
PRELIMINARY INVENTORY OF GREENHOUSE-GAS SOURCES AND SINKS - COLOMBIA 1990 - EXECUTIVE SUMMARY -

INTRODUCTION

This Executive Summary outlines the findings of a project undertaken to prepare a **National Inventory of Greenhouse Gases for Colombia**, as part of the Country Studies on Global Change. The project was started in July 1995 by researchers at the Colombian Academy of Exact, Physical and Natural Sciences, with financial support from the German Agency for Technical Cooperation (GTZ) and technical advice from the task force that conducted Venezuela's country study.

The aim of the project was to draw up a national inventory of anthropogenic greenhouse-gas emissions, by source and sink, in accordance with the United Nations Framework Convention on Climate Change (UNFCCC), and using IPCC/OECD methodology.

International standards for preparing national inventories are based on a common methodology designed to ensure that all procedures and approaches adopted in estimating greenhouse emissions are consistent and transparent and the findings systematically comparable.

National inventories are a useful tool for predicting greenhouse emissions under different economic-development scenarios and identifying the best strategies that the country can use to mitigate them.

METHODOLOGY

Estimates for all sources were made on the basis of the methodology established by IPCC for preparing national greenhouse-gas inventories (IPCC/OECD, 1995). Where local information was available for source categories, emission rates were estimated by relying on bibliographic references, technical visits and interviews with experts. In all other cases, default values suggested by IPCC's methodology were used.

The project's final report presents the findings obtained for a national inventory of greenhouse gases, together with analyses and estimates for the respective categories of sources and sinks. It reviews the main forms of anthropogenic activity accountable for emissions, and describes particular situations that may introduce additional elements into the inventory-making process. The report also discusses the specific methodology, data and

sources of information used in assessing each category.

FINDINGS

The gases listed in the inventory are carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), nitrogen oxides (NO_x), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOC).

Table 1 presents the greenhouse emissions by category.

The largest anthropogenic source of carbon-dioxide emissions in Colombia is land-use change and forestry, accounting for 66.6% of total CO₂ emissions, compared with only 31.4% from the energy sector.

Table 1. Preliminary inventory of greenhouse gases, Colombia 1990 (Gg)

CATEGORIES OF GREENHOUSE GAS SOURCES AND SINKS	CO ₂	CH ₄	N ₂ O	NO _x	CO	COVDM
1 All energy sources (fuel burning & fugitives)	52383	198.25	1.19	352.91	5548.36	135.47
A Fuel burning	52200	27.46	1.19	352.91	5548.36	135.47
Energy and transformation industries	12655	0.38	0.06	61.00	5.03	
Industry	14895	0.33	0.16	68.73	80.86	
Transport	18706	5.99	0.22	170.23	1056.55	135.47
Commercial / Institutional	854	0.01	0.15	0.73	0.18	
Residential	3107	19.57	0.35	49.59	4331.85	
Agriculture/Forestry, other	1985	1.19	0.25	2.62	73.89	
Biomass burning for energy	35460	17.19	0.33	49.96	4372.28	
B Fugitive emissions	182	170.79				
Oil and natural gas systems	182	65.81				
Coal mining		104.99				
2 Industrial processes	3388					
A Non-metallic minerals (cement)	3388					
3 Agriculture		1407.97	7.35	24.01	1220.38	
A Enteric fermentation		1123.94				
B Animal wastes		37.29				
C Rice growing		198.90				
F Savanna burning		41.08	0.51	18.22	1078.36	
E Agricultural-waste burning		6.76	0.16	5.79	142.02	
D Agricultural soils			6.68			
4 Land-use change and forestry	111275	234.25	1.61	57.73	2049.68	
A Logging and forest clearance	113329	234.25	1.61	57.73	2049.68	
B Pasture conversion	0					
C Cultivated-land abandonment						
D Forest management	(2053)					
5 waste		159.77				
A Landfills		159.04				
B Wastewater		0.72				
TOTAL NET NATIONAL EMISSIONS	167046	2000	10	435	8818	135

Table 2 shows the cumulative climatic effect of greenhouse-gas emissions in Colombia for 1990, the inventory's base year. Emissions are listed by gas and

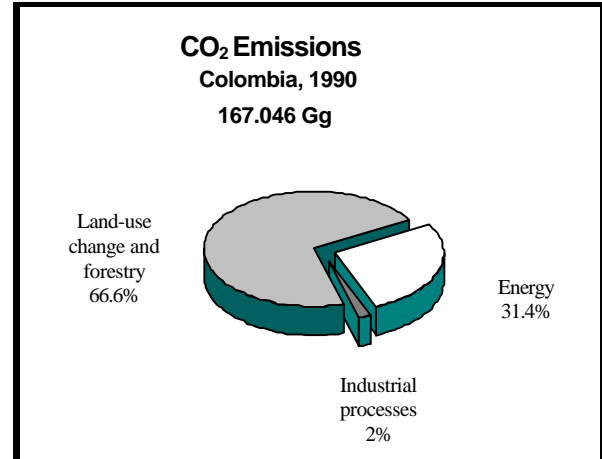
source, in terms of overall molecular weight (Gg) and percentage share of radiative forcing, based on the concept of Global Warming Potential (GWP).

Carbon dioxide is the most important greenhouse gas, accounting for 78.7% of cumulative warming effect. Methane accounts for 19.8%, with emissions produced mainly by enteric fermentation in cattle and by farming activity.

25% since then, mainly from the use of fossil fuels.

Table 2. Cumulative climatic effect of greenhouse-gas emissions

Gas	Emissions Total molecular weight (Gg)	GWP 100-year horizon	Share of radiative forcing (%)
CARBON DIOXIDE(CO₂)	167045	1	78.7
Combustion	52200		24.6
Fugitive emissions	182		0.1
Industrial Processes	3388		1.6
Land-use change and forestry	111275		52.4
METANO (CH₄)	2000	21	19.8
Combustion	25		0.2
Fugitive emissions	173		1.7
Agriculture	1408		13.9
Land-use change and forestry	234		2.3
Waste	160		1.6
OXIDO NITROSO (N₂O)	10.14	310	1.5
Combustion	1.18		0.2
Agriculture	7.35		1.1
Land-use change and forestry	1.61		0.2
TOTAL			100



In 1990 carbon-dioxide emissions in Colombia amounted to 167,046 Gg, giving a per-capita rate of 5.2 tons /year. The major sources were land-use change and forestry (especially logging and forest clearance), as well as the energy sector (fuel burning).

The following sections review each gas in turn, summarizing its estimated emissions and analyzing the relative importance of each category of emission.

Energy Sector

CARBON-DIOXIDE EMISSIONS

Emissions from this sector occur during combustion, when a fuel's carbon content combines with oxygen. Carbon content varies significantly among fossil fuels, depending on the type of fuel. Thus, coal contains the greatest amount of carbon by unit of energy, whereas oil and natural gas respectively contain 25% and 50% less than coal.

Carbon dioxide is responsible for about one third of natural greenhouse effects. The atmospheric concentration of carbon dioxide has been observed to be rising steadily worldwide since the beginning of the industrial age, because of human activity. CO₂ concentration in the earth's atmosphere has increased by more than

In 1990 Colombia's energy sector released 52,383 Gg of carbon dioxide, accounting for 31.4% of the country's CO₂ emission. Fuel-based energy was responsible for 52,200 Gg, while fugitive emissions from oil and gas barely amounted to 182 Gg (or 0.35% of the sector's total).

Top-down analysis shows that the burning of petroleum and its byproducts produced the greatest share of CO₂ emissions (30,507 Gg), followed by use of coal (13,470 Gg) and of natural gas (8,742 Gg).

Emissions from each source were estimated by bottom-up analysis. The transport sector accounted for 36% of CO₂ emissions from fuel burning, the industrial sector for 29% and energy-transformation centers for 25%. The residential sector generated only 6%, despite consuming about a third of the country's final energy output.

Stationary sources gave off 38,303 Gg of carbon-dioxide emissions, mostly from the burning of oil and coal. The industrial sector produced the largest share with 14,895 Gg (39%), followed by thermoelectric generation with 8,398 Gg (22%), oil and gas transformation with 4,257 Gg (11%) and the residential sector with 3,107 Gg (8%). The rest came from the commercial, farming and construction sectors.

The electric sector's CO₂ emissions by fuel type were as follows: 4,380 Gg from natural gas, 3,526 Gg from coal, and 492 Gg from distillates of petroleum, industrial gases and crude oil.

Emissions from mobile sources amounted to 14,895 Gg, produced mostly by motor gasoline with a share of 12,162 Gg (81.7%), followed by diesel with 2,481 Gg (16.7%), the remainder being attributed to compressed natural gas, fuel oil and coal.

Cement Industry

Calcination of CaCO₃ in cement making released 3,388 Gg of carbon dioxide, accounting for 2% of total CO₂ emissions.

Land-Use Change and Forest Management

The concentration of greenhouse gases in the atmosphere has been rising steadily through human activity that alters the biosphere in the process of producing food, fuel and fibers. Carbon dioxide is regarded as the most important gas associated with changes in land use. Two source categories are considered in the national inventory: deforestation (logging and forest clearance), and forest management and exploitation. In a departure from the methodology followed, conversion of pastures to cultivated land and abandonment of managed lands were not considered as the third and fourth categories because of the dearth of reliable information, which calls for research.

Change in land use is the major cause of greenhouse-gas emissions in Colombia. In 1990 it generated 111,275 Gg of carbon-dioxide emissions, accounting for 66.6% of the national total for this gas. The chief source of these emissions was deforestation and the burning of deforested sites, a common practice in the past forty years for extending agricultural frontiers.

Deforestation

The main causes of deforestation in Colombia are new settlements, infrastructure building, energy use, illegal crops, forest clearing and non-sustainable forest management. The exact damage caused by each of these factors is not known because of the lack of studies and of forest-monitoring by remote sensing. The annual rate of deforestation in Colombia is variously estimated, but the Environment Ministry's official figure is the rate reported by FAO in 1993 for the period 1980-1990: 367,000 hectares per year.

The base-year estimate for carbon dioxide emissions resulting from deforestation is 113,329 Gg, representing 68% of total CO₂ emissions.

Forest Management and Exploitation

This category sequesters 1,409 kt of carbon, equivalent to 5,166 Gg of carbon dioxide (ktC^{44/12}). Although it is important as a carbon-dioxide sink, its effect may not appear significant compared with the country's total greenhouse emissions, for it represent barely 3% of these emissions, but its potential impact can be very great. Over 1970-1990, a total of 310,000 hectares of natural forest were exploited to supply raw materials to forest-product industries, and some 222,647 hectares of forest were planted.

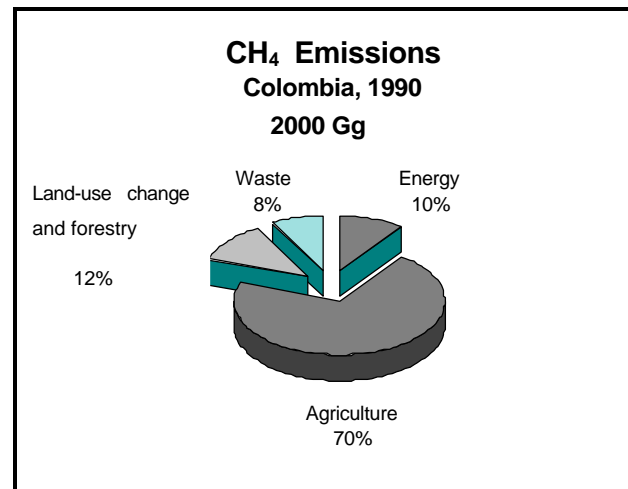
The release of carbon in this sector is caused by the removal of biomass to meet domestic industrial demand for timber. Total biomass removal in 1990 is estimated at 1,886 kt of dry material, resulting in the emission of 849 kt of

carbon into the atmosphere. In terms of molecular weight of carbon dioxide, this gives 3,112 Gg.

In this sector, the difference between the amount of carbon released and the amount sequestered is 560 kt of accumulated carbon, equivalent to 2,053.4 Gg of carbon dioxide.

METHANE EMISSIONS

Methane produces the second largest global-warming effect. During the eighties it was responsible for about 15% of radiative forcing worldwide. Methane concentration has doubled over the past 300 years and is growing at a rate of about 1% a year. Although methane emissions are significantly lower than carbon-dioxide emissions, they play a large part in global warming, because, given their direct and indirect impact, methane's Global Warming Potential over 100 years is 21 times that of carbon dioxide.



Methane emissions in Colombia are estimated at 2,000 Gg for the base year. Their main anthropogenic sources are

connected with farming and account for 70% of the total, followed by land-use change (12%) and the energy sector (10%). Methane emissions resulting from waste management make up only 8% of the total.

Energy Sector

The energy sector produced 198 Gg of methane emissions: 27 Gg from fuel burning, and the rest (171 Gg) as fugitive emissions. Coal mining was responsible for 105 Gg (60%) of these fugitive emissions, while the oil and gas industry gave off 66 Gg (40%).

It is noteworthy that the residential sector, by using wood as fuel, accounted for 19.5 Gg (70%) of CH₄ emissions from fuel burning.

Agriculture

Farming is the major source of methane emissions, producing 70% (1408 Gg) of the national total. Stockbreeding is responsible for 80% of this category's CH₄ emissions, while rice growing and savanna burning cause only 14% and 3% respectively. The burning of farm residues in the field is a negligible source.

Enteric Fermentation

Methane emissions from enteric fermentation are estimated at 1,124 Gg, representing 56% of the country's total CH₄ emissions and about 80% of the agriculture sector's. Dairy and meat cattle are responsible for 95.5% of enteric-fermentation emissions of methane, while other domestic animals, such as sheep, pigs, horses, mules, donkeys and goats,

produce only 4.5% of the total. Estimations for enteric fermentation were made by using the IPCC's simplified Tier 1 method.

Manure Management

Manure management is not common practice in Colombia, because stockbreeding is mostly carried out on an extensive scale. Almost all dung from domestic animals is used as a solid fertilizer for pastures or left where it is dropped. Methane released by dung is estimated at 37.3 Gg, amounting to 1.9% of total CH₄ emissions and 3.2% of emissions produced by domestic animals. The major sources are cattle (58%), pigs (18.5%) and poultry (11%).

Rice Growing

Approximately 10% of the country's methane emissions and 14% of the agriculture sector's are caused by rice growing, which produces an estimated emission of 199 Gg. This estimate was made on the basis of data from the 1990 National Rice Census, which gives a figure of 65% for continually flooded rice paddies, and 35% for upland rice fields (including manual upland fields).

Savanna Burning

On Colombia's Eastern Plains burning is traditionally carried out during two seasons of the year to eliminate weeds and pests and also to renew pastures. Highland savannas are burned at the start of the rainy season, whereas lowland savannas, wet during the rainy season, are subjected to burning at the start of the dry season.

The total area of savanna burned each year is not known exactly, the relevant data being highly uncertain because of the lack of national statistics on the frequency and extension of savanna burning. However, as a first approximation, the overall savanna area may be assumed to be burned in its entirety once every three years. This assumption has been confirmed by various Colombian experts, some of whom suggest a higher frequency.

Savanna burning is estimated to release 41 Gg of methane, accounting for 2% of the country's CH₄ emissions and 3% of the agriculture sector's.

Burning of Crop Residues

In Colombia the burning of crop residues causes very little methane emission: barely 6.8 Gg. Estimates are based on the following crops: sugar cane, maize, rice, cotton and African palm. Crops are usually burned for phytosanitary reasons.

Landfills

Landfills do not figure as a significant source of methane emission in Colombia because 70% of solid waste matter is deposited in open-air dumps. Methane given off by landfills is estimated at 158 Gg, 8% of the national total.

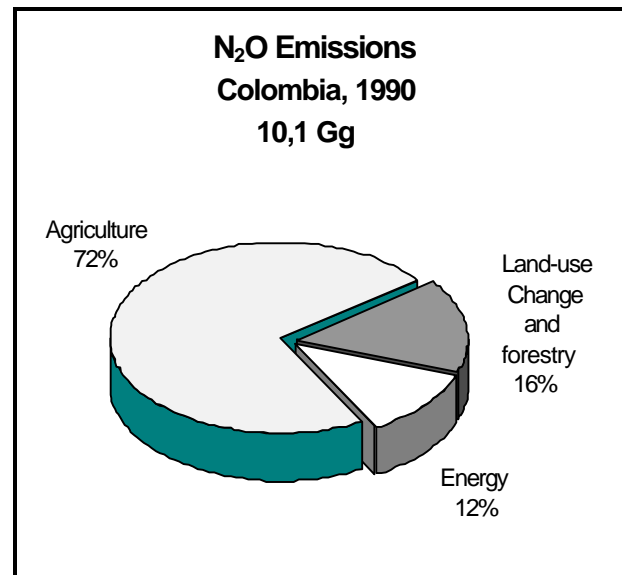
Other Methane Sources

Other activities that generate methane in Colombia are connected with land-use change and wastewater management. Biomass burning in deforestation is included in the national inventory, with emissions estimated at 234 Gg, or 11.7% of the national total. For greenhouse-

accounting purposes, wastewater treatment is a negligible source of methane: 0.7 Gg.

NITROUS OXIDE EMISSIONS

Nitrous oxide is another gas that contributes to infrared absorption and hence to greenhouse effect. According to the World Meteorological Organization (WMO), the current atmospheric concentration of nitrous oxide is 8% higher than in pre-industrial times. Nitrous oxide's capacity to trap heat in the atmosphere, over 100 years, is 310 times as great as carbon dioxide's, and its annual rate of atmospheric accumulation is between 0.2% and 0.3%.



Nitrous-oxide emissions in Colombia are estimated at 10 Gg for 1990. The agricultural sector provided the greatest share (72%), mainly from the use of fertilizers in farm-soil management, followed by land-use change (16%) and the energy sector (12%). N₂O emissions

were also caused by the use of biomass as a fuel and by fossil-fuel burning. Although it is not certain how nitrous oxide is produced by these sources, it is a fact that its production depends strongly on temperature.

Energy Sector

Colombia's energy sector emitted 1.19 Gg of nitrous oxide. The residential sector, by burning wood for cooking, produced the most: 0.35 Gg (29% of emissions from combustion). The transport sector generated 0.22 Gg (18%), the agricultural sector and other sources 0.25% (21%), and the commercial/official and industrial sectors 0.15 Gg (13%) and 0.16 Gg (14%) respectively. The energy-transformation sector's share was 5% of the total.

Agriculture

The farming sector was the main source of nitrous-oxide emissions, producing 72% of the national total. Emissions from the chemical fertilizers used in soil management amounted to 6.7 Gg, or 91% of the sector's total. Organic fertilizers were not included in estimates, for lack of reliable data.

Savanna burning produced 0.5 Gg of nitrous oxide, while the burning of crop residues in the field accounted for 1.6% of the national estimate.

Other Sources

Another source of nitrous-oxide emission in Colombia is biomass burning, mostly occurring in the process of forest clearance. Emissions from this source

amounted to 1.6 Gg, representing 16% of the national total.

EMISSIONS OF CARBON MONOXIDE AND NMVOCs.

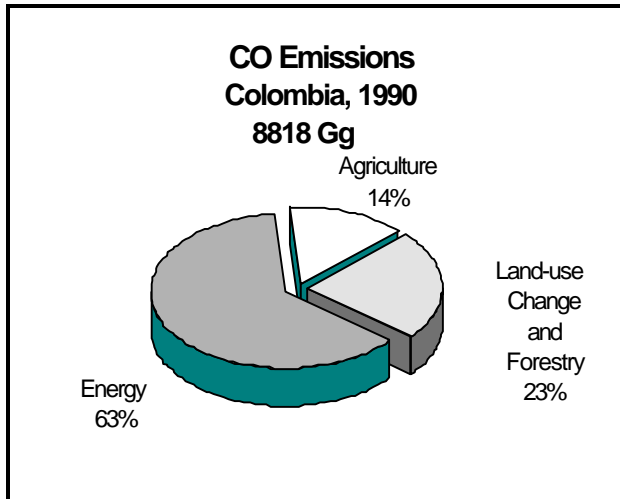
Non-methane volatile organic compounds (NMVOCs) are gas compounds release into the atmosphere in small amounts, as a result of incomplete combustion. NMVOCs and carbon monoxide contribute to smog formation in cities and have become the subject of emission-control policies in a number of countries. These gases have an indirect impact on global climate. Acting as precursors of tropospheric ozone is their major role. Besides contributing to ozone formation, they alter the average lifetime of other greenhouse gases.

Carbon-monoxide emissions in Colombia were estimated at 8,818 Gg. The energy sector produced 63% of this amount, while agricultural activity and changes in land use together accounted for 37%.

Energy Sector

The energy sector's share of carbon-monoxide emissions was estimated at 5,548 Gg. Wood burning by the residential sector produced 4,332 Gg, accounting for about 79% of CO emissions from fuel burning, or 49% of the national total.

The transport sector was responsible for 1,056 Gg of carbon- monoxide emissions, 12% of the country's total.



Emissions of non-methane volatile organic compounds amounted to 135 Gg, generated exclusively by the transport sector.

Savanna Burning

The amount of carbon monoxide produced by savanna burning was 1,078 Gg, 12% of the national total.

Land-Use Change

Forest clearance by burning, which goes hand in hand with deforestation, accounted for 23% (about 2,050 Gg) of total CO emissions.

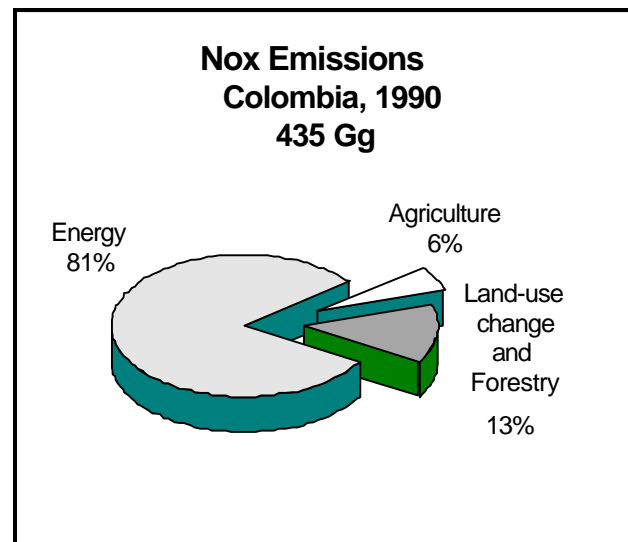
EMISSIONS OF NITROGEN OXIDES

Nitrogen oxides produce direct acidification effects in the atmosphere and play a part in ozone formation; they have therefore been a subject of constant concern in environmental policymaking in most countries. Like carbon monoxide, they are generated by incomplete combustion. Colombia's NO_x emissions for 1990 were estimated at 435 Gg: 81% from fossil-fuel

burning, and the remaining 19% from biomass-burning in non-energy sectors.

Energy Sector

Fossil-fuel burning is the largest source, discharging 353 Gg of nitrogen oxides: 183 Gg from stationary sources and 170 Gg from mobile ones.



Other Sources

As in the case of nitrous oxide, biomass burning associated with land-use change and certain farming practices was another source of nitrogen-oxide emissions. The burning of deforested sites, savanna land and crop residues produced 82 Gg of nitrogen oxides, accounting for 19% of total NO_x emissions.

UNCERTAINTIES

Uncertainties are bound to occur in estimating the emissions and removals of atmospheric gases, for any country. Major causes of uncertainty include:

1. Differing interpretations of source and sink categories, definitions and assumptions, units, etc.
2. Use of average values, especially for emission factors and population assumptions.
3. Uncertainty in the basic socio-economic data used to make estimates for each category.
4. Scientific uncertainty in understanding the basic processes that lead to emissions and removals.

Regarding points 2 and 3, uncertainty ranges were estimated for each source category, following IPCC methodology, which lists the ranges separately for emission factors and for data. Table 3 presents these estimates and overall uncertainty.

In Table 3 the figures under "Emission factor" refer to uncertainty in both methodology and emission factors.

As can be seen, the category of land-use change and forestry as a carbon-dioxide source (accounting for 70% of the country's CO₂ emissions) has a 33% emission-factor uncertainty and a 50% data uncertainty, giving an overall uncertainty of 60%. This category requires further attention in future to reduce uncertainty in Colombia's inventory.

Despite the weakness and limitations reflected by such a broad range of uncertainties, this preliminary inventory

presents a complete picture of greenhouse-gas emissions and removals in Colombia, and provides a powerful tool for assessing and planning mitigation strategies that Colombia should implement to cut future emissions of these gases.

Table 3. Uncertainty in Emission Factors and Data

Gas	Source Category	Emission factor	Data	Overall uncertainty
CO ₂	Energy	7%	5%	9%
CO ₂	Cement	5%	1%	5%
CO ₂	Land-use change	33%	50%	60%
CH ₄	Biomass burning	50%	50%	70%
CH ₄	Oil and Natural gas	55%	5%	55%
CH ₄	Coal mining	55%	5%	55%
CH ₄	Rice growing	>60%	10%	n.c.
CH ₄	Waste	>60%	30%	n.c.
CH ₄	Animals	25%	10%	36%
N ₂ O	Biomass burning	> 60%	50%	n.c.
N ₂ O	Agricultural soils	> 60%	10%	n.c.

n.c.: Not calculable.

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