Protocol for the quantification of greenhouse gases emissions from waste management activities

Entreprises pour l'Environnement

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Acknowledgements and Contact

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EpE is a partner of the WBCSD (World Business Council for Sustainable Development) which unites 170 international companies to promote the role of companies in sustainable development.
EpE relays in France the W.B.C.S.D.'s main publications, and both players have frequent exchanges on their current works.

Foreword

Greenhouse gases (GhG) emissions are of major environmental concern. New policies have been implemented by authorities and companies to reduce emissions from the main emission sources since United Nations Framework Convention on Climate Change (UNFCCC) and the 1997 Kyoto Protocol.

Therefore, under the initiative of the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI), the GhG Protocol[1] was published enabling guidance to companies for GhG emissions accounting. In North America, a GhG emission trading system, the Chicago Climate Exchange was created.

In Europe, the IPPC[2] Directive led to the creation of the EPER[3] register and to the annual declaration for European sites of their emissions to the authorities. In parallel, a GhG emissions trading market for some industrial sectors was implemented on January 1st 2005.

In France, the Entreprises pour l'Environnement (EpE) Association drew up a GhG emissions quantification, reporting and verification protocol for industries, with 14 sector specific protocols annexed to it. The 32 AERES[4] companies committed to reducing or controlling their GhG emissions over the 2003-2004 and 2005-2007 periods; they used the protocol established by EpE.

On the basis of data provided by countries to Secretariat of the UNFCCC, the waste sector emissions represented about 3,3 % of worldwide anthropic emissions, all greenhouse gases together, in 2002.

For several years, most companies in the waste sector have implemented emission reporting systems, notably for GhG emissions. Several calculation tools were published for specific emissions from various waste treatment methods. The aim of this protocol is to homogenize calculation methods and to have a GhG global reporting protocol that can be applied to all of the waste management activities. The EpE protocol tool is exclusively dedicated to annual GHG reporting. It is not intended to be used to compare scenarios.

An emissions QUANTIFICATION, REPORTING and VERIFICATION system is an essential core tool for any action or commitment on GhG emissions. Such a tool is also an essential basis to allow comparisons between the waste sector and other industrial sectors on the basis of comparable reporting principles. It aims at giving support to waste management plant managers for preparing their GhG emissions inventory.

Three companies, Veolia Environmental Services, Séché Environnement and Suez Environnement, members of the association Entreprises pour l'Environnement, established a Working Group led by EpE and contributed their competence and expertise.

The present document along with the Excel emissions calculation worksheet, constitutes the waste management sector specific protocol of the general EpE protocol.

1. http://www.GhGprotocol.org
2. Integrated Pollution Prevention and Control
3. European Pollutant Emission Register
4. Association des Entreprises pour la Réduction de l'Effet de Serre – French association of companies for the reduction of greenhouse effect.

Waste Management Sector Presentation

Sector Specificities

The primary objective of the waste sector is to treat – or recover – as efficiently as possible undesirable residues from anthropic activities to limit their impacts on the environment. The main specificity of companies in this sector lies in their paradoxical position: as actors of the products' « end of life », they generate environmental impacts that **they are not the cause of**, since they are not responsible for the very creation of these wastes.

In this context, one of the main issues is the determination of the scope of responsibility scope for the impacts caused. Whether it be during the transportation phase (collection, transport) or waste treatment, **waste management activities generate atmospheric emissions. The waste sector companies must act with waste producers to have an influence on the quantity and quality of the waste they receive**. The implementation of pre-treatment method already allows the reduction of atmospheric emissions from treatment activities or downstream recovery.

In general, the waste sector is under strict monitoring regulations in terms of environmental impacts. This is why treatment facility emissions and discharges are reported as accurately as possible by the operators.

However, GhG emissions monitoring presents an important uncertainty today, because of several factors:

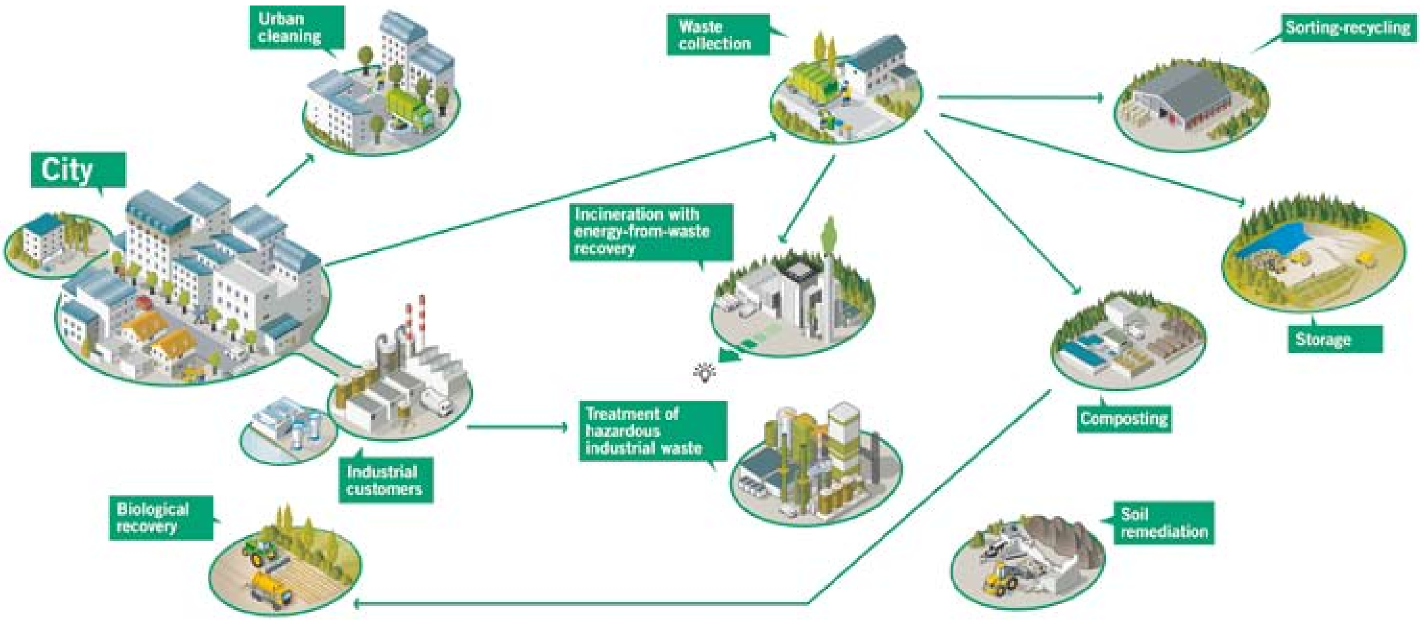
- Firstly, an important number of waste treatment activities incorporate complex processes (notably biological) for which it is difficult to reach the same accuracy as in the other industrial activities' emissions to quantify GhG emissions,
- Secondly, waste management activities are interdependent,
- Finally, the composition of treated wastes is often very heterogeneous, for which a statistical approach is recommanded and most practicable, introducing important but unavoidable bias.

Finally, the waste sector supports the definition of specific atmospheric emissions:

- **Emissions from biomass**: products containing vegetal or animal matter (biodegradable wastes, wood, green waste , wastes from agriculture and food industry…) emit greenhouse gases – when decaying or burning. International conventions[1] agree that carbon dioxide from biomass should not be accounted for, since it comes from carbon captured by living organisms in the first place.
- **Avoided emissions**: one of the goals of the waste management sector is to recover as much as possible the treated products, either as material (reuse, recycling, composting…), or as energy (landfill gas recovery, incineration with energy recovery…). The materials and energy recovered subsitute for the materials/energy whose production would have emitted GhG. For example, one tonne of steel from selective recycling can be re-used, therefore avoiding the manufacturing of one tonne of steel in a steelworks plant and the associated atmospheric emissions. A definition of avoided emissions is given in paragraph 1.15.

1. 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»

Treatment Activities



The waste cycle is presented above, with the different existing waste management routes.

The various steps of the waste cycle are briefly presented below. Emissions sources presented here are direct emissions sources. Their definitions are presented in section 1.
To be noted is that only emissions related to waste management activities are considered here. For the calculation of other types of emissions, other tools should be used (for example emissions related to transporting of persons : refer to the EpE Transport Protocol).

Collection and transportation

Principle
Collection is the first step of the waste cycle. It aims at gathering waste before treatment and recovery. Collection can be done door-to-door, using dedicated vehicles, or after preliminary voluntary drop-off in specific containers (packaging, paper, and glass). Waste that is collected this way from communities, individuals or companies are consolidated and then transported to a treatment or material recovery facility.

GhG emission source
No source is attributed to the waste itself. Emitted GhG comes from fuel used for transport. Fuel change can result in GhG emissions reduction.

Mechanical pre-treatment

Principle
Waste can undergo several methods of pre-treatment to facilitate their recovery or recycling. For example, electric and electronic equipment waste can be dismantled.

GhG emission source
This step does not generate direct emissions, apart from potential fuel consumption for equipment. However, this step allows optimization of downstream treatment activities and thereby reduces their environmental impact.

Sorting, recycling and material recovery

Principle
Waste is sorted to separate the diverse materials. Recyclable materials are then recycled by introducing them in the production cycle as a partial or total substitution (paper, glass, steel, etc.) or prepared to obtain a Solid Recovered Fuel (SRF).

GhG emission source
No source is attributed to the waste itself. Emitted GhG come from energy consumption associated with the sorting operation of the recycling center. Recycling results in avoided GhG emissions since the recycled products are used to replace materials whose production would have generated GhG emissions.

Physico-chemical treatment

Principle
Mechanical, physical or chemical treatment of hazardous waste in dedicated installations.

GhG emissions source
No source is attributed to the waste itself. The emitted GhG come from consumed electricity or on-site fuel consumption.

Biological treatment (composting, anaerobic digestion)

Principle
This treatment type allows the recovery of organic waste through aerobic/anaerobic fermentation to get an organic amendment that can be used in agriculture. This process can be applied to agro-food industry waste, biowaste as well as sewage sludge.

GhG emission source
Composting allows waste stabilization through aerobic fermentation. In facilities using proper operating practices, wastes are regularly aerated and their degradation only generates carbon dioxide. (Good operation practices on the composting site should prevent methane emissions). This carbon dioxide is not taken into account in the final balance since it comes from biomass.
In the case of methanization, controlled anaerobic fermentation of waste in a methanizer results in the production of biogas which is mainly composed of methane. Produced biogas is captured and combusted in flares or recovered to produce thermal or electric energy. Here as well, carbon dioxide from combustion is not taken into account in the final balance since it comes from biomass.
During these treatment processes, nitrous oxide (N_2O) emissions might occur. Research programs are underway to evaluate these emissions. However, there is insufficient knowledge today to measure the N_2O emissions accurately. Available data (European BREF on waste management[1]) seem to show that these emissions would be negligible.

See Annex 3 for a synthesis of values encountered in the literature for N_2O and CH_4 emissions factors from composting activities.

Landfilling

Principle
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) may be 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 wastes.

GhG emission source
Organic waste decomposition produces landfill gas (made of methane and carbon dioxide in nearly the same amounts). Part of this landfill gas can be captured and destroyed through flares or recovered to produce energy. Combustion converts the captured methane into carbon dioxide, which has an impact on the greenhouse effect that is 21 times less. Moreover, this carbon dioxide comes from biomass and is therefore not taken into account in the final balance. However, all of the produced landfill gas cannot be captured and part of it is emitted to the atmosphere (diffuse emissions). These are difficult to measure and are therefore estimated using modeling methods mentioned in this protocol.

Carbon sequestration in landfills
In parallel to the common approach which consists in taking into account the methanogenic potentials of the waste fractions disposed in landfills, it is possible to consider, in an opposite logic, the carbon storage factors of the different waste fractions. See Annex 3 for a compiling of existing studies on the subject.

Incineration

Principle
Waste is degraded through thermal treatment in incinerators. Incineration can concern municipal solid waste, industrial waste and sometimes sewage sludge. Recovering the energy produced can feed heating networks and/or electric turbines. Furthermore, solid residue from combustion (bottom ash) are recovered and scrap metal can be recycled.

1. Reference document on best available techniques for the waste treatments industry (BREF), 08/2005

GhG emission source

As in any burning process, carbon dioxide and nitrous oxide are produced. Part of these emissions comes from the biomass waste, the waste itself having various compositions and depending on local population habits.

For municipal solid waste incineration, an emission factor is used to estimate the GhG emissions. For hazardous waste incineration, waste composition varies significantly, making it necessary to measure the emissions by mean of continuous measurement methods at the stack.

Energy production linked to waste incineration results in avoiding emissions from the production of an equivalent quantity of energy from a power plant using fossil fuels.

Wastewater treatment

Principle

Wastewater, from companies or households, is collected in a sewer system and treated in wastewater treatment plants. They are treated through successive processes (mechanical, biological, chemical), some of which use aerobic or anaerobic treatment. At the end of this process, treated water is discharged to the environment. Produced sewage sludge can be recovered for agricultural use or treated through one of the treatment options presented above.

GhG emission source

Wastewater treatment plants need power to operate. If they do not rely on supplied electricity from the local grid, they may use fossil fuels (fuel oil or natural gas) thereby generating direct emissions.

During the process, apart from the methanization stages during which methane is produced and captured, it is considered that in a properly operated facility, methane or nitrous oxide emissions are negligible. However, there is not enough knowledge today to measure and account for these emissions. Research programs are ongoing.

Objectives and principles

Protocol's objectives

This document is intended to guide local authorities and companies whose activity is waste management, as well as companies managing their own wastes, to quantify, report and verify greenhouse gases (GhG) emissions, in order to obtain a GhG emissions inventory. The purpose of this protocol is to establish best practice for the implementation of an annual inventory of GhG emissions.

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 is compatible with the Greenhouse Gas Protocol – A Corporate Accounting and Reporting Standard – Revised edition, elaborated by the WBCSD[1] and the WRI[2]. It is also compatible with the ISO standards projects 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.

GhG Emissions Accounting Principles

It is essential that the data submitted be as complete and as accurate as possible. The following recommended principles for developing and reporting a corporate GhG emission inventory are based on "International Financial Reporting Standards" (IFRS), established for financial accounting and reporting.

Consistency:

Inventory and reported data must be prepared in such a way that valid year to year comparisons can be made. Any changes in the basis of reporting should derive from continuous improvement of inventory quality. Changes must be clearly stated and documented to allow year to year comparison.

Completeness:

The choice of the boundaries and scope of the inventory must be representative of the entity's activities. All material source types within the chosen boundary must be included in the inventory.
However, in some cases, the entity may define a minimum threshold below which emissions are excluded from the inventory, or choose to exclude some source types.
This will be possible only if the entity documents and justifies its choices in a transparent manner (see Section 2).

Accuracy:

Care must be taken to ensure that systematic errors are avoided, that random errors are minimized through effective controls and that uncertainties are quantified as far as practicable (see Section 5). It is highly recommended to use specific emission factors reflecting the entity situation. As a default, national or international factors can be used.

Transparency / Verifiability:

The basis of the reported data must be clear and state any assumptions made and the methodologies used. Records should be kept to provide a clear audit trail.
To be noted is that the realization of an annual inventory consists in the evaluation of emissions from waste management activities for a given year, but that, because of the deferred emissions from certain devices, these emissions are not only related to the waste amounts generated during this precise year.

1. World Business Council for Sustainable Development
2. World Resources Institute

Section 1: Scope

Data Characteristics

1.1 The protocol applies to the following greenhouse gases :

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O) :

Emission factors are available for N_2O emissions from municipal solid waste incineration; they are included in the present protocol.
For the waste sector's other activities, research is on-going, but, today, there are no accurate methods to identify N_2O potential sources nor to quantify them. This is why these emissions are not currently included in the calculation tool. A bibliographical synthesis of values encountered in the literature is presented in annex 3.
It is considered that waste management does not generate sulfur hexafluoride (SF_6), and does not generate HFC (Hydrofluorocarbons) or PFC (Perfluorocarbons) in normal operating conditions.

1.2 Reporting unit : metric tons equivalent CO_2 (t CO_2 eq)

1.3 Period: GhG emissions are reported on the basis of activity data cumulated over one year exercice.

1.4 An entity is a group, a company, a subsidiary, a local authority or a site performing a GhG emissions annual inventory.

1.5 The entity reporting boundary takes into account all of its operations that collect, receive or treat wastes or have a commercial activity.

Direct / Indirect / Avoided emissions

1.6 A definition of direct and indirect GhG emissions is given below. It must be underlined that the term "direct GhG emissions" applies to the source type of emissions. In the same way the term "indirect GhG emissions" does not mean emissions of indirect greenhouse gases but emissions from indirect source types.

1.7 **Direct GhG emissions (scope 1):** emissions from process or equipment owned or controlled by the entity.
Example : emissions from combustion installations (CO_2, N_2O), landfills (CO_2, CH_4), company-owned vehicles (CO_2, N_2O*).
* It has been decided, as it is the case in EPE's Transport Protocol and in the WBCSD's sectoral protocols, to mention the existence of N_2O emissions related to transport (fuel combustion). Likewise, N_2O emissions from landfill gas combustion in engines can be mentioned. These emissions are currently not quantified and therefore do not appear in the recap table presented in Section 2, Annual Inventory.

This protocol differentiates between **gross direct emissions and net direct emissions.**
Gross direct emissions are total direct emissions generated by waste management activities; they take into account GhG emissions from biomass, such as CO_2 emissions from landfill gas flaring.
Net direct emissions are those ultimately taken into account in the inventory and reporting of emissions, after applying conventions concerning biomass[1], whereby the GhG emissions originating from biomass combustion are accounted for zero.
Biomass is defined[2] as non-fossil and biodegradable organic material from plants, animals and micro-organisms. Biomass also takes into account products, by-products, residues and waste from agriculture, forestry and associated industries, as well as the biodegradable and non-fossil organic fractions from industrial and municipal waste. It takes into account gases and fluids recovered from the decomposition of non-fossil biodegradable organic material.

1. See for instance Annex IV of Directive 2003/87/CE of the European Parliament and of the council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community
2.Commission decision of 29 January 2004 establishing guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council.

1.8 **Indirect GhG emissions** : emissions linked to the activity of the entity, but physically occurring at sites or operations owned or controlled by an organization other than the reporting entity.
Direct emissions from the waste management activities therefore correspond to part of the indirect emissions from waste producers.
Examples : emissions from the following activities:

- Production of the electricity (CO_2 and N_2O** emissions) used by the entity but produced by a third party,
- waste transport in vehicles not owned (or not controlled) by the entity (CO_2 and N_2O** emissions).

  ** It has been decided, as it is the case in EPE's Transport Protocol and in the WBCSD's sectoral protocols, to mention the existence of N_2O emissions related to transport (fuel combustion) and to the production of purchased electricity. These emissions are currently not quantified and therefore do not appear in the recap table presented in Section 2, Annual Inventory.

1.9 Indirect emissions are separated in two parts:

- emissions from imports of electricity, heat or steam that are not self-produced (scope 2);
- other indirect emissions, for instance construction equipment and reagents consumption (scope 3).

1.10 The inventory must include the net direct GhG emissions.
Direct gross emissions may also be calculated and the calculation will be kept.

1.11

- The reporting of indirect emissions arising from electricity or other imported energy (Scope 2) is required. In order to obtain a GhG emissions inventory as complete as possible, entities may also wish to report other indirect GhG emissions (scope 3).
- **The reporting of direct and indirect emissions must be clearly differentiated.**

1.12 **Indirect emissions linked to import and/or export of electricity, heat and steam** :
To be consistent with the WBCSD/WRI Greenhouse Gas Protocol, it is recommended to indicate the quantities of electricity and thermal energy purchased and consumed.
The corresponding GhG emissions must therefore be completed with the applied emission factor descriptions and their source.
In the case of electricity for example, the emission factor will not be the same if the electricity is bought from the grid or from an external cogeneration plant.

1.13 **Electricity transport and distribution**: related GhG emissions are reported by the electricity producer. The electricity consumer reports GhG emissions corresponding to the electricity quantity displayed on the electricity meter.

1.14 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.

1.15 Avoided emissions :

Certain waste management activities contribute to energy generation or the re-use of materials or fuels. This is why greenhouse gases emissions linked to the production of an equivalent quantity of energy or material from raw materials or fossil fuels are avoided. Avoided emissions occur in the following situations:

- Electric and thermal energy production from landfill gas and biogas from anaerobic digestion: avoided emissions correspond to CO_2 emissions that would have occurred to produce an equivalent quantity of energy.
- Electric and thermal energy production from waste incineration: avoided emissions correspond to CO_2 emissions that would have occurred to produce an equivalent quantity of energy.
- Recycling of the following materials:
  - Paper/Cardboard
  - Glass
  - Steel
  - Aluminum
  - Plastics
  - Incineration residues
    - Bottom ashes
    - Scrap metal (slag)
  - Others
- Avoided emissions correspond to emissions that would have occurred to produce an equivalent quantity of materials.

Avoided emissions cannot be deduced from direct or indirect emissions calculated by the entity, and have to be reported separately.

Avoided emissions associated with material recovery are calculated using a Life Cycle Analysis (LCA) approach.
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 three major studies:

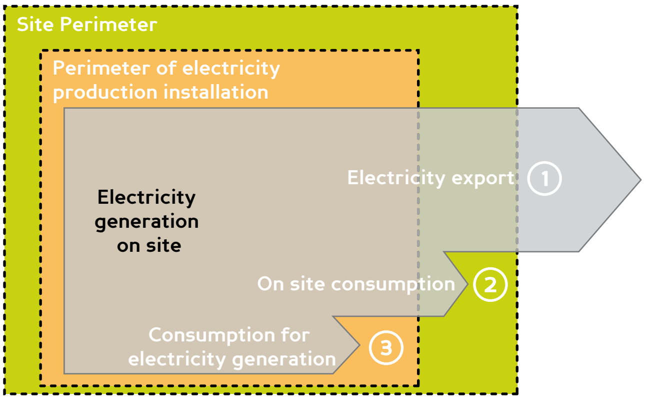
- Waste management options and climate change, AEA Technology, study for the DG Environnement, 2001
- Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks, 3rd edition, US EPA, 2006
- Etude technico-économique sur le bilan des filières de recyclage, ADEME/Ecobilan, 2007

The users will have to choose between these three 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 his figures.

Avoided emissions by energy production from landfill gas or incineration can be calculated in the same way as indirect emissions linked to energy.

Avoided emissions linked to electricity generation will be taken into account as described in the diagram below:
1 and 2: The electricity generated on site is taken into account as an avoided emission, whether it is supplied to the grid or intended for on - site uses other than auto-consumption (uses that would have required electricity purchase from the grid if there was no on-site generation);
3 : Electricity auto-consumption linked to electricity production is not taken into account for avoided emissions.

If there are no accurate onsite measurements for and , only the emissions associated with will



GhG Accounting when there is a shared ownership

Because of the waste management activities' specificities, which often enter in the framework of the delegation of services, it seems necessary to enlarge the control perimeter taken into account in the GHG Protocol.

1.16 **Operational control**: Boundary approach that takes into account GhG emissions from source types under operational control.

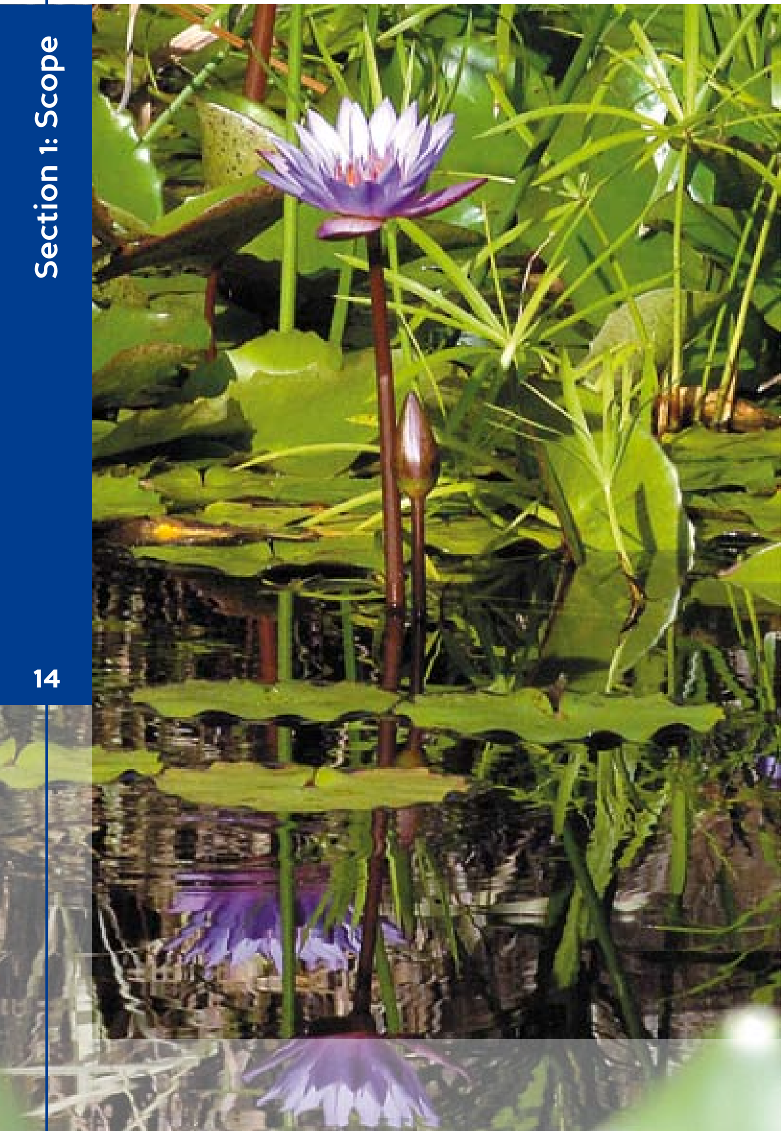
An entity has operational control over a source type when it exercises **dominant influence** over the emissions from a source type, by having the ability to direct the operating policies governing the emissions from a source type.

In the operational control approach, the entity includes 100% of the GhG emissions from a source type in its inventory.

1.17 Examples :

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 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. [1],
- by virtue of the terms and conditions contained in the contract governing the operation of the source type.



1.18 The « operational control » approach has been adopted in this protocol.

It has to be underlined that en 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.

For some source types, an entity could have financial control shared with other entities, but not have operational control. In this case, the entity will have to refer to contractual agreements to establish which partner has the authority to introduce and implement operational procedures and therefore has the responsibility to report GhG emissions according to the operational control approach.

1.19 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 will be integrated into the indirect emissions. 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.

1.20 **Consolidation at multiple levels**: 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.

1. European Directive 2003/87/CE

Section 2: Annual Inventory

Definitions

2.1 **Source type**: Process or equipment which releases direct and indirect GhG emissions into the atmosphere. Source types are characterized by an identical calculation methodology. Homogeneous source types must be added and considered as a single source type, within the previously defined scope.

2.2 The following table summarizes the source types linked to the waste management activities. Among the direct emissions, it distinguishes direct gross emissions, i.e. the total amount of direct GhG emissions, from direct net emissions, corresponding to direct emissions actually taken into account in the inventory as a result of the conventions applicable to CO_2 emissions from biomass. For biomass combustion, the emission factor is taken at zero[1].

In these different source types, point source emissions (stacks, flares, etc.) as well as diffuse emissions (landfills) are taken into account.

1. According to the Annex IV of the Directive 2003/87/CE from European Parliament and of the October 13 Council establishing a greenhouse gases emission quotas trading scheme in the Community and modifying the 96/61/CE directive from the Council.

Activity	Direct Emissions		Indirect Emissions	Avoided Emissions	Emission Reducing Actions
	Gross Emissions	Net Emissions			
Transport associated with collection, cleaning and sewerage[1] services	• CO_2 from fuels	• CO_2 from fuels	• CO_2 from electric vehicles • CO_2 from outsourced transport		• Use of electric vehicles • Uses of alternative fuels (diester, biofuels, etc.) • Development of alternative means of transportation (rail and waterway transport...)
Landfilling	• CH_4 from landfill gas • CO_2 from landfill gas	• CH_4 not captured (based on the use of calculation models • CO_2 from equipment fuel consumption	• CO_2 from purchased electricity consumption	• CO_2 avoided through energy production	• Optimization of CH_4 capture and combustion • Optimization of energy recovery
Incineration	• CO_2 (from waste and additional fossil fuels) • CO_2 from decarbonatation during flue-gas treatment. • N_2O	• CO_2 from waste (except fraction from biomass) and additional fossil fuels. • CO_2 from decarbonatation is considered as negligible. • N_2O	• CO_2 from purchased electricity consumption	• CO_2 avoided through energy production • CO_2 avoided through slag and ash recycling	• Optimization of energy recovery
Biological Treatment (composting - anaerobic digestion)	• CO_2 from biomass • CH_4 and N_2O considered as negligible under normal practices	• CH_4 and N_2O considered as negligible under normal practices • CO_2 from equipment fuel consumption	• CO_2 from purchased electricity consumption	• CO_2 avoided through energy production	• Optimization of aerobic conditions for composting processes • Optimization of energy and/or material recovery

1. This category includes auxiliary engines and duty or company light vehicle.

Activity	Direct Emissions		Indirect Emissions	Avoided Emissions	Emission Reducing Actions
	Gross Emissions	Net Emissions			
Hazardous waste incineration	• CO_2 from combustion • CO_2 from VOCs considered as negligible	• CO_2 from combustion	• CO_2 from purchased electricity consumption	• CO_2 avoided through energy production	• Energy recovering optimization
Physico-chemical waste treatment			• CO_2 from purchased electricity consumption	• CO_2 avoided through potential production of alternative fuels	• CO_2 avoided through potential production of alternative fuels
Sorting, Recycling and Recovering	• CO_2 from fuels	• CO_2 from fuels	• CO_2 from purchased electricity consumption	• Avoided GhG corresponding to the emissions resulting form the production of an equivalent quantity of materials • CO_2 avoided through potential production of recovered fuels	• Actions done to improve sorting rate before selective sorting • Recovery of sorting rejects
Wastewater treatment[2]	• N_2O not quantifiable today • Other gases (CH_4 from sludge) considered as negligible under normal practices • There is no accurate and accepted method today to quantify CH_4 emissions.	• N_2O not quantifiable today	• CO_2 from purchased electricity consumption		

1. Potential N_2O emissions will not be taken into account in the present version of the protocol, due to insufficient reliable quantification method and lack of studies revealing that their presence is significant. The protocol will be updated whenever the emissions are significant and a reliable and accepted method exists.

Exclusions

2.3 Under the definition of the completeness principle given in the introduction, every source type that is in the chosen perimeter must be included in the inventory.
However, in practice, the entity can encounter obstacles in the quantification of some sources types:

- Missing data,
- Negligible emissions,
- Disproportionate cost associated with data collection,
- High level of uncertainty of data, etc.

The entity may then choose to remove its inventory some source types' emissions, as long as it is documented and clearly justified.
A third party verifier could evaluate the potential impact and the relevance of the exclusion.
If the need arises (when reporting for several sites), the entity will indicate its data coverage rate in its reporting. The data coverage rate refers to the proportion of the activity or the turnover covered by the sites that reported data, over the total reporting perimeter, expressed through a relevant indicator (activity data, turnover, etc.).

Identifying the Source type List

2.4 Source type list: List describing the source types included by the entity in the inventory, according to the repartition presented in the table on pages 16 to 17.

2.5 An annual inventory is made up of consolidated annual emissions from all source types. Therefore, an entity must identify, every year, the Source types, it is taking into account to calculate the annual inventory emissions. The entity should keep a written record of the decisions taken during the identification of the Source Type List.

2.6 To determine its Source List, **the entity must identify all sources over which it has operational control**. This list must be as exhaustive, complete and accurate as possible.

Calculating the annual emissions

2.7 The entity should follow the following steps:

1. Quantify annual GhG emissions over year N for all source types in the Source type list.
2. If any source included in the annual inventory is not covered by the calculation tool annexed to this protocol, the entity should indicate and document the specific calculation protocol it uses. This additional protocol should present an estimate of the uncertainty in emission calculation inherent in its use.

2.8 After completing these two steps, the entity will have completed its annual inventory.

Adjustments to the source type list and reported annual emissions

2.9 Changes may relate to the entity's group structure or to their 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.

2.10 Each time an entity changes its structure or operations, adjustments must be made to the source list and corresponding annual emissions calculations.

2.11 Any adjustment to the source 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

2.12 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).

2.13 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.

2.14 In case of closure of a source type, GhG annual emissions will be taken into account until the final closing.

2.15 The method to take into account structural changes must be explained.

Adjustments for taking operational control

2.16 Adjustments when acquiring operational control over certain source type An entity can acquire operational control over source types outside of its Source list through:

- A merger,
- An acquisition,
- Internalization of an activity,
- A re-organization of operational control (contractor's change, ...),
- Opening a new source type.

2.17 Should an entity acquires operational control over source types outside of its source list, that entity will be required to make an adjustment to its source type list and to its annual GhG emissions.

2.18 In the case the start up of a new activity, GhG emissions will be taken into account from the start date.

2.19 The method to take structural changes into account must be explained.

Historic Emission Adjustments

2.20 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.

2.21 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.

2.22 Historic emissions are not adjusted in case of an activity stopping or starting.

2.23 The entity must indicate if the necessary historic data are not available. It can then choose not to adjust the concerned historic data.

Section 3: Emissions Calculation

Approach/Hierarchy

3.1 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.

3.2 Different levels of accuracy can be achieved depending on the type of methodology used (use of standard emission factors, periodic measurement, continuous measurement, etc).

3.3 In order to ensure continuous improvement, it would be recommended that participants move to more accurate methods wherever practical. However, it is recognized that the chosen method will depend on the significance of the source type and the uncertainties associated with the available methods of assessment. The level of uncertainty remaining for certain methods continues to act as a barrier to the establishment of universally accepted methods. Moreover, even when measurements are involved, there can be accuracy differences between alternative measurement techniques.

3.4 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 (for example fuel consumption) and an emission factor.
In this case, the proper functioning of the emissions analyser should be verified, and a preventive maintenance program should be implemented to avoid any deviation in the operation of the measuring device. Maintenance records should be archived.

Methodology

3.5 In some cases, several methods can be used.

In case of continuous measurement, there might be several sampling protocols applicable to perform a representative sampling for analysis.
Likewise, for the same calculation, several emission factors from different bibliographic sources can be used.

The entity needs to clearly document the methodology used and the reasons for its choice.

3.6 The present document does not make any recommendation concerning specific techniques of sampling, measurement or analysis. All sampling, measurement and testing methods employed shall be performed in compliance with appropriate national or international standards. If such standards do not exist, a complete documentation concerning applied methods shall be archived.

Global Warming Potentials

3.7 Global warming potentials are given in Annex 1 for CO_2, CH_4 and N_2O (Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories – Reference Manual - Volume 3).
The considered GWP values come from the second IPCC[1] assessment report and are used within the context of the Kyoto Protoco for the first commitment period (2008-2012).

Global warming potentials have been successively revised and updated in IPCC third and fourth reports.

Calculation Tool

3.8 An Excel calculation tool has been developed as an annex of this protocol. It is an integral part of the present protocol.
3.9 This tool is made of several spreadsheets:

1. Intergovernemental Panel on Climate Change

- 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.
- Combustion and indirect emissions: calculation of emissions due to fossil fuels, electricity and/or heat consumption
- Factors: sheet summarizing the emission factors
- 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…)
- Incineration: calculation of emissions due to waste incineration (all types)
- Wastewater: calculation of emissions from wastewater treatment
- Avoided: calculation of avoided emissions through waste recovery following the principles presented in the present protocol
- Synthesis: tab summarizing the inventory

3.10 The user has different types of data entry fields:

- Fields where the user has to enter the site's specific values (such as 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 his site situation. However, in this case, selected values will have to be documented and justified.

3.11 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.

3.12 **Specific case of hazardous waste incineration**: emissions due to hazardous waste incineration using a calculation associating the tonnage of the different categories of incinerated wastes and corresponding emission factors, or, preferably, using measurements done at the stack, as long as a greater accuracy of this method can be proven.

In this second case, the user must avoid a double count:

- The implementation of a calculation based on the waste tonnage incinerated requires filling in the section in the calculation tool concerning incineration as well as the section 1 concerning fossil fuels used as an extra fuel.
- Stack measurements apply to all of the incinerated carbon containing products. It is therefore not necessary to do a second calculation for the emissions due to additional fuels.

Specific case of landfill emission modelling

3.13 Accounting for GhG emissions captured in landfills can be easily done using flowmeters placed on the landfill gas collection system and composition analysis. However, field conditions make diffuse emissions accounting difficult. To date, the most common approach has been to use landfill gas production models to estimate the diffuse emission.

Annex 2 presents a comparative study of the existing models. Conclusions and recommendations that we can obtain from it that are useful to make a GhG emissions inventory are listed below:

- The use of models is required to estimate diffuse emissions. 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 certain conditions and provide standard factors for waste that can be adapted. They each 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 modeling exercise, no model is recommended over another. 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.
- 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 Modellor. There are a number of on-going research studies assessing field monitoring approaches for diffuse landfill methane emission. 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.

Reporting requirements

Section 4: Reporting requirements

4.1 The reporting process must be detailed in order to ensure the data transparency and verifiability, for efficient internal control and external verification.

Data to be reported

4.2 The following minimum information shall be reported in the **management GhG emissions inventory report**:

- Management 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,
- Source type list defined for year N, and changes made to the source type list during year N (example: structural changes),
- Annual direct GhG emissions, with their respective level of uncertainty and methodologies used,
- Corresponding activity data.

4.3 At a minimum, the **documentation**, necessary for internal control and external verification, should consist of the following elements:

- Internal protocol developed by the entity, including calculation and computation methods and evidence of the sources of emission factors used. When an entity uses a calculation method different from the protocol, it must describe its methodology precisely and explain its choice,
- Explanation of the inclusions and exclusions which have been decided regarding the definition of the source type list,
- Any changes in the methodology that may influence the comparability of data reported to historic data,
- Description of any events that may have impacted the reported data,
- Any background data needed to assess data quality.

4.4 The provided information shall be clear and concise.

4.5 The entity is required to record in a systematic manner (such as using an electronic database) both the data and the methods that underpin the data collection and consolidation. Recording should concern all annual emissions and baseline year emissions.

Activity Data Reporting

4.6 **Activity data**: Representative data of an activity taking place during a given period of time. The entity is free to select activity data as long as its choice is justified.

4.7 Data might be directly linked to the activity, such as collected, treated, sorted or recycled waste tonnage. However, activity data might differ from waste annual tonnage. Examples : unit of GDP, turnover.

4.8 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.

Section 5: Managing Uncertainty

5.1 A simplified calculation method for global uncertainty is given in the EpE protocol on GhG emissions quantification, reporting and verification (section 5 of the « REGES » Protocol). The entity could refer to it to make a calculation.

5.2 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 industry, 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,
- Waste treatment methods are interdependent,
- Some emissions are diffuse and, therefore, are estimated by theoretical 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 in GhG emissions inventories

5.3 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.

5.4 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.

Sources of uncertainty

5.5 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.

Recommendations to reduce residual uncertainty

5.6 Uncertainty is inherent to the establishment of a GhG emissions inventory. However, the entity should aim at reducing this uncertainty and to keep residual uncertainty as low as possible.

5.7 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

5.8 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.

Uncertainty standard-values

5.9 A table presenting uncertainties associated with instrumentation commonly used on waste management sites and the data entered in GhG emissions calculation is presented below. This table is indicative, and has been made through data given by experts from Veolia Environmental Services, Séché Environnement and Suez Environment.

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.

5.10 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.

Section 6: Verification

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

Scope of the Verification

6.2 The purpose of the verification is to assess that:

- An internal protocol has been developed and complies with this guidance (including the verification of the completeness of source types within the source type list),
- Reported data are free from material discrepancies (validation of GhG emissions and associated uncertainty for each source type).

Material discrepancy within annual emissions

6.3 A verifier's assessment of materiality will include consideration of both the amount and nature of 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 the aggregate of uncorrected discrepancies.
Therefore, verifiers will take into account any omission or error that could lead to material discrepancies on annual figures.

Annex 1: Global Warming Potentials

Gas	Global Warming Potential[1]
CO_2	1
CH_4	21
N_2O	310

1. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories – Reference Manual (Volume 3) - http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm

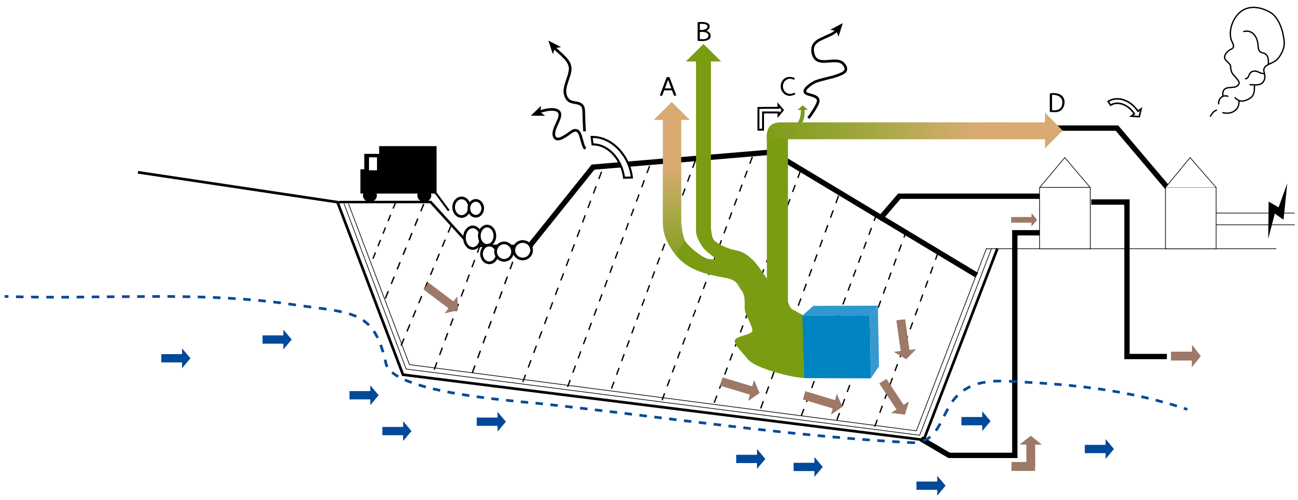
Annex 2: Comparative analysis of the greenhouse gases models for landfills

Context – 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 (source: EAA 2005):



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 combusted in a turbine or a boiler – CO_2 only

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

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.

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.

Accounting for captured greenhouse gases can easily be done using flowmeters installed in the landfill gas collection system (presenting a high level of certainty) 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.

Existing models can be separated in 2 main categories:

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

- **«0» order** models (IPCC Tier I 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 II type): These models take into account a landfill's waste filling history or yearly average inputs and the site operating life (years). 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.

EPER Specific Context

The implementation of the European Pollutant Emission Register (EPER) accelerated the development of national GhG emissions estimation models for landfills.

According to the 2000/479/EC European directive (also know as EPER), the activities registered in the Annexe I of the IPPC (Integrated Pollution Prevention and Control) Directive and exceeding the thresholds set in the Annex I of the EPER decision must declare their polluting emissions to competent authorities. Landfills may fall under the 5.4 category – Installations for the disposal of non-hazardous waste (>50t/day) and landfills (>10t/day) – or 5.1 – Installations for the disposal or recovery of hazardous waste (>10t/day) or municipal waste (>3t/hour).

As part of the EPER 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 EPER, uncertainties remain in assessing diffuse atmospheric emissions from landfills in some countries.

National models used for EPER

Within the European Union, the models used by the member states are listed below (source: EPER 2004):

Country	Model used	Short description
Germany	National model	Order 0 – adaptation of the tier I model from IPCC + some elements from tier II for CH_4 emissions
Austria	2 (national) models depending if waste is residual (Tabasaran and Rettenberger metho-dology) or not (Martico-rena 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*	
Spain	*No data available*	
Finland	Adapted tier 2 IPCC model	IPCC model: Order 1 with a change on methane corrective factor
France	National models (ADE-ME) – one tier 2 type model and another one based on captured lan-dfill 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 effi-ciency and the quantity of captured landfill gas
Greece	*Tier 1 IPCC model*	Order 0
Ireland	LandGem (USEPA)	Order 1 – only 1 waste category, takes into account cover oxidation and captured landfill gas – For-merly created to model landfill gas production and not diffuse emissions
Italy	*Taken from IPCC tier 2Model*	Order 1
Luxembourg	*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.
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*	

Outside the EPER 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 EPER model),
- GasSim (UK, national EPER model),
- LandGem (USA, EPA model),
- IPCC Tier II model (international reference).

Modeling methodology

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

$$Q_{CH4} = L_o \cdot M \cdot k \cdot e^{-k(t-x)}$$

Where :
Q_{CH4} : Quantity of methane produced per year (Nm^3/year)
L_o : 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_o and M depend on "x". The result is sometimes detailed by waste categories, the L_o, 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 (default data (*)) of the various models (source: Ogor and Guerbois 2005).

	Tier II	LandGem (EPA) (8)	GasSim	ADEME
Model type	Monophase (1)		Multiphase (6)	
Input data	Historic of landfilled waste tonnages + % of inert waste		Historic of landfilled waste tonnages + waste composition	
Methane generation potential L_o	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)	(3) Capture efficiency average based on cover type in proportion to the surface areas
Inputs due to capture	Average flow of methane captured during the year			(4) surface area every cover type
Oxidation (7)	10%	10%	Automatically calculated	10%

(*) In most models, the factors mentioned here (L_o, k, etc.) can be modified by the user to be more representative of the modeled landfills' actual conditions.

(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 to 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. 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 Lo). 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 II) 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),

1. 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.

- 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.

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 similate 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 asses. 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 Nm^3 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

- Interviews with experts of ADEME, CITEPA, European Topic Center for Resources and Waste Management, VEOLIA PROPRETÉ, SITA and SECHE ENVIRONNEMENT.
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- European Environment Agency : Waste Management in Europe and the Landfill Directive – Background paper from the ETC/RWM to the ETC/ACC workshop 'Inventories and Projections of Greenhouse Gas Emissions from Waste' (2005)
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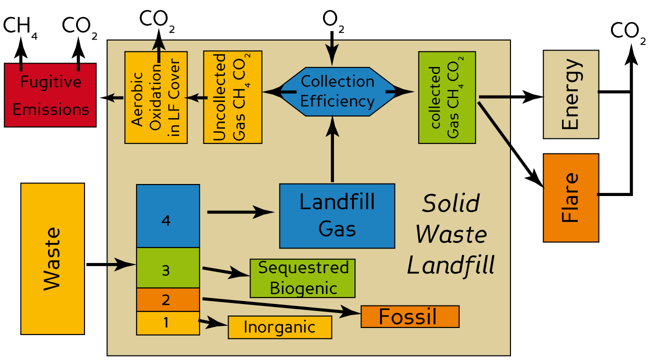
- JACOBS J., SCHARFF H. : Comparison of methane emission models and methane emission measurements (2004)
- OGOR Y., GUERBOIS M., "Comparison of Landfill Methane Emission Models : a Case Study", Proceedings Sardinia 2005, Tenth International Waste Management and Landfill Symposium, S. Margherita di Pula, Cagliari, Italy, 3-7 October 2005
- UK Environment Agency : GasSIM – landfill gas risk assessment tool (2002)
- USEPA : LandGEM User's Manual Landfill Gas Emissions Model - Version 2.0 (1998)
- Workshop on Inventories and Projections of Greenhouse Gas Emissions from Waste – Organized by the European Environment Agency – Copenhagen (Denmark), 2 – 3 may 2005
- http://air-climate.eionet.eu.int/docs/meetings/050502_GhGEm_Waste_WS/meeting050502.html

Annex 3: Additional information concerning waste landfilling and composting

1. Carbon sequestration in landfills – Compiling of reference documents on the subject

In mass balance terms, carbon storage can be characterized as the carbon that remains (stored over long time periods) after accounting for the carbon exiting the system as landfill gas or dissolved in leachate. Below is a diagram representing the carbon flow in solid waste landfills.

Carbon Flow in Solid Waste 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 degrade to a significant extent under anaerobic conditions. Although cellulose and hemicellulose biodegradation does occur, the extent of decomposition varies with landfill conditions, and these materials do not appear to completely degrade based on a number of excavation studies. In addition, the presence of lignin actually prevents some cellulose and hemicellulose biodegradation. Thus, landfills in effect store some of the cellulose and hemicellulose and all of the lignin that is buried initially. The amount of storage will vary with environmental conditions in the landfill; pH and moisture content have been identified as the two most important variables controlling decomposition.

Carbon storage in solid waste landfills has been subject of discussion and further review, namely in the US, as can been seen in US EPA's report Solid Waste Management and Greenhouse Gases - Solid Waste Management and Greenhouse Gases : A Life-Cycle Assessment of Emissions and Sinks, based largely on preliminary and funding work by Barlaz (Carbon storage during biodegradation of municipal solid waste components in laboratory-scale landfills, 1998). This document discusses carbon storage in landfills and proposes values for materials' Carbon Storage Factors.

Another major reference is the IPCC 2006 Guidelines for National Greenhouse Gas, that provides a methodology for estimating changes in carbon stored in landfills (Volume 5 Waste, Chapter 3, Solid Waste Disposal).

Today, continued effort is needed to develop a recognized methodology that considers the carbon sequestration within the models used to estimate landfill gas production and diffuse landfill emissions.

References:

- **Barlaz**, M.A. 1998. Carbon storage during biodegradation of municipal solid waste components in laboratory-scale landfills. Global Biochem. Cycles 12(2):373-380.
- **USEPA**, 2004. Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks
- **IPCC** 2006 Guidelines for National Greenhouse Gas Inventories

  Volume 5 Waste, Chapter 3, Solid Waste Disposal, provides a methodology for estimating changes in carbon stored in solid waste disposal sites (landfills), which is reported as an information item in the Waste Sector (see also Volume 4, AFOLU, Chapter 12, Harvested Wood Products).
- **Solid Waste Industry Climate Solutions Group** (SWICS) - Recommended Protocol for Estimating Greenhouse Reductions Due To Landfill Carbon Storage and Sequestration.

2. Composting - N_2O and CH_4 Emission Factors[1]

Homogenized emission factors for direct N_2O emissions

Source	Emission factor g N_2O/t WW[2]	Emission factor kg CO_2e / t	% of initial N	Methodology	Substrate
ADEME05	24 [2.4-59.1]	7.3 [0.7-18.4]		Review of bibliography Default [min-max]	Biowaste
	210 [10.5-262]	65 [3.2-81.3]			MSW
Bar02	158	49			Biowaste
Bec01	7.15	2	0.02	Measurements in reactors	Greenwaste
	149.5	46	0.4		
	210.6	65	0.6		
CITEPA07	161	50			
Cl03	15	5		On-site measurements	MSW
	400	124			
ERM06	165	51			Paper, cardboard, park waste
He98	232	72	0.5	On-site measurements	Greenwaste
	1247.52	77	0.4	Measurements in reactors	
	382	118	0.7		
IPCC06b	300 [60-600]	93 [18.6-185]		Default [min-max]	

Recommended values

Homogenized emission factors for direct CH_4 emissions

Source	Emission factor g CH_4/t WW[2]	Emission factor kg CO_2e / t	Methodology	Substrate
ADEME05	1240 [310-6190]	26 [6.5-130]	Review of bibliography Default [min-max]	MSW (65% dry)
CITEPA07	952	20		Biowaste
Cl03	400	8	On-site measurements	MSW
	1200	25		
	10000	210		
ERM06	30.3	0.64		Paper, cardboard, park waste
He98	6760	142	On-site measurements	Greenwaste
IPCC06b	4000 [30-8000]	84 [0.63-168]	Default [min-max]	

Recommended values

1. Factors found in litterature, compiled thanks to a BIO Intelligence Service study carried out in 2007
2. WW = wet weight

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.
- **CITEPA07**: CITEPA (2007), Organisation et méthodes des inventaires nationaux des émissions atmosphériques en France (OMINEA), 4e 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.
- **IPCC06b**: IPCC (2006), Guidelines for National Greenhouse Gas Inventories: Chapter 4: Biological treatment of solid waste

Annex 4: Bibliography

General bibliography

- The Greenhouse Gas Protocol – A Corporate Accounting and Reporting Standard – Revised edition - 2004 - WBCSD / WRI – www.GhGprotocol.org
- Revised 1996 IPCC Guidelines for national Greenhouse Gas Inventories
- 2000 IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories
- Directive 2003/87/CE of the European Parliament and of the council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community.
- Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control
- Commission decision of 29 January 2004 establishing guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council
- 2000/479/EC: Commission Decision of 17 July 2000 on the implementation of a European pollutant emission register (EPER) according to Article 15 of Council Directive 96/61/EC concerning integrated pollution prevention and control (IPPC) (notified under document number C(2000) 2004)
- Arrêté of July 28th 2005 of French Ministry of Ecology[1] and sustainable development relating to the verification and quantification of declared emissions within the frame of the GhG allowances trading scheme
- Methodological guide relating to the control of declarations of GhG emissions, prepared by the Ministry of ecology and sustainable development in application of article 62 of arrêté of February 2nd, 1998 modified.
- ADEME Bilan Carbone®[2] Method: www.ademe.fr/Outils/BilanCarbone
- ISO 14064 – 1:2006; Greenhouse gases -- Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals
- ISO 14064 – 2:2006; Greenhouse gases -- Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements
- ISO 14064 – 3:2006; Greenhouse gases -- Part 3: Specification with guidance for the validation and verification of greenhouse gas assertions

Waste industry specific bibliography

- VEOLIA PROPRETÉ, Measuring and reporting protocol (2004)
- Suez Environnement, Internal Protocol
- Séché Environnement, Internal Protocol
- Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Simplified Manual - Module 6 : Waste
- UNFCC, Consolidated baseline methodology for landfill gas project activities - ACM0001 (2004)
- EPER: Supporting Document for the determination of diffuse methane emissions from landfill sites (2004)
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- CORINAIR, Emission Inventory Guidebook - Waste incineration (2001)
- AEA Technology, Waste management options and climate change, Study for DG Environment, European Commission (2001)
- COWI, A Study on the Economic Valuation of Environmental Externalities from Landfill Disposal and Incineration of Waste, Final Appendix Report for the European Commission (2000)
- European Commission – Joint Research center,

1. Ministère de l'Ecologie et du Développement Durable, France.
2. Bilan Carbone® is an ADEME registered trademark..

Integrated pollution prevention and control, Reference document on best available techniques for the waste treatments industry (BREF), August 2005

- ADEME : Calculation tool of emissions to air of CH_4, CO_2, SOx, NOx from waste storage sites and comparable – user manual (2003)
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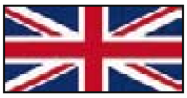
- US Environment Protection Agency, Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks (2002)
- ATILH, Guideline for collecting annual data on CO_2 emissions et check possibilities of those emissions values (2002)
- P. Bajeat, L'effet de serre dans les filières de gestion des déchets ménagers – Greenhouse effect in household waste management routes; Ademe seminar, 21 & 22 November 2002
- Jacobs et Scharff, Comparison of methane emission models and methane emission measurements, ICLRS 2004 Session, Whole site methane emissions
- Gutierrez et al., Nitrous Oxide (N_2O) emissions from waste and biomass to energy plants, Waste manage Res 2005:23:133-147
- European Topic Center on Air and Climate Change Symposium proceedings, "Inventories and projections of greenhouse gas emissions from waste", 2-5 may, 2005, Copenhagen

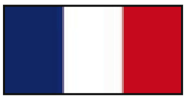
Additional bibliographic elements are available in the annex 2 of "Landfill greenhouse gases emissions models comparative analysis"

Annex 5: Calculation tool - Quantification Protocol

Protocol for the quantification of GHG emissions from waste management activities1

Choisissez votre langue / choose your langage:





This Excel tool is appended to the protocol prepared by Entreprises pour l'Environnement to assist operators in their greenhouse gas emissions inventory associated with waste management activities.

This tool has to be used as part of an inventory done according to the principles described in the Word file protocol.

It is made of the following sheets:

Transport	Emissions due to waste collection and transport
Comb & Indirect	Emissions due to fuel, electricity or thermic energy consumption
Landfilling	Specifications for the emissions calculations for landfilling
Incineration	Emissions due to waste incineration (all types)
Wastewater	Emissions due to wastewater treatment
Avoided	Emissions avoided during one of the above activities
Factors	Indicative factors that can be used
Recycling factors	Indicative factors for avoided emissions related to material recovery
Synthesis	Inventory recapitulative sheet

Automatic information will be provided in certain cells, helping to complete the form.

EpE Contact: 50 rue de la Chaussée d'Antin
Paris 75009
Tél : + (33) 1 49 70 98 50
Fax : + (33) 1 49 70 02 50
E-mail : contact@epe-asso.org
http://www.epe-asso.org

January 2008

GREENHOUSE GAS EMISSIONS DUE TO TRANSPORTS

These tables are extracted for the GHG emissions calculation tool from transport activities developped together by EpE and ADEME

COLOUR CODE:

(blue)	Direct emissions from transportation vehicles owned or operated by the reporting entity
(pink)	Emissions due to the production of electricity that is used by the electric or hybrid vehicles operated by the entity
(green)	Emissions from transportation vehicles owned or operated by a subcontractor of the reporting entity

This sheet has to be used to assess emissions from transport. Direct emissions from vehicles owned or operated by the entity, indirect emissions from electric vehicles and indirect emissions from contracted transport operations should also be reported. The 3 emission-types listed above should not be added together.
According to the available data, the user could use one or several of the following tables.
If a mean of transport is not mentioned (railway, shipping, river transport for example), or if the user wishes to use a model that allows estimation of tonnes.km, he is invited to use the GHG emissions calculation tool developped by EpE / ADEME.
The used factors are the ones from the French Environment Ministry or the IPCC for fuels. They are from ADEME for the other calculation methods.

1 - Road freightage: calculated from fuel puchases (unit: L)

	Consumption (litre)		kg CO2-e per litre	t CO2-e	
Fuel	**owned, controlled or operated**	**outsourced goods transportation activity**		**owned, controlled or operated**	**outsourced goods transportation activity**
Gasoline			2,425	-	-
Diesel oil			2,662	-	-
LPG			1,584	-	-
Other fuel			1,00	-	-
Total				-	-

2 - Road freightage: calculated from fuels' puchases (unit: tonnes)

	Consumption (tons)		kg CO2-e per ton	t CO2-e	
Fuel	**owned, controlled or operated**	**outsourced goods transportation activity**		**owned, controlled or operated**	**outsourced goods transportation activity**
Natural gas			2 827	-	-
Gasoline			3 212	-	-
Diesel oil			3 150	-	-
LPG			2 944	-	-
Other fuel			1 000,00	-	-
Total				-	-

3 - Road freightage with electrical traction: calculated from electricity purchases

	Consumption (MWh)		kg CO2-e par kWh	t CO2-e	
	owned, controlled or operated	outsourced goods transportation activity		owned, controlled or operated	outsourced goods transportation activity
France, Transport use			0,038	-	-
France			0,091		
Austria			0,225	-	-
Belarus			0,299	-	-
Belgium			0,268	-	-
Bulgaria			0,448	-	-
Croatia			0,311	-	-
Czech Republic			0,516	-	-
Denmark			0,284	-	-
Estonia			0,665	-	-
Finland			0,194	-	-
Germany			0,349	-	-
Greece			0,776	-	-
Hungary			0,339	-	-
Iceland			0,001	-	-
Ireland			0,584	-	-
Italy			0,405	-	-
Latvia			0,162	-	-
Lithuania			0,130	-	-
Luxembourg			0,328	-	-
Netherlands			0,387	-	-
Norway			0,006	-	-
Poland			0,659	-	-
Portugal			0,498	-	-
Romania			0,394	-	-
Russia			0,338	-	-
Slovak Republic			0,232	-	-
Slovenia			0,328	-	-
Spain			0,394	-	-
Sweden			0,045	-	-
Switzerland			0,026	-	-
Ukraine			0,314	-	-
United Kingdom			0,473	-	-
United States			0,573	-	-
Annex I Countries[UNFCCC], moyenne			0,349	-	-
Autre pays				-	-
Total				-	-

4 - Road freightage: calculated from vehicles.km and average consumptions

Vehicle's designation	vehicle.km		litres aux 100	kg CO2-e par litre	t CO2-e	
	owned, controlled or operated	outsourced goods transportation activity			owned, controlled or operated	outsourced goods transportation activity
Gasoline vehicle, 1				2,425	-	-
Gasoline vehicle, 2				2,425	-	-
Gasoline vehicle, 3				2,425	-	-
Diesel oil vehicle, 1				2,662	-	-
Diesel oil vehicle, 2				2,662	-	-
Diesel oil vehicle, 3				2,662	-	-
Other vehicle, 1					-	-
Other vehicle, 2					-	-
Other vehicle, 3					-	-
Total					-	-

Global balance

EMISSIONS BY ORIGIN	tonnes CO2-e	%
Direct emissions from transportation vehicles owned or operated by the reporting entity	-	
Emissions due to the production of electricity that is used by the electric or hybrid vehicles operated by the entity	-	
Emissions of transport means owned or operated by a sub-contractor of the entity performing the inventory	-	
Total emissions	-	0%

DIRECT GREENHOUSE GAS EMISSIONS (FUEL CONSUMPTION) AND INDIRECT EMISSIONS (ELECTRICITY AND THERMAL ENERGY CONSUMPTION) (NOT SECTOR SPECIFIC)

COLOUR CODE:

(pink)	Default values
(grey)	Calculated values
(green)	Values to enter

This sheet is intended for all energy consumption, whatever the waste treatment method is: it can be additional fuel consumption for incinerators or for engines or turbines in landfills, the use of liquid fuel, gas or electricity in wastewater treatment plants, etc. It is up to the user to make sure that all the fuel consuming points are taken into account.

Direct emissions from permanent combustion facilities and on-site mobile equipment

1 - Calculation from fuels tonnages

Fuel type	Used quantities *tons*	Emission factor *kgCO2 / t*	CO2 gross accounting *t CO2*	Accounting *%*	CO2 net emissions *t CO2*
Gas oil		3,15		100	
Diesel		3,15		100	
Heavy Fuel oil		3,10		100	
Natural gas		2 827		100	
Others (to be specified)					
Total					-

2 - Calculation from fuels' volume

Fuel type	Used quantities *L*	Emission factor (*) *kg CO2 / L*	CO2 gross accounting *t CO2*	Accounting (0 or 100%) *%*	CO2 net emissions *t CO2*
Gas oil		2,662		100	
Diesel		2,662		100	
Heavy Fuel oil		3,12		100	
Natural gas		0,00193		100	
Others (to be specified)					
Total			-		-

** default factors are the GIEC factors. These can be revised (see other factors in the 'Factors' thumbnail)*

Indirect emissions

3 - Indirect emissions from electricity or purchased heat consumption

Consumed electricy or heat production area	Energie consommée *MWh*	Emission factor (*) *kgCO2 / MWh*	Indirect net emissions *t CO2*	Accounting (0 or 100%) *%*	Indirect net emissions *t CO2*
				100	
				100	
				100	
				100	
				100	
				100	
				100	
				100	
Total					-

** see factors given in the 'Factors' tab*

Annex 5

GREENHOUSE GAS EMISSIONS FROM LANDFILLS (LANDFILLING)

COLOUR CODE:

Default values

Calculated values

Values to enter

Direct emissions from landfills

1 - Calculation from existing models

To calculate GHG emissions from landfills the entity should refer to the regulatory methologies recommended by the competent authorities of the country where the site(s) is (are) located.
By default, the entity could use one of the following models.

France	ADEME Model	"Outil de calcul des émissions dans l'air de CH4, CO2, SOx, NOx issues des centres de stockage de déchets ménagers et assimilés"
USA	LandGEM	www.epa.gov/ttn/catc/products.html
United Kingdom	GasSIM	www.gassim.co.uk/
IPCC	Tier II Model	http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm

Calculation to be made for operating sites.

2 - Calculation from a model drawn up internally

An operator could use a different model from the ones listed above. This model needs to present at least the following caracteristics:

1) This model has to resort to a kinetic equation on the model of the equation presented below as an example

$$Q_{CH4} = L_O \cdot M \cdot k \cdot e^{-k(t-x)}$$

Où :
Q_{CH4} : Quantity of methane produced per year (Nm3/year)
L_0 : methane generation potential (Nm3 CH4 / t of waste)
M : tonnes of landfilled waste (t)
k : kinetic constant (year-1)
x : year when waste was landfilled
t : year of emissions inventory ($t \geq x$)

2) It should not resort to direct emission factors that would be applied to waste tonnages
3) It should consider waste's composition
4) It should clearly specify the rules followed for diffuse emissions and oxidation factors
5) It should be published, accepted and available in scientific and technical papers
6) The methane content of biogas should be based on specific analysis and avoid standard values as much as possible
0

3 - Calculation of CO2 emissions from used fuels

If you use fossil fuels to feed thermal facilities (engines, compressors, boilers…), you should calculate the corresponding emissions using the "Comb & Indirect thumbnail"

4 - Presentation of the four theoretical models

Summary of the four methane production and emission theoretical models

Model	Methane production calculation equation	Major parameters		Emissions calculation
		k° (year-1)	**Methane generation potential L0 (Nm3 CH4 / t)**	
GIEC **(Tier 2)** **First order decay model** **(GIEC, 2005)**	$P_{CH4} = A * k * DSM_T(x) * DSM_F * L_0(x) * e^{-k(t-x)}$ A = normalisation factor* DSMT = Total MSW produced DSMF= Fraction of total MSW disposed in landfill	**0,05**	$L_0 = FCM * COD * COD_F * F * 16/12$ With : FCM= Methane correction factor F (fraction of CH4 in landfill gas) = 0.5 COD= degradable organic carbon, based on the waste's flow	Theoretical production – collected volume * (1-oxidation rate) Oxidation = 10 % (default)
ADEME **First order multiphase** **(Taramini, 2002)**	$P_{CH4} = \sum_{i=1}^{n} FE_0 * (\sum A_i * p_i * k_i * e^{-k(t-x)})$ Ai= normalisation factor* pi= fraction of waste with a methane generation rate constant ki	**k1=0,5** **k2= 0,1** **k3= 0,04** *Moy. :0.14*	$FE_0 = 0,934 * C_0 * (0,014 * T + 0,28)$ FE0= 100 (MSW) et 50 (Non hazardous industrial waste)	Depending on a theoretical collection rate, defined by zone, + 10% oxidation Collection rate by zone : - in operation : 35% - semi-permeable cover : 65% - natural impermeable cover :85% - geomembrane : 90%
GasSIM **First order multiphase** **(UK, 2005)**	$C_t = C_0 - (C_{0,1}e^{(-k1t)} + C_{0,2}e^{(-k2t)} + C_{0,3}e^{(-k3t)})$ $C_x = C_t - C_{t-1}$ C = quantity of degradable carbon	**k1 = 0,116** **k2 = 0.076** **k3 = 0.046**	Calculated by the model according to waste's composition	Calculated by the software according to the cover type
LandGEM **First order** **(US-EPA, 2005)**	$Q_{CH4} = \sum_{i=1}^{n} kL_0 M_i (e^{-ktj})$ M= Quantity of waste disposed in landfill	**0,04** (Inv) **0,05** (CAA)	**100 (Inv) US EPA's pollutants' emissions inventory** **170 (CAA) Emissions control within the US Clean Air Act**	Theoretical production – collected volume * (1-oxidation rate) Oxidation = 10 % (default)

* Normalisation factor to assure that the sum of the discrete values for each year are equal to the CH4 generation potential for the waste's complete degradation, Ai = (1- e-ki)/ki. This factor is always <1 and reduces the production calculated through the model.

* The kinetic decay constant (k) refers to the time reuired for the degradable organic carbon contained in the waste to decay until half of its initial mass ("half-time" or t½).

$$k = \frac{\ln 2}{t_{1/2}}$$

GREENHOUSE GAS EMISSIONS FROM INCINERATORS

COLOUR CODE:

(pink)	Default values
(grey)	Calculated values
(green)	Values to enter

Two methods are presented to calculate CO2 emissions from incineration: from tonnage of waste combusted and from flue gas monitoring. Measurement use is possible if the operating manager shows that the result's uncertainty is below that of the first method.
The emission factor should be consitent with the accounting %: if the emission factor considers the biomass content of waste, the % is taken at 100%; if not, it corresponds to the fossil carbon content of the waste

BEWARE: the user should avoid any double counting
• The implementation of a calculation based on incinerated tonnage requires to fill the tab concerning incineration as well as the tab concerning eventual additional fossil fuels
• On the opposite, flue gas monitoring concerns all of the incinerated carbonated products. It is therefore not necessary to double calculate emissions from additional fuels. However, it is necessary to deduce CO2 emissions coming from the incinerated biomass.

Direct emissions from incinerators - CO2

1 - Calculation of waste CO2 emissions based on the tonnages of incinerated waste

Emission factors that consider biogenic carbon content

Incinerated waste type	Incinerated quantity *Tonnes*	Emissions factor *t CO2 / t*		Net emissions *t CO2*
Household waste		0,293	*Source: MODECOM / ADEME*	-
Non-hazardous industrial waste		0,293	*Source: MODECOM / ADEME*	-
Hazardous waste		0,636	*Source: CITEPA*	-
Hospital waste		0,900	*Source: CITEPA*	-

Incinerated waste after an MBT pre treatment *Tonnes*	Fraction of biogenic C / total C (t CO2/tC) in waste coming out from MBT %	Emissions factor *t CO2 / t*		Net emissions
	20%	0,172		-

Case by case calculation of the emission factor

Incinerated tonnage (tonnes)	Total carbon content (%)	Biogenic carbon as fraction of total carbon (%)	Combustion efficiency (%)	Emissions factor *t CO2 / t*	Net emissions *t CO2*
100	24%	66%	98%	0,293	29

Others (waste type to be specified; the chosen emission factors need to be documented)				
				-
				-
				-

Emission factors that do NOT consider biogenic carbon content

Incinerated waste type	Incinerated quantity *Tonnes*	Emissions factor *t CO2 / t*		Direct CO2 emissions *t CO2*	Biogenic carbon content *tC2O / t waste*	CO2 net emissions direct emissions *t CO2*
Household waste				-		-
Non-hazardous industrial waste				-		-
Hazardous waste				-		-
Others (waste type to be specified; the chosen emission factors need to be documented)						
				-		-
				-		-
				-		-
Total				-		-

2 - Calculation of waste CO2 emissions from flue gas monitorings

Incinerated waste type	Incinerated quantity Tonnes	Annual flue gas volume m3	CO2 content t CO2 / m3	CO2 gross accounting t CO2	Biogenic carbon content tC2O / t waste	Emissions that are accounted for t CO2
Household waste				-		-
Non-hazardous industrial waste				-		-
Hazardous waste				-		-
Others (waste type to be specified; the chosen emission factors need to be documented)						
				-		-
				-		-
				-		-
Total				-		-

N2O gross direct emissions

3 - Calculation of waste N2O emissions from incinerated waste tonnages

	Incinerated quantity (1) Tonnes	Emissions factor (Source : CITEPA) kgN20 / t waste	N2O gross direct emissions Tonnes	Accounting (0 or 100%) %	N2O emissions that are accounted for Tonnes	GHG emissions that are accounted for t CO2 eq.
Total quantity (Household waste + non-dangerous industrial waste)		0,031	-	100	-	-
Hazardous waste		0,127	-	100	-	-
Hospital waste		0,060	-	100	-	-

The IPCC gives default values for N2O emission factors from incineration (2006 IPCC Guidelines for National Greenhouse Gas Inventories - Volume 5 Waste).

Default N2O emission factors for different types of waste and management practices			
Type of waste	**Technology / Management practice**	**Emission factor (g N2O / t waste)**	**weight basis**
MSW	Continuous and semi-continuous incinerators	50	wet weight
MSW	Batch-type incinerators	60	wet weight
MSW	Open burning	150	dry weight
Industrial waste	All types of incineration	100	wet weight
Sludge (except sewage sludge)	All types of incineration	450	wet weight
Sewage sludge	Incineration	990	dry weight
		900	wet weight

4 - Calculation of CO2 emissions due the type of fuels used

If you use fossil fuels or electricity to feed the incinerator from time to time (temperature preservation, flue gas treatment), you should calculate the corresponding emissions using the 'Comb & Indirect' sheet

Global balance

Total CO2 and N2O emissions associated with waste incineration	t CO2 eq.	-

GREENHOUSE GAS EMISSIONS FROM WASTEWATER TREATMENT

COLOUR CODE:

(pink)	Default values
(grey)	Calculated values
(green)	Values to enter

Direct emissions from wastewater treatment

1 - Methane emitted from water treatment

Currently, there are no available methods to accurately quantify CH4 emissions from wastewater treatment.

2 - N2O emitted from waste water treatment

There is not enough knowledge today to monitor and quantify these emissions. Research programs are underway and the calculation tool will be updated as soon as data are available.

3 - Calculation of CO2 emissions from used fuels

If you use fossil fuels or electricity to feed thermal facilities (engines, compressors, boilers...) you must calculate the corresponding emissions using the 'Comb & Indirect' sheet.

AVOIDED GREENHOUSE GAS EMISSIONS

COLOUR CODE:

(pink)	Default values
(grey)	Calculated values
(green)	Values to enter

Avoided emissions

Landfill

1 - Avoided CO2 emissions through energetic recovering of the produced biogas

Sold energy production area (electricity/heat)	Produced and sold quantity *MWh*	Emissions factor (*) *kgCO2 / MWh*	CO2 avoided emissions *t CO2*
			-
			-
			-
			-
			-
			-
			-

* see factors proposed in the 'Factors' sheet

Total	-

Incineration

2.1 - Calculation of the avoided emissions from the quantity of produced electricity

Sold electricity production area	Produced and sold quantity *MWh*	Emissions factor (*) *kgCO2 / MWh*	CO2 avoided emissions *t CO2*
			-
			-
			-
			-
			-
			-
			-

* see factors proposed in the 'Factors' sheet

Total	-

2.2 - Calculation of the avoided emissions from the quantity of produced heat

Sold heat productrion area	Produced and sold quantity *MWh*	Emissions factor (*) *kgCO2 / MWh*	CO2 avoided emissions *t CO2*
			-
			-
			-
			-
			-
			-
			-

* see factors proposed in the 'Factors' sheet

Total	-

3- Calculation of avoided emissions from the quantity of recovered waste

Recovered waste	Sold tonnages *t*	Emissions factor *t CO2 / t*	CO2 avoided emissions *t CO2*
Bottom ash			-
Slag			-
Others			-

Total	-

Physico- chemical treatments

4 - Calculation of avoided emissions from the generation of alternative fuels

	Quantity *t*	Emissions factor *t CO2 / t*	CO2 avoided emissions *t CO2*
Alternative fuel produced			-

Total	**-**

Sorting and recycling

5- Calculation of avoided emissions from the quantity of recovered waste

Waste type	Sold tonnages *t*	Emissions factor (*) *t CO2 / t*	CO2 avoided emissions *t CO2*
Paper / Cardboard			-
Glass			-
Steel			-
Aluminium			-
Plastics (HDPE)			-
Plastics (PET)			-
Others (to be specified)			-
Others (to be specified)			-
Others (to be specified)			-
Others (to be specified)			-
Others (to be specified)			-

* see factors proposed in the 'Factors' sheet

Total	**-**

Total avoided emissions	**-**

EMISSION FACTORS

Type of factor	**Used in sheets**	
1 - Emission factors by fuel type	Comb & Indirect	Avoided
2 - Emission factors per MWh (distinction depending on the producing country)	Comb & Indirect	Avoided
3 - Organic carbon average rate in household waste (European countries)	Avoided	
4 - Factors for wastewater treatment	Wastewater	
5 - Factors for the recovery of slag and bottom ash from incineration	Avoided	

1 - Emission factors by fuel type

CO2 emission factors from combustion facilities per type of used fuels

IPCC : Revised IPCC guidelines for national greenhouse gas inventories : reference manual
http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm

GhG Protocol : http://www.ghgprotocol.org/templates/GHG5/layout.asp?MenuID=849
CITEPA : http://www.citepa.org/publications/Inventaires.htm

Fuel type	Unit	Emission Factors		
		GIEC, 1996	CITEPA, 2005	ADEME 2005
Fuel oil	t CO2/t	3,10	3,12	ND
Gasoil	t CO2/t	3,21	3,15	3,15
Natural Gas	t CO2/t	-	2,83	2,83
Natural Gas	t CO2/GJ	0,0561	0,057	ND

Fuel type	Unit	Emission Factors			
		GIEC, 1996	GhG protocol (IEA)	CITEPA, 2005	ADEME 2005
Fuel oil	t $CO2/m^3$	ND	3,12	3,06	ND
Gasoil	t $CO2/m^3$	2,685	2,68	2,66	2,662
Natural Gas	t $CO2/m^3$	ND	0,00193	ND	ND

2 - Emission factors per MWh (distinction depending on the producing country)

CO2 emissions per kWh for heat production processes

Thermal energy source replaced	Emission Factor (gCO2eq / kWh)	Source
Oil boiler	268	ADEME and Gaz de France, LCA report on the different types of biogas recovery, 2007
Natural gas boiler	202	
Collective oil heating	491	ADEME and BIO Intelligence Service, LCA report on Collective and Industrial wood heating, 2005
Collective natural gas heating	242	
Industrial oil heating	473	
Industrial natural gas heating	231	
Heat, european average	279	AEA Technology, Waste management options and climate change, 2001

CO2 emissions per kWh for electricity production processes

Emission factors (in grams CO2 / kWh) linked to fuel consumption by electricity and heat production plants : oil, gas, coal, nuclear, hydro, geothermal, solar and biomass.

Source :International Energy Agency 'CO2 Emissions from Fuel Combustion (2007 Edition)', available on the GHG Protocol website (http://www.ghgprotocol.org), Section 'Corporate Standard' - 'Calculation tools'.

Average factors on a geographic area are presented in red.

Country — **g CO_2 / kWh**

Year / Annex I Countries	2000	2001	2002	2003	2004	2005
Australia	865	845	892	872	844	873
Austria	183	194	194	236	230	225
Belarus	307	297	300	296	303	299
Belgium	285	272	266	274	269	268
Bulgaria	431	463	433	470	471	448
Canada	217	226	213	225	207	199
Croatia	299	310	354	377	298	311
Czech Republic	567	560	546	502	504	516
Denmark	339	336	332	357	308	284
Estonia	697	685	672	723	701	665
Finland	211	240	253	293	255	194
France	83	71	76	80	78	91
Germany	496	506	518	438	436	349
Greece	814	832	815	774	777	776
Hungary	412	395	392	421	390	339
Iceland	1	1	1	1	1	1
Ireland	639	675	637	597	572	584
Italy	504	485	509	525	411	405
Japan	399	400	420	442	425	429
Latvia	200	190	188	183	167	162
Lithuania	158	144	120	112	110	130
Luxembourg	255	240	329	330	334	328
Netherlands	447	462	459	467	440	387
New Zealand	230	276	247	290	241	275
Norway	4	6	5	8	7	6
Poland	672	660	662	662	665	659

Portugal	480	443	513	414	452	498
Romania	395	412	412	451	418	394
Russia	321	322	327	329	325	338
Slovak Republic	267	249	224	256	247	232
Slovenia	331	341	372	367	337	328
Spain	430	383	437	381	383	394
Sweden	42	43	52	60	51	45
Switzerland	22	21	22	23	24	26
Turkey	526	551	478	448	427	433
Ukraine	344	327	323	379	313	314
United Kingdom	449	476	461	480	486	473
United States	586	602	575	575	575	573

Data for non-Annex 1 countries are less accurate that the ones for Annex 1 countries. These emissions factors should be used carefully.

g CO_2 / kWh

Year / Non-Annex 1 countries	2000	2001	2002	2003	2004	2005
Albania	49	61	58	30	32	34
Algeria	686	687	699	700	700	671
Angola	383	382	354	373	337	343
Argentina	338	267	258	275	317	306
Armenia	236	243	153	148	120	138
Azerbaijan	651	562	491	524	512	505
Bahrain	868	840	835	883	881	890
Bangladesh	556	602	604	574	627	557
Benin	602	955	950	752	740	710
Bolivia	298	509	470	456	537	481
Bosnia and Herzegovina	702	715	621	644	601	619
Brazil	88	104	86	79	85	84
Brunei	795	799	818	811	811	789
Cameroon	10	16	27	31	28	39
Chile	331	261	262	279	341	357
Chinese Taipei	604	616	606	633	628	632
Colombia	201	191	187	176	163	163
Congo	0	0	0	0	0	0
Costa Rica	8	14	15	20	17	27
Cote d'Ivoire	379	394	409	384	404	518
Cuba	1024	991	1090	1131	1014	987
Cyprus	842	781	760	837	776	792
Democratic Republic of Con	4	4	4	3	3	3
Dominican Republic	760	658	734	644	586	574
DPR of Korea	583	582	567	541	528	521
Ecuador	215	272	281	299	302	369
Egypt	412	381	437	432	473	471
El Salvador	288	302	310	297	275	263
Eritrea	714	749	659	694	722	696
Ethiopia	11	9	8	6	6	7
Former Yugoslav Republic of	681	778	723	665	679	645
Gabon	326	272	282	306	322	368
Georgia	193	133	52	53	78	89
Ghana	78	129	212	298	84	204
Gibraltar	763	757	764	758	770	743
Guatemala	392	421	484	404	434	384
Haiti	346	340	400	320	301	307
Honduras	280	329	282	352	451	411
Hong Kong [China]	711	719	724	794	829	810
India	938	934	919	903	942	943
Indonesia	643	739	714	775	750	771
Iraq	731	813	751	787	703	701
Islamic Republic of Iran	568	578	560	534	532	534
Israel	761	773	823	818	807	767
Jamaica	821	823	803	794	785	713
Jordan	708	702	741	680	683	660

Kazakhstan	1216	1012	1178	1192	1179	1137
Kenya	562	392	271	200	280	307
Korea	501	502	425	445	444	418
Kuwait	689	670	624	663	753	807
Kyrgyzstan	106	101	106	94	90	82
Lebanon	733	751	722	709	564	667
Libya	1023	1012	971	979	889	899
Malaysia	517	541	591	525	531	557
Malta	868	1028	820	814	902	892
Mexico	566	568	558	560	522	515
Morocco	770	764	765	736	749	778
Mozambique	5	4	3	3	3	1
Myanmar	457	405	376	426	415	365
Namibia	21	29	28	27	27	26
Nepal	12	7	2	1	1	1
Netherlands Antilles	717	717	717	717	717	718
Nicaragua	610	613	563	558	557	539
Nigeria	407	340	354	340	400	403
Oman	796	817	830	854	885	855
Other Africa	407	412	411	419	420	420
Other Asia	382	370	384	369	365	361
Other Latin America	562	561	568	583	525	518
Pakistan	479	463	443	370	397	380
Panama	231	400	270	356	266	277
Paraguay	0	0	0	0	0	0
People's Republic of China	765	740	749	776	806	788
Peru	152	120	143	148	206	198
Philippines	498	530	482	460	457	495
Qatar	771	781	782	779	649	618
Republic of Moldova	743	773	745	756	513	516
Saudi Arabia	810	778	751	740	760	748
Senegal	782	799	645	520	555	634
Serbia and Montenegro	750	711	739	767	732	748
Singapore	664	635	595	574	556	544
South Africa	893	829	819	845	866	848
Sri Lanka	427	406	435	378	429	398
Sudan	533	534	632	743	828	848
Syria	567	559	554	562	556	587
Tajikistan	41	41	27	27	28	27
Thailand	564	562	538	528	538	531
Togo	359	1094	217	130	499	474
Trinidad and Tobago	691	694	772	731	759	709
Tunisia	574	584	564	554	532	482
Turkmenistan	795	795	795	795	795	795
United Arab Emirates	728	746	769	803	913	844
United Republic of Tanzania	193	70	57	51	60	607
Uruguay	57	3	4	2	150	103
Uzbekistan	459	467	475	454	443	443
Venezuela	210	282	278	245	245	225
Vietnam	420	392	424	375	407	406
World	489	491	490	499	503	502
Yemen	930	930	919	884	879	845
Zambia	7	7	7	7	7	7
Zimbabwe	740	848	717	515	572	572
Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**

3 - Organic carbon average rate in household waste (European countries)

Average content of biogenic carbon in Household Waste (HW)
Source (except France): European Environment Agency, 2005
For France: source ADEME 2004

Country	Unit	Biogenic carbon content in MSW	Fraction of biogenic carbon in total carbon (t Cbio/tC)
Allemagne	tC/tMSW	1,83	0,66
Autriche	tC/tMSW	0,44	
Chypre	tC/tMSW	0,66	
Danemark	tC/tMSW	1,83	
Espagne	tC/tMSW	0,62	
Estonie	tC/tMSW	0,62	
Finlande	tC/tMSW	0,73	
France	tC/tMSW	0,57	
Grèce	tC/tMSW	0,55	
Hongrie	tC/tMSW	1,72	
Italie	tC/tMSW	0,40	
Pays Bas	tC/tMSW	0,33	
Portugal	tC/tMSW	0,66	
République Tchèque	tC/tMSW	0,32	
Royaume Uni	tC/tMSW	0,26	
Slovaquie	tC/tMSW	0,44	
Suède	tC/tMSW	0,51	
USA	tC/tMSW	0,89	0,74

4 - Factors for wastewater treatment

Emissions from wastewater treatment
Source: IPCC (1996)
CH4 emissions converted in tCO2 equivalent

Country	Unit	Emissions
Africa	t CO2 eq / tDBO5	0,777
Asia & Latin America	t CO2 eq / tDBO5	0,840
OECD Countries	t CO2 eq / tDBO5	1,050

5 - Factors for the recovery of slag and bottom ash from incineration

Avoided emissions related to the recovery of slag and bottom ash

Material	Unit	Avoided emissions
Slag	t CO2 eq / t	1,600
Bottom ash	t CO2 eq / t	0

Remark : Bottom ash from waste incineration can be used instated of gravel. The calculation of the avoided emissions related to bottom ash recovery depend on the local context : quantity of fuel and electricity used for the fabrication of one tonne of gravel. Studies currently available state that using bottom ashes in roads provides virtually no GHG savings.

FACTORS FOR AVOIDED EMISSIONS FROM RECYCLING

The values below originate from three publications : a European study by AEA Technology for the Environment DG, a publication from US EPA and a French study ADEME/Ecobilan.
The user will choose the most appropriate values according to the geographical location of the considered sites.

All these values are given in metric tonnes of CO_2 / metric tonne of material.
As far as the American values are concerned, factors have been converted into metric tonnes of CO_2 / metric tonne of material taking as a starting point the original values given in metric tonnes of CO_2 / short ton of material (conversion factor : division by 0,9071847).

Remark : If the user wants to use values other than those cited below, he should document them and give the references of the LCA study at the origin of his figures.

Title of the document	**Waste management options and climate change, AEA Technology pour la DG Environnement**	**Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks, 3rd edition, US EPA**	**Etude technico-économique sur le bilan des filières de recyclage, ADEME/Ecobilan**
Perimeter	Includes transport and emissions from sorting facilities	Includes transport, emissions from sorting facilities and sequestered carbon (carbon sequestration in the trees that would have been cut in the absence of recycling).	Recycling only (impact of the recycling of 1 tonne of waste at the entrance of the recycling facility)
Publication year	2001	2006	2007

Material	Unit	Avoided emissions
Paper	t CO2 / t	0,600
HDPE	t CO2 / t	0,491
PET	t CO2 / t	1,761
Glass	t CO2 / t	0,253
Ferrous metal	t CO2 / t	1,487
Aluminium	t CO2 / t	9,074
Textiles	t CO2 / t	3,169

Material	Unit	Avoided emissions
Aluminum Cans	t CO2 / t	14,96
Steel Cans	t CO2 / t	1,97
Copper Wire	t CO2 / t	5,42
Glass	t CO2 / t	0,31
HDPE	t CO2 / t	1,53
LDPE	t CO2 / t	1,86
PET	t CO2 / t	1,70
Corrugated Box	t CO2 / t	3,43
Magazines	t CO2 / t	3,38
Newspaper	t CO2 / t	3,08
Office Paper	t CO2 / t	3,14
Phonebook	t CO2 / t	2,93
Textbook	t CO2 / t	3,43
Dimensional Lumber	t CO2 / t	2,71
Fiberboard	t CO2 / t	2,72
Mixed Paper Board	t CO2 / t	3,90
Mixed Paper - Residential	t CO2 / t	3,90
Mixed Plastics	t CO2 / t	1,64
Mixed Recyclables	t CO2 / t	3,21
Carpets	t CO2 / t	7,91
PCs	t CO2 / t	2,49
Aggregate	t CO2 / t	0,01
FlyAsh	t CO2 / t	0,96
Tires	t CO2 / t	2,01

Material	Unit	Avoided emissions
Steel	t CO2 / t	1,60
Aluminium	t CO2 / t	7,10
Lead	t CO2 / t	0,69
Copper Wire	t CO2 / t	1,13
Cardboard packing	t CO2 / t	0,16
Graphic papers	t CO2 / t	0,37
Special and hygiene papers	t CO2 / t	0,39
Glass	t CO2 / t	0,46
PE	t CO2 / t	2,30
PET	t CO2 / t	2,70

EMISSIONS SYNTHESIS

COLOUR CODE:

(yellow)	Direct emissions
(orange)	Indirect emissions
(lilac)	Avoided emissions

Source	Net direct emissions *t CO2 eq*
Permanent combustion facility	-
Operated transport	-
Landfill	
Incineration	-
Total direct emissions	-

Emissions related to the use of electricity or thermal energy	-
Indirect emissions related to transport	-
Total indirect emissions	-

TOTAL	-

Beware: for incineration, the calculation could have been made without a prior calculation of the gross emissions before, according to available data. As a consequence, every analysis or comparison of gross and net emissions should be done carefully.

Source	Total avoided emissions *t CO2 eq*
Energy recovery from the produced biogas	-
Energy production from incineration	-
Recovery of incineration by-products	-
Alternative fuels	-
Sorting and recycling	-
Total avoided emissions	-

Avoided emissions shouldn't be deduced from the total of direct/indirect emissions calculated above.

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