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University of Brescia

Research centre on appropriate technologies for environmental management in developing Countries

A methodology for the calculation of Greenhouse Gases emissions from office-based projects

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Index

Introduction

Scientists worldwide have come to the conclusion that human-induced emissions of greenhouse gases are mainly responsible for the earth's current above-normal changes in weather conditions. According to the United Nations Framework Convention on Climate Change (UNFCCC), "climate change" refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.

Anthropogenic Greenhouse Gases (GHG) emissions occur (directly or indirectly) in every human activity. A complete assessment of the environmental impact of every activity should consider not only the emissions related to the final outputs, but also the emissions caused by secondary actions such as travel, car use, meetings, consumption of paper and materials. A sustainable approach to environmental management must keep in mind this issue, implementing appropriate measures to reduce and offset the emissions produced by the implementation of the actions.

CeTAmb is dealing with this issue applied to international cooperation programmes. With reference to the activities the programmes are directly delivering, their evaluation in term of environment impact become an important measure to help achieving a better understanding of their sustainability and of their impact on the environment. The calculation of the environment impact from one hand , and of the value of carbon sequestration on the other hand, can also provide ground to experiment and develop methodologies and tools to be used on a wider scale. Such exercise has a potentially wide impact, as the development of a methodology to calculate impact and mitigation could be applied in many other areas and sectors, benefitting organizations and even individuals. The research of an agreed methodology to calculate and estimate impact and mitigation of human activities is still debated, and there is not an agreed methodology among practitioners and scientists to be used so far.

This research was carried out by the authors within the activities of Limpopo Transboundary Programme, funded by the Italian Development Cooperation and executed by CESVI NGO. In this document the authors, basing on a wide literature research, propose a methodology for the calculation of GHG emissions from office-based activities, with particular reference to international cooperation projects.

This document consists of 5 chapter.

Chapter 1 gives a number of main concepts regarding the issue of climate change. Greenhouse effect, climate change due to human behaviours and activities and their impacts on the Earth system are simply explained. Some updated data are presented, describing the situation at global level. Concepts presented are necessary to correctly understand the estimation of GHG produced by the programme.

Chapter 2 illustrates the methods available for the calculation: first of all it presents the standard methodology proposed by the Intergovernmental Panel on Climate Change (IPCC) for national Greenhouse Gases inventories. Then, standard methodology for the calculation of GHG emission from a single office-based organization. Finally the last part of the chapter contains an overview on existing emission calculation tools and methodology available.

Chapter 3 presents the proposed methodology for the estimation of GHG emissions from an office-based organization with special reference to South Africa, where Limpopo Transboundary Programme is based. Activity data and emission factors for the different emission categories are presented and explained.

Chapter 4 illustrates briefly common-sense suggestions and opportunities for the reduction of emissions from office-based activities and offsets.

Chapter 5 shows a calculation instance based on the tool set in collaboration with CESVI NGO.

1. General concepts on climate change due to GHGs emissions

In this chapter a number of main concepts are explained in order to define a shared vocabulary and to focus natural processes and policies ongoing with regard to the objectives of the project/this report.

1.1.The greenhouse effect

Scientists worldwide have come to the conclusion that human-induced emissions of greenhouse gases are mainly responsible for the earth's current above-normal changes in weather conditions. Greenhouse gases (GHGs), which include carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), ozone, and water vapour, allow the energy-rich radiation falling onto the earth from the sun to pass through them almost unhindered, while at the same time they partially absorb the long-wave radiation emitted by the heated earth. Greenhouse gases then re-emit the absorbed energy in the form of infrared radiation, which in turn warms the earth's surface. The intensity of this warming depends on the concentration of the GHGs in the atmosphere. Greenhouse gases play an important natural role in life on earth. Without greenhouse gases, life on our planet would not be possible, as the earth's average temperature would be about -20°C instead of the approximately 15°C that makes the earth habitable by both animal and plant species (DEAT, 2009).

1.2.Climate change

According to the United Nations Framework Convention on Climate Change (UNFCCC), "climate change" refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods. Climate change in IPCC (Intergovernmental Panel on Climate Change) usage refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity. Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level (IPCC, 2007).

Global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004 (Figure 1).

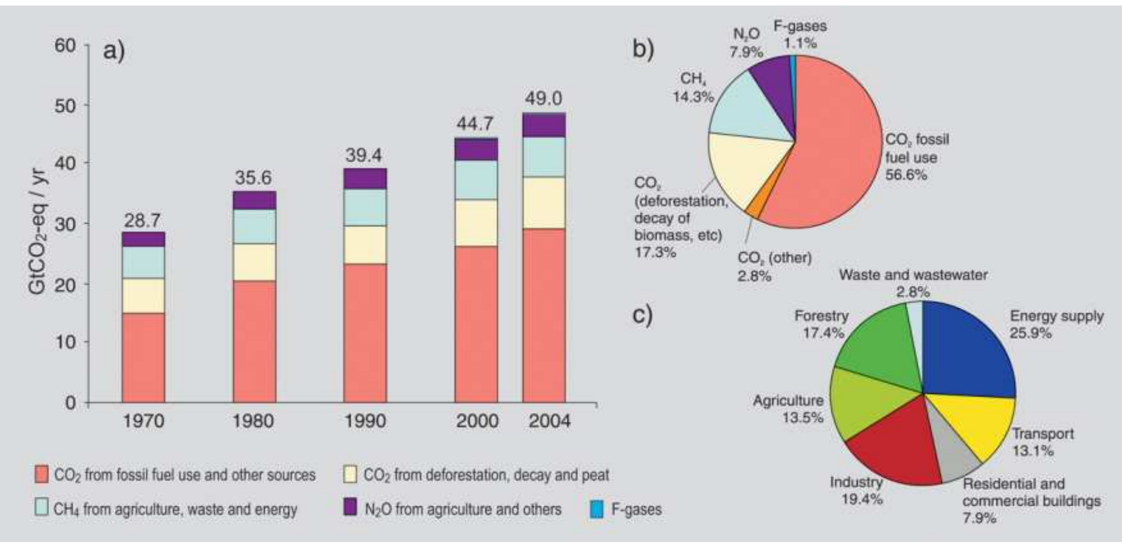

Figure 1: (a) Global annual emissions of anthropogenic GHGs from 1970 to 2004. Share of different anthropogenic GHGs in total emissions in 2004 in terms of CO_2-eq. (c) Share of different sectors in total anthropogenic GHG emissions in 2004 in terms of CO_2-eq. (IPCC, 2007)

The distinction between natural and anthropogenic emissions and removals follows straightforwardly from the data used to quantify human activity. Carbon dioxide is the human-produced greenhouse gas that contributes most of radiative forcing from human activity. CO_2 is produced by fossil fuel burning and other human activities such as cement production and tropical deforestation. Because it is a greenhouse gas, elevated CO_2 levels will contribute to additional absorption and emission of thermal infrared in the atmosphere, which could contribute to net warming. In fact, according to Assessment Reports from the Intergovernmental Panel on Climate Change, "most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations". Figure 2 shows a comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using either natural or both natural and anthropogenic forcings. (IPCC, 2007)

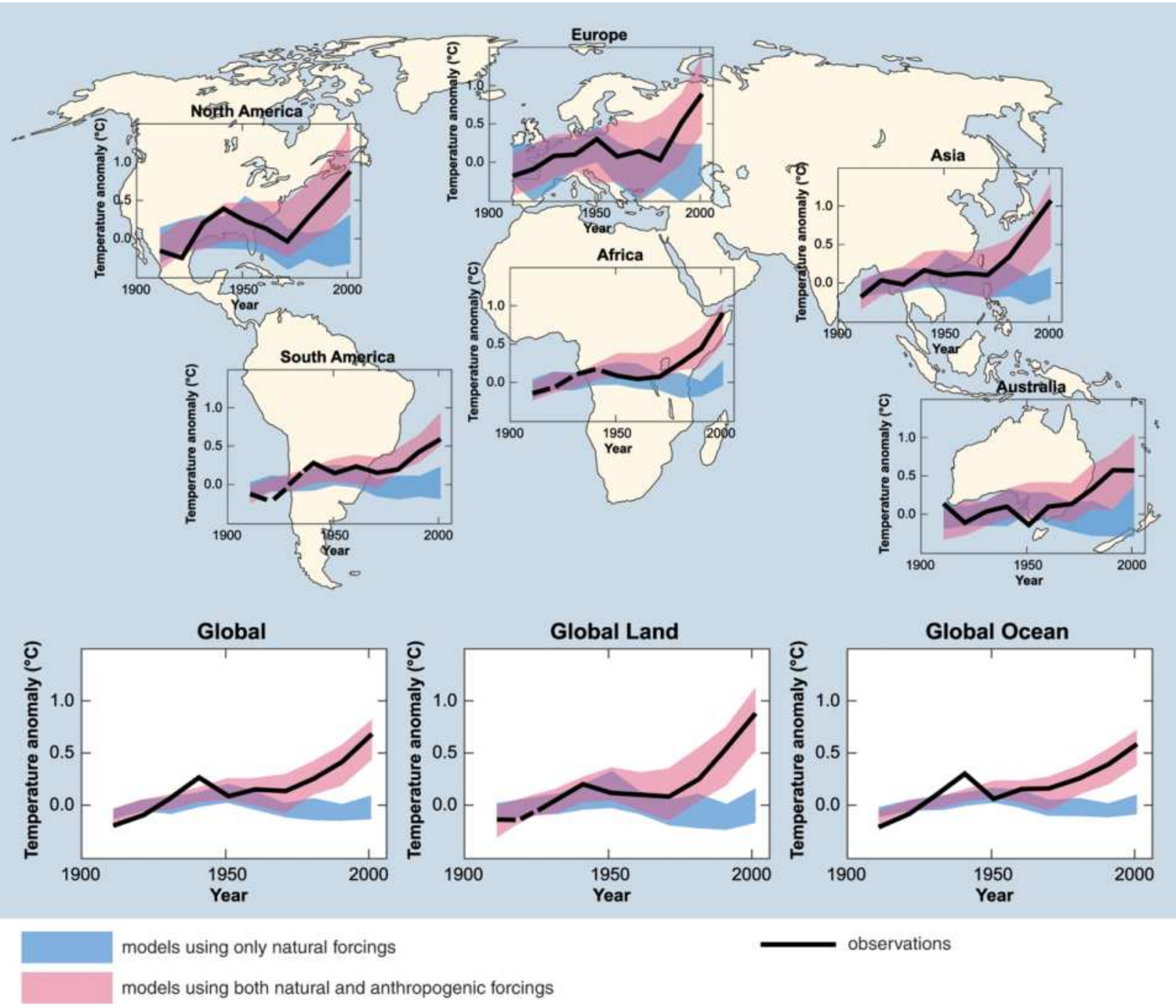

Figure 2: Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using either natural or both natural and anthropogenic forcings. (IPCC, 2007)

The Kyoto Protocol[1], the international climate change agreement, lists six greenhouse gases (or groups of gases) whose emissions signatories to the Protocol agree to reduce. There are also other GHGs apart from the ones covered by the Protocol. But these six gases/groups of gases make up a big chunk of overall GHG emissions from human activities and are the most relevant in terms of immediate human responsibility:

- carbon dioxide (CO_2)
- methane (CH_4)
- nitrous oxide (N_2O)
- sulphur hexafluoride (SF_6)
- hydrofluorocarbons (HFCs)
- perfluorocarbons (PFCs)

The last three (SF6, HFCs and PFCs) are sometimes known collectively as F-gases. The industrial revolution of the 19th century marked a significant change in the concentration of carbon dioxide and other greenhouse gases in the atmosphere. Concentrations of CO_2 have risen by approximately 30% compared with levels in pre-industrial times, whilst those of methane (CH_4) have increased by 145% and those of nitrous oxide (N_2O) by 15%. To compound the problem, a number of new substances such as chlorofluorocarbons (CFCs), halons, perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF_6) have entered the atmospheric equation: these gases do not occur in nature and are generated almost exclusively by anthropogenic activities.

1.2.1. Global Warming Potential (GWP) and CO_2 equivalence

GHGs differ in their warming influence (radiative forcing) on the global climate system due to their different radiative properties and lifetimes in the atmosphere. These warming influences may be expressed through a common metric based on the radiative forcing of CO_2. CO_2-equivalent emission is the amount of CO_2 emission that would cause the same time-integrated radiative forcing, over a given time horizon (100-years GWPs to be consistent with reporting under the UNFCC), as an emitted amount of a long-lived GHG or a mixture of GHGs. Gases which cause much more warming than CO_2 may in turn decay faster than it does, so they may pose a considerable problem for a few years but a smaller one later. Equally, others may decay slower and pose a greater problem over a long period of time.

The equivalent CO_2 emission is obtained by multiplying the emission of a GHG by its Global Warming Potential (GWP) for the given time horizon. For a mix of GHGs it is obtained by summing the equivalent CO_2 emissions of each gas. Equivalent CO_2 emission is a standard and useful metric for comparing emissions of different GHGs but does not imply the same climate change responses.

1.3. Impacts of climate change

Current climate models predict a global warming of about 1.4 - 5.8°C between 1990 and 2100. These projections are based on a wide range of assumptions about the main forces driving future emissions (such as population growth and technological change) but do not assume any climate change policies for reducing emissions. Even a 1.4°C rise would be larger than any century-timescale trend for the past 10,000 years. These projections take into account the effects of aerosols and the delaying effect of the oceans. Oceanic inertia means that the earth’s surface and lower atmosphere would continue to warm for hundreds of years even if greenhouse gas concentrations stopped rising in 2100.

[1] See paragraph 1.4

The average sea level is predicted to rise by 9 to 88 cm by 2100.This would be caused mainly by the thermal expansion of the upper layers of the ocean as they warm, with some contribution from melting glaciers. The uncertainty range is large, and changing ocean currents, local land movement and other factors will cause local and regional sea levels to rise much more or much less than the global average. Slightly faster melting of the Greenland and Antarctica ice sheets is likely to be counteracted by increased snowfall in both regions. As the warming penetrates deeper into the oceans and ice continues to melt, the sea level will continue rising long after surface temperatures have levelled off.

Table 1: main green house gases: atmospheric concentration and lifetime, human activity sources and GWPs (UNEP, 2009)

Gas name	Pre-industrial concentration (ppmv*)	Concentration in 1998	Atmospheric lifetime (years)	Main human activity source	GWP**
Water vapour	~0 to 56,000	~0 to 56,000	a few days	-	-
Carbon dioxide (CO_2)	280	365	variable	Fossil fuels, cement production, land use change	1
Methane (CH_4)	0.7	1.75	12	Fossil fuels, rice paddies, waste dumps, livestock	21
Nitrous dioxide (NO_2)	0.27	0.31	114	Fertilizers, combustion, industrial processes	310
HFC 23 (CHF_3)	0	0.000014	250	Electronics, refrigerants	12,000
HCF 134a (CF_3CH_2F)	0	0.0000075	13.8	Refrigerants	1,300
HCF 152a (CH_3CHF_2)	0	0.0000005	1.4	Industrial processes	120
Perfluoromethane (CF_4)	0.0004	0.0008	>50,000	Aluminium production	5,700
Perfluoroethane (C_2F_6)	0	0.000003	10,000	Aluminium production	11,900
Sulphur hexafluoride (SF_6)	0	0.0000042	3,200	Dielectric fluid	22,200
ppmv = parts per million by volume **GWP = Global warming potential (for 100 years horizon) * For water vapour there is no definitive value as it is highly variable depending on temperature and atmospheric gas movements.*					

Regional and seasonal warming predictions are much more uncertain. Although most areas are expected to warm, some will warm much more than others. The largest warming is predicted for cold northern regions in winter. The reason is that snow and ice reflect sunlight, so less snow means more heat is absorbed from the sun, which enhances any warming: a strong positive feedback effect. By the year 2100, winter temperatures in northern Canada, Greenland and northern Asia are predicted to rise by 40% more than the global average.

Inland regions are projected to warm faster than oceans and coastal zones. The reason is simply the ocean delay, which prevents the sea surface from warming as fast as the land. The size of this delay depends on how deep any warming penetrates into the oceans. Over most of the oceans, the uppermost few hundred meters do not mix with the water beneath them. These upper layers will warm within just a few years, while the deep ocean stays cold. Water mixes down into the ocean depths in only a few very cold regions, such as the Atlantic south of Greenland and the Southern Ocean near Antarctica. In these regions, warming will be delayed because much more water needs to be warmed up to get the same temperature change at the surface.

Global precipitation is predicted to increase, but at the local level trends are much less certain. By the second half of the 21st century, it is likely that wintertime precipitation in the northern mid- to high latitudes and in Antarctica will rise. For the tropics, models suggest that some land areas will see more precipitation, and others less. Australia, Central American and southern Africa show consistent decreases in winter rainfall. More rain and snow will mean wetter soil conditions in high-latitude winters, but higher temperatures may mean drier soils in summer. Local changes in soil moisture are clearly important for agriculture, but models still find it difficult to simulate them. Even the sign of the global change in summertime soil moisture - whether there will be an increase or a decrease - is uncertain.

The frequency and intensity of extreme weather events are likely to change. With increasing global temperatures the world is likely to experience more hot days and heat waves and fewer frost days and cold spells. Climate models also consistently show extreme precipitation events becoming more frequent over many areas and the risk of drought becoming greater over continental areas in summer. There is also some evidence to show that hurricanes could be more intense (with stronger winds and more rainfall) in some areas. There is little agreement amongst models concerning changes in mid-latitude storms. There are also other phenomena, such as thunderstorms and tornadoes, where knowledge is currently inadequate for making projections.

Rapid and unexpected climate transitions cannot be ruled out. The most dramatic such change, the collapse of the West Antarctic ice sheet, which would lead to a catastrophic rise in sea level, is now considered unlikely during the 21st century. There is evidence that changes in ocean circulation having a significant impact on regional climate (such as a weakening of the Gulf Stream that warms Europe) can take place in only a few decades, but it is unknown whether or not greenhouse warming could trigger any such change. Climate models that do show a weakening in the Gulf Stream still project warming over Europe.

1.4. The international response to climate change

From 3 to 14 June 1992 heads of state and representatives from 172 governments across the whole world met in Rio de Janeiro in Brazil. The background to the meeting was gloomy. Two years previously the UN's climate panel (IPCC), in its first synthesis report, pointed out that there was a real risk that human activities – especially the consumption of coal, oil and gas – could affect the earth's environment to a hither to unseen and potentially very serious extent. "The earth's future is in danger" was the message. The conference in Rio – which officially was called the United Nations Conference on Environment and Development, but went under the name "Earth Summit" – was set up on the basis of this warning. It resulted in the first international agreement to limit emissions of greenhouse gases: the United Nations Framework Convention on Climate Change (UNFCCC). The climate change convention is a so-called framework convention. This means that it does not represent the last word on the fight against climate change. It is stated in the treaty that it is to be revised and expanded over time. Neither does it set any binding targets, but aims to get member countries to reduce their emissions in order to prevent dangerous anthropogenic interference with the Earth's climate system. The target was for emissions of greenhouse gases in 2000 to stabilize with those in 1990. More than 150 countries signed the climate convention at the Rio conference itself, and on 21 March 1994 the convention came into force after it had been ratified or approved by other means by at least 50 countries. It thereby became legally binding. During the 1990s it soon became clear that the UNFCCC convention in itself would not change developments towards growing emissions of greenhouse gases. In 1997 the convention was therefore expanded to include the so-called Kyoto Protocol, which for the first time sets binding targets for how much the industrialised countries should reduce their emissions by 2012. The protocol sets binding targets for the greenhouse gas emissions of 37 industrialised countries. A group of countries that have ratified the UNFCCC have not ratified the Kyoto Protocol and are therefore not covered by the Kyoto Protocol. The most prominent of these is the USA. The Kyoto Protocol sets targets for emissions from 2008 to 2012. The Kyoto Protocol sets the rules and procedures needed to achieve the ultimate objective of the Convention, which is: “(...) to achieve, (...), stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.” Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner. At the 13th annual conference of member countries (COP13) in Bali it was decided to work towards a new agreement for the subsequent years. The plan – which is called the Bali Action Plan – aims towards a new agreement which is to be negotiated at the 15th annual conference – COP15 – in Copenhagen in 2009. (UN, 2009).

2. Existing tools and methodologies

This chapter introduces existing methodologies to estimate CO_2 emissions from human activities. The main reference point is the IPCC Guidelines methodology which is internationally agreed for comply national greenhouse gases inventories: a general overview with explanation of key words is given in paragraph 2.1.

The methodology provides a calculation method for all sectors causing emissions; in fact, only some categories are meaningful for institutional activities, such as the ones this document is addressed for. Paragraph 2.1.3 illustrates the methodology proposed by IPCC guidelines for some chosen categories.

Because the IPCC guidelines addresses to national inventory compliers, the methods suggested often don't suit to a lower level such as the one of a single organization. Thus, alternatives are proposed in paragraph 2.2 to gather appropriate activity data and choose correct emission factors.

Paragraph 2.3 provides a review of existing calculators for CO_2 emissions.

2.1. IPCC Guidelines Methodology

The Intergovernmental Panel on Climate Change is the leading body for the assessment of climate change, established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to provide the world with a clear scientific view on the current state of climate change and its potential environmental and socio-economic consequences.[2]

The *2006 IPCC Guidelines for National Greenhouse Gas Inventories* were produced at the invitation of the United Nations Framework Convention on Climate Change (UNFCCC) to update the *Revised 1996 Guidelines* and associated *good practice guidance* which provide internationally agreed methodologies intended for use by countries to estimate greenhouse gas inventories to report to the UNFCCC. 2006 Guidelines are chosen as main methodical reference in this report because they provide a standard method almost applicable also to project-level inventories.

Inventory year and time series: national inventories contain estimates for the calendar year during which the emissions to (or removals from) the atmosphere occur. Where suitable data to follow this principle are missing, emissions/removals may be estimated using data from other years applying appropriate methods such as averaging, interpolation and extrapolation. A sequence of annual greenhouse gas inventory estimates (e.g., each year from 1990 to 2000) is called a time series. Because of the importance of tracking emissions trends over time, countries should ensure that a time series of estimates is as consistent as possible.

Greenhouse gas emission and removal estimates are divided into the following main sectors, which are groupings of related processes, sources and sinks:

- Energy
- Industrial Processes and Product Use (IPPU)
- Agriculture, Forestry and Other Land Use (AFOLU)
- Waste
- Other (e.g., indirect emissions from nitrogen deposition from non-agriculture sources)

[2] http://www.ipcc.ch/organization/organization.htm

Each sector comprises individual categories (e.g., transport) and sub-categories (e.g., cars). A single organization inventory is much less complicated than a national one, thus only some categories are significant and few impacting activities have to be considered.

2.1.1. Estimation methods

The most common simple methodological approach is to combine information on the extent to which a human activity takes place (called *activity data* or *AD*) with coefficients which quantify the emissions or removals per unit activity. These are called *emission factors (EF)*. The basic equation is therefore:

Emissions = AD • EF

For example, in the energy sector fuel consumption would constitute activity data, and mass of carbon dioxide emitted per unit of fuel consumed would be an emission factor. The basic equation can in some circumstances be modified to include other estimation parameters than emission factors. Where time lags are involved, due for example to the time it takes for material to decompose in a landfill or leakage of refrigerants from cooling devices, other methods are provided, for example first order decay methods. The *2006 Guidelines* also allow for more complex modelling approaches, particularly at higher tiers.

IPCC methods use the following concepts:

Tiers: A *tier* represents a level of methodological complexity. Usually three tiers are provided. Tier 1 is the basic method, Tier 2 intermediate and Tier 3 most demanding in terms of complexity and data requirements. Tiers 2 and 3 are sometimes referred to as *higher tier* methods and are generally considered to be more accurate.

Default data: Tier 1 methods for all categories are designed to use readily available national or international statistics in combination with the provided default emission factors and additional parameters that are provided, and therefore should be feasible for all countries.

Key Categories: The concept of *key category* is used to identify the categories that have a significant influence on a country's total inventory of greenhouse gases in terms of the absolute level of emissions and removals, the trend in emissions and removals, or uncertainty in emissions and removals. *Key Categories* should be the priority for countries during inventory resource allocation for data collection, compilation, quality assurance/quality control and reporting.

2.1.2. Inventory quality

2006 *guidelines* provide guidance on ensuring quality on all steps of the inventory compilation – from data collection to reporting. A *good practice* approach is a pragmatic means of building inventories that are consistent, comparable, complete, accurate and transparent – and maintaining them in a manner that improves inventory quality over time. Indicators of inventory quality are:

Comparability: the greenhouse gas inventory should be reported in a way that allows it to be compared with inventories for other countries/projects.

Consistency: meaningful comparison of emissions performance over time should be allowed. Any changes to the basis of reporting should be clearly stated to enable continued valid comparison with inventories of previous years.

Completeness: estimates should be reported for all relevant categories of emission sources. Specific exclusions must be justified.

Accuracy: calculations should be precise and reasonable assurance of the integrity of reported GHG information should be provided.

Transparency: all relevant issues should be addressed in a factual and coherent manner, based on a clear audit trail. Important assumptions are disclosed and the calculation methodologies used are cited.

2.1.3. Meaningful categories for a single organization inventory

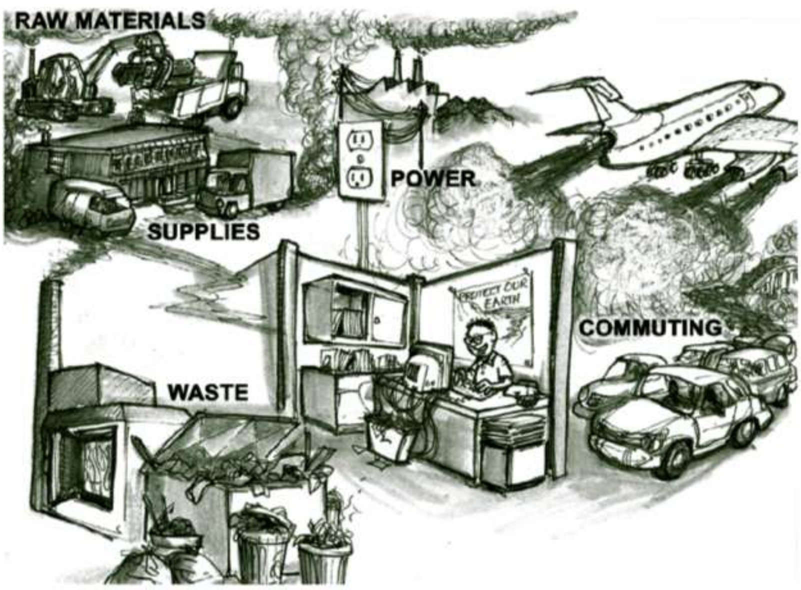

Figure 3: common emissions sources for an office

A CO_2 "inventory" for a single organization is a list of CO_2 emissions sources and their quantities. It enables to identify reduction opportunities, set a reduction target, and manage and reduce CO_2 emissions to meet a fixed goal. Figure 3 gives an overview on possible sources of emissions linkable to an office activity.

Meaningful categories for the calculation of CO_2 emission by an organization/office are described below according to the methodology suggested by the IPCC guidelines 2006.

2.1.3.1. Energy

Energy systems are for most economies largely driven by the combustion of fossil fuels. During combustion the carbon and hydrogen of the fossil fuels are converted mainly into carbon dioxide (CO_2) and water (H_2O), releasing the chemical energy in the fuel as heat. This heat is generally either used directly or used (with some conversion losses) to produce mechanical energy, often to generate electricity or for transportation. The energy sector is usually the most important sector in greenhouse gas emission inventories, and typically contributes over 90 percent of the CO_2 emissions and 75 percent of the total greenhouse gas emissions in developed countries. CO_2 accounts typically for 95 percent of energy sector emissions with methane and nitrous oxide responsible for the balance. Stationary combustion is usually responsible for about 70 percent of the greenhouse gas emissions from the energy sector. About half of these emissions are associated with combustion in energy industries mainly power plants and refineries. Mobile combustion (road and other traffic) causes about one quarter of the emissions in the energy sector.

Combustion processes are optimized to derive the maximum amount of energy per unit of fuel consumed, hence delivering the maximum amount of CO_2. Efficient fuel combustion ensures oxidation of the maximum amount of carbon available in the fuel. CO_2 emission factors for fuel combustion are therefore relatively insensitive to the combustion process itself and hence are primarily dependent only on the carbon content of the fuel. The carbon content may vary considerably both among and within primary fuel types on a per mass or per volume basis:

- For natural gas, the carbon content depends on the composition of the gas which, in its delivered state, is primarily methane, but can include small quantities of ethane, propane, butane, and heavier hydrocarbons.

- Natural gas flared at the production site will usually contain far larger amounts of non-methane hydrocarbons. The carbon content will be correspondingly different. Carbon content per unit of energy is usually less for light refined products such as gasoline than for heavier products such as residual fuel oil.
- For coal, carbon emissions per ton vary considerably depending on the coal's composition of carbon, hydrogen, sulphur, ash, oxygen, and nitrogen.

By converting to energy units this variability is reduced. A small part of the fuel carbon entering the combustion process escapes oxidation. This fraction is usually small (99 to 100 percent of the carbon is oxidized) and so the default emission factors in Table 2 are derived on the assumption of 100 percent oxidation. For some fuels, this fraction may in practice not be negligible and where representative country-specific values, based on measurements are available, they should be used. In other words: the fraction of carbon oxidised is assumed to be 1 in deriving default CO_2 emission factors. Table 3 gives carbon contents of fuels from which emission factors on a full molecular weight basis can be calculated (Table 2). These emission factors are default values that are suggested only if country-specific factors are not available. More detailed and up-to-date emission factors may be available at the IPCC EFDB. Note that CO_2 emissions from biomass fuels are not included in the national total but are reported as an information item. Net emissions or removals of CO_2 are estimated in the AFOLU sector and take account of these emissions. Note that peat is treated as a fossil fuel and not a biofuel and emissions from its combustion are therefore included in the national total. The data presented in Table 3 is used to calculate default emission factors for each fuel on a per energy basis. If activity data are available on a per mass basis, a similar approach can be applied to these activity data directly. Obviously the carbon content then should be known on a per mass basis.

Table 2: default CO_2 emission factors for fuel combustion (IPCC, 2006)

Fuel type English description		Default carbon content (kg/GJ)	Default carbon oxidation factor	Effective CO_2 emission factor (kg/TJ) [2]		
				Default value [3]	95% confidence interval	
		A	B	C=A*B*44/ 12*1000	Lower	Upper
Crude Oil		20.0	1	73 300	71 100	75 500
Orimulsion		21.0	1	77 000	69 300	85 400
Natural Gas Liquids		17.5	1	64 200	58 300	70 400
Gasoline	Motor Gasoline	18.9	1	69 300	67 500	73 000
Gasoline	Aviation Gasoline	19.1	1	70 000	67 500	73 000
Gasoline	Jet Gasoline	19.1	1	70 000	67 500	73 000
Jet Kerosene		19.5	1	71 500	69 700	74 400
Other Kerosene		19.6	1	71 900	70 800	73 700
Shale Oil		20.0	1	73 300	67 800	79 200
Gas/Diesel Oil		20.2	1	74 100	72 600	74 800
Residual Fuel Oil		21.1	1	77 400	75 500	78 800
Liquefied Petroleum Gases		17.2	1	63 100	61 600	65 600
Ethane		16.8	1	61 600	56 500	68 600
Naphtha		20.0	1	73 300	69 300	76 300
Bitumen		22.0	1	80 700	73 000	89 900
Lubricants		20.0	1	73 300	71 900	75 200
Petroleum Coke		26.6	1	97 500	82 900	115 000
Refinery Feedstocks		20.0	1	73 300	68 900	76 600
Other Oil	Refinery Gas	15.7	1	57 600	48 200	69 000
Other Oil	Paraffin Waxes	20.0	1	73 300	72 200	74 400
Other Oil	White Spirit & SBP	20.0	1	73 300	72 200	74 400
Other Petroleum Products		20.0	1	73 300	72 200	74 400
Anthracite		26.8	1	98 300	94 600	101 000
Coking Coal		25.8	1	94 600	87 300	101 000
Other Bituminous Coal		25.8	1	94 600	89 500	99 700
Sub-Bituminous Coal		26.2	1	96 100	92 800	100 000
Lignite		27.6	1	101 000	90 900	115 000
Oil Shale and Tar Sands		29.1	1	107 000	90 200	125 000
Brown Coal Briquettes		26.6	1	97 500	87 300	109 000
Patent Fuel		26.6	1	97 500	87 300	109 000
Coke	Coke oven coke and lignite Coke	29.2	1	107 000	95 700	119 000
Coke	Gas Coke	29.2	1	107 000	95 700	119 000
Coal Tar		22.0	1	80 700	68 200	95 300
Derived Gases	Gas Works Gas	12.1	1	44 400	37 300	54 100
Derived Gases	Coke Oven Gas	12.1	1	44 400	37 300	54 100
Derived Gases	Blast Furnace Gas [4]	70.8	1	260 000	219 000	308 000
Derived Gases	Oxygen Steel Furnace Gas [5]	49.6	1	182 000	145 000	202 000

Table 2(continued): default CO_2 emission factors for fuel combustion (IPCC, 2006)

Fuel type English description		Default carbon content (kg/GJ)	Default carbon oxidation Factor	Effective CO_2 emission factor (kg/TJ) [2]		
				Default value	95% confidence interval	
		A	B	C=A*B*44/12*1000	Lower	Upper
Natural Gas		15.3	1	56 100	54 300	58 300
Municipal Wastes (non-biomass fraction)		25.0	1	91 700	73 300	121 000
Industrial Wastes		39.0	1	143 000	110 000	183 000
Waste Oil		20.0	1	73 300	72 200	74 400
Peat		28.9	1	106 000	100 000	108 000
Solid Biofuels	Wood/Wood Waste	30.5	1	112 000	95 000	132 000
	Sulphite lyes (black liquor)[5]	26.0	1	95 300	80 700	110 000
	Other Primary Solid Biomass	27.3	1	100 000	84 700	117 000
	Charcoal	30.5	1	112 000	95 000	132 000
Liquid Biofuels	Biogasoline	19.3	1	70 800	59 800	84 300
	Biodiesels	19.3	1	70 800	59 800	84 300
	Other Liquid Biofuels	21.7	1	79 600	67 100	95 300
Gas biomass	Landfill Gas	14.9	1	54 600	46 200	66 000
	Sludge Gas	14.9	1	54 600	46 200	66 000
	Other Biogas	14.9	1	54 600	46 200	66 000
Other non-fossil fuels	Municipal Wastes (biomass fraction)	27.3	1	100 000	84 700	117 000

Notes:

[1] The lower and upper limits of the 95 percent confidence intervals, assuming lognormal distributions, fitted to a dataset, based on national inventory reports, IEA data and available national data. A more detailed description is given in section 1.5

[2] TJ = 1000GJ

[3] The emission factor values for BFG includes carbon dioxide originally contained in this gas as well as that formed due to combustion of this gas.

[4] The emission factor values for OSF includes carbon dioxide originally contained in this gas as well as that formed due to combustion of this gas

[5] Includes the biomass-derived CO_2 emitted from the black liquor combustion unit and the biomass-derived CO_2 emitted from the kraft mill lime kiln.

Table 3: default values of carbon content (IPCC, 2006)

Fuel type English description	Default carbon content [1] (kg/GJ)	Lower	Upper
Crude Oil	20.0	19.4	20.6
Orimulsion	21.0	18.9	23.3
Natural Gas Liquids	17.5	15.9	19.2
Motor Gasoline	18.9	18.4	19.9
Aviation Gasoline	19.1	18.4	19.9
Jet Gasoline	19.1	18.4	19.9
Jet Kerosene	19.5	19	20.3
Other Kerosene	19.6	19.3	20.1
Shale Oil	20.0	18.5	21.6
Gas/Diesel Oil	20.2	19.8	20.4
Residual Fuel Oil	21.1	20.6	21.5
Liquefied Petroleum Gases	17.2	16.8	17.9
Ethane	16.8	15.4	18.7
Naphtha	20.0	18.9	20.8
Bitumen	22.0	19.9	24.5
Lubricants	20.0	19.6	20.5
Petroleum Coke	26.6	22.6	31.3
Refinery Feedstocks	20.0	18.8	20.9
Refinery Gas [2]	15.7	13.3	19.0
Paraffin Waxes	20.0	19.7	20.3
White Spirit & SBP	20.0	19.7	20.3
Other Petroleum Products	20.0	19.7	20.3
Anthracite	26.8	25.8	27.5
Coking Coal	25.8	23.8	27.6
Other Bituminous Coal	25.8	24.4	27.2
Sub-Bituminous Coal	26.2	25.3	27.3
Lignite	27.6	24.8	31.3
Oil Shale and Tar Sands	29.1	24.6	34
Brown Coal Briquettes	26.6	23.8	29.6
Patent Fuel	26.6	23.8	29.6
Coke Oven Coke and Lignite Coke	29.2	26.1	32.4
Gas Coke	29.2	26.1	32.4
Coal Tar [3]	22.0	18.6	26.0
Gas Works Gas [4]	12.1	10.3	15.0
Coke Oven Gas [5]	12.1	10.3	15.0
Blast Furnace Gas [6]	70.8	59.7	84.0
Oxygen Steel Furnace Gas [7]	49.6	39.5	55.0
Natural Gas	15.3	14.8	15.9

Table 3(continued): default values of carbon content (IPCC, 2006)

Fuel type English description	Default carbon content [1] (kg/GJ)	Lower	Upper
Municipal Wastes (non-biomass fraction)[8]	25.0	20.0	33.0
Industrial Wastes	39.0	30.0	50.0
Waste Oils [9]	20.0	19.7	20.3
Peat	28.9	28.4	29.5
Wood/Wood Waste [10]	30.5	25.9	36.0
Sulphite lyes (black liquor) [11]	26.0	22.0	30.0
Other Primary Solid Biomass [12]	27.3	23.1	32.0
Charcoal [13]	30.5	25.9	36.0
Biogasoline [14]	19.3	16.3	23.0
Biodiesels [15]	19.3	16.3	23.0
Other Liquid Biofuels [16]	21.7	18.3	26.0
Landfill Gas [17]	14.9	12.6	18.0
Sludge Gas [18]	14.9	12.6	18.0
Other Biogas [19]	14.9	12.6	18.0
Municipal Wastes (biomass fraction) [20]	27.3	23.1	32.0

Notes:

[1] The lower and upper limits of the 95 percent confidence intervals, assuming lognormal distributions, fitted to a dataset, based on national inventory reports, IEA data and available national data. A more detailed description is given in section 1.5

[2] Japanese data; uncertainty range: expert judgement;

[3] EFDB; uncertainty range: expert judgement

[4] Coke Oven Gas; uncertainty range: expert judgement

[5] Japan & UK small number data; uncertainty range: expert judgement

[6] 7. Japan & UK small number data; uncertainty range: expert judgement

[8] Solid Biomass; uncertainty range: expert judgement

[9] Lubricants ; uncertainty range: expert judgement

[10] EFDB; uncertainty range: expert judgement

[11] Japanese data; uncertainty range: expert judgement

[12] Solid Biomass; uncertainty range: expert judgement

[13] EFDB; uncertainty range: expert judgement

[14] Ethanol theoretical number; uncertainty range: expert judgement

[15] Ethanol theoretical number; uncertainty range: expert judgement

[16] Liquid Biomass; uncertainty range: expert judgement

[17-19] Methane theoretical number; uncertainty range: expert judgement

[20] Solid Biomass; uncertainty range: expert judgement

2.1.3.1.1. Stationary combustion

This category includes all fuel combustion activities in energy industries, manufacturing industries and construction and other sectors . Auto-production of electricity by means of a generator can be considered here. Methods are provided for the sectorial approach in three tiers based on:

- Tier 1: fuel combustion from national energy statistics and default emission factors;
- Tier 2: fuel combustion from national energy statistics, together with country-specific emission factors, where possible, derived from national fuel characteristics;
- Tier 3: fuel statistics and data on combustion technologies applied together with technology-specific emission factors; this includes the use of models and facility level emission data where available.

In general, emissions of each greenhouse gas from stationary sources are calculated by multiplying fuel consumption by the corresponding emission factor. In the Sectorial Approach, "Fuel Consumption" is estimated from energy use statistics and is measured in terajoules. Fuel consumption data in mass or volume units must first be converted into the energy content of these fuels. Using a Tier 3 approach to estimate emissions of CO_2 is often unnecessary because emissions of CO_2 do not depend on the combustion technology. Default emission factors are reported in Table 4 for different fuel types.

Table 4: default CO_2 emission factors and uncertainty ranges for fuel types (IPCC guidelines, 2006)

Fuel		CO_2			CH_4			N_2O		
		Default Emission Factor	Lower	Upper	Default Emission Factor	Lower	Upper	Default Emission Factor	Lower	Upper
Crude Oil		73 300	71 100	75 500	10	3	30	0.6	0.2	2
Orimulsion		r 77 000	69 300	85 400	10	3	30	0.6	0.2	2
Natural Gas Liquids		r 64 200	58 300	70 400	10	3	30	0.6	0.2	2
Gasoline	Motor Gasoline	r 69 300	67 500	73 000	10	3	30	0.6	0.2	2
	Aviation Gasoline	r 70 000	67 500	73 000	10	3	30	0.6	0.2	2
	Jet Gasoline	r 70 000	67 500	73 000	10	3	30	0.6	0.2	2
Jet Kerosene		r 71 500	69 700	74 400	10	3	30	0.6	0.2	2
Other Kerosene		71 900	70 800	73 700	10	3	30	0.6	0.2	2
Shale Oil		73 300	67 800	79 200	10	3	30	0.6	0.2	2
Gas/Diesel Oil		74 100	72 600	74 800	10	3	30	0.6	0.2	2
Residual Fuel Oil		77 400	75 500	78 800	10	3	30	0.6	0.2	2
Liquefied Petroleum Gases		63 100	61 600	65 600	5	1.5	15	0.1	0.03	0.3
Ethane		61 600	56 500	68 600	5	1.5	15	0.1	0.03	0.3
Naphtha		73 300	69 300	76 300	10	3	30	0.6	0.2	2
Bitumen		80 700	73 000	89 900	10	3	30	0.6	0.2	2
Lubricants		73 300	71 900	75 200	10	3	30	0.6	0.2	2
Petroleum Coke		r 97 500	82 900	115 000	10	3	30	0.6	0.2	2
Refinery Feedstocks		73 300	68 900	76 600	10	3	30	0.6	0.2	2
Other Oil	Refinery Gas	n 57 600	48 200	69 000	5	1.5	15	0.1	0.03	0.3
	Paraffin Waxes	73 300	72 200	74 400	10	3	30	0.6	0.2	2
	White Spirit and SBP	73 300	72 200	74 400	10	3	30	0.6	0.2	2
	Other Petroleum Products	73 300	72 200	74 400	10	3	30	0.6	0.2	2
Anthracite		r 98 300	94 600	101 000	10	3	30	1.5	0.5	5
Coking Coal		94 600	87 300	101 000	10	3	30	1.5	0.5	5
Other Bituminous Coal		94 600	89 500	99 700	10	3	30	1.5	0.5	5
Sub-Bituminous Coal		96 100	92 800	100 000	10	3	30	1.5	0.5	5
Lignite		101 000	90 900	115 000	10	3	30	1.5	0.5	5
Oil Shale and Tar Sands		107 000	90 200	125 000	10	3	30	1.5	0.5	5
Brown Coal Briquettes		n 97 500	87 300	109 000	n 10	3	30	r 1.5	0.5	5
Patent Fuel		97 500	87 300	109 000	10	3	30	n 1.5	0.5	5
Coke	Coke Oven Coke and Lignite Coke	n 107 000	95 700	119 000	10	3	30	1.5	0.5	4
	Gas Coke	n 107 000	95 700	119 000	5	1.5	15	0.1	0.03	0.3

Table 4(continued): default CO_2 emission factors and uncertainty ranges for fuel types (IPCC guidelines, 2006)

Fuel		CO_2			CH_4			N_2O		
		Default Emission Factor	Lower	Upper	Default Emission Factor	Lower	Upper	Default Emission Factor	Lower	Upper
Coal Tar		n 80 700	68 200	95 300	n 10	30	30	n 1.5	0.5	5
Derived Gases	Gas Works Gas	n 44 400	37 300	54 100	5	1.5	15	0.1	0.03	0.3
Derived Gases	Coke Oven Gas	n 44 400	37 300	54 100	5	1.5	15	0.1	0.03	0.3
Derived Gases	Blast Furnace Gas	n 260 000	219 000	308 000	5	1.5	15	0.1	0.03	0.3
Derived Gases	Oxygen Steel Furnace Gas	n 182 000	145 000	202 000	5	1.5	15	0.1	0.03	0.3
Natural Gas		56 100	54 300	58 300	5	1.5	15	0.1	0.03	0.3
Municipal Wastes (non-biomass fraction)		n 91 700	73 300	121 000	300	100	900	4	1.5	15
Industrial Wastes		n 143 000	110 000	183 000	300	100	900	4	1.5	15
Waste Oils		n 73 300	72 200	74 400	300	100	900	4	1.5	15
Peat		106 000	100 000	108 000	n 10	3	30	n 1.4	0.5	5
Solid Biofuels	Wood / Wood Waste	r 112 000	95 000	132 000	300	100	900	4	1.5	15
Solid Biofuels	Sulphite lyes (Black Liquor)[a]	n 95 300	80 700	110 000	n 3	1	18	n 2	1	21
Solid Biofuels	Other Primary Solid Biomass	n 100 000	84 700	117 000	300	100	900	4	1.5	15
Solid Biofuels	Charcoal	n 112 000	95 000	132 000	200	70	600	1	0.3	3
Liquid Biofuels	Biogasoline	n 70 800	59 800	84 300	10	3	30	0.6	0.2	2
Liquid Biofuels	Biodiesels	n 70 800	59 800	84 300	10	3	30	0.6	0.2	2
Liquid Biofuels	Other Liquid Biofuels	n 79 600	67 100	95 300	10	3	30	0.6	0.2	2
Gas Biomass	Landfill Gas	n 54 600	46 200	66 000	5	1.5	15	0.1	0.03	0.3
Gas Biomass	Sludge Gas	n 54 600	46 200	66 000	5	1.5	15	0.1	0.03	0.3
Gas Biomass	Other Biogas	n 54 600	46 200	66 000	5	1.5	15	0.1	0.03	0.3
Other non-	Municipal Wastes (biomass fraction)	n 100 000	84 700	117 000	300	100	900	4	1..5	15

(a) Includes the biomass-derived CO_2 emitted from the black liquor combustion unit and the biomass-derived CO_2 emitted from the kraft mill lime kiln.
n indicates a new emission factor which was not present in the 1996 Guidelines
r indicates an emission factor that has been revised since the 1996 Guidelines

2.1.3.1.2. Mobile combustion

Mobile sources produce direct greenhouse gas emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) from the combustion of various fuel types, as well as several other pollutants such as carbon monoxide (CO), Non-methane Volatile Organic Compounds (NMVOCs), sulphur dioxide (SO_2), particulate matter (PM) and oxides of nitrate (NOx), which cause or contribute to local or regional air pollution (IPCC Guidelines, 2006).

2.1.3.1.2.1. Road transportation

This category includes all types of light-duty vehicles such as automobiles and light trucks, and heavy-duty vehicles such as tractor trailers and buses, and on-road motorcycles (including mopeds, scooters, and three-wheelers). These vehicles operate on many types of gaseous and liquid fuels.

Estimated emissions from road transport can be based on two independent sets of data: fuel sold and vehicle kilometres. Emissions can be estimated from either the fuel consumed (represented by fuel sold) or the distance travelled by the vehicles. In general, the first approach (fuel sold) is appropriate for CO_2 and the second (distance travelled by vehicle type and road type) is appropriate for CH_4 and N_2O. Emissions of

CO_2 are best calculated on the basis of the amount and type of fuel combusted and its carbon content. Figure 2 shows the decision tree for CO_2 that guides the choice of either the Tier 1 or Tier 2 method. Each tier is defined below.

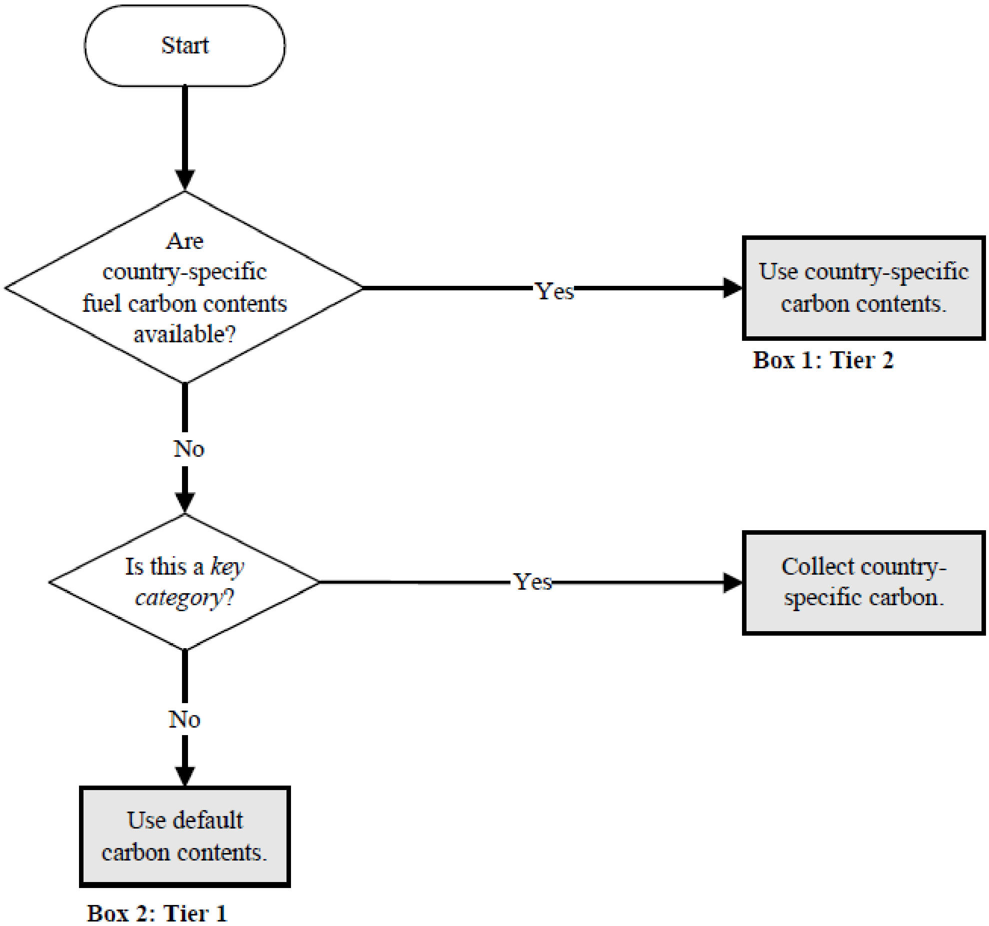

Figure 4: decision tree for CO_2 emissions from fuel combustion in road vehicles (IPCC Guidelines, 2006)

The Tier 1 approach calculates CO_2 emissions by multiplying estimated fuel sold with a default CO_2 emission factor. The Tier 2 approach is the same as Tier 1 except that country-specific carbon contents of the fuel sold in road transport are used. At Tier 2, the CO_2 emission factors may be adjusted to take account of un-oxidized carbon or carbon emitted as a non-CO_2 gas. There is no Tier 3 as it is not possible to produce significantly better results for CO_2 than by using the existing Tier 2. In order to reduce the uncertainties, efforts should concentrate on the carbon content and on improving the data on fuel sold.

CO_2 emission factors are based on the carbon content of the fuel and should represent 100 percent oxidation of the fuel carbon. It is *good practice* to follow this approach using country-specific net-calorific values (NCV) and CO_2 emission factor data if possible. It is *good practice* to ensure that default emission factors, if selected, are appropriate to local fuel quality and composition. At Tier 1, the emission factors should assume that 100 percent of the carbon present in fuel is oxidized during or immediately following the combustion process (for all fuel types in all vehicles) irrespective of whether the CO_2 has been emitted as CO_2, CH_4, CO or NMVOC or as particulate matter. At higher tiers the CO_2 emission factors may be adjusted to take account of un-oxidized carbon or carbon emitted as a non-CO_2 gas.

Refining emission factors for mobile sources in developing countries

In some developing countries, the estimated emission rates per kilometre travelled may need to be altered to accommodate national circumstances, which could include:

- **Technology variations** - In many cases due to tampering of emission control systems, fuel adulteration, or simply vehicle age, some vehicles may be operating without a functioning catalytic converter. Consequently, N_2O emissions may be low and CH_4 may be high when catalytic converters are not present or operating improperly. Díaz et al (2001) provides information on THC values for Mexico City and catalytic converter efficiency as a function of age and mileage.
- **Engine loading** - Due to traffic density or challenging topography, the number of accelerations and decelerations that a local vehicle encounters may be significantly greater than that for corresponding travel in countries where emission factors were developed. This happens when these countries have well established road and traffic control networks. Increased engine loading may correlate with higher CH_4 and N_2O emissions.
- **Fuel Composition** - Poor fuel quality and high or varying sulphur content may adversely affect the performance of engines and conversion efficiency of post-combustion emission control devices such as catalytic converters. For example, N_2O emission rates have been shown to increase with the sulphur content in fuels (UNFCCC, 2004). The effects of sulphur content on CH_4 emissions are not known. Refinery data may indicate production quantities on a national scale.

Further information on emission factors for developing countries is available from Mitra et al. (2004).

Emission factor uncertainty

For CO_2, the uncertainty in the emission factor is typically less than 2 percent when national values are used. Road Transport Default Carbon Dioxide Emission Factors have an uncertainty of 2-5 percent, due to uncertainty in the fuel composition.

Inventory Quality Assurance/Quality Control (QA/QC)

For CO_2 emissions, the inventory compiler should compare estimates using both the fuel statistics and vehicle kilometre travelled data. Any anomalies between the emission estimates should be investigated and explained. The results of such comparisons should be recorded for internal documentation. Revising the following assumptions could narrow a detected gap between the approaches: off-road/non transportation fuel uses, annual average vehicle mileage, vehicle fuel efficiency, vehicle breakdowns by type, technology, age, etc., use of oxygenates/biofuels/other additives, fuel use statistics and fuel sold/used.

If default emission factors are used, the inventory compiler should ensure that they are applicable and relevant to the categories. If possible, the default factors should be compared to local data to provide further indication that the factors are applicable.

The inventory compiler should review the source of the activity data to ensure applicability and relevance to the category. Where possible, the inventory compiler should compare the data to historical activity data or model outputs to detect possible anomalies.

2.1.3.1.2.2. Off-road transportation

The off-road category includes vehicles and mobile machinery used within the agriculture, forestry, industry (including construction and maintenance), residential, and sectors, such as airport ground support equipment, agricultural tractors, chain saws, forklifts, snowmobiles. Engine types typically used in these off-road equipment include compression-ignition (diesel) engines, spark ignition (motor gasoline), 2-stroke engines, and motor gasoline 4-stroke engines.

Emissions from off-road vehicles are estimated using the same methodologies used for mobile sources. The preferred method of determining CO_2 emissions is to use fuel consumption for each fuel type on a country-specific basis. Default CO_2 emission factors assume that 100% of the fuel carbon is oxidized to CO_2. This is irrespective of whether the carbon is emitted initially as CO_2, CO, NMVOC or as particulate matter. Country-specific NCV and CEF data should be used for Tiers 2 and 3. The default emission factors for CO_2 and their uncertainty ranges are provided in Table 5.

Greenhouse gas emissions from off-road sources are typically much smaller than those from road transportation, but activities in this category are diverse and are thus typically associated with higher uncertainties because of the additional uncertainty in activity data.

Table 5: default emission factors for off-road mobile sources and machinery (IPCC, 2006)

	CO_2			CH_4 (b)			N_2O (c)		
Off-Road Source	**Default (kg/TJ)**	**Lower**	**Upper**	**Default (kg/TJ)**	**Lower**	**Upper**	**Default (kg/TJ)**	**Lower**	**Upper**
Diesel									
Agriculture	74 100	72 600	74 800	4.15	1.67	10.4	28.6	14.3	85.8
Forestry	74 100	72 600	74 800	4.15	1.67	10.4	28.6	14.3	85.8
Industry	74 100	72 600	74 800	4.15	1.67	10.4	28.6	14.3	85.8
Household	74 100	72 600	74 800	4.15	1.67	10.4	28.6	14.3	85.8
Motor Gasoline 4-stroke									
Agriculture	69 300	67 500	73 000	80	32	200	2	1	6
Forestry	69 300	67 500	73 000						
Industry	69 300	67 500	73 000	50	20	125	2	1	6
Household	69 300	67 500	73 000	120	48	300	2	1	6
Motor Gasoline 2-Stroke									
Agriculture	69 300	67 500	73 000	140	56	350	0.4	0.2	1.2
Forestry	69 300	67 500	73 000	170	68	425	0.4	0.2	1.2
Industry	69 300	67 500	73 000	130	52	325	0.4	0.2	1.2
Household	69 300	67 500	73 000	180	72	450	0.4	0.2	1.2

Source: EEA 2005.

Note: CO_2 emission factor values represent full carbon content.

[a] Data provided in Table 3.3.1 are based on European off-road mobile sources and machinery. For gasoline, in case fuel consumption by sector is not discriminated, default values may be obtained according to national circumstances, e.g. prevalence of a given sector or weighting by activity

[b] Including diurnal, soak and running losses.

[c] In general, off-road vehicles do not have emission control catalysts installed (there may be exceptions among off-road vehicles in urban areas, such as ground support equipment used in urban airports and harbours). Properly operating catalysts convert nitrogen oxides to N_2O and CH_4 to CO_2. However, exposure of catalysts to high-sulphur or leaded fuels, even once, causes permanent deterioration (Walsh, 2003). This effect, if applicable, should be considered when adjusting emission factors.

2.1.3.1.2.3. Railways

Railway locomotives generally are one of three types: diesel, electric, or steam. Diesel locomotives generally use diesel engines in combination with an alternator or generator to produce the electricity required to power their traction motors. Diesel locomotives are in three broad categories – shunting or yard locomotives, railcars, and line haul locomotives. Shunting locomotives are equipped with diesel engines having a power output of about 200 to 2000 kW. Railcars are mainly used for short distance rail traction, e.g., urban/suburban traffic. They are equipped with a diesel engine having a power output of about 150 to 1000 kW. Line haul locomotives are used for long distance rail traction – both for freight and passenger. They are equipped with a diesel engine having a power output of about 400 to 4000 kW (EEA, 2005). Electric locomotives are powered by electricity generated at stationary power plants as well as other sources: the corresponding emissions are covered under the stationary combustion. Steam locomotives are now generally used for very localized operations, primarily as tourist attractions and their contribution to greenhouse gas emissions is correspondingly small. However for a few countries, up to the 1990s, coal was used in a significant fraction of locomotives. For completeness, their emissions should be estimated using an approach similar to conventional steam boilers, which are covered in the stationary combustion. The default emission factors for CO_2 and their uncertainty ranges for Tier 1 are provided in Table 6.

Table 6: default emission factors for the most common fuels used for rail transport

	Diesel (kg/TJ)			Sub-bituminous Coal (kg/TJ)		
	Default	Lower	Upper	Default	Lower	Upper
CO_2 emission factor	74 100	72 600	74 800	96 100	72 800	100 000

National level fuel consumption data are needed for estimating CO_2 emissions for Tier 1 and Tier 2 approaches. The railway or locomotive companies, or the relevant transport authorities may be able to provide fuel consumption data for the line haul and yard locomotives. The contribution from yard locomotives is likely to be very small for almost all countries.

2.1.3.1.2.4. Civil aviation

Emissions from aviation come from the combustion of jet fuel (jet kerosene and jet gasoline) and aviation gasoline. Aircraft engine emissions are roughly composed of about 70 percent CO_2, a little less than 30 percent H_2O, and less than 1 percent each of NOx, CO, SOx, NMVOC, particulates, and other trace components including hazardous air pollutants. Emissions depend on the number and type of aircraft operations, the types and efficiency of the aircraft engines, the fuel used, the length of flight, the power setting, the time spent at each stage of flight, and, to a lesser degree, the altitude at which exhaust gases are emitted. For the purpose of the guidelines, operations of aircraft are divided into Landing/Take-Off (LTO) cycle and Cruise. Generally, about 10 percent of aircraft emissions of all types, except hydrocarbons and CO, are produced during airport ground level operations and during the LTO cycle. The bulk of aircraft emissions (90 percent) occur at higher altitudes.

Three methodological tiers for estimating emissions of CO_2, CH_4 and N_2O from aviation are presented. Tier 1 and Tier 2 methods use fuel consumption data. Tier 1 is purely fuel based, while Tier 2 method is based on the number of landing/take-off cycles (LTOs) and fuel use. Tier 3 uses movement data for individual flights. All tiers distinguish between domestic and international flights. However, energy statistics used in Tier 1 often do not accurately distinguish between domestic and international fuel use or between individual source categories. Tiers 2 and 3 provide more accurate methodologies to make these distinctions. The choice of methodology depends on the type of fuel, the data available, and the relative importance of aircraft emissions. For aviation gasoline, though country-specific emission factors may be available, the numbers of LTOs are generally not available. Therefore, Tier 1 and its default emission factors would probably be used for aviation gasoline. All tiers can be used for operations using jet fuel, as relevant emission factors are available for jet fuel.

The Tier 1 method is based on an aggregate quantity of fuel consumption data for aviation (LTO and cruise) multiplied by average emission factors. Tier 1 method should be used to estimate emissions from aircraft that use aviation gasoline which is only used in small aircraft and generally represents less than 1 percent of fuel consumption from aviation. Tier 1 method is also used for jet-fuelled aviation activities when aircraft operational use data are not available.

Carbon dioxide emission factors are based on the fuel type and carbon content. National emission factors for CO_2 should not deviate much from the default values because the quality of jet fuel is well defined. It is *good practice* to use the default CO_2 emission factors in Table 7 for Tier 1. National carbon content could be used if available. CO_2 should be estimated on the basis of the full carbon content of the fuel.

Table 7: default emission factors for the most common fuels used for civil aviation

Fuel	Default (kg/TJ)	Lower	Upper
Aviation Gasoline	70 000	67 500	73 000
Jet Kerosene	71 500	69 800	74 400

Tier 2 method is only applicable for jet fuel use in jet aircraft engines. Operations of aircraft are divided into LTO and cruise phases. To use Tier 2 method, the number of LTO operations must be known for both domestic and international aviation, preferably by aircraft type. In Tier 2 method a distinction is made between emissions below and above 914 m (3000 feet); that is emissions generated during the LTO and cruise phases of flight. Tier 2 method breaks the calculation of emissions from aviation into the following steps:

1. Estimate the domestic and international fuel consumption totals for aviation.
2. Estimate LTO fuel consumption for domestic and international operations.
3. Estimate the cruise fuel consumption for domestic and international aviation.
4. Estimate emissions from LTO and cruise phases for domestic and international aviation.

Tier 2 approach uses the following equations to estimate emissions:

Total Emissions = LTO Emissions + Cruise Emissions
LTO Emissions = Number of LTOs • Emission Factor LTO
Cruise Emissions = (Total Fuel Consumption – LTO Fuel Consumption) • Emission Factor Cruise
LTO Fuel Consumption = Number of LTOs • Fuel Consumption per LTO

In Tier 2 method, the fuel used in the cruise phase is estimated as a residual: total fuel use minus fuel used in the LTO phase of the flight. Fuel use is estimated for domestic and international aviation separately. The estimated fuel use for cruise is multiplied by aggregate emission factors (average or per aircraft type) in order to estimate the CO_2 and NOx cruise emissions.[3] Emissions and fuel used in the LTO phase are estimated from statistics on the number of LTOs (aggregate or per aircraft type) and default emission factors or fuel use factors per LTO cycle (average or per aircraft type). Tier 2 method considers activity data

[3] Current scientific understanding does not allow other gases (e.g., N2O and CH4) to be included in calculation of cruise emissions. (IPCC,1999).

at the level of individual aircraft types and therefore needs data on the number of domestic LTOs by aircraft type and international LTOs by aircraft type. The estimate should include all aircraft types frequently used for domestic and international aviation.

For Tier 2 method, it is good practice to use emission factors from Table 8 (or updates reflected in the EFDB) for the LTO emissions. CO_2 cruise emissions are calculated using Tier 1 CO_2 emission factors (Table 7).

Table 8: LTO emission factor for typical aircraft (IPCC, 2006)

	AIRCRAFT	LTO emissions factors (kg/LTO/) (12)							LTO FUEL CONSUMPTION (Kg/LTO)
		CO_2 (11)	CH_4 (7)	N_2O (9)	NO_x	CO	NMVOC (8)	SO_2 (10)	
Large Commercial Aircraft (1)(2)	A300	5450	0.12	0.2	25.86	14.80	1.12	1.72	1720
	A310	4760	0.63	0.2	19.46	28.30	5.67	1.51	1510
	A319	2310	0.06	0.1	8.73	6.35	0.54	0.73	730
	A320	2440	0.06	0.1	9.01	6.19	0.51	0.77	770
	A321	3020	0.14	0.1	16.72	7.55	1.27	0.96	960
	A330-200/300	7050	0.13	0.2	35.57	16.20	1.15	2.23	2230
	A340-200	5890	0.42	0.2	28.31	26.19	3.78	1.86	1860
	A340-300	6380	0.39	0.2	34.81	25.23	3.51	2.02	2020
	A340-500/600	10660	0.01	0.3	64.45	15.31	0.13	3.37	3370
	707	5890	9.75	0.2	10.96	92.37	87.71	1.86	1860
	717	2140	0.01	0.1	6.68	6.78	0.05	0.68	680
	727-100	3970	0.69	0.1	9.23	24.44	6.25	1.26	1260
	727-200	4610	0.81	0.1	11.97	27.16	7.32	1.46	1460
	737-100/200	2740	0.45	0.1	6.74	16.04	4.06	0.87	870
	737-300/400/500	2480	0.08	0.1	7.19	13.03	0.75	0.78	780
	737-600	2280	0.10	0.1	7.66	8.65	0.91	0.72	720
	737-700	2460	0.09	0.1	9.12	8.00	0.78	0.78	780
	737-800/900	2780	0.07	0.1	12.30	7.07	0.65	0.88	880
	747-100	10140	4.84	0.3	49.17	114.59	43.59	3.21	3210
	747-200	11370	1.82	0.4	49.52	79.78	16.41	3.60	3600
	747-300	11080	0.27	0.4	65.00	17.84	2.46	3.51	3510
	747-400	10240	0.22	0.3	42.88	26.72	2.02	3.24	3240
	757-200	4320	0.02	0.1	23.43	8.08	0.20	1.37	1370
	757-300	4630	0.01	0.1	17.85	11.62	0.10	1.46	1460
	767-200	4620	0.33	0.1	23.76	14.80	2.99	1.46	1460
	767-300	5610	0.12	0.2	28.19	14.47	1.07	1.77	1780
	767-400	5520	0.10	0.2	24.80	12.37	0.88	1.75	1750
	777-200/300	8100	0.07	0.3	52.81	12.76	0.59	2.56	2560
	DC-10	7290	0.24	0.2	35.65	20.59	2.13	2.31	2310
	DC-8-50/60/70	5360	0.15	0.2	15.62	26.31	1.36	1.70	1700
	DC-9	2650	0.46	0.1	6.16	16.29	4.17	0.84	840
	L-1011	7300	7.40	0.2	31.64	103.33	66.56	2.31	2310

Table 8 (continued): LTO emission factor for typical aircraft (IPCC, 2006)

	Aircraft	LTO emissions factors (kg/LTO/) ([12])							LTO Fuel Consumption (kg/LTO)
		CO_2[(11)]	CH_4[(7)]	N_2O[(9)]	NO_x	CO	NMVOC[(8)]	SO_2[(10)]	
	MD-11	7290	0.24	0.2	35.65	20.59	2.13	2.31	2310
	MD-80	3180	0.19	0.1	11.97	6.46	1.69	1.01	1010
	MD-90	2760	0.01	0.1	10.76	5.53	0.06	0.87	870
	TU-134	2930	1.80	0.1	8.68	27.98	16.19	0.93	930
	TU-154-M	5960	1.32	0.2	12.00	82.88	11.85	1.89	1890
	TU-154-B	7030	11.90	0.2	14.33	143.05	107.13	2.22	2230
Regional Jets	RJ-RJ85	1910	0.13	0.1	4.34	11.21	1.21	0.60	600
Regional Jets	BAE 146	1800	0.14	0.1	4.07	11.18	1.27	0.57	570
Regional Jets	CRJ-100ER	1060	0.06	0.03	2.27	6.70	0.56	0.33	330
Regional Jets	ERJ-145	990	0.06	0.03	2.69	6.18	0.50	0.31	310
Regional Jets	Fokker 100/70/28	2390	0.14	0.1	5.75	13.84	1.29	0.76	760
Regional Jets	BAC111	2520	0.15	0.1	7.40	13.07	1.36	0.80	800
Regional Jets	Dornier 328 Jet	870	0.06	0.03	2.99	5.35	0.52	0.27	280
Regional Jets	Gulfstream IV	2160	0.14	0.1	5.63	8.88	1.23	0.68	680
Regional Jets	Gulfstream V	1890	0.03	0.1	5.58	8.42	0.28	0.60	600
Regional Jets	Yak-42M	2880	0.25	0.1	10.66	10.22	2.27	0.91	910
Jets (3) (Fn	Cessna 525/560	1070	0.33	0.03	0.74	34.07	3.01	0.34	340
Turboprops[4)]	Beech King Air [(5)]	230	0.06	0.01	0.30	2.97	0.58	0.07	70
Turboprops[4)]	DHC8-100 [(6)]	640	0.00	0.02	1.51	2.24	0.00	0.20	200
Turboprops[4)]	ATR72-500 [(7)]	620	0.03	0.02	1.82	2.33	0.26	0.20	200

Notes:

(1) ICAO Engine Exhaust Emissions Data Bank (ICAO, 2004) based on average measured data. Emissions factors apply to LTO (Landing and Take off) only.

(2) Engine types for each aircraft were selected on a consistent basis of the engine with the most LTOs. This approach, for some engine types, may underestimate (or overestimate) fleet emissions which are not directly related to fuel consumption (eg NO_x, CO, HC).

(2) Emissions and Dispersion Modelling System (EDMS) (FAA 2004b)

(4) FOI (The Swedish Defence Research Agency) Turboprop LTO Emissions database

(5) Representative of Turboprop aircraft with shaft horsepower of up to 1000 shp/engine

(6) Representative of Turboprop aircraft with shaft horsepower of 1000 to 2000 shp/engine

(7) Representative of Turboprop aircraft with shaft horsepower of more than 2000 shp/engine

(8) Assuming 10% of total VOC emissions in LTO cycles are methane emissions (Olivier, 1991) (as in the *1996 IPCC Guidelines*).

(9) Estimates based on Tier I default values (EF ID 11053) (as in the *1996 IPCC Guidelines*).

(10) The sulphur content of the fuel is assumed to be 0.05% (as in the *1996 IPCC Guidelines*).

(11) CO_2 for each aircraft based on 3.16 kg CO_2 produced for each kg fuel used, then rounded to the nearest 10 kg.

(12) Information regarding the uncertainties associated with this data can be found in: Lister and Norman, 2003; ICAO, 1993.

Table prepared in 2005 updates will be available in the Emission Factor Data Base.

Tier 3 methods are based on actual flight movement data, either: for Tier 3A origin and destination (OD) data or for Tier 3B full flight trajectory information. Tier 3A takes into account cruise emissions for different flight distances. Details on the origin (departure) and destination (arrival) airports and aircraft type are needed to use Tier 3A, for both domestic and international flights. In Tier 3A, inventories are modelled using average fuel consumption and emissions data for the LTO phase and various cruise phase lengths, for an array of representative aircraft categories. The data used in Tier 3A methodology takes into account that the amount of emissions generated varies between phases of flight. The methodology also takes into account that fuel burnt is related to flight distance, while recognizing that fuel burn can be comparably higher on relatively short distances than on longer routes. This is because aircraft use a higher amount of fuel per distance for the LTO cycle compared to the cruise phase. The EMEP/CORINAIR Emission inventory guidebook (EEA 2002) provides an example of Tier 3A method for calculating emissions from aircraft. The EMEP/CORINAIR Emission inventory guidebook is continually being refined and is published electronically via the European Environment Agency Internet web site[4]. EMEP/CORINAIR provides tables with emissions per flight distance. Tier 3B methodology is distinguished from Tier 3A by the calculation of fuel burnt and emissions throughout the full trajectory of each flight segment using aircraft and engine-specific aerodynamic performance information. To use Tier 3B, sophisticated computer models are required to address all the equipment, performance and trajectory variables and calculations for all flights in a given year. Tier 3A emission factors may be found in the EMEP/CORINAIR emission inventory guidebook, while Tier 3B uses emissions factors contained within the models necessary to employ this methodology. Inventory compilers should check that these emission factors are in fact appropriate.

2.1.3.2. Waste

Typically, CH_4 emissions from Solid Waste Disposal Sites are the largest source of greenhouse gas emissions in the Waste Sector. CH_4 emissions from wastewater treatment and discharge may also be important. Incineration and open burning of waste containing fossil carbon, e.g. plastics, are the most important sources of CO_2 emissions in the Waste Sector.

The starting point for the estimation of greenhouse gas emissions from solid waste disposal, biological treatment and incineration and open burning of solid waste is the compilation of activity data on waste generation, composition and management. Solid waste is generated from households, offices, shops, markets, restaurants, public institutions, industrial installations, water works and sewage facilities, construction and demolition sites, and agricultural activities: in this report only waste generating activities linkable to office sector are considered.

It is good practice that countries use data on country-specific MSW generation, composition and management practices as the basis for their emission estimation. Country-specific data on MSW generation and management practices can be obtained from waste statistics, surveys (municipal or other relevant administration, waste management companies, waste association organizations, other) and research projects (World Bank, OECD, ADB, JICA, U.S.EPA, IIASA, EEA, etc.). Large countries with differences in waste generation and treatment within the domestic regions are encouraged to use data from these regions to the extent possible. MSW treatment techniques are often applied in a chain or in parallel. A more accurate but data intensive approach to data collection is to follow the streams of waste from one treatment to another taking into account the changes in composition and other parameters that affect emissions. Waste composition is one of the main factors influencing emissions from solid waste treatment, as different waste types contain different amount of degradable organic carbon (DOC) and fossil carbon. Waste compositions,

[4] http://www.eea.europa.eu/

as well as the classifications used to collect data on waste composition in MSW vary widely in different regions and countries. In this report, default data on waste composition in MSW are provided for the following waste types: food waste, garden (yard) and park waste, paper and cardboard, wood, textiles, nappies (disposable diapers), rubber and leather, plastics, metal, glass (and pottery and china), other (e.g., ash, dirt, dust, soil, electronic waste). Default values for DOC and fossil carbon content in different waste types is given in Table 9. All fractions in the Table are given as percentages.

Table 9: default dry matter content, DOC content, total carbon content and fossil fraction of different MSW components (IPCC, 2006)

MSW component	Dry matter content in % of wet weight [1]	DOC content in % of wet waste		DOC content in % of dry waste		Total carbon content in % of dry weight		Fossil carbon fraction in % of total carbon	
	Default	Default	Range	Default	Range [2]	Default	Range	Default	Range
Paper/cardboard	90	40	36 - 45	44	40 - 50	46	42 - 50	1	0 - 5
Textiles [3]	80	24	20 - 40	30	25 - 50	50	25 - 50	20	0 - 50
Food waste	40	15	8 - 20	38	20 - 50	38	20 - 50	-	-
Wood	85 [4]	43	39 - 46	50	46 - 54	50	46 - 54	-	-
Garden and Park waste	40	20	18 - 22	49	45 - 55	49	45 - 55	0	0
Nappies	40	24	18 - 32	60	44 - 80	70	54 - 90	10	10
Rubber and Leather	84	(39) [5]	(39) [5]	(47) [5]	(47) [5]	67	67	20	20
Plastics	100	-	-	-	-	75	67 - 85	100	95 - 100
Metal [6]	100	-	-	-	-	NA	NA	NA	NA
Glass [6]	100	-	-	-	-	NA	NA	NA	NA
Other, inert waste	90	-	-	-	-	3	0 - 5	100	50 - 100

[1] The moisture content given here applies to the specific waste types before they enter the collection and treatment. In samples taken from collected waste or from e.g., SWDS the moisture content of each waste type will vary by moisture of co-existing waste and weather during handling.

[2] The range refers to the minimum and maximum data reported by Dehoust *et al.*, 2002; Gangdonggu, 1997; Guendehou, 2004; JESC, 2001; Jager and Blok, 1993; Würdinger *et al.*, 1997; and Zeschmar-Lahl, 2002.

[3] 40 percent of textile are assumed to be synthetic (default). Expert judgement by the authors.

[4] This value is for wood products at the end of life. Typical dry matter content of wood at the time of harvest (that is for garden and park waste) is 40 percent. Expert judgement by the authors.

[5] Natural rubbers would likely not degrade under anaerobic condition at SWDS (Tsuchii et al., 1985; Rose and Steinbüchel, 2005).

[6] Metal and glass contain some carbon of fossil origin. Combustion of significant amounts of glass or metal is not common.

2.1.3.2.1. Solid waste disposal

Treatment and disposal of municipal, industrial and other solid waste produce significant amounts of methane (CH_4). In addition to CH_4, solid waste disposal sites (SWDS) also produce biogenic carbon dioxide (CO_2) and non-methane volatile organic compounds (NMVOCs). CH_4 produced at SWDS contributes approximately 3 to 4 percent to the annual global anthropogenic greenhouse gas emissions (IPCC, 2001). In many industrialized countries, waste management has changed much over the last decade. Waste minimization and recycling/reuse policies have been introduced to reduce the amount of waste generated, and increasingly, alternative waste management practices to solid waste disposal on land have been implemented to reduce the environmental impacts of waste management. Also, landfill gas recovery has become more common as a measure to reduce CH_4 emissions from SWDS. Decomposition of organic material derived from biomass sources (e.g., crops, wood) is the primary source of CO_2 released from waste.

2.1.3.2.2. Biological treatment of solid waste

Composting and anaerobic digestion of organic waste, such as food waste, garden (yard) and park waste and sludge, is common both in developed and developing countries. Advantages of the biological treatment include: reduced volume in the waste material, stabilization of the waste, destruction of pathogens in the waste material, and production of biogas for energy use. The end products of the biological treatment can, depending on its quality, be recycled as fertilizer and soil amendment, or be disposed in SWDS. Anaerobic treatment is usually linked with methane (CH_4) recovery and combustion for energy, and thus the greenhouse gas emissions from the process should be reported in the Energy Sector.

Composting is an aerobic process and a large fraction of the degradable organic carbon (DOC) in the waste material is converted into carbon dioxide (CO_2). CH_4 is formed in anaerobic sections of the compost, but it is oxidized to a large extent in the aerobic sections of the compost. The estimated CH_4 released into the atmosphere ranges from less than 1 percent to a few per cent of the initial carbon content in the material (Beck-Friis, 2001; Detzel et al., 2003).

Anaerobic digestion of organic waste expedites the natural decomposition of organic material without oxygen by maintaining the temperature, moisture content and pH close to their optimum values. Generated CH_4 can be used to produce heat and/or electricity, wherefore reporting of emissions from the process is usually done in the Energy Sector. The CO_2 emissions are of biogenic origin, and should be reported only as an information item in the Energy Sector.

2.1.3.2.3. Incineration and open burning of waste

Waste incineration is defined as the combustion of solid and liquid waste in controlled incineration facilities. Emissions from waste incineration without energy recovery are reported in the Waste Sector, while emissions from incineration with energy recovery are reported in the Energy Sector.

Open burning of waste can be defined as the combustion of unwanted combustible materials such as paper, wood, plastics, textiles, rubber, waste oils and other debris in nature (open-air) or in open dumps, where smoke and other emissions are released directly into the air without passing through a chimney or stack. This waste management practice is used in many developing countries while in developed countries open burning of waste may either be strictly regulated, or otherwise occur more frequently in rural areas than in urban areas.

Incineration and open burning of waste are sources of greenhouse gas emissions, like other types of combustion. Relevant gases emitted include CO_2, methane (CH_4) and nitrous oxide (N_2O). Normally, emissions of CO_2 from waste incineration are more significant than CH_4 and N_2O emissions.

Consistent with the *1996 Guidelines* (IPCC, 1997), only CO_2 emissions resulting from oxidation, during incineration and open burning of carbon in waste of fossil origin (e.g., plastics, certain textiles, rubber, liquid solvents, and waste oil) are considered net emissions and should be included in the national CO_2 emissions estimate. The CO_2 emissions from combustion of biomass materials (e.g., paper, food, and wood waste) contained in the waste are biogenic emissions and should not be included in national total emission estimates._However, if incineration of waste is used for energy purposes, both fossil and biogenic CO_2 emissions should be estimated.

The methods for estimating CO_2, CH_4 and N_2O emissions from incineration and open burning of waste vary because of the different factors that influence emission levels. Estimation of the amount of fossil carbon in the waste burned is the most important factor determining the CO_2 emissions. The non-CO_2 emissions are more dependent on the technology and conditions during the incineration process.

The general approach to calculate greenhouse gas emissions from incineration and open burning of waste is to obtain the amount of dry weight of waste incinerated or open-burned (preferably differentiated by waste type) and to investigate the related greenhouse gas emission factors (preferably from country-specific information on the carbon content and the fossil carbon fraction). For CO_2 emissions from incineration and open burning of waste, the basic approach is given here as an example of a consecutive approach:

- Identify types of wastes incinerated/open-burned: MSW, sewage sludge, industrial solid waste, and other wastes (especially hazardous waste and clinical waste) incinerated/open-burned.
- Compile data on the amount of waste incinerated/open-burned including documentation on methods used and data sources (e.g., waste statistics, surveys, expert judgment). The default data should be used only when country-specific data are not available. For open burning, the amount of waste can be estimated based on demographic data.
- Use default values provided on dry matter content, total carbon content, fossil carbon fraction and oxidation factor for different types of wastes: for MSW, preferably identify the waste composition and calculate the respective dry matter content, total carbon content, and fossil carbon fraction using default data provided for each MSW component (plastic, paper, etc).
- Calculate the CO_2 emissions from incineration and open burning of solid wastes.

The Tier 1 method is a simple method used when CO_2 emissions from incineration/open burning are not a *key category*. The calculation of the CO_2 emissions is based on an estimate of the amount of waste (wet weight) incinerated or open-burned taking into account the dry matter content, the total carbon content, the fraction of fossil carbon and the oxidation factor. The method based on the total amount of waste combusted is outlined in the following equation

$$CO_2 \ emissions = (SW \cdot dm \cdot CF \cdot FCF \cdot OF) \cdot 44/12$$

where:

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

SW = total amount of solid waste of type i (wet weight) incinerated or open-burned, Gg/yr

dm = dry matter content in the waste (wet weight) incinerated or open-burned, (fraction)

CF = fraction of carbon in the dry matter (total carbon content), (fraction)

FCF = fraction of fossil carbon in the total carbon, (fraction)

OF = oxidation factor, (fraction)

44/12 = conversion factor from C to CO_2

For MSW, it is *good practice* to calculate the CO_2 emissions on the basis of waste types/material (such as paper, wood, plastics) in the waste incinerated or open-burned as shown in the following equation.

$$CO_2 \ emissions = MSW \cdot \Sigma_j (WF_j \cdot dm_j \cdot CF_j \cdot FCF_j \cdot OF_j) \cdot 44/12$$

where:

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

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

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

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

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

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

OF_j = oxidation factor, (fraction)

44/12 = conversion factor from C to CO_2

with: $\Sigma_j WF_j = 1$

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

It is preferable to apply the second equation for MSW, but if the required MSW data are not available, the first equation should be used instead. If CO_2 emissions from incineration and open burning of waste is a *key category*, it is *good practice* to apply a higher tier.

The Tier 2 method is based on country-specific data regarding waste generation, composition and management practices. Tier 2a requires the use of country-specific activity data on the waste composition and default data on other parameters for MSW. For other categories of waste, country-specific data on the amounts are required. Country-specific MSW composition, even if using default data on other parameters, will reduce uncertainties compared to the use of aggregated MSW statistics. Tier 2b requires country-specific data on the amount of waste incinerated/open-burned by waste type or MSW composition, dry matter content, carbon content, fossil carbon fraction and oxidation factor, in addition to country-specific waste composition data. If these data are available, an estimate according to Tier 2b will have lower uncertainty than Tier 2a.

The Tier 3 method utilizes plant-specific data to estimate CO_2 emissions from waste incineration. It is *good practice* at this tier level to consider parameters affecting both the fossil carbon content and the oxidation factor. Factors affecting the oxidation factor include:

- type of installation/technology: fixed bed, stoker, fluidized bed, kiln,
- operation mode: continuous, semi-continuous, batch type,
- size of the installation,
- parameters such as the carbon content in the ash.

The total fossil CO_2 emissions from waste incineration are calculated as the sum of all plant-specific fossil CO_2 emissions. It is good practice to include all waste types and the entire amount incinerated as well as all types of incinerators in the inventory.
Table 10 gives an overview on Tier levels at which default values or country-specific data are to be applied for calculating CO_2 emissions.

Table 10: overview of data sources of different tier levels

	Total waste amount (W)	Waste fraction (WF)*	Dry matter content (dm)	Carbon fraction (CF)	Fossil carbon fraction (FCF)	Oxidation factor (OF)
Tier 1	default / country-	default	default	default	default	default
Tier 2a	country-specific	country-specific	default	default	default	default
Tier 2b	country-specific	country-specific	country-specific	country-specific	default / country-specific	default / country-specific
Tier 3	plant- / management specific	plant- / management specific	plant- / management specific	plant- / management specific	plant- / management specific	plant- / management specific
**% of each component mainly for MSW*						

Choice of activity data

General guidance for activity data collection for solid waste treatment and disposal as well as default values on waste generation, management practices and composition are given previously. Activity data needed in the context of incineration and open burning of waste includes the amount of waste incinerated or open-burned, the related waste fractions (composition) and the dry matter content. As the type of waste combusted and the applied management practice are relevant for the CO_2, CH_4 and N_2O emissions, the choice of activity data section is outlined according to the common factors related to activity data and not separately for each of the emitted gases. In addition, the waste composition is particularly relevant for the CO_2 emissions.

In developing countries, basic data on amount of waste and treatment practices may not be available. Waste incineration in some developing countries is likely to take place only in minor quantities. Therefore, emissions from open burning of waste should be considered in detail, while emissions from incineration should also be quantified if expected to be relevant.

Obtaining data on the **amount of waste incinerated** is a prerequisite for preparing an emission inventory for incineration of waste. Many countries that use waste incineration should have plant-specific data on the amount of MSW and other types of waste incinerated.

The **amount of waste open-burned** is the most important activity data required for estimating emissions from open burning of waste.

Equation below can be used to estimate the total amount of MSW open-burned.

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

where:

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

P = population (capita)

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

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

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

365 = number of days by year
10^{-6} = conversion factor from kilogram to gigagram

Open burning includes regularly burning and sporadically burning. In a developing country, mainly in urban areas, P_{frac} can be roughly estimated as being the sum of population whose waste is not collected by collection structures and population whose waste is collected and disposed in open dumps that are burned. In general, it is preferable to apply country- and regional-specific data on waste handling practices and waste streams.

B_{frac} means the fraction of waste for which carbon content is converted to CO2 and other gases. When all the amount of waste is burned B_{frac} could be considered equal to 1. However, in some cases, mainly when a substantial quantity of waste in open dumps is burned, a relatively large part of waste is left unburned (in open dumps the fraction not compacted often burns). In this situation B_{frac} should be estimated using survey or research data available.

An important distinction needs to be made between dry weight and wet weight of waste, because the water content of waste can be substantial. Therefore, the dry matter content of the waste or waste fraction is an important parameter to be determined.

The weight of waste incinerated should be converted from wet weight to dry weight, if the related emission factors refer to dry weight. The dry matter content of waste can range from below 50 percent in countries with a higher percentage of food waste to 60 percent in countries with higher fractions of paper-based and fossil carbon-based wastes.

Table in Appendix provides default data on dry matter content for different waste types/material that can be used to estimate dry matter content in MSW, according to the following equation.

$dm = \Sigma_i (WF_i \cdot dm_i)$

where:

dm = total dry matter content in the MSW
WF_i = fraction of component i in the MSW
dm_i = dry matter content in the component i.

Choice of emission factors

Emission factors in the context of incineration and open burning of waste relate the amount of greenhouse gas emitted to the weight of waste incinerated or open-burned. In the case of CO_2, this applies data on the fractions of carbon and fossil carbon in the waste.

It is generally more practical to estimate CO_2 emissions from incineration and open burning of waste using calculations based on the carbon content in the waste, instead of measuring the CO_2 concentration. Default values for oxidation factor in % of carbon input are 100 for incineration practice and 58 for open-burning[5]. Each of these factors is discussed in detail below.

While a fraction of the carbon in waste incinerated or open-burned is derived from biomass raw materials (e.g., paper, and food waste), part of the total carbon is plastics or other products made from fossil fuel. The **total carbon content** in MSW can be estimated by means of the equation below.

$CF = \Sigma_i (WF_i \cdot CF_i)$

where:

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[5] When waste is open-burned, refuse weight is reduced by approximately 49 to 67 percent (US-EPA, 1997, p.79). A default value of 58 percent is suggested.

CF = total carbon content in MSW
WF_i = fraction of component i in the MSW
CF_i = carbon content in the waste type/material *i* in MSW

In estimating emissions from incineration and open burning of waste, the desired approach is to separate carbon in the waste into biomass and fossil fuel based fractions. For the purposes of calculating anthropogenic CO_2 emissions from incineration and open burning of waste, the amount of fossil carbon in the waste should be determined. The **fraction of fossil carbon** will differ for different waste categories and types of waste. The carbon in MSW and clinical waste is of both biogenic and fossil origin. Default data for these waste categories and different waste types/materials included in MSW are provided in Table in Appendix.
Where plant-specific data are available, the exact composition of the waste being incinerated should be collected and used in CO_2 emission calculations. If such data are not readily available, country-specific data may be used. Different fossil fuel-based waste products will contain different percentages of fossil carbon. For each waste stream, an analysis should be performed for each waste type. In general, plastics will represent the waste type being incinerated with the highest fossil carbon fraction. In addition, the fossil carbon content of toxics, synthetic fibres and synthetic rubbers is particularly relevant. A certain amount of tire waste is also considered as source of fossil carbon, since tires can be composed of synthetic rubbers or carbon black. If neither plant-specific waste types nor country-specific waste stream information are available, default fossil carbon fractions should be used for the most relevant waste fractions in MSW.

It is *good practice*, under Tier 2a, that inventory compilers use country-specific data on composition of MSW and default values provided previously, to estimate fossil carbon fraction (FCF) in MSW using the equation below.
$FCF = \Sigma_i (WF_i \cdot FCF_i)$
where:
FCF = total fossil carbon in the MSW
WF_i = fraction of waste type i in the MSW
FCF_i = fraction of fossil carbon in the waste type *i* of the MSW

When waste streams are incinerated or open-burned most of the carbon in the combustion product oxidises to CO2. A minor fraction may oxidise incompletely due to inefficiencies in the combustion process, which leave some of the carbon unburned or partly oxidised as soot or ash. For waste incinerators it is assumed that the combustion efficiencies are close to 100 percent, while the combustion efficiency of open burning is substantially lower. If **oxidation factors** of waste incineration below 100 percent are applied, these need to be documented in detail with the data source provided. If the CO_2 emissions are determined on a technology- or plant-specific basis in the country, it is *good practice* to use the amount of ash (both bottom ash and fly ash) as well as the carbon content in the ash as a basis for determining the oxidation factor.

Emission factor uncertainties

There is a high level of uncertainty related to the separation of biogenic and fossil carbon fractions in the waste. This uncertainty is mainly related to the uncertainties in waste composition. The major uncertainty associated with CO_2 emissions estimate is related to the estimation of the fossil carbon fraction.
Uncertainties associated with CO_2 emission factors for open burning depend on uncertainties related to fraction of dry matter in waste open-burned, fraction of carbon in the dry matter, fraction of fossil carbon

in the total carbon, combustion efficiency, and fraction of carbon oxidised and emitted as CO2. A default value of ± 40 percent is proposed for countries relying on default data on the composition in their calculations.

2.2.Data for a single organization inventory

Because IPCC methodology is addressed for the compliance of national inventories, it is often not suitable for the calculation of CO_2 emissions by a single organization: certain data are likely not easy to be found or to be charged totally to the organization (for example flights shared with other passengers or fuel consumption for the production of electricity at the power plant). This section suggests alternative methods for a variety of direct and indirect emissions sources common to offices.

The first step is to set the “organizational boundary” for the inventory. This means deciding which spaces, facilities, or entities will be part of the inventory. The more inclusive the boundary, the more opportunities are likely to find to reduce emissions. Second, all the ways operations generate emissions must be considered (e.g. through business travel, heating, cooling, or employee commuting). This is called setting the “operational boundary” for the inventory. To determine operational boundary, two categories of greenhouse gas emissions—“direct” emissions and “indirect” emissions— are considered.

Direct Emissions

These are emissions from sources that are owned or directly controlled, like a boiler in the basement of the office building, or business travel in a company car. If the organization leases vehicles or equipment and pays for the fuel used, these emissions are also counted as direct emissions for your organization, even though it does not own the vehicle or equipment. For reporting purposes, direct emissions are called “Scope 1” emissions.

Indirect Emissions

These emissions are consequences of the organization’s activities but occur from sources owned or controlled by another organization. For reporting purposes, indirect emissions are divided into “Scope 2” emissions—those from the generation of purchased electricity, steam, or heat—and “Scope 3” emissions—a label which covers everything else. Accounting for and reporting on Scope 2 emissions is required under the GHG Protocol[6] because these are likely to make up a significant percentage of any organization’s inventory and are relatively easy to quantify. Accounting for and reporting on relevant Scope 3 emissions is not mandatory in the GHG Protocol but is encouraged because it increases emissions reduction opportunities.

Deciding what to report

Deciding which emissions sources to include in your operational boundary requires careful thought. For example, if you include business travel in your boundary, you must decide if you will include only the business travel undertaken by your staff, or also business travel by consultants, partners, or other non-

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[6] The Greenhouse Gas Protocol (GHG Protocol) is the most widely used international accounting tool for government and business leaders to understand, quantify, and manage greenhouse gas emissions. The GHG Protocol, a decade-long partnership between the World Resources Institute and the World Business Council for Sustainable Development, is working with businesses, governments, and environmental groups around the world to build a new generation of credible and effective programs for tackling climate change.
It provides the accounting framework for nearly every GHG standard and program in the world - from the International Standards Organization to The Climate Registry - as well as hundreds of GHG inventories prepared by individual companies. The GHG Protocol also offers developing countries an internationally accepted management tool to help their businesses to compete in the global marketplace and their governments to make informed decisions about climate change.

employee colleagues with whom you work. Reporting on emissions from non-employee travel requires more record keeping by your organization's staff—the people whose projects generate the trips by those outside parties—and, occasionally, the cooperation of your partners and consultants to help you track the emissions they generated working for or with your organization. Of course, tracking all the travel-related emissions you're generating as a result of your organization's business—directly and indirectly—makes your inventory more complete. Sometimes the best choice is a manageable middle ground.
Whether to include emissions generated by employees commuting to work is another example of a difficult operational boundary decision. Some employees consider their commuting arrangements to be a matter of personal privacy and fear they'll be pressured to give up their SUV, ride the bus, or join a carpool. However, organizations that choose to include employee commuting in their inventory will create an additional opportunity for achieving emissions reductions and the employees can reap some benefits too, even beyond awareness of their impact. Businesses that have a large proportion of their CO_2 emissions generated by employee commutes may choose to move their offices closer to mass transportation options, or opt to implement a telework or rideshare program (less dramatic but very useful alternatives from an employee perspective). Some businesses offer incentive programs to encourage employees to use mass transit or carpooling, which benefits employees financially and can be implemented in a nonjudgmental way. In general, you may find it simpler to draw narrow boundaries. However, a more comprehensive inventory provides greater opportunities for emissions reductions. Let the GHG Protocol accounting principles guide your decisions on what to include in your inventory. In other words, obtain the most accurate, complete, and relevant data possible and be transparent and consistent in your choices.

As shown in the IPCC guidelines methodology two kinds of data are needed to calculate CO_2 emissions. For each emissions source identified in the previous step, the appropriate "activity data" and "emissions factor" need to be found to apply the following equation:

activity data · emissions factor = GHG emissions

2.2.1. Activity data

This quantifies an activity in units that will help calculate the emissions generated. Each activity is presented in a specific unit, for example:

- terms or cubic meters of natural gas
- gallons or litres of heating oil
- kilowatt hours of electricity
- business air miles or kilometres travelled
- business train miles or kilometres travelled

A simple, efficient method of capturing the data on a regular basis must be developed: one approach is to centralize a system through the Accounting Department of the organization in exam.

2.2.1.1. Activity Data for Direct Emissions

Direct emissions occur from organization-owned vehicles or from combustion of fossil fuels such as natural gas, heating oil, coal, fuel oil, diesel, etc. in company-owned equipment. Emissions are a result of the combustion of these fuels. Here's how you would gather activity data—in this case fuel usage—for combustion of natural gas or heating oil and travel by corporate jet:

- Figure out what units you should be using in your calculations. For natural gas, the common units are terms, cubic meters, or cubic feet. For heating oil, the units are gallons or litres. For travel in a company-owned jet, the relevant units are gallons or litres of jet fuel.

- Obtain the activity data in the appropriate units from your organization's monthly fuel-use records, or convert the data in your organization's records to the appropriate unit.

2.2.1.2. Activity Data for Indirect Emissions from purchased Electricity

When coal, gas, and other fossil fuels are combusted to generate electricity, CO_2 and other GHGs are emitted. The emissions take place at the point of combustion (the power plant), not at the location the electricity is used, like your office. However, you share responsibility because you generated the demand and used the power. On the other hand, if you use non-fossil fuel-based energy, such as wind and solar power, you are not responsible for any CO_2 emissions, because none are generated. The activity data you need to calculate the CO_2 emissions generated by your office's electricity use is kilowatt hours (kWh).

If your organization owns and occupies the entire building, or if your utilities are separately metered, all the information you need can be obtained from your monthly electric bill.

If your organization does not occupy the whole building or if it occupies leased office space, you will need to estimate your electricity use based on information from your property manager:

- total area of the building
- total area occupied by your organization
- total building energy use in kWh

Using this information and the following formula, you can estimate the approximate kWh of electricity attributable to your organization:

(area of organization's space ÷ total building area) × total building usage of electricity = approximate kWh used by your organization

Also the percentage of losses in the net should be integrated in the total amount consumed by the user: such data can be supplied by the local electricity provider or from average national database published by the International Energy Agency.

2.2.1.3. Activity Data for Other Indirect Emissions

A variety of emissions fall under this category. We describe methods of collecting activity data for business travel in non-company-owned vehicles (car, plane, and train) and employee commuting.

2.2.1.3.1. Business Travel in Non-Company-Owned Vehicles

a) Car travel

The activity data required for calculating emissions from car travel include:

- Total fuel use in gallons or litres
- Type of fuel (e.g., gasoline or diesel)
- Number of occupants if non-company staff are in the vehicle. The goal is to calculate the amount of fuel attributed to the organization's employees, so if all occupants are employees of the organization, this data won't be needed. If some are non-company staff, the share of emissions attributable to the office's staff has to be calculated.

There are two ways to obtain fuel-use data. The most accurate and simple method is to obtain the data from fuel purchase receipts. If you do not have access to fuel purchase receipts, estimate fuel use using the following:

- Total distance travelled
- Average fuel efficiency of the vehicle

- Number of occupants if non-company staff are in the vehicle

The calculation to estimate fuel used is:

distance travelled ÷ fuel efficiency ÷ number of occupants = approximate fuel use per occupant

If the fuel efficiency of the vehicle is unknown, emissions can be calculated using distance travelled activity data and an emissions factor that assumes a default fuel efficiency value for the size of car. This is a less accurate method. If an employee uses his/her own car for business travel, distance travelled will usually be indicated on the form submitted for reimbursement of travel expenses. If a rental car is used, information on distance travelled and type of car can often be obtained from the receipt.

b) Air Travel

The activity data needed to determine for commercial air travel is distance travelled. The units are either miles or kilometres. This information can sometimes be found on flight itineraries. If you are unable to determine actual distance travelled, refer to a guide or website[7]. A large portion of CO_2 emissions from air travel occur during takeoff and landing. Therefore, emissions per mile or kilometre travelled for short flights are higher than emissions for long flights. Ideally, you should implement a tracking system to distinguish domestic, short, and long flights, since different emissions factors apply for each.

c) *Train Travel*

Activity data for train travel is distance travelled, measured in either miles or kilometres. This information is collected in the same way as air travel—that is, check with your in-house travel staff or your organization's travel agent, refer to an on-line distance guide, and/or add a question to your organization's travel authorization or travel reimbursement forms that requests the information from the employee. As with air travel, make sure the distance includes round trip miles or kilometres travelled.

2.2.1.3.2. Employee Commuting in Non-Company Owned Vehicles

To calculate commuting emissions, you will need to obtain activity data on the distance employees travel to and from work and the mode of transportation they use. For relatively small organizations, you may be able to obtain this information from each employee. For larger organizations, it may be more efficient to take a sample and estimate total activity data from it. Using a sample will lead to a less accurate estimate of emissions, so make the sample as large as possible. The activity data for employee commuting is described below. For each employee in your organization or survey group, gather the following information:

- Round trip distance travelled by employee to work and home each day
- Number of days per week employee commutes
- If the employee drives to work on any day, the fuel efficiency of the employee's vehicle, fuel type, and the number of people who travel with the employee
- Distance travelled by the employee in various commuting combinations.

Once you have collected this information, use the following method to estimate annual activity data for each mode of transport, except cars:

number of days per week vehicle is used x distance travelled x number of weeks worked by the organization per year = total annual distance travelled by survey group for each mode of transport

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[7] For instance, http://www.indo.com/cgi-bin/dist or http://www.chooseclimate.org/flying/mf.html

d) Car Travel

Employees are unlikely to use their cars exclusively for commuting, so obtaining fuel use activity data from fuel purchase receipts is not usually possible. Instead, use a three-step calculation to estimate fuel

# of days used per week × distance travelled × number of weeks worked by the organization per year = total annual distance travelled by employee

total annual distance travelled by employee ÷ fuel economy of employee's car = approximate fuel used

approximate fuel use ÷ number of people in car = approximate fuel use attributable to employee

Add the total quantity of fuel used by each employee who drives to work to obtain the total fuel use for all employees.

2.2.2. Emissions factors

Emissions factors convert activity data to emissions values. Emissions factors are published by various entities such as local, state, or national government agencies and intergovernmental agencies. Emissions factors are source-specific. For example, the emissions factors for electricity produced by coal will be higher than for electricity produced by natural gas. Similarly, emissions factors for car travel vary depending on if the car is powered by gasoline, diesel fuel, or electricity, and on how efficiently the car uses fuel. Most relevant emissions factor available must be selected for each of the activities defined. Emissions factors are frequently updated to reflect new information or technologies. Using the most up to-date emissions factor available is strongly recommended to obtain an high quality inventory.

2.2.2.1. Fuel consumption

Emission factor for fuel combustion have been already presented in paragraph 2.1.3.1.1; national specific factor should be gathered at local fuel delivery companies. Otherwise, Table 11 sums up the emission factors for most common fuel types (IPCC, 2006).

Table 11: default CO_2 emission factors and uncertainty ranges for most common fuel types (IPCC guidelines, 2006)

Fuel type	Emission factor			Net Calorific Value		
	Default (kg/TJ)	Lower	Upper	Default (TJ/Gg)	Lower	Upper
Motor Gasoline	69 300	67 500	73 000	44,3	42,5	44,8
Gas/ Diesel Oil	74 100	72 600	74 800	43,0	41,4	43,3
Liquefied Petroleum Gases	63 100	61 600	65 600	47,3	44,8	52,2
Kerosene	71 900	70 800	73 700	43,8	42,4	45,2
Lubricants	73 300	71 900	75 200	40,2	33,5	41,2
Compressed Natural Gas	56 100	54 300	58 300	48,0	46,5	50,4
Liquefied Natural Gas	56 100	54 300	58 300	48,0	46,5	50,4

In alternative, emission factor referring to unit of fuel used should be gathered. For instance, DEFRA (2009) provides the emission factor reported in Table 12 for UK.

Table 12: converting from fuel use to carbon dioxide equivalent on a Net CV basis (DEFRA, 2009)

		CO_2	CH_4	NO_2	Total GHGs
Fuel Type	Units	kg CO_2 per unit	kg CO_2eq per unit	kg CO_2eq per unit	kg CO_2eq per unit
Burning Oil	tonnes	3149,7	6,7	8,6	3164,9
	kWh	0,25847	0,00055	0,00071	0,25972
	litres	2,5319	0,0054	0,0069	2,5442
Diesel	tonnes	3164,3	2,3	34,0	3200,6
	kWh	0,26328	0,00019	0,00283	0,26630
	litres	2,6391	0,0019	0,0283	2,6694
Fuel Oil	tonnes	3215,9	2,4	11,2	3229,5
	kWh	0,27927	0,00021	0,00097	0,28045
Gas Oil	tonnes	3190,0	3,3	305,1	3498,4
	kWh	0,26542	0,00027	0,02539	0,29108
	litres	2,7619	0,0028	0,2642	3,0289
LPG	kWh	0,22546	0,00009	0,00017	0,22572
	therms	6,6077	0,0026	0,0049	6,6153
	litres	1,4951	0,0006	0,0011	1,4968
Lubricants	tonnes	3171,1	1,9	8,5	3181,5
	kWh	0,27537	0,00017	0,00074	0,27628
Naphtha	tonnes	3131,3	2,9	8,0	3142,2
	kWh	0,24989	0,00023	0,00064	0,25076
Natural Gas	kWh	0,20374	0,00031	0,00012	0,20417
	cubic metre	2,0091	0,0030	0,0012	2,0133
	therms	5,9712	0,0090	0,0036	5,9837
Petrol	tonnes	3135,0	6,4	30,7	3172,1
	kWh	0,25238	0,00052	0,00247	0,25537
	litres	2,3035	0,0047	0,0226	2,3307

2.2.2.2. Electricity

Emissions factors for electricity vary depending on the fuel used to generate the electricity and the technologies employed by the power plant. You can obtain the most accurate emissions factor directly from your electric company. Several national bodies provide a specific database of emission information for power plants around the country If an emissions factor is not available for your provider, use a published emissions factor for your state, province, or region. This may be available from your national government agency in charge of energy. The last (and least accurate) choice is to use a national average emissions factor for your country; this can be obtained from the International Energy Agency[8]. Table 13 reports electricity emission factors for CO_2 in several Sub-Saharan Countries, according to fuel employed.

[8] http://www.iea.org/

Table 13: African Countries Electricity Emission Factors for CO2 (International Energy Agency9, 2007)

grammes CO_2 / kilowatt hour

	1990	1995	1999	2000	2001	2002	2003	2004	2005	2006	2007	Average 05-07
Non-OECD Total	..	**473**	**513**	**512**	**511**	**519**	**536**	**552**	**555**	**564**	**564**	**561**
Algeria	..	633	627	620	621	632	632	632	606	621	597	608
Angola	..	177	341	382	381	354	373	216	154	98	153	135
Benin	..	951	659	601	955	950	752	740	709	696	694	700
Botswana	..	1 800	1 575	1 876	1 318	1 323	1 320	1 739	1 851	1 851	1 852	1 852
Cameroon	..	10	11	10	16	27	31	28	40	83	301	141
Congo	..	9	114	-	-	-	82	97	103	102	102	102
Dem. Rep. of Congo	..	4	4	4	4	4	3	3	3	3	3	3
Côte d'Ivoire	..	275	414	379	394	409	384	356	457	385	368	403
Egypt	..	443	455	412	381	437	432	473	474	473	450	466
Eritrea	..	1 463	700	713	749	659	694	722	677	690	666	678
Ethiopia	..	42	10	11	9	8	6	6	3	3	36	14
Gabon	..	255	326	326	272	282	306	329	390	365	446	400
Ghana	..	3	187	68	115	255	277	84	147	276	360	261
Kenya	..	72	412	562	392	265	196	274	301	312	305	306
Libyan Arab Jamahiriya	..	1 131	1 056	1 022	996	971	978	888	907	879	846	877
Morocco	..	869	758	770	764	766	737	756	728	713	712	718
Mozambique	..	64	3	5	4	3	3	3	1	1	1	1
Namibia	..	37	30	5	6	-	13	1	29	95	100	74
Nigeria	..	292	350	407	340	354	340	400	383	386	413	394
Senegal	..	881	908	782	799	645	520	555	634	726	713	691
South Africa	..	878	890	893	829	819	849	871	852	832	845	843
Sudan	..	465	428	508	481	592	662	690	509	512	516	512
United Rep. of Tanzania	..	284	126	192	70	57	51	121	361	431	248	347
Togo	..	185	399	561	1 493	333	216	442	352	459	404	405
Tunisia	..	588	598	574	584	564	554	532	476	546	557	526
Zambia	..	7	7	7	7	7	7	7	7	7	7	7
Zimbabwe	..	920	812	740	848	717	515	572	572	573	573	573
Other Africa	..	413	431	480	586	594	598	592	594	646	646	629
Africa	..	**684**	**677**	**665**	**622**	**624**	**637**	**651**	**636**	**628**	**627**	**630**

2.2.2.3. Road transportation

Car travel emissions factors are based on fuel use. Table 14 reports CO_2 emission factors by fuel type according to DEFRA (2009): such factors are calculated on the basis of net calorific value. Similar factor are provided also by DEFRA (2009) for UK.

Table 14: standard road transport fuel emission factors (DEFRA, 2009)

Fuel used	Units	CO_2 kg CO_2 per unit	CH_4 kg CO_2eq per unit	NO_2 kg CO_2eq per unit	Total GHGs kg CO_2eq per unit
Petrol	litres	2,3035	0,00470	0,02260	2,33070
Diesel	litres	2,6391	0,00190	0,02830	2,66940
Compressed Natural Gas (CNG)	kg	2,7278	0,00415	0,00161	2,73356
Liquid Petroleum Gas (LPG)	litres	1,4951	0,00060	0,00110	1,49680

If it is not possible to gather data about total fuel use in gallons or litres, fuel efficiency must be estimated: refer to a guide such as the one available for USA from the EPA at http://www.epa.gov/autoemissions. Note that fuel efficiencies for cars vary depending on highway versus city travel. If the trip is a combination of both, use the average of the two to determine the car's approximate fuel efficiency. If you do not have a guide in your country to reference, then use an emissions factor that incorporates default fuel efficiency values based on the size of car. Table 15 reports emission factors (on distance basis) proposed by UK DEFRA (2009).

[9] http://data.iea.org/ieastore/product.asp?dept_id=101&pf_id=305

Table 15: UK vehicle transport emission factors (on distance basis) for CO_2 (UK DEFRA, 2009)

Petrol Cars		**CO_2**	**CH_4**	**N_2O**	**Total GHG**
Size of car	Units	kg CO_2 per unit	kg CO_2eq per unit	kg CO_2eq per unit	kg CO_2eq per unit
Small petrol car, up to 1.4 litre engine	miles	0,28944	0,00050	0,00296	0,29290
	km	0,17985	0,00031	0,00184	0,18200
Medium petrol car, from 1.4 - 2.0 litres	miles	0,34246	0,00048	0,00296	0,34590
	km	0,21280	0,00030	0,00184	0,21493
Large petrol cars, above 2.0 litres	miles	0,47555	0,00045	0,00296	0,47897
	km	0,29549	0,00028	0,00184	0,29762
Average petrol car	miles	0,33100	0,00049	0,00296	0,33445
	km	0,20567	0,00030	0,00184	0,20781
Diesel Cars		**CO_2**	**CH_4**	**N_2O**	**Total GHG**
Size of car	Units	kg CO_2 per unit	kg CO_2eq per unit	kg CO_2eq per unit	kg CO_2eq per unit
Small diesel car, up to 1.7 litre or under	miles	0,24293	0,00013	0,00280	0,24586
	km	0,15095	0,00008	0,00174	0,15277
Medium diesel car, from 1.7 to 2.0 litre	miles	0,30187	0,00013	0,00280	0,30480
	km	0,18757	0,00008	0,00174	0,18939
Large diesel car, over 2.0 litre	miles	0,41167	0,00013	0,00280	0,41460
	km	0,25580	0,00008	0,00174	0,25762
Average diesel car	miles	0,31627	0,00013	0,00280	0,31921
	km	0,19652	0,00008	0,00174	0,19835
Alternative Fuel Cars		**CO_2**	**CH_4**	**N_2O**	**Total GHG**
Type of alternative fuel car	Units	kg CO_2 per unit	kg CO_2eq per unit	kg CO_2eq per unit	kg CO_2eq per unit
Medium petrol hybrid car	miles	0,20309	0,00028	0,00296	0,20634
	km	0,12620	0,00018	0,00184	0,12821
Large petrol hybrid car	miles	0,36042	0,00034	0,00296	0,36372
	km	0,22395	0,00021	0,00184	0,22601
Medium LPG or CNG car	miles	0,29966	0,00048	0,00296	0,30310
	km	0,18620	0,00030	0,00184	0,18834
Large LPG or CNG car	miles	0,41611	0,00045	0,00296	0,41952
	km	0,25856	0,00028	0,00184	0,26068
Average LPG or CNG car	miles	0,35788	0,00049	0,00296	0,36133
	km	0,22238	0,00030	0,00184	0,22452

These emissions factors may be expressed in vehicle miles or kilometres, or passenger miles or kilometres. An emissions factor for vehicle miles or kilometres is used to calculate emissions if there is only one occupant in the vehicle. A passenger miles or kilometres emissions factor is used to calculate emissions if there is more than one occupant in the vehicle (and therefore fewer per-person emissions). It is also acceptable to divide the distance travelled by the number of occupants and then use a vehicle miles or kilometres emissions factor to complete the calculation.

2.2.2.4. Train, Light Rail, and Bus Travel

These emissions are measured in CO_2 per passenger mile or kilometre. The emissions factor assumes an average level of occupancy. Table 16 reports emission factors for public transport in UK and USA.

Table 16: UK and US public transport emission factors for CO_2 per passenger(UK DEFRA, 2008 and US EPA, 2008)

		UK Defra emission factors		US EPA emission factors	
		kg CO_2/ km	kg CO_2/ km	kg CO_2/ km	kg CO_2/ km
Taxis		0,1613	0,259587187	0,142915374	0,23
Buses	Local bus	0,1073	0,172682611	0,066486718	0,107
	Coach	0,029	0,046670976	0,066486718	0,107
	Default	0,0686	0,110400998	0,066486718	0,107
Trains	Light rail	0,09735	0,156669638	0,101283504	0,163
	Tram	0,04205	0,067672915	0,101283504	0,163
	Average	0,078	0,125528832	0,101283504	0,163
	National rail	0,0602	0,096882509	0,114953671	0,185
	Subways	0,065	0,10460736	0,101283504	0,163
Large RoPax ferry		0,1152	0,185396429	Not available	Not available

2.2.2.5. Civil aviation

Emissions factors for air travel in commercial planes assume an average level of occupancy on the plane Additionally, airplane type affects the amount of emissions that occur. The emissions factors recommended for air travel in the GHG Protocol are from UK DEFRA (2009) and do not take airplane type into consideration. This is partly for simplicity and partly because comprehensive information is not yet available. Emissions factors for jet fuel and aviation gasoline are available from the Energy Information Administration (http://www.eia.doe.gov/). Note that jet fuel is used by jet engines only. Aviation gasoline is used in piston-powered airplanes. Jet fuel is more common.

Table 17: civil aviation emission factors per passenger (DEFRA, 2009)

Method of travel		CO_2	CH_4	N_2O	Total GHG
		kg CO_2 per passenger	kg CO_2eq per passenger	kg CO_2eq per passenger	kg CO_2eq per passenger
Flight type	*Cabin class*				
Domestic	**Average**	0,17102	0,00013	0,00168	0,17283
Short-haul international	**Average**	0,09826	0,00001	0,00097	0,09924
	Economy class	0,09365	0,00001	0,00092	0,09457
	Business class	0,14047	0,00001	0,00138	0,14186
Long-haul international	**Average**	0,11220	0,00001	0,00110	0,11331
	Economy class	0,08191	0,00000	0,00081	0,08272
	Premium economy class	0,13105	0,00001	0,00129	0,13235
	Business class	0,23753	0,00001	0,00234	0,23988
	First class	0,32763	0,00002	0,00322	0,33087

According to the IPCC Guidelines (2006), a 9% uplift factor must be applied to distance travelled (i.e. multiply such datum for 1.09): Guidelines state that 9-10% should be added to take into account non-direct routes (i.e. not along the straight line great circle distances between destinations) and delays/circling. Airline industry representatives have indicated that the percentage uplift for short-haul flights will be higher and for long-haul flights will be lower, however specific data is not currently available to provide separate factors.

2.2.2.6. Waste

Emission factor for solid waste management depend on the treatment processes, that the waste undergoes. Thus a most suitable factor can only be obtained by means of a deep assessment of the waste cycle in the local context. That is not easily practicable and usually goes over the objective of the inventory compiler. Default emission factor can be suggested by local authorities or waste management companies. Table 18 reports emission factor for waste processes according to waste type provided by DEFRA Waste Strategy (2009). Data are provided in CO_{2eq}.

Table 18: emission factors for waste treatment processes (kg CO_{2eq}/tonnes of waste processed (Defra Waste Strategy, 2009)

Waste fraction	Recycled material	Virgin material	Recycling	Incineration (moving grate)	Anaerobic Digestion	Composting	Landfill
Paper and Card	950	950	-713	-500	-121	57	550
Kitchen/ food waste		2.428		-89	-100	30	365
Garden/ plant waste		89		-121	-100	57	210
Other organic	0	0	44	-271	-330	34	230
Wood	6	256	250	-700		250	930
Textiles		19.294	-3.800	600			300
Plastic (dense)	1.600	3.100	-1.500	1.800			40
Plastic (film)	1.500	2.500	-1.000	1.800			35
Ferrous metal	1.800	3.100	-1.300	-786			10
Non-ferrous metal	2.000	11.000	-9.000	23			10
Silt/soil	4	4	16	35			10
Aggregate materials	4	8	-4	35			10
Misc combustibles		102	58	242			305
Glass	525	840	-315	5			10
Estimated impact of other materials (municipal and C&I)	2.860	2.860	-259	97	-13	7	81

2.2.2.7. Water supply and water treatment

Emission factor for water use (including supply and disposal) can be obtained through specific analysis of the water integrated cycle: such a study take into account different processes implemented, energy and products consumption for transport and treatments. Therefore, a study like that appears such a too onerous task for the inventory aims and default emission factor (provided by local water company) should be used.

For instance, Water UK, a framework representing all UK water and wastewater service suppliers at national and European level, provides in its annual sustainability report among several indicators also the ones reported in Table 19.

Table 19: emission factor for water use (supply and disposal) in UK (Water UK, 2008)

	Units	E.F.
Greenhouse gas emitted in supplying water	Tonnes CO_{2eq}/Megalitre	0.276
Greenhouse gas emitted in wastewater treatment	Tonnes CO_{2eq}/Megalitre	0.693

These values are calculated according to processes and treatment in water supply and wastewater management systems in UK.

2.2.2.8. Consumables, product use and materials

The consumption of materials and products does not load heavy the GHGs total account of an office activity, thus this category can be considered negligible.

GHG emission related to the use of office material supplied can be calculated from complex models of Life Cycle Analysis (LCA) of single products. A simplified method considers default values from local authorities (such as the environmental agency or the department of Environments Affairs and Tourism) or from sectorial producers frameworks.

Paper use

Emissions from paper result from the manufacturing and disposal processes, not to the use of the paper itself. Being the program an office-based activity, great paper use can occur, but likely it does not has a meaningful impact in terms of indirect emissions related. Emission can be estimated using default factors: some cases are reported below as examples.

In its CO_2 inventory report for calendar years 2006 & 2007, WRI (World Resources Institute) details its paper use in three categories: office paper, checks and publications paper. Emission factors, obtained from Environmental Defence's Paper Task Force (1995, 2002) are 4.474 kg_{CO2} per kg of office paper used, 4.763 kg_{CO2} per kg of check written and 4.649 kg_{CO2} per kg of publication paper produced.

PE Europe enterprises uses an emission factor equal to 1.356 kg_{CO2eq} per kg of paper used on the basis of values given by UBA (Umweltbundesamt, the Austrian Federal Environment Agency). This emission factor is calculated from the ratio between total GHGs emissions by paper and pulp industry sector on total amount of paper produced.

Refrigeration & Air-conditioning Equipment

Refrigeration and air-conditioning is composed of many end-uses, including household refrigeration, domestic air conditioning and heat pumps, mobile air conditioning, chillers, retail food refrigeration, cold storage warehouses, refrigerated transport, industrial process refrigeration, and commercial unitary air conditioning systems. Historically, this sector has used various ozone-depleting substances (ODS) such as CFCs and HCFCs as refrigerants. These ODS are being phased out under the Montreal Protocol and are being replaced with HFCs.

HFC emissions from the refrigeration and air conditioning sector result from the manufacturing process, from leakage over the operational life of the equipment, and from disposal at the end of the useful life of the equipment. These gases have 100-year global warming potentials (GWP), which are 140 to 11,700 times that of carbon dioxide, so their potential impact on climate change can be significant.

IPCC guidelines (2006) recommends for equipment manufacturers and for equipment users who maintain their own equipment to estimate HFC emissions based on the amount of refrigerant purchased and used (Sales-Based Approach) and for equipment users who have contractors service their equipment to track emissions at each stage of the lifecycle of the equipment (Lifecycle Stage Approach).

In an office-based activity GHG emissions inventory, this category can be meaningful according to the number and size of A/C equipment. A preliminary estimation of emissions due to HFC leakage can be done considering default assumption from IPCC Guidelines reported inTable 20. Activity data to gather are the charge of each A/C equipment owned and the type of HFC used, in order to associate the correct GWP factor in the conversion to CO_2equivalent. In Table 21 GWPs of Common Greenhouse Gases and Refrigerants are reported.

Table 20: default assumption from IPCC Good Practice Guidelines (2006) for HFC-emitting A/C equipments

Application	Lifetime (years)	Charge (kg)	Emission Factors (% of initial charge/yr)		
			Assembly	Annual Leakage Rate	Recycling Efficiency
Domestic Refrigeration	12 - 15	0.05 - 0.5	0.2 – 1 %	0.1 – 0.5 %	70 % of remainder
Residential and commercial A/C	10 - 15	0.5 - 100	0.2 – 1 %	1 – 5 %	70 – 80 % of remainder

Table 21: GWPs of Common Greenhouse Gases and Refrigerants (adapted from IPCC, 1995)

Gas or Blend	GWP	Gas or Blend	GWP
CO_2*	1	**R-410B**	1833
CH_4*	21	**R-411A**	15
N_2O*	310	**R-411B**	4
HFC-23	11700	**R-412A**	350
HFC-32	650	**R-413A**	1774
HFC-125	2800	**R-414A**	0
HFC-134a	1300	**R-414B**	0
HFC-143a	3800	**R-415A**	25
HFC-152a	140	**R-415B**	105
HFC-236fa	6300	**R-416A**	767
R-401A	18	**R-417A**	1955
R-401B	15	**R-418A**	4
R-401C	21	**R-419A**	2403
R-402A	1680	**R-420A**	1144
R-402B	1064	**R-500**	37
R-403A	1400	**R-501**	0
R-403B	2730	**R-502**	0
R-404A	3260	**R-503**	4692
R-406A	0	**R-504**	313
R-407A	1770	**R-505**	0
R-407B	2285	**R-506**	0
R-407C	1526	**R-507 or R-507A**	3300
R-407D	1428	**R-508A**	10175
R-407E	1363	**R-508B**	10350
R-408A	1944	**R-509 or R-509A**	3920
R-409A	0	**PFC-218 (C_3F_8)**	7000
R-409B	0	**PFC-116 (C_2F_6)**	9200
R-410A	1725	**PFC-14 (CF_4)**	6500

** Included for reference purposes only.*

2.3.Information about calculators available

Quantifying GHG emission is under the interest of the international scientific community since climate change has become one of the major issue threatening the environment.

The need of broad and balanced information about climate change led to the creation of the Intergovernmental Panel on Climate Change in 1989. It was set up by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) as an effort by the United Nations to provide the governments of the world with a clear scientific view of what is happening to the world's climate. The methodology reports provide practical guidelines for the preparation of greenhouse gas inventories. They are aimed to meet the inventory reporting requirements of Parties to the UNFCCC. The IPCC Guidelines were first accepted in 1994 and published in 1995. UNFCCC COP3 held in 1997 in Kyoto reaffirmed that the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories should be used as "methodologies for estimating anthropogenic emissions by sources and removals by sinks of greenhouse gases".

The IPCC Guidelines refer to a national level inventory, therefore they do not completely suit for the redaction of single organization inventories. Some organizations choose to define their own approach for carbon foot-printing. However, it is usually quicker and better to use a methodology that is already widely accepted and understood. The results may be seen to be more credible, and can be compared with other organizations using the same methodology. One commonly used methodology is the GHG Protocol, produced by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). This methodology provides detailed guidance on corporate emissions reporting and is available free of charge online. A more recent standard from the International Organization for Standardization, ISO 14064, also provides guidance on corporate footprint calculation and emissions reporting. It builds on many of the concepts introduced by the GHG Protocol.

A number of cross-sector and sector-specific calculation tools are available on the GHG Protocol Initiative website (http://www.ghgprotocol.org/calculation-tools/all-tools), including a guide for small office-based organizations. These tools provide step by- step guidance and electronic worksheets to help users calculate GHG emissions from specific sources or industries. The tools are consistent with those proposed by the Intergovernmental Panel on Climate Change (IPCC) for compilation of emissions at the national level. The tools uses default emission factors, which vary by country: currently, separate sets of emission factors are available only for the UK and US, while for other countries, default values are used, that will therefore lead to less accurate calculations. No specific tools are available for office-based organizations:

- worksheet for scope 1 emissions (i.e. emission occurred from combustion of fossil fuels in organization-owned vehicles/devices; see paragraph 2.2.1.1) uses default emission factors, which can be modified in the "settings" page. Therefore it appears appropriate to be used to calculate emissions from this category. A simplified version (based on the same criteria) is suggested in paragraph 3.1;
- worksheet for scope 2 emissions (i.e. emission occurred from purchased electricity; see paragraph 2.2.1.2) uses emission factor from IEA (2006). Calculation methodology agrees with the one proposed in this document: by default the worksheet uses IEA-2006 country specific emission factors, but user can in-put local specific emission factor or national updated ones, as the ones reported in paragraph 3.2;
- worksheet for scope 3 emission (i.e. other indirect emission occurred from employee commuting, waste production, water and products use) reports only a long list of default emission factors

without table already set for the calculation. Moreover, emission factors should be substituted with more updated and local specific ones, as suggested in paragraph 3.3. Finally, for some minor emission categories (such as waste production, water and material use) no tools are available.

According to DEFRA (2008), the GHG tools do contain the necessary detail, and are quite clear and transparent, but since this is designed as a set of tools rather than a single, integrated methodology, this could cause problems with collating all of the outputs. Integrating all the components together into a single tool may then make the tool appear too large and overwhelming. It is self-evident that the above mentioned tools cannot be used directly as downloadable for the project aims.

Furthermore a number of calculators that estimate an individual's CO_2 emissions have become prevalent on the internet. Those could be used to estimate the emission inventory of an office-based organization (being similar the most of the categories), but this appears an inappropriate choice. As stated in a study on U.S.-based calculators by Padgett et al. (2008), even with similar inputs these calculators can generate varying results, often by as much as several metric tons per annum per individual activity. These variations may be due to differences in calculating methodologies, behavioural estimates, conversion factors, or other sources. However, the lack of transparency makes it difficult to determine the specific reasons for these variations and to assess the accuracy and relevance of the calculations.

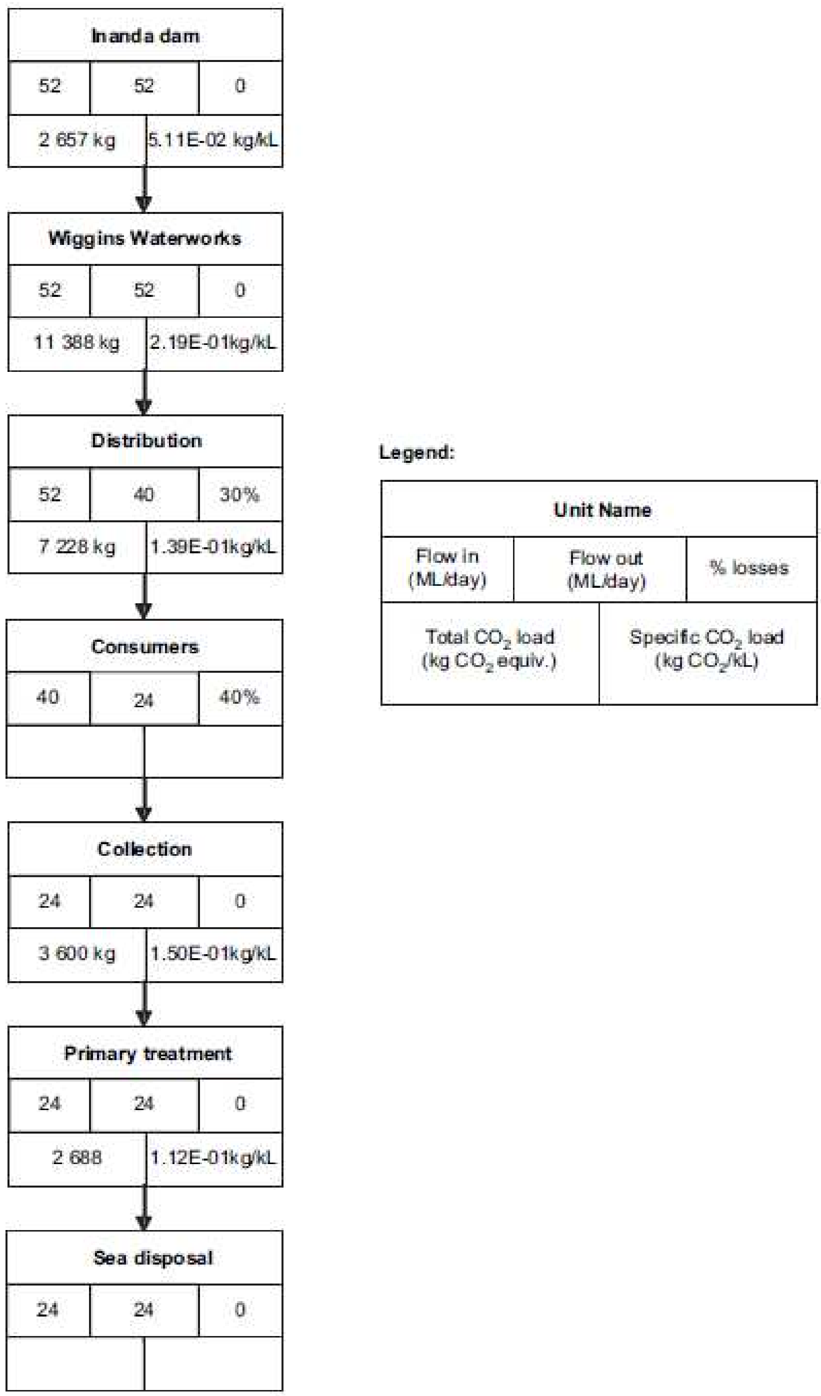
Overall, the calculators lack consistency, especially for estimates of CO_2 emissions from household electricity consumption. For this category, calculators return CO_2 emission levels that differ up by a order of magnitude per year, as shown in Table 22. This difference is likely because power utilities employ various methods of electricity production that result in different levels of CO_2 emissions for the electricity consumer depending on their geographic location.

Table 22: comparison of values for household electricity use and CO_2 emissions (adapted from Padgett et al., 2008)

	Average annual electricity use (kWh)	CO_2 emitted for average electricity use (kg/year)	Electricity conversion factor (kg CO_2/KWh)	CO_2 emitted for 12,000 kWh (kg/year)
American Forests	11827	8047	0,68	8165
Be Green			0,68	8123
BEF	11256	7102	0,63	7571
CarbonCounter.org			0,62	7385
Chuck Wright			0,91	10886
Clear Water			0,25	2994
The Conservation Fund	11827	7348	0,62	7457
EPA	12000	7457	0,62	7457
Safe Climate			0,47	7076
Terra Pass	14087	8754	0,63	7457

These results of the study reveal a lack of uniformity among calculators. These variations may be a result of different conversion factors employed or distinct methodologies utilized to calculate these estimates of CO_2 emissions. Although these differences may appear small in some cases, when compounded in calculations they can produce considerable variation in results. In addition, the reasons for the selection of different conversion factors or calculating methodologies are unclear. The lack of background information emphasizes the need for greater transparency.

On the other hand, several recent scientific works estimate the carbon footprint of different systems (such as households consumptions or waste/water treatment processes) using complex models, specifically designed for specific case studies. Kenny and Gray (2009) presented a preliminary survey of household and carbon dioxide emission in Ireland according to 2001 IPCC Guidelines and calibrated a model developed on purpose. Ad hoc surveys were conducted with a large sample of households in order to test the robustness of the model and to get background emission data. As values available in literature were not reliable, new conversion factors were calculated using specific fuel mixes and calorific values for Ireland.



Friedrich et al. (2009) analyzed the carbon footprint for increasing water supply and sanitation in a case study in South Africa: a number of Life Cycle Analysis studies were performed using standard methodologies (ISO 14040) and calculation were elaborated by proper software[10]. Local data (for the production of cement, stone and sand as well as local data on energy consumption for the excavation and fill) were used to calculate the emission of the different stages of the processes. The figure at the left shows the values of emissions (in therms of kg CO_2eq, for each stage of the water system studied, obtaining a total 0.67 kg CO_2eq per 1000 L supplied.

[10] Demo versions of these software are available on the net, for instance Gabi 4 (downloadable at http://www.pe-international.com/consulting/carbon-footprint/corporate-carbon-footprint/)

Stokes and Horvath (2008) provided a review of different studies based on LCA for energy and air emission effects of water supply. As shown in Table 23 the results are very variable according to treatment processes implemented.

Table 23: Life-Cycle Assessment results for different water supply treatment (adapted from Stoke and Horvath, 2008)

Water source	Energy (MJ/m^3)	GHG ($g\ CO_2eq/m^3$)
Imported water	18	1093
Desalinated ocean water, conventional pretreatment	42	2465
Desalinated ocean water, membrane pretreatment	41	2395
Desalinated brackish groundwater	27	1628
Recycled water	17	1023

Cadena et al. (2009) propose a complex experimental methodology to determine gaseous emissions associated to a composting plant is composed of four different steps: (i) data collection on plant characteristics and operation, (ii) determination of atmospheric emissions, (iii) laboratory analysis and (iv) calculation of emission factors. Following this method not only the gaseous emissions are determined but also their relationship with specific plant operation.

Clemens and Chulcs (2002) study the greenhouse gas emissions from mechanical and biological waste treatment of municipal waste on four different treatment plants, and comparing the results with other sectorial studies. The results, reported in Table 24, show the great variability of emission factor according to each case study.

Table 24: Comparison of the EF of different studies (adapted from Clemens ad Chulcs, 2002)

	CO_2 (kg/ton)	CH_4 (g/ton)	NO_2 (g/ton)
Municipal Solid Waste *(Clemens and Chulcs 2002)*	13-208	7-11493	3-792
Biowaste *(Gronauer et al., 1997)*	216-612	108-5021	43-966
Biowaste *(Helmann, 1995)*	216-612	60-1589	41-375
Biowaste *(Hellbrand, 1998)*	865	6757	177
Farm yard manure *(Hao et al., 2001)*	271	8400-10800	361-624

Also Baldasano and Soriano (1999) compared emission of greenhouse gases from anaerobic digestion processes with other MSW treatments. Results are reported in Table 25.

Table 25: Emission factors for different MSW management systems (adapted from Baldasano and Soriano, 1999)

Treatment	Emission factor (tons CO2eq/tons MSW)
Landfill	1.97
Incineration	1.67
Sorting + Composting + Landfill	1.61
Sorting + Composting + Incineration	1.41
Sorting + Dry biomethanization + Landfill	1.42
Sorting + Wet biomethanization + Incineration + Landfill	1.19

Results of the studies on emission from solid waste management show a great variability according to local conditions of the case study and methodology applied from the authors in the calculation. That implies that an appropriate emission factor should be evaluated on the basis of data and information gathered in the specific application context.

Finally, the documentation acquired led to state that:

- the worldwide recognized standard methodology to comply national GHG inventories is given by IPCC; the GHG Protocol provides also some simplified guides for lower level inventories and tools to support the calculation. Those methodologies use default emission factors and suggest to choose updated local specific ones to reduce the uncertainty in the estimations. Unfortunately, the methodology do not include some emission categories for office-based organizations;
- the use of default calculators already available on the web should be avoided because they provide varying results even with similar inputs and need improved consistency and transparency in the methods and estimates;
- calculation of specific emission factors can be done by consistent LCA studies and calibrating models on the local context using a number of specific indicators. That requires significant skills and resources, whose use seems too onerous for the aims of this project.

3. Proposed methodology

According to GHG Protocol, three “scopes” (scope 1, scope 2, and scope 3) are defined for GHG accounting and reporting purposes to help delineate direct and indirect emission sources, improve transparency, and provide utility for different types of organizations and different types of climate policies and business goals. Figure 5 gives an overview of emissions due to organization activity and their distribution in different scopes.

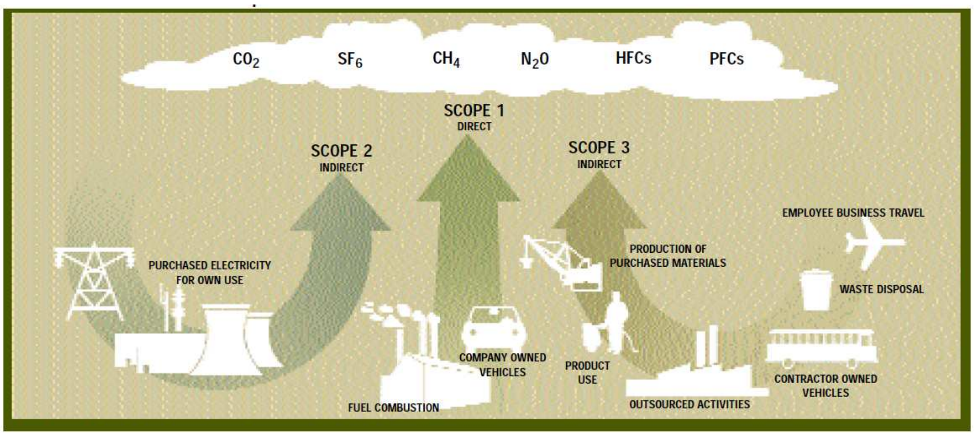


Figure 5: overview of scope and emission across a value chain (The Greenhouse Gas Protocol, 2004)

Scope 1:

- Production of heat
- Fuel use in the organization’s vehicles and devices

Scope 2:

- Imports of electricity

Scope 3:

- Employees business travel
- Employees commuting to and from work
- Outsourced activities, contract manufacturing and franchises
- Emissions from the use of goods; e.g. printing or copy paper
- Emissions from waste
- Emissions from the use and the end of life of products and services
- (Transportation of products, materials and waste)

From the above list, the emission sources written in brackets can be not considered for various reasons, which are explained in the relative paragraphs.

The emission inventory should refer to a defined time period, that could be the length of the project or, as common, the year. A “base year” is a benchmark against which an entity’s emissions are compared over time. Setting and updating a base year provides a standardized benchmark that reflects an entity’s evolving structure over time, allowing changes in organizational structure to be tracked in a meaningful fashion and comparison with emission inventories of other organizations.

3.1.Fuel used in organization owned vehicles/devices

The activity data required are the types and the consumptions of fuel in organization owned vehicles or devices (boilers using natural gas, electricity generators) during the reference period. This can be obtained from invoices and receipts or from register of the administrative desk.

Country specific emission factors, derived from national fuel characteristics may be provided by local fuel delivery company. Default emission factor are reported in Table 26 for the most common fuel types with relative Net Calorific Values (identical for stationary of mobile combustion).

Table 26: default CO_2 emission factors and uncertainty ranges for most common fuel types (IPCC guidelines, 2006)

Fuel type	Emission factor			Net Calorific Value	Density*
	CO_2	CH_4	NO_2	Default	Default
	(kg/TJ)	(kg/TJ)	(kg/TJ)	(TJ/Gg)	(kg/m^3)
Motor Gasoline/Petrol	69300	10	0.6	44,3	734,8
Gas/ Diesel Oil	74100	10	0.6	43,0	834,0
Liquefied Petroleum Gases	63100	5	0.1	47,3	508,1
Kerosene	71900	10	0.6	43,8	803,9
Natural Gas	56100	5	0.1	48,0	175,0
**data source: DEFRA (2009)*					

GHG emissions result from the equation below:

$$E_F = \Sigma_{i,j} (F_i \cdot NCV_i \cdot \rho_i \cdot EF_{ij} \cdot GWP_j)$$

where:

E_F	GHG emissions due to fuel used in company owned vehicles/devices	(kg CO_2eq/ year)
F_i	quantity of fuel type "i" used in the reference period	(L/year)
NCV_i	net calorific value of fuel type "i"	(J/kg)
ρ_i	fuel type "i" density	(kg/L)
GWP_j	Global warming potential of "j" greenhouse gas	($kg_{CO2}/kg_{GHG\ j}$)
EF_{ij}	emission factor (on NCV basis) for fuel type "i"	($kg_{GHG\ j}$/J)
i	fuel type	
j	greenhouse gas type	

Fuel density, Net Calorific Values and country specific emission factors should be determined locally through experimental analysis or asking the fuel delivery company or sectorial agencies.

Otherwise emission factors reported in Table 27 could be used, obtaining an easier estimation, according to the equation below.

$$E_F = \Sigma_i (F_i \cdot EF_i)$$

where:

E_F	GHG emissions due to fuel used in company owned vehicles/devices	(kg CO_2eq/ year)
F_i	quantity of fuel type "i" used in the reference period	(unit/year)
EF_i	emission factor (on NCV basis) for fuel type "i" (see Table 27)	($kg_{GHG\ j}$/unit)
i	fuel type	

Table 27: emission factors for fuel type on the basis of Net CV (DEFRA, 2009)

Fuel used	Units	Total GHGs kg CO_2eq per unit
Petrol	litres	2,33070
Diesel	litres	2,66940
Compressed Natural Gas (CNG)	kg	2,73356
Liquid Petroleum Gas (LPG)	litres	1,49680
Coal (domestic)	kg	2,87380
Naphtha	kg	3,14220
Natural gas	m^3	2,01330

3.2.Electricity use

The activity datum required is the consumption of electricity during the reference period. This can be easily obtained from electricity bills, expressed in total kilowatt hours.

Plant specific emission factors could be obtained contacting directly the local provider: for instance, in South Africa there is Eskom, which publish an annual report[11]. Eskom supplies an average emission factor equal to 1.015 kg CO_2eq/kWh.

Table 28: Emission factors for Eskom-generated electricity in kg CO_2eq per kWh (ERC, 2008)

	Value	*Units per kWh electricity*	*Reference*
% electricity generated from coal	92.0		Eskom (2007)
% electricity generated from gas (kerosene)	0.0000836		Eskom (2007)
% electricity without carbon emissions	8.0		Eskom (2007)
Total emissions from coal-fired plants	0.993	kg CO_2-eqt	
CO_2 emissions from coal power plants	0.978	kg CO_2	Zhou, Yamba et al. (unknown)
N_2O-eqt emissions from coal mining NO_x	0.000038	kg N_2O-eqt	Zhou, Yamba et al. (unknown)
CH_4 emissions from coal mining	0.000178	kg CH_4	Zhou, Yamba et al. (unknown)
CO_2 emissions from kerosene plants	0.955	kg CO_2	Eskom (2007)
Overall power plant emissions	*0.914*	*Kg CO_2-eqt*	
Transmission losses	8.33	%	Eskom (2007)
Distribution losses	1.74	%	Eskom (2007)
Eskom average Emission Factor	1.015	kg CO_2-eqt/kWh	

[11] http://www.eskom.co.za/annreport08/

GHG emissions result from the total electricity used in the buildings linked to organization activity, according to the equation below:

$E_{el} = \Sigma_i \, (F_{el\,i} \cdot EF_{el\,i})$

where:

E_{el}	GHG emissions due to electricity use	(kg CO_2eq/ year or other)
F_{el}	total kilowatt hours used, registered by counter "i"	(kWh/ year or other)
EF_{el}	emission factor for electricity use	(kg CO_2eq/ kWh)
i	electricity counter for buildings linked to organization activity	

3.3. Employee passenger travel

This category includes all commuting and travels of the organization's staff. External consultants' expenses or other transport activity related to the organization activities, should be included in the emission inventory whether appropriate activity data can be gathered (according to criteria showed in paragraph 2.1.2).

According to transport, emission estimate should be done according to methodologies illustrated in the previous paragraphs and summed in below.

3.3.1. Car travel

Two methods are applicable: one on fuel use basis (more accurate), the other on mileage basis (less accurate).

The activity datum required to implement the calculation is fuel consumption of each employee using the car from home to job or used during missions or job travels, and the relative type of fuel.

If these data are directly available and reliable, the steps for the calculation are the same for the emissions occurred from fuel used in company owned vehicles (see paragraph 3.1).

If it is not possible to gather these data, approx fuel usage must be estimated for each employee, according to the equation below. Fuel economy can be obtained through experimental tests or from the vehicles producer

$F = dist \cdot eff$

Where:

F	approximate fuel used	(L/year or other)
dist	distance travelled by employee	(km/year or other)
eff	fuel economy of employee's car	(L/km)

In fact, often employees use their own car also for personal purposes, thus fuel used and consequent emissions occurred should not be totally imputed to their commuting in the organization inventory. If fuel used share for commuting cannot be exactly determined (according the two methods discussed above), distance travelled by each employee should be considered as activity datum and appropriate emission factors should be used. Table 29 reports UK vehicle emission factors on distance basis for type of fuel used and size of car: South Africa specific emission factor should be gathered.

Table 29: UK vehicle transport emission factors (on distance basis) for CO_2 (UK DEFRA, 2009)

Petrol Cars		CO_2	CH_4	N_2O	Total GHG
Size of car	Units	kg CO_2 per unit	kg CO_2eq per unit	kg CO_2eq per unit	kg CO_2eq per unit
Small petrol car, up to 1.4 litre engine	miles	0,28944	0,00050	0,00296	0,29290
	km	0,17985	0,00031	0,00184	0,18200
Medium petrol car, from 1.4 - 2.0 litres	miles	0,34246	0,00048	0,00296	0,34590
	km	0,21280	0,00030	0,00184	0,21493
Large petrol cars, above 2.0 litres	miles	0,47555	0,00045	0,00296	0,47897
	km	0,29549	0,00028	0,00184	0,29762
Average petrol car	miles	0,33100	0,00049	0,00296	0,33445
	km	0,20567	0,00030	0,00184	0,20781
Diesel Cars		CO_2	CH_4	N_2O	Total GHG
Size of car	Units	kg CO_2 per unit	kg CO_2eq per unit	kg CO_2eq per unit	kg CO_2eq per unit
Small diesel car, up to 1.7 litre or under	miles	0,24293	0,00013	0,00280	0,24586
	km	0,15095	0,00008	0,00174	0,15277
Medium diesel car, from 1.7 to 2.0 litre	miles	0,30187	0,00013	0,00280	0,30480
	km	0,18757	0,00008	0,00174	0,18939
Large diesel car, over 2.0 litre	miles	0,41167	0,00013	0,00280	0,41460
	km	0,25580	0,00008	0,00174	0,25762
Average diesel car	miles	0,31627	0,00013	0,00280	0,31921
	km	0,19652	0,00008	0,00174	0,19835
Alternative Fuel Cars		CO_2	CH_4	N_2O	Total GHG
Type of alternative fuel car	Units	kg CO_2 per unit	kg CO_2eq per unit	kg CO_2eq per unit	kg CO_2eq per unit
Medium petrol hybrid car	miles	0,20309	0,00028	0,00296	0,20634
	km	0,12620	0,00018	0,00184	0,12821
Large petrol hybrid car	miles	0,36042	0,00034	0,00296	0,36372
	km	0,22395	0,00021	0,00184	0,22601
Medium LPG or CNG car	miles	0,29966	0,00048	0,00296	0,30310
	km	0,18620	0,00030	0,00184	0,18834
Large LPG or CNG car	miles	0,41611	0,00045	0,00296	0,41952
	km	0,25856	0,00028	0,00184	0,26068
Average LPG or CNG car	miles	0,35788	0,00049	0,00296	0,36133
	km	0,22238	0,00030	0,00184	0,22452

In this case, GHG emissions can be calculated applying the equation below:

$E_{car} = \Sigma_i \, (dist_i \cdot EF_i)$

where:

E_{car}	GHG emissions due to car travel	(kg CO_2eq/ year)
$dist_i$	total distance travelled by car type "i"	(km/ year)
EF_i	emission factor for car type "i" (see Table 29)	(kg CO_2eq/ km)

i car type (according to fuel used and size)

3.3.2. Train, Light Rail, and Bus Travel

Because specific fuel consumption for each passenger is quite a not simple datum to estimate (depending on transport type, occupancy and several external factors), the calculation may be estimated on the basis of average default values.

The activity datum required is distance travelled by each employee; default emission factors such as the ones reported in Table 30 for UK and USA should be gathered at local public transport companies or at least country specific values should be found.

Table 30: UK and US public transport emission factors for CO_2 (UK DEFRA, 2008 and US EPA, 2008)

		UK Defra emission factors		US EPA emission factors	
		kg CO_2/ passenger km	kg CO_2/ passenger mile	kg CO_2/ passenger km	kg CO_2/ passenger mile
Taxis		0,1613	0,259587187	0,142915374	0,23
Buses	Local bus	0,1073	0,172682611	0,066486718	0,107
	Coach	0,029	0,046670976	0,066486718	0,107
	Default	0,0686	0,110400998	0,066486718	0,107
Trains	Light rail	0,09735	0,156669638	0,101283504	0,163
	Tram	0,04205	0,067672915	0,101283504	0,163
	Average	0,078	0,125528832	0,101283504	0,163
	National rail	0,0602	0,096882509	0,114953671	0,185
	Subways	0,065	0,10460736	0,101283504	0,163
Large RoPax ferry		0,1152	0,185396429	Not available	Not available

GHG emissions can be calculated applying the equation below:

$E_{pub} = \Sigma_i \, (dist_i \cdot EF_i)$

where:

E_{pub}	GHG emissions due to public transport	(kg CO_2eq/ year)
$dist_i$	total distance travelled by public transport type “i”	(km/ year)
EF_i	emission factor for public transport type “i” (see Table 30 or other)	(kg CO_2eq/passenger km)
i	public transport	

3.3.3. Civil aviation

GHG emission for air travel in commercial planes can be estimated according to different methods. The most accurate method considers several influencing factors: the fuel use, the different emission share during the cruise and the Landing and Take Off phase (LTO), the level of occupancy on the plane, the airplane type.

In this case, the activity data required are the number of flights, the fuel consumption per flight (depending on the airplane type and on the distance travelled) and the level of occupancy on the plane.

Emission factors are reported in Table 8 for the LTO phase (according to airplane type) and in Table 31 for the cruise phase.

Table 31: default emission factors for the most common fuels used for civil aviation (IPCC, 2006)

Fuel	CO_2 (kg/TJ)	CH_4 (kg/TJ)	NO_2 (kg/TJ)	NCV (TJ/Gg)	Density (kg/m^3)
Aviation Gasoline	70 000	10	0.6	44,3	711,7
Jet Kerosene	71 500	10	0.6	44,1	802,6

The equations below give the emission for each flight phase.

$$E_{LTO} = \#_{LTO} \cdot EF_{LTO}$$

$$E_{Cruise} = (F_{TOT} - F_{LTO}) \cdot EF_{Cruise}$$

where:

E_{LTO}	CO_2 emissions during the LTO phase	(kg CO_2eq/ flight)
$\#_{LTO}$	number of LTOs	(LTO)
EF_{LTO}	LTO emission factor for typical aircraft (see Table 8[12])	(kg CO_2eq/LTO)
E_{Cruise}	GHG emissions during the cruise phase	(kg CO_2eq/ flight)
F_{TOT}	total fuel consumption per flight: refer to flight company (preferable) or to web calculator such as www.webflyer.com or http://www.chooseclimate.org/flying/mf.html	(kg/flight)
F_{LTO}	fuel consumption during LTO phase given by number of LTOs multiplied for specific fuel consumption per LTO (varying for different airplane type, seeTable 8)	(kg/LTO)
EF_{Cruise}	cruise emission factor (see Table 31)	

Once the amount of fuel used is known, the steps for the calculation are the same for the emissions occurred from fuel used in organization owned vehicles (see paragraph 3.1). Total GHG emissions are given by the sum of the different phases and gases contribution, according to relative GWP. A single passenger share must be calculated considering an average level of occupancy of the airplane: this datum can be provided by travel agencies or flight delivery company.

If all these data are not available, a simpler method may be used, considering only total fuel consumption per flight (provided by flight company) and applying emission factors in Table 31 above. A 9% safety factor (i.e. equal to 1.09) should be applied in order to take into account greater emissions during the LTO phase.

[12] Emission factors contained in Table 8 refer to single green house gases. Emission factor (expressed in CO_2eq) is given by the sum of GHGs under the Kyoto protocol as explained at paragraph 1.2.

Finally, an alternative less accurate method considers total distance travelled and uses default emission factors in Table 32. Such emission factors are calculated on average basis but take into account several aspects with conservative coefficient (i.e. +10% for LTO cycle, +9% for deviations).

Table 32: civil aviation emission factors per passenger (DEFRA, 2009)

Method of travel		CO_2	CH_4	N_2O	Total GHG
		kg CO_2 per km	kg CO_2eq per km	kg CO_2eq per km	kg CO_2eq per km
Flight type	*Cabin class*				
Domestic	**Average**	0,17102	0,00013	0,00168	0,17283
Short-haul international	**Average**	0,09826	0,00001	0,00097	0,09924
	Economy class	0,09365	0,00001	0,00092	0,09457
	Business class	0,14047	0,00001	0,00138	0,14186
Long-haul international	**Average**	0,11220	0,00001	0,00110	0,11331
	Economy class	0,08191	0,00000	0,00081	0,08272
	Premium economy class	0,13105	0,00001	0,00129	0,13235
	Business class	0,23753	0,00001	0,00234	0,23988
	First class	0,32763	0,00002	0,00322	0,33087

GHG emissions can be calculated applying the equation below:

$E_{air} = \Sigma_i \, [(1.09 \cdot dist_i) \cdot EF_i]$

where:

E_{air}	GHG emissions due to air flights	(kg CO_2eq/ year)
1.09	LTO conservative coefficient (DEFRA, 2009)	(-)
$dist_i$	total distance flighted on flights type “i”	(km/ year)
EF_i	emission factor for flight type “i” (see Table 30 or other)	(kg CO_2eq/passenger km)
i	flight type	

3.4.Waste disposal/recycling

Waste production can be a significant GHGs emission source in big organizations or companies. The caused municipal waste of a small organization office is too small to be relevant in comparison with other contributors, because main business focus is a consulting/managing service.

According to final destiny of solid waste produced, GHGs emissions can be estimated according to the methodology suggested by IPCC (see chapter 2.1.3.2). This procedure requires a large amount of data to be gathered and a deep survey about solid waste management at local level. Thus, an estimation can be done using default factors, such as the ones reported in Table 18 regarding different kinds of waste and treatment processes implemented.

Activity data required are the quantity and the composition of solid waste produced: these data can be assumed or experimentally found by means of a specific analysis. For each waste type, treatment process and final destiny have to be known. Emission factors in Table 18 are provided by DEFRA and refer to UK. If available, local factors by waste management companies or national factors by local authorities (such as the environmental agency or the department of Environments Affairs and Tourism) should be gathered.

An average emission factor can be obtained through a weighted average of fraction specific emission factors, as explained in the equation below.

$EF_{waste} = \Sigma_i (f_i \cdot EF_i)$

where

EF_{waste}	emission factor	(kg CO_2eq/kg $_{\text{waste produced}}$)
f_i	percentage of waste kind i	(%)
EF_i	waste kind i specific emission factor	(kg CO_2eq/kg $_{\text{waste i produced}}$)
i	waste kind	

Total emissions from waste can be calculated using this average emission factor, updated with experimental analysis when possible (1-2 time per year) , multiplied for waste production in the reference period.

3.5.Water supply and water treatment

An office activity does not consume high water quantity such as an industrial one. Water use can be considered in GHGs emissions accounting if local agencies or authorities provide specific emission factors for volume of water supplied or treated. Otherwise the study of the water management system seems to be a too heavy activity for the accounting purposes.

3.6.Consumables, product use and materials

The consumption of materials and products does not load heavy the GHGs total account of an office activity, thus this category can be considered negligible. GHG emission related to the use of office material supplied can be calculated from complex models of Life Cycle Analysis (LCA) of single products. A simplified method considers default values from local authorities (such as the environmental agency or the department of Environments Affairs and Tourism) or from sectorial producers frameworks.

3.6.1. Paper use

Emissions from paper result from the manufacturing and disposal processes, not to the use of the paper itself. Being the program an office-based activity, great paper use can occur, but likely it does not has a meaningful impact in terms of indirect emissions related. Emission can be estimated using default factors provided by local paper consortia; related activity datum is the consumption of paper in the reference period.

3.6.2. Refrigeration & Air-conditioning Equipment

In an office-based activity GHG emissions inventory, this category can be meaningful according to the number and size of A/C equipment. A preliminary estimation of emissions due to HFC leakage can be done considering default assumption from IPCC Guidelines reported in Table 20. Activity data to gather are the charge of each A/C equipment owned and the type of HFC used, in order to associate the correct GWP factor in the conversion to CO_2equivalent.

4. Emission reduction and offsets

Once the organization GHG inventory has been redacted, different opportunities can be identified to achieve an established reduction target. This section describes two categories of emissions reductions: “internal” reductions and “offsets.” Internal reductions are those that take place within the organization’s operations, like switching to energy-efficient lighting. An offset is the reduction or removal of emissions through a project outside the organization’s operations, such as carbon removal from the atmosphere through a tree planting project. Internal reductions are recommended as a priority, but offset options should be considered as a supplemental effort to help achieve the emission reduction goal.

Suggestion here reported are adapted from “Working 9 to 5 on climate change: an office guide” published by the World Resources Institute.

4.1.Internal reductions

A variety of internal reduction opportunities are possible depending on the type of organization and which emissions are included in the inventory. A good practice is to start by pursuing those actions that will provide the greatest emissions savings for the organization at the lowest cost.

4.1.1. Reducing Energy Consumption

An office can achieve significant energy savings by promoting a number of good practices described below.

4.1.1.1. Energy

Equipment

- Employees should ensure equipment is off when not in use and if use energy-efficient mode if the equipment has it. Timers for equipment such as photocopiers and printers could be purchased, so they switch off automatically when not in use during non-office hours. Awareness actions should be promoted, such as internal advertising campaign (for instance the employ “Switch Me Off!” stickers as reminders) or competitions among departments to see who has the best record of turning off equipment, or can generate the best ideas for other energy-saving ideas.
- When it’s time to upgrade your office equipment, equipment that is certified energy- efficient should be purchased.

Computers

- Employees should be encouraged to activate computers power management features. Power management features are now common on most computers. When activated, they enable the computer’s monitor to automatically power down after a specified period of inactivity, saving significant energy. The EPA estimates that if all computers in the U.S. utilized this feature, the reductions in CO_2 emissions would be equivalent to removing 1.5 million cars from the road.

Lighting

- Lights should be turned off when offices and meeting rooms are empty. Motion sensors can be installed so that lights turn off when offices are unoccupied for more than a few minutes.
- Compact fluorescent lamps (CFLs) typically save a consumer 50 to 80 percent of the energy costs associated with incandescent bulbs and the average CFL lasts more than 10 times longer. Therefore, office lighting should be provided with them.
- If the organization offices have access to sufficient natural light, the lights should be dimmed or turned off during brighter parts of the day. If new office space are going to be built, architects and

designers should incorporate as much natural light and reflective ceiling tiles as possible into the design phase.

Other

- Old air conditioning equipment should be replaced with energy-efficient systems. This measure can save up to 25 to 35 percent of electricity use in an office building. The financial payback period ranges from 3 to 5 years.
- Old boilers should be upgraded to more energy-efficient ones.
- Green building practices should be incorporated into new buildings.

4.1.1.2. Greener energy use

Green power is electricity that is generated from clean, non-fossil fuel based sources such as solar, wind, and some forms of biomass. Therefore, the use of such energy should be promoted

4.1.2. Reducing Travel-Related Emissions

Business Travel

- Recognizing that air travel is the most carbon-intensive travel method, alternatives to plane trips should be explored. For example, depending on where businesses are located and the trip planned, sometimes it's as easy to travel by train as by plane.
- When possible, trips should be organized multipurpose, maximizing the trip productivity, or consolidated: for example, combining the trips into one, rather travelling to the same area at two different times. Besides reducing emissions, reducing travel will save money.
- Organization's need for travel or the number of employees who go on each trip could be reduced. Alternatives to travel include telephone, video, and web conferencing. The cost and reliability of video conferencing technologies have greatly improved over the past few years.

Employee Commuting

- Teleworking—that is, using communications technology to work at a distance rather than commuting – ould be considered as an alternative to traditional commuting for some employees. AT&T (http://www.att.com/telework) estimates that in 1999, its teleworkers avoided 87 million miles of driving, preventing emissions of 41,000 tons of CO_2, 93,000 tons of nitrogen oxides, 1.4 million tons of carbon monoxide, and 180,000 tons of hydrocarbons. Telework can also help with employee retention.
- Incentives should be created for employees to use car pool or other alternative methods for their work commute, such as walking, cycling, and mass transit. For example, discounts could be offered on mass transit to employees or employees could be allowed to use pre-tax dollars to pay for commuting. Some government incentive programs offer pre-tax benefits. A place should be provided where employees can secure their bicycles.
- When relocating offices, proximity to public transportation should be considered as a factor in selecting a site.

Other Suggestions

- Other companies could be encouraged and helped conduct a GHG inventory and set a reduction target. This might be a business partner or neighbouring organization.
- Suppliers and other business partners should be informed about the organization actions and commitment in GNG emission reduction.
- Employees should be encourage and supported in their efforts to reduce GHG emissions at home.

4.2.Offsets

Even after the best reduction efforts, the goal fixed may still have not reached. If this is the case, compensative actions are needed to be taken to goal the fixed target, especially if this is a net zero balance of emissions and the inventory includes employee commuting and business travels.

The purchase of offsets is controversial, partly because it could be implied that companies are “buying their way out” of their climate responsibilities, and partly because there is still uncertainty about how to calculate the CO_2 benefits of certain offset projects like tree planting. Nevertheless, carbon offsets can be an effective and often necessary tool to reduce CO_2 emissions. It is important, however, to first vigorously pursue actual emissions reductions within your organization. Maximizing in-house emissions reduction opportunities so that the need for offsets can be gradually reduced is a good long-term strategy.

Carbon offsets are measured in metric tons of carbon dioxide-equivalent (CO_2eq). One carbon offset represents the reduction of one metric ton of carbon dioxide or its equivalent in other greenhouse gases. There are two markets for carbon offsets. In the larger, compliance market, companies, governments, or other entities buy carbon offsets in order to comply with caps on the total amount of carbon dioxide they are allowed to emit. In the much smaller, voluntary market, individuals or companies purchase carbon offsets to mitigate their own greenhouse gas emissions from transportation, electricity use, and other sources.

Offsets are typically achieved through financial support of projects that reduce the emission of greenhouse gases in the short- or long-term. The most common project type is renewable energy, such as wind farms, biomass energy, or hydroelectric dams. Others include energy efficiency projects, the destruction of industrial pollutants or agricultural byproducts, destruction of landfill methane, and forestry projects. The Kyoto Protocol has sanctioned offsets as a way for governments and private companies to earn carbon credits which can be traded on a marketplace. The protocol established the Clean Development Mechanism (CDM), which validates and measures projects to ensure they produce authentic benefits and are genuinely "additional" activities that would not otherwise have been undertaken. Organizations that are unable to meet their emissions quota can offset their emissions by buying CDM-approved Certified Emissions Reductions: a long list of issued CERs can be found at http://cdm.unfccc.int/Issuance/cers_iss.html.

Operating outside the carbon market, emission offsets can be achieved through projects similar to the ones described above. For instance, the well-known carbon-storage capacity of trees and forest can be used to implement a reforestation programme, which can provide an actual offset for the project emissions. The IPCC Guidelines (2006) provide a methodology that, when combined with default biomass growth rates, allows for any country to calculate the annual increase in biomass, using estimates of area and mean annual biomass increment, for each land-use type and stratum (e.g., climatic zone, ecological zone, vegetation type). Using appropriate conversion factors, the equivalent amount of GHG sequestrated can be calculated. This and other models can be deeper studied in order to provide a simplified methodology for the calculation of GHG sinks obtained through this offset actions.

5. Calculation instance

This paragraph contains a calculation instance for GHG emissions from an office-based activity. Activity data were assumed according to common sense for a reference time equal to a month; similar calculations should be repeated for the other months in order to observe the emission trend of the organization during the year and to report the sum of the total emission at the end of the reference year. Emission factors were chosen among the ones reported in the previous paragraphs.

In this calculation instance, the organization/project occupies two offices, one in Cape Town and the other one in the field (Limpopo). Therefore both of them are included in the inventory boundaries.

5.1. Scope 1 emissions (fuel)

Scope 1 emissions are relative to the use of fuel in the office-based activity considered. Activity data assumed are listed below.

Transports

- Petrol use in the Cape Town office car: 200 L/month
- Diesel use in the Cape Town office car: 220 L/month
- Diesel use in the Limpopo office car: 300 L/month

Heating

- Natural gas use in the Cape Town office 250 m^3/month
- Coal use in the Limpopo office 150 kg/month

Electricity generation

- Diesel use in the Limpopo generator: 200 L/month

No specific emission factors were founded for the local context; updated default emission factors were used for the calculation of GHG emissions (compare paragraph 3.1). Table 33 sums up the GHG emissions from scope 1 activities.

Table 33: scope 1 emissions

Scope 1 (fuel)		**Source of emissions**	**Activity data**	**Emission factor**	**Emissions**
		Petrol car park	200 L	2.331 kg CO_2eq/L	466.2 kg CO_2eq
		Diesel car park	520 L	2.669 kg CO_2eq/L	1387.9 kg CO_2eq
		Naphtha	0 L	3.142 kg CO_2eq/L	0 kg CO_2eq
		Natural gas for heating	250 m^3	2.013 kg CO_2eq/ m^3	503.3 kg CO_2eq
		Diesel for generator	200 L	2.669 kg CO_2eq/L	533.8 kg CO_2eq
		Coal for heating	150 kg	2.874 kg CO_2eq/kg	431.1 kg CO_2eq
				Total	**3322.2 kg CO_2eq**

5.2.Scope 2 emissions (electricity purchased)

Scope 2 emissions are relative to electricity imports in the office-based activity considered. In this calculation instance, only electricity consumed by the office in Cape Town (connected to the grid) are considered. The emissions from electricity generated in the Limpopo office were already included in the scope 1 emissions. Emission factor used is sourced by paragraph 3.2. Table 34 sums up the GHG emissions from scope 2 activities.

Table 34: scope 2 emissions

Scope 2 (electricity)		**Source of emissions**	**Activity data**	**Emission factor**	**Emissions**
		Purchased electricity	625 kWh	1.015 kg CO_2eq/kWh	634.4 kg CO_2eq
				Total	**634.4 kg CO_2eq**

5.3.Scope 3 emissions (other indirect emissions)

Scope 3 emission are relative to fuel use in transport activities of the organization/project, not directly controllable by the organization (such as employee commuting and business travel) and other indirect emissions occurred in the use of products and of services (water supply and disposal, waste disposal).

For employee commuting, 7 employees are supposed to work in the Cape Town office and 2 in the Limpopo office. Data regarding their commuting modalities were surveyed by means of an annual questionnaire, aimed at gathering information about the kind of transport used and the distance home-office. Working days per months were registered by the administrative desk of the organization/project. Total distance per month (i.e. the activity datum required) was obtained by doubling the distance office-home and multiplying it for the number of working days.

Table 35: employee commuting data for the calculation instance

	Office	Kind of transport for commuting	Distance office-home	Working days per month	Total distance per month
Employee 1	CP	Bus (local)	10 km	21	420 km
Employee 2	CP	Car petrol 1.4-2.0	40 km	18	1440 km
Employee 3	CP	Car diesel > 2.0	3 km	20	120 km
Employee 4	CP	Bus (coach)	25 km	20	1000 km
Employee 5	CP	Car petrol >1.4-2.0	5 km	12	120 km
Employee 6	CP	Car petrol >2.0	10 km	20	400 km
Employee 7	CP	Walk	2 km	20	80 km
Employee 8	LMP	Car diesel > 2.0 (office)	3 km	20	120 km
Employee 9	LMP	Bike	5 km	20	200 km

No specific emission factors were found for the local context; therefore, updated default emission factors were used for the calculation of GHG emissions (compare paragraph 3.3).

Table 36: employee commuting emissions

		Source of emissions	Activity data	Emission factor	Emissions
Scope 3 (employee commuting)		Bus (local)	420 km	0.107 kg CO_2eq/km	44.9 kg CO_2eq
		Bus (coach)	1000 km	0.029 kg CO_2eq/km	29.0 kg CO_2eq
		Car – petrol >2.0L	400 km	0.298 kg CO_2eq/km	119.2 kg CO_2eq
		Car – petrol 1.4-2.0L	1560 km	0.215 kg CO_2eq/km	335.4 kg CO_2eq
		Car – diesel >2.0L	120 km	0.258 kg CO_2eq/km	31.0 kg CO_2eq
		Bike	200 km	0 kg CO_2eq/km	0.0 kg CO_2eq
		Walk	80 km	0 kg CO_2eq/km	0.0 kg CO_2eq
				SubTotal	**559.5 kg CO_2eq**

Table 36 sums up the GHG emissions from employee commuting. Note that emissions occurred in organization-owned vehicles (employee 8) were not considered as they are already included in scope 1 emissions.

For business travels, consultant travel plans and employee irregularly transports were considered. Activity data were gathered by the administrative desk of the organization/project. A round trip for a consultant from Italy (Milano Malpensa – Cape Town – Miilano Malpensa) and a single flight Milano-Cape Town (for instance for a CESVI employee) were considered as international flights, a double round trip Cape Town – Pretoria (for instance for a meeting or workshop) was calculated as domestic flight. Different emissions factors were used according to paragraph 3.3. Table 37 sums up the GHG emissions from employee commuting.

Table 37: business travel emissions

		Source of emissions	Activity data	Emission factor	Emissions
Scope 3 (business travels)		Taxi	90 km	0.161 kg CO_2eq/km	14.5 kg CO_2eq
		International flights	26700 km	0.083 kg CO_2eq/km	2208.6 kg CO_2eq
		Domestic flights	5240 km	0.095 kg CO_2eq/km	495.5 kg CO_2eq
				SubTotal	**2718.7 kg CO_2eq**

For other activities, different data were gathered. Water supply volume was obtained from water bill; wastewater volume was estimated assuming a 80% share of the water supply volume. Relative emission factors were obtained from UK Water.

Waste production was recorded from the administrative desk. Once per year a composition analysis of waste produced in the office is performed, in order to weight the different emission factors provided by DEFRA (see paragraph 2.2.2.6) with the percentage of each fraction. In this calculation instance, total waste production per month in the two offices was 10 kg of paper and 8 kg of plastics. Assuming that the material was virgin and it was disposed in a landfill, emission factor for paper resulted 1.5 kg CO_2eq/kg and for plastics 3.14 kg CO_2eq/kg. For paper use a default value equal to 1.3 kg CO_2eq/kg was used, according to a case study reported in paragraph 2.2.2.8. Table 38 sums up the GHG emissions from other sources.

Table 38: other indirect emissions

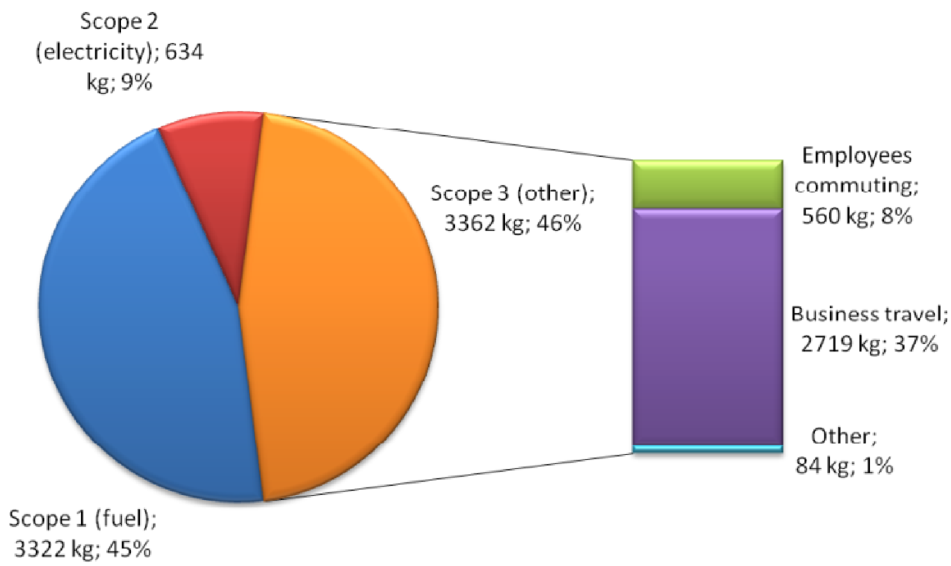
		Source of emissions	Activity data	Emission factor	Emissions
Scope 3 (other)		Water supply	5500 L	0.000276 kg CO_2eq/L	1.5 kg CO_2eq
		Water disposal	4400 L	0.000693 kg CO_2eq/L	3.1 kg CO_2eq
		Waste	18 kg	2.2 kg CO_2eq/kg	40.1 kg CO_2eq
		Paper use	30 kg	1.3 kg CO_2eq/kg	39.0 kg CO_2eq
				SubTotal	**83.7 kg CO_2eq**

Scope 3 total emission resulted equal to 3362 kg CO_2eq per the month considered.

5.4.Summary

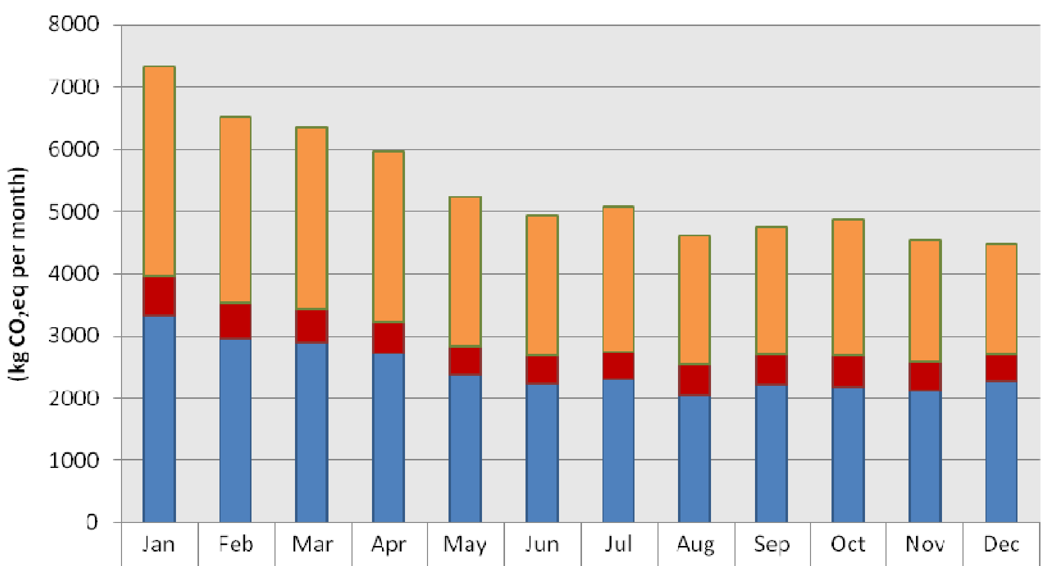
Figure 6 reports different scope emissions for the calculation emissions referred to a month. Total emission resulted equal to 7318 kg CO_2eq.

Figure 6: different scope emissions for the calculation instance (kg CO_2eq)



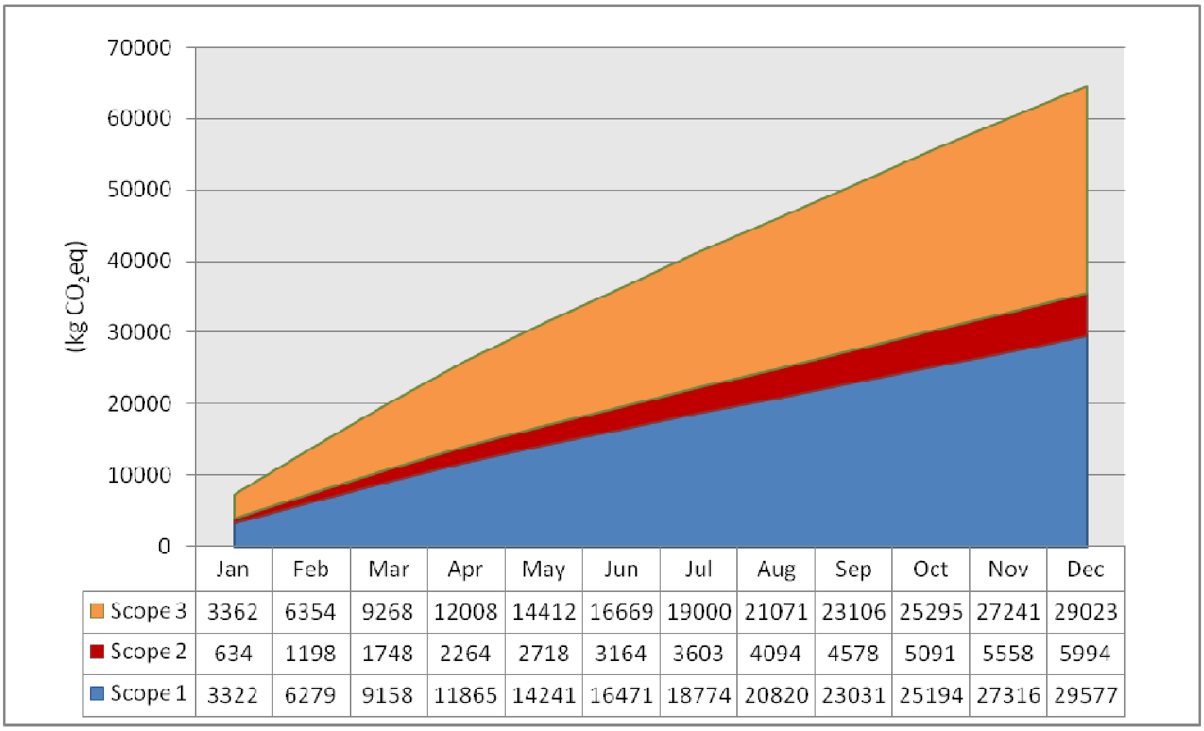
Total GHG emissions were calculated each month and registered separately; at the end of the reference year data were reported in a single output graphic, shown in Figure 7. Figure 8 shows the cumulated trend of emissions during the year.

Figure 7: emission trend in different months, according to scope



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Scope 3	3362	2992	2914	2740	2405	2257	2331	2071	2035	2189	1946	1782
Scope 2	634	564	549	517	453	446	440	491	484	513	467	436
Scope 1	3322	2957	2879	2707	2376	2230	2303	2046	2211	2163	2122	2261

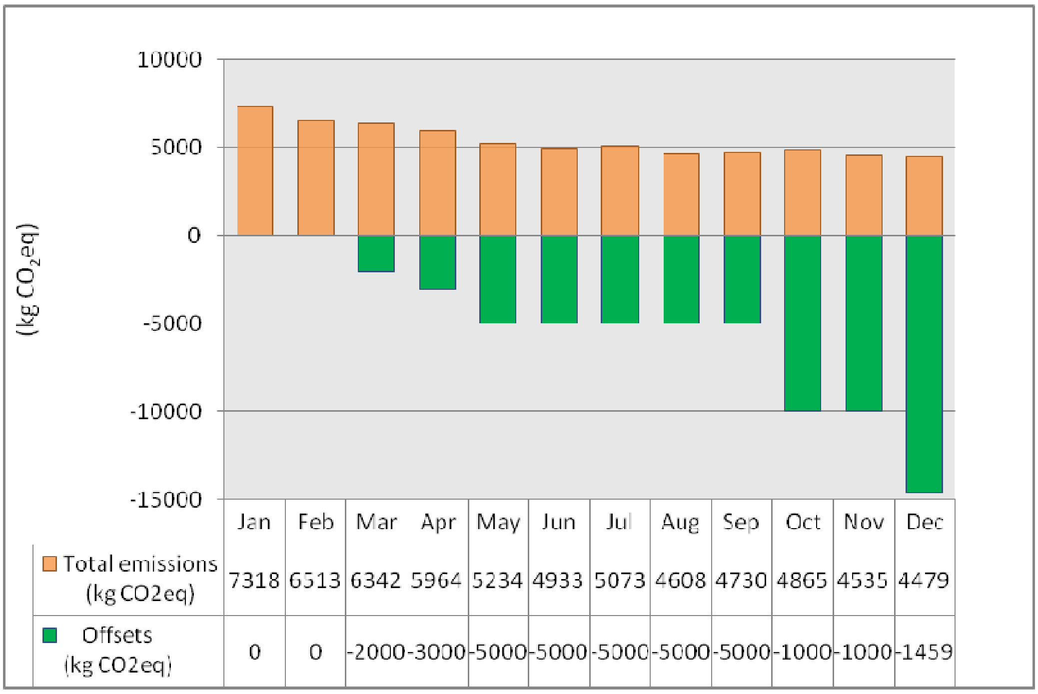
Figure 8: cumulated emission trend in different months, according to scope



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Scope 3	3362	6354	9268	12008	14412	16669	19000	21071	23106	25295	27241	29023
Scope 2	634	1198	1748	2264	2718	3164	3603	4094	4578	5091	5558	5994
Scope 1	3322	6279	9158	11865	14241	16471	18774	20820	23031	25194	27316	29577

Figure 9 shows the comparison between the emission produced by the organization and the offsets purchased or achieved through specific projects to compensate, in order to reach a “net zero” carbon emission balance at the end of the reference year.

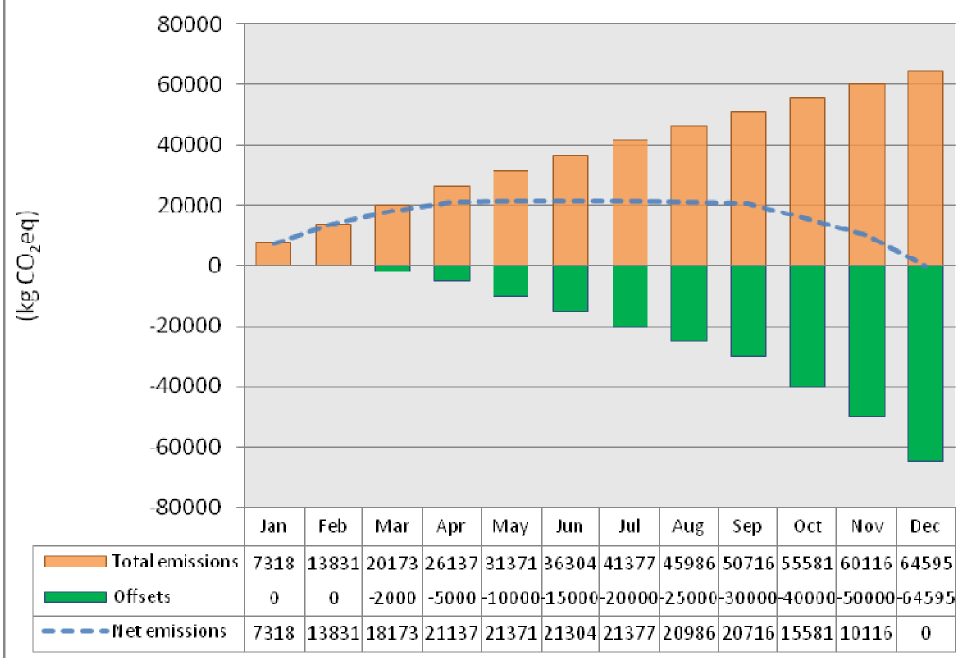
Figure 9: total emissions versus offsets per month



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total emissions (kg CO2eq)	7318	6513	6342	5964	5234	4933	5073	4608	4730	4865	4535	4479
Offsets (kg CO2eq)	0	0	-2000	-3000	-5000	-5000	-5000	-5000	-5000	-1000	-1000	-1459

Figure 10 shows the trend of cumulated emissions, compensated by the increasing amount of offsets achieved or purchased, reaching a "net zero" balance at the end of the year.

Figure 10: net emission trend in different months, per month and cumulated



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total emissions	7318	13831	20173	26137	31371	36304	41377	45986	50716	55581	60116	64595
Offsets	0	0	-2000	-5000	-10000	-15000	-20000	-25000	-30000	-40000	-50000	-64595
Net emissions	7318	13831	18173	21137	21371	21304	21377	20986	20716	15581	10116	0

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