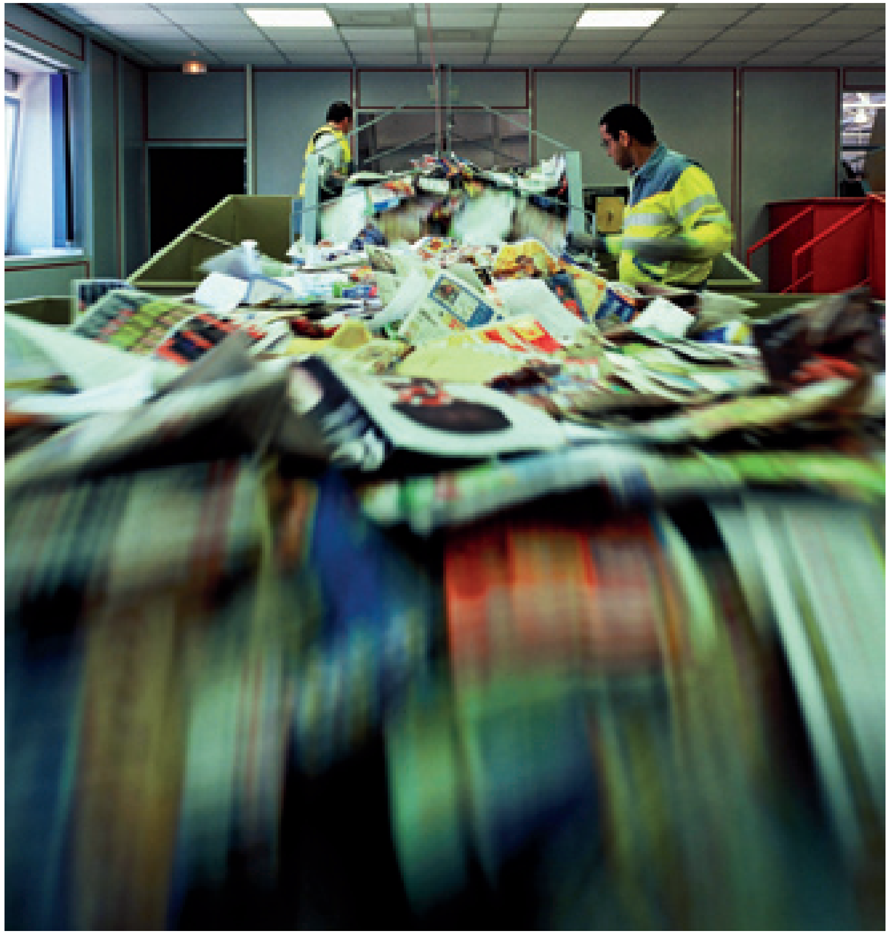
If the entity considers that it has a significant impact on the inventory, historic emissions have to be recalculated. The process must be clearly documented and justified. Historic emissions are not adjusted in case of an activity stopping or starting. The entity must indicate if the necessary historic data are not available. It can then choose not to adjust the concerned historic data.

For more information on historic Emissions Recalculations, please refer to Chapter 5 of the Corporate Accounting and Reporting Standard of the Greenhouse Gas Protocol.

Managing Uncertainty

- 5.1. Uncertainty in GHG emissions inventories -

Definition[1]: "A general and imprecise term which refers to the lack of certainty in emissions related data resulting from any causal factor, such as the application of non-representative factors or methods incomplete data on sources and sinks, lack of transparency etc. Reported uncertainty information typically specifies a quantitative estimates of the likely or perceived difference between a reported value and a qualitative description of the likely causes of the difference".



By their nature, data inventory, evaluation and collection lead to uncertainties. Assessing this uncertainty is essential in GHG emissions reporting. It does not aim at questioning the validity of inventory data but to determine the level of reliability. It also helps identifying possible areas of improvement in reporting accuracy, and to direct methodological choices.

Emissions totals reported by entities are usually provided as a unique figure with implicit or explicit confidence intervals. For example, reported total emissions of 125,000 tons of CO_2 equivalent could be more accurately phrased as "total emissions likely to be between 115,000 and 135,000 tons" or "total emissions are 125,000 tons plus or minus 10%". The degree of uncertainty will vary widely for different emissions estimates, depending upon the emissions source type, the calculation method used and the level of effort expended to gather and validate data.

- 5.2. Uncertainty calculations -

-> Sources of uncertainty

Even when the best available calculation methodologies are used, there are many sources of uncertainty for GHG emissions totals:

- Estimation to compensate for missing data (e.g. non-reporting facilities, or missing fuel bills),
- Imprecise measurement of emissions-producing activity,
- Calculation errors and omissions,
- Use of "average case" emission factors not perfectly matched to certain circumstances,
- Assumptions that simplify the estimation of emissions from highly complex processes,
- Use of approximative emission factors.

However, at this stage, it is difficult to perform a calculation whose result will be relevant in the specific case of waste management. In this sector, GHG emissions monitoring shows a significant uncertainty, due to several factors:

- An important number of waste treatment methods rely on complex processes (notably biological) for which it is difficult to reach the same level of accuracy as in other industrial sectors,
- Some emissions are diffuse and, therefore, are estimated using theoretical mathematical models,
- Treated waste shows very heterogeneous compositions, for which a statistical approach is compulsory, introducing important but unavoidable biases. Standard factors, which precision is unknown, can be used.

-> Uncertainty standard-values

The table below gathers uncertainty ranges associated with instrumentation commonly used on waste management sites. This table was built with data provided by experts from Veolia Environmental Services, Séché Environnement and Suez Environment. This table is indicative and should be used as default data only if more accurate information is not available from manufacturers or sites.

Table 3 -> Uncertainty ranges associated with instrumentation

Type of device/ measure	Examples of use	Uncertainty-type	Observations
Flow meter	Flow measurement for used natural gas for incinerators	2%	Commercial measurement or integrated in a preventive maintenance approach. Constructor's value cannot be used, it is necessary to take into account real use and maintenance conditions. It is recommended to archive calibration certificates and monitoring and maintenance documents.
	Captured landfill gas measurement	5 – 10%	Non-commercial measurement and instrumentation used for daily operational monitoring. Corrective maintenance only.
	Incinerators flue gas flow measurements	5 – 10%	Difficult operating conditions (location of meter, variability of measured flow); risks of equipment failure.
Weighbridge	Determination of tonnage of waste collected, treated or recycled	2%	Commercial or integrated in a preventive maintenance programme. It is recommended to archive calibration certificates and maintenance monitoring documents.
Tank levels	Visual plotting of tank levels of additional liquid fuels	10%	Uncertainty due to the imprecise methods to determine the fuel oil or domestic oil tank levels.
Analyzers	CO_2 content determination of flue gas using on site devices	5 – 10%	Difficult operating conditions (localization); frequent failure risks. However, analyzers undergo strict regulatory monitoring.
	Determination of the carbon content of fuel using laboratory analyzers (gas chromatography)	5%	Devices that require preventive maintenance and periodical calibration. It is recommended to archive maintenance monitoring documents. It is necessary to have a sampling frequency that guarantees the representativeness of the measured values and to document the choice of the frequency.

Furthermore, it is noted that uncertainty principles apply to data from measures or analysis. This is the reason why these principles cannot be applied to the modelling that is performed to estimate methane emissions from landfills.

The entity could refer to the Chapter 7 of the Corporate Standard to make a calculation.

- 5.3. Reducing uncertainty -

-> Recommendations

Uncertainty is inherent to the establishment of a GHG emissions inventory.
However, the entity should aim at reducing this uncertainty and keeping residual uncertainty as low as possible.
To do so, the following principles should be implemented by the entity.
This entity will have to:

- Make sure it uses measurement and analysis instrumentation, as well as all means necessary for preparing an inventory that are adapted and commonly used within the sector,
- Implement a preventive maintenance on measurement and analysis instrumentation, supported by procedures and records to avoid potential deviation of the instrumentation.
  These documents should be kept and presented to the verifier, if necessary,
- Implement internal controls that will be formalized and archived (see below) as well as a management validation process for the reporting entity,
  - Make sure GHG emissions quantification process and used methods are constant, and that the reporting is consistent over the years.

-> Internal Controls

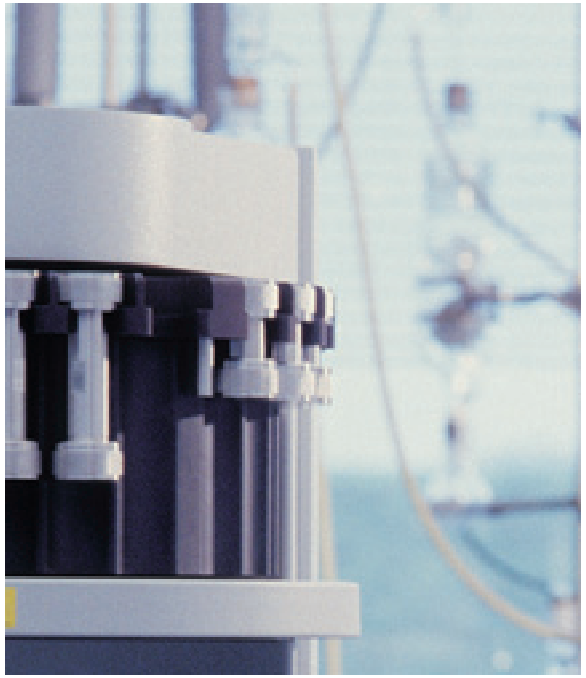
The entity will have to implement the necessary internal controls to reduce significant error risks to an acceptable level.
These controls will have to be documented and formalized.
It could be for example:

- Consistency check on year to year reported data,
- Order of magnitude check on reported data,
- Consistency check of calculated data to activity data,
- Validation of the calculation by a third party within the entity.

Guidelines for GHG Reporting Presentation

- 6.1 Content of the GHG inventory report -

The GHG Protocol Corporate Standard considers the following information as the minimum content of a public GHG inventory:



-> 1. Description of the company and inventory boundary

1.1. Outline of organizational boundaries chosen and the approach used

• See Section 3, Paragraph 3.1.

1.2. Outline of the operational boundaries chosen (in particular, the source type list defined for year N, and changes made to the source type list during year N) and, if Scope 3 emissions are included, a list specifying which types of activities are covered;

• See Section 3, Paragraph 3.2.

1.3. Reporting period covered

• See Section 4, Paragraph 4.1.

-> 2. Information on emissions

2.1. Total Scope 1 & Scope 2 Emissions independent of biogenic CO_2 emissions, avoided emissions and sequestrated carbon
• See Section 4 and use the calculation Excel tool

2.2. Emissions data separately for each scope
• See Section 4 and use the calculation Excel tool

2.3. Emissions data for all seven GHGs separately in metric tonnes
• See Section 3, Paragraph 3.2 and use the calculation Excel tool

2.4. Year chosen as base year, and an emissions profile over time that is consistent with and clarifies the chosen policy for making base year emissions calculations
• See Section 4.8

2.5. Appropriate context for any significant emissions changes that trigger base year emissions recalculations (acquisitions/divestitures, outsourcing/insourcing, changes in reporting boundaries or calculation methodologies, etc.)
• See Section 3.4

2.6. Emissions data for direct biogenic CO_2 emissions, reported separately from the scopes
• See Section 4.7

2.7. Methodologies used for calculations
• See Section 4, Paragraph 4.2.

2.8. Any specific exclusions of sources, facilities and/or operations
• See Section 3, Paragraph 3.3

The present Protocol adds the following section which is not mentioned by the GHG Protocol Corporate Standard:

2.9. Total avoided emissions
• See Section 4, Paragraph 4.5

The public GHG emissions report may include, when applicable, the following additional information:

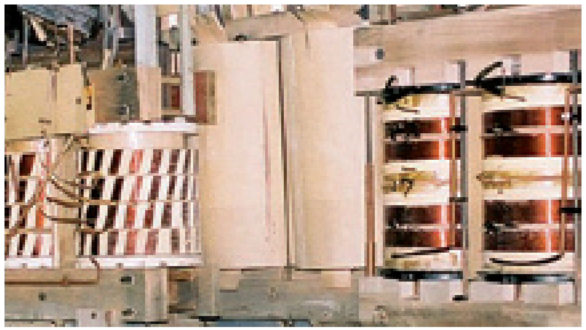
- Emissions data from Scope 3 emissions activities
- Information on the quality of the inventory (e.g. information, on the causes and magnitude of uncertainties in emission estimates) and an outline of policies in place to improve inventory quality - See Section 5
- Information on any GHG sequestration.

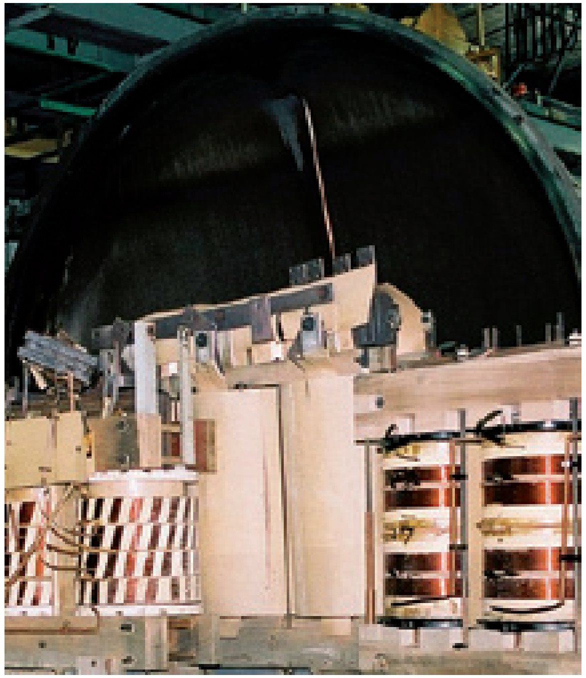
The GHG emissions inventory report is accompanied by a letter, signed by management or a designated representative, attesting that the data reported is a faithful representation of the entity's emissions, and complies with the Protocol's requirements.

- 6.2 Use of ratio indicators -

Ratio indicators may generally provide information on the efficiency of an activity, on the intensity of an impact or on the progress on a specified objective. Intensity ratios may be established and provided. They are presented as relative or specific emissions and express GHG impact per unit of activity or unit of value.
Example: tonnes CO_2 equivalent per tonne of waste treated.

The present Protocol does not make any recommendations concerning ratio indicators definition and use. It is up to the user to determinate if such data can be relevant of its GHG emissions management.





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Verification -> page 52

- Verification -

It is highly recommended that GHG annual emissions inventory from the entities are verified by a third party.

-> Scope of the verification

The purpose of the verification is to assess that:

- An internal protocol has been developed and complies with this guidance; this protocol should include calculation and computation methods and evidence of the sources of emissions factors used.
  When an entity uses an assessment method different from the Protocol, it must describe its methodology precisely and explain its choice.
- Reported data are free from material discrepancies (validation of GHG emissions and associated uncertainty for each source type).

-> Material discrepancy within annual emissions

A verifier's assessment of materiality will include consideration of both the amount and nature the errors.
For example, a relatively small omission or error repeated frequently could, once accumulated, have a material impact on the total emissions figure.
A verifier will assess the materiality of any individual misstatement as well as aggregate of uncorrected discrepancies.

Therefore, verifiers will take into account any omission or error that could lead to material discrepancies on annual figures.

- Annexes -
- of the Protocol -

- Annex 1 Comparative analysis of the greenhouse gases models for landfills -

-> Overview of emission sources

Landfills are one of the main greenhouse gases emissions sources in the waste management sector. Disposal of waste in landfills generates landfill gas, due to waste decay. This landfill gas is mainly composed of CO_2 and CH_4, as well as trace elements such as N_2, O_2, H_2S, CO, NH_3, H_2, VOC. Carbon dioxide comes from waste's organic components aerobic decomposition, methane coming from anaerobic decomposition.

Most controlled landfills are now equipped with recovery equipment for landfill gas produced in cells. Their efficiency may vary, from 10% to more than 90% of recovered gas. These gases are then flared or used to produce electricity and/or heat. However, a part of the gases produced cannot be recovered. They may become fugitive emissions, going into the atmosphere after passing through the cells cover, undergoing partial oxidation.

The following scheme shows the different emissions sources:

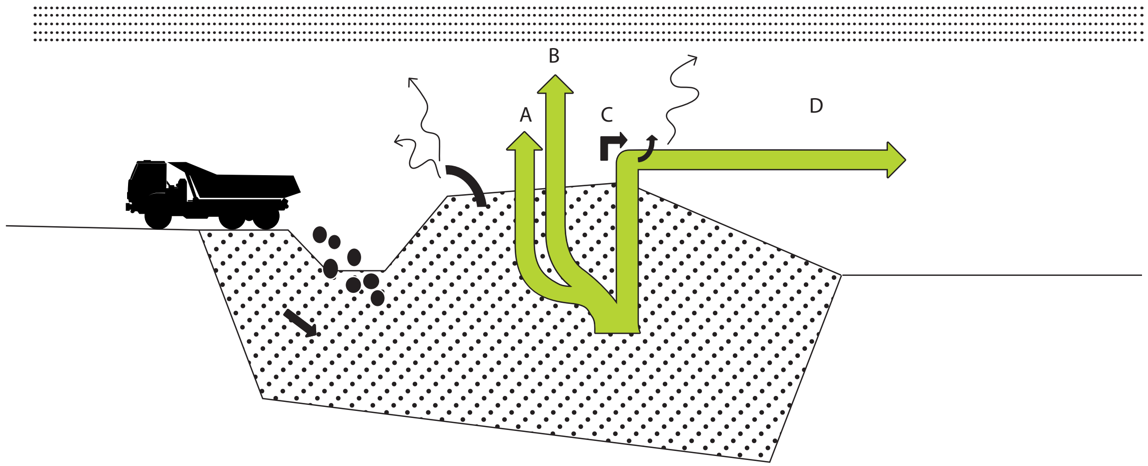
Figure 1 -> Overview of emissions sources of landfill

A
landfill gas oxidized within the cover layer and diffused in the atmosphere – CO_2 only

B
landfill gas diffusion in the atmosphere – CO_2 and CH_4

C
leak in the landfill gas collection system – CO_2 and CH_4

D
landfill gas flared or recovered to produce energy CO_2 and potentially CH_4 from incomplete combustion



It is also necessary to keep in mind that the lifetime of a landfill is made of several phases, during which landfill gas formation and emissions conditions are different:

For instance:
1. Operating cell: aerobic conditions, no landfill gas recovering,
2. "Completely filled" cell, not yet covered: aerobic and anaerobic conditions, important atmospheric diffusion, not optimum landfill gas recovery,
3. Covered cell: aerobic and anaerobic conditions, optimum landfill gas recovery, reduced diffusion.

The landfill gas quantity produced by a landfill and its composition (and therefore the quantity of greenhouse gases) depend on several criteria. The main criteria are:

- Landfilled waste quantity,
- Age of landfilled waste,
- Composition of landfilled waste[1],
- Environmental physico-chemical conditions (humidity, temperature, pH, etc),
- Efficiency of the landfill gas collecting system,
- Cover type.

Accounting for captured greenhouse gases can be done using flowmeters installed in the landfill gas collection system and analysis of the gas composition. However, diffused emissions accounting shows a limit due to the difficulty, because of field conditions, to assess the quantities of landfill gas emitted to the atmosphere. Diffuse emissions measurements can indeed be done, but they are complex and expensive to implement and are of limited accuracy.

To solve this difficulty, research has been done to model landfills atmospheric emissions. An inventory of these models and a comparative analysis of the main models are presented below. It appears that landfill generated emissions modeling is a complex exercise that requires taking into account numerous factors.

-> Existing models

Model diversity

Numerous models exist to assess pollutants emissions from landfills, whose goals and complexity vary significantly. In this analysis, we are interested in the models that allow an estimation of landfill gas production, so that we can assess greenhouse gas emissions.

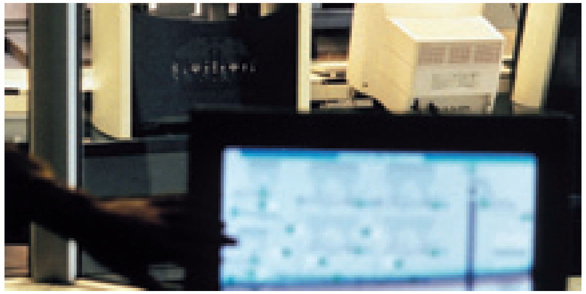
Models based on a theoretical production calculation require knowledge of landfilled tonnage. According to their accuracy, we distinguish:

- «0» order models (IPCC Tier 1 type): the methods used require emission factors and take into account the tonnages landfilled on the year of the calculation. Resorting to standard values, they do not take into account the complexity of the landfill specific conditions and rather aim at making estimated calculations, typically at a regional or national level. They do not allow reaching the accuracy that is necessary for the emissions calculation that has to be performed in the present Protocol.
- 1st order model (IPCC Tier 2 type): These models take into account a landfill's waste filling history or yearly average inputs and the site operating life (years).

1. This factor is highly variable from one region to another (food habits, waste sorting efficiency etc.). It explains the significant discrepancies that one might observe between the models of the different countries.

They are based on first order kinetic equation, and are more or less complex, depending on whether they take into account recovered landfill gas, methane oxidation through the cover, or other types of parameters.
The most sophisticated models (known as multi-phase) distinguish several waste types according to the speed at which they degrade.

The most frequently used models (older or more accomplished) in the literature are the IPCC Tier II model, Landgem (developed by the US EPA), GasSim (developed by the British Administration) and the ADEME model in France.



E-PRTR Specific Context

The implementation of the European Pollutant Release and Transfer Register (E-PRTR), replacing the European Polluant Emission Register (EPER) since 2006, accelerated the development of national GHG emissions estimation models for landfills. According to the regulation 166/2006 of the European Parliament and of the Council (also known as E-PRTR), the activities registered in the Annex I of the IPPC (Integrated Pollution Prevention and Control) Directive and exceeding the thresholds set in the Annex I of the E-PRTR regulation must declare their polluting emissions to competent authorities. Landfills may fall under the 5.c category «Installation for the disposal of non hazardous waste (>50t/day)» or the 5.d category «landfills (>10t/day).
As part of the E-PRTR reporting, Member States have to collect data from sites that are subject to declaration and transmit them to the European Commission. Member States are free to choose the model they use to assess emissions. It should be noted that, according to the E-PRTR, uncertainties remain in assessing diffuse atmospheric emissions from landfills in some countries.

Within the European Union, the models used by the member states are listed below (source: E-PRTR 2004):
Table 1 -> National models used for E-PRTR

Country	Model used	Short description
Germany	National model	Order 0 – adaptation of the tier 1 model from IPCC + some elements from tier 2 for CH4 emissions
Austria	2 (national) models depending if waste is residual (Tabasaran and Rettenberger methodology) or not (Marticorena methodology)	Order 1 – takes into account historical emissions Deduces captured landfill gas, cover oxidation – 2 waste types (1-20 and 20-100 years half-life)
Belgium	National model	Order 1, based on IPCC tier 2 – Deduces captured landfill gas, cover oxidation – only 1 waste type
Denmark	No data available	No data available
Spain	No data available	No data available
Finland	Adapted tier 2 IPCC model	IPCC model: Order 1 with a change on methane corrective factor
France	National models (ADEME) – one tier 2 type model and another one based on captured landfill gas	1st model: order 1 – captured landfill gas, cover oxidation – 3 categories of waste and 4 categories of waste age 2nd model: order 0 – uses the collecting device efficiency and the quantity of captured landfill gas
Greece	Tier 1 IPCC model	Order 0

Table 1 (continued)

Country	Model used	Short description
Ireland	LandGem (USEPA)	Order 1 – only 1 waste category, takes into account cover oxidation and captured landfill gas – Formerly created to model landfill gas production and not diffuse emissions
Italy	Taken from IPCC tier 2 Model	Order 1
Luxembourg	No data available	No data available
Netherlands	2 national models (TNO)	The 2 models are order 1 models – Takes into account captured landfill gas, cover oxidation. The difference between the 2 models is made on the number of waste category: 1 or 3. These TNO models are used by government to provide NOR reporting, but landfill operators are using a variety of models, developed by various consultants.
Portugal	LandGem (USEPA)	See Ireland
United Kingdom	National model (GasSim)	Order 1 – takes into account cover oxidation and deduces recovering from cover characteristics – 3 waste categories
Sweden	No data available	No data available

Outside the E-PRTR scope and outside the model developed by US EPA (see below), Norway also developed a national First Order Decay model, that takes into account the various types of stored wastes.

-> Comparison of main models

The comparison presented below concerns models that are the most usually referred to, and that are sometimes used outside their source country:

- ADEME model (France, national E-PRTR model),
- GasSim (UK, national EPER model),
- LandGem (USA, EPA model),
- IPCC Tier 2 model (international reference).

Modeling methodology

All the studied models are based on a first-order kinetic equation of the following type:

$$Q_{CH4} = L_0 \,.\, M \,.\, k.\, e^{-k(t-x)}$$

Where :

Q_{CH4}: Quantity of methane produced per year (Nm^3/year)

L_0: methane generation potential (Nm^3 CH_4 / t of waste)

M: tonnes of landfilled waste (t)

k: kinetic constant ($year^{-1}$)

x: year when waste has been landfilled

t: year of emissions inventory ($t \geq x$)

This formula is the models' core equation. The number of years "x" when waste was landfilled is summed. L_0 and M depend on "x". The result is sometimes detailed by waste categories, the L_0, M and k values depend on the waste categories. Depending on the models, other parameters can also be taken into account, such as landfill gas capture, oxidation through the cover, physico-chemical factors, etc.

The following table summarizes the main technical characteristics and default data of the various models (source: Ogor and Guerbois 2005). In most models, the factors mentioned here (L0, k, etc.) can be modified by the user to be more representative of the modeled landfills' actual conditions.

Table 2 -> Model's characteristics description

	IPCC Tier 2	LandGem (EPA) (8)	GasSim	ADEME
Model type	Monophase (1)	Monophase (1)	Multiphase (6)	Multiphase (6)
Input data	Historic of landfilled waste tonnages + % of inert waste	Historic of landfilled waste tonnages + % of inert waste	Historic of landfilled waste tonnages + waste composition	Historic of landfilled waste tonnages + waste composition
Methane generation potential L_0	110 (does not take into account inert waste) (5)	170 (does not take into account inert waste)	Automatically calculated	(2) Fast: 88 Medium: 44 Slow: 0
Kinetic constant k	Determined by the user	0,05	Fast: 0.016 Medium: 0.076 Slow: 0.046	Fast: 0.50 Medium: 0.10 Slow: 0.04
Biogas capture efficiency	Calculated (ratio capture / theoretical production)	Calculated (ratio capture / theoretical production)– maximum at 85%	Calculated (ratio capture / theoretical production)	Capture efficiency average based on cover type in proportion to the surface areas (3)
Inputs due to capture	Average flow of methane captured during the year	Average flow of methane captured during the year	Average flow of methane captured during the year	(4) surface area every cover type
Oxidation (7)	10%	10%	Automatically calculated	10%

(1) The terms multiphase or monophase refer to the fact that the model takes into account one or several types of waste. For LandGem, its use in multiphase has been mentioned during the interviews with the companies' experts.

(2) Takes into account the fact that the ADEME considers that during the first year, methane production is nil (aerobic conditions) – initial factors are respectively 100, 50 and 0.

(3) Used capture efficiencies are the followings: no capture (0%), operated area connected to a combustion unit (35%), semi-permeable cover (65%), natural impermeable cover (85%) and geomembrane (90%).

(4) A second approach has been developed by the ADEME. It uses the same capture rates as in the theoretical models, but is applied to the measured production.

(5) The Tier 2 methodology does not set any value for the methane generation potential but indicates a calculation method according to the quality of the landfilled waste. The value reported in the table above and used in the VEOLIA PROPRETÉ internal study was calculated under the hypothesis of a composition of 25% of putrescible waste and 30% of papers & textiles, but has to be adapted for every site.

(6) 3 waste categories: highly degradable, moderately degradable, and inert. For highly and moderately degradable waste, 3 kinetic constants are considered (fast, medium, slow), respectively associated to 15, 55 and 30% of waste.

(7) The oxidation rate applies only to the uncaptured methane.

(8) AP42 parameters. These are the parameters used for regulatory reporting in the USA, with CAA parameters.

Ease of use

All models show some complexity and require time to have a thorough knowledge so that they can be used in the best conditions, and be an accurate image of a landfill characteristics. The ADEME and GasSim models are considered to be more complex than the others, since the EPA and Tier2 models only allow to consider one type of waste . The calculation codes underlying the models are not complex[2]. It has to be noted that the equations used by GasSim are integrated in the calculation software and are therefore, unlike in the other tools, inacessible by the users.
In all cases, it came out of the discussions that the initial parameters of a model are not relevant to reflect the specific situation of each site. It is therefore essential to know how to modify the model's key factors (especially waste composition and kinetic constant) to adapt them to site specific conditions. This work has to be part of a long term approach, which makes constancy a primary target in the model choice.

Furthermore, it is sure that all available measured data (captured gas measurement that has to be completed by diffuse gas measures) constitutes a reliability and refinement source for the parameter setting of the used model.

Consistency of results

Studies were done to compare the different models, and also to compare them with typical landfills. The results of these studies vary significantly and show the extreme complexity of modelling (the results are very sensitive to factors' variation, notably k and L_o). The difficulty to measure diffuse methane should be pointed out; the different methods used in the comparative studies can show highly significant deviations.

To solve this methodological difficulty, the best way we can use to assess models' performances lies in the comparison of the estimations made for each model of the total methane production within the cells as compared to the captured methane quantity. This comparison inevitably induces a bias due to uncaptured landfill gas but, in the case of high capture output, it allows validation of the order of magnitude of the models' results.

Such a study shows that:

- When tests are done on several landfills, net tendencies appear: some models (EPA, Tier 2) systematically predict higher productions than others (GasSim, Ademe). The estimations vary almost from simple to double, regardless of the landfill,
- However, the total production estimations made by the models are sometimes below the captured gas quantity (and therefore below the quantity of landfill gas actually produced).

The comparison between the estimated results of diffuse methane emissions and their in-situ measurements is much more random, and tendencies are not easily found.

- According to the type of measure done, the results on the quantity of methane diffused in the atmosphere range from 1 to 10 (even if it is possible to explain part of these gaps),
- For the models that substract the measured quantity of captured methane from the estimated production, the result is sometimes negative, therefore inconsistent. The ADEME model eliminated this problem through its unique approach (capture rate estimation) and the EPA model defines a capture rate threshold at 85%.
- In cases where results are not negative, it is not possible to identify tendencies: the results of these models vary significantly, whether we compare the results of the different models or the models with field measurements.
- The uncertainty for measured emissions is much higher than for theoretical production.

2. Remark: the term "complex" refers here to the model's conception and use (necessary input date, implemented calculation types, etc.). The complexity of model and of the implemented calculation methods is not necessarily linked to the final results accuracy.

-> Conclusions

General Conclusion

The outcome of this study is that, because of its very nature and unless costly emissions monitoring devices are set up, the best means for diffuse emissions estimates are the use of emission models.
Modelling is a difficult exercise, because of the diversity of physical, chemical and mainly biological factors that governs the waste degradation process. However, several models exist, that try to simulate the actual landfill conditions.

As a consequence,

- The use of models is essential to assess diffuse emissions
- Among the diversity of existing models, only the order 1 models can today take into account the various factors that have an impact on landfill gas production. It is therefore advised to favor these models and to avoid using order 0 models (or models using standard emission factors).
- It is necessary to keep in mind that the use of these tools implies a very high level of uncertainty, a level difficult to assess. This level of uncertainty cannot be compared to the one that can be reached in GhG emissions calculation in other industrial facilities.
- The different existing models were created to reflect certain condition and include standard factors that can be adapted. They each have their pros and cons and can show wide variations in their numerical results. Today, because of the very nature of the modeling exercise, no model is recommended over another. Nonetheless, it is advised to resort to the model accepted by local authorities for regulatory declarations. If there is no locally accepted model, the entity should use a model that is published, accepted and available in scientific and technical literature, and the parameters of the model should be adapted to reflect the site's specific situation. The choice of the model as well as the parameter adaptation should be documented and justified.
- Because of the necessary adaptation of the model's parameters, the reporting entity will have to make sure the same model is used every year, unless another model can give a better representation of the landfills' situation.

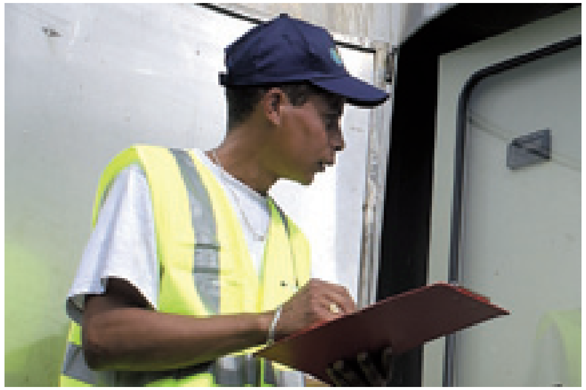
Validity of the models

- In the present state of our knowledge, it is impossible to validate the models' results on the quantity of diffuse methane. It is also in vain to suggest an estimation of the uncertainty of these results,
- Total methane production assessments seem consistent, when we compare the different models and as compared to captured landfill gas measurements. An uncertainty of +/- 50% is conceivable on these results,
- The determination of a ranking based on model's performance seems unrealistic, for two main reasons:
  - The uncertainties due to the entire modelling exercise are too important,
  - There is a great sensitivity of the results to input factors (notably k and L_0), so that the results obtained for one single model can have a wide range of variations.

  Furthermore, a model that has used only default values does not seem pertinent; it has to be considered as a gross tool that needs to be refined to reflect the local situation,
- On the long term, methane production potential is a crucial parameter since it will influence directly the total cumulated methane production from a landfill.

It is therefore important to make sure that these parameters' values are consistent from one model to another,

- Methane oxidation through the cover has been set at 10% in almost all models, according to the IPCC recommendations. However it is difficult to validate this hypothesis with precision.
- It is also recommended that the user converts the landfill gas production results in Nm3 so that a consistent base of comparison with other sites is available.



Recommendations for use

- Multiphase models are more accurate in biochemical mechanisms' modelling and should allow sites to gain a more accurate image of their emissions,
- The ADEME model (in both versions) shows the non-negligible interest of suggesting an estimation of the diffuse landfill gas quantity in all cases, unlike the other models. This model was drawn up to show the 30-year evolution of a landfill.
- The measurement of the captured landfill gas remains by far the most accurate data. It can therefore be interesting to use it. However there is no method today to assess the efficiency of the collection system (or the cover efficiency),
- Good use of a landfill's emissions estimation model requires a real competence (essentially because of the great sensitivity of input data). The accuracy of the results also highly depends on the knowledge of the landfill to be modelled (biogenic carbon rate, waste age, collection system efficiency), as well as cultural criteria (food, habit of waste sorting). This is why it is recommended that the sites' operational staff work in close collaboration with the reporting entities' management. The entity should provide pertinent indicative elements on input parameters and perform a consistency check on the calculated data, even make the calculation using data given by the operators on site.
- The "management" of a model's constants according to the measured results (captured and diffuse landfill gas) appears to be an important source of progress in making the models more accurate. But this work needs to be done with extreme care:

  - So that the output of the capture system is not overestimated, inducing a reduction of the diffuse emissions (this would lead to bring the total methane production in line with the captured methane quantity),
  - Technically, diffuse methane measurements are uncertain and need to be done in good conditions to make sure the results are representative.
  - It is also recommended to update the parameters every year so that the waste characteristics' variations are considered.

-> References

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- Annex 2: Carbon Sequestration in Landfills and Soils after compost spreading -

-> Background on carbon sequestration

Definitions

Carbon is considered as stored when it is removed from the global carbon cycle over long time periods.

Carbon is present under gaseous form in the atmosphere, especially in the form of greenhouse gases (mainly carbon dioxide). Carbon storage, whether natural (photosynthesis, ocean absorption) or artificial (manufactured products of biogenic origin), helps to reduce the amount of greenhouse gases in the atmosphere. Therefore, it participates positively in climate change mitigation.

Carbon sequestration in waste management

What exactly is the role of the waste sector in carbon sequestration? Two activities are concerned: landfilling and compost spreading. Both contribute to carbon sequestration: more precisely, they prolong the phenomena of sequestration over time (cf. Figure 1) and, in this sense, play the role of carbon sinks.

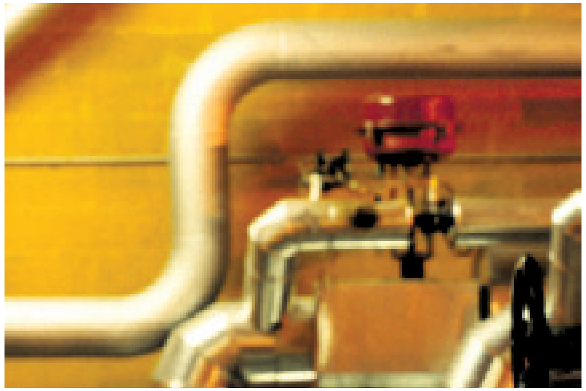
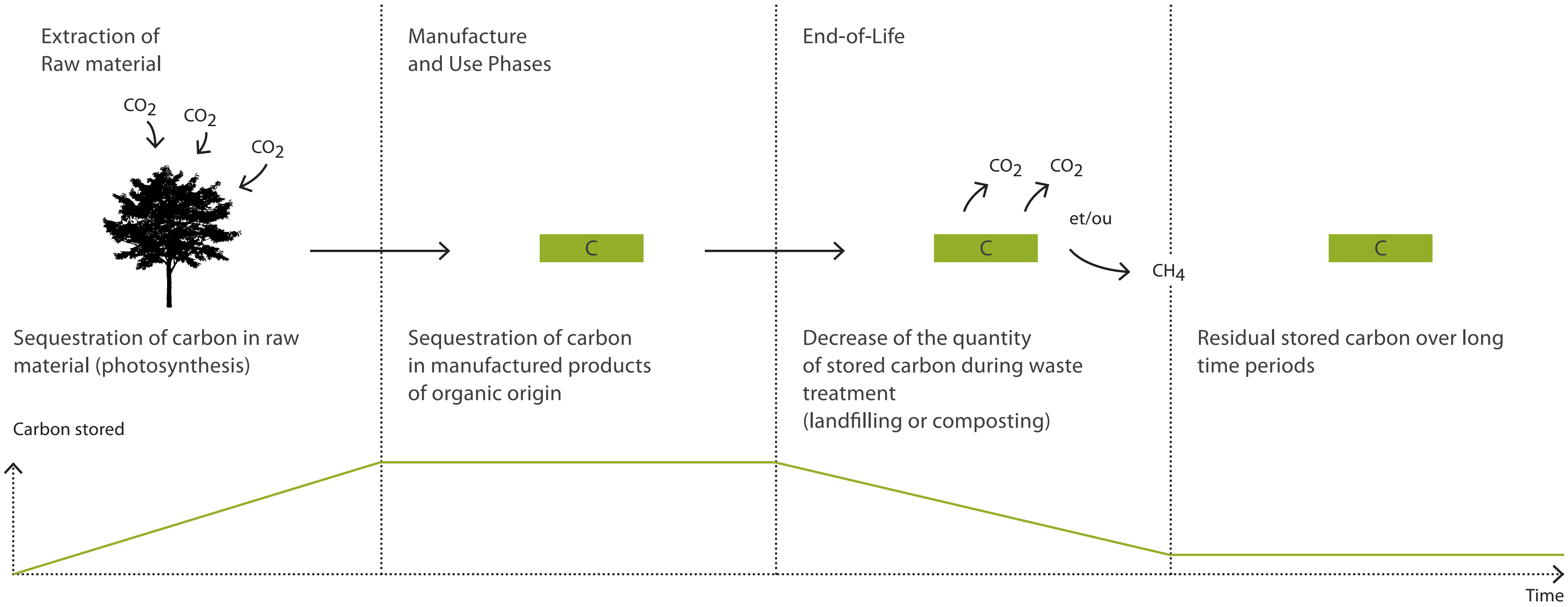


Figure 1 -> Evolution of stored organic carbon versus time



Organic wastes and compost contain organic matter whose carbon has been sequestrated during the production of the raw material (via photosynthesis) and the product manufacturing (wooden board production for instance). During landfilling or composting, the organic matter contained in such products decomposes and part of its carbon is emitted as CO_2 and/or CH_4, back to the atmosphere.

However, part of the organic matter does not decompose completely or very slowly and part of its carbon thus remains in soils.

In landfills, wood and paper decay very slowly and accumulate in the landfills (long-term storage). Carbon fractions in other waste types decay over varying time periods. Lignin does not decompose to a significant extent because of the anaerobic conditions. Cellulose and hemicellulose decompose, but the extent of their decomposition depends on the environmental conditions in the landfill (e.g. pH and moisture). In addition, the presence of lignin actually prevents some cellulose and hemicellulose biodegradation.

In the same way, after compost spreading, part of the carbon present in compost is not mineralized but retained in the soil. Indeed, the stable organic matter has a turnover of 100 to 1 000 years and thus a fraction of the carbon is bound in soil for long periods.

In both cases, the result is that a fraction of biogenic carbon contained in organic waste/compost remains stored in soils.

-> Biogenic carbon versus fossil carbon

Carbon sequestration only concerns biogenic carbon.

There are two distinct organic carbon cycles: the short-term cycle (biogenic carbon) and the long-term cycle (fossil carbon).

• Biogenic carbon is involved in the short-term organic carbon cycle which reflects carbon interactions between the atmosphere and the biosphere. Carbon, as CO_2, is first absorbed during the green plants growth (photosynthesis). Temporarily sequestrated, it is then emitted as CO_2 again, when plants decompose. Assuming a sustainable biosphere, while plants are decomposing, others are growing and CO_2 emitted by the previous is thus absorbed by the latter. A neutral equilibrium of carbon is resulting.

• Fossil carbon is involved in the long-term organic carbon cycle. Instead of decaying, part of the organic matter is being buried and incorporated into fossil fuels deposits or sediments. This process is very slow since it extends over geological timescales (thousands and millions of years). The residence time of carbon in geological reservoirs is estimated at more than 200 millions years.

Figure 2 -> Biogenic Carbon Cycle versus Fossil Carbon Cycle

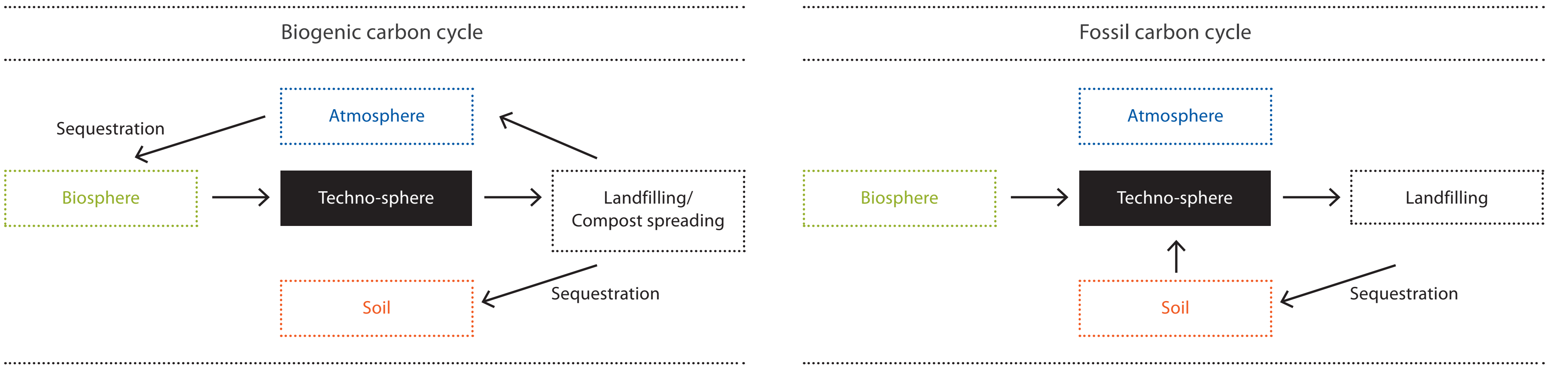


Figure 2 describes the impact of landfilling and compost spreading in both biogenic and fossil carbon cycles. It shows that:

• In the case of biogenic carbon, landfilling and compost spreading avoid carbon emissions, by extending carbon sequestration in the soils;

• Whereas in the case of fossil carbon, landfilling has no impact. It does not avoid any carbon emission since fossil carbon, initially extracted from soil, simply returns to the soil.

-> Estimating carbon sequestration

From a mass balance standpoint, carbon sequestration can be considered as a negative emission.

By convention, only the biogenic carbon that is stored for longer than the time horizon adopted for global warming (100 years) can be considered as having been sequestrated.

Avoided emissions are calculated by converting tons of sequestrated carbon to avoided tons of carbon dioxide equivalents, by multiplying by the molecular weight ratio for carbon dioxide to carbon (44/12).

-> Estimating carbon sequestration in landfills

Three positions are presented here: the Intergovernmental Panel on Climate Change (IPCC) position, the United States Environmental Protection Agency position (USEPA) and the Solid Waste Industry for Climate Solutions (SWICS) position.

IPCC 2006

As proposed in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Landfill C sequestration is estimated and reported as an information item within the Waste Sector Inventory, but is accounted for in the Agriculture, Forestry and other Land Use Inventory. The Waste Sector guidelines explain how to estimate the amount of biogenic carbon that is long-term stored in landfills.

$$DOC_{m\ \text{long-term stored}\ T} = W_T \times DOC \times (1 - DOC_f) \times MCF \quad \text{(Equation 1)}$$

W_T: mass of waste disposed in year T (Gg)
DOC: degradable organic carbon in disposal year (Gg C/Gg waste)
DOC_f: fraction of DOC than can decompose in the anaerobic conditions in the landfill (fraction)
MCF: CH_4 correction factor for year of disposal (fraction)

Avoided emissions from carbon sequestration can then be calculated by multiplying $DOC_{m\ \text{long-term stored}\ T}$ by 44/12.

To ensure consistency between the amount of sequestrated carbon calculated and the amount of emitted methane reported, the use of Equation 1 imposes the use of the IPCC Waste model to estimate methane emissions.

USEPA 2006

In its study entitled "*Solid Waste Management and Greenhouse Gases, A Life Cycle Assessment of Emissions and Sinks*" (2006), USEPA estimates carbon sequestration that will result from landfilling organic waste, based on experiments conducted by Dr. Morton Barlaz of North Carolina State University in 1998. Carbon storage factors (CSF) presented in this study should be updated (CSF of leaves and MSW) because they have been slightly modified in 2008 by Dr M. Barlaz after errors were found in its original calculation (See Table 1).

SWICS 2009

SWICS has developed its approach to carbon sequestration in its study entitled "*Current MSW Industry Position and State-of-the-Practice on LFG Collection Efficiency, Methane Oxidation, and Carbon Sequestration in Landfills*" (Version 2.2, Revised January, 2009). Here as well, the approach proposed is based on the research work performed by Dr. Morton Barlaz and the USEPA. SWICS proposes the following carbon storage values for refuse placed in landfills, taking into account the update performed by Dr. Morton Barlaz in 2008:

Table 1 –> Carbon storage factors (CSF) from SWICS's study

	Amount of Carbon Stored TeqC/Wet Ton	Avoided CO_2 emissions $TeqCO_2$/Wet Ton
Paper and Paperboard		
Old Corrugated Containers	0,24	0,89
Old Newsprint	0,40	1,46
Office Paper	0,04	0,16
Coated Paper, Magazines and 3rd Class Mail	0,25	0,93
Food		
Food	0,02	0,08
Yard Trimming		
Grass	0,08	0,28
Leaves	0,28	1,01
Branches & wood	0,34	1,25
Municipal Solid Waste		
15% moisture	0,10	0,36
20% moisture	0,10	0,36
25% moisture	0,09	0,32

PROGNOS 2008

PROGNOS proposes emission factors for landfilling of residual waste both with and without the accounting of the carbon sink. In its calculations, PROGNOS considered that the carbon sink equals 300 $kgCO_2$ equivalent per tonne of landfilled waste.

Table 2 -> Carbon storage factors from RECORD's report

	Amount of Carbon Stored TeqC/Wet Ton	Avoided CO_2 emissions $TeqCO_2$/Wet Ton	Source
Paper			
Newspaper	0,391	1,43	USEPA 2006
Office Paper	0,046	0,17	USEPA 2006
Magazines	0,245	0,90	USEPA 2006
Mixed paper	0,200	0,73	USEPA 2006
Paper	0,147	0,54	ERM 2006
Paper/Newspaper	0,214	0,78	AEA 2001
Newspaper/Magazines	0	0,00	Fridriksson 2002
Other papers	0	0,00	Fridriksson 2002
Newspaper	0,229	0,84	Finnveden 2000
Paper	0,235	0,86	Lobo et al. 2006
Value selected by RECORD	0,198	0,73	

RECORD 2008

In 2008, RECORD, - a French network open to all public or privately owned organizations in which industry, public bodies and researchers can engage in collaborative research projects -, has published a study entitled "*Application of the Bilan Carbone method to waste management activities*" in which a literature review of carbon storage factors is made. The results of this work are presented in the Table below.

Table 2 (continued)

	Amount of Carbon Stored TeqC/Wet Ton	Avoided CO_2 emissions $TeqCO_2$/Wet Ton	Source
Cardboard			
Corrugated cardboard	0,245	0,90	USEPA 2006
Corrugated cardboard	0,207	0,76	Finnveden 2000
Mixed cardboard	0,161	0,59	Finnveden 2000
Mixed paper	0,234	0,86	Lobo et al. 2006
Value selected by RECORD	0,224	0,82	
Food Discards			
Food Discards	0,024	0,09	USEPA 2006
Food Discards	0,064	0,23	ERM 2006
Food Discards	0,038	0,14	AEA 2001
Food Discards and garden waste	0	0	Fridriksson 2002
Food Discards	0,06	0,22	Finnveden 2000
Food Discards	0,069	0,25	Lobo et al. 2006
Value selected by RECORD	0,036	0,13	
MSW			
Value selected by RECORD	0,063	0,23	

-> Estimating carbon sequestration in soils after compost spreading

Three positions are presented here.

USEPA 2006

In its study entitled "*Solid Waste Management and Greenhouse Gases, A Life Cycle Assessment of Emissions and Sinks*" (2006), USEPA explains that its research efforts did not yield any primary data that could be used to develop quantitative estimates of the soil carbon sequestration benefits of compost. Therefore, it decided to use a simulation model able to be applied to the issue of soil carbon sequestration from compost application. CENTURY is a Fortran model of plant-soil ecosystems that simulates long-term dynamics of carbon, nitrogen, phosphorus, and sulfur. It tracks the movement of carbon through soil pools and can show changes in carbon levels due to the addition of compost. In addition to this soil carbon restoration effect, USEPA considers the impact of compost on humus formation. Indeed, USEPA reports that some studies considering other compost feedstocks (e.g. farmyard manure, legumes) have indicated that the addition of organic matter to soil plots may increase the potential for sequestration of soil organic carbon.

USEPA proposes the following carbon storage factor for compost application. This factor takes into account carbon sequestration from both the soil restoration and the humus formation.

Table 3 -> Carbon storage factors from USEPA's report

	Amount of Carbon Stored $TeqCO_2$/Wet Ton
Food Discards	0,26
Yard Trimming	0,26
Mixed organics	0,26

AEA Technology 2001

AEA Technology details the phenomena of carbon sequestration in soils in case of compost application and purposes a quantification in its study entitled "*Waste Management options and climate change*" (2001). According to this study, 8,2% of the carbon contained in compost would remain sequestrated after 100 years.

PROGNOS 2008

PROGNOS proposes emission factors for compost production from biowaste and application both with and without the accounting of the carbon sink. In its calculations, PROGNOS considered a storage rate of carbon of 24%, corresponding to 52 kgCO2 equivalent per tonne of collected and composted biowaste.

Boldrin A. et al 2009

A. Boldrin *et al* of Departement *of Environmental Engineering of the Technical University of Denmark* and E. Favoino of Suola Agraria del Parco di Monza have both published an article entitled "*Compost and compost utilization: accounting of greenhouse gases and global warming contributions" in Waste management & research* (Volume 27, Issue 8 , November 2009).

They purpose the following formula to calculate the avoided CO_2 emissions due to carbon sequestration:

$$CO_{2,bind} = C_{input} \times C_{bind} \times 44/12$$

$CO_{2,bind}$: sink of CO_2 (kg)
C_{input}: C content in compost (kg)
C_{bind}: fraction of C which is stable

According to different studies, the article reminds that the C still bound to soil after 100 years has been estimated to be 2-14% of the input in compost, depending on the soil type and the crop rotation.

Table 4 -> Carbon storage factors from Boldrin A. and Favoino E.'s article

	Carbon content (kg/Wet ton)	Carbon bound in soil (kg/Wet Ton)	Avoided CO_2 emissions $TeqCO_2$/Wet Ton
Compost from food waste	63-386	1-54	4-198
Compost from garden waste	56-202	1-28	4-103

->Waste Sector Protocol position regarding the incorporation of carbon sequestration in the Protocol

Carbon sequestration in landfills and soils has been and continues to be a subject of debate which requires further research.

In an annual reporting approach, such as the one described by the Waste Sector Protocol, taking into account carbon sequestration is a challenging task because of the confrontation of two time horizons. On the one hand, carbon sequestration is most often based on a 100 year time horizon whereas on the other hand, the time period for reporting is typically one year. However, this carbon, that will only be considered as sequestrated if stored for more than 100 years after its disposal in the soil, is effectively present in the soil right from the first year.

Besides, it is important to adopt a position that would be coherent with the approach considered for methane emissions from landfills. In the Protocol, the emissions occurring in year N (reporting year) due to the waste disposed up to and including year N are taken into account; the Protocol does not consider the emissions that will occur on year N and afterwards originating from the waste disposed during the reporting year.

In the case of carbon sequestration in landfills and soils through carbon spreading, the Protocol's position is to display the carbon stored under the heading "carbon sequestration" if adequate information is available (for example if the reporting entity has made use of a first order decay model calculating this sequestration such as the IPCC model). Under no circumstances, this sequestrated carbon should be subtracted from the direct emissions or presented as avoided emissions in the reporting entities' inventory.
As such, this sequestrated carbon can only be reported for information purposes.

- Annex 3: Composting – N_2O, CH_4 and biogenic CO_2 Emissions Factors [1] -

-> Homogenized emission factors for direct N2O emissions

Source	Emission factor gN2O/t WW [2]	% of initial N	Methodology	Substrate
ADEME 05	24 [2.4 – 59.1] 210 [10.5 – 262]		Review of bibliography Default [min – max]	Biowaste MSW
Bar02	158			Biowaste
Bec01	7.15 149.5 210.6	0.02 0.4 0.6	Measurements in reactors	Greenwaste
CITEPA13	221			Mixed waste
Cl03	15 400		On-site measurements	MSW
ERM06	165			Paper, cardboard, park waste
He98	232 1247.52 382	0.5 0.4 0.7	On-site measurements Measurements in reactors	Greenwaste
Heres07	69 [40 – 100]		Default [min – max]	Vegetable, fruit and garden waste (VFG)
IPCC06b	300 [60 – 600]		Default [min – max]	
Recommended values				

1. Factors found in littérature, compiled thanks to a BIO Intelligence Service study carried out in 2007
2. WW = Wet Weight

-> Homogenized emission factors for direct CH_4 emissions

Source	Emission factor gCH4/t WW	Methodology	Substrate
ADEME 05	1240 [310 – 6190]	Review of bibliography Default [min – max]	MSW (65% dry)
CITEPA13	1094		Mixed waste
CI03	400 1200 10000	On-site measurements	MSW
ERM06	30.3		Paper, cardboard, park waste
He98	6760	On-site measurements	Greenwaste
Heres07	170 [80 – 300]	Default [min – max]	Vegetable, fruit and garden waste (VFG)
IPCC06b	4000 [30 – 8000]	Default [min – max]	
FNADE09	90 130 220 5111	On-site measurements	Residual MSW Greenwaste Wastewater Treatment sludge Organic fraction of MSW

Recommended values

-> Homogenized emission factors for biogenic CO2 emissions

Source	Emission factor kgCO2/t WW	Methodology	Substrate
FNADE09	78400	On-site measurements	Residual MSW
	30900		Greenwaste
	128600		WWT sludge
	247000		Organic fraction of MSW

Remark: EF for direct CH_4 emissions should be in coherence with EF for composting biogenic CO_2 in order to respect to total carbon balance.

-> Legend of above mentioned bibliographical sources:

ADEME05: ADEME (2005), *Impacts environnementaux de la Gestion Biologique des Déchets.*

Bar02: Barton, P. K. and Atwater, J. W. (2002), *Nitrous Oxide Emissions and the Anthropogenic Nitrogen in Wastewater and Solid Waste Journal of Environmental Engineering* 128(2):137-150.

Bec01: Beck-Friis B., S. Smars, H. Jonsson, H. Kirchmann, (2001). *Gaseous emissions of carbon dioxide, ammonia and nitrous oxide from organic household waste in a compost reactor under different temperature regimes. Journal of Agricultural Engineering Research,* 78(4):423-430.

CITEPA13: CITEPA (2013), *Organisation et méthodes des inventaires nationaux des émissions atmosphériques en France* (OMINEA), 10e Edition.

Cl03: Clemens J., C. Cuhls, (2003). *Greenhouse gas emissions from mechanical and biological waste treatment of municipal waste. Environmental Technology,* 24(6):745-754.

ERM06: Fisher, K., Aumonier, S. (2006) *Impact of Energy from Waste and Recycling Policy on UK Greenhouse Gas Emissions, ERM for DEFRA.*

He98: Hellebrand H.J., 1998. *Emission of nitrous oxide and other trace gases during composting of grass and green waste. Journal of Agricultural Engineering Research,* 69(4):365-375.

Heres07: *Research determining indicator for methane and laughing gas composting plants.* (Onderzoek bepalen kentallen methaan en lachgas composteerbedrijven), R-J Heres, Tauw BV, Deventer, 22 November 2007 (in Dutch).

IPCC06b: IPCC (2006), *Guidelines for National Greenhouse Gas Inventories: Chapter 4: Biological treatment of solid waste*

FNADE09: *Guide d'aide à la déclaration annuelle des émissions polluantes et des déchets des installations de compostage,* FNADE, validation ADEME, February 2009