NATIONAL INVENTORY REPORT OF GREENHOUSE GAS EMISSIONS AND REMOVALS IN UKRAINE FOR 1990-2004

KYIV 2006

PREFACE

This report is National Inventory Report (NIR) of Greenhouse Gas (GHG) Emissions and Removals in Ukraine for 1990-2004. NIR has been prepared under supervision of the Ministry of Environmental Protection of Ukraine (MEP) by Ukrainian Institute of Hydrometeorology (UIH) staff with methodological and informational support of the European commission project for the technical assistance "Technical Assistance to Ukraine and Belarus with Respect to their Global Climate Change Commitments" and also ICF consortium (Great Britain) and Agency for Rational Energy Use and Ecology (ARENA-ECO) (Ukraine). The main inventory developers are the following:

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RESUME

R1 Information about Inventories of Greenhouse Gas Emissions and Climate Change

Ukraine signed the United Nations Framework Convention on Climate Change (UNFCCC) в in June 1992, the Parliament ratified it in October 1996, and Ukraine became the Party in August 1997. UNFCCC Parties commit themselves to develop, update periodically, publish and submit to the UNFCCC Secretariat their national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases.

This GHG Inventory considers the emissions of four direct greenhouse gases provided in Kyoto Protocol (KP) to the UNFCCC, namely carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs). Emissions of other direct GHG, i.e. hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF_6), are not assessed in this inventory, because these gases are not produced in Ukraine and information of their use is not available.

Emissions of the precursor gases, namely carbon monoxide (CO), nitrogen oxides (NO_x), and non-methane volatile organic compounds (NMVOCs) are also provided in the Inventory, as well as the emissions of sulphur dioxide (SO_2).

Format of National Inventory Report for 1990-2004 meets the requirements of the UNFCCC provided in Decision 18/CP8 and described in the Guidelines UNFCCC/CP/2002/8. In addition to this NIR the results of GHG inventory in common reporting format (CRF) are also submitted to the UNFCCC Secretariat. All materials are available on the web-site of MEP (www.menr.gov.ua).

NIR has the following structure. Introduction (chapter 1) contains background information on greenhouse gas inventories and climate change, as well as the brief description of the process of inventory preparation. Chapter 2 gives description and interpretation of emission trends for aggregated greenhouse gas emissions and greenhouse gas emissions by gases and sources. Chapters 3-9 describe GHG emission source categories according to the sectors of Intergovernmental Panel on Climate Change (IPCC). Chapter 10 provides information about recalculations and improvements to the inventory. The annexes to the NIR include key sources analysis, detailed discussion of methodology and data for estimating GHG emissions for individual sources, assessment of completeness and uncertainty of the inventory, as well as the summary CRF tables.

R2 Brief Description of National Emissions Trends

Emissions of all direct GHG in CO_2 and carbon equivalents are presented at the Tables R.1 and R.2 respectively.

The year 1990 is the base year for CO_2, CH_4, N_2O, whereas 1995 is the base year for HFCs, PFCs and SF_6.

Table R. 1. GHG Emissions in CO_2 equivalent by gas, mln t

Gas	Mln t, CO_2 equivalent																Change, %
	Base year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Base year-2004
CO_2 (excluding net emissions of CO_2 from LULUCF)	719.37	719.37	620.18	535.12	480.48	430.98	393.51	357.85	344.60	308.19	309.29	296.53	298.87	301.29	320.54	316.94	-55.94
CH_4	151.17	151.17	138.28	131.32	118.61	107.30	94.35	86.93	79.98	76.55	75.53	76.89	76.48	75.78	74.52	74.11	-50.97
N_20	54.64	54.64	50.57	46.06	41.59	36.72	33.15	27.85	26.75	25.23	23.14	21.58	23.52	23.34	20.89	22.28	-59.22
HFCs																	
PFCs	0.15	0.20	0.16	0.12	0.12	0.14	0.15	0.12	0.13	0.10	0.09	0.10	0.10	0.09	0.07	0.08	-47.58
SF_6																	
Total emissions without LULUCF	925.38	925.38	809.18	712.62	640.81	575.15	521.17	472.75	451.46	410.08	408.05	395.10	398.97	400.50	416.03	413.42	-55.32
Net CO_2 emissions from LULUCF	-33.84	-33.84	-36.00	-31.87	-30.94	-39.29	-42.43	-48.42	-46.94	-52.50	-43.56	-38.04	-42.01	-37.34	-39.22	-32.14	-5.02
CO_2 (including net emissions of CO_2 from LULUCF)	685.53	685.53	584.18	503.25	449.54	391.69	351.08	309.44	297.67	255.69	265.73	258.49	256.86	263.95	281.32	284.80	-58.46
Total (net) emissions (including net emissions of CO_2 from LULUCF)	891.54	891.54	773.18	680.75	609.87	535.86	478.74	424.33	404.52	357.57	364.48	357.06	356.96	363.15	376.80	381.27	-57.23

Table R. 2. GHG Emissions in carbon equivalent by gas, mln t

Gas	Mln t, C equivalent																Change, %
	Base year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Base year-2004
CO_2 (excluding net emissions of CO_2 from LULUCF)	196.19	196.19	169.14	145.94	131.04	117.54	107.32	97.60	93.98	84.05	84.35	80.87	81.51	82.17	87.42	86.44	-55.94
CH_4	41.23	41.23	37.71	35.81	32.35	29.26	25.73	23.71	21.81	20.88	20.60	20.97	20.86	20.67	20.32	20.21	-50.97
N_20	14.90	14.90	13.79	12.56	11.34	10.02	9.04	7.59	7.30	6.88	6.31	5.89	6.42	6.37	5.70	6.08	-59.22
HFCs																	
PFCs	0.04	0.06	0.04	0.03	0.03	0.04	0.04	0.03	0.03	0.03	0.02	0.03	0.03	0.02	0.02	0.02	-47.58
SF_6																	
Total emissions without LULUCF	252.38	252.38	220.69	194.35	174.77	156.86	142.14	128.93	123.13	111.84	111.29	107.76	108.81	109.23	113.46	112.75	-55.32
Net CO_2 emissions from LULUCF	-9.23	-9.23	-9.82	-8.69	-8.44	-10.72	-11.57	-13.20	-12.80	-14.32	-11.88	-10.38	-11.46	-10.18	-10.70	-8.77	-5.02
CO_2 (including net emissions of CO_2 from LULUCF)	186.96	186.96	159.32	137.25	122.60	106.83	95.75	84.39	81.18	69.73	72.47	70.50	70.05	71.99	76.72	77.67	-58.46
Total (net) emissions (including net emissions of CO_2 from LULUCF)	243.15	243.15	210.87	185.66	166.33	146.14	130.57	115.73	110.32	97.52	99.40	97.38	97.35	99.04	102.76	103.98	-57.23

R3 Review of emission estimations and trends for individual source and sink categories

GHG emissions are assessed in the following IPCC sectors:

- Energy;
- Industrial Processes;
- Solvents;
- Agriculture;
- Land-Use, Land-Use Change and Forestry (LULUCF);
- Waste.

GHG emissions trends for the period 1990-2004 by sector are presented at the Table R.3 according to UNFCCC /CP/2002/8.

Table R. 3. Emissions trends by sector, mln t CO_2 equivalent

Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1. Energy	687.6	595.1	508.3	465.5	427.7	387.2	351.1	327.5	287.9	285.4	270.7	271.4	272.5	287.2	282.5
2. Industrial Processes	128.1	112.0	109.7	86.4	68.9	63.4	62.9	72.1	73.3	77.0	82.7	83.5	84.3	89.6	91.4
3. Solvents	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3
4. Agriculture	101.4	93.6	86.2	80.3	69.9	62.0	50.2	43.2	40.1	36.9	32.9	35.1	34.7	30.1	30.4
5. LULUCF (net absorption)	-33.8	-36.0	-31.8	-30.9	-39.2	-42.4	-48.4	-46.9	-52.5	-43.5	-38.0	-42.0	-37.3	-39.2	-32.1
6. Waste	7.9	8.0	8.1	8.2	8.2	8.2	8.2	8.2	8.3	8.3	8.4	8.5	8.7	8.7	8.9
7. Other															
Total (with LULUCF)	891.5	773.2	680.8	609.9	535.9	478.7	424.3	404.5	357.6	364.5	357.1	357.0	363.2	376.8	381.3
Total (without LULUCF)	925.4	809.2	712.6	640.8	575.1	521.1	472.7	451.5	410.1	408.0	395.1	398.9	400.5	416.0	413.4

Note: emissions in sector «Solvents», excluding nitrous oxide, represent NMVOC emissions and are not taken into account in this table.

GHG emissions in Energy sector account for the largest share in the total emissions. In 2004 the share of this sector was 68.3% of total emissions (without LULUCF). CO_2, CH_4 and N_2O are emitted in Energy sector. In 2004 emissions decreased by 59% compared to 1990. The main emission sources were fuel combustion and fugitive emissions.

The next significant emission source (22.1% of total emissions without LULUCF) was sector «Industrial Processes», where CO_2, CH_4, N_2O and PFCs emissions occurred. In 2004 emissions in this sector decreased by 29% compared to 1990. The main emission sources were metal production and mineral products.

Mainly NMVOC are emitted in the sector «Solvents». Direct GHG emissions are practically lacking. This inventory has taken into account only N_2O emissions from medicine. The share of these emissions was approximately 0.1 % in 2004. In 2004 emissions in this sector decreased by 9% compared to 1990.

CH_4 and N_2O are emitted in the sector «Agriculture» in Ukraine. In 2004 emissions in this sector decreased by 70% compared to 1990. Such sharp decline was caused by reduction of livestock population and fertilizers use due to economic crisis. In 2004 the share of this sector was 7.4% of total emissions (without LULUCF). The main emission sources were enteric fermentation and agricultural soils.

Sector LULUCF differs from the other sectors, because it includes both emission sources and sinks. CO_2, CH_4 and N_2O are emitted in this sector, whereas the net CO_2 absorption in this sector totaled nearly 10% from the total GHG emissions in other five sectors. In 2004 the net absorption in this sector decreased by 5% compared to 1990.

The share of emissions in the sector «Waste» totaled 2.1%. The main CH_4 emission source in this sector is solid waste disposals on land, N_2O emissions source – human sewage. In 2004 emissions from this sector increased by 12% compared to 1990.

R4 Other Information

Table R.4 presents indirect GHG emissions trends in 1990-2004.

Table R. 4. Indirect GHG emissions trends, thous. t

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
NO_x	2 162	1 857	1 536	1 405	1 278	1 153	1 049	956	821	779	729	733	729	756	736
CO	6 167	4 881	3 770	3 206	2 728	2 295	1 966	1 681	1401	1265	1129	1132	1129	1141	1127
NMVOC	2 241	1 897	1 432	1 124	911	772	636	551	487	511	431	445	456	526	516
SO_2	5 298	4 372	3 564	3 188	2 847	2 531	2 260	2 027	1674	1633	1452	1456	1435	1453	1378

Emissions of precursors decreased in comparison to 1990 in Ukraine. The main source of these emissions is Energy sector, the second one – Industrial processes.

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1 INTRODUCTION

1.1 Information about Inventories of Greenhouse Gas Emissions and Climate Change

1.1.1 National Inventory Report Preparation

Ukraine signed the United Nations Framework Convention on Climate Change (UNFCCC) в in June 1992, the Parliament ratified it in October 1996, and Ukraine became the Party in August 1997. UNFCCC Parties commit themselves to develop, update periodically, publish and submit to the UNFCCC Secretariat their national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases.

This report is National Inventory Report on GHG emissions and removals in Ukraine for the period 1990-2004. It includes estimations of national GHG emissions and removals in 1990-2004, as well as methodology of calculations.

Format of National Inventory Report for 1990-2004 meets the requirements of the UNFCCC provided in Decision 18/CP8 and described in the Guidelines UNFCCC/CP/2002/8. In addition to this NIR the results of GHG inventory in common reporting format (CRF) are also submitted to the UNFCCC Secretariat. All materials are available on the web-site of MEP (www.menr.gov.ua).

NIR has the following structure. Introduction (chapter 1) contains background information on greenhouse gas inventories and climate change, as well as the brief description of the process of inventory preparation. Chapter 2 gives description and interpretation of emission trends for aggregated greenhouse gas emissions and greenhouse gas emissions by gases and sources. Chapters 3-9 describe GHG emission source categories according to the sectors of Intergovernmental Panel on Climate Change (IPCC). Chapter 10 provides information about recalculations and improvements to the inventory. The annexes to the NIR include key sources analysis, detailed discussion of methodology and data for estimating GHG emissions for individual sources, assessment of completeness and uncertainty of the inventory, as well as the summary CRF tables.

This report is National Inventory Report (NIR) of Greenhouse Gas (GHG) Emissions and Removals in Ukraine for 1990-2004. NIR has been prepared by researches of Ukrainian under supervision of the Ministry of Environmental Protection of Ukraine (MEP) by Ukrainian Institute of Hydrometeorology (UIH) staff with methodological and informational support of the European commission project for the technical assistance “Technical Assistance to Ukraine and Belarus with Respect to their Global Climate Change Commitments” and also ICF consortium (Great Britain) and Agency for Rational Energy Use and Ecology (ARENA-ECO) (Ukraine).

1.1.2 Greenhouse Gases and Global Warming Potential

This GHG Inventory considers the emissions of four direct greenhouse gases provided in Kyoto Protocol (KP) to the UNFCCC, namely carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N2O), perfluorocarbons (PFCs). Emissions of other direct GHG, i.e. hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF_6), were not assessed in this inventory, because these gases are not produced in Ukraine and information of their use is not available.

Emissions of the precursor gases, namely carbon monoxide (CO), nitrogen oxides (NO_x), and non-methane volatile organic compounds (NMVOCs) are also provided in the Inventory, as well as the emissions of sulphur dioxide (SO_2).

Inventory developers used global warming potential (GWP) values provided by the IPCC (UNFCCC guidelines on reporting and review inventories adopted by 5th Conference of the Parties (Bonn, 1999) and confirmed by 8th Conference of the Parties (New-Deli, 2002) to express the emissions of different gases in CO_2 equivalent terms. GWP values are presented at the Table 1.1.

Table 1.1. IPCC global warming potential[1] values based on the effects of greenhouse gases over a 100-year time horizon

Greenhouse gas	Chemical formula	Global warming potential
Carbon dioxide	CO_2	1
Methane	CH_4	21
Nitrous oxide	N_2O	310
Hydrofluorocarbons		
HFC-23	CHF_3	11 700
HFC-32	CH_2F_2	650
HFC-41	CH_3F	150
HFC-43-10mee	$C_5H_2F_{10}$	1 300
HFC-125	C_2HF_5	2 800
HFC-134	$C_2H_2F_4$ (CHF_2CHF_2)	1 000
HFC-134-a	$C_2H_2F_4$ (CH_2FCF_3)	1 300
HFC-152-a	$C_2H_4F_2$ (CH_3CHF_2)	140
HFC-143	$C_2H_3F_3$(CHF_2CH_2F)	300
HFC-143-a	$C_2H_3F_3$(CF_3CH_3)	3 800
HFC-227ea	C_3HF_7	2 900
HFC-236fa	$C_3H_2F_6$	6 300
HFC-245ca	$C_3H_3F_5$	560
Perfluorocarbons		
Perfluoromethane	CF_4	6 500
Perfluoroethane	C_2F_6	9 200
Perfluoropropane	C_3F_8	7 000
Perfluorobutane	C_4F_{10}	7 000
Perfluorocyclobutane	C_4F_8	8 700
Perfluoropentane	C_5F_{12}	7 500
Perfluorohexane	C_6F_{14}	7 400
Sulphur hexafluoride	SF_6	23 900

[1] GWP values provided by the IPCC in its Second Assessment Report (1995)

1.2 GHG Inventory Preparation Process

Inventory preparation process includes the following stages:

1. Identifying information needs to meet methodological requirements provided by IPCC Revised Guidelines and Good Practice Guidance.

2. Preparing and distributing information inquiry (official letters, telephone calls, e-mails) for identifying data sources.

3. Identifying potential data sources, including organizations and experts.

4. Preparing and distributing specific inquiry, as well as further work with data sources, including placement of contracts for consulting services.

5. Receiving initial data and its verification to establish completeness and correspondence to inquiry. Analyzing information from the point of view of its direct use for GHG emission calculation.

6. Analyzing significant differences in the time series of initial data or sharp divergence from initial data of previous inventories and specifying initial data as a result of additional inquiry.

7. Expert consulting on complicated problems of GHG inventory preparation.

8. Systematization of initial data and preparation for its use for the calculations.

9. Archiving initial data for inventory.

10. Calculating GHG emissions and removals.

11. Eliminating calculation errors and lacks.

12. Preparing draft inventory report using format recommended by IPCC.

13. Placing inventory report on the web-site of MEP for receiving comments and suggestions.

14. Revising inventory taking into account received suggestions.

15 Preparing final inventory report.

16. Submitting inventory report to the UNFCCC Secretariat.

Quality assurance and quality control (QA/QC) procedures followed inventory preparation from its initial development through to final reporting. QA/QC checks for activity data and emission estimation were conducted by internal review of calculations to identify significant divergence in time series of emission estimations and other inventory indicators. QA/QC activities were also provided by Climate Change Center under MEP. Emission estimations were reviewed by leading experts from relevant organizations.

Besides inventory development process included the following stages:

- Conducting researches for development of national GHG emission factors GHG for key source categories;
- Improvement of methodologies taking into account UNFCCC recommendations, comments and suggestions of IPCC experts, which participated in the review of previous inventory.

1.3 Methodological issues and data sources

Methodologies used for emission estimation are described in detail in the corresponding chapters of this report. Direct and indirect GHG emissions were calculated using Tier 1 and Tier 2 approaches. At the same time emissions from key source categories were estimated mainly using Tier 2 approach. Table 1.2 presents summarized information about methodologies used in this inventory.

Table 1.2. Summarized information about methodologies of GHG emission estimations

CRF category	Emission source category	Comments
1A	Fuel combustion	Special software for calculation of GHG emissions from stationary sources (Annex 2). Special software for calculation of GHG emissions from transport (Annex 2).
1B	Fugitive emissions	Electronic tables for GHG emission calculation based on coal, oil and natural gas production data; information on pipeline infrastructure; data on natural gas consumption by population and industry.
2A1	Cement Production	Good Practice Guidance (Tier 2) and national CO_2 emission factors.
2A2 2B2 2B3	Lime Production; Nitric Acid Production	Good Practice Guidance and default emission factors.
2A3 2A4 2A5 2A6 2A7 2B4 2B5 2C2	Limestone and Dolomite Use; Soda Ash Use; Asphalt Roofing; Road Paving with Asphalt; Glass Production; Carbide Production; Other ; Ferroalloys Production	IPCC revised Guidelines and default CO_2 emission factors.
2B1	Ammonia Production	IPCC revised Guidelines (Tier 1a) and national CO_2 emission factors.
2C1	Iron and Steel Production	Good Practice Guidance (Tier 2) and national CO_2 emission factors and default emission factors for other GHG.
2C3	Aluminium Production	IPCC revised Guidelines and default CO_2 emission factors, Good Practice Guidance and default emission factors – for perfluorocarbons.
3D	Other	Emissions were estimated on the basis of data on population in Ukraine and specific consumption of nitrous oxide for anesthesia.
4A	Enteric Fermentation	Emissions from cattle were estimated using Tier 2 approach from Good Practice Guidance, emissions from other livestock (goats, sheep, horses and swine) were estimated using Tier 1 approach.
4B	Manure Management	Methane emission from manure of cattle, swine and poultry were estimated using Tier 2 approach from Good Practice Guidance, emissions from other livestock (goats, sheep and horses) were estimated using Tier 1 approach. N_2O emissions from Manure Management were estimated using Tier 2 approach from Good Practice Guidance.
4C	Rice Cultivation	Emissions were estimated using Tier 1 approach from Good Practice Guidance
4D	Agricultural Soils	Emissions from soil residuals were estimated using national methodology, emissions from other sources were estimated using Good Practice Guidance.
5	Land-Use, Land-Use Change and Forestry	Specially developed methodology for assessment of areas which is used without changes and areas with land use change. Good Practice Guidance (Tier 2) and national factors for forestry and Tier 1 and default factors for other sources.

Table 1.3 presents the main data sources, from which the activity data for estimation of GHG emissions were obtained.

Table 1.3. Summarized information about main sources of activity data for GHG emission estimation

Data source	Activity data
State Committee on Statistics of Ukraine	Fuel consumption; Calorific values for different fuels; Fuel production, import and export; Industrial production, import and export; Lime use in agriculture, glass, cement and soda production; Iron consumption for steel production; Livestock population by species/categories; Milk production; Crop production; Fertilizers use; Total population and urban population; Forest areas in Ukraine; Areas of different land-use.
Ministry for Fuel and Energy of Ukraine	Fuel consumption by power plants and calorific values; Oil and natural gas production; Import/export of oil and oil products.
Ministry for Coal Industry of Ukraine	Coal production, import and export.
Ministry for Industrial Policy of Ukraine	Industrial production, import and export; Carbon fraction in coke, iron and steel.
Ministry for Construction, Architecture and Household of Ukraine	Data on solid waste; Data on domestic wastewater; Information about sanitary purification of settlements; Data on wastewater management; Fuel consumption by household sector.
State Committee on Water Management of Ukraine	Data on industrial wastewater.
State Regional Departments for Ecology and Natural Resources	Data on waste incineration; Volumes of recuperated methane.
State Committee on Land Management of Ukraine	Data on land use in Ukraine; Available land in Ukraine.
State Committee on Forestry of Ukraine	Data on forest areas for 1988, 1996 and 2002.
Ministry for Environmental Protection/ State Departments for Ecology and Natural Resources	Data on recuperated landfill methane; Data on waste composition; Data on domestic wastewater.
National Agrarian University	Data on manure excretion for cattle, swine and poultry; Data on systems of manure management for cattle, swine and poultry; Data on mature weight and average weight gain per day for cattle.

1.4 Brief Description of Key Source Categories

According to the requirements of Good Practice Guidance key source analysis was conducted using Tier 1 approach, which includes the level and the trend assessment of the national emissions inventory.

Table 1.4 presents the results of key source analysis.

Table 1.4. The results of key source analysis

Quantitative analysis was used. Tier 1					
A		B	C	D	E
IPCC Source Category		Gas	Key Source Category Indicator	Criteria for Definition	Comments
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of liquid fuels	CO_2	Yes	Level, Trend	
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of solid fuels	CO_2	Yes	Level, Trend	
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of gaseous fuels	CO_2	Yes	Level, Trend	
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of other fuels	CO_2	No		
1.A.3	Mobile combustion of liquid fuels	CO_2	Yes	Level, Trend	
1.A.3	Mobile combustion of gaseous fuels	CO_2	Yes	Level, Trend	
1.A.3	Mobile combustion of other fuels	CO_2	No		
2	Other industrial processes	CO_2	No		
2.A.1	Cement Production	CO_2	Yes	Level	
2.A.2	Lime production	CO_2	No		
2.A.3	Limestone and Dolomite Use	CO_2	Yes	Level, Trend	Large level of uncertainty
2.B.1	Ammonia Production	CO_2	Yes	Level, Trend	
2.C.1	Iron and Steel Production	CO_2	Yes	Level, Trend	
2.C.5	Aluminium and Ferroalloys Production	CO_2	Yes	Trend	
5.A	Forest Land	CO_2	Yes	Level, Trend	
5.B	Cropland	CO_2	Yes	Level, Trend	
5.C	Grassland	CO_2	Yes	Level, Trend	
5.D	Wetlands	CO_2	No		
5.E	Settlements	CO_2	Yes	Trend	
1.A.1 1.A.2 1.A.4 1.A.5	Stationary fuel combustion	CH_4	No		
1.A.3	Mobile fuel combustion	CH_4	No		
1.B.1.a	Coal production and processing	CH_4	Yes	Level, Trend	Large level of uncertainty
1.B.2.a	Oil processing	CH_4	No		
1.B.2.b	Fugitive emissions of natural gas	CH_4	Yes	Level, Trend	Large level of uncertainty
2	Industrial processes	CH_4	No		
4.A	Enteric Fermentation	CH_4	Yes	Level, Trend	
4.B	Manure Management	CH_4	No		
4.C	Rice Cultivation	CH_4	No		
5	LULUCF	CH_4	No		
6.A	Landfills	CH_4	Yes	Level, Trend	Large level of uncertainty
6.B	Wastewater management	CH_4	No		
1.A.1 1.A.2 1.A.4 1.A.5	Stationary fuel combustion	N_2O	No		
1.A.3	Mobile fuel combustion	N_2O	No		
2.B.2	Nitric Acid Production	N_2O	No		
2.B.3	Adipic acid production	N_2O	No		
3	Solvents	N_2O	No		
4.B	Manure Management	N_2O	Yes	Trend	Large level of uncertainty
4.D	Agricultural Soils	N_2O	Yes	Level, Trend	Large level of uncertainty
5	LULUCF	N_2O	No		
6.B	Wastewater management	N_2O	No		
2	Industrial processes	PFCs	No		

1.5 Information on QA/QC Plan

This subchapter describes the general QA/QC plan for GHG Inventory development in Ukraine. The main QA/QC procedures have been used throughout the previous inventory development in 2005 according to the recommendations of Good Practice Guidance. Now QA/QC system conforms to the QA/QC procedures using Tier 1 approach of Good Practice Guidance with some elements of Tier 2 for key source categories. QA/QC procedures are component parts of the inventory development process

UIH was the leading inventory agency for 1990-2004 inventory preparation in Ukraine according to the contract with MEP. Inventory team has been formed from the staff of the Institute. QC procedures were conducted by inventory team with getting experts from relevant organizations to obtain necessary additional information if it is necessary. QA activities included an independent system of review procedures conducted by personnel not directly involved in the inventory development process. Climate Change Center under MEP has taken part in such activity on continuing basis.

1.5.1 General QC procedures (Tier 1)

The following checks of calculations, reporting tables and NIR text for all emission source categories (including not-key categories) have been conducted:

1) Check of documentation on assumptions and criteria for the selection of activity data and emission factors.

2) Check for transcription errors in data input and reference. Confirmation of properly citing bibliographical data the internal documentation. Cross-check of a sample of input data from each source category for transcription errors.

3) Check of correct calculation of emissions. For these purposes a representative sample of emissions calculations, abbreviated calculations to judge relative accuracy were reproduced.

4) Check of correct recording parameter and emission units, as well as using appropriate conversion factors. For these purposes check of proper labeling units in calculation sheets and correct carrying through from beginning to end of calculations.

5) Check of the integrity of database files. Confirmation of correct representing the appropriate data processing steps and data relationships. Check of proper labeling data fields and correct design specifications. Check of archiving adequate documentation of database and model structure and operation.

6) Check for consistency in data between source categories. For these purposes parameters (e.g. activity data, constants) that are common to multiple source categories were identified and consistency in the values used for these parameters in the emissions calculations was confirmed.

7) Check of the correctness of the movement of inventory data among processing steps including aggregation from lower reporting levels to higher reporting levels when preparing summaries and transcription between different intermediate products.

8) Check of the correct estimation of the uncertainties in emissions and removals. Check of the appropriate level and record of qualifications of individuals providing expert judgment for uncertainty estimates. Check of the correctness and completeness of uncertainties calculation. If necessary, duplicate error calculations were fulfilled according to Good Practice Guidance.

9) Check for the completeness of internal documentation to support the estimates and enable duplication of the emission and uncertainty estimates, archiving all necessary data to facilitate detailed review. Check for integrity of any data archiving arrangements of outside organizations involved in inventory preparation.

10) Check of methodological and data changes resulting in recalculations. Check for temporal consistency in time series input data for each source category. Check for consistency in the algorithm/method used for calculations throughout the time series.

11) Completeness checks. Checks of completeness of documentation for all source categories and for all years from the appropriate base year to the period of the current inventory. Checks of completeness of documentation on all known data gaps that result in incomplete source Emission Categories estimates.

12) Comparison estimates to previous estimates. If there were significant changes or departures from expected trends, estimates were rechecked and any difference was explained.

1.5.2 Detailed QC procedures (Tier 2)

Detailed QC procedures were focused on the key sources and required serious efforts. Source category-specific QC activities have included the following checks:

A. Emission Data QC

1) Emissions comparison using available historical inventory data for multiple years.

The significant changes were indicated and analyzed on this stage (more than 10% per year). This check was provided separately for the most considerable sub-source categories of key sources categories.

2) Order of magnitude checks. Method-based comparisons may be made depending on whether the emissions for the source category were determined using a top-down or bottom-up approach.

3) Reference calculations. Another emission comparison may be used for source categories that rely on empirical formulas for the calculation of emissions, which are taken from bibliographical sources.

B. Emission factors QC

1) Where IPCC default emission factors were used, it was assessed the applicability of these factors to national circumstances. This assessment may include an evaluation of national conditions compared to the context of the studies upon which the IPCC default factors were based. Inventory team also considered options for obtaining emission factors that are known to be representative of national circumstances.

2) Where national emission factors were used country-specific factors and circumstances should be compared with relevant IPCC default factors and the characteristics of the studies on which the default factors are based. Large differences between country-specific factors and default factors should be explained and documented.

Inventory team also compared the country-specific factors with site-specific or plant-level factors. The inventory team have taken into account the applicability of the data for use in emissions estimates and established whether the secondary data have undergone peer review and record the scope of such a review. If it was determined that the QA/QC associated with the secondary data is adequate, then the inventory team simply referenced the data source for QC documentation. If it was determined that the QA/QC associated with the secondary data is inadequate, then the inventory team reassessed the uncertainty of emission factors.

3) Where direct measurement data from individual sites were used, inventory team compared site-specific emission factors between sites and also to IPCC or national level defaults. Significant differences between sites or between a particular site and the IPCC defaults should elicit further review and checks on calculations. Large differences should be explained and documented.

C. Activity Data QC

1) When national statistics, departmental reporting or other national sources of data were used, QC activities included the following checks:

a) so most activity data were originally prepared for purposes other than as input to estimates of GHG emissions, inventory team evaluated the applicability of data for inventory purposes including completeness, compatibility and adequacy to the category;

b) National level activity data were compared with previous year's data for the source category being evaluated. If the national activity data for any year diverged greatly from the historical trend, the activity data were checked for errors. If the general mathematical checks did not reveal errors, the characteristics of the source category were identified and documented;

c) A comparison check of activity data from multiple reference sources was undertaken, especially for source categories that have a high level of uncertainty associated with their estimates. When alternative data sources were lacked, inventory team compared data with regional data;

d) The Inventory team has analyzed the availability of internal QC procedures at the data sources (e.g., independent review, QC procedures similar to those for inventory etc.). If it was determined that the QC associated with the secondary data is inadequate, then the inventory team reassessed the uncertainty of activity data and documented all information. Then inventory team analyzed the possibility of using IPCC reference data or international databases.

2) When site-specific activity data were used, QC activities included the following checks:

a) The Inventory team has compared data from different sites and analyzed inconsistencies between sites to establish whether these reflect errors, different measurement techniques, or real differences in emissions, operating conditions or technology.

b) The Inventory team has compared summary of data for all sites with national statistical data;

c) The Inventory team has established whether recognized national or international standards were used in measuring activity data at the individual sites. If the measurements were not made using standard methods and QA/QC is not of an acceptable standard, then the use of these activity data should be carefully evaluated, uncertainty estimates reconsidered, and qualifications documented.

1.5.3 External Review

Independent external review of inventory and its separate parts is Tier 1 QA procedure. While the current inventory was developed this procedure was conducted in two stages.

At the first stage preliminary emission estimates by category were transferred to the Climate Change Center (CCC) under the MEP for review. Then inventory team obtained comments and revisions. Besides, leading experts from relevant organizations were engaged to the preliminary review of key source categories. Information package for review included Excel Worksheets and necessary description of methodologies used. Experts from the European Commission project also took part in the preliminary inventory review for 1990-2004 inventory. In addition, current emission estimates by sector as much as possible were presented and discussed at sectoral seminars and conferences.

At the second stage after revisions of preliminary estimates the final version of NIR and reporting tables were placed on the web-site of MEP (www.menr.gov.ua) with informing relevant experts and organizations. Availability of the final inventory information gave an opportunity to public review. All comments and revisions were transferred to the inventory team for consideration. While 1990-2004 inventory has been developed, materials of UNFCCC Secretariat in-depth review of previous inventory were very helpful. Most revisions and suggestions have been taken into account in the current inventory.

1.5.4 Documentation

Careful documentation of all activity data, methodologies and assumptions used for the estimations is prerequisite for continuity of inventory development and improvement. Besides, complete documentation facilitates necessary external expertise including UNFCCC Secretariat in-depth review. In addition to the proper inventory materials include the checks/audits/reviews reports and contact information about experts.

Detailed database has been developed in the CCC for proper documentation of all inventory materials and facilitating availability of the information for the experts. Database provides accumulating, archiving and processing inventory data, submitting information to the MEP, as well as regulated access to the information taking into account integrity and confidentiality data retention.

Special software provides a system of information collecting and accumulating, bank of ecological data, system of analytical data processing and sub-system of interaction with national GHG Registry. Analytical data processing includes calculation of necessary indicators, determination of changes in indicators in time and emission category, as well as comparison of indicators in time and emission category.

1.6 Uncertainty Assessment

Uncertainty assessment of current inventory was carried out using Tier 1 Approach provided by Good Practice Guidance. The entire uncertainty assessment totals 9.41% (table 7.2 Annex 7) in 2004 and 5.8% - in 1990. Uncertainty in the overall inventory trend over time amounts to 2.8%.

Sectors LULUCF and Waste makes the main contribution to the entire uncertainty.

Data on uncertainty assessment for the current inventory by GHG and by sector are presented at the tables 1.5 and 1.6. The lowest uncertainty is associated with CO_2 emissions in Energy sector.

Table 1.5. Uncertainty assessment for the current inventory by GHG

Gas	Share in the net emissions, %		Uncertainty, %	
	1990	**2004**	**1990**	**2004**
CO_2	76.9	74.7	3.3	8.11
CH_4	17.0	19.4	19.2	32.4
N_2O	6.1	5.8	66.0	60.3

Table 1.6. Uncertainty assessment for the current inventory by sector (without LULUCF)

Sector	Share in the net emissions, %		Uncertainty, %	
	1990	**2004**	**1990**	**2004**
Energy	74.3	68.3	4.0	5.5
Industry	13.8	22.1	8.8	9.4
Agriculture	11.0	7.4	36.0	44.2

Waste	0.9	2.1	181.8	214.2

Uncertainty assessment for LULUCF in 2004 totals 65.1%.

More detailed information on uncertainty assessment of current inventory is presented in the Annex 7.

1.7 Completeness

Table 1.7 presents data on GHG source categories, which are not considered in the current inventory. More detailed information on completeness of current inventory is presented in the Annex 5.

Table 1.7. GHG source categories, which are not considered in the current inventory

Gas	Sector	Source Category	Reason
CO_2, CH_4, N_2O	1 Energy	1.A.3.a Civil Aviation International Bunkers	It is impossible to separate International Bunkers from the activity data on fuel consumption
CH_4	1 Energy	1.B.1.a.i Underground mines Emissions from abandoned mines	Lack of IPCC Methodology
CH_4	1 Energy	1.B.2.a.i Oil exploration	Lack of activity data
CH_4	1 Energy	1.B.2.b.i Natural gas exploration	Lack of activity data
CO_2	2. Industrial processes	2.A.4.1 Soda ash production 2.A.5. Asphalt Roofing 2.A.6. Road Paving with Asphalt	Lack of IPCC Methodology
CO_2	2. Industrial processes	2.B.3. Adipic acid production 2.B.5.2. Ethylene production	Lack of IPCC Methodology
CO_2	2. Industrial processes	2.C.1.4. Coke Production	Lack of IPCC Methodology
CH_4	2. Industrial processes	2.B.1. Ammonia Production 2.B.4.2. Calcium Carbide Production	Lack of IPCC Methodology
CH_4	2. Industrial processes	2.C.1.1. Steel production 2.C.2. Ferroalloys Production 2.C.3. Aluminium Production	Lack of IPCC Methodology
N_2O	2. Industrial processes	2.B.1. Ammonia Production 2.B.5.2. Ethylene production	Lack of IPCC Methodology
CH_4	4 Agriculture	4D Agricultural Soils Emission methane from agricultural soils	Lack of Methodology
CH_4	4 Agriculture	4A Enteric Fermentation 4A7 Mules and Asses	Lost in the noise
CH_4	4 Agriculture	4B Manure Management 4B7 Mules and Asses	Lost in the noise
CO_2	5. LULUCF	All categories of Land-Use excluding 5.A.1. Not-converted Forest Lands\Emissions from forest fires	Lack of statistical data on fires
CO_2	5.B. Croplands	5.A.1. Forest Lands 5.B.1. C, \5.C.1. Not-converted grasslands and \5.C.2. Not-converted lands \5.D.1. Not-converted wetlands \ and 5.D.2 Lands converted to wetlands\ 5.E.1 Not-converted settlements \ and 5.E.2 Lands converted to settlements \ Carbon changes in woody biomass	Lost in the noise

Gas	Sector	Source Category	Reason
CH_4	5. LULUCF	All categories of Land-Use excluding 5.A.1. Not-converted Forest Lands\Emissions from forest fires	Lack of statistical data on fires
N_2O	5. LULUCF	All categories of Land-Use excluding 5.A.1. Not-converted Forest Lands\Emissions from forest fires	Lack of statistical data on fires
CH_4	6. Waste	6.C. Waste Incineration	Emissions are not significant, Lack of IPCC Methodology

2 GREENHOUSE GAS EMISSION TRENDS

2.1 Total Greenhouse Gas Emission Trends

Results of GHG inventory in Ukraine for 1990-2004 by sector and by gas and GHG emissions by category in 1990 and 2004 are presented in the Annex 8. Sum of GHG emissions in Ukraine in 1990 has achieved 892 mln t CO_2-eq. GHG emissions has halved during the period 1990-2004 and totaled 381 mln t CO_2-eq. The total results are the sum by all 6 inventory sectors (with net absorption in LULUCF sector) and by all considered GHG. Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are emitted in all sectors, excluding Agriculture and Waste, where CO_2 emissions is lacking, and sector Solvents, where only N_2O from direct GHG is emitted. Inventory also takes into account PFCs emissions in the sector «Industrial Processes». Sector LULUCF, except emissions, absorption of CO_2 is considered

According to the Kyoto Protocol Ukraine undertook obligation do not exceed base level, that is total level emissions in the five sectors (without LULUCF) in the base year. 1990 is the base year for all GHG, except PFCs, for which 1995 is the base year. According to the current inventory the base level totaled 925.4 mln t CO_2-eq. Total actual emissions in 2004 in the five sectors made to 413.4 mln t CO_2-eq., i.e. shortened in comparison with the base level by 55.3%. Absolute value of this decrease has amounted 512 mln t CO_2-eq.

2.2 Emission trends by gas

Figure 2.1 gives total emissions in six sectors of carbon dioxide, methane and nitrous oxide in Ukraine. PFCs emissions during aluminium production did not take into account at this figure, because its share in the total emissions did not exceed 0.02 %. Carbon dioxide emissions accounted for the largest share - approximately 77 percent (with absorption in LULUCF) in 1990. Methane accounted for 17 percent of total emissions. The nitrous oxide emissions are less important comprising 6 percent of total emissions.

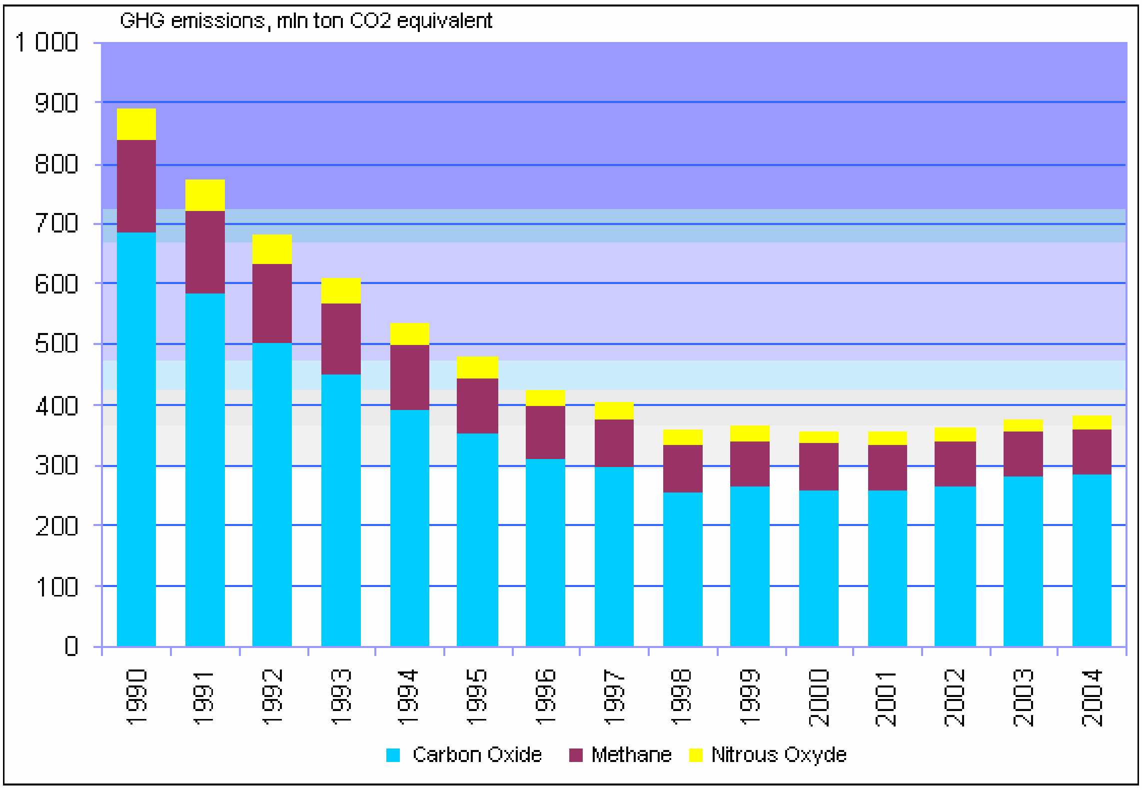

Figure 2.1. Direct GHG emissions in Ukraine for 1990-2004, mln t CO_2-eq.

Analysis of Figure 2.1 evidences the primary importance CO_2 emissions for total GHG emissions (nearly 73-77%) during the period 1990-2004. Recession in production due to economic restructurization has produced the sharp decrease of CO_2 emissions in 1990-1999 (approximately twice), deceleration and further CO_2 emissions raising in 2001-2004 has been caused by growth in national economy. The similar behavior has been typical for the other direct GHG.

2.2.1 Carbon dioxide emissions

Figure 2.2 presents CO_2 emissions from Energy and Industrial Processes, as well as net CO_2 emissions (emissions minus absorption) from LULUCF. CO_2 emissions from Solvents, Agriculture and Waste have been lacking in Ukraine. Net CO_2 emissions in 1990 in Ukraine have amounted to 685.5 mln t and exceeded net CO_2 emissions in 2004 by a factor 2.4.

CO_2 emissions from Energy and Industrial Processes in 1990 totaled 719.4 mln t, 83% of these emissions were emissions from fuel combustion. Such structure of CO_2 emissions was caused by high energy intensity of national economy. During the last years some measures to increase energy efficiency were undertaken in Ukraine. Energy balance structure was slightly improved due to increase of natural gas share for combustion (from 47 % in 1990 to 62% in 2004). Economic crisis after the USSR collapse resulted in significant decrease of energy consumption. That is why reduction of CO_2 emissions in energy sector reached 405 mln t in 1990-2004. National economy rising in the last years led to some increase of energy consumption and consequently CO_2 emissions. So CO_2 emissions have increased by 5 mln t.

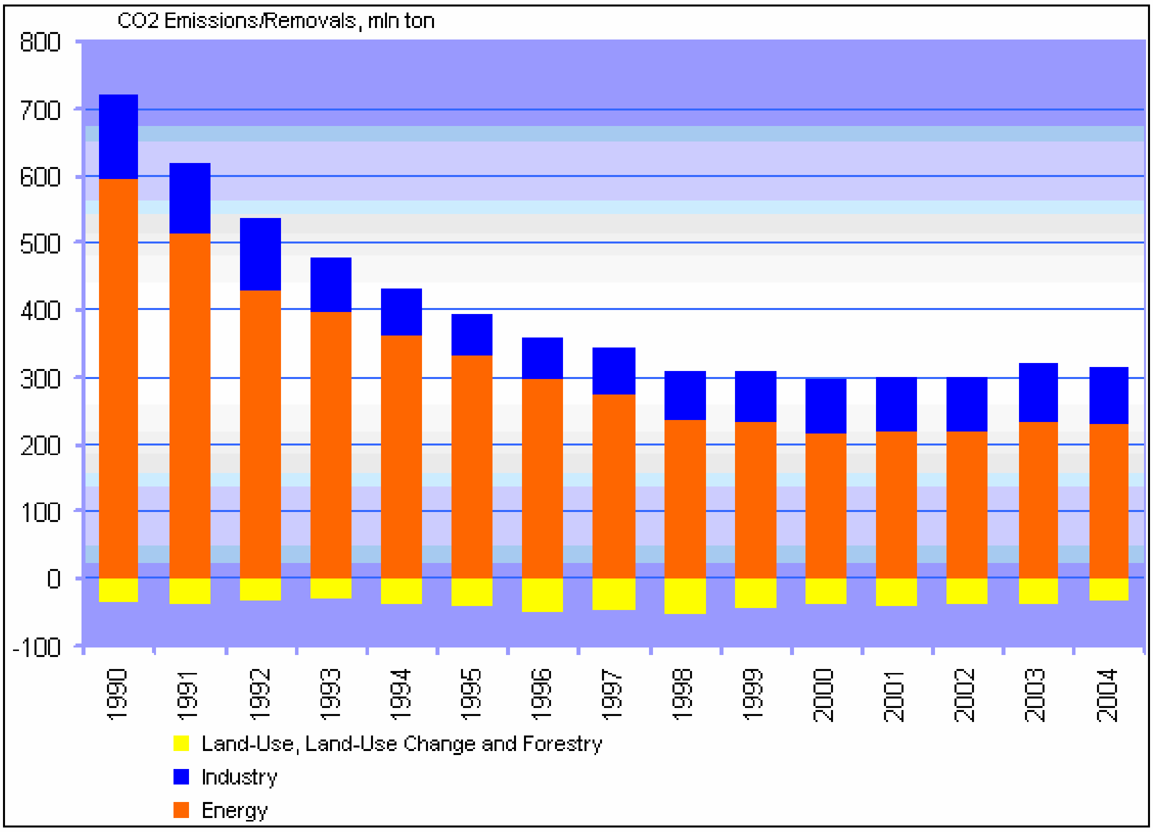

Figure 2.2. Carbon dioxide emissions and absorption in Ukraine by source during the period 1990-2004, mln t

2.2.2 Methane emissions

CH_4 emissions are the second significant source of GHG emissions after CO_2. CH_4 emission aggregated 7.3 mln t in 1990 in Ukraine. The main sources of methane emissions (Figure 2.3) were energy sector (60% in 1990), agriculture (36%) and waste (4%). Methane emissions from Industrial Processes were not taken into account at the Figure 2.3, because its share is less than 1% of total methane emissions.

The largest CH_4 emissions have taken place in energy sector, namely fugitive methane emissions from coal mines and natural gas production, transport, storage and distribution – 57% in 1990 and 70% in 2004. Livestock Enteric Fermentation was the main source of CH_4 emissions in agriculture (23% from total methane emissions in 1990). Economic fall has entailed decrease of agricultural production and consequent decrease of methane emissions from sector in 2004 by a factor 4 in comparison to 1990 level.

Solid waste was the main source of CH_4 emissions in waste sector (3.1% from total methane emissions in 1990). Emissions from landfills have increased by 0.073 mln t in 2004 due to larger content of degradable organic matter in waste, which was disposed at the landfills before 1990.

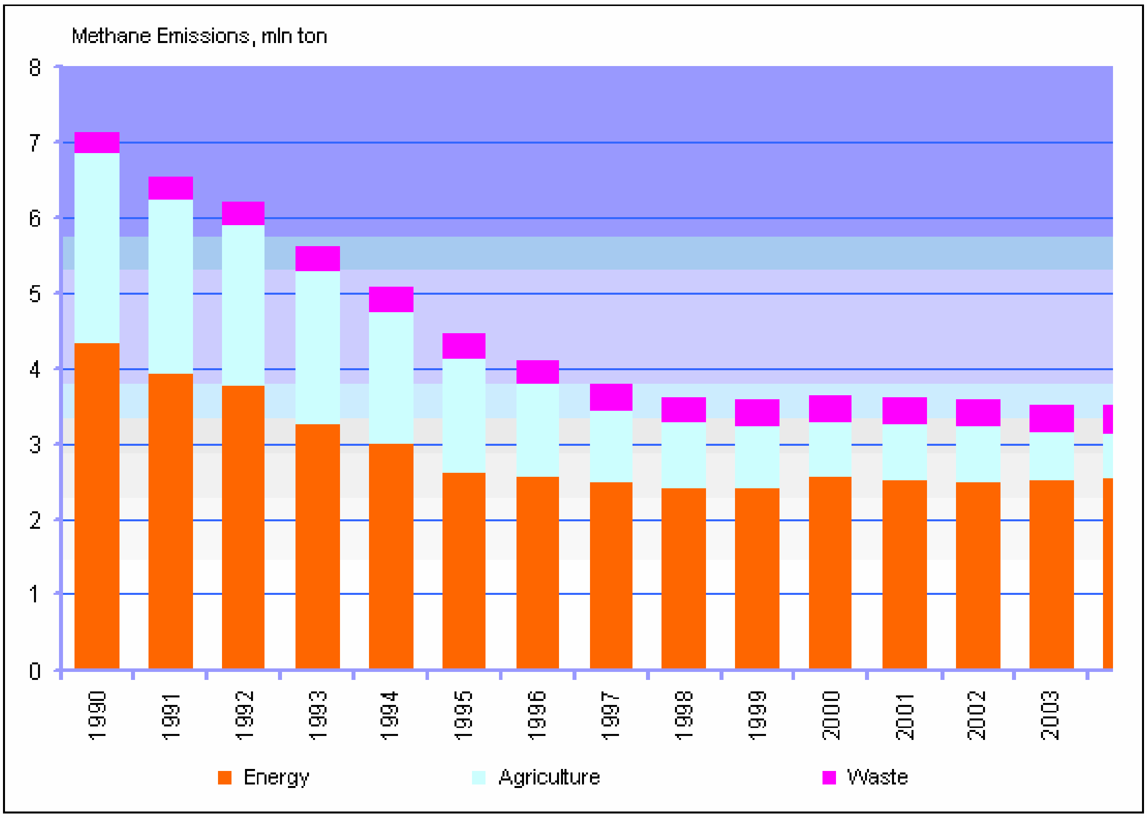

Figure 2.3. Methane emissions in Ukraine by source in 1990-2004, mln t

2.2.3 Nitrous oxide emissions

Nitrous oxide emissions in Ukraine made to 0.175 mln t in 1990. Figure 2.4 gives nitrous oxide emissions from energy sector, industrial processes, agriculture and waste. Some nitrous oxide emissions occurred in the sector «Solvents», but the share of these emissions was negligible (approximately 1%).

Emissions from agricultural soils (75% from total nitrous oxide emissions in 1990) and manure management (14.5%) were the main sources of nitrous oxide emissions in Ukraine. Nitrous oxide emissions from energy sector (2.9% from total nitrous oxide emissions in 1990) were caused by fuel combustion, from waste (2.9%) – human sewage and from industry (4.7%) – adipic and nitric acid production. Annual nitrous oxide emissions in 2004 have been shortened by 0.104 mln t in comparison with 1990 mainly as a result of decrease of agricultural production.

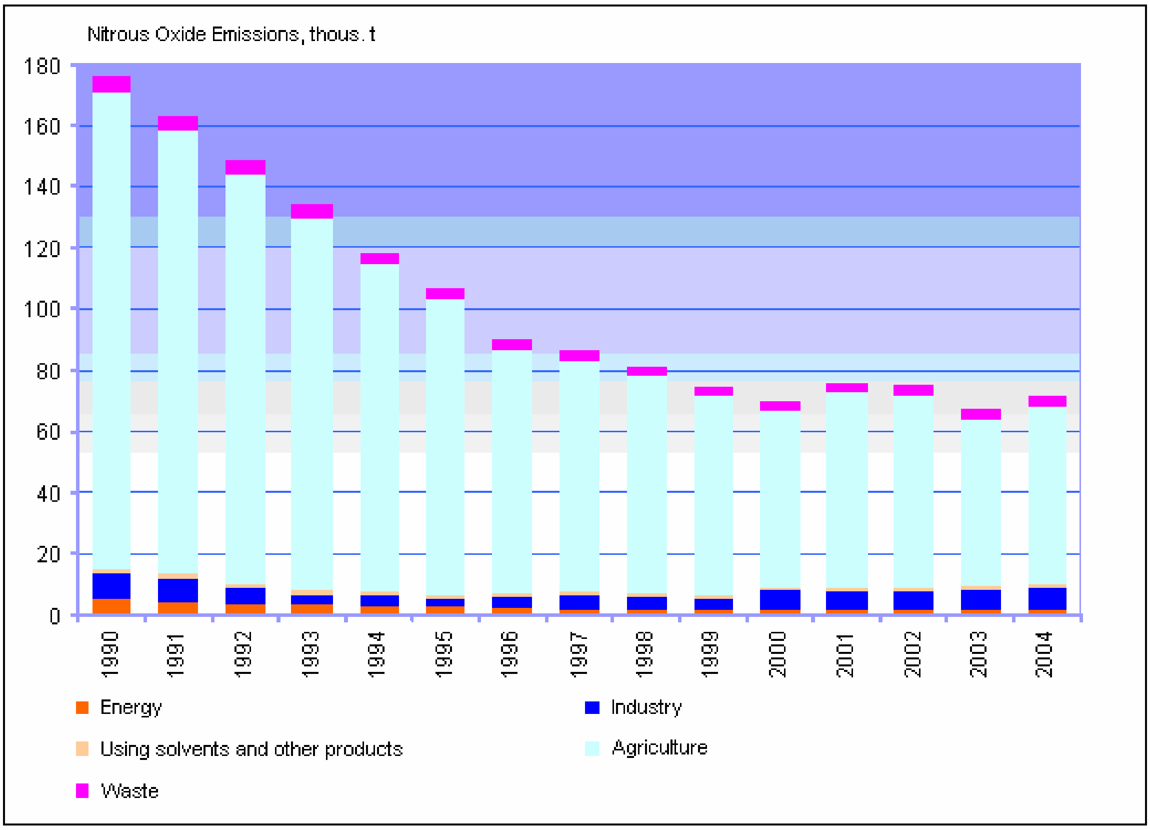

Figure 2.4. Nitrous oxide emissions in Ukraine by source in 1990-2004, thous. t

2.3 Emission Trends by Source

Figure 2.5 shows GHG emissions and absorption by source. Emission from sector «Solvents» were omitted due to its negligibility (less than 0.1%).

GHG emissions in Energy sector account for the largest share in the total emissions. In 1990-2004 the share of this sector was 74-83% of total emissions. In 2004 emissions decreased by 59% compared to 1990 from 687.6 mln t CO_2-eq. to 282.5 mln t CO_2-eq. The minimum value has been observed in 2000 at the level 270.7 mln t CO_2-eq. Then the gradual increase of emissions has begun as a result of economic raise.

In 1990-2004 the share of industrial processes was 13-24% of total emissions. The maximum values were observed in 2001-2004 as a result of rehabilitation of heavy industry. In 2004 emissions decreased by 28% compared to 1990 from 128.1 mln t CO_2-eq. to 91.4 mln t CO_2-eq. The minimum value has been observed in 1996 at the level 62.9 mln t CO_2-eq. Then the constant increase of emissions has begun.

In 1990-2004 the share of agriculture was 8-13% of total emissions. The largest shares were typical for the beginning of the period and the smallest ones – for the end of the period. In 2004 emissions decreased more significantly than other sectors - by 70% compared to 1990 from 101.4 mln t CO_2-eq. to 30.4 mln t CO_2-eq. The reduction of livestock population and fertilizer use, as well as changes in manure management were the main reasons of such decrease. The minimum value has been observed in 2003 at the level 30.1 mln t CO_2-eq. at it is too early to say about overcoming of emission decrease.

The share of waste sector was not significant but demonstrated steady increase from 1% in 1990 to more than 2% in 2004. This fact was caused by increase of emissions in this sector while emissions in other sector were decreased. In 2004 emissions increased by 12% compared to 1990 from 7.9 mln t CO_2-eq. to 8.9 mln t CO_2-eq..

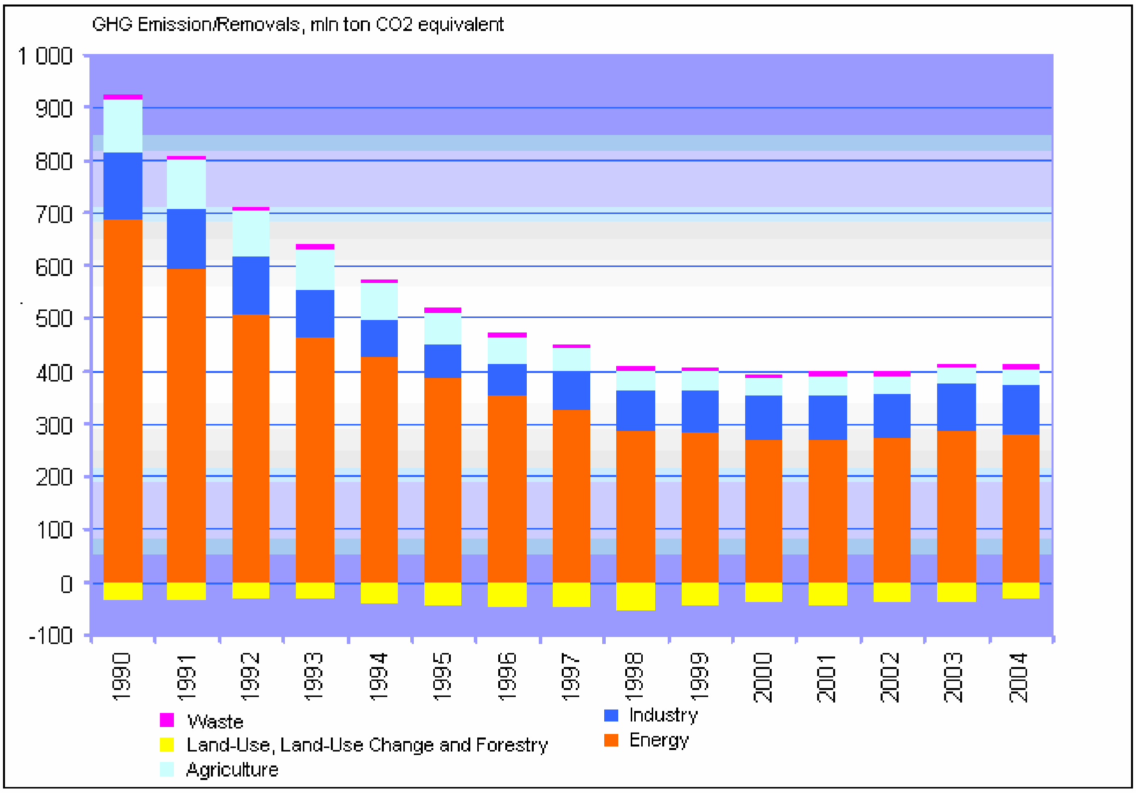

Figure 2.5. GHG emissions and removals in Ukraine by source and sink in 1990-2004, mln t CO_2-eq.

CO_2 absorption (negative values at the Figure) exceeded CO_2 emissions from LULUCF sector. Its share made to 4-14% of net emissions in 1990-2004. Net absorption totaled 33.8 mln t CO_2 in 1990, then increased to 52.5 mln t in 1998 with further growth to 32,1 mln t in 2004. Such behavior was explained by dynamic of lands which was considered as forest lands. Besides the fast shortening of longstanding garden areas since 1998 is also essential factor.

2.4 Emission Trends for Indirect GHG and SO_2

Figure 2.6 presents trends for total indirect GHG emissions (nitrous oxides, carbon monoxide, NMVOCs), as well as sulphur dioxide emissions in 1990-2004.

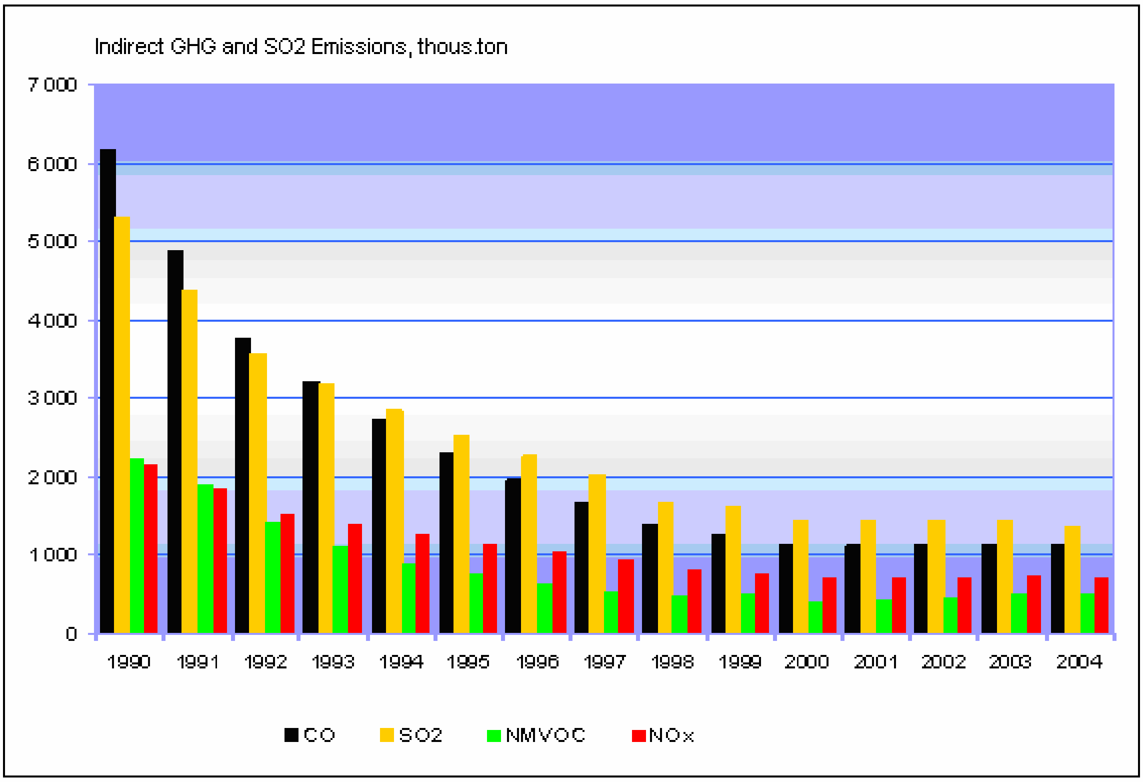

Figure 2.6. Indirect GHG and sulphur dioxide emissions in 1990-2004, thous. t

Energy sector is the main source of indirect GHG and sulphur dioxide emissions, the next significant source - sector "Industrial Processes". Essential fall of emissions in 1990-2004 is typical for all gases (approximately 3-5 times compared to 1990).

3 ENERGY (SECTOR 1 CRF)

3.1 General Sector Overview

Fuel combustion of fossil fuels (category 1.A CRF) and fugitive emissions from fuel production, transportation, storage and distribution (category 1.B CRF) relate to the Energy category.

In 2004 emissions in Energy sector totaled 282.5 mln t CO_2-eq. or 68 % of total emissions in Ukraine (without absorption in LULUCF sector) and has reduced by 1.7 % compared to 2003. The decrease of emissions in 2004 has achieved 59 % in comparison with 1990.

Fuel Combustion Category has accounted for about 81 % of total emission in Energy sector whereas Fugitive Emissions Category – for 19 % (Table 3.1).

Table 3.1. Emission in Energy sector, mln t CO_2 equivalent

Emission Category	1990	2003	2004
1 Energy total, including	**687,5**	**287,2**	**282,5**
1.A Fuel combustion	600,8	235,1	229,9
1.B Fugitive emissions	86,7	52,1	52,5

Emission uncertainty in the Energy sector was assessed as 5.5 %. Fugitive emissions from coil and natural gas (category 1.B CRF) are the main sources of uncertainty in this sector as a result of high uncertainty of methane emission factors for such activity.

3.2 Fuel Combustion (category 1.A CRF)

Fuel Combustion Category includes emissions from combustion of the fossil fuel. Fuel combustion in terms of GHG inventory is considered as the fuel oxidation processes on apparatus and plants to produce heat energy for further use or transformation in mechanical energy.

In 2004 emissions from combustion the fossil fuel made to 229.8 mln t CO_2 -eq. or 81 % of total Energy sector emissions and has reduced by 2.2 % compared to 2003. Reduction has reached 62 % in comparison to 1990.

Energy Industries (category 1.A.1 CRF) and Manufacturing Industry and Construction (category 1.A.2 CRF) were the main sources of emissions in the category Fuel Combustion in 2004, which accounted for 43.7 % and 20.5 % of total emissions respectively (Table 3.2).

Emissions from the fossil fuel combustion in 1990 and 1998-2004 were assessed on the category level which was recommended in the IPCC Revised Guidelines. Emissions in 1991-1997 were assessed on the country level for separate fuel types (solid, liquid, gaseous and others) because it was lack of disaggregated and reliable data about activity for this period.

Table 3.2. Emissions in the Fuel combustion Category, mln t CO_2 equivalent

Emission Category	1990	2003	2004
1.A Fuel combustion total, including	**600.8**	**235.1**	**229.9**
1.A.1 Energy Industries	272.0	107.9	100.5

Emission Category	1990	2003	2004
1.A.2 Manufacturing Industries and Construction	143.9	45.7	47.2
1.A.3 Transport	89.8	36.5	37.7
1.A.4 Other Sectors (in Transport)	95.1	43.2	43.1
1.A.5 Other Sectors	-	1.7	1.5

Emissions in 1991-1997 were estimated using interpolation methods between data on emissions and fuel consumption in 1990 and 1998, which are included in current inventory. Data on fuel consumption for some years of this period, i.e. 1992, 1995-1997, were used to increase accuracy of interpolation [32].

3.2.1 Energy Industries (Category 1.A.1 CRF)

3.2.1.1 Overview of Source Category

This category includes emissions from fuel stationary combustion for electricity and heat production and fuel processing. There are several subcategories in this category:

- Public Electricity and Heat Production (category 1.A.1.a CRF);
- Petroleum Refining (category 1.A.1.b CRF);
- Manufacture of Solid Fuels and Other Energy Industries (category 1.A.1.c CRF).

Emissions from fuel consumption for transportation at the enterprises of this category are presented in the category Transport (category 1.A.3 CRF).

Emissions from the category Energy Industries in 2004 made to 100.5 mln t CO_2-eq or 43.7 % from emissions in the category Fuel Combustion. The decrease has reached 7 % compared to 2003 and 63% compared to 1990.

Subcategory Public Electricity and Heat Production has accounted for 88.8% of emissions in this category in 2004, while subcategories Petroleum Refining and Manufacture of Solid Fuels and Other Energy Industries have accounted for 2.4 % and 8.8 % respectively (Table 3.3).

Table 3.3. Emissions in the Category Energy Industries, mln t CO_2-eq.

Emission Category	1990	2003	2004
1.A.1 Energy Industries total, including	**272.0**	**108.0**	**100.5**
1.A.1.a Public Electricity and Heat Production	272.0	96.6	89.2
1.A.1.b Petroleum Refining	-	2.4	2.4
1.A.1.c Manufacture of Solid Fuels and other Energy Industries	-	9.0	8.9

Public Electricity and Heat Production (category 1.A.1.a CRF)

United Power Grid of Ukraine (UPGU) includes Thermal Power Plants (TPP), which combust fossil fuel, as well as Nuclear Power Plants (NPP), Hydropower Plants (HPP) and Wind Power Plants (WPP). Directly NPPs, HPPs and WPPs do not emit GHG. So only GHG emissions from TPPs and starting-up/reserve boilers of NPPs were estimated.

Thermal Power Plants operated in Ukraine divide into condensing power plants (CPP) and combined heat power plants (CHP). Installed capacity of all TPPs achieves 34.5 GW, overall electricity production totaled 83.4 billion kWh in 2004.

Gas and coal steam turbines are the major technologies of electricity production in Ukraine. Technologies with internal fuel combustion (gas turbine and combustion engine) for electricity production do not have a wide distribution. Coal, natural gas (NG) and fuel oil (mazut) are mainly used for combustion at CPPs, and NG – at CHP.

Emissions from boilers of district heating systems and waste incineration plants, which generate electricity and heat, are also included in this category.

Emissions from power plants and boilers of the enterprises, which generate electricity and heat to provide needs of such enterprise, are not included in this category. These emissions are included into the category, in which corresponding enterprise is considered.

Petroleum Refining (category 1.A.1.b CRF)

There are 6 refineries in Ukraine with overall installed capacity over 50 mln t. The loading of refineries made up 41.5 % in 2004 [12]. Four refineries use a simple methodology of primary refining and reforming (cracking level - 46-60 %). Other two ORPs use a classic methodology of oil refining (cracking level - 68-70 %) [13].

Crude oil is refined to the oil products at the refineries during the processes of oil refining and cracking. Combustion of derived fuel (refinery gas), as well as obtained fossil fuels, are taken into account in this category. Both fuels are used for heat and electricity production to provide technological processes and own needs.

Manufacture of Solid Fuels and other Energy Industries (category 1.A.1.c CRF)

Emissions from fuel combustion at the enterprises, for extraction of fuels (coal, charcoal, NG, oil, uranium ore), coke production from coal, as well as uranium ore treatment are included in this category.

The major importance have coke production plants, its share in GHG emissions is the most significant.

In 2004 coke production plants produce 22 mln t of coke. Ten leading enterprises produce 80 %.

3.2.1.2 Methodological Issues

GHG emissions from fossil fuel combustion for all categories were calculated according to the methodology, which is described in Annex 2. Activity data were obtained from 4-MTP statistical reporting form.

National CO_2 emission factor for coal and default emission factors for other fuels were applied.

Public Electricity and Heat Production (category 1.A.1.a CRF)

Emissions from entities with sector code from groups E 40.1 Electricity Production and Distribution and E 40.3 Heat Production and Distribution according to Classifier of Kinds of Economic Activity (CKEA) are included to this category [8].

Emissions from waste incineration with power generation purposes are also included in this category. Methodological issues of emission estimation from waste incineration plants are described in the category Waste Incineration (category 6.C CRF).

Petroleum Refining (category 1.A.1.b CRF)

Emissions from entities with sector code from group D DF 23.2 Oil Refining according to CKEA are included to this category [8].

Emissions in this category was lacking in 1990, because they were included to the category Chemicals (category 1.A.2.c CRF). It was impossible to separate fuel combustion of refineries from the column Chemical and oil refining industry of the Fuel and Energy Balance (FEB) for 1990 [7].

Manufacture of Solid Fuels and other Energy Industries (category 1.A.1.c CRF)

Emissions from entities with sector code from subsection C CA Energy materials mining, groups D DF 23.1 Coke products production and D DF 23.3 Nuclear Fuel Production and Processing according to CKEA are included to this category [8].

It should be noted that combustion of coking coal was took no account in this category, because it was taken into consideration in category Iron and Steel Production from the sector Industrial Processes (category 2.C.1 CRF).

Category Manufacture of Solid Fuels and Other Energy Industries considered only coke oven gas combustion for heating and other own needs.

3.2.1.3 Uncertainty assessment and developing a consistent time series

The estimated uncertainty of emissions depends upon uncertainty in the emission factors and the corresponding activity data.

Uncertainty of activity data in this category is caused by the following reasons:

- Instrumental errors of measurements of volume (weight) of consumed fuel. These errors depend on accuracy of instrument for measuring NG and fuel oil (mazut) volumes, weighting coal. All these parameters are regulated by the System of State Standards (SSS);
- Instrumental errors of measurements of specific net calorific values of fuels. These errors differ between kinds of fuels and depend on calorimeter accuracy, which is regulated by SSS;
- Uncertainty of representativeness of samples used for calorimetric analysis. Procedure of sample composition depends upon sectoral documents and conforms to the rules of composing random sample. However the quantitative estimation of uncertainty of these errors is unknown;
- Accuracy of measuring reference values of carbon content in solid fuels, which is not available in present hand-books;
- Accuracy of measuring fraction of unoxidized carbon in the fuels.

Table 3.4 presents uncertainties of activity data and emission factors, which were used for the estimation of overall emission uncertainty in this category.

Table 3.4. Uncertainty of activity data and emission factors in the category Energy Industries

Fuel	Uncertainty of activity data[2], %	Uncertainty of emission factors, %		
		CO_2	CH_4	N_2O
Liquid fuel	5 (3)	5	150	500
Solid fuel	5 (3)	5	150	500
Gaseous fuel	2	2	150	500
Other fuels	10	20	150	500
Biomass	10	20	150	500

[2] Values in brackets concern to the category Public Electricity and Heat Production (category 1.A.1.a CRF)

Estimated emission uncertainty amounted to 3.4 %.

Uncertainty of CO_2 emission estimation in the subcategory Public Electricity and Heat Production made the most significant impact upon the overall uncertainty of GHG emission estimation in this category and mainly determined by uncertainty in emission factors and activity data for solid fuels. Influence of uncertainty of N_2O emission estimation is significantly less.

Data sources with different levels of aggregation were used for 1990 and for the period 1998-2004. Fuel and Energy Balance was use for emission estimation in 1990 and 4-MTP statistical reporting form – in 1998-2004. Since 1991 Fuel and Energy Balance was not developed in Ukraine.

In view of lack of reliable, complete, consistent and sufficiently disaggregated data on fuel consumption for 1991-1997 emissions for this category were assessed only at category the level using interpolation without division to subcategories.

3.2.1.4 QA/QC procedures

Comparison of data on fuel consumption on CPPs and CHPs from 4-MTP and 11-MTP statistical reporting forms was conducted for 1999-2004. This comparison evidenced good coincidence of data (0.05 %). Comparison of data on calorific values of fuels consumed by CPPs and CHPs from 11-MTP and 6-TP statistical reporting forms also was carried out for 1999-2004. The difference in data did not exceed 1.8%.

Checking calculation was executed with electronic table application to verify calculation algorithm and software. Results of checking calculation on the base of electronic tables and specific software evidenced absolute coincidence.

3.2.1.5 Recalculations

The following recalculations were carried out compared to the previous inventory submission:

- emissions from fuel combustion by transport at the enterprises of this category have been taken into account in the category Road Transportation (category 1.A.3.b CRF);
- emissions from fuel combustion by agricultural machines at the enterprises of this category have been taken into account in the category Agricultural Transportation (category 1.A.3.e.iii CRF);
- emissions from fuel combustion by internal transport at the enterprises of this category have been taken into account in the category Off-Road Transportation (category 1.A.3.e.ii CRF);
- national CO_2 emission factors for steam coal were used;
- specific net calorific values of fuels defined more accurately from 11-MTP statistical reporting form;
- national fraction of carbon oxidized for coal in the category Public Electricity and Heat Production (category 1.A.1.a CRF) were used.

3.2.1.6 Planned improvements

In future investigation of national CO_2 emission factors for NG and fuel oil (mazut) combustion is planned.

3.2.2 Manufacturing Industry and Construction (category 1.A.2 CRF)

3.2.2.1 Overview of Source Category

This emission category includes emissions from stationary combustion of fossil fuel from non-energy material production, industry and construction. Category Manufacturing Industry and Construction is divided to six subcategories.

In 2004 emissions in the category Manufacturing Industry and Construction amounted to 47.2 mln t CO_2-eq., or 20.5 % from emissions in the category Fuel combustion, and increased by 3.2 % compared to 2003. Emissions in this category have decreased by 67% in comparison with 1990.

Subcategory Iron and Steel has accounted for 45.5% of emissions in this category in 2004, while subcategories Other Manufacturing Industry and Construction and Food Processing, Beverages and Tobacco have accounted for 28.1 % and 11.8 % respectively (Table 3.5).

Table 3.5. Emissions in the category Manufacturing Industry and Construction, mln t CO_2-eq.

Emission Category	1990	2003	2004
1.A.2 Manufacturing Industry and Construction including:	**143.9**	**45.7**	**47.2**
1.A.2.a Iron and Steel	40.7	21.1	21.5
1.A.2.b Non-Ferrous Metals	1.1	1.4	1.8
1.A.2.c Chemicals	4.0	4.5	4.7
1.A.2.d Pulp, Paper and Print	0.2	0.5	0.5
1.A.2.e Food Processing, Beverages and Tobacco	5.8	5.7	5.6
1.A.2.f Other Manufacturing Industry and Construction	92.0	12.5	13.2

Emissions from primary and secondary fossil fuels as a feedstock or reducing agent, e.g. metallurgic coke for iron ore reduction or NG for ammonia production, were accounted in the sector Industrial Processes (sector 2 CRF).

Iron and Steel (category 1.A.2.a CRF)

Ukraine takes 7th place in the world steel production with annual level of 38.7 mln t in 2004 [14]. Five biggest enterprises, which include blast-furnace production, steel production and rolling mills, manufacture nearly 70 % of all metal products. Iron is produced mainly in blast furnaces, while significant part (43%) of steel is produced in open hearth furnaces [14].

Iron and Steel is the next significant NG consumer after power industry.

This category characterizes by the large share of non-energy fuel use, mainly coke. Coke is used as reducing agent in the blast furnaces and as fuel to hold high temperatures in the furnace.

Non-Ferrous Metals (category 1.A.2.b CRF)

The share of production of non-ferrous metals in Ukraine, in contrast to ferrous metallurgy, is not great from the point of view of production volumes and fuel consumption. However this branch consumes a lot of electricity mainly for aluminium production.

Aluminium and copper are the main produced non-ferrous metals in Ukraine. Not only primary aluminium is produced, but also alumina – the raw material for aluminium production. Aluminium is manufactured from imported bauxite ore.

Little volumes of zinc, magnesium, chromium, nickel, titanium dioxide etc. are also produced in Ukraine.

Chemicals (category 1.A.2.c CRF)

Category Chemicals is another important industrial NG consumer after power industry and ferrous metallurgy in Ukraine.

Ammonia, fertilizers (carbamide, ammonium nitrate etc.), acids (sulphuric, nitric etc.), soda ash, plastics and rubber are the main products of chemical industry in Ukraine.

The major share of NG consumed by this category (70%) is used as feedstock. Ammonia Production consumes 99% of this NG volume.

Pulp, Paper and Print (category 1.A.2.d CRF)

Emissions from the enterprises for pulp and paper, paper goods production, publishing and printing are included to this category. Fuel consumed by this category is used to provide needs of enterprises in electricity and heat.

Food Processing, Beverages and Tobacco (category 1.A.2.e CRF)

Enterprises of sugar, baking, milk and beverage production are the main emission sources in this category.

3.2.2.2 Methodological Issues

GHG emissions from fossil fuel combustion for all categories were calculated according to the methodology, which is described in Annex 2. Activity data were obtained from 4-MTP statistical reporting form.

Emissions from fuel consumption for transportation at the enterprises of this category are presented in the category Transport (category 1.A.3 CRF).

Iron and Steel (category 1.A.2.a CRF)

Emissions from entities with sector code from groups D DJ 27.1 Ferrous metallurgy, D DJ 27.2 Pipe Production and D DJ 27.3 Primary Steel Processing according to CKEA are included to this category [8].

It should be noted that metallurgical coke use in blast furnaces was took no account in this category, because it was taken into consideration in category Iron and Steel Production from the sector Industrial Processes (category 2.C.1 CRF).

Non-Ferrous Metals (category 1.A.2.b CRF)

Emissions from entities with sector code from group D DJ 27.4 Non-Ferrous metallurgy are included to this category [8].

Chemicals (category 1.A.2.c CRF)

Emissions from entities with sector code from subsections D DG Chemical Production, D DH Rubber and Plastics Production and group D DJ 27.2 Pipe Production according to CKEA are included to this category [8].

It should be noted that non-energy fuel use (e.g. NG for ammonia production) was taken into consideration in sector Industrial Processes.

Pulp, Paper and Print (category 1.A.2.d CRF)

Emissions from entities with sector code from subsection D DE Pulp and Paper Industry, Printing according to CKEA are included to this category [8].

Food Processing, Beverages and Tobacco (category 1.A.2.e CRF)

Emissions from entities with sector code from subsection D DA Food Industry and Agricultural Product Processing according to CKEA are included to this category [8].

Other Manufacturing Industry and Construction (category 1.A.2.f CRF)

This category includes emissions from fuel combustion by the enterprises, which are not included in other subcategories.

Emissions from entities with the following sector codes according to CKEA are included to this category [8]:

1) Section level:
   - F Construction;
2) Subsection level:
   - C CB Non-Energy Materials Mining;
   - D DB Textile Industry and Tailoring;
   - D DC Production of Leather and Leather Shoes;
   - D DD Wood and Woody Goods Production;
   - D DI Production of Other Non-Metal Mineral Goods;
   - D DK Production of Machine and Equipment;
   - D DL Production of Electric and Electronic Equipment;
   - D DM Production of Transport Equipment;
   - D DN Other Production;
3) Part level:
   - D DJ 28 Metal Processing;
4) Group level:
   - D DJ 27.5 Metal Casting.

3.2.2.3 Uncertainty assessment and developing a consistent time series

The estimated uncertainty of emissions depends upon uncertainty in the emission factors and the corresponding activity data.

Table 3.6 presents uncertainties of activity data and emission factors, which were used for the estimation of overall emission uncertainty in this category.

Table 3.6. Uncertainty of activity data and emission factors in the category Manufacturing Industry and Construction

Fuel	Uncertainty of Activity Data, %	Uncertainty of emission factors, %		
		CO_2	CH_4	N_2O
Liquid fuel	5	5	150	500
Solid fuel	5	5	150	500
Gaseous fuel	2	2	150	500
Other fuels	10	20	150	500
Biomass	10	20	150	500

Estimated emission uncertainty amounted to 1.5 %.

Uncertainty of CO_2 emission estimation in the subcategory Iron and Steel made the most significant impact upon the overall uncertainty of GHG emission estimation in this category and mainly determined by uncertainty in emission factors and activity data for solid and gaseous fuels.

Data sources with different levels of aggregation were used for 1990 and for the period 1998-2004. Fuel and Energy Balance was use for emission estimation in 1990 and 4-MTP statistical reporting form – in 1998-2004. Since 1991 Fuel and Energy Balance was not developed in Ukraine.

In view of lack of reliable, complete, consistent and sufficiently disaggregated data on fuel consumption for 1991-1997 emissions for this category were assessed only at category the level using interpolation without division to subcategories.

3.2.2.4 QA/QC procedures

In addition to general QA/QC procedures the following specific check procedures were undertaken:

- Joint analysis of metallurgic coke use in the categories Iron and Steel (category 1.A.2.a CRF) and Iron and Steel Production (category 2.C.1 CRF) was conducted to avoid double counting.
- Joint analysis of NG use in the categories Chemicals (category 1.A.2.c CRF) and Ammonia Production (category 2.B.1 CRF) was conducted to avoid double counting.
- Checking calculation was executed with electronic table application to verify calculation algorithm and software. Results of checking calculation on the base of electronic tables and specific software evidenced absolute coincidence.

3.2.2.5 Recalculations

The following recalculations were carried out compared to the previous inventory submission:

- emissions from coke use in blast furnace were transferred to the sector Industrial Processes (sector 2 CRF);
- emissions from fuel combustion by transport at the enterprises of this category have been taken into account in the category Road Transportation (category 1.A.3.b CRF);
- emissions from fuel combustion by agricultural machines at the enterprises of this category have been taken into account in the category Agricultural Transportation (category 1.A.3.e.iii CRF);
- emissions from fuel combustion by internal transport at the enterprises of this category have been taken into account in the category Off-Road Transportation (category 1.A.3.e.ii CRF);
- national CO_2 emission factors for steam coal were used;
- specific net calorific values of fuels defined more accurately from 11-MTP statistical reporting form.

3.2.2.6 Planned improvements

In future investigation of national CO_2 emission factors for NG and fuel oil (mazut) combustion is planned.

3.2.3 Transport (category 1.A.3 CRF)

This emission category includes emissions from fuel combustion from civil aviation, road transportation, railways, navigation and other transportation.

In 2004 emissions in the category Transport amounted to 37.7 mln t CO_2-eq., or 16.4 % from emissions in the category Fuel Combustion, and increased by 3.2 % compared to 2003. Emissions in this category have decreased by 58% in comparison with 1990.

Subcategories Road Transportation and Other Transportation have accounted for 55.4% and 41% of emissions in this category in 2004 respectively (Table 3.7).

Table 3.7. Emissions in the category Transport, mln t CO_2-eq.

Emission Category	1990	2003	2004
1.A.3 Transport, including	**89.8**	**36.5**	**37.7**
1.A.3.a Civil Aviation	3.0	0.3	0.3
1.A.3.b Road Transportation	46.7	19.8	20.9
1.A.3.c Railways	3.8	0.9	0.8
1.A.3.d Navigation	2.6	0.2	0.3
1.A.3.e Other Transportation, including	33.7	15.4	15.5
1.A.3.e.i Pipeline Transportation	6.6	9.7	10.1
1.A.3.e.ii Off-Road Transportation	2.0	1.1	1.2
1.A.3.e.iii Agriculture Transportation	19.8	4.6	4.2
1.A.3.e.iv Other	5.4	NO	NO

3.2.3.1 Overview of Source Category

Category Transport includes emissions from fuel combustion from all kinds of transportation in Ukraine. This category is divided to the following subcategories:

- Civil Aviation (category 1.A.3.a CRF);
- Road Transportation (category 1.A.3.b CRF);
- Railways (category 1.A.3.c CRF);
- Navigation (category 1.A.3.d CRF);
- Other Transportation (category 1.A.3.e CRF).

3.2.3.2 Methodological Issues

GHG emissions from fossil fuel combustion for category Transport were calculated according to the methodology, which is described in Annex 2.

Civil Aviation (category 1.A.3.a CRF)

Civil aviation includes emissions from all civil commercial use of airplanes (international and domestic). Stationary combustion and ground transport at airports are to be included in other appropriate categories.

Emissions were estimated using Tier 1 sectoral approach recommended IPCC Revised Guidelines [6]. Activity data were taken from part I 62 Aviation according to CKEA [8].

Emissions from international bunkers were not estimated separately due to lack of necessary activity data.

Road Transportation (category 1.A.3.b CRF)

This category embraces emissions from fuel combustion by motor transport including private cars.

Emissions were estimated using Tier 1 sectoral approach recommended IPCC Revised Guidelines [6].

Railways (category 1.A.3.c CRF)

This category includes emissions from fuel combustion by railway transport. Diesel fuel is used as the fuel for diesel locomotives in. This category does not include emissions, occurring during production of electricity for electric locomotives.

Emissions from entities with sector code from group I 60.1 Railways according to CKEA are included to this category [8].

Emissions were estimated using Tier 1 sectoral approach recommended IPCC Revised Guidelines [6].

Navigation (category 1.A.3.d CRF)

This category includes emissions from fuel combustion by water transport.

Emissions from entities with sector code from part I 60 Water Transport according to CKEA are included to this category [8].

Emissions were estimated using Tier 1 sectoral approach recommended IPCC Revised Guidelines [6].

Emissions from International Bunkers did not taken into account in the total emissions and presented separately in CRF for references.

Other Transportation (CRF category 1.A.3.e)

This category includes emissions from fuel combustion by compressors of pipelines, agriculture machines and equipment and off-road transportation.

Pipeline Transportation (category 1.A.3.e.i CRF). This category includes emissions from NG combustion by gas turbines of gascompressor unit of pipelines. NG consumption was taken from [2,3], because 4-MTP statistical reporting form does not contain all NG consumption for the needs of pipeline transportation.

Emission factors for non-CO_2 gases were accepted equal to those for the category Public Electricity and Heat Production, because performance attributes of pipeline gas turbines are the similar to power plant.

Off-Road Transportation (category 1.A.3.e.ii CRF). This category includes emissions from fuel combustion from in-plant transport of all economy branches, as well as construction machines.

Emissions were estimated using Tier 1 sectoral approach recommended IPCC Revised Guidelines [6].

Agriculture Transportation (category 1.A.3.e.iii CRF). This category includes emissions from fuel combustion from combines, tractors and other machines which are used for agricultural purposes.

Emissions were estimated using Tier 1 sectoral approach recommended IPCC Revised Guidelines [6].

3.2.3.3 Uncertainty assessment and developing a consistent time series

The estimated uncertainty of emissions depends upon uncertainty in the emission factors and the corresponding activity data.

Table 3.8 presents uncertainties of activity data and emission factors, which were used for the estimation of overall emission uncertainty in this category.

Table 3.8. Uncertainty of activity data and emission factors in the category Transport

Fuel	Uncertainty of activity data, %	Uncertainty of emission factors, %		
		CO_2	CH_4	N_2O
Liquid fuel	5	5	40	50
Gaseous fuel	5	2	150	500

Estimated emission uncertainty amounted to 4.3 %.

Uncertainty of CO_2 emission estimation in the subcategory Road Transportation made the most significant impact upon the overall uncertainty of GHG emission estimation in this category.

Data sources with different levels of aggregation were used for 1990 and for the period 1998-2004. Fuel and Energy Balance was use for emission estimation in 1990 and 4-MTP statistical reporting form – in 1998-2004. Since 1991 Fuel and Energy Balance was not developed in Ukraine.

In view of lack of reliable, complete, consistent and sufficiently disaggregated data on fuel consumption for 1991-1997 emissions for this category were assessed only at category the level using interpolation without division to subcategories.

3.2.3.4 QA/QC procedures

General QA/QC procedures were used.

3.2.3.5 Recalculations

The following recalculations were carried out compared to the previous inventory submission:

- Emissions from transport belong to enterprises and private cars were taken into account in the category Road Transportation;
- Category Agriculture Transportation has taken into consideration all machines which are used for agricultural purposes;
- Category Off-Road Transportation has taken into consideration emissions from in-plant Transport;
- Bunker fuel is subtracted from the category Navigation;
- Specific net calorific values of fuels defined more accurately from 11-MTP statistical reporting form.

3.2.3.6 Planned improvements

It is planned to use higher order approach for emission estimation in the category Road Transportation, based on information about stock of cars, distances, specific fuel consumption. In addition national CO_2-emission factors for gasoline and diesel oil combustion are planned to develop.

3.2.4 Other Sectors (category 1.A.4 CRF)

In 2004 emissions in the category Other Sectors amounted to 43.1 mln t CO_2-eq, or 18.7 % from emissions in the category Fuel Combustion, and decreased by 0.2 % compared to 2003. Emissions in this category have decreased by 55% in comparison with 1990.

Subcategory Residential has accounted for 84% of emissions in this category in 2004 (Table 3.9).

Table 3.9. Emissions in the category Other Sectors, mln t CO_2-eq.

Emission Category	1990	2003	2004
1.A.4 Other Sectors, including	**95.1**	**43.2**	**43.1**
1.A.4.a Commercial/Institutional	23.0	5.7	5.8
1.A.4.b Residential	68.3	36.3	36.1
1.A.4.c Agriculture/Forestry/Fisheries	3.8	1.1	1.2

3.2.4.1 Overview of Source Category

This category includes the following subcategories:
- Commercial/Institutional (category 1.A.4.a CRF);
- Residential (category 1.A.4.b CRF);
- Agriculture/Forestry/Fisheries (category 1.A.4.c CRF).

Emissions in this category are caused mainly by fuel combustion for heating.

3.2.4.2 Methodological Issues

GHG emissions from fossil fuel combustion for category Other Sectors were calculated according to the methodology, which is described in Annex 2.

Commercial/Institutional (category 1.A.4.a)

Emissions from entities with the following sector codes according to CKEA are included to this category [8]:
- Wholesale and Retail Trade (G);
- Hotels and Restaurants (H);
- Financial Activity (J);
- Real Estate Activities (K);
- Public Administration (L);
- Education (M);
- Health Authorities (N);
- Collective, Public and Private Service (O);
- Transport (I);
- Water Collection, Treatment and Distribution (E 41).

Residential (category 1.A.4.b CRF)

Activity data were obtained from column 10 of part 4 of 4-MTP statistical reporting form, which presents the volumes of fuel consumed by population.

GHG emissions from private cars have been taken into account in the Road Transportation (category 1.A.3.b CRF).

Agriculture/Forestry/Fisheries (category 1.A.4.c CRF)

This category includes emissions from stationary fuel combustion in agriculture (CKEA code [8] – A) and fish industry (CKEA code [8] – B). Emissions from transportation have been taken into account into the category Transport.

3.2.4.3 Uncertainty assessment and developing a consistent time series

The estimated uncertainty of emissions depends upon uncertainty in the emission factors and the corresponding activity data.

Table 3.10 presents uncertainties of activity data and emission factors, which were used for the estimation of overall emission uncertainty in this category.

Estimated emission uncertainty amounted to 7.3 %.

Table 3.10. Uncertainty of activity data and emission factors in the category Other Sectors

Fuel	Uncertainty of activity data[3], %	Uncertainty of emission factors, %		
		CO_2	CH_4	N_2O
Liquid fuel	10 (5)	5	150	500
Solid fuel	10(5)	5	150	500
Gaseous fuel	10 (5)	2	150	500
Other fuels	20 (10)	20	150	500
Biomass	20 (10)	20	150	500

Uncertainty of CO_2 emission estimation in the subcategory Residential made the most significant impact upon the overall uncertainty of GHG emission estimation in this category due to uncertainties of gaseous fuel consumption as a result of lack of gas meters in many private consumers.

Data sources with different levels of aggregation were used for 1990 and for the period 1998-2004. Fuel and Energy Balance was use for emission estimation in 1990 and 4-MTP statistical reporting form – in 1998-2004. Since 1991 Fuel and Energy Balance was not developed in Ukraine.

In view of lack of reliable, complete, consistent and sufficiently disaggregated data on fuel consumption for 1991-1997 emissions for this category were assessed only at category the level using interpolation without division to subcategories.

3.2.4.4 QA/QC procedures

General QA/QC procedures were used.

3.2.4.5 Recalculations

The following recalculations were carried out compared to the previous inventory submission:

- Emissions from private cars were taken into account in the category Road Transportation;
- Emissions from transport of enterprises belong to this category were taken into account in the category Road Transportation;

[3] The values in brackets related to the category «Commercial/Institutional» (category 1.A.4.a CRF)

- Category Agriculture Transportation (category 1.A.3.e.iii CRF) has taken into consideration all machines which are used for agricultural purposes.

3.2.4.6 Planned improvements

In future investigation of national CO_2 emission factors from NG combustion is planned.

3.2.5 Other (Not Included to Other Fuel Combustion) (category 1.A.5 CRF)

3.2.5.1 Overview of Source Category

This GHG emission category includes emission sources, which were not included in other categories of fuel combustion.

In 2004 emissions in the category Other Sectors (Not Included to Other Fuel Combustion) amounted to 1.5 mln t CO_2-eq., or 0.7 % from emissions in the category Fuel Combustion, and decreased by 9.4 % compared to 2003 (Table 3.11). Emissions in this category in 1990 were absent.

Table 3.11. Emissions in the category Other (Not Included to Other Fuel Combustion), mln t CO_2-eq.

Emission Category	1990	2003	2004
1.A.5 Other (Not Included to Other Fuel Combustion)	NO	1.7	1.5

3.2.5.2 Methodological Issues

GHG emissions from fossil fuel combustion for category Other Sectors were calculated according to the methodology, which is described in Annex 2.

Emissions in this category are caused mainly by fuel combustion for heating enterprises which were not included to the other categories of fuel combustion.

3.2.5.3 Uncertainty assessment and developing a consistent time series

The estimated uncertainty of emissions depends upon uncertainty in the emission factors and the corresponding activity data.

Table 3.12 presents uncertainties of activity data and emission factors, which were used for the estimation of overall emission uncertainty in this category.

Table 3.12. Uncertainty of activity data and emission factors in the category Other (Not Included to Other Fuel Combustion)

Fuel	Uncertainty of activity data, %	Uncertainty of emission factors, %		
		CO_2	CH_4	N_2O
Liquid fuel	10	5	150	500
Solid fuel	10	5	150	500
Gaseous fuel	5	2	150	500
Other fuels	10	20	150	500
Biomass	10	20	150	500

Estimated emission uncertainty amounted to 5.5 %.

Uncertainty of CO_2 emission estimation made the most significant impact upon the overall uncertainty of GHG emission estimation in this category due to uncertainties of activity data.

Data sources with different levels of aggregation were used for 1990 and for the period 1998-2004. Fuel and Energy Balance was use for emission estimation in 1990 and 4-MTP statistical reporting form – in 1998-2004. Since 1991 Fuel and Energy Balance was not developed in Ukraine.

In view of lack of reliable, complete, consistent and sufficiently disaggregated data on fuel consumption for 1991-1997 emissions for this category were assessed only at category the level using interpolation without division to subcategories.

3.2.5.4 QA/QC procedures

General QA/QC procedures were used.

3.2.5.5 Recalculations

This category has not been included in the previous inventory.

3.2.5.6 Planned improvements

No improvements in this category are planned.

3.3 Fugitive Emissions (category 1.B CRF)

Fugitive emissions are caused by methane release from fossil fuel production, processing, transportation and storage. Venting and flaring are also included in this category.

This category is divided to two subcategories:

- Fugitive emissions from coal mining and handling (category 1.B.1 CRF);
- Fugitive emissions from oil and gas operations (category 1.B.2 CRF).

In 2004 emissions in the category Fugitive Emissions amounted to 52.5 mln t CO_2-eq., or 18.6 % from emissions in the sector Energy, and increased by 0.8 % compared to 2003. Emissions in this category have decreased by 39% in comparison with 1990.

Subcategory Fugitive Emissions from Solid Fuels has accounted for 56% of emissions in this category in 2004, while subcategory Fugitive Emissions from Oil, NG and Other source has accounted for 44 % (Table 3.13).

Table 3.13. Emissions in the category Fugitive Emissions, mln t CO_2-eq.

Emission Category	1990	2003	2004
1.B Fugitive emissions, including	**86.7**	**52.1**	**52.5**
1.B.1 Fugitive Emissions from Solid Fuels	55.4	29.0	29.2
1.B.2 Fugitive Emissions from Oil, NG and Other sources	31.3	23.1	23.3

3.3.1 Fugitive Emissions from Solid Fuels (category 1.B.1 CRF)

3.3.1.1 Overview of Source Category

The coal production of the Ukraine is a complicated economic complex that includes 196 underground mines in operation and 3 open-pit (surface) coal mines, 119 mines in different stages of closing, processing, transporting, prospecting and other enterprises. Annual raw coal production has been decreased from is 165 mln t in 1990 to 81 mln t in 2004.

3.3.1.2 Methodological Issues

Results of researches conducted in the Ukraine [30] were used during estimation of methane emissions from coal enterprises in 1990-2000. The average weighted methane emission factors for 1990-2000 and coal production volumes from 1-P statistical reporting form were used for estimation of methane emissions in 2001-2004. These factors are as follows:

- 25.6 m^3/t – for underground mines;
- 1,4 m^3/t – for surface mines;
- 2.0 m^3/t – for coal handling and transportation (underground mines);
- 0.2 m^3/t - for coal handling and transportation (surface mines).

Volumes of recovered methane in 1990-2000 were obtained from the study [30]. Amount of recovered methane in 2001 was taken from [31], in 2002-2004 – with annual growth of 10 %.

Methane emissions from coke production were taken into account in the category Iron and Steel Production (category 2.C.1 CRF).

3.3.1.3 Uncertainty assessment and developing a consistent time series

Uncertainty of methane emission estimation from coal mining and handling was assessed as 33 %. The main share of uncertainty in this category is caused by uncertainties of methane emission factors for underground mining, handling and transportation.

Study [30], which was used for underground mining, did not touch upon a question of emission uncertainty. So emission estimation uncertainty was determined on the basis of default data on uncertainty sources recommended by Tier 3 approach from Good Practice Guidance [20]. Emission estimation uncertainty for surface mining, handling and transportation was determined on the basis of default data on methane emission factor uncertainty recommended by Tier 1 approach from Good Practice Guidance [20].

3.3.1.4 QA/QC procedures

Methane emission factors used for GHG inventory of coal enterprises show the best correlation with default values [6, 20].

3.3.1.5 Recalculations

Activity data on surface mining have made more accurate.

3.3.1.6 Planned improvements

It is necessary to study methane emissions from closed mines and define more exactly volumes of recuperated methane.

3.3.2 Fugitive Emissions from Oil, NG and Other Sources (category 1.B.2 CRF)

3.3.2.1 Overview of Source Category

Fugitive emissions are caused by methane release from oil and NG production, processing, transportation and storage.

Oil (category 1.B.2.a)

Oil Production. In 2004 oil and NG liquids production have amounted to 3 and 1.3 mln t in Ukraine respectively. Above 90 % of total production is provided by Open Joint Stock Company Ukrnafta under National Joint Stock Company Naftogaz of Ukraine (NJSC Naftogaz of Ukraine) (in 2004 – 3 mln t) and Subsidary Company Ukrgazvydobuvannia.

Oil Transportation. The developed system of oil pipelines is functioning in Ukraine. Oil pipelines provide oil supply of Ukrainian refineries, as well as oil transit to the European countries.

Oil-trunk pipelines are exploited by Open Joint Stock Company Ukrtransnafta under NJSC Naftogaz of Ukraine. Length of pipelines with diameter from 150 to 1200 mm amounts to nearly 4570 km, and annual input capacity -114 mln t of oil. Transmission of oil to carrying on by 51 oil-transfer stations (176 oil-transfer pumps with total capacity 357 MW [18]). 80 oil tanks with tankage 1 mln m^3 are exploited to provide reliable and regular functioning.

During last years capacity loading of oil pipelines makes up 40-50 % and amounts to 55.3 mln t in 2004, including transit – 32.4 mln t, supply of Ukrainian oil refining plants – 22.4 mln t.

Oil Processing. There are 6 refineries in Ukraine with overall installed capacity over 50 mln t. The loading of refineries made up 41.5 % in 2004 [12]. Four refineries use a simple methodology of primary refining and reforming (cracking level - 46-60 %). Other two refineries use a classic methodology of oil refining (cracking level - 68-70 %) [13].

Natural gas (category 1.B.2.b)

Natural Gas Production. Natural gas production in Ukraine has long history, which began from exploitation of Dashava oil field on the Ukrainian West and construction of the first NG pipeline in 1924. Intense growth of NG production industry has resulted to achieving the peak level 68.7 billion m^3 (www.naftogaz.com) in 1975. Then NG production has constantly decreased and amounted to 28.1 billion m^3 in 1990, and 19.6 billion m^3 – in 2004.

Above 94 % of total production is provided by enterprises under NJSC Naftogaz of Ukraine: Subsidary Company Ukrgazvydobuvannia, Open Joint Stock Company Ukrnafta, State Joint Stock Company Chornomornaftogaz.

Natural Gas Transportation. NG transportation system (GTS) is the second largest one in Europe. It includes 37.5 thous. km of pipelines, 13 underground NG storages (UGS), developed system of NG distribution stations (GDS) and NG measuring units (GMU). GTS annual input capacity totals 290.7 billion m^3, output capacity – 175 billion m^3 annually including 140 billion m^3 in the European countries.

GTS is exploited mainly by Subsidiary Company Ukrtransgaz under NJSC Naftogaz of Ukraine. Ukrtransgas manages 36.4 thous. km of pipelines, 71 compressor stations (CS) with total capacity 5380 MW, 12 UGS with active tankage over 30 billion m^3, 1392 GDS, and system of GMU [15]. State Joint Stock Company Chornomornaftogaz also exploits

GTS on the Crimean territory. It manages 1.2 thous. km of pipelines, 1 UGS with active tankage over 1 billion m^3 and 43 GDS.

Recently annual volumes of NG transportation for domestic consumption amounts to 70-80 billion m^3, and transit supply – 110-120 billion m^3.

Natural Gas Distribution. Recently NG distribution network (GDN) is actively developing. Since 1990 length of GDN has increased from 90 thous. km to 270 thous. km in 2004. It should be noted that the main growth is observed for low-pressure networks with small diameter for residential sector supply.

Necessary regime of NG sully is provided by 48 thous. gas control points. 46 thous. NG consumed enterprises are functioning now in Ukraine and approximately 11.6 mln flats and dwellings are gasified with 16.1 mln gas-stoves, over 3.2 mln gas water heaters and over 4.1 mln heaters. Subsidiary Company Gas of Ukraine under NJSC Naftogaz of Ukraine is leading organization to coordinate functioning enterprises on NG distribution and provision. Regional NG provision enterprises exploit GDN and directly supply consumers [16,17].

3.3.2.2 Methodological Issues

Oil (category 1.B.2.a)

Emissions from oil sector were estimated according to IPCC Revised Guidelines [6]. The following default methane emission factors were used [6]:

- 4500 kg CH_4/PJ – for oil production;
- 1000 kg CH_4/PJ – for oil processing;
- 200 kg CH_4/PJ – for oil storage.

Oil transportation in Ukraine is realized mainly by pipelines. The following default emission factors recommended by Good Practice Guidance [20] were used:

- $4.9 \cdot 10^{-7}$ Gg/thous. m^3 - for CO_2;
- $5.4 \cdot 10^{-6}$ Gg/thous. m^3 - for CH_4.

Average density of Russian export oil Urals - 0.865 t/m^3 [28] – was used to convert oil volumes from mass units as is customary in Ukraine to the volume units.

The amount of transmitted oil was obtained from [11] and information from NJSC Naftogaz of Ukraine (www.naftogaz.com).

Natural gas (category 1.B.2.b)

Natural Gas Production. Emissions from NG production were estimated according to the Good Practice Guidance [20]. Default emissions factors were used.

Natural Gas Transportation. Results of published studies and consultations with staff of Ukrtransgas and Institute of Gas (National Academy of Sciences) were used for estimation of methane emissions from GTS of Ukraine.

Ukrainian Research Institute of Natural Gas (UkrNIIGas) has investigated pipelines and GDS in 1998 to identify gas leakages and methane releases due to not compact valves and piping connections. Total annual methane emissions amounted to 4240 m^3/km [21, 22]. This value included leakages from linear pipeline portions and GDS, but not included release from compressor stations.

The results of last study "Greenhouse Gas Emission from the Russian Natural Gas Export Pipeline System" based on results of new measurements of Wuppertal Institute [23] determined specific annual methane emissions from linear pipeline portions - 6458 m^3/km and specific annual methane emissions from compressor stations - 12 thous. m^3/MW. Construction regulations and equipment of GTS in Russia are similar to Ukraine.

Annual specific methane emission factors were determined from the data on NG consumption of Ukrtransgas [24]:

- linear pipeline portions - 7500 m^3/km;
- compressor stations – 11970 m^3/MW;
- GDS - 8100 m^3/GDS.

It should be noted that specific annual methane emissions from linear pipeline portions concern the length of trunk pipeline without pipe-bends.

Taking into account limited data about GTS infrastructure for 1990-2004, which include length of trunk pipelines and pipe-bends, as well as capacity of compressor stations, specific emission factors were reduced to the total length of pipelines and installed capacity of compressors. So annual specific methane emissions of linear pipeline portions totaled 5100 m^3/km. This value is close to estimations [23].

Analysis of different data sources and expert judgments have evidenced quite reliability of results [23] for assessments of fugitive methane emissions from NG transportation in Ukraine in the current circumstances.

Natural Gas Distribution. It should be noted that losses of gas distribution enterprises, so called business losses are required to separate from methane emissions from gas distribution networks. Business losses appear due to the difference between actual NG consumption and consumption estimated according standards [25]. Standards of NG consumption [26] are applied if gas meter is absent. There were 850 thousands gas meters in 1996, but 5.3 millions – in 2005 [25, 27].

According to the data [19, 25] actual NG releases to the atmosphere from gas distribution networks totaled to: approximately 270 mln m^3 in 1996-1998; 198 mln m^3 – in 1999; 188 mln m^3 – in 2000. Starting from these absolute values average annual specific methane emission factor amounted to $8{,}2 \cdot 10^{-4}$ Gg for 1 km of gas distribution networks.

Natural Gas Consumption. Methane leakages from consumer were estimated according to the IPCC Revised Guidelines [6]. Average default methane emission factors were taken from [6] for Former USSR:

- 280 t/PJ - leakages from industrial consumers;
- 140 t/PJ - leakages from residential and institutional sectors.

The amounts of NG consumption in corresponding categories were used as activity data.

3.3.2.3 Uncertainty assessment and developing a consistent time series

Estimated emission uncertainty amounted to 48 %.

Uncertainty of methane emission factors for industrial consumers made the most significant impact upon the overall uncertainty.

Data on uncertainty of emission factors, which were given in [20], and recommended range of emission factors [6] were used for uncertainty assessment.

3.3.2.4 QA/QC procedures

Comparison of data from different sources, consultations with independent experts on gas and oil sectors have been carried out.

3.3.2.5 Recalculations

Recalculations of emissions from oil sector concerned only improvement of activity data and not entailed serious changes.

Recalculations of emissions from NG transportation and distribution were the result of use of national emission factors. Rejection of national statistical data on NG losses was induced by impossibility of their use for inventory purposes because these data includes not only NG release to the atmosphere but also business losses and technological needs.

Besides, the current inventory has been supplemented by estimation of methane leakages for end-use consumers.

3.3.2.6 Planned improvements

Additional investigations of emission sources and national methane emission factors for end-use consumers are planned.

3.4 Additional Issues (category 1.C CRF)

3.4.1 International Bunkers (category 1.C.1 CRF)

In accordance with the IPCC Guidelines, international aviation and marine bunker fuel emissions from fuel sold to ships or aircraft engaged in international transport should be excluded from national totals and reported separately for informational purposes only.

3.4.1.1 Civil Aviation (category 1.C.1.A CRF)

Emissions from international aviation bunkers were not estimated due to the lack of activity data.

3.4.1.2 Navigation (category 1.C.1.B CRF)

National statistics does not include data on international navigation bunkers. So indirect methodology based on total fuel consumption by water transport (statistical reporting form 4-MTP) and turnover of goods by sea transport during coastwise trade and foreign navigation was used [9-11]. Inventory team assumed that fuel consumed for foreign navigation depends upon turnover of goods during foreign navigation (Table 3.14).

Table 3.14. International Navigation Bunkers

Fuel	1990	1998	1999	2000	2001	2002	2003	2004
Diesel oil, thous. t	358.4	112.7	88.7	83.0	85.2	37.9	35.6	43.6
Petrol, thous. t	405.0	26.6	17.7	16.6	18.8	14.8	6.2	4.8
Fuel Oil (Mazut), thous. t	193.9	7.6	6.6	7.3	7.4	6.1	0.8	1.4
Bunker Oil, thous. t	179.5	1.9	7.0	2.2	5.5	10.7	6.4	9.3
Lubricants, t	-	1.1	8.9	0.0	0.5	3.8	0.8	1.1

3.4.2 CO_2 emissions from biomass

According to the IPCC Revised Guidelines, CO_2 emissions from biomass combustion for energy use were excluded in the total emissions in sector Energy from national totals and reported separately for informational purposes only. CH_4 and N_2O emissions from biomass combustion for energy use were included in the total emissions in category Fuel Combustion.

3.5 Other Issues

3.5.1 Comparison of Sectoral and Reference Approaches

Comparison of Sectoral and Reference Approaches was carried out for cross check of CO_2 emission estimation from fuel combustion (Table 3.15). This check was accomplished for 1990 and 1998-2004 and included in CRF.

Table 3.15. Comparison of Sectoral and Reference Approaches

Year	CO_2 emissions (Reference Approach), mln t	CO_2 emissions (Sectoral Approach), mln t	Difference, %
1990	589.2	595.3	-1.0
1998	237.9	236.8	0.0
1999	229.9	234.1	-2.7
2000	208.2	216.5	-4.5
2001	225.5	218.0	2.9
2002	220.2	219.6	0.1
2003	233.5	233.8	-1.3
2004	254.9	228.6	11.0

CO_2 emissions estimated by sectoral and reference approaches are quite approximate (excluding 2004).

Annex 4 presents analysis of total consumption of all fuel kinds and identified discrepancies.

3.5.2 Feedstock and Non-Energy Use of Fuels

Emissions in the category Fuel combustion include only emissions from fuel combustion for energy purposes. But fuel is also used for non-energy purposes (e.g., as solvents, lubricants and so on; as a feedstock for production of ammonia, rubber, plastics etc.; as a reducing agent – coke in blast furnaces). Emissions from non-energy use of fuels are presented in sectors Industrial Processes and Solvents. Fuel losses during transportation are also necessary to include in non-energy use.

The volumes of non-energy fuel use were taken from 4-MTP statistical reporting form (column 1 of part 4). Besides, coke used in blast furnaces was also included in non-energy fuel use, because in this case coke was a reducing agent. The amount of coke used in blast furnaces was obtained from data in the category Iron and Steel Production (sector Industrial Processes).

Emissions from coke used in blast furnaces and NG for ammonia production are presented in sector Industrial Processes.

3.5.3 CO_2 Sequestration

CO_2 sequestration from fuel combustion is not occurred in Ukraine and, consequently, CO_2 sequestration in sector «Energy» was not assessed.

4 INDUSTRIAL PROCESSES (SECTOR 2 CRF)

4.1 General Sector Overview

GHG emissions in the category «Industrial Processes» include emissions from technological processes in industrial production. Energy consumption for production is considered in the Energy sector. Ukraine has great industrial potential and GHG emissions from industrial processes are sufficiently large.

GHG emissions were estimated for the different industrial sectors taking into account specific character of technological processes, i.e. mineral products manufacture; chemical industry; metal production; pulp and food&drink production. Hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride are not produced in Ukraine and information on their application is not available. That is why only emissions of perfluorocarbons from aluminium production have been considered in the current inventory.

GHG emission trend in the sector "Industrial Processes" for 1990–2004 is presented in the Table 4.1.

Table 4.1. GHG Emission Trends in Industry

Gas	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
CO_2	Thous. t CO_2	123995	108326	106799	84378	67099	61851	61035	70085	71399	75204	80016	80865	81652	86709	88262
CH_4	Thous. t CH_4	62	51	49	37	28	25	24	28	28	30	34	35	35	39	41
N_2O	Thous. t N_2O	9	8	6	4	3	3	4	4	4	4	6	6	6	6	7
PFCs	Thous. t CO_2-e	203	162	123	124	139	153	123	127	104	88	100	97	85	66	80
NOx	Thous. t NO_X	31	27	24	20	16	13	15	16	14	15	17	17	20	20	18
CO	Thous. t CO	115	101	99	80	68	66	68	74	73	80	84	86	88	94	96
NMVOC	Thous. t NMVOC	875	792	561	365	297	292	223	186	174	234	180	175	172	240	231
SO_2	Thous. t SO_2	190	158	134	95	76	69	68	71	70	75	75	76	77	85	94
Total	Thous. t CO2-eq.	128150	112042	109654	86438	68864	63405	62859	72128	73324	77026	82741	83537	84302	89583	91350

GHG emissions from industrial processes amounted to 128149.9 thous. t in the base 1990 year, and – 91350.2 thous. t – in 2004. The lowest values were observed in 1994–1999.

Subcategories «Iron and Steel Production», "Cement Production", "Lime Production" and "Limestone and Dolomite Use" were the most significant sources of CO_2. Iron and coke production caused the largest amount of CH_4 emissions. N_2O is emitted mainly from adipic and nitric acid production, and perfluorocarbons – from aluminium production.

4.2 Cement Production (Emission Category 2.A.1 CRF)

4.2.1 Overview of Source Category

The main components of cement are calcium and silicon with small content of aluminum and iron oxides. The production process includes: clinker production, calcinations and drying. The mixture of natural limestone and clay is the typical feedstock for this. Dry the feedstock or wet cuttings are heated (calcined) in the kiln for clinker production. Carbon dioxide is released as by-product of limestone calcinations process.

The statistical data concerning industrial production in Ukraine were used as activity data on volumes of produced cement and clinker.

Cement production emits only CO_2 emissions and is the key source category. According to the Good Practice Guidance, CO_2 emissions were estimated on the basis of clinker production data.

National methodology and CO_2 emission factors were developed to make more precise calculations of CO_2 emissions from clinker production. Technological indicators of 12 enterprises in Ukraine, which produced more than 85% of clinker, were analyzed in 1985, 1986, 1992 and 2001, as well as GHG inventory results for cement production [1].

4.2.2 Methodological Issues

Methodology based on clinker production (Tier 2) was used to estimate CO_2 emissions. National CO_2 emission factors were determined on the basis of technological indicators of 12 enterprises in Ukraine:

$$k = V / m^{K},$$

where V – total CO_2 emissions from clinker production at 12 enterprises, t;

m^{K} – total annual amount of clinker production at 12 enterprises, t.

Investigations made it possible to specify CO_2 emissions from every enterprise taking into account the following additional (to the Good Practice Guidance) factors:

- CaO content in clinker, which is produced from non-carbonate the feedstock (e.g. blast-furnace slag);
- Use of $MgCO_3$, which is obtained from carbonate sources, as the feedstock ;
- The amount of Cement Kiln Dust (CKD) which is recycled to the kiln.

CO_2 emissions from clinker production were estimated as follows:

$$V = 0.785(m^{K}{}_{CaO} + m^{n}{}_{CaO} - m^{H}{}_{CaO}) + 1.092(m^{K}{}_{MgO} + m^{n}{}_{MgO}), \quad (4.1)$$

where 0.785 – the molecular weight ratio of CO_2 to CaO in the raw material;

$m^{K}{}_{CaO}$ – CaO content (weight fraction) in clinker, t;

$m^{H}{}_{CaO}$ – CaO content in CKD, t;

$m^{H}{}_{CaO}$ –CaO content in clinker from non-carbonate raw materials (e.g. blast-furnace slag), t;

1.092 – the molecular weight ratio of CO_2 to MgO;

$m^{K}{}_{MgO}$ –MgO content (weight fraction) in clinker, t;

$m^{n}{}_{MgO}$ – MgO content in CKD, t.

Equation (4.1) can be converted to the equation from Good Practice Guidance:

$$V = k^{K} \cdot k^{n} \cdot A^{K}, \quad (4.2.)$$

where A^{K} - clinker production, t;

k^{K} - CO_2 emission factors for clinker production;

k^n - CKD correction factor.

So CO_2 emission factor for clinker production can be estimated as follows:

$$k^K = [0,785 \cdot (m^K{}_{CaO} - m^H{}_{CaO}) + 1,092 \cdot m^K{}_{MgO}] / A^K,$$

and CKD correction factor:

$$k^n = 1 + (0,785 \cdot m^n{}_{CaO} + 1,092 \cdot m^n{}_{MgO}]/[0,785 \cdot (m^K{}_{CaO} - m^H{}_{CaO}) + 1,092 \cdot m^K{}_{MgO}].$$

Results of calculations in 1985, 1986, 1992 and 2001 were used for defining CO_2 e-mission factors and CKD correction factor through linear interpolation for the period 1990-2001. CO_2 emission factors and CKD correction factor in 2002-2004 were used at the level of 2001. CO_2 emission factors in 1990 are higher by 4 % compared to the default values and smaller by 3.5 % in comparison to [1], which were used in the previous inventory. More accurate values of CKD correction factor lie in the range of 1.006-1.008, which is significantly lower than the default value 1.05, which was used in the previous inventory according to the Good Practice Guidance.

4.2.3 Uncertainty assessment and developing a consistent time series

The main sources of uncertainty in the category are as follows:

- Accuracy of results of chemical analysis concerning composition of clinker, which influences the uncertainty of emission factors;
- Accuracy of activity data on clinker production;
- Temporal straggling results of chemical analysis concerning composition of clinker during the year (CaO and MgO content).

The first two factors brings uncertainty at the level 1-2 % according to the Good Practice Guidance. Investigations at the 12 cement enterprises show that temporal straggling results of chemical analysis concerning CaO and MgO content in clinker during the year is not significant, and the total uncertainty of CO_2 emission factors during cement production made up 1 %. Uncertainty of CKD correction factor is negligible, because it is a smaller one. Taking into account uncertainty of activity data on clinker production at the level 2 % recommended by the Good Practice Guidance the overall uncertainty of CO_2 emission estimation for cement production has totaled 2.2 %.

4.2.4 QA/QC procedures

The general QC procedures for estimation of GHG emissions were used for estimation of CO_2 emissions from cement production.

4.2.5 Recalculations

The accomplished investigations made it possible to specify national CO_2 emission factors for cement production. Subchapter 4.2.2 presents additional factors, which were considered in this study, and subchapter 4.2.3 gave improved CO_2 emission factors and CKD correction factor. The Table 4.2 presents inventory results in 2005 and 2006.

Table 4.2. Comparison of estimation of CO_2 emissions from cement production in Ukraine, thous.t

Value	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Inventory submitted in 2005														
CO_2 Emis-	9548	9058	8798	6498	5069	3468	2203	2467	2853	2594	2319	2542	2895	3711

Value	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
sions														
Inventory submitted in 2006														
CO_2 Emissions	9287	8814	8566	6306	4913	3356	2129	2381	2750	2497	2229	2440	2778	3562
Difference, %	2.7	2.7	2.6	3.1	3.2	3.4	3.5	3.6	3.7	3.7	3.9	4.0	4.0	4.0

4.2.6 Planned improvements

No improvements in this category are planned.

4.3 Lime Production (category 2.A.2 CRF)

4.3.1 Overview of Source Category

Lime production emits CO_2 through the thermal decomposition (calcination) of the calcium carbonate ($CaCO_3$) in limestone to produce quicklime (CaO), or through the decomposition of dolomite ($CaCO_3 \cdot MgCO_3$) to produce dolomitic “quick” lime (CaO·MgO). The emission volumes depend upon activity data on lime production and efficiency of kiln.

Lime is produced in the different branches of industry and used for construction, agriculture and industry – steel, magnesium, copper soda ash and sugar production. There are the following main types of lime: quicklime and hydrated lime, construction lime and technological lime, calcium (CaO) and dolomitic (CaO*MgO) lime. They are distinguished by chemical and mechanical content.

Quicklime is the product of thermal decomposition (calcination) of the calcium carbonate ($CaCO_3$) in limestone. Slaked lime $Ca(OH)_2$ is the product of quicklime hydratation.

4.3.2 Methodological Issues

CO_2 emissions from lime production were estimated according to the chapter 3.1.2 of the Good Practice Guidance. Activity data on overall lime production were obtained from statistical reporting forms of the State Committee on Statistics of Ukraine. These data do not include lime production for agriculture. Hydraulic lime is not produced in Ukraine.

Before 2004 lime production was divided into construction lime and technological lime in statistical reporting forms. In 2004 Ukraine accepted the international nomenclature of statistical information with division into quicklime and hydrated lime. According to the State Committee on Statistics of Ukraine, the proportion of quick and hydrated lime was equal to 67/33 in 2004. For the other years this proportion also was used. Inasmuch as there were no disaggregated data for the breakdown of calcium and dolomitic lime types in Ukraine, the default value for high calcium/dolomitic lime 85/15 was used.

CO_2 emission factors were determined by stoichiometric ratios, default ranges of CaO/MgO in lime and proportion of CaO and CaO*MgO content in lime. CO_2 emission factor 0.75 was used for high calcium lime and 0.86 – for dolomitic lime (Table 3.4 from the Good Practice Guidance).

Correction of activity data for hydrated lime was carried out with default correction factor on water content – 0.28 (Table 3.5 from the Good Practice Guidance).

4.3.3 Uncertainty assessment and developing a consistent time series

Uncertainty of activity data on lime production is caused by lack of disaggregated activity data on quicklime and hydrated lime, calcium and dolomitic lime over the whole period. That is why uncertainty of activity data was assessed at the level of 100 % according to the Good Practice Guidance for calcium and dolomitic lime. Uncertainty of CO_2 emission factors for quick calcium and dolomitic lime was assessed at the level of 2 %, according to the Good Practice Guidance. The overall uncertainty of emission estimation amounted to 84.7%.

4.3.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions from lime production.

4.3.5 Recalculations

Transition to the Good Practice Guidance from IPCC Revised Guidelines led to decrease of CO_2 emission estimation for lime production by 15-20 % compared to the previous inventory. The Table 4.3 presents comparison of inventory results in 2005 and 2006.

Table 4.3. Comparison of estimation of CO_2 emissions from lime production in Ukraine, thous.t

Value		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Inventory submitted in 2005														
CO_2 Emissions	5671	4999	4892	3872	3048	2550	2183	2310	2191	2214	2374	2854	2913	3200
Inventory submitted in 2006														
CO_2 Emissions	6637	5850	6106	4848	3816	3196	2738	2898	2749	2780	2979	3589	3661	4023
Difference, %	14.6	14.6	19.9	20.1	20.1	20.2	20.3	20.3	20.3	20.4	20.3	20.5	20.5	20.4

4.3.6 Planned improvements

No improvements in this category are planned.

4.4 Limestone and Dolomite Use (Category 2.A.3 CRF)

4.4.1 Overview of Source Category

Limestone ($CaCO_3$) and dolomite ($CaCO_3$*$MgCO_3$) are used in the many branches of industry, especially in chemical industry for cement, lime, calcium carbide, soda ash production, in construction as a material or additive to construction materials. A significant amount of limestone is used in metallurgy as a flux. In agriculture limestone is applied for soils liming, in sugar industry – for beet juice refining. The paper industry uses whitewash (some kind of limestone).

Dolomite is used as refractory material and the feedstock for cement, calcium and magnesium carbonate production.

4.4.2 Methodological Issues

CO_2 emissions are generated only from limestone and dolomite use. Activity data on limestone and dolomite use were obtained from their production, export and import information of the State Committee on Statistics and the Ministry of Industrial Policy of Ukraine. Unfortunately, full export and import data covered only the period 1996-2004. Data on dolomite import for 1990-1995 were provided by the Ministry of Industrial Policy of Ukraine. So, limestone export and import data and dolomite export in 1990-1995 were assumed at the level of 1996.

CO_2 emissions were estimated by subtracting emissions in other sectors (cement, soda ash, and lime and sugar production). The structure of limestone production for different industries was obtained from statistical reporting forms for 2004 (before, such statistics records were not kept).

Default CO_2 emission factors were used: 440 kg CO_2 /t – for limestone use and 477 kg CO_2/t – for dolomite use.

4.4.3 Uncertainty assessment and developing a consistent time series

The following main factors have influenced the uncertainty of estimation of CO_2 emissions from limestone and dolomite use:

- Accuracy of activity data on production, export and import of limestone and dolomite;
- Lack of national statistical data on limestone use in sugar and soda ash industries, for lime and cement production in the period 1990-2003;
- Lack of study of the fractional purity of limestone ($CaCO_3$) and dolomite ($CaCO_3$*$MgCO_3$) per ton of total raw material weight.

Uncertainty of activity data on limestone and dolomite use was assessed at the level of 100 %. Uncertainty of CO_2 emission factors was assessed at the level of 5 %. The overall uncertainty of emission estimation amounted to 96.7%.

4.4.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions from limestone and dolomite use.

4.4.5 Recalculations

This category was absent in the previous inventory.

4.4.6 Planned improvements

This GHG emission category is the key source category. So it is necessary to identify national CO_2 emission factors for limestone and dolomite use, specifically, the fractional purity of limestone and dolomite per tone of total raw material weight.

4.5 Soda Ash Production and Use (Category 2.A.4 CRF)

4.5.1 Overview of Source Category

Soda ash (sodium carbonate, Na_2CO_3) is used as the feedstock in a large number of industries including glass manufacture, soap and detergents, chemical industry, pulp and paper production and metal and oil refining. The raw materials for soda ash production are sodium chloride brine and trona.

Carbon dioxide is emitted from use of soda ash and during production (through the natural processes). Soda ash is manufactured only by Solvay technology (synthetic process). The methodology of CO_2 emissions estimation from Solvay technology is not available. So, only CO_2 emissions from soda ash use have been taken into account in the current inventory.

4.5.2 Methodological Issues

CO_2 emissions from soda ash use were estimated according to the Revised IPCC Guidelines with default CO_2 emission factors use.

Activity data on soda ash use were obtained from the previous inventories for the period 1990-1998, and from the information on soda ash production, export and import provided by the State Committee on Statistics – for the period 2000-2004.

4.5.3 Uncertainty assessment and developing a consistent time series

Inventory team made more precise data on soda ash export and import, and consequently soda ash use. Pro tanto, estimation of CO_2 emission CO_2 was improved. The most significant differences were observed in 1990, 1994 and 1995 (increase of volumes), and the last five years (decrease of volumes).

Uncertainty of activity data on soda ash production, export and import from national statistics was assessed at the level of 5 %. Uncertainty of default CO_2 emission factor was assessed also at the level of 5 %. The overall uncertainty of emission estimation in this category amounted to 7%.

4.5.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions from soda ash production and use.

4.5.5 Recalculations

Improvement of activity data on soda ash export and import resulted in more precise definition of CO_2 emissions. The Table 4.4 presents comparison of inventory results in 2005 and 2006.

Table 4.4. Comparison of estimation of CO_2 emissions from soda ash production in Ukraine, thous.t

Value	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Inventory submitted in 2005														
CO_2 emissions	301	392	382	242	170	141	118	129	105	141	178	202	210	203
Inventory submitted in 2006														
CO_2 emissions	368	328	350	245	272	197	98	124	110	109	131	131	146	126
Difference, %	-22	16	8	-1	-60	-40	17	4	-5	23	27	35	30	38

4.5.6 Planned improvements

Investigations on determination of soda ash production by direct carbonation technology are planned in this category.

4.6 Asphalt Roofing (category 2.A.5 CRF)

4.6.1 Overview of Source Category

Oil asphalt is produced by oxidation of residues of oil refining products and their mixtures with asphalt and butyraceous products. So, it is referred also as oxidized oil asphalt.

Saturated felts and siding shingles are used in roofing. CO and NMVOCs are emitted from their production.

4.6.2 Methodological Issues

CO and NMVOCs emissions were estimated according to the Revised IPCC Guidelines (chapter 2.7.1) with default emission factors for saturation without spray.

4.6.3 Uncertainty assessment and developing a consistent time series

Activity data on asphalt roofing were obtained in the State Committee on Statistics. Default NMVOC emission factors for saturation without spray were equal to 0.048 kg/t.

Direct GHGs are not emitted in this category. So, uncertainty assessment of NMVOC emission estimation was not carried out.

4.6.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions from asphalt roofing.

4.6.5 Recalculations

NMVOC emissions have been decreased in 50 times compared to the previous inventory due to the use of default NMVOC emission factors for technology (saturation without spray) without any mitigation measures.

4.6.6 Planned improvements

No improvements in this category are planned.

4.7 Road Paving with Asphalt (Category 2.A.6 CRF)

4.7.1 Overview of Source Category

Greenhouse gases are emitted from the asphalt plant, the road surfacing operations in the category «Road Paving with Asphalt». SO_2, NO_x, CO and NMVOCs emissions from road paving production are emitted from the asphalt plants, and only NMVOCs – from the road surfacing operations.

4.7.2 Methodological Issues

Specific investigations of national emission factors in this category were not carried out. So default GHG emission factors from Table 2.4 (Volume 3 of the IPCC revised Guidelines) were used in the current inventory. Activity data on asphalt production were obtained in the State Committee on Statistics.

4.7.3 Uncertainty assessment and developing a consistent time series

Direct GHG are not emitted in this category. So uncertainty assessment of NMVOC emission estimation was not carried out.

4.7.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions from road paving with asphalt.

4.7.5 Recalculations

GHG emissions inventory in this category has been conducted for the first time in Ukraine.

4.7.6 Planned improvements

No improvements in this category are planned.

4.8 Glass Production (category 2.A.7 CRF)

4.8.1 Overview of Source Category

Glass is non-organic material, which is produced by raw material melting, forming and cooling without crystallization. Soda-lime glass is the main type of produced glass. Soda ash (Na_2CO_3) and limestone ($CaCO_3$) are the main raw materials for glass production.

There are two technologies of glass plate production: Furko and Float.

4.8.2 Methodological Issues

CO_2 and NMVOCs are emitted from glass production. CO_2 emissions from glass production were considered in the «Limestone and Dolomite Use». Only NMVOC emissions are estimated in the category "Glass Production".

Activity data on glass production were obtained in the State Committee on Statistics. Default NMVOC emission factor (4.5 kg/t) was used according to the IPCC revised Guidelines.

4.8.3 Uncertainty assessment and developing a consistent time series

CO_2 emissions from glass production were considered in the «Limestone and Dolomite Use». Other direct GHG are not emitted in this category. So uncertainty assessment of NMVOC emission estimation was not carried out.

4.8.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions from glass production.

4.8.5 Recalculations

Recalculations were not carried out because this category was lacked in the previous inventory.

4.8.6 Planned improvements

No improvements in this category are planned.

4.9 Ammonia Production (Emission Category 2.B.1 CRF)

4.9.1 Overview of Source Category

Natural gas used as the feedstock for ammonia production in Ukraine. Ammonia production is a catalytic process with high temperature and pressure.

GHG emissions from fuel combustion, including natural gas, for providing high temperature for NG reforming were considered in the sector «Energy» and were not taken into account in this category.

CO_2 emissions from ammonia production is key source category in Ukraine. The investigations at the typical Ukrainian enterprises were carried out to specify national CO_2 emission factors.

4.9.2 Methodological Issues

Carbon dioxide emissions from ammonia production were estimated according the Revised IPCC Guidelines:

$$V = A_g \cdot m_c \cdot 44/12,$$

where A_g – consumption of natural gas, thous. t;

m_c – carbon content in NG, t/t;

44/12 – the molecular weight ratio of CO_2 to C.

Activity data on ammonia production were obtained in the State Committee on Statistics. For the base year activity data were given from Fuel and Energy Balance (Chapter 5.1.2, column 4 – «Used as feedstock in chemistry, petrochemistry and other non-fuel production»).

For the period 1998-2004 activity data were obtained from 4-MTP statistical reporting form about NG consumption for fertilizers and nitric compound production in the sector «Chemistry and Petrochemistry». Natural gas consumption for these purposes has accounted for 99 % of total non-energy consumption for chemistry and petrochemistry. So in the base year natural gas consumption for ammonia production were calculated from data on NG used as feedstock in chemistry, petrochemistry and other non-fuel production with adjustment factor 0.99.

For the period 1991-1997 data on natural gas consumption for ammonia production were calculated by multiplying specific NG consumption (interpolated data from 1990 to 1998) and volumes of ammonia production (1-P statistical reporting form).

National statistics gives data on volumes of ammonia production in units of thous.m^3. Conversion factor - 0.693 t/thous.m^3 (NG density) - was used to convert in the units of weight [4].

Carbon content in NG – 0.738 t/t – was estimated from information of structure net gas in Ukraine [5,6].

Default emission factors (IPCC revised Guidelines, V.2) were used for the estimation of NMVOC, CO and SO_2 emissions from ammonia production.

4.9.3 Uncertainty assessment and developing a consistent time series

The main sources of uncertainties in ammonia production data are as follows:

- Accuracy of data on NG consumption for ammonia production;
- Accuracy of data on ammonia production;
- Accuracy of data on carbon content in NG.

Two first indicators were obtained from national statistical reporting. Uncertainty of data on NG consumption for ammonia production was assumed at the level of uncertainty of statistical data in energy sector - 5 %. Data on ammonia production were used only for interpolation of data on specific NG consumption for ammonia production, which were applied to define NG consumption in the period 1991-1997. So uncertainty of data on ammonia production did not influence upon the uncertainty of data for the base year and in the period 1998-2004 and were not taken into account.

Calculations of carbon content in NG were based on information of structure net gas in Ukraine, which was quite stable during the last 30 years. Taking into account possible changes of gas indicators due to the import of Turkmenian gas (since 1990), uncertainty of data on carbon content in NG were assumed at the level 10 %. The overall uncertainty of CO_2 emissions from ammonia production has amounted to 11.2 %.

Trends of ammonia production and specific NG consumption evidenced increase of efficiency of ammonia production in Ukraine for the period 1990-2004 by 32 %.

4.9.4 QA/QC procedures

Detailed QC procedures were carried out in this category. Comparison of national and default emission factors showed 1.6-1.8 times increase. The main reason of such fact is out of date technologies and equipment (capital manufacturing capacities were put into operation in Ukraine 15-20 years ago and are needed modernization). So specific NG consumption for ammonia production at the Ukrainian enterprises (1522 m^3/t – in 1990, 1287 m^3/t – in 2004) is significantly higher than average world ones, including Russian enterprises [7].

Comparison of volumes of ammonia production obtained from State Committee on Statistics of Ukraine and Ministry of Industrial Policy was carried out. Also comparison of CO_2 emissions obtained by different methods, cross-check of initial data and so on were fulfilled.

4.9.5 Recalculations

National CO_2 emission factors were used in the current inventory.

The Table 4.5 presents comparison of inventory results in 2005 and 2006.

Table 4.5. Comparison of estimation of CO_2 emissions from ammonia production in Ukraine, thous.t

Value		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Inventory submitted in 2005														
CO_2 Emissions	7411	6963	7231	5907	5482	5674	6026	6213	5976	6772	6527	6750	6734	7178
Inventory submitted in 2006														
CO_2 Emissions	14108	13021	13279	10650	9699	9848	10257	10368	9771	10937	10666	10806	10661	11568
Difference, %	90.4	87.0	83.6	80.3	76.9	73.6	70.2	66.9	63.5	61.5	63.4	60.1	58.3	61.2

4.9.6 Planned improvements

No improvements in this category are planned.

4.10 Nitric Acid Production (category 2.B.2 CRF)

4.10.1 Overview of Source Category

Nitric acid (HNO_3) is used as a raw material in the manufacture of nitrogenous-based fertilizer, production of explosives, paint industry, for metal etching and in the processing of ferrous metals and so on.

The production of nitric acid (HNO_3) generates nitrous oxide (N_2O) and nitrogen oxides (NOx) as a by-product of the high temperature catalytic oxidation of ammonia (NH_3) to the nitrogen oxides and then their absorption by water. Concentration of manufactured nitric acid totals 60%.

4.10.2 Methodological Issues

Activity data on nitric acid production were obtained from the Ministry of Industrial Policy. Nitrous oxide emissions were estimated according to the Good Practice Guidance (chapter 3.2). N_2O emission factor was assumed at the level of 2.2 kg/t.

Nitrogen oxide emissions were estimated according to the IPCC revised Guidelines (chapter 2.9).

4.10.3 Uncertainty assessment and developing a consistent time series

Uncertainty of activity data and emission factors for nitric acid was assessed at the level of 10 %. The overall uncertainty of emission estimation in this category amounted to 14.1%.

4.10.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions from nitric acid production.

4.10.5 Recalculations

Recalculations were not carried out because this category was lacked in the previous inventory.

4.10.6 Planned improvements

No improvements in this category are planned.

4.11 Adipic acid production (Category 2.B.3 CRF)

4.11.1 Overview of Source Category

Adipic acid ($HOOC(CH_2)_4COOH$) is a dicarboxylic acid manufactured by a two-stage process. The first stage of manufacturing involves the oxidation of cyclohexane or cyclohexanone to form a cyclohexanone/cyclohexanol mixture. The mixture is then oxidised by nitric acid in the presence of a vanadium catalyst to form adipic acid. N_2O is generated as a by-product of the nitric acid oxidation stage.

Adipic acid production also results in the emissions of NMVOC, CO and NO_x.

4.11.2 Methodological Issues

Activity data on adipic acid production were obtained from the Ministry of Industrial Policy.

Nitrous oxide emissions were estimated according to the Good Practice Guidance.

NMVOC, CO and NO_x emissions were estimated according to the IPCC revised Guidelines with use of default emission factors.

Default N_2O emission factor was assumed at the level of 300 kg/t.

Catalytic destruction of N_2O is commonly used in Ukraine during adipic acid production. So N_2O destruction factor and abatement system utilization factor were defined from the Table 3.7 of Good Practice Guidance for this technology. The lowest values from recommended range were used: N_2O destruction factor – 0.9, abatement system utilization factor –0.8.

4.11.3 Uncertainty assessment and developing a consistent time series

The main sources of uncertainties for adipic acid production are as follows:

- Uncertainty of data on adipic acid production;
- Uncertainty of emission factors;
- Uncertainty of N_2O destruction factor;
- Uncertainty of abatement system utilization factor.

Data on adipic acid production were obtained from national statistical reporting (1-P form) and their uncertainty was assumed at the level of uncertainty of usual statistical data - 5 %.

Uncertainty of N_2O emission factor was assumed at the level 10% according to the Good Practice Guidance. Uncertainties of N_2O destruction factor and abatement system utilization factor were assumed 5% and 10% respectively according to the Table 3.7 of Good Practice Guidance.

The overall uncertainty of N_2O emissions from adipic acid production has amounted to 15.8 %.

4.11.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions from adipic acid production.

4.11.5 Recalculations

Underestimated N_2O emissions were reported in the previous inventory because abatement system utilization factor was not taken into account, and N_2O destruction factor was overestimated by 5 %. That is why emission estimations were underestimated in 5.5 times.

4.11.6 Planned improvements

No improvements in this category are planned.

4.12 Carbide Production (Category 2.B.4 CRF)

4.12.1 Overview of Source Category

Information about silicon carbide production is not available in Ukraine. Hence only calcium carbide production is considered in this category.

Calcium carbide CaC_2 is made by heating limestone and subsequently reducing CaO with carbon (e.g., breeze). Both steps lead to emissions of CO_2.

4.12.2 Methodological Issues

Activity data on silicon carbide production, export and import were obtained in State Committee on Statistics of Ukraine. Unfortunately, the data on silicon carbide export and import are not available in the State Committee on Statistics of Ukraine for the period 1990-1995. The data for 1996-2004 made it possible to conclude that Ukraine's import of silicon carbide is higher than production in 1.7-4.4 times. Export and import were assumed at the level of first available 1996 year to avoid underestimation of CO_2 emissions. This assumption corresponds to conservative assessment of silicon carbide use in the base year, because industrial production (including silicon carbide production) in 1990 and therefore silicon carbide use and import were significantly higher than in 1996.

Default specific limestone consumption for production of 1 t of silicon carbide, as well as CO_2 emission factors for limestone and reducing agent use were taken from the Table 2.8 of IPCC revised Guidelines (Volume 2).

4.12.3 Uncertainty assessment and developing a consistent time series

Uncertainty of data on silicon carbide production was assumed at the level 5%, export and import data -100%. Uncertainties of specific limestone consumption and default CO_2 emission factors were assumed at the level 10%.

The overall uncertainty of CO_2 emissions from silicon carbide production and use has amounted to 62.4 %.

4.12.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions from silicon carbide production and use.

4.12.5 Recalculations

Previous inventory did not take into account data on silicon carbide export and import. So CO_2 emissions were significantly underestimated (Table 4.6).

Table 4.6. Comparison of estimation of CO_2 emissions from silicon carbide production in Ukraine, thous.t

Value	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Inventory submitted in 2005														
CO_2 emissions	40	40	44	42	43	42	32	34	31	35	27	29	26	24
Inventory submitted in 2006														
CO_2 emissions	26	26	30	28	29	28	17	19	20	23	14	16	11	9
Difference, %	54	55	47	51	48	50	85	80	57	55	98	88	127	153

4.12.6 Planned improvements

No improvements in this category are planned.

4.13 Other Chemical Production (category 2.B.5 CRF)

4.13.1 Overview of Source Category

Chemistry and petrochemistry is the significant economic sector in Ukraine. Approximately 3000 enterprises, 2600 from which are not large, compose this sector. Near 220 enterprises produce 90-92 % emissions in the atmosphere.

Methane and precursor (CO, SO_2, NO_x, NMVOCs) emissions from chemical manufacture of chemical black carbon, ethylene, methanol, polystyrene, propylene, sulphuric acid and phtalic anhydride were considered in this category.

Black carbon (C) is used in tyre, rubber and paint industries.

Ethylene (C_2H_4) is the product of oil and NG refining. It is used as raw material for polyethylene, ethyl alcohol and polyvinylchloride.

Methanol (methyl alcohol CH_3OH) is produced from carbon oxide and hydrogen in the presence of a catalyst under the high pressure, as well as from wood destructive distillation. Methanol is used for ethyl alcohol denaturation, formaldehyde production, as well as solvent and reagent in the organic synthesis.

Polystyrene ($C_8H_{8)}$) is produced by catalytic dehydrating of ethylbenzene and used for plastics and synthetic rubber production.

Propylene (C_3H_6) occurs in cracking and oil pyrolysis gases, as well as in the coke gas. It is producted by extraction from refinery gases and catalytic dehydrating of propane and light oils. Propylene is used as raw material for petrochemistry, plastics, rubber, solvent and motor fuel production.

Sulphuric acid (H_2SO_4) is produced by catalytic oxidation of SO_2 to SO_3. Metallurgy, chemical and coke enterprises produce sulphuric acid in Ukraine. It is used for production of fertilizers, various salts and acids, as well as in the organic synthesis, oil, metal processing, textile and tanning industries.

Phtalic anhydride is used as raw material for production of various softeners and water soluble polyester resins.

4.13.2 Methodological Issues

GHG emissions estimation in this category was provided according to the Revised IPCC Guidelines. Activity data were obtained in State Committee on Statistics of Ukraine with default emission factors (Table 2.9 and 2.10 Revised IPCC Guidelines).

4.13.3 Uncertainty assessment and developing a consistent time series

Uncertainty of activity data in this category was assumed at the level 5% as for usual statistical data. Uncertainty of methane emission factors was assumed at the level of 10%.

The overall uncertainty of methane emissions from other chemical production has amounted to 7.8 %.

4.13.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions from other chemical production.

4.13.5 Recalculations

GHG emissions from propylene, sulphuric acid and phtalic anhydride were considered in addition to previous inventory. The Table 4.7 presents comparison of inventory results in 2005 and 2006.

Table 4.7. Comparison of estimation of CO_2 emissions from other chemical production in Ukraine, thous.t

Gas		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Inventory submitted in 2005														
CH_4	4.704	3.964	3.523	2.351	1.730	1.104	0.797	0.994	1.008	1.073	1.053	1.578	1.553	2.085
Inventory submitted in 2006														
CH_4	4.579	3.964	3.253	2.351	1.730	1.139	0.797	0.993	1.008	0.809	0.761	1.092	1.138	1.520
Difference, %	-2.7	0.0	0.0	0.0	0.0	-0.1	0.0	-0.1	0.0	-24.6	-27.7	-30.8	-26.7	-27.1
Inventory submitted in 2005														
NO_x	0.110	0.084	0.063	0.045	0.027	0.021	0.020	0.027	0.027	0.031	0.028	0.046	0.039	0.055
Inventory submitted in 2006														
NO_x	0.104	0.084	0.063	0.046	0.027	0.021	0.020	0.027	0.027	0.022	0.017	0.029	0.024	0.034
Difference, %	-5.5	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	-29.0	-39.3	-37.0	-38.5	-38.2
Inventory submitted in 2005														
CO	2.720	2.109	1.572	1.119	0.666	0.515	0.505	0.666	0.684	0.786	0.695	1.156	0.975	1.379
Inventory submitted in 2006														
CO	2.604	2.109	1.572	1.119	0.666	0.515	0.505	0.666	0.684	0.542	0.430	0.714	0.597	0.860
Difference, %	-4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-31.0	-38.1	-38.2	-38.8	-37.6
Inventory submitted in 2005														
NMVOC	12.23	10.12	7.13	4.92	3.04	2.34	2.20	2.88	2.98	3.35	3.00	4.92	4.23	5.94
Inventory submitted in 2006														
NMVOC	12.51	10.43	7.64	5.19	3.24	2.59	2.37	3.01	3.12	2.45	2.08	3.27	2.89	4.07
Difference, %	2.3	3.1	7.2	5.5	6.6	10.7	7.7	4.5	4.7	-26.9	-30.7	-33.5	-31.7	-31.5
Inventory submitted in 2005														
SO_2	0.84	0.65	0.49	0.35	0.21	0.16	0.16	0.21	0.21	0.24	0.22	0.36	0.30	0.43
Inventory submitted in 2006														
SO_2	0.81	0.65	0.49	0.35	0.21	0.16	0.16	0.21	0.21	0.17	0.13	0.22	0.19	0.27
Difference, %	-3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-29.2	-40.9	-38.9	-36.7	-37.2

GHG emissions in this category have decreased due to specifying data on carbon black production for the period 1999-2003 (GHG emissions from carbon black production have decreased by 45-60% for this period).

4.13.6 Planned improvements

No improvements in this category are planned.

4.14 Iron and Steel Production (Category 2.C.1 CRF)

4.14.1 Overview of Source Category

Crude iron is produced by the reduction of iron oxide ores mostly in blast furnaces. Carbon in coke plays the dual role of fuel and reductant.

According to the Good Practice Guidance CO_2 emissions from the use of coke may be considered in sector «Energy» or in the sector «Industrial Processes». In the current inventory all CO_2 emissions from the use of coke for crude iron production were taken into account in the sector «Industrial Processes». The advantages of this approach lay in the conformity of sectoral and regional data on CO_2 emissions from the iron production, and possibility of direct comparison of national and default CO_2 emission factors from the iron production.

Methane emissions during production of coke from coal were also considered in this category.

Methane emissions from agglomerate production were not considered, because all methane combusts under the high temperature conditions.

4.14.2 Methodological Issues

Iron production. Iron and steel production is a key source category in Ukraine. That is why inventory team has applied Tier 2 approach recommended by the Good Practice Guidance for GHG emission inventory in this category.

Coke from coal is used as reducing agent in Ukraine. Iron ore which is used for iron production in Ukraine does not contain carbon. CO_2 emissions from iron production were estimated as follows:

$$V = k_c \cdot A_c - (m_c / 100) \cdot A_i \cdot 44/12,$$

where k_c - CO_2 emission factor for coke used as fuel and/or reducing agent, t CO_2/t coke;

A_c - mass of coke used for iron production, thous.t;

m_c - carbon content in crude iron, %;

A_i - iron production, thous.t.

CO_2 emission factor for use of coke was determined as follows:

$$k_c = (d_c / 100) \cdot 44/12, \qquad (4.3)$$

where d_c - carbon content in coke used for iron production, %.

Carbon content in coke used for iron production was assumed according to the data of Ministry of Industrial Policy.

Results of calculations according (4.3) gave values 3.01-3.04 t CO_2/t coke, which is slightly less than default factor 3.1 (Table 3.6 from the Good Practice Guidance).

Carbon content in crude iron was assumed according to the data of Ministry of Industrial Policy (4.26-4.5 %).

Mass of coke used for iron production was obtained from:

- Fuel and Energy Balance for 1990 (Table 55.2) – in 1990;
- Data of 4-MTP statistical reporting form: sector (ferrous metallurgy) №121093 – in the period 1998-2001 and № 27.1 – in the period 2002-2004, columns 5 of part 3 and columns 3 of part 4 – data on coke consumption, as well as columns 3 of part

3 – data on coking coke consumption for coke production (with productivity factor 0.65) - in the period 1998-2004;

- Linear interpolation of specific coke consumption for iron production (between available data in 1990 and 1998) – in the period 1991- 1997.

In the current inventory all CO_2 emissions from the use of coke as fuel to hold high temperature conditions and reducing agent were taken into account in this category. Coke from coal is produced mainly by the petrochemical plants in Ukraine. A single great metallurgical enterprise has the own coke production. So data on coke used for iron production in the period 1998-2004 were obtained from sector "Iron and Steel" of 4-MTP statistical reporting form:

- Columns 5 of part 3 – coke used in blast furnaces;
- Columns 3 of part 4 – end-use of coke for industrial production
- Columns 3 of part 3 – coke used by the enterprises which produce coke.

Iron production was obtained from the State Committee on Statistics of Ukraine. Information is practically equal to the data from the Ministry of Industrial Policy.

Default methane emission factors from iron production were used (Volume 3 of the IPCC Revised Guidelines [1].

Default emission factors for other GHG from iron production were used (chapter 2.13.2.2 of the IPCC revised Guidelines.

Steel production

CO_2 emissions from steel production were estimated according to the equation (3.6B) of the Good Practice Guidance with 1% carbon content in steel. Default mass of carbon dioxide emitted from consumed electrodes - 5 kg CO_2 per t of steel produced in electric arc furnaces – was used.

Mass of Carbon in the Crude Iron used for Crude Steel Production in 1990-1993 was determined from the data of 9-SN statistical reporting form. Unfortunately this form was not provided by the State Committee on Statistics of Ukraine since 1994. Reliable data were obtained in the Ministry of Industrial Policy only for the period 2000-2004. Interpolation has been used to estimate Mass of Carbon in the Crude Iron used for Crude Steel Production for the other years 1994-1999.

Steel production volumes were obtained from State Committee on Statistics of Ukraine for the period 1990-2003 and from the Ministry of Industrial Policy – in 2004. The differences in data for the period 1990-2003 did not exceed 1-4.5 % and were explained more complete account of steel production in the State Committee on Statistics of Ukraine. The changes in statistical data structure in 2004 led to decrease of steel production data from the State Committee on Statistics of Ukraine by 34% compared to the information of the Ministry of Industrial Policy. In future it will be helpful to reconcile data on steel production from the State Committee on Statistics of Ukraine since 2004.

Default emission factors for other GHG from steel production were used (chapter 2.13.2.2 of the IPCC revised Guidelines.

Coke production

The main share of coke is consumed by ferrous metallurgy in Ukraine. Therefore methane emissions from all coke production were considered in this category, however some volumes of coke are produced by the petrochemical enterprises.

Coke production was obtained in the Ministry of Industrial Policy. Default methane emission factor – 0.5 kg CH_4 per 1 t coke – was used (Table 2.10 of the IPCC revised Guidelines, Volume 3).

4.14.3 Uncertainty assessment and developing a consistent time series

The main sources of uncertainty associated with iron and steel production, are as follows:

- Accuracy of statistical data on iron and steel production;
- Accuracy of data on specific coke consumption for iron production;
- Accuracy of data on carbon content in iron, coke and steel;
- Accuracy of data on specific iron consumption for steel production;
- Accuracy of data on CO_2 emission from consumed electrodes in electric arc furnaces.

The first two indicators as well as specific iron consumption for steel production in the period 1990-1993 were obtained from the national statistics. Statistical data on iron and steel production in Ukraine are quite reliable. So uncertainty of activity data on iron and steel production may be accepted at the level of uncertainty of data on reducing agent consumption. Good Practice Guidance recommends assuming this value at the level of uncertainty of energy statistics of about 5 %.

Other specific values were given from the Ministry of Industrial Policy and were average values for all enterprises in Ukraine, which produced iron and steel. Therefore uncertainty of these indicators was also assumed at the level 5 %, excluding data on carbon content in steel, which were accepted at the level 20 % according to the expert judgement. Uncertainty of default CO_2 emission factor from consumed electrodes in electric arc furnaces was higher and assumed at the level 30 % according to the expert judgement. It should be noted that CO_2 emissions from consumed electrodes in electric arc furnaces are significantly less than other emissions in this category. Hence uncertainty of this source practically did not influence upon the overall uncertainty of emission estimation which was estimated at the level 7.4%.

Uncertainty of methane emission factors from iron and coke production was assumed at the level 20%. Taking into account uncertainty of activity data (about 5 %) the overall uncertainty of methane emission estimation was estimated at the level 15.9 %.

Analysis of time series of specific iron consumption for steel production showed the increase of this indicator from 1990 to 1998 and furter decrease to the 1990 level. Such trend was explained by industrial decline in the period 1991-1998, when maintaining blast furnaces operation without production (slow speed) was required and so the increased coke consumption for heating blast furnaces was observed. Then growth of iron and steel production has resulted in gradual decrease of coke consumption.

Respectively the implied CO_2 emission factor for iron production, which is equal to quotient of CO_2 emissions CO_2 to the iron production, has increased from 1.708 in 1990 to 2.22 in 1998 and later decreased to 1.757 in 2004. Trend of this indicator showed the possibility of its further reduction. For comparison Table 2-12 of the IPCC Revised Guidelines, Volume 2 gives default value of 1.5-1.6 t CO_2 per 1 t of iron production.

4.14.4 QA/QC procedures

Detailed QC procedures were carried out in this category. National and default emission factors were compared and the reasons of difference were explained.

Comparison of volumes of iron and steel production obtained from State Committee on Statistics of Ukraine and Ministry of Industrial Policy was carried out. Also comparison of CO_2 emissions obtained by different methods, cross-checks of initial data and so on were fulfilled.

4.14.5 Recalculations

The following recalculations were carried out compared to the previous inventory submission in this category:

- National CO_2 emission factors for iron production were used;
- CO_2 emissions from coke combustion in blast furnaces were transferred from the sector “Energy” to this category;
- CO_2 emissions from iron and steel production were estimated separately;
- Methane emissions from iron and coke production were first estimated.

The Table 4.8 presents comparison of inventory results in 2005 and 2006.

Table 4.8. Comparison of estimation of CO_2 emissions from iron and steel production in Ukraine, thous.t

Value	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Inventory submitted in 2005														
CO_2 emissions	0 971	33 398	32 303	24 729	18 433	16 425	16 243	18 798	24 129	25 983	28 298	27 079	26 387	30 051
Inventory submitted in 2005														
CO_2 emissions	0 459	68 167	67 983	53 941	41 431	38 314	39 369	47 067	49 142	51 901	56 020	56 900	57 176	57 994
Difference, %	96.4	104.1	110.5	118.1	124.8	133.3	142.4	150.4	103.7	99.8	98.0	110.1	116.7	93.0

Significant increase of CO_2 emissions (sometimes twice) was caused by account of carbon in all coke, which was used both as fuel and reducing agent. The separate estimation of emissions from iron and steel production led to some increase of NO_x and NMVOC emissions while CO and SO_2 emissions were not changed.

4.14.6 Planned improvements

In future harmonization of data on steel production from the State Committee on Statistics of Ukraine since 2004 is planned to avoid inconsistency in time series after changes in statistical data structure in 2004 (subchapter 4.3.1.2).

4.15 Ferroalloys Production (category 2.C.2 CRF)

4.15.1 Overview of Source Category

Ferrosilicon, ferromanganese, silicon manganese and ferrochromium are produced in Ukraine.

4.15.2 Methodological Issues

Default CO_2 emission factors were used for ferroalloys production, where average value from the recommended range – for ferrosilicon-50% Si and ferrosilicon-90% (Table 2.17 from the IPCC revised Guidelines).

IPCC revised Guidelines give values of CO_2 emission factors only for ferrosilicon with silicon content - 50%, 75% and 90%. Approximation of dependence of CO_2 emission factors upon silicon content in ferrosilicon was fulfilled to determine CO_2 emission factors for silicon contents from 20% to 45% (Figure 4.1).

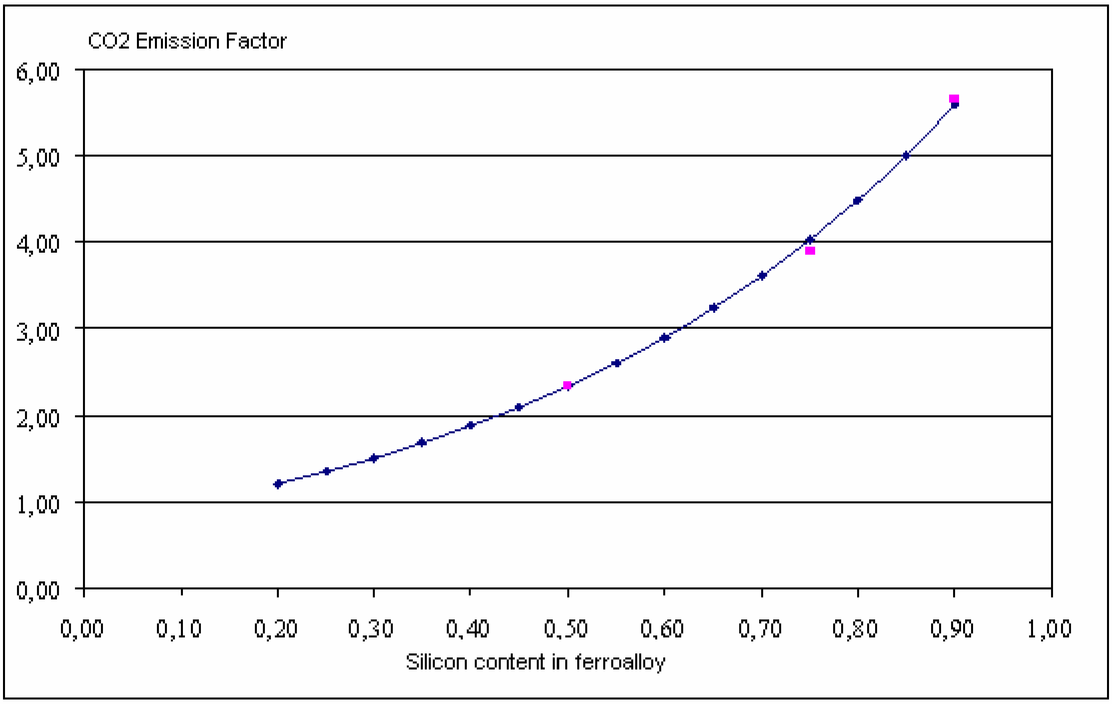

Figure 4.1. CO_2 emission factors (t/t of ferroalloy) for ferrosilicon production

The following exponential dependence of CO_2 emission factors upon silicon content in ferrosilicon was derived:

$$k = 0.7828 \times e^{2.1833\kappa}, \quad (4.4)$$

where κ – silicon content fraction.

Analysis of (4.4) shows that reliability of approximation is 0.9991. CO_2 emission factors calculated by (4.4) for ferrosilicons with silicon content from 20% to 90% are presented in the Annex 6.1.

Activity data were obtained from statistical information from Ministry of Industrial Policy.

4.15.3 Uncertainty assessment and developing a consistent time series

The main sources of uncertainties in this category are as follows:

- Accuracy of activity data on ferroalloys production;
- Accuracy of CO_2 emission factors.

Uncertainty of 5% was assumed for activity data, because these data were obtained from the enterprises.

Default uncertainty level of 30% was assumed for CO_2 emission factors for production of ferrosilicon – Si 50%, ferrosilicon – Si 75% and ferrosilicon – Si 90%.

Uncertainty of CO_2 emission factors calculated by (4.1) for ferrosilicon with silicon content from 20% to 90% was estimated at the level 50 %.

4.15.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions from ferroalloys production.

4.15.5 Recalculations

GHG emissions in this category were not considered in the previous inventory.

4.15.6 Planned improvements

No improvements in this category are planned.

4.16 Aluminium Production (Category 2.C.3 CRF)

4.16.1 Overview of Source Category

In Ukraine primary aluminium is produced in electrolysis cells with horizontal stud Soderberg anodes, i.e. by horizontal stud Soderberg technology (working current – 65 kA).

4.16.2 Methodological Issues

CO_2 emissions from aluminium production are estimated only for horizontal stud Soderberg technology according to the IPCC revised Guidelines (Table 2.18). Default CO_2 emission factor of 1.8 t CO_2/t aluminium was assumed.

Two PFCs, carbon tetrafluoride (CF_4) and carbon hexafluoride (C_2F_6), are known to be emitted from the process of primary aluminium smelting. PFCs are formed during a phenomenon known as the Anode Effect (AE), when alumina levels are low. AE frequency and duration are registered at the enterprises.

CF_4 emissions from aluminium production were calculated according Tier 1b approach of IPCC revised Guidelines (Tier 1b, Table 2.19). Average fraction of CF_4 in the pot gas during anode effects was assumed to 0.04.

Default rate for C_2F_6 emissions was assumed 1/10 that of CF_4.

NO_x, CO, SO_2 emissions were estimated according to the IPCC revised Guidelines (Table 2.21). Default NO_x, CO, SO_2 emission factors were applied.

Activity data on aluminium production were received from the Ministry of Industrial Policy, which obtains information from industrial enterprises in Ukraine.

4.16.3 Uncertainty assessment and developing a consistent time series

The main sources of uncertainties in this category are as follows:

- Accuracy of activity data on aluminium production;
- Accuracy of CO_2 emission factors;
- Accuracy of CF_4 and C_2F_6 emission factors.

Uncertainty of 5% was assumed for activity data, because these data were obtained from the enterprises.

Default uncertainty level of 30% was assumed for CO_2, CF_4 and C_2F_6 emission factors for aluminium production, AE frequency and duration.

4.16.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions from aluminium production.

4.16.5 Planned improvements

No improvements in this category are planned.

4.17 SF_6 Used in Aluminium and Magnesium Foundries (Category 2.C.4 CRF)

SF_6 is not used in Aluminium and Magnesium Foundries in Ukraine according to the information of the Ministry of Industrial Policy.

4.18 Pulp and Paper Production (category 2.D.1 CRF)

4.18.1 Overview of Source Category

Pulp and paper industry manufactures various kinds of paper and carton. Paper is produced from pulp by different technologies depending upon the requirements to the quality of paper.

Wood is a raw material for pulp and paper production. Paper in Ukraine is produced by Kraft (sulphate) technology, which referred as alkaline process. Sulphur added to the digestion liquor, which is soda ash solution, quickens the process. Obtained wood material is easily bleached and resistant to the mechanical attrition. NMVOCs, NOx, CO and SO_2 are emitted from pulp production.

4.18.2 Methodological Issues

NMVOCs, NO_x, CO, SO_2 emissions were estimated according to the Revised IPCC Guidelines (Chapter 2.14).

Activity data on pulp production were received from the Ministry of Industrial Policy, which obtains information from industrial enterprises in Ukraine.

Default NMVOCs, NO_x, CO, SO_2 emission factors were applied for pulp production by sulfate technology (Table 2.23 from the IPCC revised Guidelines).

4.18.3 Uncertainty assessment and developing a consistent time series

Direct GHG are not emitted in this category. So uncertainty assessment of NMVOC, NO_x, CO and SO_2 emission estimation was not carried out.

4.18.4 QA/QC procedures

General QC procedures were carried out for pulp and paper production.

4.18.5 Recalculations

GHG emissions in this category were not considered in the previous inventory.

4.18.6 Planned improvements

No improvements in this category are planned.

4.19 Food and Drink Production (Emission Category 2.D.2 CRF)

4.19.1 Overview of Source Category

Food and drink industry manufactures various kinds of products with different production technologies. These technologies are very specific and often emit strong smell gases. The smell is often caused by aldehydes, ketones, organic acids, sulfides and mercaptans.

NMVOCs emissions are released to the atmosphere in result of treatment of organic matter, which are contained in food products. Industrial processes of brew, fry-up and smoking are associated with smell gases. The majority of NMVOCs emissions are occurred during production of drinks, bread, cakes, solid cooking fats, meat and fish.

4.19.2 Methodological Issues

NMVOCs emissions in this category were estimated according to the Revised IPCC Guidelines (Chapter 2.15) with default NMVOCs emission factors (Tables 2.25, 2.26 from the IPCC revised Guidelines).

NMVOCs emissions were estimated for production of bread, cakes, animal feeding, margarine and solid cooking fats, sugar, meat, fish and poultry, spirits, wine and beer.

Activity data on food and drink production were received from the State Committee on Statistics of Ukraine.

4.19.3 Uncertainty assessment and developing a consistent time series

Direct GHG are not emitted in this category. So uncertainty assessment of NMVOC emission estimation was not carried out.

4.19.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions from food and drink production.

4.19.5 Recalculations

The Table 4.8 presents comparison of inventory results in 2005 and 2006.

Table 4.9. Comparison of estimation of NMVOCs emissions from food and drink production in Ukraine, thous.t

Value		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Inventory submitted in 2005														
NMVOCs emissions	380.59	377.95	382.60	411.23	365.38	372.32	263.52	262.91	216.81	311.64	320.61	280.11	289.56	369.57
Inventory submitted in 2006														
NMVOCs emissions	158.30	138.03	124.30	130.03	112.44	111.71	87.16	70.70	62.73	90.30	91.56	86.46	88.04	111.08
Difference, %	-140.4	-173.8	-207.8	-216.3	-225.0	-233.3	-202.3	-271.9	-245.6	-245.1	-250.2	-224.0	-229.9	-232.7

Difference in the estimation of NMVOCs emissions was caused by error in conversion of national units to hecalitres, which was made in the previous inventory.

4.19.6 Planned improvements

No improvements in this category are planned.

4.20 Production of Halocarbons and SF_6 (Category 2.E CRF)

There is lack of activity data on perfluorocarbons, hydrofluorocarbons and sulphur hexafluoride production in Ukraine. Therefore, GHG emissions were not estimated in this category.

4.21 Refrigeration and Air Conditioning Equipment (Category 2.F.1 CRF)

Cyclopentane, isobutane R600a and R134a (HFC 134) were used as refrigerants in refrigerators produced in Ukraine. R134a is used only in the export refrigerators, and this refrigerant is not produced in Ukraine. Cyclopentane and isobutane are absent in the IPCC list of GWP values. Therefore, GHG emissions were not estimated in this category.

4.22 Foam Blowing (Category 2.F.2 CRF)

R141a was used in Ukraine as foam blowing for refrigerator production for the period 1995-2001, and cyclopentane – since 2001. These hydrocarbons are absent in the IPCC list. The majority of foam blowing is imported to Ukraine. There is lack of activity data on perfluorocarbons, hydrofluorocarbons and sulphur hexafluoride use in foam blowing in Ukraine. Therefore GHG emissions were not estimated in this category.

4.23 Fire Extinguishers (Category 2.F.3 CRF)

There is lack of activity data on perfluorocarbons, hydrofluorocarbons and sulphur hexafluoride use in fire extinguishers in Ukraine. Therefore, GHG emissions were not estimated in this category.

4.24 Aerosols/ Metered Dose Inhalers (Category 2.F.4 CRF)

The majority of aerosols are imported to Ukraine. There is lack of activity data on perfluorocarbons, hydrofluorocarbons and sulphur hexafluoride use for aerosols production in Ukraine. Therefore, GHG emissions were not estimated in this category.

4.25 Solvents (Category 2.F.5 CRF)

There is lack of activity data on perfluorocarbons, hydrofluorocarbons and sulphur hexafluoride use for solvents production in Ukraine. Therefor,e GHG emissions were not estimated in this category.

4.26 Semiconductor Manufacture (Category 2.F.6 CRF)

There is lack of activity data on perfluorocarbons, hydrofluorocarbons and sulphur hexafluoride use for semiconductor manufacture in Ukraine. Therefore, GHG emissions were not estimated in this category.

4.27 Electrical Equipment (Category 2.F.7 CRF)

There is lack of activity data on perfluorocarbons, hydrofluorocarbons and sulphur hexafluoride use for electrical equipment production in Ukraine. Therefore. GHG emissions were not estimated in this category.

4.28 Other Industrial Processes (Category 2.F.8 CRF)

GHG emissions in this category were not estimated.

5 SOLVENT AND OTHER PRODUCT USE (SECTOR 3 CRF)

5.1 General Sector Overview

GHG emissions from paint and solvent use for domestic purposes were estimated in this sector. Use of solvents and paints with inclusive solvents emits NMVOCs. NMVOCs emissions from production and processing of some chemicals were also considered in the Sector «Solvent and Other Products Use». Besides specific category in this sector considered nitrous oxide emissions from use of N_2O for anesthesia.

NMVOCs emissions were estimated by the simplest algorithm [1] recommended by EMEP/CORINAIR methodology [2].

Total NMVOCs emissions in the sector «Solvent and Other Products Use» totaled 346.12 thous. t in 1990 and further decreased to 113.2 thous. t in 2004. Paint application, oil refining, as well as degreasing and dry cleaning were the largest emission sources. NMVOCs emissions in 2004 took a third part of emissions in 1990 in Ukraine.

Nitrous oxide emissions in the sector «Solvent and Other Products Use» totaled 1.22 thous. t in 1990 and further decreased to 1.11 thous. t in 2004.

5.2 Paint Application (category 3.A. CRF)

5.2.1 Overview of Source Category

NMVOCs emissions from use of paints, lacquers, enamels, spackling and priming were estimated in this category. Machine building, woodworking industry, light industry, repair and construction are the main industries of their use in Ukraine. NMVOCs are released to the atmosphere from the solvents (NMVOCs content - 100% [3]) which are used for paint production and constituted their volatile part - xylene, paint naphtha, nefras-150/200, toluene, acetone, butanol etc.

5.2.2 Methodological Issues

NMVOCs emissions in this category were estimated according to EMEP/CORINAIR methodology [2].

Activity data on paint and lacquer production were obtained from the State Committee on Statistics of Ukraine. Activity data on paint and lacquer production, export and import were taken from the Ministry of Industrial Policy. The amount of paint and lacquer use was calculated by summarizing of production and import with substracting export.

In fact emission factors are the content of solvent, which contains NMVOCs, in paints and lacquers [2]. Average emission factors for the composition of paints, lacquers, enamels, spackling and priming were determined from the data of joint-stock company «LAKMA» - the biggest enterprise in Ukraine joint-stock company «LAKMA» (accordindg to the statistical information about 90% paint and lacquer consumption in Ukraine are from domestic production). Estimated national NMVOCs emission factor amounts to 0.33 t NMVOCs/t.

5.2.3 Uncertainty assessment and developing a consistent time series

Linear interpolation was used for the period 1991-1994, where statistical data were not available.

5.2.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions from paint application.

5.2.5 Recalculations

NMVOCs emissions in this category were not considered in the previous inventory.

5.2.6 Planned improvements

Obtaining activity data for separate emission calculation for different kinds of paints are planned.

5.3 Degreasing and Dry Cleaning (category 3.B CRF)

5.3.1 Overview of Source Category

NMVOCs emissions from degreasing surfaces (domestic and industrial) and dry cleaning were estimated in this category. NMVOCs emissions from degreasing by technical kerosene and paint naphtha [5], as well as dry cleaning by trichloroethylene and tetrachloroethylene [6] were considered in this category.

5.3.2 Methodological Issues

According to [2] the simplest methodology of NMVOCs emission estimation is multiplying activity data on solvent use for degreasing and dry cleaning by emission factors.

Activity data on commonly used solvents in Ukraine (technical kerosene and paint naphtha) were obtained from [4]. Data on solvent use for paint and lacquers production (4-MTP-statistical reporting form) were subtracted from the data on end-use non-energy consumption.

According to [3, 5] imported trichloroethylene and tetrachloroethylene are the main reagents used for dry cleaning. Activity data on import of trichloroethylene and tetrachloroethylene were obtained from the State Committee on Statistics of Ukraine.

NMVOCs emission factor for degreasing agent was assumed at the level of 1. NMVOCs emission factor for dry cleaning agent was assumed at the level of 0.8 [2].

5.3.3 Uncertainty assessment and developing a consistent time series

Linear interpolation or correlation with national GDP was used for the period 1990-1997, where statistical data were not available.

5.3.4 QA/QC procedures

The following QC procedures were carried out:

- Comparison of data from time series, trend analysis;
- Comparison of activity data from different information sources;
- Comparison of activity data, emission factors and estimation with inventories in other countries.

5.3.5 Recalculations

NMVOCs emissions in this category were not considered in the previous inventory.

5.3.6 Planned improvements

Any improvements are not planned in this category.

5.4 Chemical Products, Manufacture and Processing (category 3.C CRF)

5.4.1 Overview of Source Category

The largest category considers emission from production and processing of different chemicals. NMVOCs emissions from the following industries have been taken into account in the current inventory:

- Oil refining;
- Xylene and benzole production;
- Paint and lacquer production;
- Production of chemical fiber and threads;
- Production of fiber glass;
- Production of rubbers and tyres.

NMVOCs emissions from polystyrene, propylene and phtalic anhydride production were considered in the sector «Industrial processes».

NMVOCs emissions are significant in thus category due to strong chemical industry in Ukraine.

5.4.2 Methodological Issues

Activity data on production of chemicals were received from the State Committee on Statistics of Ukraine.

NMVOCs emission factor for similar technologies in Belarus were used due to the lack of national information.

The Table 5.1 presents NMVOCs emissions in this category by chemical. The Table 5.2 gives the structure of total NMVOCs emissions in the sector «Solvent and Other Products Use» taking into account emission assessment in this category.

5.4.3 Uncertainty assessment and developing a consistent time series

Linear interpolation or correlation with national GDP was used for the period 1991-1994, as well as some indicators for 1990, where statistical data were not available.

5.4.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions from chemical products, manufacture and processing.

5.4.5 Recalculations

NMVOCs emissions in this category were not considered in the previous inventory.

Table 5.1. NMVOCs emission from chemical products, manufacture and processing, thous.t

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Oil Refining	86.73	79.18	71.35	61.21	47.20	24.84	19.85	18.82	19.70	16.17	13.38	23.67	29.69	32.19	32.34
Tyres	2.69	2.42	2.02	1.96	1.10	1.39	1.53	1.81	2.02	1.91	1.64	1.74	1.59	1.57	1.91
Rubber Products	0.79	0.72	0.65	0.56	0.43	0.38	0.33	0.33	0.17	0.24	0.23	0.32	0.34	0.42	0.42
Xylene	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.03
Benzole	3.34	3.05	2.75	2.36	1.82	1.60	1.41	1.44	1.47	1.12	1.21	1.76	2.27	2.55	2.85
Fibre glass	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.04	0.08	0.12	0.07	0.08	0.10
Polymeric paints, lacquers and enamels	6.7	5.7	4.6	4.4	3.1	1.9	1.8	1.8	1.6	1.6	1.5	1.7	2.0	2.0	1.9
Rubber Shoes	0.58	0.49	0.40	0.31	0.22	0.13	0.09	0.04	0.04	0.04	0.04	0.05	0.05	0.06	0.06
Chemical fiber and threads	0.90	0.75	0.73	0.57	0.33	0.21	0.17	0.13	0.12	0.11	0.15	0.13	0.13	0.15	0.18
Total	101.89	92.40	82.59	71.50	54.30	30.57	25.31	24.45	25.27	21.26	18.24	29.56	36.21	39.03	39.76

Table 5.2. Total NMVOCs.emissions in the sector "Solvent and other products use", thous.t

Emission Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
3 A. Paint Application	225.82	190.25	154.68	148.77	105.27	66.42	63.25	62.98	57.65	56.40	52.47	60.98	70.36	67.86	66.19
3 B. Degreasing and Dry Cleaning	18.41	16.82	15.17	13.04	10.09	8.88	7.87	7.82	7.97	4.49	5.51	4.82	4.85	4.88	7.25
3 C. Chemical Products Manufacture and Processing	101.89	92.40	82.59	71.50	54.30	30.57	25.31	24.45	25.27	21.26	18.24	29.56	36.21	39.03	39.76
Total	346.12	299.47	252.44	233.31	169.66	105.87	96.44	95.25	90.89	82.16	76.22	95.36	111.41	111.78	113.21

5.4.6 Planned improvements

It will be reasonable to determine national NMVOCs emission factors for the different industrial branches.

5.5 Other Solvents (category 3.D CRF)

5.5.1 Overview of Source Category

Nitrous oxide emissions from use of N_2O for anesthesia were considered in this category.

5.5.2 Methodological Issues

Activity data on population of Ukraine were obtained from the State Committee on Statistics of Ukraine. Average use of N_2O for anesthesia per capita in Belarus was used as emission factor [6].

5.5.3 Uncertainty assessment and developing a consistent time series

Uncertainty of 5% for activity data is assumed as for typical statistical data. Uncertainty of 100% is accepted for emission factors. The overall uncertainty is assessed at the level of 100%.

5.5.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions from the use of N_2O for anesthesia.

5.5.5 Recalculations

GHG emissions in this category were not considered in the previous inventory.

5.5.6 Planned improvements

It will be reasonable to determine national data on use of N_2O for anesthesia.

6 AGRICULTURE (SECTOR 4 CRF)

6.1 General Sector Overview

Two direct GHG - methane (CH_4) and nitrous oxide (N_2O) are emitted from this sector in Ukraine.

GHG emission trends for the period 1990–2004 are presented at the Table 6.1.

Table 6.1 GHG Emissions in Agriculture sector

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
CH_4, thous.t CH_4	2518	2315	2125	2024	1746	1524	1221	946	862	801	719	732	721	627	583
N_2O, thous.t N_2O	156	145	134	122	107	97	79	75	71	65	57	64	63	55	59
Total, thous.t CO_2-eq.	101355	93592	86177	80282	69879	61976	50171	43240	40134	36932	32886	35130	34691	30101	30417

Categories «Enteric Fermentation», «Agricultural Soils» and «Manure Management» are the most significant sources of GHG emissions in this sector.

Methane emissions from enteric fermentation amounted to 34.5 mln t CO_2-eq. in the base 1990 year and 11.6 mln t CO_2-eq. – in 2004 showing decrease in three times during the period 1990-2004.

Methane and nitrous oxide emissions from manure management amounted to 26.1 mln t CO_2-eq. in the base 1990 year and 3.7 mln t CO_2-eq. – in 2004 showing decrease by 86% during the period 1990-2004.

Reduction of methane emissions from enteric fermentation and methane and nitrous oxide emissions from manure management is explained by shortening livestock population due to the economic crisis after the USSR disintegration and changes in agricultural management.

Direct and indirect nitrous oxide emissions from agricultural soils amounted to 40.6 mln t CO_2-eq. in the base 1990 year and 15.1 mln t CO_2-eq. – in 2004. Reduction of N_2O emissions from agricultural soils by above 60% during the period 1990-2004 was caused mainly by shortening of synthetic, organic fertilizer and crop residues application.

Field burning of agricultural residues is prohibited by law. That is why activity data in this category are not available in Ukraine.

CH_4 and N_2O emissions from prescribed burning of savannas were not estimated because of absence of this emission source in Ukraine.

Total GHG emissions in this sector amounted to 101.4 mln t CO_2-eq. in the base 1990 year and 30.4 mln t CO_2-eq. – in 2004 showing decrease by 70% during the period 1990-2004.

6.2 Enteric Fermentation (category 4.A CRF)

6.2.1 Overview of Source Category

Methane is emitted from enteric fermentation of livestock. The amount of methane emissions is driven primarily by [6]:

- the number of animals;
- the type of digestive system;

- the type and amount of feed consumed.

Ruminant animals have the highest emissions because a significant amount of methane-producing fermentation occurs within the rumen. The main ruminant animals are cattle, buffalo, goats, sheep and camels. Pseudo-ruminant animals (horses, mules, asses) and monogastric animals (swine) have relatively lower methane emissions because much less methane-producing fermentation takes place in their digestive systems.

Buffalo and camels as domestic livestock are not reared in Ukraine.

6.2.2 Methodological Issues

Methane emissions from enteric fermentation of dairy and non-dairy cattle were calculated according to Tier 2 approach from the Good Practice Guidance by multiplying the emission factors by the number of animals. To reflect the variation in production rates and other characteristics among animal types, the population of cattle was divided into categories in accordance with belonging to agricultural enterprises or households and sex and age of animals (Annex 3, chapter A3.1.1).

Emission factors for each cattle category were estimated based on values of gross energy intake and CH4 conversion rates (the fraction of gross energy in feed converted to methane) according to the recommendations of the Good Practice Guidance.

Emissions from other livestock species (goats, sheep, horses and swine) were calculated according Tier 1 approach with use of default emission factors from the IPCC Revised Guidelines. Methane emissions from poultry were not considered.

Activity data on livestock population per species and categories were obtained from the State Committee on Statistics of Ukraine [2-5]. Statistical data on mules and asses population are lacked in Ukraine. Data on asses population are available on the website of FAO (http://faostat.fao.org) for the period 1992-2004. Taking into account negligible amount of asses (11-19 thous. heads) methane emissions from these animals were not considered.

Methodology used is described in details in Annex 3, chapter A3.1.2.

6.2.3 Uncertainty assessment and developing a consistent time series

The main sources of uncertainties in this category are as follows:

- Accuracy of activity data on livestock population;
- Accuracy of emission factors.

Uncertainty of 5% was assumed for activity data according to the assessment of experts from the State Committee on Statistics of Ukraine.

Default uncertainty of 20 % for Tier 2 approach and 50% for Tier 1 approach for emission factors was assumed because of lack of all necessary data to determine uncertainty of emission factors according Tier 1 approach from the Good Practice Guidance [6].

The overall uncertainty of methane emission estimation from enteric fermentation has totaled to approximately 12%.

The same methodology was used for emission estimation during the whole period. Activity data on livestock population were identically collected and processed in the State Committee on Statistics of Ukraine during the whole period. Therefore consistent time series were developed in this category.

6.2.4 QA/QC procedures

The general QC procedures were used for estimation of methane emissions from enteric fermentation. In addition activity data on cattle, sheep, goats, horses and swine population from the data of State Committee on Statistics of Ukraine were compared to the information from FAO website in accordance with the Good Practice Guidance. Discrepancies were not founded.

Calculated gross energy intake values for cattle were checked by conversion to feed intake in dry matter (kg/day). The obtained values have fallen with the range of 1% to 3% of the weight of the animals which is recommended by the Good Practice Guidance.

National emission factors (Annex 3, Table A3.1.3 and A3.1.4) were compared with default values from the IPCC Revised Guidelines (for dairy and non-dairy cattle - 81 and 56 kg CH4/head/year accordingly). Comparison showed good consistency.

6.2.5 Recalculations

Recalculations of methane emissions in this category are resulted from:

- Improvement of activity data on livestock population for the period 1990-2001;
- Use of Tier 2 approach for estimation of methane emissions from cattle enteric fermentation instead of Tier 1 in the previous inventory;
- Division of cattle into categories in accordance with belonging to agricultural enterprises or households and sex and age of animals.

6.2.6 Planned improvements

Developing country-specific methodology for estimation of methane emissions from cattle enteric fermentation is planned.

In addition assessment of emission factors uncertainty is planned to carry out in accordance with Tier 1 approach from the Good Practice Guidance.

6.3 Manure Management (category 4.B CRF)

6.3.1 Overview of Source Category

Livestock manure is principally composed of organic material. When this organic material decomposes in an anaerobic environment (i.e., in the absence of oxygen), methanogenic bacteria, as part of an interrelated population of micro-organisms, produce methane. These conditions often occur when large numbers of animals are managed in a confined area (e.g., dairy farms, beef feedlots, and swine and poultry farms), where manure is typically stored in large piles or disposed of in lagoons [6].

The principal factors affecting methane emissions from animal manure are as follows [9-11]:

- Manure management practices;
- Climate;
- Quality of feed for animals;
- Type of manure;
- Dry matter content in manure.

Nitrous oxide is also emitted from manure. This gas may be produced both in aerobic conditions of nitrification of NH_3 to NO_3, and in anaerobic conditions as a result of reducing denitrification processes. Denitrification process produces the primary releases of gaseous nitrogen to the atmosphere. During denitrification nitrate ion (NO_3-) is dissociated to nitrite, than to nitrogen oxides (NO_x), further to nitrous oxide (N_2O) and finally to nitrogen (N_2).

Besides, portion of nitrogen is loosed in the forms of ammonia (NH_3) and nitrogen oxides (NO_x) during the decay of such components as urea, proteins, hippuric and uric acids. The portion of nitrogen in manure, which is released in form of ammonia, depends upon on duration of manure storage and to the smaller extent temperature. The simple compounds of nitrogen e.g.

urea (mammal) and uric acid (poultry) are rapidly converted to the ammonia nitrogen and released to the atmosphere [12, 13].

The proportion of total nitrogen intake that is excreted and partitioned between urine and faeces is dependent on the retention of nitrogen in animal products, and the nitrogen concentration of the diet. The retention of nitrogen in animal products, i.e., milk, meat, wool and eggs, ranges from about 5 to 20 % of the total nitrogen intake, generally. The remainder is excreted via dung and urine [1].

6.3.2 Methodological Issues

6.3.2.1 Methane emissions from manure management

Methane emissions from manure management of cattle, swine and poultry were calculated according Tier 2 approach from the Good Practice Guidance by multiplying the emission factors by the number of animals. To reflect the variation in the amount of manure excreted and manure management practices among animal types, the population of animals was divided into categories in accordance with belonging to agricultural enterprises or households as well as sex and age of animals (Annex 3, chapter A3.1.1).

Emission factors for each category of cattle, swine and poultry were calculated by multiplication of volatile solid excretion values, maximum CH4 producing capacity for the manure and average weighted CH4 conversion factor according to the recommendations of the Good Practice Guidance.

Emissions from other livestock species (goats, sheep and horses) were calculated according Tier 1 approach with use of default emission factors from the IPCC Revised Guidelines.

Values of volatile solid excretion rate for cattle, swine and poultry were calculated by multiplication of amount of manure excreted in dry matter and ash content of the manure in percent, which are standardized [14-16]. Default values of maximum CH4 producing capacity for the manure were used from the IPCC Revised Guidelines (Table B.1 and B.2, values for Eastern Europe and developed countries), because it is lack of information about national data.

Data on the fractions of cattle, swine and poultry manure per manure management systems were obtained from the expert judgement for agricultural enterprises and households in 1990-2004. Expert calculations for agricultural enterprises were based on information about livestock population and manure management systems. Default values for the portions of manure in each manure management system [1] (for Eastern Europe) were used for other livestock species (sheep, horses and goats).

Default CH4 conversion factors for manure management systems from the Good Practice Guidance (Table 4.10 for cool climate) were used, because of lack of information about national data.

6.3.2.2 Nitrous oxide emissions from manure management

Nitrous oxide emissions for each manure management system were calculated according the Good Practice Guidance by multiplication of total N excretion from all animal species and categories, fraction of manure that is managed in each manure management system and corresponding N2O emission factor.

The disaggregation of cattle, swine and poultry into categories in accordance with belonging to agricultural enterprises or households and sex and age of animals is the similar to division for methane emissions calculation.

Values of nitrogen excreted with manure of cattle, swine and poultry were calculated with use of manure amount on a dry-matter weight basis and N fraction in manure in percent, which are standardized [14-16]. Default values of nitrogen excreted with manure of sheep, horses and goats were used from the IPCC Revised Guidelines.

Methodology used is described in details in Annex 3, chapter A3.1.3.

6.3.3 Uncertainty assessment and developing a consistent time series

The main sources of uncertainties for methane emissions from manure management are as follows:

- Accuracy of activity data on livestock population;
- Accuracy of methane emission factors.

Uncertainty of 5 % was assumed for activity data according to the assessment of experts from the State Committee on Statistics of Ukraine.

Uncertainty of emission factors was calculated according to Tier 1 approach (rules A and B) of the Good Practice Guidance [6] and amounts to 25 %.

The overall uncertainty of methane emission estimation from manure management has totaled to approximately 26 %.

The main sources of uncertainties for nitrous oxide emissions from manure management are as follows:

- Accuracy of activity data on livestock population;
- Accuracy of activity data on the portions of manure managed in each manure management system;
- N excretion rate;
- Accuracy of nitrous oxide emission factors.

Uncertainty of 5 % was assumed for activity data on livestock population according to the assessment of experts from the State Committee on Statistics of Ukraine.

Uncertainty of data on the portions of manure managed in each manure management system were assessed at the levels of 10% for agricultural enterprises and 25% - for the households according to the expert judgement.

Uncertainty of nitrogen excretion rate for different species/categories of animals fell within the range 20-70%.

Uncertainty of nitrous oxide emission factors was calculated on the base of factor uncertainty range from the Good Practice Guidance and was assessed at the level of 75%.

The overall uncertainty of nitrous oxide emissions estimation from manure management has totaled to approximately 76 %.

The same methodology was used for emission estimation during the whole period. Activity data on livestock population were identically collected and processed in the State Committee on Statistics of Ukraine during the whole period. Therefore consistent time series were developed in this category.

6.3.4 QA/QC procedures

The general QC procedures were used for estimation of methane and nitrous oxide emissions from manure management.

Values of national volatile solid excretion rate and N excretion rate from cattle, swine and poultry manure were compared with default values from the IPCC Revised Guidelines. Comparison showed good consistency.

6.3.5 Recalculations

Recalculations of nitrous oxide emissions in this category are resulted from:

- Improvement of activity data on livestock population for the period 1990-2001;
- Use of Tier 2 approach for estimation of methane emissions from manure management from cattle, swine and poultry instead of Tier 1 in the previous inventory;
- Use of national data on nitrogen excretion with manure of cattle, swine and poultry;

- Use of country-specific data on the portions of manure managed in each manure management system;
- Division of cattle into categories in accordance with belonging to agricultural enterprises or households as well as sex and age of animals.

6.3.6 Planned improvements

Any improvements are not planned in this category.

6.4 Rice Cultivation (category 4.C CRF)

6.4.1 Overview of Source Category

Anaerobic decomposition of organic material in flooded rice fields produces methane (CH_4). The annual amount emitted from an area of rice acreage is a function of [6]:

- sort of rice,
- number and duration of crops grown,
- soil type and temperature,
- water management practices,
- use of fertilizers and other organic and inorganic amendments.

Areas of rice cultivation in the Ukraine are not large and are allocated in Crimea, Kherson and Odessa regions. Total rice harvested areas amounted to 21.3 thousand hectares in 2004 and 27.7 thousand hectares – in 1990 [17].

6.4.2 Methodological Issues

Methane emissions from rice cultivation were calculated according to the Good Practice Guidance with use of data on annual rice harvested areas obtained from the State Committee on Statistics of Ukraine and amount of organic amendments applied [17, 18].

Default values from the Good Practice Guidance for seasonally integrated emission factor, scaling factor for water management regime and soil type, as well as scaling factors for organic fertilizers were used.

According to the data from Crimea and Kherson region rice fields are constantly flooded. Organic fertilizers in form of compost are used. According to the Good Practice Guidance the amount of amendment applied was divided by 6 because of use of fermented amendments.

Methodology of calculations is described in details in Annex 3, chapter A3.4.4.

6.4.3 Uncertainty assessment and developing a consistent time series

The main sources of uncertainties for methane emissions from rice cultivation are

- Accuracy of activity data on rice harvested areas obtained from the State Committee on Statistics of Ukraine;
- Accuracy of seasonally integrated emission factor;
- Accuracy of scaling factors.

Uncertainty of 5 % was assumed for activity data according to the assessment of experts from the State Committee on Statistics of Ukraine.

Uncertainty of seasonally integrated emission factor and scaling factor for soil types was assessed on the base of factor uncertainty range from the Good Practice Guidance (Table 4.22).

Uncertainty of scaling factors for organic amendments and water management regime were assessed by experts.

Table 6.2 gives applied factors, their ranges and uncertainty assessment.

Table 6.2. Factors, their ranges and uncertainty assessment

Factor	Value	Range	Uncertainty
Seasonally integrated emission factor	20 g/m^2	12-28 g/m^2	40%
Scaling factor for water management regime	1	0.5-1.5	50%
Scaling factors for organic amendments	1	0.5-1.5	50%
Scaling factors for soil types	1	0.1-2	95%

The overall uncertainty of methane emission estimation from rice cultivation has totaled to approximately 125 %.

The same methodology was used for emission estimation during the whole period. Activity data on rice harvested areas were identically collected and processed in the State Committee on Statistics of Ukraine during the whole period. Therefore consistent time series were developed in this category.

6.4.4 QA/QC procedures

The general QC procedures were used for estimation of methane emissions from rice cultivation. In addition inventory team compared data on rice harvested areas in this category with rice cultivated areas which were used for the calculations in LULUCF sector.

Comparison showed that rice harvested areas were less than rice cultivated areas by upon the average 1% for the period 1990-2004.

Such fact proved good correspondence of data, because harvested areas are always slightly less or equal to cultivated areas due to low germination or other reasons.

6.4.5 Recalculations

Recalculations of GHG emissions in this category are resulted from:

- Use of scaling factors for fermented organic fertilizers instead of non-fermented in the previous inventory;
- Use of data on harvested rice areas instead of cultivated rice areas;
- Use of interpolation for obtaining data on applied organic fertilizers in 1991-1992 and 1994-1995 (chapter A3.1.4).

6.4.6 Planned improvements

Any improvements in this category are not planned.

6.5 Agricultural Soils (category 4.D CRF)

6.5.1 Overview of Source Category

Nitrous oxide (N_2O) is produced naturally in soils through the microbial processes of nitrification and denitrification. A number of agricultural activities add nitrogen to soils (synthetic fertilizers, manure, crop residues) increasing the amount of nitrogen (N) available for nitrification and denitrification, and ultimately the amount of N_2O emitted. The emissions of N_2O that result from anthropogenic N inputs occur through both a direct pathway (i.e. directly from the soils to which the N is added), and through two indirect pathways - volatilization as NH_3 and NO_x and subsequent deposition as ammonia (NH_4) and NO_x, and through leaching and runoff [6].

6.5.2 Methodological Issues

6.5.2.1 Direct nitrous oxide emissions from agricultural soils

Direct nitrous oxide emissions were estimated for the following sources:

- synthetic fertilizers applied to soils;
- animal manure applied to soils;
- biological N-fixation by N-fixing crops cultivated;
- crop residues applied to soils;
- organic soils cultivation;
- animal manure on the pastures.

Default emission factors for all sources listed above were used (Table 4.12 and 4.17 from the Good Practice Guidance).

Use of synthetic fertilizers. Nitrous oxide emissions from synthetic fertilizer application were calculated according to the Good Practice Guidance by multiplication of amounts of fertilizers applied to soils (data source - the State Committee on Statistics of Ukraine [18]) with adjusting for volatilization of NH_3 and NO_x and emission factor.

The default value of fraction that volatilizes as NH_3 and NO_x was used from the Good Practice Guidance.

Animal Manure Used as Fertilizers. Nitrous oxide emissions from animal manure used as fertilizer were calculated according to the Good Practice Guidance but with adjusting for volatilization of N_2O, NH_3 and NO_x during manure storage. So emissions were estimated by multiplication of N in manure of all animal species applied to soils with adjusting for volatilization of nitrogen during manure storage and application and emission factor.

The values of N fraction that volatilizes as NH_3 and NO_x during manure storage and application were obtained from national norms [14, 15, 19].

To reflect the variation in the amount of manure excreted among animal types, the population of animals was divided into categories in accordance with belonging to agricultural enterprises or households, types (poultry) and sex and age of animals (cattle and swine) (Annex 3, chapter A3.1.1)

Values of N excretion rate from the manure and fractions of manure per manure management systems were used the same as for calculations of nitrous oxide from manure management (Annex 3, Table A3.1.8 and A.3.1.11).

Biological N-fixation by N-fixing crops cultivated. Nitrous oxide emissions from N-fixation were calculated according to Tier 1b approach from the Good Practice Guidance by multiplication of croppage of N-fixing crops (data source - the State Committee on Statistics of Ukraine [18]), the ratio of aboveground biomass to crop product mass, nitrogen and dry matter fraction in aboveground biomass and on emission factor.

The ratio of aboveground biomass to crop product mass, N and dry fraction in aboveground biomass were obtained from the national data [20, 21, 22].

Crop residues applied to soils. Nitrous oxide emissions were calculated by multiplication of N in crop residues applied to soils and emission factor.

Amount of crop residues returned to soils was estimated according to national methodology [23] on the basis of data on annual crop productivity.

The advantage of this methodology is taking into account not only mass of stubbles but also the mass of roots and therefore the amount of nitrogen in crop residues is estimated more completely. For each crop the specific amount of nitrogen in crop stubbles and roots per 1 hectare was multiplied by harvested area. Then amounts for each crop type were summed to obtain the total amount of nitrogen in crop residues applied to soils.

Values of annual crop productivity and harvested areas were obtained from the State Committee on Statistics of Ukraine [17].

The amounts of nitrogen in crop stubbles and roots were taken from published data sources [20, 21].

Organic soil cultivation. Nitrous oxide emissions from organic soil cultivation were calculated by multiplication of area of organic soils cultivated and emission factor.

Animal manure on the pastures. Nitrous oxide emissions from animal manure on the pastures were calculated according to the Good Practice Guidance similarly to the other waste management systems.

6.5.2.2 Indirect nitrous oxide emissions as a result of nitrogen use in agriculture

Indirect nitrous oxide emissions were estimated for the following sources:

- Atmospheric deposition as NH_3 and NO_x on soils;
- Leaching/runoff of applied or deposited nitrogen.

Default emission factors for all sources listed above were used (Table 4.18 from the Good Practice Guidance).

Atmospheric deposition as NH_3 and NO_x on soils.. Nitrous oxide emissions from atmospheric deposition as NH_3 and NO_x on soils were calculated according to the Tier 1a approach of the Good Practice Guidance but with adjusting for volatilization of N_2O, NH_3 and NO_x during manure storage.

Emissions were estimated by multiplication of N in applied synthetic fertilizers and animal manure, corresponding fractions of N that volatilize as NH_3 and NO_x during application to soils and emission factor.

The values of fraction that volatilizes as NH_3 and NO_x during manure storage and application were obtained from national norms [14, 15, 19].

The default values of N fractions that volatilizes as NH_3 and NO_x from animal manure on the pastures and synthetic fertilizers application to soils were used from the Good Practice Guidance, because of absence of national data.

Leaching/runoff of applied or deposited nitrogen. Nitrous oxide emissions from leaching/runoff of applied or deposited nitrogen were calculated according to the Good Practice Guidance but with adjusting for volatilization of N_2O, NH_3 and NO_x during manure storage.

Emissions were estimated by multiplication of N in applied synthetic fertilizers and animal manure, corresponding fractions of N that is lost through leaching and runoff and emission factor.

The default value of N fraction that is lost through leaching and runoff was used from the Good Practice Guidance.

Methodology of calculations is described in details in Annex 3, chapter A3.1.5.

6.5.3 Uncertainty assessment and developing a consistent time series

The main sources of uncertainties for nitrous oxide emissions from agricultural soils are as follows:

- Accuracy of activity data;
- Accuracy of nitrous oxide emission factors.

Uncertainty of 5 % was assumed for activity data in this category according to the assessment of experts from the State Committee on Statistics of Ukraine.

Uncertainty of emission factors was assessed on the base of factor uncertainty range from the Good Practice Guidance.

Table 6.2 gives applied factors for N_2O emissions from soils, their ranges and uncertainty assessment.

Table 6.3. Factors for N_2O emissions from soils, their ranges and uncertainty assessment

Factor	Value	Range	Uncertainty
Emission factor for N-inputs in the soils	0.0125 kg N_2O-N/kg N	0.0025-0.06 kg N_2O-N/kg N	240%
Emission factor for organic soils	8 kg N_2O-N/ra-year	1-80 kg N_2O-N/ra-year	494%
Emission factor for atmospheric deposition of nitrogen	0.01 kg N_2O-N/kg N	± 50%	50%
Emission factor for nitrogen leaching/runoff	0.025 kg N_2O-N/kg N	± 50%	50%

The overall uncertainty of nitrous oxide emission estimation from agricultural soils has totaled to approximately 87 %.

The same methodology was used for emission estimation in this category during the whole period. Activity data were identically collected and processed in the State Committee on Statistics of Ukraine during the whole period. Therefore consistent time series were developed in this category.

6.5.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions from direct and indirect N_2O emissions from agricultural soils. In addition activity data of State Committee on Statistics of Ukraine on synthetic fertilizer application were compared to the information from FAO website in accordance with recommendations of the Good Practice Guidance.

Comparison for the years where both national and FAO statistics is available shows that there are no discrepancies in 1996-1999, but in 1993, 2000-2002 differences falls into the range of 16-37%. Discrepancies in the last years may be explained by use of preliminary data of the State Committee on Statistics of Ukraine.

Such data from the State Committee on Statistics of Ukraine as rice and sunflower harvested area correspond with the data used in LULUCF sector. Therefore inventory team compared data on rice and sunflower harvested areas in this category with rice and sunflower cultivated areas which were used for the calculations in LULUCF sector according to the Good Practice Guidance.

Comparison showed that rice and sunflower harvested areas were less than rice and sunflower cultivated areas by upon the average 1% and 3% respectively for the period 1990-2004.

Such fact proved good correspondence of data, because harvested areas are always slightly less or equal to cultivated areas due to transformation of sown areas, low germination or other reasons.

6.5.5 Recalculations

Recalculations of nitrous oxide emissions in this category are resulted from:

- improvement of activity data on livestock population for the period 1990-2001;
- division of cattle into categories in accordance with belonging to agricultural enterprises or households as well as sex and age of animals;
- use of national data on N excretion rate from manure of cattle, swine and poultry;
- use of country-specific data on the portions of manure managed in each manure management system;
- application of national methodology for nitrous oxide emission estimation from crop residues applied to soils and supplement estimation by such crops as sorghum, vetch, perennial plants, fibre flax, annual crops, rape etc.;
- use of national values of nitrogen fraction that is lost during manure application to soils;

- Corrections to take into account N fraction that volatilizes as NH_3, N_2O and NO_x during manure storage;
- Use of FAO data on synthetic fertilizers applied in 1992, 1994-1995 to reach consistency time series;
- Supplement of estimation of nitrous oxide emission from N-fixation by such crops as vetch and perennial plants, and use of national values of the ratio of aboveground biomass to crop product mass, nitrogen and dry matter fraction in aboveground biomass.

Inventory of nitrous oxide emissions in the subcategory «Organic soils cultivation» was carried for the first time in Ukraine.

6.5.6 Planned improvements

The investigations of national N_2O emission factors for N-inputs in soils and national values for nitrogen fractions that are lost during synthetic fertilizer application to soils and leaching/run off are planned.

6.6 Prescribed Burning of Savannas (category 4.E CRF)

CH_4 and N_2O emissions from prescribed burning of savannas were not estimated because of absence of savannas in Ukraine.

6.7 Field burning of agricultural residues (category 4.F CRF)

Field burning of agricultural residues is prohibited by law. That is why activity data in this category are not available in Ukraine.

6.8 Other (category 4.G CRF)

GHG emissions were not considered in this category.

7 LAND-USE, LAND-USE CHANGE AND FORESTRY (SECTOR 5 CRF)

7.1 General Sector Overview

Sector LULUCF differs from the other sectors in presence of both sources of emissions and removals by sinks in the biomass and soil carbon pools[4] (organic and mineral). Land-use categories are divided to two types:

- Lands which are constantly remaining in the same land-use category (default period of 20 years of remaining in the same land-use category is generally accepted);
- Lands with changeable use, i.e. lands converted to another land use category.

The following sources of CO_2, CH_4, N_2O, CO and NO_x emissions are occurred in LULUCF sector: biomass burning in the forests, N_2O emissions from soils, CO_2 emissions and removals from biomass and soils. Net CO_2 emissions/removals from the sector LULUCF in Ukraine has gradually changed from 33839 thous. t in 1990 to 32141.8 thous. t 2004 with gradual increase of removals to 52 mln t CO_2 in 1998. Changes are explained by conversion of lands from the one category to another. Analysis of results by category showed that sharp carbon stock change is not occurred in the lands remaining in the same land-use category. So category «Forest land remaining forest land» showed stable level of removals by living biomass pool with slight maximum of 14240 thous. t in 1998. Carbon removals by living biomass pool on the lands converted to forest lands corresponded to area trends and demonstrates trend to increase from 144 thous. t C in 1990 to 1518 thous. t C in 2004 with maximum of 1551 thous. t in 1998. The similar trends were observed for pools of litter and forest soils.

Category «Cropland remaining cropland» demonstrated trend to decrease of carbon stock due to shortening the total garden areas. Carbon emissions from living biomass pools gradually increased from 1999 to 2004 and amounted to approximately 3 mln t C, which was in correspondence with garden areas and total areas in this category. Carbon removals by soils gradually decreased from 8.6 mln t C in 1990 to 7.1-7.3 mln t C in 2003- 2004 correspondingly. Maximum of 193.75 thous. hectares in 1995 was observed for grassland areas converted to cropland areas, which led to the maximum of 685.6 thous.t C in emissions from living biomass pool and maximum of removals by pools of living biomass and soils - 685.6 and 90.36 thous.t C correspondingly. Maximums of 7.8 and 20.35 thous. hectares in 1996 were observed for wetland and settlement areas converted to croplands areas, which led to the maximums of 39 thous.t C and 101.58 thous.t C in emissions from living biomass pool and maximum of emissions of 266.6 thous.t C from soils.

Carbon stock change in soil pool was estimated in the category «Grassland remaining grassland», because information about tree plantations was not available. Carbon emissions from soil pool gradually increased from 1235 thous. t C in 1990 to 3764 thous. t C in 2004, which corresponded to increase of grassland areas from 6853 thous. hectares in 1990 to 7968 thous. hectares in 2004. Carbon removals by living biomass and soil pools with maximum in 1996 dominated for the areas converted to grasslands.

Carbon emissions in the category «Wetland remaining wetland» gradually decreased from 35 thous. t C in 1990 to 9.9 thous. t C in 2004, which corresponded to decrease of wetland areas from 32 thous. hectares in 1990 to 9 thous. hectares in 2004. The maximum of carbon emissions from lands converted to wetlands was observed in 1990 – 1513 thous. t CO_2, and in 2004 emissions amounted to 465.7 thous. t CO_2, which was caused by conversion of grasslands, croplands

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[4]Carbon Pool -a system which has the capacity to accumulate or release carbon, e.g.. forest biomass, wood products, soils and the atmosphere.

and settlements to wetlands and led to emissions from biomass at the level of 412.7 thous. t C in 1990 г. and 127 thous. t C in 2004.

Carbon removals in the category «Settlements remaining settlements» gradually increased from 308 thous. t C in 1990 to 447 thous. t C in 2004, which corresponded to dynamics of settlement areas from 1420.8 thous. hectares in 1990 to 1191.7 thous. hectares in 2004.

CO_2 emission from forest fires reached the maximum of 479.3 thous. t in 1994. CH_4 and N_2O emissions also reached maximums of 2.25 and 0.04 thous. t in 1994. N_2O emissions from land conversion corresponded to trends in carbon stock in soils.

Removals in LULUCF sector were included to inventory reporting tables with negative values. Net removals in this sector totaled approximately 3.8% in 1990. The current inventory used methodology [1] instead of [4] in the previous inventory. That is why comparison of results is provided only for total values from 1990 to 2003 (Table 7.1).

GHG emission/removal estimating and reporting were carried out according to the methodology provided by [1]. Tier 2 approach [1] was used for the category «Forest Lands» (sector 5.1 CRF) with national emission factors. Tier 1 approach [1] was used for the other categories with default emission factors.

Activity data on total areas of land-use categories were obtained from statistical yearbooks. The following assumptions were made on:

- Correspondence of national land-use categories from 6-zem statistical reporting form and categories recommended by [1];
- Methodology for assessment of converted areas, because such information is not provided in national statistics;
- Correspondence of national soil types and soil types recommended by [1];
- Stability of soil stratification.

Table 7.1. Comparison of estimation of GHG emissions in LULUCF sector in Ukraine, thous.t

Value	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Inventory submitted in 2005														
Net CO_2 emissions/removals	-38938.0	-31443.8	-54521.9	-47108.1	-48997.8	-48936	-61625.1	-65442.6	-63637.5	-63284.3	-61494.5	-59694.7	-57308.5	-55761.3
Inventory submitted in 2006														
Net CO_2 emissions/removals	-33839.16	-35998.32	-31870.04	-30943.47	-39290.01	-42433.06	-48416.72	-46938.44	-52503.18	-43564.31	-38044.37	-42011.83	-37342.21	-39223.40
Difference, %	14.98	22.21	23.14	32.90	12.88	22.81	15.51	19.93	14.02	29.07	39.42	33.45	41.66	42.33

Correctness of assumptions was proved by expert judgement. Annex 3.2.1 contains detailed description of these assumptions.

The overall uncertainties of emission estimations were assessed at the levels:

- CO_2 – 65%,
- CH_4 – 19%;
- N_2O – 159%.

7.2 Forest Land (category 5.A CRF)

7.2.1 Overview of Source Category

Forests are defined in Forest code of Ukraine (2006) as the type of ecosystem, which consists mainly of tree and bush stands with proper soils, grass vegetation, fauna, microorganisms and other natural components that mutually develop and influence upon each other and environment.

Lands of the Forest Fund are lands covered with forest vegetation as well as those not covered with forest vegetation permanently or temporarily (due to discontinuity of forests, forestry activities or natural disaster. Lands, which are covered with bush plantations, are also referred as forest lands.

Practically all forests in Ukraine are managed.

7.2.2 Methodological Issues

Carbon stock change was estimated for all forests as managed. Forest areas gradually increased from 1990 and reached to 9630 thous. hectares in 2004, i.e. 16.0 % of Ukrainian territory.

Hardwood broadleaf stands dominate in Ukraine and accounted for 43.6 %. Smaller areas are occupied by coniferous (42.6 %) and softwood broadleaf stands – 13.8 %. The total wood stock in Ukraine is constantly growing and reached to over 19 billion m^3. The main reasons for this increase are change of age structure and growth of forest areas. Felling volumes has increased last five years and amounted to 17.3 mln m^3 in 2004.

Forest management rules presumed reforestation of total felling area during two years. Recently reforestation area has totaled 30-40 thous. hectares annually. Approximately 20% of felling area restored naturally.

The category “Forest land” is subdivided to the subcategories «Forest land” remaining Forest land” (category 5.A.1 CRF) and “Land Converted to Forest land “(category 5.A.2 CRF) according to IPCC methodology [1].

IPCC methodology [1] was used for calculations carbon stocks GHG emissions and removals. The calculations were based on the activity data from the State Committee on Statistics, Ukrainian State Forest Inventory Enterprise and additional study fulfilled by national forest experts in 2004-2005 years. Some default emission factors were specified and adjusted for the Ukrainian circumstances (Annex 3.2.2).

The following assumptions were made for calculations for taking into account the specific features of forest activity in Ukraine:

- the amount of dead wood and wood waste is approximately constant for the whole period, and all stages of decomposition are similarly considered;
- decay of organic matter in humus and litter is constantly countervailed with organic matter input from biomass falling (mechanism of decay of organic matter was not taken into account);
- annual reforestation areas are approximately countervailed with areas of commercial felling;
- carbon losses, which are caused by biomass falling, are countervailed with carbon growth in biomass increment.

The three main sources of CO_2 emissions in category “Forest land” were considered:

- wood biomass changes in forest and other carbon pools;
- conversion of forests and grasslands;
- abandonment of managed lands.

Emission of indirect GHG gases from forest fires were also considered in the current inventory.

7.2.3 Uncertainty assessment and developing a consistent time series

The main sources of uncertainties in this category are as follows:

- Accuracy of data on forest areas and sharing to the forest categories;
- Accuracy of data on biomass increment;
- Accuracy of conversion factor.

Uncertainty of data on forest areas was assessed at the level of approximately 10% (expert judgment), data on biomass increment – approximately 25% [8], ratio of underground and aboveground biomass - 15% [8,9]. Uncertainty of 2% was assessed for estimation of carbon content in biomass [1]. Data on uncertainty were obtained from different sources and so they were considered as non-correlated. The overall uncertainty of estimation of CO_2 removals amounted to 31 %.

The overall uncertainty of estimation of emissions amounted to 31 %, taking into account uncertainties of 10% for harvested wood, and forest fires, and 15 % for emission factors.

7.2.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions and removals from carbon stock change in forest lands. All activity data (forest areas by tree species and climatic zones, wood harvesting, forest fires) and emission factors were verified and formally checked before input in calculation worksheets and CRF.

7.2.5 Recalculations

Fulfilled study made more precise values for national factors in this category. Chapter 7.2.2 listed additional factors, which were taken into account in the current inventory. Table 7.2 presents comparison of inventory results in 2005 and 2006.

Table 7.2. Comparison of net CO_2 emissions/removals in forestry, mln t

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Inventory submitted in 2005														
Net CO_2 emissions/removals	-48,8	-49,8	-50,7	-59,1	-60,1	-60,3	-61,3	-60,1	-60,5	-60,4	-59,1	-58,5	-57,6	-56,8
Inventory submitted in 2006														
Net CO_2 emissions/removals	-55,4	-57,7	-57,2	-57,2	-58,5	-60,1	-57,6	-58,2	-61,0	-61,1	-59,8	-59,1	-58,0	-56,9
Difference, %	11,9	13,7	11,4	-3,3	-2,7	-0,3	-6,4	-3,3	0,8	1,1	1,2	1,0	0,7	0,2

7.2.6 Planned improvements

Ukraine has plan on improvement of statistical data and national factors by enhancement of observations at the net monitoring of forests, national forest inventory and extension of scientific investigations. Taking into account all forest categories, including those not reported previously, is planned.

7.3 Croplands (category 5.B CRF)

7.3.1 Overview of Source Category

The following types of land are considered in this category [2]:

- systematically tilled and used for agricultural crops, including the perennial grasses as well as lands set at rest, greenhouses and hothouses; the category excludes rangelands and pasture lands, which are ploughed up for the purposes of their improvement and constantly used for grass fodder crops by way of hay and pasture of livestock; and garden row-spacing used for crops;
- Lands, which were cultivated, but are not cultivated and set at rest now;
- Anthropogenic perennial plantations for fruit production.

7.3.2 Methodological Issues

The category “Cropland” is subdivided to the subcategories «Cropland remaining cropland” (category 5.B.1 CRF) and “Land Converted to Cropland“(category 5.B.2 CRF) according to IPCC methodology [1].

Calculations were carried out for biomass and carbon organic pools according to IPCC methodology [1].

For both categories data on the following areas were used:

- Arable lands;
- Sunflower (it is assumed that cultivation of this crop produces a high level of organic residues at the soils);
- Rice cultivation;
- Lands set at rest;
- Gardens.

The national statistics did not provide data on lands set at rest for the period 1992-1997 and gardens – for the period 1994-1998. These omissions were filled by interpolation method 7.

Emission factors for the calculation of carbon stock change in soils in garden were assumed equal to default values for lands set at rest [1], because soil in garden is not ploughed and covered by vegetation.

Carbon emissions from lime input were calculated by multiplying the amount of lime applied to soil and default emission factor. These emissions were taken into account in the subcategory «Cropland remaining cropland”.

Emissions of non-CO_2 gases were not considered in the subcategory of «Cropland remaining cropland” [1]. These emissions were calculated in the sector «Agriculture». GHG emissions from biomass burning were not considered due to lack of statistical data.

N_2O emissions from mineralization of soil organic matter resulting from conversion of other land-use category to cropland. These emissions were calculated by multiplying the results of calculation of carbon stock change in soils and default emission factors.

7.3.3 Uncertainty assessment and developing a consistent time series

The main sources of uncertainties in this category are as follows:

- Accuracy of data on cropland areas remaining croplands;
- Accuracy of data on cropland areas converted from other land-use category;
- Accuracy of estimation of carbon stock change (increment and harvesting) in living biomass;
- Accuracy of estimation of soil organic carbon for different soil and climatic variables;
- Accuracy of estimation of soil organic carbon stock change factors for management of lands.

Data on areas of land use categories were obtained from the State Committee on Statistics of Ukraine. For lands remaining in the same land use category uncertainty of activity data was assumed at the level of 10%, for lands converted to this category – approximately 50%. Uncertainties of 95% for mineral soils and 90% for organic soils were assessed for soil organic carbon stock [1].

Soil organic carbon stock change factors for management of lands introduced the different levels of uncertainty:

- Stock change factor for land use type (F_{LU}):
  - Long-term cultivated soils in the wet climate – 12%;
  - Rice cultivation – 90%;
  - Temporary cropland set at rest in the wet climate – 18%, in the dry climate – 10%;
- stock change factor for input of organic matter (F_i):
  - Temporary cropland set at rest in the wet climate – 4%, in the dry climate – 8%;
  - Croplands with great residue return– 10%.

Uncertainties of estimation of carbon stock change were estimated in this category taking into account levels of uncertainty of stock change factors of 75% for living biomass increment and harvesting:

- Croplands remaining croplands for biomass carbon pool – 73%, soil carbon pools – 50%;
- Lands converted to croplands for biomass carbon pool – 53%, soil carbon pools – 163%.

The overall uncertainty of estimation of emissions amounted to 48 % in this category. Uncertainty of estimations of N_2O emissions from mineralization of soil organic matter resulting from conversion of land to cropland was assumed equal to uncertainty of CO_2 emissions, because N_2O emissions were estimated on the basis of the same factors.

7.3.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions in this category. Correctness of assumptions used for estimation was proved by expert judgement.

All statistical data were documented, approved by the letter from the State Committee on Statistics and archived in such manner that it is possible to recalculate emissions if needed.

Sharp changes in statistical data on the areas under following land use type were identified:

- Lands set at rest from 1991 to 1998;
- Hayfield from 1990 to 1993;
- Drainage lands from 1992 to 1993;
- Covered by forest plantations from 1997 to 1993;
- Artificial lakes in 1992-1993 and 2003-2004.

According to IPCC [1] these changes in data were corrected by interpolation. Cross-check with soil areas considered in sector 6 «Agriculture» was fulfilled; however sector “Agriculture” and LULUCF sector used different parameters. Only total cultivated areas are considered in the sector «Agriculture», while LULUCF sector took into account segregated data on croplands (including sunflower and rice cultivation), lands set at rest, perennial plantations (e.g. gardens). The difference has amounted to 1-2% and explained by including of berry plantations, mulberry trees, hop-gardens, and other plantations to croplands [2].

7.3.5 Recalculations

The current inventory used methodology [1] instead of [4] in the previous inventory. That is why comparison of results is provided only for total values from 1990 to 2003 (Table 7.1).

7.3.6 Planned improvements

Specifying activity data on lands converted to croplands, using Tier 2 approach with more accurate information about soil types by region and improving national factors for soil carbon stock are planned in this category.

7.4 Grassland (Sector 5.C CRF)

7.4.1 Overview of Source Category

Agricultural lands [2], which are systematically used for hay production, livestock grazing, including areas with less than 20% of tree and bush vegetation were considered in this category.

This category includes rangelands and pasture lands, which are ploughed for their improvement and continuously used for forage plantations and garden row-spacing, which is used for crops.

7.4.2 Methodological Issues

The category “Grassland” is subdivided to the subcategories «Grassland remaining Grassland” (category 5.C.1 CRF) and “Land Converted to Grassland” (category 5.C.2 CRF) according to IPCC methodology [1].

Calculations were carried out for soil carbon organic pools in the subcategory «Grassland remaining Grassland” and biomass and carbon organic pools in the subcategory “Land Converted to Grassland» according to IPCC methodology [1].

For both categories data on the following areas were used:

- Rangelands and pastures;
- Improved rangelands and pasture lands.

The national statistics did not provide data on lime applied to soils and wood biomass in this category. Instruction to 6-zem statistical reporting form points the maximum percent of wood biomass of 20% from grasslands. That is why carbon stock change was calculated for 80% of total areas from the national statistics.

Emissions of non-CO_2 gases were not considered in the subcategory «Grassland remaining Grassland” [1]. These emissions were calculated in the sector «Agriculture». GHG emissions from biomass burning were not considered due to lack of statistical data.

7.4.3 Uncertainty assessment and developing a consistent time series

The main sources of uncertainties in this category are as follows:

- Accuracy of data on grassland areas remaining grassland;
- Accuracy of data on other land-use categories converted to grassland;
- Accuracy of estimation of carbon stock change in living biomass during conversion the other land-use categories to grassland;
- Accuracy of estimation of soil organic carbon for different soil and climatic variables;
- Accuracy of estimation of soil organic carbon stock change factors for management of lands converted to wetlands.

Data on areas of land use categories were obtained from the State Committee on Statistics of Ukraine. For lands remaining in the same land use category uncertainty of activity data was assumed at the level of 10%, for lands converted to this category – approximately 50%. Uncertainties of 95% for mineral soils and 90% for organic soils were assessed for soil organic carbon stock [1].

Soil organic carbon stock change factors for management of lands introduced the different levels of uncertainty:

- Management factor (F_{MG}) for overgrazed or moderately degraded grassland, with somewhat reduced productivity (relative to the native or nominally managed grassland) -12%;
- Stock change factor for input of organic matter (F_i) for grassland, where one or more additional management inputs/improvements have been used – 8%.

The overall uncertainty of estimation of emissions amounted to 49 %, taking into account uncertainty of 75% for factors used for carbon stock change calculation during biomass growth and loss.

7.4.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions in this category. Correctness of assumptions used for estimation was proved by expert judgement.

All statistical data were documented, approved by the letter from the State Committee on Statistics and archived in such manner that it is possible to recalculate emissions if needed.

Sharp changes in statistical data on the areas of the hayfieldfs from 1990 to 1993 were identified.

According to IPCC [1] these changes in data were corrected by interpolation.

7.4.5 Recalculations

The current inventory used methodology [1] instead of [4] in the previous inventory. That is why comparison of results is provided only for total values from 1990 to 2003 (Table 7.1).

7.4.6 Planned improvements

Specifying activity data on lands converted to grasslands, using Tier 2 approach with more accurate information about soil types by region and improving national factors for soil carbon stock are planned in this category.

7.5 Wetland (Sector 5.D CRF)

7.5.1 Overview of Source Category

Wetlands is defined in Ukraine as land that is continuously, temporal or partially covered by water or saturated by water [2] and does not occupy by forest plantations. Vegetation is presented mainly by decomposed moss.

The following types of land are considered in this category according [1]:

- Land under peat management – land, where peat is extracted with transport lines, territory for services, excluding worked-out peat lands;
- Artificial channels, which were constructed for stream force use, rational water use irrigation and other purposes, as well as drainage water-drip channels;
- Artificial lakes, which were constructed for potable water supply, electricity production, irrigation and livestock, including the part of natural or artificial water turnover with capacity more than 1 mln m^3.

7.5.2 Methodological Issues

The category “Wetlands” is subdivided to the subcategories «Wetlands remaining Wetlands” (category 5.D.1 CRF) and “Land Converted to Wetlands” (category 5.D.2 CRF) according to IPCC methodology [1].

Calculations were carried out for the following types of lands [1]:

1) Subcategory “Wetland remaining Wetland”:

- Organic soils managed for peat extraction (carbon emissions);
- Drained peat land (N_2O emission) and flooded areas from the subcategory;

- Flooded areas (carbon and N_2O emissions);

2) Converted to the category «Wetlands”:

- Biomass which is lost before land use change for peat extraction;
- Drained peat land before land use change for peat extraction;
- Biomass which is lost before land use change for flooding.

Data on the following areas were used:

- Peat management on the stage of exploitation;
- Drained peat lands;
- Artificial channels;
- Artificial lakes.

GHG emissions from biomass burning were not considered due to lack of statistical data.

N_2O emissions were calculated for drained peat lands from the data of State Committee on Statistics of Ukraine and default emission factors.

7.5.3 Uncertainty assessment and developing a consistent time series

The main sources of uncertainties in this category are as follows:

- Accuracy of data on wetlands areas remaining wetlands;
- Accuracy of data on other land-use categories converted to wetlands;
- Accuracy of estimation of carbon stock change in living biomass during conversion the other land-use categories to wetlands;
- Accuracy of estimation of soil organic carbon for different soil and climatic variables for lands converted to wetlands;
- Accuracy of estimation of soil organic carbon stock change factors for management of lands converted to wetlands.

Data on areas of land use categories were obtained from the State Committee on Statistics of Ukraine. For lands remaining in the same land use category uncertainty of activity data was assumed at the level of 10%, for lands converted to this category – approximately 50%. Uncertainties of 95% for mineral soils and 90% for organic soils were assessed for soil organic carbon stock [1].

Soil organic carbon stock change factors for management of lands introduced the different levels of uncertainty (chapters 7.4.3 and 7.3.3).

The following levels of uncertainties of estimation of emissions were assessed, taking into account uncertainty of 0.03-2.9% for CO_2 emission factor for organic soils after drainage for the wetlands remaining wetlands [1]:

- Carbon stock change in biomass on lands converted to wetlands – 88%;
- Carbon stock change in soils on wetlands remaining wetlands – 185%.

The overall uncertainty level in this category amounted to 97%.

7.5.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions in this category. Correctness of assumptions used for estimation was proved by expert judgement.

All statistical data were documented, approved by the letter from the State Committee on Statistics and archived in such manner that it is possible to recalculate emissions if needed.

Sharp changes in statistical data on the artificial lakes from 1992-1993 and 2003-2004 were identified.

According to IPCC [1] these changes in data were corrected by interpolation.

7.5.5 Recalculations

The current inventory used methodology [1] instead of [4] in the previous inventory. That is why comparison of results is provided only for total values from 1990 to 2003 (Table 7.1).

7.5.6 Planned improvements

Specifying activity data on lands converted to wetlands is planned in this category.

7.6 Settlements (Sector 5.E CRF)

7.6.1 Overview of Source Category

This category includes all lands, which are occupied by industrial enterprises, houses, roads, mines and other buildings constructed for human activities, including services [2]. In this category national statistics considers lands covered by public green plantations (parks, gardens, squares, boulevards etc.) not included in the forest category.

7.6.2 Methodological Issues

The category "Settlements" is subdivided to the subcategories « Settlements remaining Settlements" (category 5.E.1 CRF) and "Land Converted to Settlements" (category 5.E.2 CRF) according to IPCC methodology [1].

Calculations were carried out for living biomass pools for the both subcategories using approach with crown cover area and default emission factors [1].

For both categories data on the following areas were used:

- Built-up areas;
- Public green plantations.

GHG emissions from biomass burning were not considered due to lack of statistical data.

7.6.3 Uncertainty assessment and developing a consistent time series

The main sources of uncertainties in this category are as follows:

- Accuracy of data on settlements areas remaining settlements;
- Accuracy of data on living biomass areas for settlements areas remaining settlements;
- Accuracy of data on other land-use categories converted to settlements;
- Accuracy of estimation of carbon stock change growth and loss in living biomass for settlements remaining settlements;
- Accuracy of estimation of carbon stock change in living biomass during conversion the other land-use categories to settlements.

Data on areas of land use categories were obtained from the State Committee on Statistics of Ukraine. For lands remaining in the same land use category uncertainty of activity data was assumed at the level of 10%, for lands converted to this category – approximately 50%.

The overall uncertainty of estimation of emissions amounted to 76 %, taking into account uncertainty of 75% for factors used for carbon stock change factor for biomass.

7.6.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions in this category. Correctness of assumptions used for estimation was proved by expert judgement.

All statistical data were documented, approved by the letter from the State Committee on Statistics and archived in such manner that it is possible to recalculate emissions if needed.

7.6.5 Recalculations

The current inventory used methodology [1] instead of [4] in the previous inventory. That is why comparison of results is provided only for total values from 1990 to 2003 (Table 7.1).

7.6.6 Planned improvements

Specifying activity data on lands converted to settlements is planned in this category.

7.7 Other lands (Sector 5.F CRF)

The category "Other lands" includes [4] bare soils with scarce vegetation or without vegetation, i.e. unbuilt areas with scarce vegetation or without vegetation, namely rock areas, drafts and other bare soils (solonchak and so on).

The category "Other lands" is subdivided to the subcategories "Other Land Remaining Other Land" (category 5.F.1 CRF) and "Land Converted to Other Land"(Category 5.F.2 CRF) according to IPCC methodology [1].

Change in carbon stocks and non-CO_2 emissions and removals are not considered for the category "Other Land Remaining Other Land" [1]. The category "Land Converted to Other Land" was not considered in the current inventory due to high uncertainty of activity data.

8 WASTE (SECTOR 6 CRF)

8.1 General Sector Overview

The following GHG emission sources were considered:

- Solid Waste Disposal on Land;
- Industrial and Domestic Wastewater, Human Sewage;
- Waste Incineration.

GHG emissions were estimated according to the Good Practice Guidance [1]. In Ukraine methane (CH_4) is emitted during the anaerobic decomposition of organic waste disposed of in solid waste disposal sites, industrial and domestic wastewater handling. Nitrous oxide (N_2O) in this sector is emitted during human sewage handling and waste incineration. Carbon dioxide (CO_2) emissions are produced during the waste incineration. Waste is incinerated in facilities with heat recovery capabilities in Ukraine, so GHG emissions from waste incineration were taken into account in Energy sector. However methodology of their calculation is described in this chapter.

Methane emissions in the Waste sector amounted to 300.78 thous. t in 1990 and increased to 370.36 thous. t - in 2004. Nitrous oxide emissions in the Waste sector amounted to 5.0278 thous. t in 1990, decreased to 3.28 thous. t – in 1999 and then increased to 3.46 thous. t - in 2004. Solid Waste Disposal on Land is the most significant GHG source in this sector. The total GHG emissions in this sector made to 7 872.52 thous.t CO_2 –eq. – in 1990 and 8 850.13 thous.t CO_2 –eq. – in 2004.

8.2 Solid Waste Disposal on Land (category 6.A. CRF)

8.2.1 Overview of Source Category

Methane emissions in this category are produced by anaerobic decomposition of organic matter in Municipal Solid Waste (MSW) at landfills. Methane emissions in this category amounted to 224.61 thous. t in 1990 and increased to 297.91 thous. t - in 2004.

MSW management system in Ukraine. Sanitary cleaning of settlements and further waste management is one of the most important environmental problems in Ukraine. Approximately 40 mln m^3 of waste are annually produced by settlements in Ukraine according to the information from the State Committee on Public Service of Ukraine. MSW is removed mainly to disposal sites and unmanaged landfills.

Waste utilization. Enterprises on complex waste recycling are not enough though the availability of many state-of-the-art technologies. Recently waste recycling begins to develop at the local level (by enterprises), but as a whole this problem is quite far from solution.

Thermal treatment of waste is also very limited. There are two waste incineration plants (WIP) now in Ukraine instead of four plants functioning previously. WIPs in Kyiv and Dnepropetrovsk are mounted with equipment which does not meet the recent normative requirements, and pollutes the environment.

Sanitary cleaning of settlements and waste removing are performed in the following way. 1053 enterprises remove MSW in Ukraine according to the information from the State Committee on Public Service of Ukraine (2004). Amount of MSW, which were disposed at the solid waste disposal sites (SWDS), has totaled to 39.13 mln m^3 in 2004. Municipal dust-carts with deterioration of 72% mainly remove MSW. MSW are disposed at 3386 SWDS. 177 disposal sites are overloaded, 467 SWDS (13.8 %) do not meet the environmental requirements, 362 SWDS are needed sanitation and 280 - recultivation.

Total SWDS area makes to 5848 ha including 33% under the SWDS which are overloaded environmentally hazardous. Most of these disposal sites operate without taking appropriate measures to prevent underground water and air pollution. The lack of equipment for methane utilization and filtrate cleaning is the most serious environmental problem. It causes pollution of underground water and air, as well as other adverse effect on environment.

Therefore solid waste management system does not complied with up-to-date technologies. Any environmental prevention measures (including mitigation measures) are not provided at the 80% of SWDS.

Cabinet of Ministers of Ukraine has adopted "Program on municipal solid waste management" in Ukraine to provide state-of-the-art level of waste collection, removing, recovery, neutralization and burial, as well as environmental protection measures.

8.2.2 Methodological Issues

First Order Decay (FOD) method (Tier 2 approach) for methane emission estimation from SWDS was used in the current inventory instead of Tier 1 in the previous inventory [1]. The necessity of FOD method application is stipulated by inclusion of this category to the key source categories in the previous inventory.

FOD method gives the possibility to estimate annual methane emissions from waste disposed in current and previous years [1].

8.2.2.1 Activity data

The methane generation rate constant k that appears in the FOD method is related to the time taken for the DOC in waste to decay to half its initial mass (the "half life") as follows [1]:

$$k = \frac{\ln 2}{t^{\frac{1}{2}}}.$$

No data on the methane generation rate constant k were available in Ukraine; hence the default value of 0.05, i.e. «half life» - 14 years, was used [1].

The FOD method requires historical data on waste generation and management practices. It is usually necessary to include data for 3 to 5 half lives in order to achieve an acceptably accurate result [1]. In our circumstances data for 42 years (3 "half life") is required. Therefore inventory team developed time series of MSW since 1948.

Developing a consistent time series of MSW landfilled was of primary importance, because statistical data from the State Committee on Public Service of Ukraine covered only the period 1999-2004. Data on the previous years was not kept in the archives according to the information from the State Committee on Statistics of Ukraine.

Statistical data on urban population from the State Committee on Statistics of Ukraine [2, 3], specific normatives of MSW generation rates for urban population published in the different years [4, 5, 6, 7, 8] and fraction of waste landfilled were used to form consistent time series in 1948-2004. In Ukraine there is no organized waste collection or disposal takes place in rural areas, so inventory team have taken into account only urban population [12].

MSW generation rates for the period 1948-2004 were estimated by taking average values for well and badly organized domestic building from handbooks [4, 5, 6, 7, 8, 9]:

- in 1966 – 200 kg/cap/year;
- in 1977 – 224.5 kg/cap/year;
- in 1989 – 285 kg/cap/year;
- in 1996 – 297.5 kg/cap/year;
- in 2004 – 333 kg/cap/year.

Linear interpolation was used for estimation of MSW generation rates for the omitted years to take into account gradual increase of MSW generation rates from year to year [4] and to avoid discontinuous changes from period to period.

The period from 1991 to 2000 was exceptional due to the economic crisis and GDP drop. MSW generation rates for this period were brought in line with GDP changes according to the expert recommendations. It was preliminary assumed that the minimal value was reached in 1994 and was estimated in accordance with the difference in GDP between 2001 and 1994, i.e. waste amount in 2001, which was equal to 9167.5 thous. t (statistical data of the State Committee on Public Service of Ukraine), was divided to 1.45. According to this approach waste production was estimated at the level 6322 thous. t in 1994, and MSW generation rate – 200.1 kg/cap/year. Calculation methodology and corrected values are presented at the Table 8.1.

MSW volumes, which were landfilled in each year, were estimated according to MSW volumes, which were removed to landfills. Fraction of MSW removed to landfills in 1948-1988 was assumed as 85% [7] with further increase to 90% in 1990, which was calculated as average value on the basis of calculated data on waste production and data on actual (the State Committee on Public Service of Ukraine) waste removing in 2003-2004 (density of MSW – 250 kg/m^3 [7]). Remaining 10-15 % of waste accumulated on unmanaged landfills and incinerated. According to the expert judgement half of this waste was decomposed in the shallow-unmanaged SWDS [1].

Table 8.1. Correction of activity data on MSW in 1991-2000

Years	Statistical data on MSW removing, thous.t	Estimated values of MSW production, thous.t	Estimated MSW generation rate, kg/cap/year	Estimated minimum		Corrected values	
				MSW production, thous.t	Norms of MSW generation rate, kg/ cap/year	Norms of MSW generation rate, kg/ cap/year	MSW production, thous.t
2004	9782.5	9593.2	333.0			No changes	
2003	9412.5	9505.9	328.6				
2002	8097.5	9430.6	324.1				
2001	9167.5	9372.3	319.7				
2000	7445.0	9349.2	315.2		Linear interpolation	302.7	8990.2
1999	6577.5	9325.8	310.8			285.6	8559.4
1998	Not available	9202.9	306.4			268.5	8143.6
1997	– " –	9252.5	301.9			251.4	7692.8
1996	– " –	9207.3	297.5			234.3	7253.9
1995	– " –	9253.2	295.7			217.2	6802.7
1994	– " –	9290.1	293.9	6322	200.1	200.1	6321.2
1993	– " –	9307.8	292.1		Linear interpolation	221.8	7066.5
1992	– " –	9269.3	290.4			243.5	7779.8
1991	– " –	9167.1	288.6			265.2	8425.4
1990	– " –	9055.7	286.8			No changes	

8.2.2.2 Emission factors

Methane correction factor (MCF). MCF estimation is very important, because it accounts for conditions of waste management and organic matter decomposition (aerobic or anaerobic). GHG emissions significantly depend upon MCF.

The range of 0.4-1 is recommended for MCF according to the Good Practice Guidance [1]. SWDS may be managed and unmanaged. Managed SWDS must have controlled placement of waste and will include at least one of the following: cover material, mechanical compacting or leveling of the waste. It is assumed that organic matter decomposes in anaerobic conditions and released methane is recovered.

All SWDS are unmanaged in Ukraine in accordance of information from the State Committee on Public Service of Ukraine and requirements of the Good Practice Guidance [1].

Division of landfills on categories was made more accurate in the current inventory. 80% of deep SWDS (≥5 m) and 20% of shallow SWDS were assumed according to [10] and corrected by the expert judgement.

Such division was assumed for the period 1990-2004 in the current inventory. Default values of 0.8 and 0.4 for deep and shallow SWDS correspondingly. Besides the value of 0.4 was used for unmanaged SWDS. The value of 0.6 (uncategorized SWDS [1]) was assumed for the period 1948-1989 due to the lack of information for this period.

Degradable organic carbon (DOC). Degradable organic carbon is the organic carbon that is accessible to biochemical decomposition. It is based on the composition of waste and can be calculated from a weighted average of the carbon content of various components of the waste stream.

DOC was estimated according to [1] for the period 1948-2004. Composition of waste for this period was obtained from handbooks [4, 5, 6, 7, 9]. Linear interpolation was used for estimation of DOC for the omitted years to avoid discontinuous changes from period to period. All information on waste composition for the period 1948-2004 is given in Annex 3, Table A3.3.1.

Figure 8.1 presents DOC trends in 1948-2004.

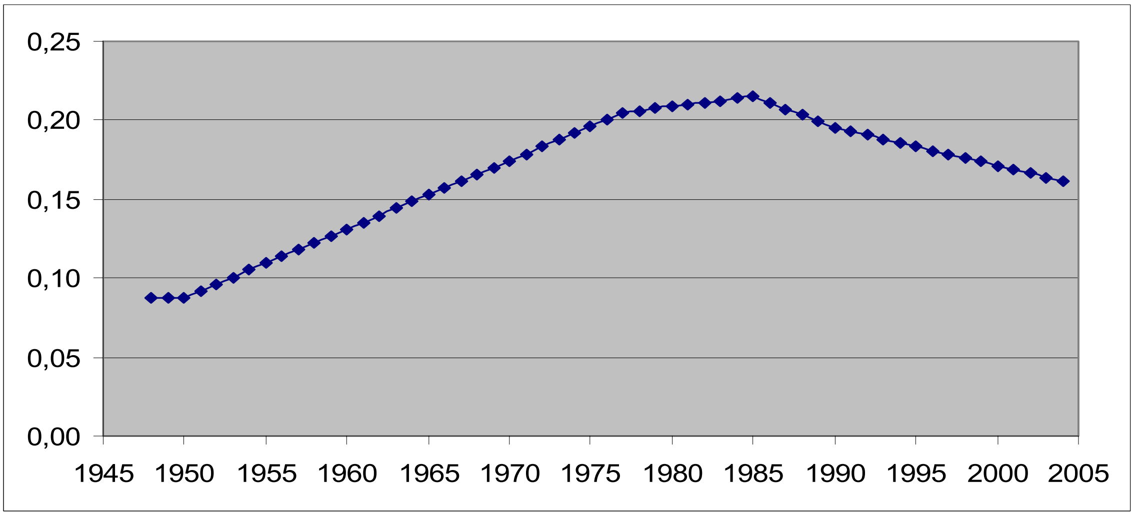

Figure 8.1. DOC trends in 1948-2004, thous.t

Fraction of degradable organic carbon dissimilated (DOCF). DOCF is an estimate of the fraction of carbon that is ultimately degraded and released from SWDS, and reflects the fact that some organic carbon does not degrade, or degrades very slowly, when deposited in SWDS.

The average default value of 0.55 was used in the current inventory [1].

Fraction of CH_4 in landfill gas (F). The default value of 0.5 was used in the current inventory [1].

Methane recovery (R). Methane from landfills is recovered only in Lugansk region in Ukraine according to the information from data of the State Committee on Public Service of Ukraine. Data from Regional Lugansk Department of Ecology and Resources was used for the calculations. Recovered methane is burned in a flare.

Oxidation factor (OX). The oxidation factor (OX) reflects the amount of CH_4 from SWDS that is oxidized in the soil or other material covering the waste. Default value of 0 was used, because information on the oxidation factor in Ukraine is lacked [1].

8.2.3 Uncertainty assessment and developing a consistent time series

The uncertainty range for the first three indicators was assessed from the expert judgement. For other indicators default uncertainty range was assumed [1] (Table 8.2).

Table 8.2. Comparison of calculated data with statistical data from the State Committee on Public Service of Ukraine

Indicator	Uncertainty range *
Urban population in Ukraine	-5%, +5%
MSW generation rate	-12%, +12%
Fraction of MSW sent to SWDS	-35%, +0%
Degradable organic carbon, DOC	-50%, +20%
Fraction of degradable organic carbon dissimilated, DOCf	-9%, +9%
Methane correction factor, MCF	-50%, +60%
Fraction of CH_4 in landfill gas, F	-0%, +20%
Methane recovery, R	-5%, +5%
Oxidation factor, OX	Not included/NA

Methane generation rate constant, k	-40%, +300%

The overall uncertainty of 303% was estimated in this category.

8.2.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions from SWDS. Expert review of emission levels and the following detailed QA/QC procedures were carried out, because this category was included to key emission sources:

- Comparison of data obtained from the different sources;
- Comparison of emissions calculated by the different IPCC methodologies;
- Analysis of time series of emissions and activity data;
- Comparison of activity data, emission factors and calculated emissions with inventories in other countries.

The comparison of calculated data on MSW generation with statistical data from the State Committee on Public Service of Ukraine in 1999-2004 and [11] - in 1990 (Table 8.3) was carried out.

First Order Decay method for methane emission estimation from SWDS was used in the current inventory. Default IPCC methodology was applied to check calculations.

Table 8.4 presents the comparison of results.

Table 8.3. Comparison of calculated data with statistical data from the State Committee on Public Service of Ukraine

	1990	1999	2000	2001	2002	2003	2004
MSW sent to SWDS according to the data of the State Committee on Public Service of Ukraine, mln m^3	----	26.31	29.78	36.67	32.39	37.65	39.13
MSW sent to SWDS according to the data of the State Committee on Public Service of Ukraine excluding 1990 [11], thous. t	10120.0	6577.5	7445	9167.5	8097.5	9412.5	9782.5
Calculated value for MSW sent to SWDS in Ukraine, thous. t	9055.7	8559.4	8990.2	9372.3	9430.6	9505.9	9593.2
Difference, %	-11	30	21	2	16	1	-2

Table 8.4. Comparison of emission calculations by the different methodologies, thous. t

Emission	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
FOD method	224.60	236.19	244.55	250.94	255.32	257.67	260.18	263.595	267.83	272.84	277.44	282.6	288.42	293.7	297.90
Default method	492.9	435.62	401.95	365.4	327.03	332.93	355.22	377.38	398.95	396.47	415.32	433.6	436.31	413.6	417.43

Figure 8.2 presents trends of emission calculations by the different methodologies.

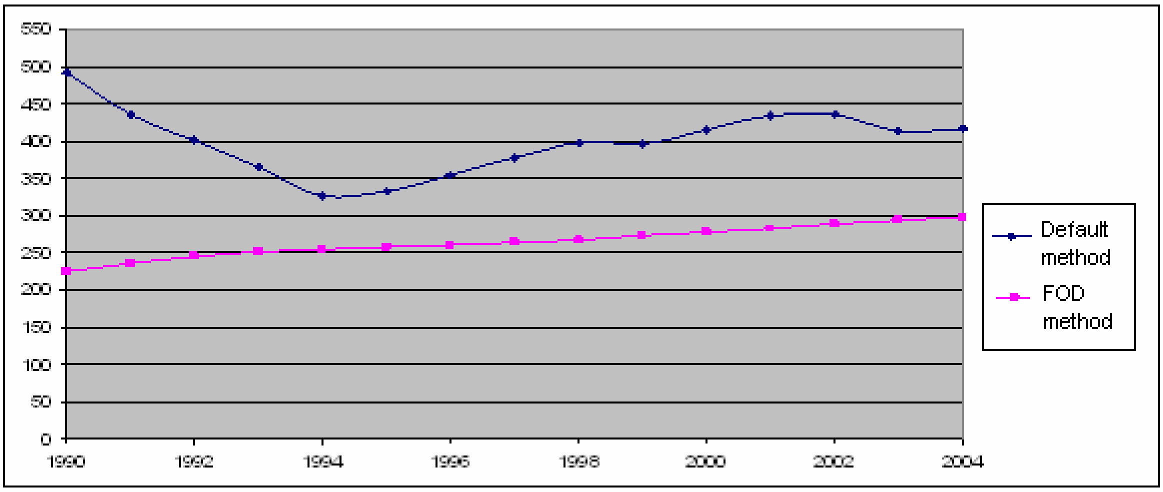

Figure 8.2. CH_4 emissions from SWDS in Ukraine calculated by the different methodologies, thous. t

Methane emission trends calculated by the default methodology correspond to the GDP trends 1990-2004, while emissions calculated by the FOD method are gradually increased. Such behavior is explained by peculiarities of the methods. Figure 8.3 presents DOC trends in 1948-2004.

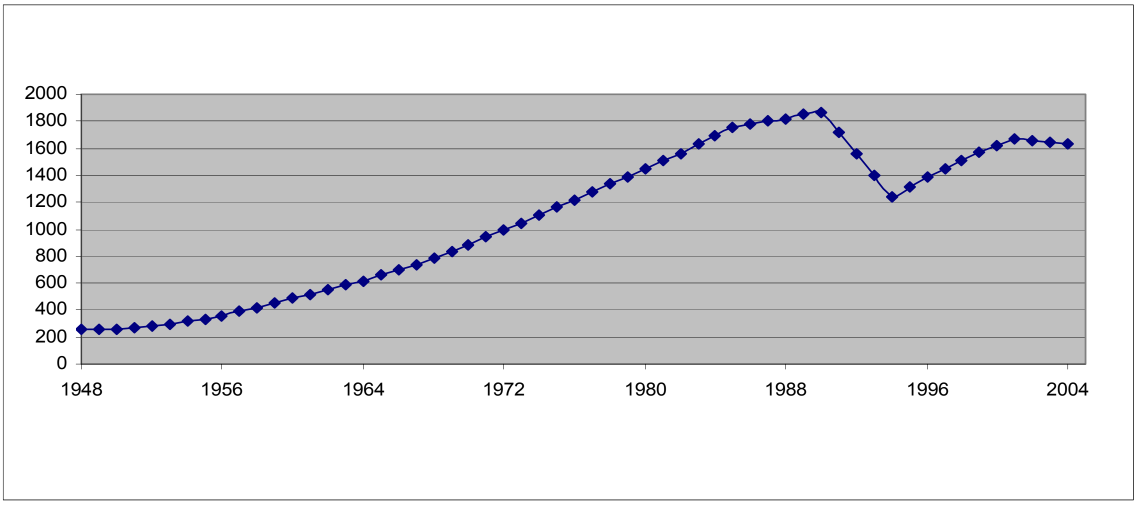

Figure 8.3. Degradable organic carbon at the SWDS in 1948-2004, thous. t

Default methodology assumes that waste disposed at the SWDS is fully decomposed during the current year. Emissions, calculated by this methodology, recurred the trends at the Figure 8.3 for the period 1990-2004. FOD method use cumulative amount of waste for the each year of the considered period (42 years) [1]. Emissions, calculated by this methodology, recurred the trends at the Figure 8.2 for the period 1948-1990 due to the inertness of the method.

FOD method more correctly reflects physical processes of methane emission production at the SWDS and is preferable [1].

The FOD method produces a time-dependent emission profile that better reflects the true pattern of the degradation process over time, whereas the default method is based on the assumption that all potential CH_4 is released in the year the waste is disposed of. The default method will give a reasonable annual estimate of actual emissions if the amount and composition of deposited waste have been constant or slowly varying over a period of several decades. But the amount or composition of waste disposed of at SWDS is changing rapidly over time in Ukraine, so the IPCC default method overestimates emissions.

8.2.5 Recalculations

Data on waste disposed at the SWDS and division by categories of SWDS were made more accurate in comparison to the previous inventory, which led to the decrease of MCF.

DOC value of 0.17 was used in the previous inventory due to the lack of information about waste composition (paper, textile, food waste etc.). DOC value was specified in the current inventory on the basis of data on waste composition [4, 5, 6, 7, 9].

DOC_F value of 0.77 [1] was used in the previous inventory, that led to the overestimation of emissions, so DOC_F value of 0.55 [1] was used in the current inventory. This level is recommended in the case when lignin C is included in the DOC value.

Methane recovery at the SWDS in Lugansk region was taken account in the current inventory.

The Table 8.5 presents comparison of inventory results in this category in 2005 and 2006.

Table 8.5. Comparison of estimation of methane emissions from SWDS in Ukraine, thous.t

Emissions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Inventory submitted in 2005														
CH_4 emis-	677,8	683,6	697,3	689,5	689,5	689,5	677,8	671,9	668,1	508,8	575,8	728,2	626,2	727,9

sion														
Inventory submitted in 2006														
CH_4 emission	224,60	236,19	244,55	250,94	255,32	257,67	260,18	263,59	267,83	272,84	277,44	282,6	288,42	293,7
Difference, %	-67	-65	-65	-64	-63	-63	-62	-61	-60	-46	-52	-61	-54	-60

8.2.6 Planned improvements

The following improvements would be planned:

- Determining national factors for k and MCF;
- Specifying waste composition;
- Improving national data on DOC by testing some SWDS;
- Determining national factor for DOC_F, which should be well documented;
- Improving national data on OX by testing some SWDS.

8.3 Wastewater Handling (category 6.B CRF)

The following emission sources were considered in this category:

- methane emissions from domestic wastewater;
- methane emissions from industrial wastewater;
- nitrous oxide emissions from human sewage.

8.3.1 Methane emissions from domestic wastewater (category 6.B.2.1. CRF)

8.3.1.1 Overview of emission source subcategory

Handling of domestic wastewater under anaerobic conditions produces CH_4.

Methane emissions from domestic wastewater made to 71.89 thous. t in 1990, then increased to 76.55 thous. t – in 1996 and further decreased to 71.98 thous. t - in 2004 due to the reduction of recovered methane.

8.3.1.2 Methodological Issues

Methane emissions domestic wastewater handling is a function of the amount of waste generated and an emission factor that characterizes the extent to which this waste generates CH_4. They were estimated according to the equation (5.5) from [1].

Activity data. The total amount of organic matter was estimated according to [1] on the basis of data on urban population from the State Committee on Statistics of Ukraine and recommended level of 0.05 kg/cap/year for BOD_5 generation in the domestic wastewater [1] (Table 6.5, chapter 6.3.2. [12]). National experts justified the validity of this default value to the Ukrainian circumstances.

According to the data of the State Committee on Public Service of Ukraine approximately 50% of settleable solids are decomposed under anaerobic conditions in Ukraine. Fraction of settleable solids was assumed at the level of 28% from the total amount of organic matter in the treated domestic wastewater according to [13-16]. The fraction of activated sludge in the remaining 72 % of organic matter equals to 17.6 % [13-16]. Inventory team also has taken into account methane recovery from domestic wastewater handling, which has totaled to 6.24 thous. t in 1990 [11] and 0.013 thous. t in 2004 (information from the State Committee on Public Service of

Ukraine). Such decrease was caused by the reduction of quantity of methanetanks in Ukraine from 126 to 12.

Emission factors. Default maximum methane producing capacity of 0.6 kg CH /kg BOD was assumed according to [1]. Default weighted average of methane emission factors (MCF) of 0.088 was assumed for activated sludge and 0.5 – for settleable solids [13-16]. The MCF is an estimate of the fraction of BOD that will ultimately degrade anaerobically.

8.3.1.3 Uncertainty assessment and developing a consistent time series

Default ranges of uncertainty of uncertainty of data on urban population and maximum methane producing capacity were used [1]. Uncertainty ranges for other indicators were obtained from expert judgement (Table 8.6).

Table 8.6. Uncertainty ranges

Indicator	Uncertainty ranges
Human population	-5%, +5%
BOD/person	-0%, +2,6%
Maximum methane producing capacity (B_o)	-30%, +30%
Fraction of sludge in the wastewater	-1%, +1%
Fraction treated anaerobically	-12%, +6%

The overall uncertainty of emission estimations totaled to 32% in this category.

8.3.1.4 QA/QC procedures

Expert review of emission estimations and the following QC procedures were carried out:

- Comparison of MCF values, which were used in the current inventory, with those in other countries;
- Analysis of time series;
- Comparison of data from different sources;
- Comparison of activity data, emission factors and emission estimations with those in other countries.

8.3.1.5 Recalculations

Data on urban population were made more accurate according to the letter from the State Committee on Statistics of Ukraine. Time series on BOD_5 amounts were recalculated from 1990. BOD_5 amount was divided to wastewater (72%) and sludge (28%). Fractions of BOD_5 treated anaerobically of 50% and 8.8% were used for settleable solids and activated sludge. The Table 8.7 presents comparison of inventory results in this category in 2005 and 2006.

Table 8.7. Comparison of estimation of methane emissions from domestic wastewater handling in Ukraine, thous.t

Emission	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Inventory submitted in 2005														
CH_4 e-missions	304.85	307.48	313.61	310.1	310.1	310.1	304.85	302.22	300.47	297.81	291.71	288.2	285.58	282.95

Inventory submitted in 2006														
CH_4 e-missions	71.89	73.39	74.82	75.70	76.11	76.36	76.55	75.79	75.02	74.21	73.36	72.52	71.98	71.57
Differ-ence, %	-76.42	-76.13	-76.14	75.59	-75.46	-75.38	-74.89	-74.92	-75.03	-75.08	-74.85	-74.84	-74.80	-74.71

8.3.1.6 Planned improvements

Any improvements in this category are not planned.

8.3.2 Greenhouse Gas Emissions from industrial wastewater handling (category 6.B.1 CRF)

8.3.2.1 Overview of emission source subcategory

Shrinkage of industrial production led to the reduction of methane emissions from industrial wastewater handling. These emissions amounted to 4.28 thous. t in 1990 with further decrease to 1.19 thous.t in 2004.

8.3.2.2 Methodological Issues

Methane emissions from industrial wastewater handling were estimated according to the algorithm (5.4) on the basis of equation (5.5) from [1]. Industrial wastewater sources with high COD level in untreated wastewater were characterized as follows [14]:

- ferrous metallurgy;
- non-ferrous metallurgy;
- oil refining;
- fertilizer manufacture;
- food and drink production;
- paper and pulp manufacture;
- textile manufacture;
- others.

Biological methods of wastewater treatment (including anaerobic decomposition) are not applied for ferrous and non-ferrous metallurgy. Only own domestic wastewater (from toilets, wash sinks, shower-baths, overalls washing and dining rooms) are treated at the own equipment of biological handling. Some technological wastewater, e.g. from laboratories, departments of goods production for the population) also may be got into these wastewater. Mainly metal oxides and products of their interreaction (silicide, carbides etc.) are contained in the wastewater associated with the main technological process. This wastewater is not undergone anaerobic processes and does not emit methane. Organic matter, which produces methane emissions, is contained in own domestic wastewater.

Wastewater from pulp and paper manufacture, textile and petrochemical industries are treated by the biological methods, practically all of these methods are anaerobic. All industrial and own domestic wastewater are treated in such manner. Anaerobic processes occur at the stage of settleable solids and activated sludge storage. The similar treatment technology is applied for fertilizer manufacture; food and drink production and others.

Activity data. Wastewater volumes for the different industries which were locally treated were taken from the State Committee on Water Management of Ukraine (2-tp statistical reporting form). COD levels in wastewater were estimated from the data on BOD in wastewater before handling [11] and COD/BOD ratio of 1.7 [12]. Fraction of settleable solids was assumed at the level of 28% from the total amount of organic matter in the treated wastewater according to [13-16]. The fraction of activated sludge in the remaining 72 % of organic matter equals to 17.6 % [13-16].

Methane recovery in methanetanks was not executed according to the information of Regional Departments of Ecology and Resources.

Emission factors. Default maximum methane producing capacity of 0.25 kg CH /kg COD was assumed according to [1]. Default weighted average of methane emission factors (MCF) of 0.088 was assumed for activated sludge and 0.5 – for settleable solids [13-16]. The MCF is an estimate of the fraction of COD that will ultimately degrade anaerobically.

8.3.2.3 Uncertainty assessment and developing a consistent time series

Default range of uncertainty of maximum methane producing capacity was used [1]. Uncertainty ranges for other indicators were obtained from expert judgement (Table 8.8).

Table 8.8. Uncertainty ranges

Indicator	Uncertainty range
Wastewater volumes, m^3	-15%, +15%
COD/ m^3	-15%, +15%
Maximum methane producing capacity (B_o)	-30%, +30%
Fraction of sludge in the wastewater	-1%, +1%
Fraction treated anaerobically	-12%, +6%

The overall uncertainty of emission estimations totaled to 38% in this category.

8.3.2.4 QA/QC procedures

The following QC procedures were carried out:

- Comparison of MCF values, which were used in the current inventory, with those in other countries;
- Analysis of time series.

8.3.2.5 Recalculations

Data on COD levels in the wastewater before treatment were made more. COD amount was divided to wastewater (72%) and sludge (28%). Fractions of BOD_5 treated anaerobically of 50% and 8.8% were used for settleable solids and activated sludge. The Table 8.9 presents comparison of inventory results in this category in 2005 and 2006.

Table 8.9. Comparison of estimation of methane emissions from industrial wastewater handling in Ukraine, thous.t

Emission	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Inventory submitted in 2005														
CH_4 emissions	10.49	9.41	8.39	7.65	6.07	5.22	3.99	4.24	3.94	3.39	3.43	3.49	3.4	3.1

Inventory submitted in 2006														
CH_4 e-missions	4.28	3.99	3.46	3.24	2.95	2.69	2.33	2.08	1.62	1.37	1.12	1.39	1.17	1.27
Differ-ence, %	-59.2	-57.6	-58.7	-57.6	-51.3	-48.5	-41.6	-50.9	-59.0	-59.7	-67.4	-60.1	-65.7	-59.1

8.3.2.6 Planned improvements

The following improvements are planned in this category:

- Specifying COD levels in industrial wastewater before treatment;
- Improving value of fraction treated anaerobically.

8.3.3 Nitrous Oxide Gas Emissions from Human Sewage (category 6.B.2.2 CRF)

8.3.3.1 Overview of emission source subcategory

Annual per capita protein intake made to 105.3 g/cap/day in 1990 and further gradually decreased to 79.7 g/cap/day in 2004 according to the data of the State Committee on Statistics of Ukraine. Population of Ukraine was reduced by 9% in this period. Therefore nitrous oxide emissions have decreased in 1.5 times and totaled 3.46 thous. t in 2004.

8.3.3.2 Methodological Issues

The emissions of N_2O from human sewage are calculated as follows [1]:

N_2O Emissions = Annual per capita protein intake x fraction of nitrogen in protein x number of people in country x emission factor.

Data on annual per capita protein intakes and population in 1990-2004 were obtained from the State Committee on Statistics of Ukraine.

Default value of 0.16 kg N / kg protein was assumed for the fraction of nitrogen in protein according to item 4.8.1.6, page 4.82 [1]. Default value of 0,01 kg N_2O- kg N was assumed for the emission factor according to the Table 4.18, page 4.80 [1].

8.3.3.3 Uncertainty assessment and developing a consistent time series

Default range of uncertainty [1] of all indicators was used (Table 8.10).

Table 8.10. Uncertainty ranges

Indicator	Uncertainty range
Population	-5%, +5%
Annual per capita protein intake	-5%, +5%
Emission factor, item 4.8.1.6, page 4.82 [1]	-50%, +50%

The overall uncertainty of emission estimations totaled to 50.5% in this category.

8.3.3.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions from human sewage.

8.3.3.5 Recalculations

Data on population were made more accurate according to the letter from the State Committee on Statistics of Ukraine. Time series were recalculated from 1990. The Table 8.11 presents comparison of inventory results in this category in 2005 and 2006.

Table 8.11. Comparison of estimation of methane emissions from human sewage in Ukraine, thous.t

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Inventory submitted in 2005														
N_2O emissions, thous.t	5.02	4.69	4.34	4.17	4.02	3.63	3.57	3.49	3.45	3.33	3.57	3.38	3.46	3.39
Inventory submitted in 2006														
N_2O emissions, thous.t	5.02	4.7	4.35	4.17	3.89	3.65	3.51	3.43	3.38	3.28	3.31	3.36	3.48	3.39
Difference, %	0.0	0.0	0.2	0.0	-3.3	0.5	-1.7	-1.7	-2.1	-1.5	-7.9	-0.6	0.6	0.0

8.3.3.6 Planned improvements

Any improvements in this category are not planned.

8.4 Waste Incineration (category 6.C. CRF)

8.4.1 Overview of Source Category

Four waste incineration plants (Charkov, Sevastopol, Dnepropetrovsk and Kyiv) have operated in Ukraine in 1990. Now only two waste incineration plants are functioning in Ukraine (Dnepropetrovsk and Kyiv). These plants are mounted with equipment which does not meet the recent normative requirements, and pollutes the environment.

CO_2 emissions from waste incineration amounted to 298.8 thous.t in 1990 and 140.9 thous.t in 2004. N_2O emissions from waste incineration amounted to 0.019 thous.t in 1990 and 0.009 thous.t in 2004.

Waste is incinerated in facilities with heat recovery capabilities at the all waste incineration plants in Ukraine, so GHG emissions from waste incineration were taken into account in Energy sector (CO_2 emissions from stationary fuel combustion) according to [1].

8.4.2 Methodological Issues

Incineration of waste produces emissions of CO_2, CH_4 and N_2O. Emissions of CH_4 are not likely to be significant. Only the fossil based portion should be considered for estimation of CO_2 emissions from incineration of waste according to [12]. CO_2 and N_2O emissions were estimated according to the equations from [1].

Activity data. Amounts of incinerated waste by type in 1990-2004 were obtained directly from the waste incineration plants (WIPs) in Dnepropetrovsk and Kyiv. Information evidenced that mainly MSW with small portion of clinical waste were incinerated in Ukraine Boilers Dukla produced in Chech republic are used for the waste incineration [11]. WIP in Charkov operated up to 2001, in Sevastopol up to 1998 according to the information from the Regional Departments of Ecology and Resources. Activity data from these plants are lost. Amount of incinerated waste at these plants were estimated from the following assumptions: load of plant in Charkov was the same as in Kyiv with correction to 3 functioning boilers instead of 4 in Kyiv; plant in Sevastopol operated at 25% level of design power.

Emission factors. Default CO_2 emission factor of 5.6 was used from the table 5.6 [1].

Fraction of carbon content in waste was assumed 40%, fraction of fossil carbon in waste – 40%, burn out efficiency of combustion of incinerators -95%. N_2O emission factors depend upon the type of incineration plant equipment and type of waste. The average value of 35.75 kg N_2O/ t waste from the recommended range for hearth or grate plants 5.5-66 kg N_2O/ t waste was used (Table 5.7 [1]).

8.4.3 Uncertainty assessment and developing a consistent time series

Default range of uncertainty [1] of all indicators was used (Table 8.12).

Table 8.12. Uncertainty ranges

Indicator	Uncertainty range*
Amount of incinerated waste, IW	-5%, +5%
Default N_2O emission factors	-50%, +50%
Default CO_2 emission factors	-50%, +50%

The overall uncertainty of emission estimations totaled to 50.3% for N_2O emissions and 86.7 % for CO_2 emissions.

8.4.4 QA/QC procedures

The general QC procedures were used for estimation of GHG emissions from waste incineration.

8.4.5 Recalculations

Improved data on volumes of waste incineration and its composition were used in the current inventory. Only organic carbon was taken into account for estimation of carbon dioxide emissions.

The Table 8.13 presents comparison of inventory results in 2005 and 2006.

Table 8.13. Comparison of estimation of NMVOCs emissions from food and drink production in Ukraine, thous.t

Value	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Inventory submitted in 2005														
CO_2 emissions	311.8	314.5	320.8	317.2	317.2	317.2	311.8	309.1	307.3	234.1	264.9	326.2	288.1	334.9
Inventory submitted in 2005														
CO_2 emissions	298.9	275.6	330.1	343.8	341.4	284.3	254.5	259.3	228.9	207.3	189.9	226.5	153.4	138.4
Difference, %	-4.14	-12.35	2.92	8.41	7.65	-10.36	-18.38	-16.10	-25.52	-11.43	-28.32	-30.55	-46.74	-58.66
Inventory submitted in 2005														

Value	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
N_2O emission	0.06	0.06	0.06	0.06	0.06	1.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Inventory submitted in 2006														
Emission N_2O	0.019	0.018	0.021	0.022	0.022	0.018	0.016	0.017	0.015	0.013	0.012	0.015	0.010	0.009
N_2O emission	-68.08	-70.56	-64.74	-63.28	-63.53	-98.28	-72.82	-72.30	-75.55	-77.86	-79.72	-75.81	-83.61	-85.21

8.4.6 Planned improvements

Any improvements are not planned in this category.

9 OTHER (SECTOR CRF 7)

Any GHG emissions were not considered in this sector in Ukraine.

10 RECALCULATIONS AND IMPROVEMENTS

GHG emissions and removals in 1990-2004 were recalculated for the majority of categories in the current inventory. These recalculations were caused by the following reasons:

- Inclusion of new sources compared with the previous inventory;
- Improvement of methodologies (use Tier 2 approach instead of Tier 1; use of Good Practice Guidance for LULUCF (2003) etc.);
- Refining activity data;
- Refining GHG emission factors GHG (including development of national emission factors for key source categories);
- Carrying over GHG emissions from the one category to another (e. g., emissions from coke combustion in blast furnaces were transferred from energy sector to industrial processes, emissions from waste incineration from waste sector to the energy sector);
- Inclusion of perfluorocarbon emissions from aluminium production.

The same approaches and methodologies were used for the whole time period. The comments of in-depth review of the previous inventory conducted by the UNFCCC Secretariat experts in Kyiv (September 19-23, 2005) were taken into account (http://unfccc.int/resource/docs/2005/arr/ukr.pdf), as well as Adjustment Exercise. Besides, suggestions of national experts were also taken into consideration.

Table10.1 and Figure10.1 present comparison of direct GHG emissions in the previous and current inventories.

Table10.2 contains brief description of reasons for recalculations. Detailed description is provided in the relevant chapters 3-9 of the current NIR.

Table 10.1. Direct GHG emissions trends in Ukraine, mln t CO_2-eq.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Inventory submitted in 2005	940.0	925.9	814.1	734.4	589.0	556.6	515.6	477.5	416.6	405.4	406.0	428.6	433.3	471.3
Inventory submitted in 2006	891.5	773.2	680.8	609.9	535.9	478.7	424.3	404.5	357.6	364.5	357.1	357.0	363.2	376.8
Difference, %	-5.2	-16.5	-16.4	-17.0	-9.0	-14.0	-17.7	-15.3	-14.2	-10.1	-12.1	-16.7	-16.2	-20.1

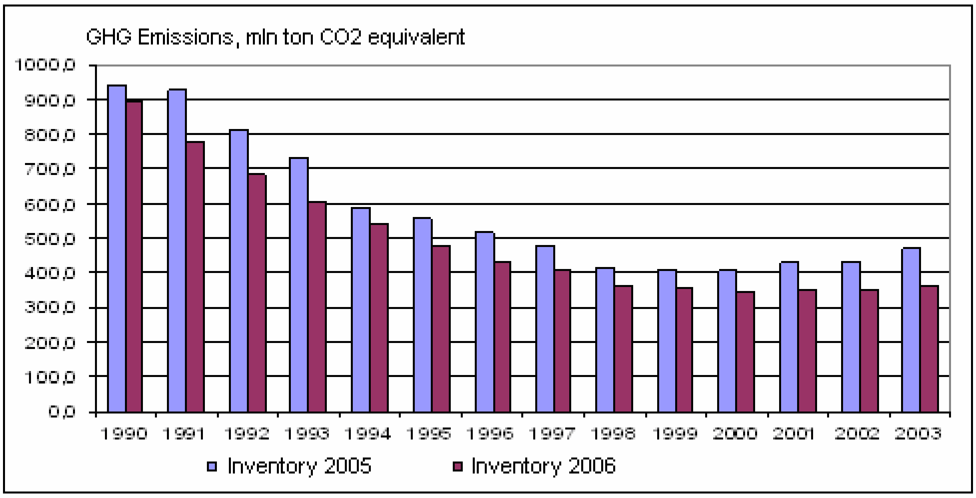

Figure 10.1. Direct GHG emissions trends in Ukraine

Table 10.2. Recalculations of GHG emissions in Ukraine

№ CRF Category	Name of the category	GHG	Emission/ removal change in 2003, Gg	Emission/ removal change in 2003, %	Approach used in Inventory submitted in 2005*	Approach used in Inventory submitted in 2006*	Brief description of reasons
1.A.1.a	Public Electricity and Heat Production	CO_2	7 067	7.9	T1	T1	1. Emissions from fuel combustion by transport have been transferred to the category 1.A.3; 2. National CO_2 emission factors for steam coal were used; 3. Specific net calorific values of fuels defined more accurately from 11-MTP statistical reporting form; 4. National fraction of carbon oxidized for coal in the category Public Electricity and Heat Production (category 1.A.1.a CRF) were used.
1.A.1.b	Petroleum Refining	CO_2	-17	-0.7	T1	T1	
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries	CO_2	-1 709	-16.0	T1	T1	
1.A.2.a	Iron and Steel	CO_2	-45 235	-68.3	T1	T1	1. Coke use in blast furnaces transport have been transferred to the sector «Industrial processes» 2. Emissions from fuel combustion by transport have been transferred to the category 1.A.3; 3. Specific net calorific values of fuels defined more accurately from 11-MTP statistical reporting form; 4. National CO_2 emission factors for steam coal were used
1.A.2.b	Non-Ferrous Metallurgy	CO_2	-19	-1.3	T1	T1	
1.A.2.c	Chemical Industry	CO_2	-144	-3.1	T1	T1	
1.A.2.d	Pulp, Paper and Print	CO_2	-35	-7.2	T1	T1	
1.A.2.e	Food Processing, Beverages and Tobacco	CO_2	-772	-11.9	T1	T1	
1.A.2.f	Other Manufacturing Industry and Construction	CO_2	-2 533	-16.9	T1	T1	
1.A.3.a	Civil Aviation	CO_2	-9	-3.4	T1	T1	Fuel used for non-aviation purposes (heating, activity in the airports etc.) were transferred to the 1.A.5
1.A.3.b	Road Transportation	CO_2	18 241	1308.5	T1	T1	1. Emissions from private cars were included 2. Emissions from road transportation from cars of enterprises which were not considered as transport enterprises, were included 3. Fuel used for non-motor drive purposes (heating, in-house needs.) were transferred to the 1.A.5 4. Specific net calorific values of fuels defined more accurately from 11-MTP statistical reporting form
1.A.3.c	Railways	CO_2	-641	-42.9	T1	T1	1. Fuel used for non-motor drive purposes (heating, in-house needs.) were transferred to the 1.A.5 2. Fuel used for road and off-road transportation were transferred to the

№ CRF Category	Name of the category	GHG	Emission/ removal change in 2003, Gg	Emission/ removal change in 2003, %	Approach used in Inventory submitted in 2005*	Approach used in Inventory submitted in 2006*	Brief description of reasons
							categories 1.A.3.b and 1.A.3.e respectively 3. Specific net calorific values of fuels defined more accurately from 11-MTP statistical reporting form
1.A.3.d	Navigation	CO_2	-244	-51.1	T1	T1	1 International bunkers were taken into account 2 Specific net calorific values of fuels defined more accurately from 11-MTP statistical reporting form 3 Fuel used for non-motor drive purposes (heating, in-house needs, activity in the ports etc.) were transferred to the 1.A.5 4 Fuel used for road and off-road transportation were transferred to the categories 1.A.3.b and 1.A.3.e respectively
1.A.3.e	Other Transportation	CO_2	5 308	52.9	T1	T1	1 Emissions from in-plant and off-road transportation were additionally estimated 2 Emissions from agricultural machines were additionally estimated 3 Specific net calorific values of fuels defined more accurately from 11-MTP statistical reporting form
1.A.4.a	Commercial/Institutional	CO_2	-743	-11.6	T1	T1	1 Fuel consumption for transportation and agricultural machines were transferred to the category 1.A.3 3 Specific net calorific values of fuels defined more accurately from 11-MTP statistical reporting form 4 National CO_2 emission factors for steam coal were used
1.A.4.b	Residential	CO_2	-8 440	-19.1	T1	T1	
1.A.4.c	Agriculture/Forestry/Fisheries	CO_2	-5 579	-83.5	T1	T1	
1.B.2.b.i	Production/Processing	CH_4	-1 350	-96.0	T1	T1	Default emission factors were used according to the Good Practice Guidance (chapter 3.3.2.2)
1.B.2.b.ii	Transport	CH_4	-3 271	-93.7	T1	T1	National emission factors were used (chapter 3.3.2.2)
1.B.2.b.ii	Distribution	CH_4	-1 176	-84.2	T1	T1	National emission factors were used (chapter 3.3.2.2)
1.B.2.b.iii	Other leakage	CH_4	600	-	T1	T1	Emissions in this category were not considered in the previous inventory. Emissions in this category were calculated with use of methodology and emission factors recommended by the IPCC Revised Guidelines (chapter 3.3.2.2)
2.A.1	Cement Production	CO_2	149.41	4.0	T2	T2	Emission factor was specified

№ CRF Category	Name of the category	GHG	Emission/ removal change in 2003, Gg	Emission/ removal change in 2003, %	Approach used in Inventory submitted in 2005*	Approach used in Inventory submitted in 2006*	Brief description of reasons
2.A.2	Lime Production	CO_2	822.58	20.4	T1	T1	Change in methodology (Use of the Good Practice Guidance)
2.A.3	Limestone and Dolomite Use	CO_2	-7 161.30	-	Not estimated	T1	Emissions in this category were not considered in the previous inventory.
2.A.4	Soda Ash Production and Use	CO_2	76.80	37.8	T1	T1	Export and import of soda ash were refined
2.B.1	Ammonia Production	CO_2	-4 390.06	-61.2	T1	T2	Emission factor was specified
2.B.4	Carbide Production	CO_2	-14.32	-152.7	T1	T1	Export and import of calcium carbide were refined
2.C.1	Iron and Steel Production	CO_2	-27 943.66	-93.0	T1	T2	National emission factors were used for CO_2 emission estimation from iron production, as well as coke use in blast furnaces transport have been included to this sector.
2.C.5	Ferroalloys and Aluminium Production	CO_2	-3 073.58	-	Not estimated	T1	Emissions in this category were not considered in the previous inventory.
2.B.4	Carbide Production	CH_4	0.418383	100.0	T1	Not estimated	Methane emissions in this category were not considered in the current inventory
2.B.5	Other	CH_4	11.87603	27.1	T1	T1	Activity data were refined
2.C.1	Iron and Steel Production	CH_4	-776.96	-	Not estimated	T1	Methane emissions from iron production and coke were estimated in the current inventory
2.B.2	Nitric Acid Production	N_2O	-706.279	-	Not estimated	T1	Emissions in this category were not considered in the previous inventory.
2.B.3	Adipic acid production	N_2O	-1061.68	-459.7	T1	T1	Methodology was made more accurate
2.C.5	Ferroalloys and Aluminium Production	PFCs	-	66.49	Not estimated	T1	Emissions in this category were not considered in the previous inventory
3.D.	Other	N_2O	344.1	-	-	T1	Emissions in this category were not considered in the previous inventory.
4.A.1	Cattle	CH_4	408.07	3.6	T1	T2	National emission factors were used, Data on livestock population in 1990-2001 were refined
4.A.3	Sheep	CH_4	0	0	T1	T1	Data on livestock population in 1990-2001 were refined
4.A.4	Goats	CH_4	0	0	T1	T1	Data on livestock population in 1990-2001 were refined

№ CRF Category	Name of the category	GHG	Emission/ removal change in 2003, Gg	Emission/ removal change in 2003, %	Approach used in Inventory submitted in 2005*	Approach used in Inventory submitted in 2006*	Brief description of reasons
4.A.6	Horses	CH_4	0	0	T1	T1	Data on livestock population in 1990-2001 were refined
4.A.8	Swine	CH_4	0	0	T1	T1	Data on livestock population in 1990-2001 were refined
4.B.1	Cattle	CH_4	-462.20	-55.8	T1	T2	National emission factors were used, Data on livestock population in 1990-2001 were refined
4.B.3	Sheep	CH_4	0	0	T1	T1	Data on livestock population in 1990-2001 were refined
4.B.4	Goats	CH_4	0	0	T1	T1	Data on livestock population in 1990-2001 were refined
4.B.6	Horses	CH_4	0	0	T1	T1	Data on livestock population in 1990-2001 were refined
4.B.8	Swine	CH_4	-486.07	-79.0	T1	T2	National emission factors were used, Data on livestock population in 1990-2001 were refined
4.B.9	Poultry	CH_4	-136.15	-58.4	T1	T2	National emission factors were used, Data on livestock population in 1990-2001 were refined
4.B.10	Anaerobic Lagoons	N_2O	-6.32	-94.5	T1	T2	National data on N excretion rate from waste management system were used. Data on livestock population in 1990-2001 were refined
4.B.12	Solid Storage	N_2O	563.43	19.9	T1	T2	National data on N excretion rate from waste management system were used. Data on livestock population in 1990-2001 were refined
4.B.13	Other (Aerobic Processing and other waste management systems)	N_2O	- 292.20	- 88.7	T1	T2	National data on N excretion rate from waste management system were used. Data on livestock population in 1990-2001 were refined Emissions from aerobic processing were included in addition
4.B.13	Other	N_2O	-312.40	-94.8	T1	T1	Data on livestock population in 1990-2001 were refined
4.C	Rice Cultivation	CH_4	0	0	T1	T1	Rice harvested areas were used instead if cultivated areas. Use of scaling factors for fermented organic fertilizers
4.D.1.1	Synthetic Fertilizers	N_2O	0	0	T1	T1	-
4.D.1.2	Animal Wastes Applied to Soils	N_2O	-2151.18	-59.9	T1a	T1a	National data on N excretion rate from waste management system were used. Data on livestock population in 1990-2001 were refined
4.D.1.3	N-fixing Crops	N_2O	-54.29	-14.4	T1b	T1b	Inclusion of forage crops, use of national data on nitrogen and dry matter fractions, as well as residue/crop ratio
4.D.1.4	Crop residues	N_2O	2201.87	184.1	CS	CS	National methodology, which allows more complete estimation of N applied to soils, was used.

№ CRF Category	Name of the category	GHG	Emission/ removal change in 2003, Gg	Emission/ removal change in 2003, %	Approach used in Inventory submitted in 2005*	Approach used in Inventory submitted in 2006*	Brief description of reasons
							The additional crops were considered.
4.D.1.5	Cultivation of Histosols	N_2O	0	-	Not estimated	T1	Emissions in this category were not considered in the previous inventory.
4.D.2	Animal manure at the pasture range and paddock	N_2O	1605.20	130.08	T1	T2	National data on N excretion rate from waste management system were used. Data on livestock population in 1990-2001 were refined
4.D.3.1	Atmospheric Deposition	N_2O	-415.27	-47.8	T1a	T1a	National data on N excretion rate from waste management system were used. Data on livestock population in 1990-2001 were refined
4.D.3.2	Nitrogen Leaching and Run-off	N_2O	-805.62	-21.45	T1a	T1a	National data on N excretion rate from waste management system were used. Data on livestock population in 1990-2001 were refined
6.A.	Solid Waste Disposal on Land	CH_4	-9118.2	-59.7	T1	T2	Activity data were refined, use of national data for refinement of emission factor.
6.B.1	Industrial wastewater handling	CH_4	-38.43	-59.0	T1	T2	Activity data were refined, national emission factor was used
6.B.2.1	Industrial domestic handling	CH_4	-4439	-74.7	T1	T2	Activity data were refined, national emission factor was used
6.B.2.2	Human sewage	N_2O	0	0.0	T1	T1	Activity data were refined. Emissions in 2003 did not changed; the biggest difference 7.9% in 2000
6.C.	Waste Incineration	N_2O	-0.051	-85.0	T1	T1	Emissions were transferred to the Energy sector, because waste is incinerated in facilities with heat recovery capabilities (in 2005 emissions from this category were considered in the sector «Waste»). Activity data were refined, Emission factor was specified
6.C.	Waste Incineration	CO_2	-196.5	-58.7**	T1	T1	Emissions were transferred to the Energy sector, because waste is incinerated in facilities with heat recovery capabilities (in 2005 emissions from this category were considered in the sector «Waste»). Activity data were refined, Emission factor was specified

Примечание: *) T1 – Tier 1; T2 – Tier 2; CS – national methodology.

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ANNEX1. KEY SOURCE CATEGORIES

Determination of key source categories gives the possibility to identify those source categories that need more detailed study in order to make the most efficient use of available resources. Identifying key source categories was provided in accordance with Good Practice methods.

Table A1.5 summarizes the results of the key source categories analysis in 2004. Tier 1 approach was used. Level assessment (Table A1.1 and A1.2) and trend assessment (Table A1.3 and A1.4) were carried out. It should be noted that level and trend assessments were implemented in two stages. The first stage includes level and trend assessments without LULUCF (Table A1.1 and A1.3). At the second stage LULUCF sector was taken into consideration (Table A1.2 and A1.4).

The categories, which were included into key source categories during the first stage and were excluded on the second stage, then were incorporated into final key source categories list. The categories identified as key source categories in Table A1.1-A1.4 are marked by color.

Table A1.1. Level assessment of the key source categories without LULUCF in 2004

A		B	C	D	E	F
IPCC Source categories		Gas	Base year emissions, CO_2-eq.	Emissions in 2004, CO_2-eq.	The share in total emissions in 2004	Cumulative total of column E
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of Gaseous fuels	CO_2	218 548	110 923	0,268	0,268
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of Solid fuels	CO_2	182 073	74 259	0,180	0,448
2.C.1	Iron and Steel Production	CO_2	80 459	58 476	0.141	0.589
1.B.1.a	Coal Mining and Handling	CH_4	55 396	29 233	0.071	0.660
1.A.3	Liquid fuels combustion from Transport	CO_2	81 450	27 188	0.066	0.726
1.B.2.b	Fugitive emissions from NG operations	CH_4	31 155	23 203	0.056	0.782
4.D	Agricultural Soils	N_2O	40 586	15 075	0.036	0.819
4.A	Enteric Fermentation	CH_4	34 481	11 581	0.028	0.847
2.B.1	Ammonia Production	CO_2	14 108	11 541	0.028	0.874
1.A.3	Gaseous fuels combustion from Transport	CO_2	7 612	10 286	0.025	0.899
2.A.3	Limestone and Dolomite Use	CO_2	9 883	7 904	0.019	0.918
6.A	MSW Landfields	CH_4	4 717	6 256	0.015	0.934
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of Liquid fuels	CO_2	100 762	4 689	0.011	0.945
2.A.1	Cement Production	CO_2	9 287	3 777	0.009	0.954
2.A.2	Lime Production	CO_2	5 671	3 427	0.008	0.962
4.B	Manure Management	N_2O	7 893	3 105	0.008	0.970
2.C.5	Aluminium and Ferroalloys Production	CO_2	4 180	2 943	0.007	0.977
2.B.3	Adipic acid production	N_2O	1 537	1 549	0.004	0.981
6.B	Waste Water Handling	CH_4	1 600	1 521	0.004	0.984
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of other fuels	CO_2	4 605	1 297	0.003	0.988
6.B	Waste Water Handling	N_2O	1 556	1 073	0.003	0.990
2	Industrial processes	CH_4	1 309	852	0.002	0.992
1.A.1 1.A.2 1.A.4 1.A.5	Stationary fuel combustion	CH_4	3 711	655	0.002	0.994
2.B.2	Nitric Acid Production	N_2O	1 105	606	0.001	0.995
4.B	Manure Management	CH_4	18 220	568	0.001	0.997
1.A.1 1.A.2 1.A.4	Stationary fuel combustion	N_2O	1 321	416	0.001	0.998

A		B	C	D	E	F
IPCC Source categories		Gas	Base year emissions, CO_2-eq.	Emissions in 2004, CO_2-eq.	The share in total emissions in 2004	Cumulative total of column E
1.A.5						
3	Total Solvent and Other Product Use	N_2O	377	343	0.001	0.999
2	Other in Industrial Processes	CO_2	408	194	0.000	0.999
1.A.3	Fuel combustion from Transport	N_2O	254	106	0.000	0.999
1.A.3	Fuel combustion from Transport	CH_4	294	100	0.000	0.999
4.C	Rice Cultivation	CH_4	175	89	0.000	1.000
2	Industrial processes	PFCs	203	80	0.000	1.000
1.B.2.a	Fugitive emissions from oil operations	CH_4	98	48	0.000	1.000
1.A.3	Other Transportation	CO_2	268	0	0.000	1.000

Table A1.2. Trend assessment of key source categories without LULUCF in 2004

A		B	C	D	E	F	G
IPCC Source categories		Gas	Base year emissions, CO_2-eq.	Emissions in 2004 , CO_2-eq.	Trend Assessment	% contribution to Trend	Cumulative total of column F
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of Solid fuels	CO_2	100 762	4 689	0.22	0.273	0.273
2.C.1	Iron and Steel Production	CO_2	80 459	58 476	0.12	0.152	0.425
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of Gaseous fuels	CO_2	218 548	110 923	0.07	0.090	0.515
1.B.2.b	Fugitive emissions from NG operations	CH_4	31 155	23 203	0.05	0.063	0.578
1.A.3	Liquid fuels combustion from Transport	CO_2	81 450	27 188	0.05	0.062	0.640
4.B	Manure Management	CH_4	18 220	568	0.04	0.051	0.691
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of Solid fuels	CO_2	182 073	74 259	0.04	0.048	0.739
1.A.3	Gaseous fuels combustion from Transport	CO_2	7 612	10 286	0.04	0.047	0.785
2.B.1	Ammonia Production	CO_2	14 108	11 541	0.03	0.035	0.821
1.B.1.a	Coal Mining and Handling	CH_4	55 396	29 233	0.02	0.030	0.851
6.A	MSW Landfields	CH_4	4 717	6 256	0.02	0.028	0.879
4.A	Enteric Fermentation	CH_4	34 481	11 581	0.02	0.026	0.905
2.A.3	Limestone and Dolomite Use	CO_2	9 883	7 904	0.02	0.024	0.929
4.D	Agricultural Soils	N_2O	40 586	15 075	0.02	0.021	0.949
2.C.5	Aluminium and Ferroalloys Production	CO_2	4 180	2 943	0.01	0.007	0.957
1.A.1 1.A.2 1.A.4 1.A.5	Stationary fuel combustion	CH_4	3 711	655	0.01	0.007	0.963
2.A.2	Lime Production	CO_2	5 671	3 427	0.00	0.006	0.969
2.B.3	Adipic acid Production	N_2O	1 537	1 549	0.00	0.006	0.975
6.B	Waste Water Handling	CH_4	1 600	1 521	0.00	0.005	0.981
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of other fuels	CO_2	4 605	1 297	0.00	0.005	0.986
4.B	Manure Management	N_2O	7 893	3 105	0.00	0.003	0.989
6.B	Waste Water Handling	N_2O	1 556	1 073	0.00	0.003	0.991
2.A.1	Cement Production	CO_2	9 287	3 777	0.00	0.003	0.994
2	Industrial Processes	CH_4	1 309	852	0.00	0.002	0.996
3	Total Solvent and Other Product Use	N_2O	377	343	0.00	0.001	0.997
1.A.1 1.A.2 1.A.4 1.A.5	Stationary fuel combustion	N_2O	1 321	416	0.00	0.001	0.998
1.A.3	Other Transportation	CO_2	268	0	0.00	0.001	0.999
2.B.2	Nitric Acid Production	N_2O	1 105	606	0.00	0.001	0.999
1.A.3	Fuel combustion from Transport	CH_4	294	100	0.00	0.000	1.000
2	Other in Industrial Processes	CO_2	408	194	0.00	0.000	1.000
4.C	Rice Cultivation	CH_4	175	89	0.00	0.000	1.000
2	Industrial processes	PFC	203	80	0.00	0.000	1.000

A		B	C	D	E	F	G
IPCC Source categories		Gas	Base year emissions, CO_2-eq.	Emissions in 2004 , CO_2-eq.	Trend Assessment	% contribution to Trend	Cumulative total of column F
		s					
1.A.3	Fuel combustion from Transport	N_2O	254	106	0.00	0.000	1.000
1.B.2.a	Fugitive emissions from oil operations	CH_4	98	48	0.00	0.000	1.000

Table A1.3. Level assessment of the key source categories with LULUCF in 2004

A		B	C	D	E	F
IPCC Source categories		Gas	Base year emissions, CO_2-eq.	Emissions in 2004, CO_2-eq.	The share in total emissions in 2004	Cumulative total of column E
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of Gaseous fuels	CO_2	218 548	110 923	0.212	0.212
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of Solid fuels	CO_2	182 073	74 259	0.142	0.354
2.C.1	Iron and Steel Production	CO_2	80 459	58 476	0.112	0.466
5.A	Forest Land	CO_2	55 408	55 602	0.106	0.572
5.B	Cropland	CO_2	28 949	38 471	0.074	0.645
1.B.1.a	Coal Mining and Handling	CH_4	55 396	29 233	0.056	0.701
1.A.3	Liquid fuels combustion from Transport	CO_2	81 450	27 188	0.052	0.753
1.B.2.b	Fugitive emissions from NG operations	CH_4	31 155	23 203	0.044	0.798
4.D	Agricultural Soils	N_2O	40 586	15 075	0.029	0.826
5.C	Grassland	CO_2	9 047	13 801	0.026	0.853
4.A	Enteric Fermentation	CH_4	34 481	11 581	0.022	0.875
2.B.1	Ammonia Production	CO_2	14 108	11 541	0.022	0.897
1.A.3	Gaseous fuels combustion from Transport	CO_2	7 612	10 286	0.020	0.917
2.A.3	Limestone and Dolomite Use	CO_2	9 883	7 904	0.015	0.932
6.A	MSW Landfields	CH_4	4 717	6 256	0.012	0.944
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of Liquid fuels	CO_2	100 762	4 689	0.009	0.953
2.A.1	Cement Production	CO_2	9 287	3 777	0.007	0.960
2.A.2	Lime production	CO_2	5 671	3 427	0.007	0.966
4.B	Manure Management	N_2O	7 893	3 105	0.006	0.972
2.C.5	Aluminium and Ferroalloys Production	CO_2	4 180	2 943	0.006	0.978
5.E	Settlements	CO_2	284	1 640	0.003	0.981
2.B.3	Adipic acid production	N_2O	1 537	1 549	0.003	0.984
6.B	Waste Water Handling	CH_4	1 600	1 521	0.003	0.987
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of other fuels	CO_2	4 605	1 297	0.002	0.989
6.B	Waste Water Handling	N_2O	1 556	1 073	0.002	0.991
2	Industrial processes	CH_4	1 309	852	0.002	0.993
1.A.1 1.A.2 1.A.4 1.A.5	Stationary fuel combustion	CH_4	3 711	655	0.001	0.994
2.B.2	Nitric Acid Production	N_2O	1 105	606	0.001	0.995
4.B	Manure Management	CH_4	18 220	568	0.001	0.997
5.D	Wetlands	CO_2	1 384	429	0.001	0.997
1.A.1 1.A.2 1.A.4 1.A.5	Stationary fuel combustion	N_2O	1 321	416	0.001	0.998
3	Total Solvent and Other Product Use	N_2O	377	343	0.001	0.999
2	Other in Industrial Processes	CO_2	408	194	0.000	0.999
1.A.3	Fuel combustion from Transport	N_2O	254	106	0.000	0.999
1.A.3	Fuel combustion from Transport	CH_4	294	100	0.000	1.000
4.C	Rice Cultivation	CH_4	175	89	0.000	1.000
2	Industrial processes	PFCs	203	80	0.000	1.000
1.B.2.a	Fugitive emissions from oil operations	CH_4	98	48	0.000	1.000

A		B	C	D	E	F
IPCC Source categories		Gas	Base year emissions, CO_2-eq.	Emissions in 2004, CO_2-eq.	The share in total emissions in 2004	Cumulative total of column E
5	LULUCF	N_2O	10	3	0.000	1.000
5	LULUCF	CH_4	8	1	0.000	1.000
1.A.3	Other Transportation	CO_2	268	0	0.000	1.000

Table A1.4. Trend assessment of key source categories with LULUCF in 2004

A		B	C	D	E	F	G
IPCC Source categories		Gas	Base year emissions, CO_2-eq.	Emissions in 2004 , CO_2-eq.	Trend Assessment	% contribution to Trend	Cumulative total of column F
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of Liquid fuels	CO_2	100 762	4 689	0.18	0.218	0.218
5.A	Forest Land	CO_2	55 408	55 602	0.10	0.126	0.345
5.B	Cropland	CO_2	28 949	38 471	0.09	0.110	0.454
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of Solid fuels	CO_2	182 073	74 259	0.07	0.089	0.543
2.C.1	Iron and Steel Production	CO_2	80 459	58 476	0.06	0.080	0.623
1.A.3	Liquid fuels combustion from Transport	CO_2	81 450	27 188	0.05	0.068	0.691
5.C	Grassland	CO_2	9 047	13 801	0.03	0.043	0.733
4.B	Manure Management	CH_4	18 220	568	0.03	0.041	0.774
1.B.2.b	Fugitive emissions from NG operations	CH_4	31 155	23 203	0.03	0.034	0.808
1.A.3	Gaseous fuels combustion from Transport	CO_2	7 612	10 286	0.02	0.030	0.837
4.A	Enteric Fermentation	CH_4	34 481	11 581	0.02	0.028	0.866
4.D	Agricultural Soils	N_2O	40 586	15 075	0.02	0.027	0.892
2.B.1	Ammonia Production	CO_2	14 108	11 541	0.02	0.020	0.912
6.A	MSW Landfields	CH_4	4 717	6 256	0.01	0.018	0.930
2.A.3	Limestone and Dolomite Use	CO_2	9 883	7 904	0.01	0.013	0.943
5.E	Settlements	CO_2	284	1 640	0.01	0.007	0.950
1.A.1 1.A.2 1.A.4 1.A.5	Stationary fuel combustion	CH_4	3 711	655	0.00	0.006	0.956
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of Gaseous fuels	CO_2	218 548	110 923	0.00	0.005	0.961
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of other fuels	CO_2	4 605	1 297	0.00	0.005	0.966
2.A.1	Cement Production	CO_2	9 287	3 777	0.00	0.005	0.971
4.B	Manure Management	N_2O	7 893	3 105	0.00	0.004	0.975
1.B.1.a	Coal Mining and Handling	CH_4	55 396	29 233	0.00	0.004	0.979
2.C.5	Aluminium and Ferroalloys Production	CO_2	4 180	2 943	0.00	0.004	0.983
2.B.3	Adipic acid production	N_2O	1 537	1 549	0.00	0.004	0.986
6.B	Waste Water Handling	CH_4	1 600	1 521	0.00	0.003	0.989
5.D	Wetlands	CO_2	1 384	132	0.00	0.003	0.992
2.A.2	Lime Production	CO_2	5 671	3 427	0.00	0.002	0.995
6.B	Waste Water Handling	N_2O	1 556	1 073	0.00	0.001	0.996
1.A.1 1.A.2 1.A.4 1.A.5	Stationary fuel combustion	N_2O	1 321	416	0.00	0.001	0.997
2	Industrial Processes	CH_4	1 309	852	0.00	0.001	0.998
3	Total Solvent and Other Product Use	N_2O	377	343	0.00	0.001	0.999
1.A.3	Other Transportation	CO_2	268	0	0.00	0.001	0.999
1.A.3	Fuel combustion from Transport	CH_4	294	100	0.00	0.000	0.999
2.B.2	Nitric Acid Production	N_2O	1 105	606	0.00	0.000	1.000
1.A.3	Fuel combustion from Transport	N_2O	254	106	0.00	0.000	1.000
2	Industrial processes	PFCs	203	80	0.00	0.000	1.000
2	Other in Industrial Processes	CO_2	408	194	0.00	0.000	1.000
5	LULUCF	CH_4	8	1	0.00	0.000	1.000

A		B	C	D	E	F	G
IPCC Source categories		Gas	Base year emissions, CO_2-eq.	Emissions in 2004 , CO_2-eq.	Trend Assessment	% contribution to Trend	Cumulative total of column F
1.B.2.a	Fugitive emissions from oil operations	CH_4	98	48	0.00	0.000	1.000
5	LULUCF	N_2O	10	3	0.00	0.000	1.000
4.C	Rice Cultivation	CH_4	175	89	0.00	0.000	1.000

Table A1.5. Key source analysis results in 2004

Quantative method: Tier 1					
A		B	C	D	E
IPCC Source categories		Gas	Key Source Category Flag	If column C is Yes, Criteria for Identification	Comments
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of Liquid fuels	CO_2	Yes	Level, Trend	
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of Solid fuels	CO_2	Yes	Level, Trend	
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of Gaseous fuels	CO_2	Yes	Level, Trend	
1.A.1 1.A.2 1.A.4 1.A.5	Stationary combustion of other fuels	CO_2	No		
1.A.3	Liquid fuels combustion from Transport	CO_2	Yes	Level, Trend	
1.A.3	Gaseous fuels combustion from Transport	CO_2	Yes	Level, Trend	
1.A.3	Other Transportation	CO_2	No		
2	Other in Industrial Processes	CO_2	No		
2.A.1	Cement Production	CO_2	Yes	Level	
2.A.2	Lime Production	CO_2	No		
2.A.3	Limestone and Dolomite Use	CO_2	Yes	Level, Trend	High uncertainty
2.B.1	Ammonia Production	CO_2	Yes	Level, Trend	
2.C.1	Iron and Steel Production	CO_2	Yes	Level, Trend	
2.C.5	Aluminium Production and ферросплавов	CO_2	Yes	Trend	
5.A	Forest Land	CO_2	Yes	Level, Trend	
5.B	Cropland	CO_2	Yes	Level, Trend	
5.C	Grassland	CO_2	Yes	Level, Trend	
5.D	Wetlands	CO_2	No		
5.E	Settlements	CO_2	Yes	Trend	
1.A.1 1.A.2 1.A.4 1.A.5	Stationary fuel combustion	CH_4	No		
1.A.3	Fuel combustion from Transport	CH_4	No		
1.B.1.a	Coal Mining and Handling	CH_4	Yes	Level, Trend	High uncertainty
1.B.2.a	Fugitive emissions from oil operations	CH_4	No		
1.B.2.b	Fugitive emissions from NG operations	CH_4	Yes	Level, Trend	High uncertainty
2	Industrial Processes	CH_4	No		
4.A	Enteric Fermentation	CH_4	Yes	Level, Trend	
4.B	Manure Management	CH_4	No		
4.C	Rice Cultivation	CH_4	No		
5	LULUCF	CH_4	No		
6.A	Landfields MSW	CH_4	Yes	Level, Trend	High uncertainty
6.B	Waste Water Handling	CH_4	No		
1.A.1 1.A.2 1.A.4 1.A.5	Stationary fuel combustion	N_2O	No		
1.A.3	Fuel combustion from Transport	N_2O	No		
2.B.2	Nitric Acid Production	N_2O	No		
2.B.3	Adipic acid Production	N_2O	No		
3	Total Solvent and Other Product Use	N_2O	No		
4.B	Manure Management	N_2O	Yes	Trend	High uncertainty
4.D	Agricultural Soils	N_2O	Yes	Level, Trend	High uncertainty
5	LULUCF	N_2O	No		
6.B	Waste Water Handling	N_2O	No		

Quantative method: Tier 1					
A		B	C	D	E
IPCC Source categories		Gas	Key Source Category Flag	If column C is Yes, Criteria for Identification	Comments
2	Industrial processes	PFCs	No		

ANNEX 2. METHODOLOGY OF ESTIMATION OF EMISSIONS FROM FOSSIL FUEL COMBUSTION

A 2.1 Activity data sources

№ 4-MTP statistical reporting form (1998-1999) and Fuel and Energy Balance (1990) were used for estimation of GHG emission in the Energy sector.

It should be noted that statistical forms and other norms were changed many times during the period 1998-2004. The current state of reporting forms (for the last reporting year) is described below with specific comments.

A 2.1.1 № 4-MTP statistical reporting form

4-MTP statistical reporting form is form of state observations on remaining and use of fuels and oil products. All enterprises despite of their belonging report according to this form. In reports to the national statistical bodies, enterprises specify code of economic activity in accordance with State Classifier of Kinds of Economic Activity (CKEA). This information gives unambiguous possibility to interlink specific kind of economic activity with CRF categories.

4-MTP statistical reporting form consists of five chapters. Each of these chapters contains information on specific aspects of fuel use. All chapters consist of table, where the rows correspond to fuel type and the columns - aspects of fuel use.

Information of chapters 3-5 are used in sectoral approach. Their structure is described below.

Chapter 3 of 4-MTP statistical reporting form contains information on fuel consumption by energy sector of enterprises and gives data on:

- column 1 – sum of columns 2-11, described below;
- column 2 – fuel consumption for coal, brown coal and peat briquettes;
- column 3 – fuel consumption for coke and coke gas production;
- column 4 –fuel consumption for production of different gases, including synthetical;
- column 5 – volume of blast furnace coke, which is equal to volume of blast furnace gas from iron and ferroalloys production in blast furnaces;
- column 6 – oil and other fuel consumption for oil products;
- column 7 – fuel consumption for public electricity and heat production;
- column 8 – fuel consumption for electricity and heat production at the enterprises;
- column 9 – fuel consumption for electricity and heat production by cogeneration plants;
- column 10 – fuel consumption for heat production at the boilers;
- column 11 – fuel consumption for fuel transformation by other enterprises not included in columns 2-10;
- column 12 – fuel consumption for all technological processes of fuel production, electricity and heat production with fuel losses during technological processes, as well as fuel consumed by in-plant transport.

It should be noted that columns 2-11 include fuel losses during transformation and other technological losses. The amounts of these losses are presented separately in column 3 of chapter 5.

Chapter 4 of 4-MTP statistical reporting form contains information on end-use fuel use and includes data on fuel consumption:

- column 1 – non-energy fuel use as feedstock in chemical, petrochemical and other industries. These values are separated and included in column 4 of chapter 5;
- column 2 – sum of columns 3-9;
- column 3 – manufacturing industries. This column dives data on fuel consumed for industrial production excluding fuel and energy production, as well as in-plant transport;
- column 4 – agricultural production;
- column 5 – transportation excluding in-plant transport;
- column 6 – building and construction works, as well as drilling;
- column 7 – trade and public feeding;
- column 8 – residential purposes;
- column 9 – other needs not included in columns 3-8, as well as fuel consumption by institutional buildings;
- column 10 – fuel realized to the population.

Chapter 5 of 4-MTP statistical reporting form contains information on fuel losses during its production, transformation, processing, transportation and distribution. This information is given in the following columns:

- column 1 – fuel losses during production;
- column 2 – fuel losses during transportation, distribution and storage;
- column 3 – fuel losses during transformation, which are taken into account in columns 2-11 of chaptera 3;
- column 4 – fuel losses during transformation to non-fuel products, which are taken into account in column 1 of chaptera 4;
- column 5 – fuel losses due to unuse, neglect or other reasons.

A2.1.2 11-MTP statistical reporting form

Data on fuels in mass or volume units are given in 4-MTP statistical reporting form. Conversion factors from Annex 1 to 11-MTP statistical reporting form were used to obtain fuel amounts in energy units. Conversion factors in 11-MTP statistical reporting do not given for some kinds of fuels from 4-MTP statistical reporting form. In such cases inventory team use reference data as described below.

A2.2 Activity Data Processing

Activity data on fuel combustion from 4-MTP statistical reporting form, as well as 11-MTP statistical reporting form are available in electronic form. This fact made it possible to automatize calculation of emissions. Original data from 4-MTP statistical reporting form and 11-MTP statistical reporting form were handled and brought in correspondence with format, which was applicable to further computerized emission estimation.

A2.3 Methodology of Fuel Combustion Estimation

Activity data for estimating fuel combustion in Ukraine were obtained from 4-MTP statistical reporting form as mentioned above.

It is impossible to use directly data on fuel consumption in 4-MTP statistical reporting for inventory purposes. Specific methodology to identify fuel consumption and bring in correspondence kinds of economic activity with categories recommended by IPCC was needed.

A2.3.1 Fuel Aggregation

Table A2.1 was used to aggregate fuel types from 4-MTP statistical reporting form to fuel types recommended by CRF.

Table A2.1. Aggregation of fuel types from 4-MTP statistical reporting form to fuel types recommended by CRF

Fuel type from CRF	Fuel type from 4-MTP statistical reporting form	Fuel code
Liquid fuel	Crude oil	004
	Gas condensate	014
	Aircraft gasoline	031
	Gasoline	032
	Gas/Diesel Oil	033
	Gas turbine fuel of gasoline type	034
	Gas turbine fuel of kerosene type	035
	Engine fuel	036
	Motor kerosene	037
	Kerosene for lighting	038
	Fuel oil	039
	Bunker fuel	040
	Stove fuel	041
	Petroleum coke	043
	Lubricants	045
	Waste oil products	051
	Liquefied gas	052
	Other oil products	053
	Refinery feedstock	054
	Other hydrocarbons	056
	Refinery gas	061
Solid fuel	Coal	001
	Coking coal	002
	Brown coal (lignite)	003
	Oil shale	006
	Peat (conventional moisture)	007
	Slurry	021
	Thermoanthracite	022
	Coke and coke breeze	023
	Coal briquettes	024
	Peat briquettes (conventional moisture)	025
	Brown coal briquettes	026
	Coke gas	063
Gaseous fuel	Natural gas	005
Biomass	Wood	008
	Wood waste	010
Other fuels	Other primary fuels	009
	Other products of fuel processing	091

A2.3.2 Stationary combustion

Table A2.2 was used to aggregate kinds of economic activity in CKEA to CRF categories.

Table A2. 2. Aggregation of kinds of economic activity from 4-MTP statistical reporting form to CRF categories 1.A.1, 1.A.2, 1.A.4

CRF category	CKEA code
1.A.1.a Public Electricity and Heat Production	E 40.1 E 40.3
1.A.1.b Oil Refining	D DF 23.2
1.A.1.c Manufacture of Solid Fuels and Other Energy Industries	C CA D DF 23.1 D DF 23.3
1.A.2.a Iron and Steel	D DJ 27.1 D DJ 27.2 D DJ 27.3
1.A.2.b Non-Ferrous Metals	D DJ 27.4
1.A.2.c Chemicals	D DG D DH
1.A.2.d Pulp, Paper and Print	D DE
1.A.2.e Food Processing, Beverages and Tobacco	D DA
1.A.2.f Other Manufacturing Industry and Construction	C CB D DB-DD D DI D DJ 27.5 D DJ 28 D DK-DN F
1.A.4.a Commercial/Institutional	G H J K L M N O 88.88.8
1.A.4.b Residential	Column 10 of Chapter 4 from 4-MTP statistical reporting form (total in Ukraine)
1.A.4.c Agriculture/Forestry/Fisheries	A B
1.A.5 Other	I (fuel consumption for non-transportation purposes)

The amount on fuel combustion in the units of mass or volume $E_{s,f}$ (to the exclusion of three cases described below) was calculated as follows:

$$E_{s,f} = k_{s,f} \cdot \sum_{j=7}^{12} E_{s,f,i=3,j} + E_{s,f,i=4,j=2} , \qquad \text{(A2.1)}$$

where s - CKEA code for kind of economic activity in 4-MTP statistical reporting form (Table A2.2);

f - fuel code (row) in 4-MTP statistical reporting form (Table A2.1);

i - chapter code in 4-MTP statistical reporting form;

j - column code from chapter i in 4-MTP statistical reporting form;

$k_{s,f}$ - fuel losses during processing;

$E_{s,f,i=3,j}$ - amount of fuel f from column j of chapter 3 from 4-MTP statistical reporting form, which contains data for kind s of economic activity;

$E_{s,f,i=4,j=2}$ - amount of fuel f from column 2 of chapter 4 from 4-MTP statistical reporting form, which contains data for kind s of economic activity.

Losses ratio for fuel f during processing by the enterprises, which were ascribed to kind s of economic activity, were estimated as follows:

$$k_{s,f} = 1 - \frac{E_{s,f,i=5,j=4}}{E_{s,f,i=3,j=1}}. \qquad \text{(A2.2)}$$

The following exclusions for applicability of equation A2.1 were made:

1 To reach correct sharing of stationary and mobile fuel combustion the following amounts of fuel consumption were considered in the sector “Transport” (category 1.A.3 CRF):

- gasoline (032), diesel oil (033) and lubricants (045) in the columns 4-6 of chapter 4 (4-MTP statistical reporting form) regardless to the kind of economic activity;
- gasoline (032) and diesel oil (033) in the column12 of chapter 3 and column 3 of chapter 4 (4-MTP statistical reporting form) regardless to the kind of economic activity;
- natural gas (005), engine fuel (036) and liquefied gas (052) in the column 5 of chapter 4 (4-MTP statistical reporting form) regardless to the kind of economic activity;
- fuel oil (039) and bunker fuel (044) in the column 5 of chapter 4 (4-MTP statistical reporting form) with CKEA code at the level of I 61;
- aircraft gasoline (031), gas turbine fuel of gasoline type (034), gas turbine fuel of kerosene type (035) and motor kerosene (037), in the column 5 of chapter 4 (4-MTP statistical reporting form) with CKEA code at the level of I 62;

2 Coke (023) consumption for manufacturing industries (column 3 of chapter 4 in 4-MTP statistical reporting form) for the kind of economic activity at the level D DJ 27.1-27.3 was not considered in the sector “Energy”. Coke consumption as reducing agent in metallurgy was taken into account in the sector «Industrial processes» (Sector 2 CRF).

3 Fuel combusted by population (CRF category 1.A.4.b), was determined as follows:

$$E_{s=0,f} = E_{s=0,f,i=4,j=10}. \qquad \text{(A2.3)}$$

Inventory team assumed that all amounts of gasoline (032), diesel oil (033) and lubricants, which were realized to the population, were consumed for transportation purposes and considered to the category «Transport» (category 1.A.3 CRF).

A2.3.3 Transport (category 1.A.3 CRF)

Table A2.3 was used to aggregate kinds of economic activity in CKEA to CRF categories in the category «Transport» (category 1.A.3 CRF). The table also includes corresponding fuel codes.

Table A2. 3. Aggregation of kinds of economic activity from 4-MTP statistical reporting form to CRF category 1.A.3

CRF category	CKEA Code	Fuel code considered in this category
1.A.3.a Civil Aviation	I 62	031 034 035 037
1.A.3.b Road Transportation	Private cars (column 10 of chapter 4 in 4-MTP statistical reporting form - total in Ukraine)	032 033 045
	Transport of enterprises (column 5 of chapter 4 in 4-MTP statistical reporting form - total in Ukraine) excluding fuel considered in other subcategories of category «Transport»	005 032 033 036 045 052
1.A.3.c Railways	I 60.1	033 045
1.A.3.d Navigation	I 61	033 036 039 040 045
1.A.3.e.i Pipeline Transportation	I 60.30.2	005
1.A.3.e.ii Off-Road Transportation	column 4 of chapter 4 in 4-MTP statistical reporting form - total in Ukraine	032 033 045
1.A.3.e.iii Agriculture Transportation	column 6 of chapter 4 in 4-MTP statistical reporting form - total in Ukraine	032 033 045

Equations for determining fuel combustion in the subcategories of category «Transport» are provided below.

Civil Aviation (category 1.A.3.a CRF)

Aircraft gasoline (031), Gas turbine fuel of gasoline type (034), Gas turbine fuel of kerosene type (035) and Motor kerosene (037) are used in engines of aircrafts [1].

Fuel consumed by engines of aircrafts $E_{S=1.A.3.a,f\in(031,034,035,037)}$ was determined according to equation:

$$E_{S=1.A.3.a,f\in(031,034,035,037)} = E_{s=I\ 62,f\in(031,034,035,037),i=4,j=5}, \qquad (A2.4)$$

where S - category code in accordance with the IPCC Revised Guidelines;
s - CKEA code for kind of economic activity in 4-MTP statistical reporting form;
f - fuel code (row) in 4-MTP statistical reporting form;
i - chapter code in 4-MTP statistical reporting form;

j - column code from chapter i in 4-MTP statistical reporting form.

$E_{s,f,i,j}$ - the amount of fuel f from column j of chapter i in 4-MTP statistical reporting form, which contains data for kind s of economic activity.

Data on international bunkers were not available in national statistics. Hence emissions presented in CRF tables include international bunkers.

Railways (category 1.A.3.c CRF)

Diesel oil (033) and lubricants (045) are used in engines of railways [1].

Fuel consumed by engines of trains $E_{S=1.A.3.c, f\in(033,045)}$ was determined according to equation:

$$E_{S=1.A.3.c, f\in(033,045)} = k^R \cdot E_{s=I\ 60.1, f\in(033,045), i=4, j=5}, \tag{A2.5}$$

where $k^R = 0.89$ [1] – fuel fraction, which is used in engines at the railways, from the value in column 5 of chapter 4 in 4-MTP statistical reporting form. Fuel fraction was estimated according to the comparison of sectoral statistics at the railways and 4-MTP statistical reporting form.

Inventory team assumed that remaining fuel not included in $E_{S=1.A.3.c, f\in(033,045)}$, i.e. $\left(1-k^R\right)\cdot E_{S=1.A.3.c, f\in(033,045)}$, were consumed for road transportation and considered in the CRF subcategory 1.A.3.a «Road Transportation».

Navigation (CRF category 1.A.3.d)

Diesel oil (033), Engine fuel (036), Fuel oil (039) and Bunker fuel (040), as well as lubricants (045) are used in engines of ships [1].

Fuel consumed by engines of ships $E_{S=1.A.3.d, f_N}$ was determined according to equation:

$$E_{S=1.A.3.d, f_N} = k^N_{f_N} \cdot E_{s=I\ 61, f_N, i=4, j=5}, \tag{A2.6}$$

where $f_N = f \in (033,036,039,040,045)$ - fuels consumed by water transport;

$k^N_{f\in(033,036,045)} = 0.94$ and $k^N_{f\in(039,040)} = 1$ [1] – – fuel fraction, which is used in engines of water transport, from the value in column 5 of chapter 4 in 4-MTP statistical reporting form. Fuel fraction was estimated according to the comparison of sectoral fuel-statistics for the water transport and 4-MTP statistical reporting form.

Inventory team assumed that remaining fuel (Diesel oil (033), Engine fuel (036) and lubricants (045)) not included in $E_{S=1.A.3.d, f\in(033,036,045)}$, i.e. $\left(1-k^N_{f\in(033,036,045)}\right)\cdot E_{S=1.A.3.d, f\in(033,036,045)}$, were consumed for road transportation and considered in the CRF subcategory 1.A.3.a «Road Transportation».

Emissions of fuel combustion from international bunkers are included in the calculations due to the structure of national statistics. In order to separate data on emissions related to coastwise trade inventory team assumed that these emissions is proportional to turnover of goods («International bunkers»).

Road Transportation (category 1.A.3.a CRF)

Gasoline (032), Diesel oil (033), Engine fuel (036), Waste oil products (051), Liquefied gas (052), Other oil products (053), as well as lubricants (045) are used in engines of cars [1].

Fuel consumed by engines of cars $E_{S=1.A.3.b,f_R}$ was determined according to equation:

.

$$E_{S=1.A.3.b,f_R} = E_{s=0,f_R,i=4,j=5} - E_{S=1.A.3.c,f\in(033,045)} - \\ - E_{S=1.A.3.d,f\in(033,036,045)} + E_{s=0,f\in(032,033,045),i=4,j=10} \quad (A2.7)$$

where $f_R = f \in (032,033,036,045,051,052,053,)$ - fuels consumed by road transport;

$s = 0$ - corresponds to data «Total in Ukraine» from 4-MTP statistical reporting form.

Equation (A2.7) assumes that all amounts of gasoline (032), diesel oil (033) and lubricants, which were realized to the population, were consumed for private cars.

4—MTP statistical reporting form does not segregate NG (005) and liquefied gas (052) consumed by population to residential and transportation purposes. That is why these fuels were considered in the CRF category 1.A.4.b «Residential».

Pipeline Transportation (CRF category 1.A.3.e.i)

Annual NG consumption for gas turbines in gas-compressor units amounts to 4.5-5.3 billion m^3 according to the data from independent sources [2], as well as information from Subsidiary Company Ukrtransgaz under NJSC Naftogaz of Ukraine [3]. The value of 3.8 billion m^3 is given in 4-MTP statistical reporting form. This fact is explained by incomplete coverage of departments of Subsidiary Company Ukrtransgaz under NJSC Naftogaz of Ukraine, which report their consumption in 4-MTP statistical reporting form.

Data from independent sources [2], which correspond to the information from Subsidiary Company Ukrtransgaz under NJSC Naftogaz of Ukraine [3] were used for emission estimation.

Off-Road Transportation (CRF category 1.A.3.e.ii)

Gasoline (032), diesel oil (033) and lubricants (045), which are consumed by building and construction works, as well as drilling, were considered in this category despite of kind of economic activity. Inventory team also assumed that the amounts of gasoline (032) and diesel oil (033) in column 12 of chapter 3 and column 3 of chapter 4 from 4-MTP statistical reporting form were consumed by in-plant transport, which was considered in this category.

Therefore fuel consumed in the category «Off-Road Transportation» was determined as follows:

$$E_{S=1.A.3.e.ii,f\in(032,033,045,052)} = E_{s=0,f\in(032,033,045,052),i=4,j=6} + \\ + E_{s=0,f\in(032,033),i=4,j=3} + E_{s=0,f\in(032,033),i=3,j=12} \quad (A2.9)$$

Gasoline (032), diesel oil (033) and lubricants (045), which are consumed for agricultural purposes, were considered in this category despite of kind of economic activity.

Therefore fuel consumed in the category «Agriculture Transportation» was determined as follows:

$$E_{S=1.A.3.E.iii, f\in(032,033,045)} = E_{s=0, f\in(032,033,045), i=4, j=4} \cdot \quad \text{(A2.10)}$$

A2.3.4 Conversion from units of volume or mass to units of energy

The amount of fuel combustion in energy units was calculated as follows:

$$E^{e}_{s,f} = Q_{s,f} \cdot E_{s,f}, \quad \text{(A2.11)}$$

where $Q_{s,f}$ – net calorific value of fuel f, which was used in s sector of activity.

Data on net calorific values were obtained from 11-MTP statistical reporting form, reference books and the Good Practice Guidance.

Information by kind of economic activity in 4-MTP and 11-MTP statistical reporting form and 11-MTP statistical reporting form is provided according to the single database of State Classifier of Kinds of Economic Activity (CKEA) [8]. Therefore conversion factors from 11-MTP statistical reporting form were applied to the corresponding kinds of economic activity in 4-MTP statistical reporting form. 11-MTP statistical reporting form does not include conversion factors for some kinds of economic activity. Inventory team has applied average values from 11-MTP statistical reporting form in such cases.

Table A1.4 presents average weighted net calorific values of fuels in Ukraine from 11-MTP statistical reporting form and reference data, which were used to convert data from 4-MTP statistical reporting form to energy units. Data obtained from 11-MTP are marked by italic font.

Table A2. 4. Net calorific values of fuel

Fuel code according to 4-MTP statistical reporting form	Fuel type	Units	1998	1999	2000	2001	2002	2003	2004
001	*Coal*	*TJ/thous. t*	*18.43*	*18.43*	*18.38*	*19.93*	*21.10*	*20.84*	*20.90*
002	*Coking coal*	*-“-*	*21.59*	*21.59*	*21.59*	*21.59*	*21.59*	*21.59*	*27.11*
003	*Brown coal (lignite)*	*-“-*	*7.65*	*7.65*	*7.56*	*7.44*	*7.24*	*7.27*	*10.61*
004	*Crude oil*	*-“-*	*42.96*	*42.96*	*42.76*	*42.12*	*41.91*	*41.91*	*41.91*
005	*Natural gas*	*TJ/mln m³*	*33.65*	*33.65*	*33.67*	*33.67*	*33.73*	*33.70*	*33.82*
006	Oil shale	TJ/thous. t	9.38	9.38	9.38	9.38	9.38	9.38	9.38
007	*Peat (conventional moisture)*	*-“-*	*10.05*	*10.05*	*10.02*	*10.02*	*8.79*	*10.14*	*10.08*
008	*Wood*	*TJ/thous.n.м³*	*7.71*	*7.71*	*7.74*	*7.71*	*7.71*	*7.74*	*7.68*
014	*Gas condensate*	*TJ/thous. t*	*42.96*	*42.96*	*42.76*	*42.12*	*41.91*	*41.91*	*40.91*
021	Slurry	-“-	28.00	28.00	28.00	28.00	28.00	28.00	28.00
022	Thermoanthracite	-“-	28.57	28.57	28.57	28.57	28.57	28.57	28.57
023	*Coke and coke breeze*	*-“-*	*28.55*	*28.55*	*28.55*	*28.57*	*28.60*	*28.57*	*28.49*
024	*Coal briquettes*	*-“-*	*16.18*	*16.18*	*16.18*	*16.18*	*16.44*	*16.18*	*16.18*
025	Peat briquettes (conventional moisture)	-“-	14.65	14.65	14.65	14.65	14.65	14.65	14.65
026	*Brown coal briquettes*	*-“-*	*17.00*	*17.00*	*16.73*	*16.82*	*16.18*	*16.18*	*16.18*
031	Aircraft gasoline	-“-	44.59	44.59	44.59	44.59	44.59	44.59	44.59
032	Gasoline	-“-	43.67	43.67	43.67	43.67	43.67	43.67	43.67
033	*Gas/Diesel Oil*	*-“-*	*42.47*	*42.47*	*42.50*	*42.50*	*42.47*	*42.50*	*42.50*
034	Gas turbine fuel of gasoline type	-“-	42.50	42.50	42.50	42.50	42.50	42.50	42.50
035	Gas turbine fuel of kerosene type	-“-	42.50	42.50	42.50	42.50	42.50	42.50	42.50
036	Engine fuel	-“-	41.91	41.91	41.91	41.91	41.91	41.91	41.91
037	Motor kerosene	-“-	43.08	43.08	43.08	43.08	43.08	43.08	43.08
038	Kerosene for lighting	-“-	43.08	43.08	43.08	43.08	43.08	43.08	43.08
039	*Fuel oil*	*-“-*	*39.92*	*39.92*	*40.00*	*39.98*	*39.80*	*39.92*	*39.98*
040	Bunker fuel	-“-	41.91	41.91	41.91	41.91	41.91	41.91	41.91
041	*Stove fuel*	*-“-*	*41.91*	*41.91*	*42.06*	*42.38*	*42.26*	*42.29*	*42.29*
043	Petroleum coke	-“-	31.65	31.65	31.65	31.65	31.65	31.65	31.65
044	Naphtha	-“-	42.44	42.44	42.44	42.44	42.44	42.44	42.44
045	Lubricants	-“-	40.15	40.15	40.15	40.15	40.15	40.15	40.15
051	Waste oil products	-“-	33.70	33.70	33.70	33.70	33.70	33.70	33.70
052	Liquefied gas	-“-	46.01	46.01	46.01	46.01	46.01	46.01	46.01
054	Refinery feedstock	-“-	44.80	44.80	44.80	44.80	44.80	44.80	44.80
055	Additives	-“-	37.68	37.68	37.68	37.68	37.68	37.68	37.68
056	Other hydrocarbons	-“-	37.68	37.68	37.68	37.68	37.68	37.68	37.68
061	Non-liquified refinery gas	-“-	48.15	48.15	48.15	48.15	48.15	48.15	48.15
063	*Coke gas*	*TJ/mln m³*	*16.73*	*16.73*	*16.85*	*16.73*	*16.73*	*16.73*	*16.73*
064	Converter gas	TJ/mln m³	8.37	8.37	8.37	8.37	8.37	8.37	8.37

A2.4 Emission factors

A2.4.1 Carbon emission factors

Carbon emission factors depend upon carbon content of fuel. Study on the development of carbon emission factors for fuel combustion practically was not carried out in Ukraine. Therefore default emission factors for all categories were used according to the IPCC Revised Guidelines [6].

Emissions factors for the similar fuel types were used, when national fuel types did not correspond to the IPCC classification and default values were not available.

Carbon emission factors for coal were determined from the data on physicochemical properties of coal mined in Donetsk coal basin [4], and data on low heat values from TPPs in Ukraine, which are included in 6-TP statistical reporting form. Such study was conducted for 1998-2004. Value for 1990 was taken from [5]. Carbon emission factors are presented at the table A 2.5.

Table A2. 5. Carbon emission factors for coal, t/TJ

Fuel code according to 4-MTP statistical reporting form	Fuel type	1990	1998	1999	2000	2001	2002	2003	2004
001	Coal	26.30	26.92	27.08	27.06	26.81	26.77	26.75	26.78

Carbon emission factors for all fossil fuels, excluding coal, were assumed constant during the whole period (Table A2.6).

Table A2. 6. Carbon emission factors, t/TJ

Fuel code according to 4-MTP statistical reporting form	Fuel type	Carbon emission factor
002	Coking coal	26.88
003	Brown coal (lignite)	27.60
004	Crude oil	20.00
005	Natural gas	15.30
006	Oil shale	29.10
007	Peat (conventional moisture)	28.90
008	Wood	27.60
009	Other primary fuels	26.80
010	Wood waste	27.60
014	Gas condensate	17.20
021	Slurry	25.80
022	Thermoanthracite	29.50
023	Coke and coke breeze	29.50
024	Coal briquettes	25.80
025	Peat briquettes (conventional moisture)	28.90
026	Brown coal briquettes	27.60
031	Aircraft gasoline	18.90
032	Gasoline	18.90
033	Gas/Diesel Oil	20.20
034	Gas turbine fuel of gasoline type	18.90

Fuel code according to 4-MTP statistical reporting form	Fuel type	Carbon emission factor
035	Gas turbine fuel of kerosene type	19.50
036	Engine fuel	20.20
037	Motor kerosene	19.60
038	Kerosene for lighting	19.60
039	Fuel oil	21.10
040	Bunker fuel	21.10
041	Stove fuel	20.20
042	Petroleum bitumen	22.00
043	Petroleum coke	27.50
044	Naphtha	20.00
045	Lubricants	20.00
051	Waste oil products	20.00
052	Liquefied gas	17.20
053	Other oil products	20.00
054	Refinery feedstock	20.00
055	Additives	20.00
056	Other hydrocarbons	20.00
061	Non-liquified refinery gas	18.20
063	Coke gas	13.00
064	Converter gas	33.00
091	Other products of fuel processing	20.00

A2.4.2 Methane emission factors

Study on the development of national methane emission factors for fuel combustion was not carried out in Ukraine. Therefore default emission factors were used according to the IPCC Revised Guidelines [6].

A2.4.3 Nitrous oxide emission factors

Study on the development of national nitrous oxide emission factors for fuel combustion was not carried out in Ukraine. Therefore default emission factors were used according to the IPCC Revised Guidelines [6].

A2.5 Carbon Oxidation Factor

Study on the development of carbon oxidation factors for fuel combustion was not carried out in Ukraine, besides the coal combustion at the Thermal Power Plants (TPPs). Therefore default emission factors for all categories, excluding coal combustion at the TPPs, were used according to the IPCC Revised Guidelines [6].

Data on mechanical and chemical coal underburning from № 3-the operative reporting form were used for developing national carbon oxidation factors for coal combustion at the TPPs in 1998-2004. The results of calculations of average weighted value for all Ukrainian TPPs are presented at the table A2.7. Value for 1990 was taken from [5].

Table A2. 7. Carbon oxidation factors for coal combustion at the TPPs in Ukraine

Fuel code according to 4-MTP statistical reporting form	Fuel type	1990	1998	1999	2000	2001	2002	2003	2004
001	Coal	0.960	0.957	0.953	0.953	0.958	0.965	0.965	0.964

Carbon oxidation factors presented at the table A.7 were used only for estimation of emissions from coal combustion in the category «Public Electricity and Heat Production». Default value of 0.98 for coal from the IPCC Revised Guidelines was used in other categories [6].

ANNEX 3. OTHER DETAILED DESCRIPTION OF THE METHODOLOGIES FOR THE SPECIFIC EMISSION OR REMOVAL SOURCE CATEGORY (IF IT IS APPROPRIATE)

A3.1 AGRICULTURE (SECTOR 4 CRF)

A3.1.1 Livestock characterization

The detailed livestock characterization for cattle, swine and poultry was developed according to the Good Practice Guidance and data available in Ukraine.

Livestock in Ukraine is divided on belonging to the agricultural enterprises or households. Agricultural enterprises are shared to the state, private, collective and other [10]. Livestock population at agricultural enterprises has been significantly decreased during the last years. Now the new private and cooperative enterprises are formed in Ukraine, but the majority of livestock is kept in households.

Activity data on livestock population by species and categories were obtained from the [2-5]. The State Committee on Statistics of Ukraine gives detailed information on livestock population by age and sex. But statistical division into the categories is not fully corresponding to the division that should be used for the inventory purposes. Livestock structure from statistical data is based upon the animal productivity and herd reproduction. Besides data are not complete, because summarized data on all livestock categories are not equal to the total livestock population. The State Committee on Statistics of Ukraine does not take into account some significant livestock categories.

Table A3.1 presents correspondence of cattle categories from the data of the State Committee on Statistics of Ukraine and categories, which were used in the current inventory.

Data on population of dairy cows at the agricultural enterprises for the period 1990-2004 were estimated by subtracting beef cows from the total cows population (without fattening cows) due to the lack of data in the State Committee on Statistics of Ukraine. Such categories as “Dairy cows, which are separated for calf suckling” and “Heifers from 2 years” were put to the dairy cows due to the similar characteristics used for emission calculation. The category “Beef and fattening cattle” was determined similarly. It was assumed that all cows from the category «Cows (without fattening cows)» in the households are dairy, because they are hold mainly for milk production [10].

Table A3.1. Correspondence of cattle categories from the data of the State Committee on Statistics of Ukraine and categories, which were used in the current inventory

Cattle categories from the data of the State Committee on Statistics of Ukraine		Cattle categories used in the current inventory	Category according to the Good Practice Guidance
Agricultural enterprises			
Heifers from 2 years		Dairy cows	Dairy cows
Cows (without fattening cows)	Dairy cows		
	Dairy cows, which are separated for calf suckling		
	Beef cows	Beef cows	Non-dairy cattle
Beef cattle (without cows)		Beef and fattening cattle	
Fattening cattle (without cows)			
Beef and dairy cows fattening		Beef and dairy cows fattening	
Calves up to 1 year		Calves up to 1 year	

Heifers from 1 to 2 years	Heifers from 1 to 2 years	
Breeding bulls	Breeding bulls	
Cattle, which is not included to the above mentioned categories	Other cattle	
Households		
Cows (without fattening cows)	Dairy cows	Dairy cows
Heifers from 2 years		
Heifers from 1 to 2 years	Heifers from 1 to 2 years	Non-dairy cattle
Breeding bulls	Breeding bulls	
Cattle, which is not included to the above mentioned categories	Other cattle	

Category «Calves up to 1 year » was included in the statistical reporting only in 2001. Calf population at the agricultural enterprises for 1990-2000 was estimated according to the structure of cattle herd in 2001-2004.

Cattle not included in statistics were considered in the category «Other cattle». Their amounts were calculated by subtracting all cattle categories used in the current inventory from the total population.

Table A3.2 presents correspondence of swine and poultry categories from the data of the State Committee on Statistics of Ukraine and categories, which were used in the current inventory.

Swine population is divided to 5 categories for agricultural enterprises and to 3 – for households. Amount of animals, which are not included in these categories, is quite significant. It is not correct to consider these animals among «Other swine».

Omitted categories include breeding boars and piglets from 2 to 4 months. Population of boars usually amounted to 1% from the total swine heads and was calculated on the basis of such assumption during the period 1990-2004. Other swine's were considered as piglets from 2 to 4 months. The amounts of breeding boars and piglets from 2 to 4 months in households were assumed of 1% and 22% from the total swine population [10]. The amount of fattening swine was estimated by subtracting of all categories used in the current inventory from the total population.

Table A3.2.Correspondence of cattle categories from the data of the State Committee on Statistics of Ukraine and categories, which were used in the current inventory

Animal categories from the data of the State Committee on Statistics of Ukraine	Animal categories used in the current inventory	Category according to the Good Practice Guidance
Agricultural enterprises		
Main sows	Main sows	Swine
Checked sows	Checked sows	
Replacement pigs from 4 months	Replacement pigs from 4 months	
Fattening swine	Fattening swine	
Piglets up to 2 months	Piglets up to 2 months	
Statistical data are not available	Breeding boars	
Statistical data are not available	Piglets from 2 to 4 months	
Mature hens and roosters	Hens and roosters	Poultry
Young hens and roosters		
Mature gooses	Gooses	
Young gooses		
Mature ducks	Ducks	
Young ducks		

Animal categories from the data of the State Committee on Statistics of Ukraine	Animal categories used in the current inventory	Category according to the Good Practice Guidance
Mature turkeys	Turkeys	
Young turkeys		
Other poultry	Other poultry	
Households		
Main sows	Main sows	Swine
Replacement pigs from 4 months	Replacement pigs from 4 months	
Piglets up to 2 months	Piglets up to 2 months	
Statistical data are not available	Piglets from 2 to 4 months	
Statistical data are not available	Breeding boars	
Statistical data are not available	Fattening swine	
Statistical data are not available	Hens and roosters	Poultry
Statistical data are not available	Gooses	
Statistical data are not available	Ducks	
Statistical data are not available	Turkeys	
Statistical data are not available	Other poultry	

Category «Piglets up to 2 months» was included in the statistical reporting for agricultural enterprises and households in 2000 and 1999 respectively. The amounts of piglets for the other years were estimated according to the structure of swine herd in 2001-2004.

Statistical data on poultry for the agricultural enterprises are provided by species (hens and roosters, gooses, ducks and turkeys). For the households only data on total poultry population are available from the State Committee on Statistics of Ukraine. This information is determined on the basis of inspection of individual holdings in rural areas. First poultry population in one household is estimated and then multiplied by the amount of households with poultry obtained from livestock census at January 1. Poultry population by species was estimated according to the poultry structure at households in 2000-2004 [24].

Annual data on livestock population at January 1 from the State Committee on Statistics of Ukraine were calculated on the basis of drove turnover for the previous year related to the current year. Drove turnover is complex of indicators characterizing livestock breeding. Sum of livestock population at the beginning of year and all incomings should be equal to the sum of livestock population at the end of year and all losses. The balance equation is as follows [25]:

$$N_b + E = Q + N_e,$$

where N_b and N_e - livestock population at the beginning and end of year;
E - all incomings (breeding, purchase, import from other regions);
Q - all losses (death, butchering, purchase, export to other regions).

Drove turnover in households is composed on the basis of inspection of individual holdings in rural areas and spread to all households [25]. Spread factor (K_1) in individual holdings is calculated as follows:

$$K_1 = \frac{H_{1j}}{H_{2j}},$$

where H_{1j} - livestock population of j type (the end of year) according to the inspection of households in rural areas;

H_{2j} - livestock population of j type (the end of year) in all households according to livestock census.

This spread factor for rotational period (from May to April) is used for each livestock species for all turnover items [25].

There are more than 6 million of households in Ukraine according to the information of the State Committee on Statistics of Ukraine. Annually 30% from this amount are surveyed. Inspection of all individual holdings is carried out every 5 years.

A3.1.2 Enteric Fermentation (category 4.A CRF)

Methane emissions from enteric fermentation of cattle were estimated according to Tier 2 approach from the Good Practice Guidance.

Methane emissions from enteric fermentation of other livestock (sheep, horses and swine) were estimated according to Tier 1 approach with default emission factors from the IPCC revised Guidelines IPCC. Methane emissions from poultry were not considered.

Emission factors for each cattle category were estimated in accordance with the Good Practice Guidance using data on gross energy intake and methane conversion factor (the fraction of gross energy, which is lost with methane emissions).

The following animal performance data were used to estimate gross energy intake: average weight, average weight gain per day, feeding situation, average milk production per day etc.

Average weight and average weight gain per day. Data on average weight and average weight gain per day for cattle were obtained from published sources [24, 27, 28]. Values of average weight gain per day were taken into account only for young growing animals (calves up to 1 year and heifers from 1 to 2 years), because mature animals are generally assumed to have no net weight gain or loss over an entire year. Average weight was assumed the same during the period 1990-2004 due to the lack of data. Default values for the average weight for the category "Other cattle" were used from the IPCC revised Guidelines IPCC (Table B-1).

Average weight loss per day. According to the Good Practice mature animals may lose weight in one season and gain in another season (in dependence on temperature and humidity). Besides cattle with high milk productivity as a rule lose weight in the beginning of lactation period.

Weight losses were not taken into account in the current inventory, because the State Committee on Statistics of Ukraine provides data for the whole year.

Mature weight. Values of mature weight were used in the calculations of gross energy intake for calves up to 1 year and heifers from 1 to 2 years. This value was calculated as average weight of cows by breeds [26, 27].

Average number of hours worked per day. Bullocks are used as draft animals in Ukraine from the cattle. But bullock population (0.1-0.5 thous. heads in 1990-2004) is negligible, so they were included in the category "Other cattle".

Feeding situation. Cattle are grazed at the open pastures during 165 days and housed during the other time (200 days) [28, 29]. Exception is made only for beef cattle (including cows) and fattening cattle (including cows), which are grazed at the closed pastures, as well as breeding bulls, which are not grazed. The combined system of grazing and stabling are used for bulls.

In connection with aforesaid the average weighted factors matched to feeding situation were calculated as follows:

$$C_{a_i} = \frac{(200 \cdot X_i + 165 \cdot Y_i)}{365},$$

where i – livestock category;

X_i - factor for stable livestock of category *i*;

Y_i - factor for grazing (closed and open pastures) livestock of category *i*.

Average milk production per day. The State Committee on Statistics of Ukraine provides data on average annual milk production from the one cow in agricultural enterprises and households [2, 3]. The average daily milk production was calculated by dividing the total annual milk production by 365 days according to the Good Practice Guidance.

Fat content in milk. Data on average fat content in milk are provided annually by the State Committee on Statistics of Ukraine [30].

Percent of females that give birth in a year. Percent of females that give birth in a year was calculated by the methodology of the State Committee on Statistics of Ukraine [25] based on the annual statistical data on calved and inseminated cows for agricultural enterprises and total number of dams at the beginning of the year [5]. The State Committee on Statistics of Ukraine does not provide such information for households, so inventory team has assumed the same data.

Feed digestibility. Default values of feed digestibility for dairy cows and non-dairy cattle for Eastern Europe were used [1] (Table A-1 and A-2).

Methane conversion rate. Fraction of gross energy in feed converted to methane is proportional to the cellulose content in feed and lays into the range 5-12% [31]. Methane conversion rate for Ukraine conditions was obtained from published sources and averaged to 6% [8]. This value is of good correspondence with default value recommended by the Good Practice Guidance for developed countries.

Table A3.3 presents some characteristics for dairy cows and calculated emission factors for agricultural enterprises and households in 1990-2004.

Changes in emission factors for dairy and beef cows during the time series are caused by changes in characteristics (fat content in milk, average milk production, percent of females that give birth in a year etc.), which were used for their estimation. Emission factors for dairy cattle in the households are constantly slightly higher than at the agricultural enterprises due to the higher productivity. Characteristics of other cattle categories (non-dairy cattle) are the same for agricultural enterprises and households, and emission factors are constant for the whole period (Table A3.4.).

At the beginning methane emissions from dairy cows were calculated separately for agricultural enterprises and households by multiplication of population and emission factor. Then emissions were summarized to obtain total emissions from dairy cows. Methane emissions from non-dairy cattle were calculated similarly. Trends of methane emissions from enteric fermentation for different livestock categories are presented at the Table A3.5.

The analysis of results evidenced that enteric fermentation of dairy and non-dairy cattle was the main methane emission source in this category. It accounted for averaged 94% from the total methane emissions in this category for the period 1990-2004. During the stated period methane emissions from dairy and non-dairy cattle were reduced by 56% and 81% correspondingly.

Amount of methane emissions is directly connected with livestock population. Economic crisis after disintegration of the USSR led to the shortening livestock population at the agricultural enterprises in Ukraine. Some increase of methane emissions from dairy and non-dairy cattle in 2001-2002 is explained by livestock population increase in the households.

Table A3.3. Some characteristics for dairy cows and calculated emission factors for agricultural enterprises and households

Indicators	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Dairy cows at the agricultural enterprises															
Average weight, kg	540	540	540	540	540	540	540	540	540	540	540	540	540	540	540
Average milk production per day, kg	8.06	7.31	5.96	5.75	5.56	5.23	4.67	3.81	4.51	4.71	4.35	5.67	6.02	5.60	6.78
Fat content in milk, %	3.48	3.45	3.37	3.38	3.37	3.35	3.38	3.36	3.41	3.43	3.47	3.49	3.49	3.49	3.52
Percent of females that give birth in a year, %	86.76	84.90	81.84	75.13	77.89	76.79	76.42	76.02	74.63	81.36	84.22	76.22	82.62	82.91	76.62
Gross energy intake, MJ/day	235.67	227.93	213.98	211.18	209.69	206.21	201.11	192.70	199.50	202.39	199.55	211.43	215.63	211.54	222.45
Emission factor, kg CH_4/head/year	92.74	89.70	84.21	83.11	82.52	81.15	79.14	75.83	78.51	79.65	78.53	83.21	84.86	83.25	87.54
Dairy cows in households															
Average weight, kg	540	540	540	540	540	540	540	540	540	540	540	540	540	540	540
Average milk production per day, kg	7.22	7.25	7.22	7.32	7.30	7.46	7.40	7.62	7.76	7.86	8.11	8.41	8.76	8.82	9.41
Fat content in milk, %	3.48	3.45	3.37	3.38	3.37	3.35	3.38	3.36	3.41	3.43	3.47	3.49	3.49	3.49	3.52
Percent of females that give birth in a year, %	86.76	84.90	81.84	75.13	77.89	76.79	76.42	76.02	74.63	81.36	84.22	76.22	82.62	82.91	76.62
Gross energy intake, MJ/day	227.64	227.33	225.87	226.08	226.20	227.32	227.05	228.83	230.58	232.53	235.74	237.81	242.06	242.68	247.95
Emission factor, kg CH_4/head/year	89.58	89.46	88.89	88.97	89.02	89.46	89.35	90.05	90.74	91.51	92.77	93.59	95.26	95.50	97.58

Table A3.4.Some characteristics for non-dairy cattle and calculated emission factors

Cattle category	Average weight, kg	Average weight gain per day, kg/head	Gross energy intake, MJ/day	Emission factor, kg CH_4/head/year
Calves up to 1 year	179	0.8	88.81	34.95
Beef and fattening cattle	500	-	123.53	48.61
Heifers from 1 to 2 years	345	0.4	125.46	49.37
Beef cows	649	-	160.9*	63.3*
Fattening dairy and beef cows	469	-	117.74	46.33
Breeding bulls	956	-	186.52	73.40
Other cattle	391	-	110.92	43.65

*Values for 2004.

Table A3.5.Methane emissions from enteric fermentation of different livestock species and categories, Gg

Year	Dairy cattle	Non-dairy cattle	Sheep	Goats	Horses	Swine
1990	908.42	625.32	63.16	2.61	13.29	29.14
1991	873.76	592.99	58.07	2.85	12.90	26.75
1992	808.83	551.27	52.77	3.20	12.72	24.26
1993	802.37	515.65	48.94	3.72	12.88	22.94
1994	771.51	445.45	38.33	3.91	13.25	20.91
1995	724.16	379.64	25.67	4.44	13.60	19.71
1996	652.04	317.22	17.54	4.26	13.56	16.85
1997	569.21	248.02	12.31	4.11	13.26	14.21
1998	543.90	224.53	9.580	4.13	12.98	15.12
1999	509.52	200.92	8.470	4.12	12.56	15.10
2000	468.51	174.05	7.700	4.55	12.62	11.47
2001	477.24	177.84	7.730	4.98	12.48	12.55
2002	467.58	174.43	7.600	5.17	12.31	13.80
2003	421.44	136.95	7.140	4.82	11.46	10.98
2004	399.11	120.54	7.000	4.47	10.63	9.690

A3.1.3 Manure Management (category 4.B CRF)

Methane emissions from manure management

Methane emissions from cattle, swine and poultry manure were calculated according to Tier 2 approach from the Good Practice Guidance by multiplication of volatile solid excretion rates, maximum CH_4 producing capacity for the manure and average weighted methane conversion factors.

Emissions from other livestock species (goats, sheep and horses) were calculated according Tier 1 approach with use of default emission factors from the IPCC Revised Guidelines.

The Good Practice Guidance recommends developing national values for volatile solid excretion rates.

Taking into account available information in Ukraine, volatile solid excretion rate for livestock species/category i VS_i was calculated based on amount of manure excreted (in dry matter) and ash content in manure by formula:

$$VS_i = DM_i \cdot (1 - ASH_i),$$

where DM_i - amount of manure excreted by livestock of category i, kg dry matter/day;
ASH_i - ash content in manure of livestock category i.

Values of amount of manure excreted in dry matter and ash content in manure are normative data [14-16].

Values of volatile solid excretion rates and indicators used for their calculations are presented at the Table A3.6.

Table A3.6.Volatile solid excretion rates and indicators used for their calculations

Livestock species and categories	Amount of manure excreted in dry matter, kg/day	Ash content in manure, fraction	Volatile solid excretion, kg/day
Dairy cows	6.30	0.16	5.29
Beef cows	6.30	0.16	5.29
Beef and fattening cattle	3.58	0.16	3.01
Fattening dairy and beef cows	5.28	0.16	4.44
Calves up to 1 year	1.05	0.16	0.88
Heifers from 1 to 2 years	3.59	0.16	3.02
Breeding bulls	5.60	0.16	4.70
Other cattle	-	-	2.68*
Main sows	1.09	0.15	0.93
Checked sows	0.88	0.15	0.75
Replacement pigs from 4 months	0.76	0.15	0.65
Piglets up to 2 months	0.048	0.15	0.041
Piglets from 2 to 4 months	0.25	0.15	0.21
Fattening swine	0.73	0.15	0.62
Breeding boars	1.29	0.15	1.10
Hens and roosters	0.043	0.173	0.036
Geese	0.111	0.173	0.092
Ducks	0.062	0.173	0.052
Turkeys	0.124	0.173	0.10
Other poultry	-	-	0.10*

*Default values for Eastern Europe and developed countries from the IPCC Revised Guidelines were used (Table B.1 and B.7).

It should be noted that volatile solid excretion rates are the same for agricultural enterprises and households and are constant for the whole period.

Default values of maximum CH_4 producing capacity for the manure were used from the IPCC Revised Guidelines (Table B.1 and B.2, values for Eastern Europe and developed countries), because it is lack of information about national data.

Data on the portions of manure from cattle, swine and poultry managed in each manure management system in dynamics for 1990-2004 were obtained from the expert judgement for agricultural enterprises and households. Expert calculations for agricultural enterprises were based on information about livestock population and systems of manure removal.

Systems of manure removal at the agricultural enterprises in Ukraine are divided into the mechanical and hydraulic. Hydraulic systems in turn are divided into automatic runoff and water wash.

Manure in mechanical systems is removed by transporters, scrapers and tractors with further storage in bulk for a long time (in solid state).

Livestock is hold at the grille floor, when automatic runoff is used. Longitudinal and lateral channels with water are located under the floor. The gates are placed at the ends of channels. Gates are periodically opened and channels are washed by water from tanks [32].

Water wash systems can operate in two practices.

When the first practice is used, manure is manually removed from stalls to channels with water circulation. Water with manure is collected in manure storages. When the second practice is used, manure is flushed by hoses [33].

Water with manure is collected in manure storages. Then after segregation solid fraction remains in the manure storages, and liquid fraction is transported to anaerobic lagoons.

75% of manure from swine farms, which are removed by water, is transported to anaerobic lagoons. Other 25% is divided to the solid and liquid fractions. Liquid fraction contains 70% of organic matter and solid – 30%. Solid fraction is stored in bulk, and liquid fraction is treated aerobically (40%) or anaerobically (60%) [10].

Methodology of manure removal from swine farms depends on their productive capacity (livestock population), from cattle farms – on specializing (milk or fattening farms) and belonging to one or another property (collective and state farms etc.).

Methodologies of manure removal depending on productive capacity and specialization of agricultural enterprises are presented at the Table A3.7.

Portions of manure managed by the different manure management systems were estimated based on cattle and swine population at the separate agricultural enterprises and in whole country as well as data from the Table A3.7

Manure from poultry at the agricultural enterprises is removed mechanically and stored only in the solid state.

Table A3.7. Methodologies of manure removal for different agricultural enterprises

Livestock population and specialization	Methodologies of manure removal
Cattle at agricultural enterprises	
Milk farms	Mechanical
Specialized fattening farms	Automatic runoff
Swine at agricultural enterprises	
Up to 5 thous. heads	Mechanical
10-12 thous. heads	Mechanical and automatic runoff
24-36 thous. heads	Automatic runoff
54-108 thous. heads	Water wash

Animal manure in the households is stored as a rule in solid state together with bedding (straw, chips or peat). After few months of storage decomposed manure is used as a fertilizer [10]. Duration of grazing period amounts to 165 days in Ukraine [29, 30]. Approximately 50% of manure remains at the pastures according to the expert judgement. The same amount of poultry manure remains at soils.

Swine in Ukraine is housed during the whole year.

Portions of manure managed by the different manure management systems were estimated according to the expert judgement and presented at the Table A3.7.

Average weighted methane conversion factors for livestock species/category i MCF_{ai} were estimated from the portions of manure managed by the different manure management systems and corresponding methane conversion factors:

$$MCF_{ai} = \sum MS_{ij} \cdot MCF_j ,$$

where MS_{ij} - portion of manure from livestock species/category *i* managed by the manure management system *j*;

MCF_j - methane conversion factor for manure management system *j*.

Methane emissions from manure significantly depend upon the climate. Average temperature in Ukraine was below 15°C on the whole territory in Ukraine for the period 1990-2004 (data from Hydrometeorological Service). According to the classification of the IPCC Revised guidelines such climate is referred as cool.

Default CH_4 conversion factors for manure management from the Good Practice Guidance (Table 4.10 for cool climate) were used, because of lack of information about national data.

Methane emission factors from manure of different livestock species/categories are presented at the Table A3.9.

Methane emissions from manure management were estimated by multiplying of emission factor for each species/category of livestock in agricultural enterprises and households by their population according to Good Practice Guidance.

Then emissions were summarized to obtain total emissions from manure management. Trends of methane emissions from manure management for different cattle species/categories are presented at the Table A3.10.

The analysis of results evidenced that manure of dairy cows was the main methane emission source in this category. It accounted for averaged 50% from the total methane emissions in this category in 1990-2004.

During the period 1990-2004 methane emissions from manure of dairy cattle were reduced by 87%, non-dairy cattle – by 99%, swine – by 97% and poultry – 38%. Such reduction is explained by the shortening livestock population at the agricultural enterprises in Ukraine. Besides, the portion of manure managed in anaerobic lagoons significantly influences upon level of methane emissions (Table A3.1.8), because of maximal value of methane emission factor – 0.9 [1].

Some increase of methane emissions from swine manure management in 1998-1999 and 2001 - 2002 is explained by import of new breeds and breeding enhancement at the expense of subsidies.

Increase of methane emissions from poultry manure management in 2001-2004 and 2001- 2002 is explained by increase of quantity of broiler farms in Ukraine and subsidies.

Table A3.8. Portions of manure managed by the different manure management systems

Manure management system	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Cattle at the agricultural enterprises															
Anaerobic lagoons	0.203	0.175	0.175	0.175	0.140	0.126	0.070	0.021	-	-	-	-	-	-	-
Solid storage	0.442	0.450	0.450	0.450	0.460	0.464	0.480	0.494	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pasture/Range/Paddock	0.355	0.375	0.375	0.375	0.400	0.410	0.450	0.485	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Cattle in the households															
Solid storage	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pasture/Range/Paddock	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Swine at the agricultural enterprises															
Anaerobic lagoons	0.2823	0.2832	0.2385	0.1938	0.1482	0.0986	0.0982	0.0780	0.0782	0.0773	0.0555	0.0474	0.0474	0.0278	0.0274
Solid storage	0.6587	0.6608	0.7155	0.7752	0.8398	0.8874	0.8838	0.8970	0.8988	0.8897	0.8885	0.8996	0.9006	0.8952	0.8886
Aerobic treatment	0.0590	0.0560	0.0460	0.0310	0.0120	0.0140	0.0180	0.0250	0.0230	0.0330	0.0560	0.0530	0.0520	0.0770	0.0840
Swine in the households															
Solid storage	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Poultry at the agricultural enterprises															
Solid storage	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Poultry in the households															
Solid storage	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pasture/Range/Paddock	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Table A3.9. Methane emission factors for manure management of different livestock species/categories, kg CH_4/head/year

Livestock species/categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Cattle at the agricultural enterprises															
Dairy cows	59.22	51.48	51.48	51.48	41.81	37.94	22.46	8.91	3.11	3.11	3.11	3.11	3.11	3.11	3.11
Beef cows	41.95	36.47	36.47	36.47	29.61	26.87	15.91	6.31	2.20	2.20	2.20	2.20	2.20	2.20	2.20
Beef and fattening cattle	23.84	20.72	20.72	20.72	16.83	15.27	9.040	3.59	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Fattening dairy and beef cows	35.16	30.56	30.56	30.56	24.82	22.52	13.33	5.29	1.84	1.84	1.84	1.84	1.84	1.84	1.84
Calves up to 1 year	6.99	6.08	6.08	6.08	4.94	4.48	2.65	1.05	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Heifers from 1 to 2 years	23.90	20.78	20.78	20.78	16.87	15.31	9.06	3.60	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Breeding bulls	37.29	32.41	32.41	32.41	26.32	23.89	14.14	5.61	1.96	1.96	1.96	1.96	1.96	1.96	1.96
Other cattle	21.24	18.47	18.47	18.47	15.00	13.61	8.06	3.20	1.11	1.11	1.11	1.11	1.11	1.11	1.11
Cattle in the households															
Dairy cows	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11
Heifers from 1 to 2 years	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Breeding bulls	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96
Other cattle	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
Swine at the agricultural enterprises															
Main sows	26.58	26.67	22.62	18.58	14.46	9.95	9.91	8.07	8.09	8.00	6.00	5.27	5.27	3.47	3.43
Checked sows	21.46	21.53	18.26	15.00	11.67	8.040	8.00	6.52	6.54	6.46	4.85	4.26	4.26	2.80	2.77
Replacement pigs from 4 months	18.53	18.59	15.77	12.95	10.08	6.94	6.91	5.63	5.64	5.58	4.19	3.68	3.68	2.42	2.39
Piglets up to 2 months	1.17	1.17	1.00	0.82	0.64	0.44	0.44	0.36	0.36	0.35	0.26	0.23	0.23	0.15	0.15
Piglets from 2 to 4 months	6.10	6.12	5.19	4.26	3.32	2.28	2.27	1.85	1.86	1.84	1.38	1.21	1.21	0.80	0.79
Fattening swine	17.80	17.86	15.15	12.44	9.68	6.67	6.64	5.41	5.42	5.36	4.02	3.53	3.53	2.33	2.30
Breeding boars	31.46	31.56	26.77	21.99	17.11	11.78	11.73	9.56	9.58	9.47	7.11	6.24	6.24	4.11	4.06
Swine in the households															
Main sows	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02

Livestock species/categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Replacement pigs from 4 months	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
Piglets up to 2 months	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
Piglets from 2 to 4 months	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Fattening swine	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Breeding boars	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21
Poultry at the agricultural enterprises															
Hens and roosters	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
Geese	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072
Ducks	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Turkeys	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Other poultry	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078
Poultry in the households															
Hens and roosters	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
Geese	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.073	0.073
Ducks	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Turkeys	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Other poultry	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078

Table A3.10. Methane emissions from manure management by livestock species/categories, Gg

Year	Dairy cattle	Non-dairy cattle	Swine	Poultry	Horses	Sheep	Goats
1990	457.86	232.37	166.84	7.99	1.026	1.500	0.063
1991	387.30	192.33	150.45	7.93	0.997	1.379	0.068
1992	364.94	178.03	112.39	6.81	0.983	1.253	0.077
1993	354.61	164.26	83.00	6.03	0.995	1.162	0.089
1994	269.23	115.28	54.20	5.32	1.024	0.911	0.094
1995	221.20	88.99	33.44	4.83	1.051	0.610	0.107
1996	118.20	44.11	26.62	4.24	1.047	0.417	0.102
1997	44.36	13.76	16.89	4.07	1.024	0.293	0.099
1998	20.05	4.870	17.48	4.27	1.003	0.228	0.099
1999	18.45	4.410	17.15	4.17	0.970	0.201	0.099
2000	16.73	3.890	8.830	4.09	0.975	0.183	0.109
2001	16.52	4.040	9.080	4.49	0.964	0.184	0.120
2002	15.81	3.990	10.51	4.83	0.951	0.181	0.124
2003	14.23	3.180	6.140	4.62	0.886	0.170	0.116
2004	13.06	2.810	5.150	4.93	0.821	0.166	0.107

Nitrous oxide emissions from manure management

Nitrous oxide emissions for each manure management system were calculated according the Good Practice Guidance by multiplication of total N excretion from all livestock species/categories, fraction of manure that is managed in each manure management system and corresponding N_2O emission factor.

The division of cattle, swine and poultry into categories in accordance with belonging to agricultural enterprises or households and sex and age of animals, as well as portions of manure managed by the different manure management systems, were the similar to division for methane emissions calculation.

For other livestock species (sheep, horses and swine) default values of portions of manure managed by the different manure management systems were used from the IPCC revised Guidelines for the Eastern Europe.

The Good Practice Guidance recommends developing national values for N excretion rates from manure.

Taking into account available information in Ukraine, N excretion rate for livestock species/category i Nex_i was calculated from amount of manure excreted in dry matter and N fraction in dry-matter manure by formula:

$$Nex_i = DM_i \cdot f_{n_i} \cdot 365,$$

where DM_i - amount of manure excreted by livestock species/category i, kg dry matter/day;

f_{n_i} - N fraction in dry matter manure of livestock species/category i.

Values of amount of manure excreted in dry matter for different livestock species/categories were used the same as for estimation of methane emissions from manure management (Table A3.6).

Values of N fraction in dry matter manure of cattle, swine and poultry are standards [14-16].

Default values of N excretion with manure of sheep, horses and goats were used from the IPCC Revised Guidelines [1].

N fractions in dry matter manure and calculated N excretion rates for each species/category of cattle, swine and poultry are presented at the Table A3.11.

Table A3.11. N fraction in dry matter manure and calculated N excretion rates with manure of cattle, swine and poultry

Livestock species/categories	N fraction in dry matter manure.	N excretion, kg/head/year
Cattle at the agricultural enterprises		
Dairy cows	0.032	73.58
Beef cows	0.032	73.58
Beef and fattening cattle	0.032	41.81
Fattening dairy and beef cows	0.032	61.67
Calves up to 1 year	0.032	12.26
Heifers from 1 to 2 years	0.032	41.93
Breeding bulls	0.032	65.41
Other cattle	-	50.0*
Cattle in the households		
Dairy cows	0.032	73.58
Heifers from 1 to 2 years	0.032	41.93
Breeding bulls	0.032	65.41
Other cattle	-	50.0*
Swine at the agricultural enterprises		
Main sows	0.06	23.87
Checked sows	0.06	19.27
Replacement pigs from 4 months	0.06	16.64
Piglets up to 2 months	0.06	1.050
Piglets from 2 to 4 months	0.06	5.480
Fattening swine	0.06	15.99
Breeding boars	0.06	28.25
Swine in the households		
Main sows	0.078	31.03
Replacement pigs from 4 months	0.078	21.64
Piglets up to 2 months	0.078	1.370
Piglets from 2 to 4 months	0.078	7.120
Fattening swine	0.078	20.78
Breeding boars	0.078	36.73
Poultry at the agricultural enterprises		
Hens and roosters	0.018	0.283
Geese	0.007	0.284
Ducks	0.0095	0.215
Turkeys	0.0085	0.385
Other poultry	-	0.60*
Poultry in the households		
Hens and roosters	0.018	0.283
Geese	0.007	0.284
Ducks	0.0095	0.215

Livestock species/categories	N fraction in dry matter manure.	N excretion, kg/head/year
Turkeys	0.0085	0.385
Other poultry	-	0.60*

*Default values from the IPCC revised Guidelines IPCC were used.

It should be noted that N excretion rates are constant for the whole period.

According to norms [15] N excretion rates with manure of swine in the households are 30% higher in comparison with swine at the agricultural enterprises due to the difference in diets. Swine at the agricultural enterprises are mostly fed by concentrated fodder, while the households use multi-component fodder.

Default nitrous oxide emission factors for manure management systems were used from the Good Practice Guidance.

It should be noted that default emission factors were developed for the total amount of N excreted by livestock that indicated in their dimension. Therefore adjusting to the N losses as NH_3 and NO_x during manure storage was not carried out.

Total nitrous oxide emissions from manure management systems are presented at the Table A3.12.

Table A3.12. Total nitrous oxide emissions from manure management systems, Gg

Year	Anaerobic lagoons	Aerobic treatment	Solid storage	Other systems
1990	0.387	0.274	24.513	0.288
1991	0.325	0.234	23.862	0.267
1992	0.292	0.168	22.656	0.245
1993	0.267	0.101	22.065	0.231
1994	0.189	0.032	20.776	0.187
1995	0.145	0.033	19.289	0.135
1996	0.072	0.033	17.277	0.100
1997	0.020	0.034	15.113	0.077
1998	0.005	0.032	14.596	0.065
1999	0.005	0.045	13.738	0.060
2000	0.002	0.048	11.824	0.058
2001	0.002	0.050	12.513	0.059
2002	0.003	0.059	12.573	0.059
2003	0.001	0.065	10.933	0.056
2004	0.001	0.060	9.902	0.053

Nitrous oxide emissions from manure at the pastures were taken into account in the category "Agricultural Soils" according to the IPCC Revised Guidelines.

The analysis of results evidenced that manure in solid storages was the main nitrous oxide emission source in this category. It accounted for approximately 98% from the total nitrous oxide emissions in this category in 1990-2004.

During the period nitrous oxide emissions from manure management systems "Anaerobic lagoons", "Aerobic treatment", "Solid storage" and "Other systems" were reduced by 99%, 78%, 60 and 82%. Such reduction is explained by the shortening livestock population and change of agricultural management in Ukraine.

Some increase of nitrous oxide emissions 2001- 2002 is explained by increase of cattle population in the households, as well as swine and poultry population.

A3.1.4 Rice Cultivation (category 4.C CRF)

Methane emissions from rice cultivation were calculated according to the Good Practice Guidance with use of data on annual rice harvested areas and amount of organic amendments applied obtained from the State Committee on Statistics of Ukraine [17, 18].

Statistical activity data on organic fertilizer application to rice from the State Committee on Statistics of Ukraine are not available for 1991-1992 and 1994-1995. So inventory team used interpolation. The amounts of organic fertilizer application to rice were assumed the same in 1991 and 1992 at the level of 11.3 t/hectares. The amounts of organic fertilizer application to rice in 1994 and 1995 were estimated from the data in 1993 and 1996 according to the following equations:

$$A = x - (x - y)/3,$$

$$B = A - (x - y)/3,$$

where A and B – organic fertilizer application to rice in 1994 and 1995 , t/hectare;
x and y – organic fertilizer application to rice in 1993 and 1996 , t/ hectare.

Default values from the Good Practice Guidance for seasonally integrated emission factor, scaling factor to account for the differences in water management regime and soil type, as well as scaling factors to account for amount of amendment applied were used.

According to the data from Crimea, Kherson and Odessa region rice fields are constantly flooded.

Only one harvest of above mentioned crop is gathered in Ukraine during the year. Solonetzic and chestnut - solonetzic soils are used for rice cultivation. The main sorts of rice in Ukraine are Ukraine-96, Dneprovsky, Antey etc. Organic fertilizers in form of compost are used. Compost contains manure with bedding (straw, peat, chips and so on), which was previously stored (2-3 months or longer) and significantly rotted through. According to the Good Practice Guidance compost is referred as fermented fertilizer (non-fermented fertilizer is fresh manure).

CH_4 emissions from fermented amendments are significantly lower than non-fermented amendments because they contain much less easily decomposable carbon. According to the Good Practice Guidance (comment to the Table 4.21) the amount of amendment applied was divided by 6 because of use of fermented amendments.

The amounts of organic amendments in 1996-2004 with adjusting for rermented fertilizers were less than 1 t/hectare. The table 4.21 does not include scaling factors for such small values. So the minimal value of range of scaling factor 1,5 equal 1 was used.

Table A3.13 presents rice harvested areas, organic amendments, scaling factors and methane emissions from rice cultivation.

Table A3.13. Methane emissions from rice cultivation

Year	Harvested areas, thous.hectares	Organic amendments, t/hectare	Applied organic amendments adjusted for fermented fertilizers, t/hectare	Scaling factor	CH_4 Emissions, Gg
1990	27.7	11.3	1.9	1.5	8.31
1991	22.9	11.3	1.9	1.5	6.87
1992	24.3	11.3	1.9	1.5	7.29
1993	23.4	11.3	1.9	1.5	7.02
1994	22.4	8.80	1.5	1.5	6.72
1995	22.0	6.30	1.1	1.5	6.60
1996	23.0	3.70	0.6	1.0	4.60
1997	22.5	0.80	0.1	1.0	4.50
1998	20.7	1.40	0.2	1.0	4.14
1999	21.9	1.50	0.3	1.0	4.38
2000	25.2	0.80	0.1	1.0	5.04
2001	18.8	2.30	0.4	1.0	3.76

Year	Harvested areas, thous.hectares	Organic amendments, t/hectare	Applied organic amendments adjusted for fermented fertilizers, t/hectare	Scaling factor	CH_4 Emissions, Gg
2002	18.9	1.00	0.2	1.0	3.78
2003	22.4	0.20	0.03	1.0	4.48
2004	21.3	0.66	0.1	1.0	4.26

Methane emissions from rice cultivation have decreased by 49% in the period 1990-2004 due to reduction of harvested areas and organic fertilizer application.

The sharp decrease of emissions in 1996 compared to 1995 is explained by use of lowest scaling factor. The amount of organic fertilizers applied to rice in 1995 calculated by interpolation has supposed use of scaling factor at the level of 1.5, whereas scaling factor of 1 was used in 1996 (Table A3.13).

Emission increase in 2000 and 2003-2004 is explained by increase of harvested areas of rice.

A3.1.5 Agricultural Soils (category 4.D CRF)

Direct N_2O emissions from agricultural soils.

Direct nitrous oxide emissions were estimated for the following sources:

- synthetic fertilizers applied to soils;
- animal manure applied to soils;
- biological N-fixation by N-fixing crops cultivated;
- crop residues applied to soils;
- organic soils cultivation;
- animal manure on the pastures.

Default emission factors for all sources listed above were used (Table 4.12 and 4.17 from the Good Practice Guidance).

Synthetic fertilizers applied to soils. Nitrous oxide emissions from synthetic fertilizer application were calculated according to the Good Practice Guidance by multiplication of amounts of fertilizers applied to soils (data source - the State Committee on Statistics of Ukraine [18]) with adjusting for volatilization of NH_3 and NO_x and emission factor.

Data on synthetic fertilizer application from the State Committee on Statistics of Ukraine were not available for 1991-1992 and 1994-1995. Data for 1992, 1994-1995 were obtained from FAO website (http://faostat.fao.org). Data for 1991 are lacked in FAO information, so inventory team used interpolation between 1990 and 1992.

The default value of fraction that volatilizes as NH_3 and NO_x was used from the Good Practice Guidance.

Animal manure applied to soils. N_2O emissions from organic fertilizers applied to soils were adjusted for volatilization as N_2O, NO_x and NH_3 during manure storage according to the national references, where N losses during manure storage are provided [14, 15, 19], and Great Britain approach to inventory development [34].

Therefore nitrous oxide emissions from animal manure applied to the soils were estimated as follows:

$$V_{(m)} = \sum_j \sum_i \left\{ \left[\left(n_i \cdot Nex_i \cdot MS_{ij} \right) \left(1 - f_{gj} \right) - N_j \right] \cdot \left(1 - f_{m\,j} \right) \right\} \cdot EF_1 \cdot \frac{44}{28},$$

where n_i - livestock population of species/category i, heads;

Nex_i - annual N excretion rates with livestock manure of species/category *i*, kg N/animal-year;

MS_{ij} - fractions of manure of animal species/category *i* handled using manure management system *j* (except “Pasture/range/paddock” system);

f_{gj} - the fraction of N losses as NO_x and NH_3 from manure management system *j*;

N_j - nitrous oxide emissions in N units from manure management system *j*, kg N_2O-N/year;

f_{mj} - the fraction of N losses as NO_x and NH_3 from animal manure applied to soils after storage in manure management system *j*;

EF_1 - the emission factor for animal manure applied to soils, kg N_2O-N/kg N;

$\frac{44}{28}$ - stoichiometric ratio between N content in N_2O-N and N_2O.

It should be noted that amount of N excreted from manure on pastures was not considered in this subcategory to avoid double counting.

The division of cattle, swine and poultry into categories in accordance with belonging to agricultural enterprises or households, species (poultry) and sex and age of animals (cattle and swine), N excretion rates and fractions of manure per manure management systems were the same as for calculations of nitrous oxide emissions from manure management.

N losses as NH_3 and NO_x during manure storage were used from norms [14, 15, 19] and amounted to 30% and 3% for solid manure, 20% and 10% for liquid manure.

According to the default values of manure fractions managed by each manure management system [1], the part of manure from sheep, goats and horses are stored in other systems. Information about manure state (solid or liquid) is not available, so the average values of N losses were calculated: 25% - for manure storage and 6.5% - for manure application. These values regard with the manure storage duration six months. After such period manure is applied to soils to avoid deteriorating manure quality. The main nitrogen losses (over 70%) are occurred during the first ten days of manure storage.

Biological N-fixation by N-fixing crops cultivated. The Tier 1b approach from the Good Practice Guidance was used for emission estimation from biological N-fixation. N_2O emissions for each crop were estimated by multiplication of the data about legumes croppage obtained from the State Committee on Statistics of Ukraine [17], the residue to crop product mass ratio, nitrogen and dry matter fraction in aboveground biomass and on emission factor.

State Committee on Statistics of Ukraine gives data on production of N-fixed crops with moisture content. That is why dry matter fractions were used for estimation of N_2O emissions. Inventory team considered such N-fixed crops as soybean, pea, forage beans for grains, vetch and perennial grasses for hay and seeds (lucerne, clover and sainfoin).

The residue/crop product mass ratio, nitrogen and dry matter fraction in aboveground biomass were obtained from the published data [20-22] and presented at the table A3.14.

It should be noted that residue/crop product mass ratios for vetch and perennial grasses are omitted, because all stubbles are harvested as crop product.

Table A3.14. Nitrogen and dry matter fraction in aboveground residues of N-fixed crops and residue/crop product ratios

N-fixed crops	Nitrogen fraction in aboveground residues	Dry matter fraction in aboveground residues	Residue/crop product ratio
Pea	0.0125	0.80	1.7
Vetch	0.0125	0.84	-

N-fixed crops	Nitrogen fraction in aboveground residues	Dry matter fraction in above-ground residues	Residue/crop product ratio
Soybean	0.0120	0.88	1.1
Perennial grasses for hay	0.0190	0.84	-
Perennial grasses for seeds	0.0190	0.84	-
Forage beans for grains	0.0125	0.86*	2.1*

* Default values from the Good Practice Guidance (Table 4.16).

Crop residues applied to soils. Nitrous oxide emissions were estimated by multiplying of N amount in crop residues applied to soils by the emission factor.

Amount of crop residues returned to soils was estimated according to national methodology [23] on the basis of data on crop productivity. This methodology is based on the long-continued study of biomass residues for non-chernozem and steppe lands of the European part of the USSR under the different ecological conditions and yield levels.

The advantage of this methodology is taking into account not only mass of stubbles but also the mass of roots and therefore the amount of nitrogen in crop residues is estimated more completely. For each crop the amount of stubbles and roots applied to soils per 1 hectare was multiplied by corresponding nitrogen fractions and then by total harvested area to obtain the total amount of nitrogen in crop residues returned to soils.

Nitrous oxide emissions from crop residues applied to soils were calculated as follows:

$$V_{(cr)} = \sum_i \left[(c_i P_i + d_i) \cdot f_{ai} + (x_i P_i + y_i) \cdot f_{ri} \right] \cdot S_i \cdot EF_1 \cdot \frac{44}{28},$$

where c_i and d_i - linear regression factors for stubbles of crop *i*;

P_i - crop productivity for crop *i*, centner/hectare;

f_{ai} - nitrogen fraction in stubbles of crop *i*;

x_i and y_i - linear regression factors for roots of crop *i*;

f_{ri} - nitrogen fraction in roots of crop *i*;

S_i - harvested area for crop *i*, hectares;

EF_1 - nitrous oxide emission factor for crop residues, kg N_2O-N/kg N;

$\frac{44}{28}$ - stoichiometric ratio between N content in N_2O-N and N_2O.

It should be noted that only crop residues (stubbles and roots) returned to soils were taken into consideration, because by-products (straw) are usually used as forage for the cattle.

Data on linear regression factors for soybean, forage bean, spring rye, rice, sorghum and rape were not available in the methodology [23]. So the data on similar crops were used (for soybean, forage bean and rape – data on pea, for spring rye – data on winter rye, for rice – data on barley, for sorghum– data on millet).

Values of crop productivity and harvested areas were taken from the State Committee on Statistics of Ukraine [17].

Fractions of nitrogen in stubbles and roots of plants were obtained from published data [20, 21] and are presented at the table A3.15.

Table A3.15. Fractions of nitrogen in crop residues

Plants	Nitrogen fraction in stubbles	Nitrogen fraction in roots *
Winter wheat	0.0045	0.0075
Spring wheat	0.0065	0.0080

Plants	Nitrogen fraction in stubbles	Nitrogen fraction in roots *
Winter rye	0.0045	0.0075
Spring rye	0.0056	0.0075
Winter and spring barley	0.0050	0.0120
Oats	0.0060	0.0075
Millet	0.0050	0.0075
Buckwheat	0.0080	0.0085
Maize for grains	0.0075	0.0100
Rice	0.0067	0.0120
Sorghum	0.0080	0.0075
Pea	0.0125	0.0170
Vetch	0.0125	0.0170
Soybean	0.0120	0.0170
Perennial grasses for hay	0.0190	0.0210
Perennial grasses for seeds	0.0190	0.0210
Forage beans for grains	0.0125	0.0170
Sugar beet	0.0140	0.0120
Sunflower	0.0075	0.0100
Potato	0.0180	0.0120
Vegetables	0.0035	0.0100
Forage roots	0.0130	0.0100
Fibre flax	0.0050	0.0080
Winter and spring rape	0.0070	0.0170
Annual grasses for hay	0.0110	0.0120

*Data on N content in roots of soybean, forage bean, spring rye, rice, sorghum and rape were not available. According to the Good Practice Guidance the data on similar crops were used (for soybean, forage bean and rape – data on pea, for spring rye – data on winter rye, for rice – data on barley, for sorghum– data on millet).

Organic soils cultivation. Nitrous oxide emissions from cultivation of histosols were estimated by multiplication of cultivation areas and emission factors according to the Good Practice Guidance.

The State Committee on Land Resources Data gives data on cultivated histosols area only for 1995. Besides for the period 1990-2004 data about total area of agricultural grounds (including histosols) are available. Hence the fraction of cultivated organic soils areas in the total areas of agricultural grounds was estimated in 1995. Data on organic cultivated areas for the other years were calculated by multiplying total cultivated areas with this fraction.

Animal manure on the pastures. Nitrous oxide emissions from animal manure grazing were calculated according to the Good Practice Guidance similarly to other manure management systems.

Indirect nitrous oxide emissions from nitrogen use in agriculture

Indirect nitrous oxide emissions were estimated for the following sources:

- Atmospheric deposition of nitrogen as NH_3 and NO_x on soils;
- Leaching/runoff of applied or deposited nitrogen.

Default emission factors for all sources listed above were used (Table 4.18 from the Good Practice Guidance).

Atmospheric deposition of nitrogen as NH_3 and NO_x on soils. Nitrous oxide emissions from atmospheric deposition of nitrogen as NH_3 and NO_x on soils were calculated according to the Tier 1a approach of the Good Practice Guidance but with adjusting for volatilization of N_2O, NH_3 and NO_x during manure storage.

Nitrous oxide emissions from atmospheric deposition of nitrogen compounds such as NH_3 and NO_x $V_{(v)}$ were estimated as follows:

$$V_{(v)} = \left\{ N_s f_s + \sum_j \sum_i \left[(n_i \cdot Nex_i \cdot MS_{ij})(1 - f_{gj}) - N_j \right] f_{mj} + \sum_i (n_i \cdot Nex_i \cdot MS_{pi}) f_{mp} \right\} EF_4 \frac{44}{28},$$

where N_s - the total amount of synthetic fertilizer applied to soils, kg/year;

f_s - fraction of nitrogen losses as NH_3 and NO_x from synthetic fertilizers applied to soils;

n_i - livestock population of species/category *i*, heads;

Nex_i - N excretion rates with manure of livestock species/category *i*, kg N/animal-year;

MS_{ij} - fractions of manure of animal species/category *i* handled using manure management system *j* (except “Pasture/range/paddock” system);

f_{gj} - the fraction of N losses as NO_x and NH_3 from manure management system *j*;

N_j - nitrous oxide emissions in N units from manure management system *j*, kg N_2O-N/year;

f_{mj} - the fraction of N losses as NO_x and NH_3 from animal manure applied to soils after storage in manure management system *j*;

MS_{pi} - the fraction of livestock manure of species/category *i* at the pasture/range/paddock;

f_{mp} - the fraction of N losses as NO_x and NH_3 from pasture/range/paddock;

EF_4 - nitrous oxide emission factor for atmospheric deposition of nitrogen as NH_3 and NO_x, kg N_2O-N/kg N;

$\frac{44}{28}$ - stoichiometric ratio between N content in N_2O-N and N_2O.

Leaching/runoff of applied or deposited nitrogen. Nitrous oxide emissions from leaching/runoff of applied or deposited nitrogen were calculated according to the Good Practice Guidance but with adjusting for volatilization of N_2O, NH_3 and NO_x during manure storage.

Nitrous oxide emissions from nitrogen leaching/runoff $V_{(L)}$ were estimated as follows:

$$V_{(L)} = \left\{ N_s + \sum_j \sum_i \left[(n_i \cdot Nex_i \cdot MS_{ij})(1 - f_{gj}) - N_j \right] + \sum_i (n_i \cdot Nex_i \cdot MS_{pi}) \right\} f_L \cdot EF_5 \frac{44}{28},$$

where the total amount of synthetic fertilizer applied to soils, kg/year;

n_i - livestock population of species/category *i*, heads;

Nex_i - N excretion rates with manure of livestock species/category *i*, kg N/animal-year;

MS_{ij} - fractions of manure of animal species/category *i* handled using manure management system *j* (except “Pasture/range/paddock” system);

f_{gj} - the fraction of N losses as NO_x and NH_3 from manure management system *j*;

N_j - nitrous oxide emissions in N units from manure management system *j*, kg N_2O-N/year;

MS_{pi} - the fraction of livestock manure of species/category *i* at the pasture/range/paddock;

f_L - the fraction of nitrogen losses through leaching and runoff;

EF_5 - the emission factor for leaching/runoff, kg N_2O-N/kg N;

$\frac{44}{28}$ - stoichiometric ratio between N content in N_2O-N and N_2O.

The default values of fractions of N losses through leaching and runoff were used from the Good Practice Guidance.

Direct and indirect N_2O emissions from agricultural soils are presented at the table A3.16.

Direct nitrous oxide emissions were accounted for upon the average 72% from the total emissions in this category in 1990-2004.

Economic fall after the USSR disintegration led to the reduction of application of synthetic fertilizers and livestock population in Ukraine. Therefore nitrous oxide emissions from application of synthetic and organic fertilizers, animal manure at the pastures, as well as nitrogen atmospheric deposition, leaching/runoff, were also decreased.

Some increase of N_2O from organic fertilizer use, nitrogen atmospheric deposition, leaching/runoff in 2001-2002 was explained by the growth of cattle population in the households, as well as the growth of swine and poultry population.

Table A3.16. Direct and indirect N_2O emissions from agricultural soils, Gg

Year	Synthetic fertilizers	Animal manure application as fertilizer	N-fixation	Crop residues applied to soils	Cultivation of histosols	Animal manure at the pastures	Atmospheric deposition of nitrogen	Nitrogen leaching/runoff
1990	31.54	14.21	3.45	18.05	2.008	19.15	5.32	37.19
1991	27.60	13.33	2.95	16.52	2.005	19.14	4.91	33.98
1992	23.65	12.47	3.32	16.04	2.003	18.30	4.43	30.48
1993	17.61	11.94	3.18	16.84	2.001	17.87	3.82	25.96
1994	13.68	10.60	2.70	14.49	2.000	17.02	3.30	22.15
1995	11.05	9.500	2.16	14.77	2.000	15.58	2.87	19.15
1996	6.580	7.960	1.71	11.84	1.999	14.51	2.28	14.79
1997	7.300	6.560	1.68	13.65	1.999	13.01	2.13	13.82
1998	7.170	6.190	1.59	11.83	1.998	12.30	2.03	13.23
1999	5.780	5.840	1.22	11.30	1.998	11.37	1.80	11.74
2000	3.950	5.020	1.13	11.63	1.998	10.52	1.53	9.680
2001	5.630	5.300	1.33	13.52	1.998	10.62	1.70	11.02
2002	5.530	5.340	1.21	13.39	1.997	10.36	1.67	10.88
2003	4.810	4.640	1.04	10.96	1.996	9.160	1.46	9.520
2004	6.460	4.210	1.38	14.59	1.995	8.410	1.52	10.07

The large levels of N_2O emissions from synthetic fertilizers use in 1997-1998 and 2001-2004 were caused by the increase of the volumes of fertilizers application.

The increase of N_2O emissions from N-fixation in 2001 and 2004 is explained by high level of harvested pea and perennial forage plants.

Nitrous oxide emissions from crop residues are directly depended upon the productivity and harvested areas. The growth of emissions in this category in 1997 and 2001-2002 is explained by the increase of harvested areas of winter wheat and some other grain crops. The growth of emissions in 2004 is explained by the high levels of productivity of grain, legumes and other crops.

A3.2 Land-Use, Land-Use Change and Forestry (sector 5 CRF)

11.1.2 A3.2.1 Land-Use Categories and Soil Types Classification

In order to develop GHG inventory in LULUCF sector it is necessary to adjust classification of land-use categories from national statistics with categories recommended by IPCC.

6-zem statistical reporting form is used for accounting land-use categories by the State Committee on land resources in the national statistics. The appropriate instruction has been developed for filling up this form [2]. Classification of lands according to the "ECC Standard statistical classification of land-use" is accepted within this document, because this classification is closed by land-use type and kind of economic activity. Table A3.17 presents definitions of land-use categories.

Table A3.17. Classification of lands according to 6-zem statistical reporting form

Column in 6-zem	Category name	Definition of category
3	Lands of agricultural purposes, total	Lands granted for the production of agricultural produce, conducting of agricultural activities (lands under farm buildings and yards , farm roads and trails, field shelter belts[5] and other protective plantings); lands in the meliorative construction or productivity restoration state; lands temporarily in conservation, other lands (mounds, pits, ditchs), as well as agricultural lands at the other land-use categories.
4	Agricultural lands, total	Agricultural lands systematically used for agricultural production. Arable lands, perennial plantations, hayfields, pastures, and fallows are included in this category (columns 5+6+7+11+12)[6].
5	Arable lands	Systematically used for annual and perennial crops, set at rest lands, greenhouses, excluding rangelands and pasture lands and garden row-spacing, which is used for crops. This category does not include rangelands and pasture lands, which are ploughed for their improvement and continuously used for forage plantations and garden row-spacing.
6	Fallows	Lands, which were cultivated previously, but are not cultivated more than one year and prepared for setting at rest.
7	Perennial plantations, total	Lands, which is covered by artificial plantations for fruit production, technical and medicine purposes
8	Gardens	Anthropogenic perennial plantations for fruit production
11	Hayfields	Agricultural lands, which are systematically used for hay production, including areas with less than 20% of tree and bush vegetation.

[5] These lands were considered in the category "Cropland" taking into account negligible value and lack of detailed statistical data.

[6] These data were not used for the calculation of GHG emissions/removals in LULUCF sector, because components of this column were used.

Column in 6-zem	Category name	Definition of category
12	Pastures	Agricultural lands, which are systematically used livestock grazing, including areas with less than 20% of tree and bush vegetation.
21	Forest land and other areas covered by forests, total, including	Lands covered by trees and bushes and lands used for forestry (columns 22 (forest land, total)+28). Forest land and other lands covered by forests in the other land categories, are considered in this category Agricultural lands, wetlands and green plantations in settlements are not considered in this category.
28	Bushes	Lands covered by bushes (50 cm – 7 m).
34	Settlements, total	All lands, which are occupied by industrial enterprises, houses, roads, mines and other buildings constructed for human activities, including services. Sum of columns: • 35 – single and two storey household buildings; • 36 – three and more storey household buildings; • 37 – industrial activity; • 38 – opened mining; • 42 - commercial buildings; • 43 – institutional buildings; • 44 – land of combined use not included in other kinds; • 45 – transportation; • 50 – technical infrastructure; • 55 – recreation and other opened lands (columns 56 (зеленые насаждения общего пользования) + 57 (motorists) +58 (construction places) + 59 (lands parceling for construction) + 60 (hydraulic works) + 61 (streets) + 62 (cemeteries)).
39	Land under peat management	Land, where peat is extracted with transport lines, territory for services, excluding worked-out peat lands
56	Public green plantations	Lands covered by public green plantations (parks, gardens, squares, boulevards etc.) not included in the forest category.
63	Wetlands, total	Land that is continuously, temporal or partially covered by water or saturated by water .
66	Dry opened lands with specific vegetation	Lands, which are not cultivated and not covered by forests, but more than 25 % of area is covered tree plantations and bushes.
67	Opened lands with scarce vegetation or without vegetation	Unbuilt areas with scarce vegetation or without vegetation, namely rock areas, drafts and other bare soils (solonchak and so on).
74	Data on artificial channels	Fully artificial channels, which were constructed for stream force use, rational water use irrigation and other purposes, as well as drainage water-drip channels.
77	Data on artificial lakes	Artificial lakes, which were constructed for potable water supply, electricity production, irrigation and livestock, including the part of natural or artificial water turnover with capacity more than 1 mln m^3.

Table A3.18 presents aggregation of categories in 6-zem statistical reporting form to categories recommended by the IPCC methodology [1].

Table A3.18. Aggregation of categories in 6-zem statistical reporting form to categories recommended by the IPCC methodology [1] (2003)

№	IPCC land-use category, 2003	Columns from 6-zem
1.	Forest land	21; 28
2.	Cropland	5; 6; 7; 8
3.	Grassland	11; 12
4.	Wetlands	39; 63; 74; 77
5.	Settlements	34; 56

6.	Other land[7]	66; 67

Carbon stock change in carbon pools is occurred during conversion of lands. National statistics does not provide data on land-use conversion areas and the kind of conversion. That is why some assumptions about land-use conversion were used on the basis of analysis of land-use area trends.

Land-use change trends in LULUCF sectors are presented at the Figure A3.1.

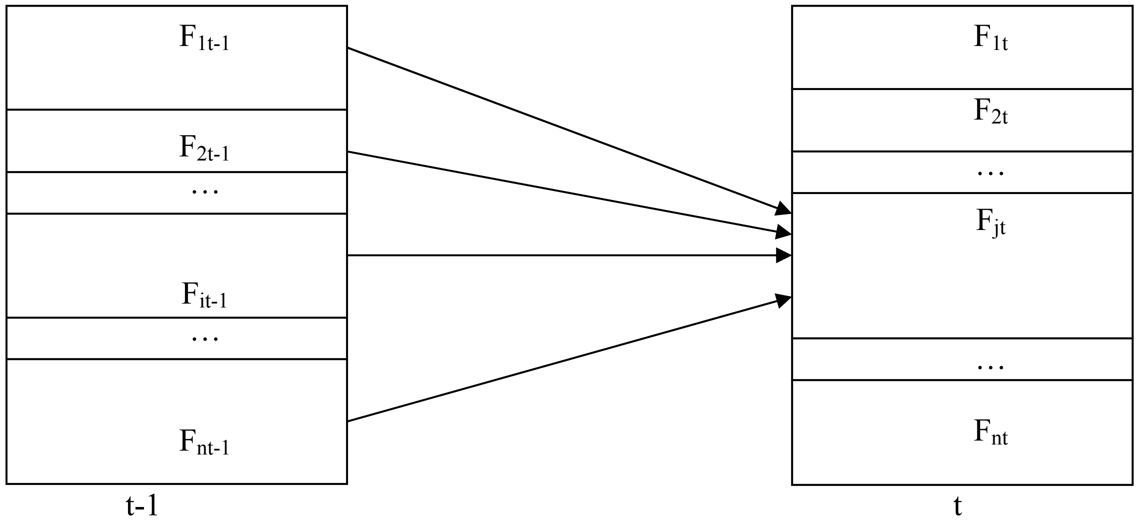

Figure A3.1. Possible change of land-use category

The main task of defining changes in land-use categories in LULUCF sector is assessment of $\Delta F_{i,j,t}$ – land area of category *i*, which is converted to category *j* in the period from *t*-1 to *t*. It is assumed for the determination of ΔF(i,j,t) that all land of category *i* remains firstly in this category. If land area of category *i* was shortened, residue was distributed among other categories, which were increased, in proportion with relative decrease of land area of category i and increase of of land area of category j in the period from *t*-1 to *t*. This assumption is expressed in the following formula:

$$\Delta F_{i,j,t} = \begin{cases} F_{i,t-1}, \ for \ \ i=j, \ while \ \ F_{i,t-1} < F_{i,t}; \\ F_{j,t}, \ for \ \ i=j, \ while \ \ F_{i,t-1} \geq F_{i,t}; \\ 0, \ for \ \ i \neq j, \ while \ \ F_{i,t-1} < F_{i,t}; \\ 0, \ for \ \ i \neq j, \ while \ \ F_{j,t-1} > F_{j,t}; \\ k_i\left(F_{j,t} - F_{j,t-1}\right), \ \ for \ \ i \neq j, \ while \ \ F_{i,t-1} > F_{i,t} \cap F_{j,t} > F_{j,t-1}, \end{cases},$$

where $F_{i,t-1}$, $F_{i,t}$, $F_{j,t-1}$, $F_{j,t}$ – land areas of categories *i* and *j* respectively for the time *t*-1 and *t*;

k_i - relative decrease of land area of category i in the period from *t*-1 to *t*.

Factor k_i is calculated according to the formula:

[7] Besides land types listed in the Table 7.1, all lands not included to the other categories were considered in this category during inventory estimations to form the total area of Ukraine.

$$k_i = \frac{F_{i,t-1} - F_{i,t}}{\sum\limits_{i:F_{i,t-1} > F_{i,t}} \left(F_{i,t-1} - F_{i,t}\right)}.$$

Table A3.19 gives the example of calculations to determine land areas, which were converted from the one category to another during *t* year.

Table A3.19. Determination of land areas, which were converted from the one category to another during t year

Category i	Land area in t-1, thous. ha	Land area in t, thous. ha	Land area change, km²	Factor k_i	Land areas, which were converted from the category i to the category j							Total
					j=1	j=2	j=3	j=4	j=5	j=6	j=7	
1. Forest land	10357.80	10494.30	136.50	0.00	10357.80	0.00	0.00	0.00	0.00	0.00	0.00	10357.80
2. Cropland	41852.90	41675.50	-177.40	0.52	71.37	41675.50	0.00	26.61	0.00	79.42	0.00	41852.90
3. Grassland	1188.70	1062.90	-125.80	0.37	50.61	0.00	1062.90	18.87	0.00	56.32	0.00	1188.70
4. Wetlands	934.90	985.80	50.90	0.00	0.00	0.00	0.00	934.90	0.00	0.00	0.00	934.90
5. Land covered by water	2418.60	2402.10	-16.50	0.05	6.64	0.00	0.00	2.48	2402.10	7.39	0.00	2418.60
6. Settlements	2313.10	2465.00	151.90	0.00	0.00	0.00	0.00	0.00	0.00	2313.10	0.00	2313.10
7. Other land	1288.80	1269.20	-19.60	0.06	7.89	0.00	0.00	2.94	0.00	8.77	1269.20	1288.80
Total	60354.80	60354.80	-339.30	1.00	41675.50	10494.30	2465.00	985.80	1062.90	1269.20	2402.10	60354.80

It is possible to take into account restrictions on land-use change from the one category to another in this methodology. These restrictions may be taken into consideration through use of weighted factors on the basis of expert judgement and international experience.

Information on character of land-use change (e.g. wood chopping, areas under different wood species etc. for gardens) is not available in the national statistics. Method based on assumptions about land use changes was used. As a result data on category «Cropland remaining cropland» were obtained, which were used to calculate carbon stock change in living biomass. Estimations were based on statistical data on land area in this category in the previous and current years. Percentage ratios between land areas of subcategories within «Cropland remaining cropland» were estimated on the basis of statistical data and then were used as constant area of the category «Cropland remaining cropland».

Possible distribution of directions of land-use change between categories are presented at the Table A3.20 Titles of land-use categories conform to the IPCC categories [1], order numbers are indicated according to the priority of land-use changes between categories.

Table A3. 20.Determination of the priority of land-use changes between categories

№	Land-use category according to the IPCC methodology (2003.), where	
	Area decreased	Area increased[8]

[8] Numbers of categories are placed according priority decrease

1.	Forest land	5	2	3	4	6
2.	Cropland	3	5	1	4	6
3.	Grassland	2	5	1	4	6
4.	Wetlands	3	1	2	5	6
5.	Settlements	1	6	2	4	3
6.	Other land	1	4	5	3	2

For example the first row in the table "Forest land"– "5-2-3-4-6" means that decreases of area in this category are occurred due to the transfer first of all to the category № 5 – «Settlements», if area of this category was increased. If not – to the category № 2 «Cropland», if area of this category was increased, if not – to the category № 3 «Grassland». If area of category «Grassland» was not increased – to the category №4 «Wetlands» and in the last place – to the category № 6 «Other land». These assumptions allow conforming land use changes between categories taking into account constant area of the territory of Ukraine (60354.8 thous. ha).

It is necessary to adjust national classification of soils with classification recommended in [1] for GHG inventory purposes. Climate and soil types directly influence upon management system, as well as potential carbon stock in soils and their reaction on cultivation type. So it is necessary to take into account climate type for developing GHG inventory in LULUCF sector. 9 climatic zones with different temperature and humidity regimes are delineated in the methodology [1] for GHG inventory preparation. Territory of Ukraine is located in warm temperate dry and wet zones. The major taxonomic classification of soils is associated with climate zones. Organic matter content in temperate zone depends upon granulometric composition and clay activity.

The territory of Ukraine should be quantitatively divided into warm temperate dry and wet zones with determination of soil types for GHG inventory in LULUCF sector. Visual analysis of agroclimatological maps gives possibility to distribute regions of Ukraine between climatic zones:

- Volhynia, Zhitomir, Transcarpathian, Ivano-Frankivsk, Lvov, Rivne, Ternopol, Khmelnitski and Chernivtsi regions are totally located in warm temperate wet zone;
- Approximately 33% of Vinnitsk, Kyiv, Sumy regions is located in warm temperate wet zone;
- Approximately 75% of Chernigivsk region is located in warm temperate wet zone.

Remaining territory of Ukraine is located in warm temperate dry zone.

Soil types by region were determined on the basis of information on physico-geographical characteristics of regions in Ukraine [3]. Distribution of soil types by climatic zone was developed on the basis of distribution of territory by climatic zones.

Information on matching of national soil types and soil types recommended in [1] is presented in [5].

Taking into account set forth above, the following distribution of soil types by clay activity level was used for inventory development in LULUCF sector in Ukraine:

- Soils with high activity clay in warm temperate wet climatic zone occupy 23781.5 thous. hectares (43.6% of the territory of Ukraine);
- Soils with high activity clay in warm temperate dry climatic zone occupy 20885.6 thous. hectares (38.29%);
- Sandy soils in warm temperate wet climatic zone occupy 3526.5 thous. hectares (6.47%);
- Sandy soils in warm temperate dry climatic zone occupy 726.8 thous. hectares (1.33%);
- Wetland soils in warm temperate wet climatic zone occupy 3344.90 thous. hectares (6.13%);

- Wetland soils in warm temperate dry climatic zone occupy 902.70 thous. hectares (1.66%);
- Organic soils in warm temperate wet climatic zone occupy 1371.10 thous. hectares (2.51%).

The development of soil type distribution is very complicated process, which lasted for ten years. So GHG inventory was developed with assumption of constant distribution of soil types.

The general approach recommended in [1] was used for inventory development in LULUCF sector– multiplication of activity data and carbon stock factor.

11.1.3 A3.2.2 Methodological Issues in Land-Use Category «Forest land»

GHG emissions/removals in the category "Forest land" were estimated for the two subcategories: a) Forest land remaining Forest land (FF) for the long time and b) Land Converted to Forest land (LF).

Living biomass, dead organic matter and soils were considered as carbon pools in the subcategory "Forest land remaining Forest land". Taking into account assumptions mentioned above and lack of initial data estimations for dead organic matter and soils were conducted according to Tier 1 approach [1].

Carbon stock change in living biomass was estimated by equation A.5.3 [1]:

$$\Delta C_{LB} = \Delta C_G - \Delta C_L$$

where: ΔC_G – annual increase in carbon stocks due to biomass growth, tonnes C/yr;

ΔC_L – annual decrease in carbon stocks due to biomass loss, tonnes C/yr.

Annual increase in carbon stocks due to biomass growth for forest land remaining forest land was estimated taking into account wood species and climatic zones:

$$\Delta C_G = \sum_{ij} \left(A_{ij} \cdot G_{ij} \right) \cdot CF \quad ,$$

where: *Aij* – area of forest land remaining forest land, by forest type (i = 1 to n) and climatic zone (j = 1 to m), h;

Gij – average annual increment rate in total biomass in units of dry matter, by forest type (i = 1 to n) and climatic zone (j = 1 to m), tonnes d.m./ha/yr;

CF – carbon fraction of dry matter (default = 0.5), tonnes C /tonne d.m. [1].

Average annual increment rate in total biomass (G_{ij}) was estimated as follows:

$$G_{ij} = G_W \cdot (1 + r),$$

где G_W – average annual aboveground biomass increment, tonnes d.m./ha/yr;

r – root-to-shoot ratio appropriate to increments, dimensionless.

Table A3.21 gives data on average annual aboveground biomass increment and root-to-shoot ratio appropriate to increments.

Data from state account of forest fund in January 1 1988, 1996 and 2002 were used for distribution of forest land by forest type and climatic zone. Linear interpolation was applied for other years in the period 1990-2004.

Table A3.21. Biomass increment by forest type and climatic zone for "Forest land remaining Forest land" (national data)

Forest type and climatic zone	Biomass increment	Root-to-shoot ratio
Polyesye		
Pine	3.60	0.16
Spruce	5.00	0.15
Other confinerous	4.20	0.14
Oak	3.30	0.16
Other hardwood broadleaf	3.10	0.14
Birch	3.40	0.12
Alder	3.50	0.12
Aspen	3.20	0.12
Other softwood broadleaf	3.10	0.12
Other wood	3.00	0.12

Forest type and climatic zone	Biomass increment	Root-to-shoot ratio
Wooded steppe		
Pine	3.40	0.16
Spruce	5.00	0.14
Other confinerous	3.50	0.14
Oak	3.20	0.16
Beech	4.00	0.14
Other hardwood broadleaf	3.80	0.15
Birch	3.30	0.12
Alder	3.40	0.12
Aspen	3.20	0.12
Other softwood broadleaf	3.10	0.12
Other wood	3.00	0.12
North Steppe		
Pine	2.60	0.17
Oak	3.00	0.17
Other hardwood broadleaf	2.80	0.15
Birch	3.20	0.12
Alder	3.30	0.12
Aspen	3.10	0.12
Other softwood broadleaf	3.00	0.12
Other wood	3.00	0.12
South Steppe		
Pine	2.40	0.17
Oak	3.00	0.17
Other hardwood broadleaf	2.80	0.15
Birch	3.10	0.12
Alder	3.20	0.12
Other softwood broadleaf	2.80	0.12
Other wood	2.80	0.12
Carpathian Mts		
Pine	3.40	0.15
Spruce	5.40	0.14
Other confinerous	5.00	0.14
Oak	3.40	0.15
Beech	4.20	0.15
Other hardwood broadleaf	4.00	0.14
Birch	3.40	0.12
Alder	3.50	0.12

Forest type and climatic zone	Biomass increment	Root-to-shoot ratio
Aspen	3.20	0.12
Other softwood broadleaf	3.00	0.12
Other wood	3.20	0.12
Crimea		
Pine	2.40	0.16
Other confinerous	2.20	0.15
Oak	2.20	0.17
Beech	2.80	0.15
Other hardwood broadleaf	2.50	0.14
Birch	3.10	0.12
Alder	3.20	0.12
Aspen	3.00	0.12
Other softwood broadleaf	2.80	0.12
Other wood	2.80	0.12
Bush (all zones)	0.4	1.25

Annual decrease in carbon stocks due to biomass loss was estimated as sum of commercial fellings and other losses:

$$\Delta C_L = L_f + L_{other},$$

where: ΔC_L – annual decrease in carbon stocks due to biomass loss in forest land remaining forest land, tonnes C/yr;

L_f – annual carbon loss due to commercial fellings, tonnes C/yr;

L_{other} – other annual carbon losses, tonnes C/yr.

Annual carbon loss due to commercial fellings was estimated as follows:

$$L_f = H \cdot \rho \cdot \tau,$$

where: H – annually extracted volume, m^3/ yr;

ρ – basic wood density in aboveground biomass, tonnes d.m./m^3;

τ – factor for converting volumes of extracted roundwood to total aboveground biomass, dimensionless.

Information on commercial felling in the forests of Ukraine from the data of State Committee on Forestry and national statistics was used for the estimation of biomass loss due to commercial fellings for the period 1990-2004 (Table A3.22).

Table A3.22. Commercial fellings, thous. m^3

Year	Commercial fellings, thous. m^3
1990	14127.8
1991	12061
1992	12514.2

1993	12497.2
1994	11782.5
1995	11651.3
1996	13782.0
1997	13546.7
1998	11521.1
1999	11244.2
2000	12735.9
2001	13365.4
2002	14692.1
2003	15953.3
2004	17300.4

Statistical data on commercial felling include total harvested wood (i.e., roundwood and wood waste) in units of cubic meters. Conversion factors for dry matter content – 1.15 and 0.5 – were used for accounting all biomass and for conversion from volume units to weight units taking into account basic density of wood. Default value of carbon fraction (default = 0.5) was assumed according [1].

Other carbon losses in managed forest land include losses from disturbances such as windstorms, pest outbreaks, or fires. In the specific case of losses from fire on managed forest land, including wildfires and controlled fires, non-CO_2 emissions from fires are also estimated.

Default methodology [1] for estimation of other carbon losses was used. The proposed generic method assumes complete destruction of forest biomass in the event of a disturbance; hence the default methodology addresses "stand-replacing" disturbances only.

Annual carbon losses from forest fires were estimated as follows:

$$L_{other} = A_{fires} \cdot B_W ,$$

where: A_{fires} –forest area affected by forest fires, ha.

B_W – average biomass stock of forest areas, tonnes d.m./ha.

The main sources of GHG emissions from forest fires are the following processes:

- Organic matter burning;
- Biological process of slow release of carbon due to decomposition of organic matter at the site of fire.

GHG emissions from forest fires depend upon organic matter volume, its composition and burning conditions. Differences in conditions of initiation and development of forest fires, their types and intensity essentially complicate the determination of total volumes of GHG emissions. Carbon emissions after forest fires were not taken into account, because management system is not changed and wood waste is removed during sanitary felling.

Burned organic matter was divided into three groups: aboveground, overground and belowground, which differ in burning conditions [6, 7]. Aboveground biomass (litter, either standing, lying on the ground) is a primary object of burning, overground (high underbrush, trunks and crowns) – the secondary object.

Forest fires were divided into upper, downstream and belowground fires.

The following information was used for emission estimations from forest fires [6,7]:

- Forest areas affected by upper, downstream and belowground fires (yf);
- Burned-out wood stock (Table A3.23)

Table A3.23. Forest areas affected forest fires and burned-out wood stock

Year	Forest areas affected forest fires, ha			Burned-out wood stock, m^3
	Upper	Downstream	Belowground	
1990	1366	1022	1	79909
1991	1042	665	10	38252
1992	3318	672	111	77758
1993	2415	712	51	174499
1994	6061	3432	537	391999
1995	1695	1416	26	147647
1996	7163	5466	42	315088
1997	1355	110	2	11850
1998	3208	1208	2	123360
1998	2896	2632	14	166721
2000	1386	232	2	20647
2001	1992	1770	3	139604
2002	4245	657	64	59625
2003	2409	359	49	20071
2004	536	37	2	1944

According to [6], volumes of aboveground combustible biomass fall within the range of 5-25 t/ha depending upon forest type. Average value of 8-12 t/ha for burnt biomass from downstream fires was assumed in view of mechanism of their spread. Upper and belowground fires as a rule lead to the death of stand, though firstly only part of wood is burned.

Volumes of burnt organic matter (without stand) is averaged 100 t/ha for belowground fires. Biomass losses total 10 t/ha for downstream fires, 10 t/ha plus burnt wood – for upper fires and 100 t/ha – for belowground fires. Carbon/Dry matter ratio 0.37 was used for downstream fires because mainly litter is burned.

Statistical data on areas and wood losses of upper fires were used assuming 70 % of wood losses from the total biomass losses. Biomass losses were estimated by multiplying wood losses with conversion factors (1.15 and 0.50) and portion of biomass losses (0.70). Default carbon content equals 0.5 [1].

Non-CO_2 (CH_4, CO, N_2O and NO_x) emissions from forest fires were also estimated. Methane and carbon monoxide were estimated through the portions of carbon released during burning. The total nitrogen content was estimated on the basis of N/C ratio [1] in dry matter (default value – 0.01). Emissions of N_2O and NO_x were calculated through the portions of this nitrogen.

Table A3.24 presents emission proportions for wood biomass burning [1].

Table A3. 24. Emission proportions for open wood biomass burning

Gas	Average value
CH_4	0.012
CO	0.06
N_2O	0.007
NO_x	0.121

CH_4 and CO emissions were calculated by multiplying released carbon with emission proportions for CH_4 and CO. CH_4 and CO emissions were multiplied with 16/12 and 28/12 respectively to obtain full molecular weight.

N_2O and NO_x emissions were calculated by multiplying released carbon with 0.01 for estimation total released nitrogen. Then this value was multiplied with emission proportions for N_2O and NO_x. N_2O and NO_x emissions were multiplied with 44/28 and 46/14respectively to obtain full molecular weight.

Finally GHG emissions were calculated as follows:

$$Q_{CH_4} = A \cdot B \cdot 16/12,$$

$$Q_{CO} = A \cdot B \cdot 28/12,$$

$$Q_{N_2O} = A \cdot B \cdot D \cdot 44/28,$$

$$Q_{NO_X} = A \cdot B \cdot D \cdot 46/14,$$

where Q – GHG emissions;
A – carbon released;
B – emission proportion;
D –N/C ratio.

GHG emissions from forest fires are presented at the Table A3.25.

Table A3.25. GHG emissions from forest fires, thous. t

Year	**Gas**			
	CH_4	N_2O	NO_x	CO
1990	0.40	0.06	0.01	0.10
1991	0.23	0.03	0.00	0.06
1992	0.58	0.08	0.01	0.14
1993	0.79	0.11	0.01	0.20
1994	2.25	0.32	0.04	0.56
1995	0.68	0.10	0.01	0.17
1996	1.80	0.25	0.03	0.45
1997	0.13	0.02	0.00	0.03
1998	0.66	0.09	0.01	0.16
1999	0.88	0.12	0.02	0.22
2000	0.16	0.02	0.00	0.04
2001	0.67	0.09	0.01	0.17
2002	0.53	0.07	0.01	0.13
2003	0.27	0.04	0.00	0.07
2004	0.04	0.01	0.00	0.01

CO_2 emissions from soil liming were not considered, because such activity is practically not applied for the forest lands.

N_2O emissions from fertilization and drainage of forest soils were not considered, because fertilization in forestry is negligible and data on drainage are lacked.

Calculations for "Land converted to Forest land" were similar to the "Forest land remaining Forest land. Peculiarities of forest plantations growth, soil changes, biomass death were taken into account, as well as the fact that GHG emissions were estimated for all forest land regardless of its age.

Table A3.26 gives data on average annual aboveground biomass increment and root-to-shoot ratio in the subcategory "Land converted to Forest land".

Table A3.26. Biomass increment by forest type and climatic zone for "Land remaining Forest land" (national data)

Forest type and climatic zone	Biomass increment	Root-to-shoot ratio
Polyesye		
Pine	3,1	1,20
Spruce	4,8	1,30
Other confinerous	3,4	1,20
Oak	2,5	1,25
Other hardwood broadleaf	2,4	1,24
Birch	2,6	1,15
Alder	3,8	1,15
Aspen	4,2	1,15
Other softwood broadleaf	4,0	1,15
Other wood	3,4	1,15
Wooded steppe		
Pine	2,5	1,20
Spruce	4,4	1,30
Other confinerous	3,4	1,20
Oak	2,6	1,25
Beech	1,6	1,22
Other hardwood broadleaf	2,0	1,20
Birch	2,6	1,20
Alder	3,8	1,20
Aspen	4,2	1,20
Other softwood broadleaf	4,0	1,20
Other wood	3,4	1,20
North Steppe		
Pine	2,0	1,22
Oak	1,4	1,27
Other hardwood broadleaf	1,5	1,25
Birch	2,5	1,21
Alder	3,6	1,21
Aspen	4,0	1,21
Other softwood broadleaf	3,8	1,20
Other wood	3,2	1,20
South Steppe		
Pine	1,6	1,22
Oak	1,2	1,28
Other hardwood broadleaf	1,4	1,25
Birch	2,4	1,20

Forest type and climatic zone	Biomass increment	Root-to-shoot ratio
Alder	3,5	1,20
Other softwood broadleaf	3,6	1,20
Other wood	3,2	1,20
Carpathian Mts		
Pine	2,4	1,20
Spruce	5,0	1,30
Other confinerous	4,8	1,20
Oak	1,6	1,25
Beech	1,8	1,22
Other hardwood broadleaf	1,5	1,20
Birch	2,6	1,20
Alder	3,8	1,20
Aspen	4,2	1,20
Other softwood broadleaf	4,0	1,20
Other wood	3,4	1,20
Crimea		
Pine	1,6	1,20
Oak	1,4	1,26
Beech	1,5	1,24
Other hardwood broadleaf	1,6	1,24
Aspen	3,2	1,20
Other softwood broadleaf	2,8	1,20
Other wood	2,6	1,20
Bush (all zones)	0,4	1,25

Annual carbon stock in litter in the subcategory "Land converted to Forest land" was estimated taking into account type of land converted to forest land and forest type:

$$\Delta C_{LT_{LF}} = A_{LT_{LF}} \cdot \Delta C_{ALT_{LF}},$$

where: $\Delta C_{LT_{LF}}$ – annual change in carbon stocks in litter in land converted to forest land, tonnes C/yr;

$A_{LT_{LF}}$ – area of land converted into forest land, ha;

$\Delta C_{ALT_{LF}}$ – average annual change in carbon stocks in litter in the subcategory "Land converted to Forest land", tonnes C/ha/yr.

Carbon stock in litter before conversion to forest land was assumed equal to zero. Data on average annual change in carbon stocks in litter are presented at the Table A3.27.

Table A3.27 Average annual change in carbon stocks in litter (tonnes C/ha)

Zone	Carbon stock in mature forests, t C/ha		Conversion period, years		Net annual carbon stock after conversion period, t C/ha/yr		Net annual carbon stock after 20-year conversion period, t C/ha/yr	
	Broadleaf	Confinerous	Broadleaf	Confinerous	Broadleaf	Confinerous	Broadleaf	Confinerous
Polyesye	5	10	50	60	0.2	0.4	0.3	0.5
Wooded steppe	7	8	50	60	0.3	0.3	0.4	0.4
Steppe	8	9	40	40	0.3	0.4	0.4	0.5
Carpathian Mts	10	12	50	60	0.3	0.4	0.5	0.5

Sources: Karpachevskiy L.O., 1981; Shumakov V.S., 1941; Pohiton P.P., 1953; Kovalevskiy A.K., 1953; Pogryebnyak P.S., Melnik M.P., 1952; Kovalevskiy S.B., 2001 Savutchik N.P., 1989; Buksha I.F., Pasternak V.P., 2005.

Estimation procedures for carbon emissions and removals from the soils in land converted to forest land include two types of forest soil carbon pools: 1) the organic fraction of mineral forest soils, and 2) organic soils. The change in carbon stocks in soils in land converted to forest land ($\Delta C_{soils_{LF}}$) is equal to the sum of changes in carbon stocks in the mineral soils ($\Delta C_{Mineral_{LF}}$) and organic soils ($\Delta C_{Organic_{LF}}$).

Calculations of emissions from organic soils were not provided due to the negligibility of drainage areas and lack of detailed activity data.

The methodology assumes a stable, spatially-averaged carbon content of mineral soils under given forest types, management practices and disturbance regimes. It is based on the following assumptions:

• Change from non-forest to forest land is potentially associated with changes in soil organic carbon (SOC), eventually reaching a stable end-point; and

• SOC sequestration/release during the transition to a new equilibrium SOC occurs in a linear fashion.

Annual carbon stock changes in mineral soils for land converted to managed forest were estimated by the following equation due to the lack of national data:

$$\Delta C_{LF_{Man}} = \frac{\left(SOC_{Man} - SOC_{NonForest}\right) \cdot A_{Man}}{T_{Man}},$$

где SOC_{Man} – stable soil organic carbon stocks of the new, managed forest, tonnes C/ha;

$SOC_{Non\ Forest}$ – soil organic carbon stocks of the non-forest land prior to its conversion, tonnes C/ha;

A_{Man} –= area of land converted to managed forest, ha;

T_{Man} – duration of the transition to managed forest, year.

Default values [1] for carbon stock in soils were used for cropland: 0.71 from carbon stock for Polyesye and Carpathian Mts; 0.82 - for Wooded steppe and Steppe. SOC content in forest soils are presented at the table A3.28.

Table A3.28. Soil organic carbon content in forest soils

Region	Cher-nozems	Brown forest soils	Flue and sod-podzol soils	Volcanic soils	Glay soils	Histisols
Polyesye	-	40	18	-	25	150
Wooded steppe	60	45	22	-	35	125
Steppe	80	-	16	-	45	110
Carpathian Mts	-	50	20	70	-	-

A3.3 Waste (sector 6 CRF)

The complete time series on the waste composition for the period 1948-2004 according to [1] are presented at the table A3.29.

Table A3.29.Waste composition, %

Waste type:	Paper and Textile	Garden and park waste and other non-food waste which are able to decompose under the anaerobic conditions	Food waste	Wood and straw waste
2004	0.220	0.014	0.400	0.037
2003	0.228	0.014	0.396	0.037
2002	0.236	0.015	0.391	0.036
2001	0.244	0.015	0.387	0.036
2000	0.251	0.016	0.383	0.035
1999	0.259	0.016	0.379	0.035
1998	0.267	0.017	0.374	0.034
1997	0.275	0.017	0.370	0.034
1996	0.283	0.017	0.366	0.033
1995	0.291	0.018	0.361	0.033
1994	0.299	0.018	0.357	0.032
1993	0.306	0.019	0.353	0.032
1992	0.314	0.019	0.349	0.031
1991	0.322	0.020	0.344	0.031
1990	0.330	0.020	0.340	0.030
1989	0.341	0.018	0.341	0.029
1988	0.352	0.016	0.342	0.028
1987	0.363	0.014	0.343	0.027
1986	0.374	0.012	0.344	0.026
1985	0.385	0.010	0.345	0.025
1984	0.375	0.014	0.361	0.024
1983	0.365	0.018	0.376	0.024
1982	0.354	0.021	0.392	0.023
1981	0.344	0.025	0.408	0.023
1980	0.334	0.029	0.423	0.022

Waste type:	Paper and Textile	Garden and park waste and other non-food waste which are able to decompose under the anaerobic conditions	Food waste	Wood and straw waste
1979	0.324	0.033	0.439	0.021
1978	0.314	0.036	0.454	0.021
1977	0.304	0.040	0.470	0.020
1976	0.298	0.039	0.459	0.019
1975	0.292	0.037	0.448	0.019
1974	0.287	0.036	0.437	0.018
1973	0.281	0.034	0.426	0.018
1972	0.275	0.033	0.415	0.017
1971	0.270	0.032	0.405	0.016
1970	0.264	0.030	0.394	0.016
1969	0.258	0.029	0.383	0.015
1968	0.252	0.027	0.372	0.015
1967	0.247	0.026	0.361	0.014
1966	0.241	0.025	0.350	0.013
1965	0.235	0.023	0.339	0.013
1964	0.229	0.022	0.328	0.012
1963	0.224	0.020	0.317	0.012
1962	0.218	0.019	0.306	0.011
1961	0.212	0.017	0.295	0.011
1960	0.207	0.016	0.285	0.010
1959	0.201	0.015	0.274	0.009
1958	0.195	0.013	0.263	0.009
1957	0.189	0.012	0.252	0.008
1956	0.184	0.010	0.241	0.008
1955	0.178	0.009	0.230	0.007
1954	0.172	0.008	0.219	0.006
1953	0.167	0.006	0.208	0.006
1952	0.161	0.005	0.197	0.005
1951	0.155	0.003	0.186	0.005
1950	0.149	0.002	0.175	0.004
1949	0.149	0.002	0.175	0.004
1948	0.149	0.002	0.175	0.004

ANNEX 4. COMPARISON OF SECTORAL AND REFERENCE APPROACHES

Comparison of sectoral and reference approaches realized in CRF needs adjustment to the Ukrainian circumstances. Data on actual fuel combustion by reference approach are always higher than in the sectoral approach. For Ukraine this difference is very significant. First of all reference approach does not taken into account non-energy fuel use (including feedstocks) while sectoral approach takes into consideration volumes of fuel combustion.

In the same time CO_2 emissions calculated by the sectoral and reference approaches are comparable values, because of inclusion of carbon stored in the reference approach.

Ukraine submitted CRF report according to the IPCC Revised Guidelines. For correct comparison of sectoral and reference approach substraction of non-energy fuel use and losses should be made from actual fuel consumption.

Table A4.1 presents corrected actual fuel consumption for the reference approach and comparison with the sectoral approach.

Table A4.1. Comparison of corrected actual fuel consumption for the reference approach with sectoral approach

Year	Energy consumption calculated by the reference approach (CRF table 1.A(c)), PJ	Non-energy fuel use and losses (CRF table1.A(d)), PJ	Corrected fuel consumption for the reference approach, PJ	Fuel consumption calculated by the sectoral approach (table 1.A(c)), PJ	Difference, %
1990	10 596	1 912	8 684	8 617	0.8
1998	4 474	846	3 627	3 583	1.2
1999	4 443	888	3 555	3 536	0.5
2000	4 202	906	3 296	3 304	-0.2
2001	4 474	918	3 557	3 284	8.3
2002	4 285	904	3 381	3 287	2.9
2003	4 478	955	3 522	3 522	0.0
2004	4 892	983	3 908	3 482	12.3

The total fuel consumption calculated by the reference and sectoral approach are closed for the all years excluding 2004. But significant differences in consumption of different fuel types are recognized in 1998-2004, while in 1990 year this difference is very small. The main reason is lack of Fuel and Energy Balance in Ukraine in and use of unmatched data on fuel supply and consumption for the inventory purposes. The sharpest differences were recognized for liquid and gaseous fuels (Tables A4.2 and A4.3).

Table A4.2. Comparison of liquid fuel consumption for the reference approach and sectoral approach

Year	Liquid fuel consumption calculated by the reference approach with substraction of non-energy use, PJ	Liquid fuel consumption calculated by the sectoral approach, PJ	Difference, %
1990	2 445	2 497	-2
1998	663	553	20
1999	513	491	4
2000	464	407	14
2001	521	430	21
2002	604	443	36
2003	668	441	51

Year	Liquid fuel consumption calculated by the reference approach with substraction of non-energy use, PJ	Liquid fuel consumption calculated by the sectoral approach, PJ	Difference, %
2004	665	448	48

Table A4.3. Comparison of gaseous fuel consumption for the reference approach and sectoral approach

Year	Gaseous fuel consumption calculated by the reference approach with substraction of non-energy use, PJ	Gaseous fuel consumption calculated by the sectoral approach, PJ	Difference, %
1990	4 070	4 051	0.5
1998	2 174	2 209	-1.6
1999	2 303	2 204	4.5
2000	2 215	2 109	5.0
2001	2 344	1 997	17.3
2002	2 008	1 951	2.9
2003	2 015	2 163	-6.8
2004	2 369	2 171	9.1

Analysis if official data on production (1-P form), export and import of oil and oil products, as well as consumption (4-MTP form) was conducted to identify the reasons of differences for liquid fuel consumption. Analysis has shown that the total balance consumption of light oil (gasoline and diesel oil) estimated from the data on their production and export was higher than its domestic consumption according to 4-MTP form. This fact would be explained by incomplete account of domestic consumption in 4-MTP form and/or incomplete account of export. Comparison of light oil consumption calculated by the different approaches is presented at the A.4.4.

Table A4. 4. Comparison of balance light oil (gasoline and diesel oil) consumption with consumption from 4-MTP-form

Year	Balance gasoline and diesel oil consumption calculated from the data on their production and export, thous. t	Gasoline and diesel oil consumption from 4-MTP form, thous. t	Difference, %	
			thous. t	%
1998	11 247	9 035	2 212	20
1999	9 383	8 708	675	7
2000	9 038	7 823	1 215	13
2001	9 650	8 254	1 396	14
2002	10 459	8 615	1 844	18
2003	10 112	8 784	1 329	13
2004	10 478	9 325	1 153	11

Analysis if official data on production (1-P form), export and import of gaseous fuels, as well as consumption (4-MTP form) was conducted to identify the reasons of differences for liquid fuel consumption. Analysis has shown that the total balance consumption of NG estimated from the data on their production and export was higher than its domestic consumption according to 4-MTP form. This fact would be explained by incomplete account of domestic consumption in 4-MTP form and/or incomplete account of export. Comparison of NG consumption calculated by the different approaches is presented at the A.4.5.

Table A4. 5. Comparison of balance NG consumption with consumption from 4-MTP-form

Year	Balance NG consumption calculated from the data on production, import and stock changes, billion m^3	NG consumption from 4-MTP form, billion m^3	Difference	
			Billion m^3	%
1998	72.5	71.3	1.2	1.7
1999	76.9	71.9	5.1	6.6
2000	73.9	68.9	5.0	6.8
2001	77.9	66.4	11.5	14.8
2002	67.3	65.8	1.5	2.2
2003	68.4	72.6	-4.2	-6.2
2004	78.1	72.4	5.7	7.3

ANNEX 5. COMPLETENESS

Detailed information about GHG source categories not considered in the current inventory are presented in the Table A5.1

Table 5.1. Emission and absorption sources not included in the current inventory

Gas	Sector of common report format	Source Category	Why source is not included in inventory
CO_2, CH_4, N_2O	1 Energy	1.A.3.a Civil Aviation International Bunkers	Activity data structure does not allow to mark out the International Bunkers
CH_4	1 Energy	1.B.1.a.i Coal Mining and Handling Emissions from Underground Mines	Lack of IPCC Methodology
CH_4	1 Energy	1.B.2.a.i Oil Exploration	Lack of activity data
CH_4	1 Energy	1.B.2.b.i Natural Gas Exploration	Lack of activity data
CO_2	2. Industrial processes	2.A.4.1 Soda Ash production	There is no methodology to CO_2 emissions assessment for the Solvay process which is used for Soda Ash production in Ukraine
CO_2	2. Industrial processes	2.A.5. Asphalt Roofing	Lack of IPCC Methodology
CO_2	2. Industrial processes	2.A.6. Road Paving with Asphalt	Lack of IPCC Methodology
CO_2	2. Industrial processes	2.A.7.1 Glass Production	Included to the Limestone Use
CO_2	2. Industrial processes	2.B.3. Adipic Acid Production	Lack of IPCC Methodology
CO_2	2. Industrial processes	2.B.4.1. Silicon Carbide Production	There is no data about Silicon Carbide Production
CO_2	2. Industrial processes	2.B.5.2. Ethylene production	Lack of IPCC Methodology
CO_2	2. Industrial processes	2.C.1.3. Sinter Production	Emissions are negligible
CO_2	2. Industrial processes	2.C.1.4. Coke Production	Lack of IPCC Methodology
CH_4	2. Industrial processes	2.B.1. Ammonia Production	Lack of IPCC Methodology
CH_4	2. Industrial processes	2.B.4.1. Silicon Carbide Production	There is no data about Silicon Carbide Production
CH_4	2. Industrial processes	2.B.4.2. Calcium Carbide Production	Lack of IPCC Methodology
CH_4	2. Industrial processes	2.B.5.3. Dichloroethylene Production	There is no Dichloroethylene Production in Ukraine
CH_4	2. Industrial processes	2.B.5.4. Styrene Production	There is no Styrene Production in Ukraine
CH_4	2. Industrial processes	2.C.1.1. Steel Production	Lack of IPCC Methodology
CH_4	2. Industrial processes	2.C.1.3. Sinter Production	Emissions are negligible
CH_4	2. Industrial processes	2.C.2. Ferroalloys Production	Lack of IPCC Methodology
CH_4	2. Industrial processes	2.C.3. Aluminium Production	Lack of IPCC Methodology
N_2O	2. Industrial processes	2.B.1. Ammonia Production	Lack of IPCC Methodology
N_2O	2. Industrial proc-	2.B.5.2. Ethylene production	Lack of IPCC Methodology

Gas	Sector of common report format	Source Category	Why source is not included in inventory
	esses		
SF_6	2. Industrial processes	2.C.4. SF_6 Used in Aluminium and Magnesium Foundries	There is no data about SF_6 using
HFCs	2. Industrial processes	HFCs Production and Use	There is no data about HFCs Production and Use
CH_4	4 Agriculture	4D Agricultural Soils Methane emissions from agricultural soils	Calculation methodology is lack
CH_4	4 Agriculture	4A Enteric Fermentation 4A7 Mules and Asses	Emissions are negligible
CH_4	4 Agriculture	4B Manure Management 4B7 Mules and Asses	Emissions are negligible
CH_4 and N_2O	4 Agriculture	4E Prescribed Burning of Savannas	Source is lack in Ukraine
CH_4 and N_2O	4 Agriculture	4F Field Burning of Agricultural Residues	This activity is forbidden in Ukraine
CO_2	5. LULUCF	Forest land converted to other Land-Use Categories\ Carbon stock change in living biomass	Carbon stock decrease in living biomass in the category «Forests» was considered in the category «Forest land remaining Forest land» as a result of harvested wood
CO_2	5. LULUCF	5.A.1. Forest land remaining Forest land and Forest land converted to other Land-Use Categories \ Carbon stock change in dead biomass	Emissions are negligible
CO_2	5. LULUCF	All Land-Use categories except 5.A.1. Forest land remaining Forest land\ Emissions from wildfires	Lack of statistical data about wildfires
CO_2	5. LULUCF	5.B.1. Cropland remaining Cropland\ Carbon stock change in dead biomass	Emissions are negligible
CO_2	5. LULUCF	5.C. Total Grassland\Carbon Emissions from agricultural lime application and dolomite ($CaMg(CO_3)_2$)	The information about volumes of agricultural lime application in Grassland category is not described in National Statistics.
CO_2	5. LULUCF	5.C.1. Grassland remaining Grassland and 5.C.2. Land converted to Grassland\Carbon stock change in living and dead biomass	There is lack of national statistics on plantations of terrs in the category «Grassland»
CO_2	5. LULUCF	5.D.1. Wetlands remaining Wetlands and 5.D.2 Land converted to Wetlands\ Carbon stock change in living and dead biomass	There is lack of national statistics on plantations of terrs in the category «Wetland»
CO_2	5. LULUCF	5.E.1 Settlements remaining Settlements and 5.E.2 Land converted to Settlements\ Carbon stock change in dead biomass	Emissions are negligible
CH_4	5. LULUCF	All Land-Use categories except 5.A.1. Forest land remaining Forest land\ Emissions from wildfires	Lack of statistical data about wildfires
N_2O	5. LULUCF	All Land-Use categories except 5.A.1. Forest land remaining Forest land\ Emissions from wildfires	Lack of statistical data about wildfires
N_2O	5. LULUCF	5.A.1. Forest land remaining Forest land and 5.A.2. Land converted to Forest land\ N_2O Emission from N fertilization	Emissions are negligible
N_2O	5. LULUCF	5.B.2. Land converted to Cropland\5.B.2.1 Forest land converted to Cropland\Emission from N fertilization	Emissions are negligible
N_2O	5. LULUCF	5.D. Wetlands\Emissions from drainage of soils\Mineral soils	Lands where peat is mined and which are organic soils were considered, N_2O emissions were estimated for mineral soils
CH_4	6.Waste	6.C. Waste Incineration	Emission is not considerable, Lack of IPCC Methodology

ANNEX 6. ADDITIONAL INFORMATION CONSIDERED AS A PART OF THIS INVENTORY (IF IT IS APPROPRIATE) OR OTHER REFERENCE INFORMATION

Table A6.1. Calculated CO_2 emission factors for Ferrosilicium Production

Ferrosilicium	Silicon content, %	Silicon fraction	Average CO_2 emission factors from Table 2-17, t CO_2/t	Calculated CO_2 emission factors, t CO_2/t
ФС 20	20	0.20		1.21
ФС 25	25	0.25		1.35
ФС 30	30	0.30		1.51
ФС 35	35	0.35		1.68
ФС 40	40	0.40		1.87
ФС 45	45	0.45		2.09
ФС 50	50	0.50	2.35	2.35
ФС 55	55	0.55		2.60
ФС 60	60	0.60		2.90
ФС 65	65	0.65		3.24
ФС 70	70	0.70		3.61
ФС 75	75	0.75	3.9	3.90
ФС 80	80	0.80		4.49
ФС 85	85	0.85		5.01
ФС 90	90	0.90	5.65	5.65

ANNEX 7. UNCERTAINTY

Uncertainty assessment was implemented using the Tier 1 approach. This approach provides uncertainty assessment by gas type for each sector recommended by IPCC.

Uncertainty assessment of the current inventory assumes assessment of uncertainty of activity data which characterizes activity level and GHG emission factors uncertainty and further combined assessment provided according to the Good Practice Guidance.

Indicators of combined uncertainty of GHG inventory by gas and by sector are shown in the Table A7.1

Table A7.1. Indicators of combined uncertainty of GHG inventory by gas and by sector

Sector	GHG				Sector Uncertainty, %
	CO_2	CH_4	N_2O	PFCs and HFCs	
Energy	2.1	27.6	224.9	-	5.5
Industry	9.7	15.2	12.0	26.9	9.4
Agriculture	-	11.6	73.6	-	44.2
Total Solvent and other products Use	-	-	100.1	-	100.1
Land-Use, Land-Use Change and Forestry	65.1	19.4	149.2	-	65.1
Waste	-	243.6	50.2	-	214.2
Uncertainty, %	8.11	32.4	60.3	26.9	-

Results of combined uncertainty assessment of GHG inventory are presented in the Table A7.2.

Table A7.2. Combined uncertainty assessment of GHG inventory

	Tier 1. Uncertainty Calculation and Reporting												
	A	B	C	D	E	F	G	H	I	J	K	L	M
	IPCC Source Category	Gas	Base year Emissions	Year t Emissions	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
			Gg CO_2 equivalent	Gg CO_2 equivalent	%	%	%	%	%	%	%	%	%
1A1	Energy Industries	CO_2	271267.0	100150.0	1.7	2.7	3.2	0.831	0.0	0.1	0.0	0.3	0.3
1A2	Manufacturing Industry and Construction	CO_2	143311.0	47056.0	1.1	1.1	1.5	0.185	0.0	0.1	0.0	0.1	0.1
1A3	Transport	CO_2	89331.0	37474.0	3.1	2.9	4.3	0.418	0.0	0.0	0.0	0.2	0.2
1A4	Other in Fuel Combustion	CO_2	91409.0	42447.0	7.2	1.6	7.3	0.815	0.0	0.0	0.0	0.5	0.5
1A5	Other	CO_2	0.0	1515.0	4.9	2.4	5.4	0.021	0.0	0.0	0.0	0.0	0.0
1B	Fugitive emissions	CO_2	53.3	37.2	5.0	100.0	100.1	0.010	0.0	0.0	0.0	0.0	0.0
2A1	Cement Production	CO_2	9287.2	3777.1	2.0	1.0	2.2	0.022	0.0	0.0	0.0	0.0	0.0
2A2	Lime Production	CO_2	5671.1	3426.9	16.9	1.7	17.0	0.153	0.0	0.0	0.0	0.1	0.1
2A3	Limestone and Dolomite Use	CO_2	9882.5	7904.0	91.5	4.6	91.6	1.898	0.0	0.0	0.0	1.1	1.1

	Tier 1. Uncertainty Calculation and Reporting												
	A	B	C	D	E	F	G	H	I	J	K	L	M
	IPCC Source Category	Gas	Base year Emissions	Year t Emissions	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
			Gg CO_2 equivalent	Gg CO_2 equivalent	%	%	%	%	%	%	%	%	%
2A4	Soda Ash Use	CO_2	367.8	172.1	5.0	5.0	7.1	0.003	0.0	0.0	0.0	0.0	0.0
2B1	Ammonia Production	CO_2	14107.6	11541.2	5.0	10.0	11.2	0.338	0.0	0.0	0.1	0.1	0.1
2B4	Calcium Carbide Production	CO_2	40.1	22.2	62.0	6.5	62.4	0.004	0.0	0.0	0.0	0.0	0.0
2C1	Iron and Steel Production	CO_2	80459.2	58476.1	5.2	5.2	7.3	1.125	0.0	0.1	0.1	0.5	0.5
2C2	Ferroalloys Production	CO_2	3806.1	2666.4	1.2	6.0							
2C3	Aluminium Production	CO_2	373.5	276.3	1.0	6.0	6.1	0.004	0.0	0.0	0.0	0.0	0.0
5A	Forest land	CO_2	-55408.3	-55602.3	12.2	3.8	12.8	-1.870	0.0	-0.1	-0.1	-1.1	1.1
5B	Cropland	CO_2	28948.5	38471.4	7.2	47.4	47.9	4.836	0.0	0.0	1.4	0.4	1.5
5C	Grassland	CO_2	-9046.7	-13800.7	11.4	47.4	48.7	-1.764	0.0	0.0	-0.5	-0.2	0.6
5D	Wetland	CO_2	1383.6	429.4	54.2	80.3	96.9	0.109	0.0	0.0	0.0	0.0	0.0
5E	Settlements	CO_2	283.7	-1639.7	10.0	75.0	75.7	-0.325	0.0	0.0	-0.1	0.0	0.2
		Total CO_2	685527.3	284799.8									
1A1	Energy Industries	CH_4	116.4	42.1	1.6	77.0	77.0	0.009	0.0	0.0	0.0	0.0	0.0
1A2	Manufacturing Industry	CH_4	238.3	71.6	1.3	71.7	71.8	0.013	0.0	0.0	0.0	0.0	0.0

	Tier 1. Uncertainty Calculation and Reporting												
	A	B	C	D	E	F	G	H	I	J	K	L	M
	IPCC Source Category	Gas	Base year Emissions	Year t Emissions	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
			Gg CO_2 equivalent	Gg CO_2 equivalent	%	%	%	%	%	%	%	%	%
	and Construction												
1A3	Transport	CH_4	293.7	100.1	4.3	35.0	35.3	0.009	0.0	0.0	0.0	0.0	0.0
1A4	Other in Fuel Combustion	CH_4	3356.4	540.9	6.7	99.8	100.0	0.142	0.0	0.0	-0.1	0.0	0.1
1A5	Other	CH_4	0.0	2.8	5.2	82.0	82.2	0.001	0.0	0.0	0.0	0.0	0.0
1B	Fugitive emissions	CH_4	86655.9	52487.0	1.6	27.9	28.0	3.849	0.0	0.1	0.5	0.1	0.5
2B5	Other	CH_4	96.2	35.9	3.5	6.9	7.8	0.001	0.0	0.0	0.0	0.0	0.0
2C1	Iron and Steel Production	CH_4	1213.1	816.5	3.9	15.4	15.9	0.034	0.0	0.0	0.0	0.0	0.0
4A	Enteric Fermentation	CH_4	34481.0	11580.6	2.9	11.8	12.1	0.368	0.0	0.0	0.0	0.1	0.1
4B	Manure Management	CH_4	18220.5	567.8	2.0	25.5	25.5	0.038	0.0	0.0	-0.2	0.0	0.2
4C	Rice Cultivation	CH_4	174.5	89.5	5.0	125.0	125.1	0.029	0.0	0.0	0.0	0.0	0.0
5A	Forest land	CH_4	8.4	0.9	12.2	15.0	19.4	0.000	0.0	0.0	0.0	0.0	0.0
6A	Emissions from MSW landfields	CH_4	4716.6	6255.9	22.0	302.0	302.8	4.968	0.0	0.0	1.4	0.2	1.5
6B	Waste Water Handling	CH_4	1599.6	1521.5	4.9	30.5	30.9	0.123	0.0	0.0	0.0	0.0	0.0
		Total CH_4	151170.5	74112.9									

	Tier 1. Uncertainty Calculation and Reporting												
	A	B	C	D	E	F	G	H	I	J	K	L	M
	IPCC Source Category	Gas	Base year Emissions	Year t Emissions	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
			Gg CO_2 equivalent	Gg CO_2 equivalent	%	%	%	%	%	%	%	%	%
1A1	Energy Industries	N_2O	662.3	272.4	2.5	422.1	422.1	0.302	0.0	0.0	0.0	0.0	0.0
1A2	Manufacturing Industry and Construction	N_2O	317.9	57.8	1.7	188.1	188.1	0.029	0.0	0.0	0.0	0.0	0.0
1A3	Transport	N_2O	254.1	105.8	3.0	159.6	159.6	0.044	0.0	0.0	0.0	0.0	0.0
1A4	Other in Fuel Combustion	N_2O	340.6	86.0	4.3	225.1	225.2	0.051	0.0	0.0	0.0	0.0	0.0
1A5	Other	N_2O	0.0	4.0	7.2	361.3	361.4	0.004	0.0	0.0	0.0	0.0	0.0
2B2	Nitric Acid Production	N_2O	1104.8	606.4	10.0	10.0	14.1	0.022	0.0	0.0	0.0	0.0	0.0
2B3	Adipic Acid Production	N_2O	1537.4	1548.6	5.0	15.0	15.8	0.064	0.0	0.0	0.0	0.0	0.0
4D	Agricultural Soils	N_2O	40586.2	15074.5	16.1	85.8	87.3	3.452	0.0	0.0	-0.2	0.4	0.4
4B	Manure Management	N_2O	7893.0	3105.0	16.1	74.2	75.9	0.618	0.0	0.0	0.0	0.1	0.1
3.D	Other	N_2O	376.7	342.9	5.0	100.0	100.1	0.090	0.0	0.0	0.0	0.0	0.0
5A	Forest land	N_2O	2.2	0.2	12.2	3.8	12.8	0.000	0.0	0.0	0.0	0.0	0.0
5D	Wetlands	N_2O	9.7	3.4	9.4	158.9	159.2	0.001	0.0	0.0	0.0	0.0	0.0
6B	Waste Water Handling	N_2O	1556.2	1072.6	7.0	50.0	50.5	0.142	0.0	0.0	0.0	0.0	0.0
		Total N_2O	54641.0	22279.7									

	Tier 1. Uncertainty Calculation and Reporting												
	A	B	C	D	E	F	G	H	I	J	K	L	M
	IPCC Source Category	Gas	Base year Emissions	Year t Emissions	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
			Gg CO_2 equivalent	Gg CO_2 equivalent	%	%	%	%	%	%	%	%	%
2C3	Aluminium Production	C_2F_6	25.2	10.0	5.0	30.0	30.4	0.001	0.0	0.0	0.0	0.0	0.0
2C3	Aluminium Production	CF_4	178.0	70.5	5.0	30.0	30.4	0.006	0.0	0.0	0.0	0.0	0.0
		Total HFC, PFC and SF_6	203.2	80.4									
	Total emissions		891542	381273	Overall uncertainty, %			9.42	Trend uncertainty, %				2.87

ANNEX 8. GHG EMISSION ESTIMATIONS

Table A8.1. GHG emissions in 1990

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 (1)	CH_4	N_2O	HFCs (2)	PFCs (2)	SF_6 (2)	Total
	CO_2 equivalent (Gg)						
Total (Net Emissions) (1)	**685 527,77**	**151 170,72**	**54 639,39**	**NA,NE,NO**	**203,23**	**NA,NE,NO**	**891 541,11**
1. Energy	**595 371,78**	**90 660,82**	**1 575,06**				**687 607,66**
A. Fuel Combustion (Sectoral Approach)	595 318,49	4 004,80	1 574,88				600 898,16
1. Energy Industries	271 267,11	116,36	662,27				272 045,74
2. Manufacturing Industries and Construction	143 311,33	238,32	317,92				143 867,57
3. Transport	89 330,85	293,69	254,07				89 878,61
4. Other Sectors	91 409,20	3 356,42	340,62				95 106,24
5. Other	NA,NO	NA,NO	NA,NO				NA,NO
B. Fugitive Emissions from Fuels	53,28	86 656,03	0,18				86 709,49
1. Solid Fuels	NA,NE	55 396,33	NA,NE				55 396,33
2. Oil and Natural Gas	53,28	31 259,70	0,18				31 313,16
2. Industrial Processes	**123 995,16**	**1 309,27**	**2 642,24**	**NA,NE,NO**	**203,23**	**NA,NE,NO**	**128 149,90**
A. Mineral Products	25 208,66	NE	NE				25 208,66
B. Chemical Industry	14 147,72	96,15	2 642,24	NO	NO	NO	16 886,11
C. Metal Production	84 638,78	1 213,12	NE	NE,NO	203,23	NE,NO	86 055,13
D. Other Production	NO						NO
E. Production of Halocarbons and SF_6				NA,NE	NA	NA	NA,NE
F. Consumption of Halocarbons and SF_6 (2)				NE,NO	NE,NO	NE,NO	NE,NO
G. Other	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NA,NE**		**376,80**				**376,80**
4. Agriculture		**52 875,92**	**48 479,37**				**101 355,29**
A. Enteric Fermentation		34 480,95					34 480,95
B. Manure Management		18 220,46	7 893,21				26 113,67
C. Rice Cultivation		174,51					174,51
D. Agricultural Soils(3)		NA,NE	40 586,17				40 586,17
E. Prescribed Burning of Savannas		NA	NA				NA
F. Field Burning of Agricultural Residues		NA,NO	NA,NO				NA,NO
G. Other		NA	NA				NA
5. Land Use, Land-Use Change and Forestry(1)	**-33 839,16**	**8,39**	**9,71**				**-33 821,06**
A. Forest Land	-55 408,31	8,39	2,17				-55 397,75
B. Cropland	28 948,54	NA,NE	NA,NE				28 948,54
C. Grassland	-9 046,72	NA,NE	NA,NE				-9 046,72
D. Wetlands	1 383,64	NE	7,54				1 391,18
E. Settlements	283,69	NE	NE				283,69
F. Other Land	NA,NE,NO	NE,NO	NE,NO				NA,NE,NO
G. Other		NE	NE				NE
6. Waste	**IE,NA,NO**	**6 316,32**	**1 556,20**				**7 872,52**
A. Solid Waste Disposal on Land	NA,NO	4 716,75					4 716,75
B. Waste-water Handling		1 599,57	1 556,20				3 155,77
C. Waste Incineration	IE	NO	IE				IE,NO
D. Other	NA	NA	NA				NA
7. Other *(as specified in Summary 1.A)*	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Memo Items: (4)							
International Bunkers	3 563,80	9,96	8,83				3 582,59
Aviation	NE	NE	NE				NE
Marine	3 563,80	9,96	8,83				3 582,59
Multilateral Operations	**NE**	**NE**	**NE**				**NE**
CO_2 Emissions from Biomass	**3 658,85**						**3 658,85**

Total CO_2 Equivalent Emissions without Land Use, Land-Use Change and Forestry (5)	925 362,17
Total CO_2 Equivalent Emissions with Land Use, Land-Use Change and Forestry (5)	891 541,11

Table A8.2. GHG emissions in 1991

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 [(1)]	CH_4	N_2O	HFCs [(2)]	PFCs [(2)]	SF_6 [(2)]	Total
	CO_2 equivalent (Gg)						
Total (Net Emissions) [(1)]	**584 176,77**	**138 275,53**	**50 565,76**	**NA,NE,NO**	**162,19**	**NA,NE,NO**	**773 180,25**
1. Energy	**511 848,81**	**82 003,76**	**1 262,06**				**595 114,63**
A. Fuel Combustion (Sectoral Approach)	511 802,59	2 363,39	1 261,90				515 427,87
1. Energy Industries	NE	NE	NE				NE
2. Manufacturing Industries and Construction	NE	NE	NE				NE
3. Transport	NA,NE,NO	NA,NE,NO	NA,NE,NO				NA,NE,NO
4. Other Sectors	NE	NE	NE				NE
5. Other	511 802,59	2 363,39	1 261,90				515 427,87
B. Fugitive Emissions from Fuels	46,22	79 640,37	0,16				79 686,75
1. Solid Fuels	NA,NE	50 566,85	NA,NE				50 566,85
2. Oil and Natural Gas	46,22	29 073,53	0,16				29 119,91
2. Industrial Processes	**108 326,28**	**1 074,07**	**2 479,19**	**NA,NE,NO**	**162,19**	**NA,NE,NO**	**112 041,72**
A. Mineral Products	23 359,58	NE	NE				23 359,58
B. Chemical Industry	13 060,98	83,24	2 479,19	NO	NO	NO	15 623,41
C. Metal Production	71 905,72	990,83	NE	NE,NO	162,19	NE,NO	73 058,74
D. Other Production	NO						NO
E. Production of Halocarbons and SF_6				NA,NE	NA	NA	NA,NE
F. Consumption of Halocarbons and SF_6 [(2)]				NE,NO	NE,NO	NE,NO	NE,NO
G. Other	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NA,NE**		**377,62**				**377,62**
4. Agriculture		**48 607,75**	**44 984,73**				**93 592,48**
A. Enteric Fermentation		32 914,00					32 914,00
B. Manure Management		15 549,49	7 653,19				23 202,67
C. Rice Cultivation		144,27					144,27
D. Agricultural Soils[(3)]		NA,NE	37 331,54				37 331,54
E. Prescribed Burning of Savannas		NA	NA				NA
F. Field Burning of Agricultural Residues		NA,NO	NA,NO				NA,NO
G. Other		NA	NA				NA
5. Land Use, Land-Use Change and Forestry[(1)]	**-35 998,32**	**4,88**	**8,27**				**-35 985,17**
A. Forest Land	-57 688,24	4,88	1,26				-57 682,11
B. Cropland	25 945,24	NA,NE	NA,NE				25 945,24
C. Grassland	-3 087,76	NA,NE	NA,NE				-3 087,76
D. Wetlands	-121,63	NE	7,01				-114,62
E. Settlements	-1 045,93	NE	NE				-1 045,93
F. Other Land	NA,NE,NO	NE,NO	NE,NO				NA,NE,NO
G. Other		NE	NE				NE
6. Waste	**IE,NA,NO**	**6 585,07**	**1 453,90**				**8 038,97**
A. Solid Waste Disposal on Land	NA,NO	4 960,03					4 960,03
B. Waste-water Handling		1 625,04	1 453,90				3 078,94
C. Waste Incineration	IE	NO	IE				IE,NO
D. Other	NA	NA	NA				NA
7. Other ***(as specified in Summary 1.A)***	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Memo Items: [(4)]							
International Bunkers	NA,NE,NO	NA,NE,NO	NA,NE,NO				NA,NE,NO
Aviation	NE	NE	NE				NE
Marine	NA,NE,NO	NA,NE,NO	NA,NE,NO				NA,NE,NO
Multilateral Operations	**NE**	**NE**	**NE**				**NE**
CO_2 Emissions from Biomass	**NA,NE,NO**						**NA,NE,NO**

Total CO_2 Equivalent Emissions without Land Use, Land-Use Change and Forestry [(5)]	809 165,42
Total CO_2 Equivalent Emissions with Land Use, Land-Use Change and Forestry [(5)]	773 180,25

Table A8.3. GHG emissions in 1992

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 [1]	CH_4	N_2O	HFCs [2]	PFCs [2]	SF_6 [2]	Total
	CO_2 equivalent (Gg)						
Total (Net Emissions) [1]	**503 254,78**	**131 317,96**	**46 056,23**	**NA,NE,NO**	**122,68**	**NA,NE,NO**	**680 751,65**
1. Energy	**428 326,30**	**78 879,50**	**1 056,12**				**508 261,92**
A. Fuel Combustion (Sectoral Approach)	428 286,69	1 977,73	1 055,98				431 320,40
1. Energy Industries	NE	NE	NE				NE
2. Manufacturing Industries and Construction	NE	NE	NE				NE
3. Transport	NA,NE,NO	NA,NE,NO	NA,NE,NO				NA,NE,NO
4. Other Sectors	NE	NE	NE				NE
5. Other	428 286,69	1 977,73	1 055,98				431 320,40
B. Fugitive Emissions from Fuels	39,62	76 901,77	0,14				76 941,52
1. Solid Fuels	NA,NE	48 874,55	NA,NE				48 874,55
2. Oil and Natural Gas	39,62	28 027,22	0,14				28 066,97
2. Industrial Processes	**106 798,52**	**1 025,16**	**1 707,32**	**NA,NE,NO**	**122,68**	**NA,NE,NO**	**109 653,67**
A. Mineral Products	21 982,81	NE	NE				21 982,81
B. Chemical Industry	13 323,04	68,32	1 707,32	NO	NO	NO	15 098,68
C. Metal Production	71 492,67	956,83	NE	NE,NO	122,68	NE,NO	72 572,18
D. Other Production	NO						NO
E. Production of Halocarbons and SF_6				NA,NE	NA	NA	NA,NE
F. Consumption of Halocarbons and SF_6 [2]				NE,NO	NE,NO	NE,NO	NE,NO
G. Other	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NA,NE**		**378,98**				**378,98**
4. Agriculture		**44 621,66**	**41 555,09**				**86 176,75**
A. Enteric Fermentation		30 514,32					30 514,32
B. Manure Management		13 954,25	7 242,12				21 196,37
C. Rice Cultivation		153,09					153,09
D. Agricultural Soils [3]		NA,NE	34 312,98				34 312,98
E. Prescribed Burning of Savannas		NA	NA				NA
F. Field Burning of Agricultural Residues		NA,NO	NA,NO				NA,NO
G. Other		NA	NA				NA
5. Land Use, Land-Use Change and Forestry [1]	**-31 870,04**	**12,08**	**10,22**				**-31 847,73**
A. Forest Land	-57 202,96	12,08	3,12				-57 187,75
B. Cropland	25 661,95	NA,NE	NA,NE				25 661,95
C. Grassland	678,93	NA,NE	NA,NE				678,93
D. Wetlands	-125,04	NE	7,10				-117,94
E. Settlements	-882,92	NE	NE				-882,92
F. Other Land	NA,NE,NO	NE,NO	NE,NO				NA,NE,NO
G. Other		NE	NE				NE
6. Waste	**IE,NA,NO**	**6 779,56**	**1 348,50**				**8 128,06**
A. Solid Waste Disposal on Land	NA,NO	5 135,61					5 135,61
B. Waste-water Handling		1 643,95	1 348,50				2 992,45
C. Waste Incineration	IE	NO	IE				IE,NO
D. Other	NA	NA	NA				NA
7. Other ***(as specified in Summary 1.A)***	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Memo Items: [4]							
International Bunkers	NA,NE,NO	NA,NE,NO	NA,NE,NO				NA,NE,NO
Aviation	NE	NE	NE				NE
Marine	NA,NE,NO	NA,NE,NO	NA,NE,NO				NA,NE,NO
Multilateral Operations	**NE**	**NE**	**NE**				**NE**
CO_2 Emissions from Biomass	**NA,NE,NO**						**NA,NE,NO**

Total CO_2 Equivalent Emissions without Land Use, Land-Use Change and Forestry [5]	712 599,38
Total CO_2 Equivalent Emissions with Land Use, Land-Use Change and Forestry [5]	680 751,65

Table A8.4. GHG emissions in 1993

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 [1]	CH_4	N_2O	HFCs [2]	PFCs [2]	SF_6 [2]	Total
	CO_2 equivalent (Gg)						
Total (Net Emissions) [1]	**449 538,48**	**118 609,17**	**41 593,99**	**NA,NE,NO**	**123,72**	**NA,NE,NO**	**609 865,36**
1. Energy	**396 103,79**	**68 389,29**	**969,91**				**465 462,99**
A. Fuel Combustion (Sectoral Approach)	396 067,33	1 856,03	969,79				398 893,14
1. Energy Industries	NE	NE	NE				NE
2. Manufacturing Industries and Construction	NE	NE	NE				NE
3. Transport	NA,NE,NO	NA,NE,NO	NA,NE,NO				NA,NE,NO
4. Other Sectors	NE	NE	NE				NE
5. Other	396 067,33	1 856,03	969,79				398 893,14
B. Fugitive Emissions from Fuels	36,46	66 533,27	0,13				66 569,85
1. Solid Fuels	NA,NE	40 587,25	NA,NE				40 587,25
2. Oil and Natural Gas	36,46	25 946,02	0,13				25 982,61
2. Industrial Processes	**84 378,16**	**778,31**	**1 157,83**	**NA,NE,NO**	**123,72**	**NA,NE,NO**	**86 438,02**
A. Mineral Products	17 019,47	NE	NE				17 019,47
B. Chemical Industry	10 691,78	49,40	1 157,83	NO	NO	NO	11 899,00
C. Metal Production	56 666,91	728,91	NE	NE,NO	123,72	NE,NO	57 519,54
D. Other Production	NO						NO
E. Production of Halocarbons and SF_6				NA,NE	NA	NA	NA,NE
F. Consumption of Halocarbons and SF_6 [2]				NE,NO	NE,NO	NE,NO	NE,NO
G. Other	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NA,NE**		**378,04**				**378,04**
4. Agriculture		**42 497,48**	**37 784,13**				**80 281,62**
A. Enteric Fermentation		29 536,91					29 536,91
B. Manure Management		12 813,16	7 025,61				19 838,76
C. Rice Cultivation		147,42					147,42
D. Agricultural Soils [3]		NA,NE	30 758,53				30 758,53
E. Prescribed Burning of Savannas		NA	NA				NA
F. Field Burning of Agricultural Residues		NA,NO	NA,NO				NA,NO
G. Other		NA	NA				NA
5. Land Use, Land-Use Change and Forestry [1]	**-30 943,47**	**16,54**	**11,38**				**-30 915,55**
A. Forest Land	-57 215,12	16,54	4,27				-57 194,30
B. Cropland	29 781,90	NA,NE	NA,NE				29 781,90
C. Grassland	-2 387,98	NA,NE	NA,NE				-2 387,98
D. Wetlands	63,86	NE	7,10				70,97
E. Settlements	-1 186,13	NE	NE				-1 186,13
F. Other Land	NA,NE,NO	NE,NO	NE,NO				NA,NE,NO
G. Other		NE	NE				NE
6. Waste	**IE,NA,NO**	**6 927,54**	**1 292,70**				**8 220,24**
A. Solid Waste Disposal on Land	NA,NO	5 269,85					5 269,85
B. Waste-water Handling		1 657,70	1 292,70				2 950,40
C. Waste Incineration	IE	NO	IE				IE,NO
D. Other	NA	NA	NA				NA
7. Other *(as specified in Summary 1.A)*	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Memo Items: [4]							
International Bunkers	NA,NE,NO	NA,NE,NO	NA,NE,NO				NA,NE,NO
Aviation	NE	NE	NE				NE
Marine	NA,NE,NO	NA,NE,NO	NA,NE,NO				NA,NE,NO
Multilateral Operations	**NE**	**NE**	**NE**				**NE**
CO_2 Emissions from Biomass	**NA,NE,NO**						**NA,NE,NO**

Total CO_2 Equivalent Emissions without Land Use, Land-Use Change and Forestry [5]	640 780,91
Total CO_2 Equivalent Emissions with Land Use, Land-Use Change and Forestry [5]	609 865,36

Table A8.5. GHG emissions in 1994

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 [(1)]	CH_4	N_2O	HFCs [(2)]	PFCs [(2)]	SF_6 [(2)]	Total
	CO_2 equivalent (Gg)						
Total (Net Emissions) [(1)]	**391 692,13**	**107 301,78**	**36 723,85**	**NA,NE,NO**	**138,94**	**NA,NE,NO**	**535 856,70**
1. Energy	**363 882,72**	**62 967,32**	**883,71**				**427 733,75**
A. Fuel Combustion (Sectoral Approach)	363 847,97	1 734,32	883,59				366 465,88
1. Energy Industries	NE	NE	NE				NE
2. Manufacturing Industries and Construction	NE	NE	NE				NE
3. Transport	NA,NE,NO	NA,NE,NO	NA,NE,NO				NA,NE,NO
4. Other Sectors	NE	NE	NE				NE
5. Other	363 847,97	1 734,32	883,59				366 465,88
B. Fugitive Emissions from Fuels	34,75	61 233,00	0,12				61 267,87
1. Solid Fuels	NA,NE	37 122,36	NA,NE				37 122,36
2. Oil and Natural Gas	34,75	24 110,64	0,12				24 145,51
2. Industrial Processes	**67 099,42**	**595,47**	**1 029,95**	**NA,NE,NO**	**138,94**	**NA,NE,NO**	**68 863,77**
A. Mineral Products	13 547,46	NE	NE				13 547,46
B. Chemical Industry	9 742,14	36,31	1 029,95	NO	NO	NO	10 808,41
C. Metal Production	43 809,81	559,15	NE	NE,NO	138,94	NE,NO	44 507,90
D. Other Production	NO						NO
E. Production of Halocarbons and SF_6				NA,NE	NA	NA	NA,NE
F. Consumption of Halocarbons and SF_6 [(2)]				NE,NO	NE,NO	NE,NO	NE,NO
G. Other	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NA,NE**		**375,24**				**375,24**
4. Agriculture		**36 669,56**	**33 209,63**				**69 879,19**
A. Enteric Fermentation		27 161,24					27 161,24
B. Manure Management		9 367,20	6 567,05				15 934,25
C. Rice Cultivation		141,12					141,12
D. Agricultural Soils[(3)]		NA,NE	26 642,58				26 642,58
E. Prescribed Burning of Savannas		NA	NA				NA
F. Field Burning of Agricultural Residues		NA,NO	NA,NO				NA,NO
G. Other		NA	NA				NA
5. Land Use, Land-Use Change and Forestry[(1)]	**-39 290,01**	**47,33**	**19,42**				**-39 223,26**
A. Forest Land	-58 567,40	47,33	12,23				-58 507,85
B. Cropland	26 359,53	NA,NE	NA,NE				26 359,53
C. Grassland	-5 754,61	NA,NE	NA,NE				-5 754,61
D. Wetlands	-132,29	NE	7,19				-125,10
E. Settlements	-1 195,24	NE	NE				-1 195,24
F. Other Land	NA,NE,NO	NE,NO	NE,NO				NA,NE,NO
G. Other		NE	NE				NE
6. Waste	**IE,NA,NO**	**7 022,10**	**1 205,90**				**8 228,00**
A. Solid Waste Disposal on Land	NA,NO	5 361,85					5 361,85
B. Waste-water Handling		1 660,26	1 205,90				2 866,16
C. Waste Incineration	IE	NO	IE				IE,NO
D. Other	NA	NA	NA				NA
7. Other ***(as specified in Summary 1.A)***	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Memo Items: [(4)]							
International Bunkers	NA,NE,NO	NA,NE,NO	NA,NE,NO				NA,NE,NO
Aviation	NE	NE	NE				NE
Marine	NA,NE,NO	NA,NE,NO	NA,NE,NO				NA,NE,NO
Multilateral Operations	**NE**	**NE**	**NE**				**NE**
CO_2 Emissions from Biomass	**NA,NE,NO**						**NA,NE,NO**

Total CO_2 Equivalent Emissions without Land Use, Land-Use Change and Forestry [(5)]	575 079,96
Total CO_2 Equivalent Emissions with Land Use, Land-Use Change and Forestry [(5)]	535 856,70

Table A8.6. GHG emissions in 1995

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 (1)	CH_4	N_2O	HFCs (2)	PFCs (2)	SF_6 (2)	Total
	CO_2 equivalent (Gg)						
Total (Net Emissions) (1)	**351 080,73**	**94 354,73**	**33 152,52**	**NA,NE,NO**	**153,45**	**NA,NE,NO**	**478 741,42**
1. Energy	**331 663,07**	**54 732,97**	**797,51**				**387 193,54**
A. Fuel Combustion (Sectoral Approach)	331 628,61	1 612,62	797,39				334 038,63
1. Energy Industries	NE	NE	NE				NE
2. Manufacturing Industries and Construction	NE	NE	NE				NE
3. Transport	NA,NE,NO	NA,NE,NO	NA,NE,NO				NA,NE,NO
4. Other Sectors	NE	NE	NE				NE
5. Other	331 628,61	1 612,62	797,39				334 038,63
B. Fugitive Emissions from Fuels	34,45	53 120,34	0,12				53 154,92
1. Solid Fuels	NA,NE	30 126,64	NA,NE				30 126,64
2. Oil and Natural Gas	34,45	22 993,71	0,12				23 028,28
2. Industrial Processes	**61 850,73**	**530,67**	**869,94**	**NA,NE,NO**	**153,45**	**NA,NE,NO**	**63 404,79**
A. Mineral Products	11 221,55	NE	NE				11 221,55
B. Chemical Industry	9 889,65	23,91	869,94	NO	NO	NO	10 783,51
C. Metal Production	40 739,53	506,75	NE	NE,NO	153,45	NE,NO	41 399,73
D. Other Production	NO						NO
E. Production of Halocarbons and SF_6				NA,NE	NA	NA	NA,NE
F. Consumption of Halocarbons and SF_6 (2)				NE,NO	NE,NO	NE,NO	NE,NO
G. Other	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NA,NE**		**372,11**				**372,11**
4. Agriculture		**32 005,61**	**29 970,74**				**61 976,35**
A. Enteric Fermentation		24 512,12					24 512,12
B. Manure Management		7 354,89	6 076,45				13 431,34
C. Rice Cultivation		138,60					138,60
D. Agricultural Soils(3)		NA,NE	23 894,29				23 894,29
E. Prescribed Burning of Savannas		NA	NA				NA
F. Field Burning of Agricultural Residues		NA,NO	NA,NO				NA,NO
G. Other		NA	NA				NA
5. Land Use, Land-Use Change and Forestry(1)	**-42 433,06**	**14,29**	**10,71**				**-42 408,07**
A. Forest Land	-60 121,95	14,29	3,69				-60 103,97
B. Cropland	24 831,38	NA,NE	NA,NE				24 831,38
C. Grassland	-5 741,75	NA,NE	NA,NE				-5 741,75
D. Wetlands	-119,59	NE	7,01				-112,57
E. Settlements	-1 281,15	NE	NE				-1 281,15
F. Other Land	NA,NE,NO	NE,NO	NE,NO				NA,NE,NO
G. Other		NE	NE				NE
6. Waste	**IE,NA,NO**	**7 071,20**	**1 131,50**				**8 202,70**
A. Solid Waste Disposal on Land	NA,NO	5 411,15					5 411,15
B. Waste-water Handling		1 660,04	1 131,50				2 791,54
C. Waste Incineration	IE	NO	IE				IE,NO
D. Other	NA	NA	NA				NA
7. Other *(as specified in Summary 1.A)*	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Memo Items: (4)							
International Bunkers	NA,NE,NO	NA,NE,NO	NA,NE,NO				NA,NE,NO
Aviation	NE	NE	NE				NE
Marine	NA,NE,NO	NA,NE,NO	NA,NE,NO				NA,NE,NO
Multilateral Operations	**NE**	**NE**	**NE**				**NE**
CO_2 Emissions from Biomass	**NA,NE,NO**						**NA,NE,NO**

Total CO_2 Equivalent Emissions without Land Use, Land-Use Change and Forestry (5)	521 149,49
Total CO_2 Equivalent Emissions with Land Use, Land-Use Change and Forestry (5)	478 741,42

Table A8.7. GHG emissions in 1996

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 [1]	CH_4	N_2O	HFCs [2]	PFCs [2]	SF_6 [2]	Total
	CO_2 equivalent (Gg)						
Total (Net Emissions) [1]	**309 436,58**	**86 928,14**	**27 846,50**	**NA,NE,NO**	**123,45**	**NA,NE,NO**	**424 334,66**
1. Energy	**296 818,13**	**53 621,06**	**652,33**				**351 091,51**
A. Fuel Combustion (Sectoral Approach)	296 783,21	1 303,02	652,21				298 738,44
1. Energy Industries	NE	NE	NE				NE
2. Manufacturing Industries and Construction	NE	NE	NE				NE
3. Transport	NA,NE,NO	NA,NE,NO	NA,NE,NO				NA,NE,NO
4. Other Sectors	NE	NE	NE				NE
5. Other	296 783,21	1 303,02	652,21				298 738,44
B. Fugitive Emissions from Fuels	34,92	52 318,04	0,12				52 353,07
1. Solid Fuels	NA,NE	28 885,63	NA,NE				28 885,63
2. Oil and Natural Gas	34,92	23 432,41	0,12				23 467,45
2. Industrial Processes	**61 035,17**	**511,85**	**1 188,41**	**NA,NE,NO**	**123,45**	**NA,NE,NO**	**62 858,88**
A. Mineral Products	9 266,93	NE	NE				9 266,93
B. Chemical Industry	10 289,09	16,73	1 188,41	NO	NO	NO	11 494,24
C. Metal Production	41 479,15	495,11	NE	NE,NO	123,45	NE,NO	42 097,71
D. Other Production	NO						NO
E. Production of Halocarbons and SF_6				NA,NE	NA	NA	NA,NE
F. Consumption of Halocarbons and SF_6 [2]				NE,NO	NE,NO	NE,NO	NE,NO
G. Other	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NA,NE**		**368,64**				**368,64**
4. Agriculture		**25 637,26**	**24 534,01**				**50 171,28**
A. Enteric Fermentation		21 451,31					21 451,31
B. Manure Management		4 089,36	5 419,21				9 508,57
C. Rice Cultivation		96,60					96,60
D. Agricultural Soils[3]		NA,NE	19 114,80				19 114,80
E. Prescribed Burning of Savannas		NA	NA				NA
F. Field Burning of Agricultural Residues		NA,NO	NA,NO				NA,NO
G. Other		NA	NA				NA
5. Land Use, Land-Use Change and Forestry[1]	**-48 416,72**	**37,71**	**15,00**				**-48 364,00**
A. Forest Land	-57 644,36	37,71	9,74				-57 596,91
B. Cropland	23 222,80	NA,NE	NA,NE				23 222,80
C. Grassland	-12 653,35	NA,NE	NA,NE				-12 653,35
D. Wetlands	-106,88	NE	5,26				-101,62
E. Settlements	-1 234,92	NE	NE				-1 234,92
F. Other Land	NA,NE,NO	NE,NO	NE,NO				NA,NE,NO
G. Other		NE	NE				NE
6. Waste	**IE,NA,NO**	**7 120,26**	**1 088,10**				**8 208,36**
A. Solid Waste Disposal on Land	NA,NO	5 463,78					5 463,78
B. Waste-water Handling		1 656,48	1 088,10				2 744,58
C. Waste Incineration	IE	NO	IE				IE,NO
D. Other	NA	NA	NA				NA
7. Other ***(as specified in Summary 1.A)***	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Memo Items: [4]							
International Bunkers	NA,NE,NO	NA,NE,NO	NA,NE,NO				NA,NE,NO
Aviation	NE	NE	NE				NE
Marine	NA,NE,NO	NA,NE,NO	NA,NE,NO				NA,NE,NO
Multilateral Operations	**NE**	**NE**	**NE**				**NE**
CO_2 Emissions from Biomass	**NA,NE,NO**						**NA,NE,NO**

Total CO_2 Equivalent Emissions without Land Use, Land-Use Change and Forestry [5]	472 698,67
Total CO_2 Equivalent Emissions with Land Use, Land-Use Change and Forestry [5]	424 334,66

Table A8.8. GHG emissions in 1997

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 (1)	CH_4	N_2O	HFCs (2)	PFCs (2)	SF_6 (2)	Total
	CO_2 equivalent (Gg)						
Total (Net Emissions) (1)	**297 665,16**	**79 975,67**	**26 752,40**	**NA,NE,NO**	**126,68**	**NA,NE,NO**	**404 519,91**
1. Energy	**274 518,70**	**52 350,69**	**613,28**				**327 482,67**
A. Fuel Combustion (Sectoral Approach)	274 484,31	1 248,48	613,16				276 345,96
1. Energy Industries	NE	NE	NE				NE
2. Manufacturing Industries and Construction	NE	NE	NE				NE
3. Transport	NA,NE,NO	NA,NE,NO	NA,NE,NO				NA,NE,NO
4. Other Sectors	NE	NE	NE				NE
5. Other	274 484,31	1 248,48	613,16				276 345,96
B. Fugitive Emissions from Fuels	34,39	51 102,20	0,12				51 136,72
1. Solid Fuels	NA,NE	28 394,95	NA,NE				28 394,95
2. Oil and Natural Gas	34,39	22 707,25	0,12				22 741,76
2. Industrial Processes	**70 084,90**	**582,57**	**1 333,55**	**NA,NE,NO**	**126,68**	**NA,NE,NO**	**72 127,70**
A. Mineral Products	10 320,85	NE	NE				10 320,85
B. Chemical Industry	10 401,44	20,84	1 333,55	NO	NO	NO	11 755,83
C. Metal Production	49 362,61	561,73	NE	NE,NO	126,68	NE,NO	50 051,01
D. Other Production	NO						NO
E. Production of Halocarbons and SF_6				NA,NE	NA	NA	NA,NE
F. Consumption of Halocarbons and SF_6 (2)				NE,NO	NE,NO	NE,NO	NE,NO
G. Other	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NA,NE**		**365,39**				**365,39**
4. Agriculture		**19 868,89**	**23 371,19**				**43 240,08**
A. Enteric Fermentation		18 083,97					18 083,97
B. Manure Management		1 690,42	4 725,49				6 415,91
C. Rice Cultivation		94,50					94,50
D. Agricultural Soils(3)		NA,NE	18 645,70				18 645,70
E. Prescribed Burning of Savannas		NA	NA				NA
F. Field Burning of Agricultural Residues		NA,NO	NA,NO				NA,NO
G. Other		NA	NA				NA
5. Land Use, Land-Use Change and Forestry(1)	**-46 938,44**	**2,66**	**5,68**				**-46 930,10**
A. Forest Land	-58 235,93	2,66	0,69				-58 232,59
B. Cropland	26 576,24	NA,NE	NA,NE				26 576,24
C. Grassland	-13 825,66	NA,NE	NA,NE				-13 825,66
D. Wetlands	-92,77	NE	5,00				-87,77
E. Settlements	-1 360,32	NE	NE				-1 360,32
F. Other Land	NA,NE,NO	NE,NO	NE,NO				NA,NE,NO
G. Other		NE	NE				NE
6. Waste	**IE,NA,NO**	**7 170,87**	**1 063,30**				**8 234,17**
A. Solid Waste Disposal on Land	NA,NO	5 535,50					5 535,50
B. Waste-water Handling		1 635,37	1 063,30				2 698,67
C. Waste Incineration	IE	NO	IE				IE,NO
D. Other	NA	NA	NA				NA
7. Other *(as specified in Summary 1.A)*	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Memo Items: (4)							
International Bunkers	NA,NE,NO	NA,NE,NO	NA,NE,NO				NA,NE,NO
Aviation	NE	NE	NE				NE
Marine	NA,NE,NO	NA,NE,NO	NA,NE,NO				NA,NE,NO
Multilateral Operations	**NE**	**NE**	**NE**				**NE**
CO_2 Emissions from Biomass	**NA,NE,NO**						**NA,NE,NO**

Total CO_2 Equivalent Emissions without Land Use, Land-Use Change and Forestry (5)	451 450,01
Total CO_2 Equivalent Emissions with Land Use, Land-Use Change and Forestry (5)	404 519,91

Table A8.9. GHG emissions in 1998

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 [(1)]	CH_4	N_2O	HFCs [(2)]	PFCs [(2)]	SF_6 [(2)]	Total
	CO_2 equivalent (Gg)						
Total (Net Emissions) [(1)]	**255 688,16**	**76 554,65**	**25 226,97**	**NA,NE,NO**	**103,97**	**NA,NE,NO**	**357 573,75**
1. Energy	**236 791,92**	**50 607,71**	**539,19**				**287 938,82**
A. Fuel Combustion (Sectoral Approach)	236 757,83	897,72	539,07				238 194,62
1. Energy Industries	101 937,56	45,51	283,02				102 266,09
2. Manufacturing Industries and Construction	45 473,86	55,54	49,13				45 578,52
3. Transport	37 013,98	94,99	105,31				37 214,29
4. Other Sectors	48 651,17	695,73	95,23				49 442,13
5. Other	3 681,26	5,94	6,38				3 693,58
B. Fugitive Emissions from Fuels	34,09	49 710,00	0,12				49 744,20
1. Solid Fuels	NA,NE	28 591,82	NA,NE				28 591,82
2. Oil and Natural Gas	34,09	21 118,18	0,12				21 152,38
2. Industrial Processes	**71 399,42**	**588,70**	**1 231,79**	**NA,NE,NO**	**103,97**	**NA,NE,NO**	**73 323,88**
A. Mineral Products	10 541,40	NE	NE				10 541,40
B. Chemical Industry	9 802,24	21,16	1 231,79	NO	NO	NO	11 055,18
C. Metal Production	51 055,78	567,55	NE	NE,NO	103,97	NE,NO	51 727,30
D. Other Production	NO						NO
E. Production of Halocarbons and SF_6				NA,NE	NA	NA	NA,NE
F. Consumption of Halocarbons and SF_6 [(2)]				NE,NO	NE,NO	NE,NO	NE,NO
G. Other	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NA,NE**		**362,11**				**362,11**
4. Agriculture		**18 110,51**	**22 023,49**				**40 134,00**
A. Enteric Fermentation		17 015,53					17 015,53
B. Manure Management		1 008,04	4 556,53				5 564,57
C. Rice Cultivation		86,94					86,94
D. Agricultural Soils[(3)]		NA,NE	17 466,96				17 466,96
E. Prescribed Burning of Savannas		NA	NA				NA
F. Field Burning of Agricultural Residues		NA,NO	NA,NO				NA,NO
G. Other		NA	NA				NA
5. Land Use, Land-Use Change and Forestry[(1)]	**-52 503,18**	**13,87**	**7,09**				**-52 482,22**
A. Forest Land	-61 029,31	13,87	3,58				-61 011,86
B. Cropland	23 285,78	NA,NE	NA,NE				23 285,78
C. Grassland	-14 379,30	NA,NE	NA,NE				-14 379,30
D. Wetlands	-58,89	NE	3,51				-55,38
E. Settlements	-321,45	NE	NE				-321,45
F. Other Land	NA,NE,NO	NE,NO	NE,NO				NA,NE,NO
G. Other		NE	NE				NE
6. Waste	**IE,NA,NO**	**7 233,87**	**1 063,30**				**8 297,17**
A. Solid Waste Disposal on Land	NA,NO	5 624,43					5 624,43
B. Waste-water Handling		1 609,44	1 063,30				2 672,74
C. Waste Incineration	IE	NO	IE				IE,NO
D. Other	NA	NA	NA				NA
7. Other *(as specified in Summary 1.A)*	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Memo Items: [(4)]							
International Bunkers	466,68	1,32	1,17				469,17
Aviation	NE	NE	NE				NE
Marine	466,68	1,32	1,17				469,17
Multilateral Operations	**NE**	**NE**	**NE**				**NE**
CO_2 Emissions from Biomass	**1 882,50**						**1 882,50**

Total CO_2 Equivalent Emissions without Land Use, Land-Use Change and Forestry [(5)]	410 055,97
Total CO_2 Equivalent Emissions with Land Use, Land-Use Change and Forestry [(5)]	357 573,75

Table A8.10. GHG emissions in 1999

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 [(1)]	CH_4	N_2O	HFCs [(2)]	PFCs [(2)]	SF_6 [(2)]	Total
	CO_2 equivalent (Gg)						
Total (Net Emissions) [(1)]	**265 726,19**	**75 531,71**	**23 136,73**	**NA,NE,NO**	**87,74**	**NA,NE,NO**	**364 482,37**
1. Energy	**234 086,77**	**50 751,19**	**532,31**				**285 370,27**
A. Fuel Combustion (Sectoral Approach)	234 052,44	835,52	532,19				235 420,16
1. Energy Industries	105 146,23	45,99	277,97				105 470,19
2. Manufacturing Industries and Construction	43 300,52	55,46	51,31				43 407,29
3. Transport	36 762,00	92,70	105,33				36 960,03
4. Other Sectors	44 930,03	634,98	90,19				45 655,21
5. Other	3 913,67	6,38	7,39				3 927,43
B. Fugitive Emissions from Fuels	34,32	49 915,67	0,12				49 950,11
1. Solid Fuels	NA,NE	28 255,59	NA,NE				28 255,59
2. Oil and Natural Gas	34,32	21 660,08	0,12				21 694,52
2. Industrial Processes	**75 203,74**	**633,62**	**1 100,42**	**NA,NE,NO**	**87,74**	**NA,NE,NO**	**77 025,52**
A. Mineral Products	10 230,62	NE	NE				10 230,62
B. Chemical Industry	10 972,26	16,99	1 100,42	NO	NO	NO	12 089,68
C. Metal Production	54 000,86	616,63	NE	NE,NO	87,74	NE,NO	54 705,23
D. Other Production	NO						NO
E. Production of Halocarbons and SF_6				NA,NE	NA	NA	NA,NE
F. Consumption of Halocarbons and SF_6 [(2)]				NE,NO	NE,NO	NE,NO	NE,NO
G. Other	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NA,NE**		**358,56**				**358,56**
4. Agriculture		**16 811,53**	**20 120,64**				**36 932,17**
A. Enteric Fermentation		15 764,96					15 764,96
B. Manure Management		954,60	4 293,11				5 247,70
C. Rice Cultivation		91,98					91,98
D. Agricultural Soils[(3)]		NA,NE	15 827,53				15 827,53
E. Prescribed Burning of Savannas		NA	NA				NA
F. Field Burning of Agricultural Residues		NA,NO	NA,NO				NA,NO
G. Other		NA	NA				NA
5. Land Use, Land-Use Change and Forestry[(1)]	**-43 564,31**	**18,38**	**7,99**				**-43 537,94**
A. Forest Land	-61 079,58	18,38	4,75				-61 056,45
B. Cropland	34 224,90	NA,NE	NA,NE				34 224,90
C. Grassland	-15 348,28	NA,NE	NA,NE				-15 348,28
D. Wetlands	2,63	NE	3,24				5,88
E. Settlements	-1 363,98	NE	NE				-1 363,98
F. Other Land	NA,NE,NO	NE,NO	NE,NO				NA,NE,NO
G. Other		NE	NE				NE
6. Waste	**IE,NA,NO**	**7 316,99**	**1 016,80**				**8 333,79**
A. Solid Waste Disposal on Land	NA,NO	5 729,79					5 729,79
B. Waste-water Handling		1 587,20	1 016,80				2 604,00
C. Waste Incineration	IE	NO	IE				IE,NO
D. Other	NA	NA	NA				NA
7. Other ***(as specified in Summary 1.A)***	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Memo Items: [(4)]							
International Bunkers	377,02	1,06	0,94				379,02
Aviation	NE	NE	NE				NE
Marine	377,02	1,06	0,94				379,02
Multilateral Operations	**NE**	**NE**	**NE**				**NE**
CO_2 Emissions from Biomass	**1 770,15**						**1 770,15**

Total CO_2 Equivalent Emissions without Land Use, Land-Use Change and Forestry [(5)]	408 020,31
Total CO_2 Equivalent Emissions with Land Use, Land-Use Change and Forestry [(5)]	364 482,37

Table A8.11. GHG emissions in 2000

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 [1]	CH_4	N_2O	HFCs [2]	PFCs [2]	SF_6 [2]	Total
	CO_2 equivalent (Gg)						
Total (Net Emissions) [1]	**258 489,73**	**76 885,97**	**21 583,52**	**NA,NE,NO**	**99,74**	**NA,NE,NO**	**357 058,96**
1. Energy	**216 517,63**	**53 693,13**	**486,68**				**270 697,44**
A. Fuel Combustion (Sectoral Approach)	216 483,71	713,39	486,56				217 683,66
1. Energy Industries	97 822,00	43,06	256,91				98 121,97
2. Manufacturing Industries and Construction	42 785,50	56,90	47,21				42 889,60
3. Transport	33 538,13	82,35	96,22				33 716,70
4. Other Sectors	39 121,80	525,43	79,70				39 726,93
5. Other	3 216,28	5,64	6,52				3 228,44
B. Fugitive Emissions from Fuels	33,93	52 979,74	0,12				53 013,79
1. Solid Fuels	NA,NE	31 381,84	NA,NE				31 381,84
2. Oil and Natural Gas	33,93	21 597,90	0,12				21 631,94
2. Industrial Processes	**80 016,47**	**704,99**	**1 919,39**	**NA,NE,NO**	**99,74**	**NA,NE,NO**	**82 740,59**
A. Mineral Products	10 536,94	NE	NE				10 536,94
B. Chemical Industry	10 692,82	15,98	1 919,39	NO	NO	NO	12 628,18
C. Metal Production	58 786,71	689,02	NE	NE,NO	99,74	NE,NO	59 575,47
D. Other Production	NO						NO
E. Production of Halocarbons and SF_6				NA,NE	NA	NA	NA,NE
F. Consumption of Halocarbons and SF_6 [2]				NE,NO	NE,NO	NE,NO	NE,NO
G. Other	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NA,NE**		**354,89**				**354,89**
4. Agriculture		**15 093,98**	**17 791,98**				**32 885,96**
A. Enteric Fermentation		14 257,36					14 257,36
B. Manure Management		730,78	3 699,15				4 429,93
C. Rice Cultivation		105,84					105,84
D. Agricultural Soils[3]		NA,NE	14 092,83				14 092,83
E. Prescribed Burning of Savannas		NA	NA				NA
F. Field Burning of Agricultural Residues		NA,NO	NA,NO				NA,NO
G. Other		NA	NA				NA
5. Land Use, Land-Use Change and Forestry[1]	**-38 044,37**	**3,44**	**4,48**				**-38 036,44**
A. Forest Land	-59 794,33	3,44	0,89				-59 790,00
B. Cropland	37 992,80	NA,NE	NA,NE				37 992,80
C. Grassland	-14 615,53	NA,NE	NA,NE				-14 615,53
D. Wetlands	-47,19	NE	3,60				-43,59
E. Settlements	-1 580,11	NE	NE				-1 580,11
F. Other Land	NA,NE,NO	NE,NO	NE,NO				NA,NE,NO
G. Other		NE	NE				NE
6. Waste	**IE,NA,NO**	**7 390,42**	**1 026,10**				**8 416,52**
A. Solid Waste Disposal on Land	NA,NO	5 826,28					5 826,28
B. Waste-water Handling		1 564,14	1 026,10				2 590,24
C. Waste Incineration	IE	NO	IE				IE,NO
D. Other	NA	NA	NA				NA
7. Other *(as specified in Summary 1.A)*	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Memo Items: [4]							
International Bunkers	342,50	0,97	0,86				344,33
Aviation	NE	NE	NE				NE
Marine	342,50	0,97	0,86				344,33
Multilateral Operations	**NE**	**NE**	**NE**				**NE**
CO_2 Emissions from Biomass	**1 956,07**						**1 956,07**

Total CO_2 Equivalent Emissions without Land Use, Land-Use Change and Forestry [5]	395 095,40
Total CO_2 Equivalent Emissions with Land Use, Land-Use Change and Forestry [5]	357 058,96

Table A8.12. GHG emissions in 2001

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 [1]	CH_4	N_2O	HFCs [2]	PFCs [2]	SF_6 [2]	Total
	CO_2 equivalent (Gg)						
Total (Net Emissions) [1]	**256 862,84**	**76 477,00**	**23 521,91**	**NA,NE,NO**	**96,59**	**NA,NE,NO**	**356 958,34**
1. Energy	**218 009,40**	**52 877,99**	**514,38**				**271 401,77**
A. Fuel Combustion (Sectoral Approach)	217 974,55	706,37	514,26				219 195,18
1. Energy Industries	101 346,61	44,89	287,95				101 679,46
2. Manufacturing Industries and Construction	41 449,31	57,89	46,58				41 553,78
3. Transport	33 731,09	89,82	94,48				33 915,38
4. Other Sectors	38 418,92	508,60	79,07				39 006,58
5. Other	3 028,63	5,17	6,18				3 039,97
B. Fugitive Emissions from Fuels	34,84	52 171,63	0,12				52 206,59
1. Solid Fuels	NA,NE	30 741,43	NA,NE				30 741,43
2. Oil and Natural Gas	34,84	21 430,20	0,12				21 465,17
2. Industrial Processes	**80 865,27**	**724,63**	**1 850,22**	**NA,NE,NO**	**96,59**	**NA,NE,NO**	**83 536,71**
A. Mineral Products	10 273,27	NE	NE				10 273,27
B. Chemical Industry	10 835,20	22,92	1 850,22	NO	NO	NO	12 708,34
C. Metal Production	59 756,80	701,71	NE	NE,NO	96,59	NE,NO	60 555,10
D. Other Production	NO						NO
E. Production of Halocarbons and SF_6				NA,NE	NA	NA	NA,NE
F. Consumption of Halocarbons and SF_6 [2]				NE,NO	NE,NO	NE,NO	NE,NO
G. Other	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NA,NE**		**351,51**				**351,51**
4. Agriculture		**15 371,94**	**19 758,09**				**35 130,03**
A. Enteric Fermentation		14 549,55					14 549,55
B. Manure Management		743,43	3 913,68				4 657,11
C. Rice Cultivation		78,96					78,96
D. Agricultural Soils[3]		NA,NE	15 844,41				15 844,41
E. Prescribed Burning of Savannas		NA	NA				NA
F. Field Burning of Agricultural Residues		NA,NO	NA,NO				NA,NO
G. Other		NA	NA				NA
5. Land Use, Land-Use Change and Forestry[1]	**-42 011,83**	**14,17**	**6,12**				**-41 991,54**
A. Forest Land	-59 150,93	14,17	3,66				-59 133,10
B. Cropland	35 234,17	NA,NE	NA,NE				35 234,17
C. Grassland	-16 532,46	NA,NE	NA,NE				-16 532,46
D. Wetlands	3,40	NE	2,46				5,86
E. Settlements	-1 566,01	NE	NE				-1 566,01
F. Other Land	NA,NE,NO	NE,NO	NE,NO				NA,NE,NO
G. Other		NE	NE				NE
6. Waste	**IE,NA,NO**	**7 488,27**	**1 041,60**				**8 529,87**
A. Solid Waste Disposal on Land	NA,NO	5 936,01					5 936,01
B. Waste-water Handling		1 552,26	1 041,60				2 593,86
C. Waste Incineration	IE	NO	IE				IE,NO
D. Other	NA	NA	NA				NA
7. Other *(as specified in Summary 1.A)*	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Memo Items: [4]							
International Bunkers	367,25	1,04	0,92				369,20
Aviation	NE	NE	NE				NE
Marine	367,25	1,04	0,92				369,20
Multilateral Operations	**NE**	**NE**	**NE**				**NE**
CO_2 Emissions from Biomass	**2 175,69**						**2 175,69**

Total CO_2 Equivalent Emissions without Land Use, Land-Use Change and Forestry [5]	398 949,88
Total CO_2 Equivalent Emissions with Land Use, Land-Use Change and Forestry [5]	356 958,34

Table A8.13. GHG emissions in 2002

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 (1)	CH_4	N_2O	HFCs (2)	PFCs (2)	SF_6 (2)	Total
	CO_2 equivalent (Gg)						
Total (Net Emissions) (1)	**263 950,53**	**75 776,99**	**23 341,26**	**NA,NE,NO**	**85,02**	**NA,NE,NO**	**363 153,79**
1. Energy	**219 640,51**	**52 288,80**	**536,40**				**272 465,71**
A. Fuel Combustion (Sectoral Approach)	219 605,09	710,68	536,28				220 852,05
1. Energy Industries	101 142,80	42,00	293,99				101 478,78
2. Manufacturing Industries and Construction	40 873,08	59,32	48,56				40 980,97
3. Transport	35 140,73	94,15	98,60				35 333,49
4. Other Sectors	40 781,40	512,24	90,26				41 383,89
5. Other	1 667,08	2,97	4,86				1 674,91
B. Fugitive Emissions from Fuels	35,43	51 578,12	0,12				51 613,67
1. Solid Fuels	NA,NE	30 034,16	NA,NE				30 034,16
2. Oil and Natural Gas	35,43	21 543,96	0,12				21 579,51
2. Industrial Processes	**81 652,22**	**741,45**	**1 823,76**	**NA,NE,NO**	**85,02**	**NA,NE,NO**	**84 302,46**
A. Mineral Products	10 924,47	NE	NE				10 924,47
B. Chemical Industry	10 686,86	23,91	1 823,76	NO	NO	NO	12 534,53
C. Metal Production	60 040,90	717,54	NE	NE,NO	85,02	NE,NO	60 843,46
D. Other Production	NO						NO
E. Production of Halocarbons and SF_6				NA,NE	NA	NA	NA,NE
F. Consumption of Halocarbons and SF_6 (2)				NE,NO	NE,NO	NE,NO	NE,NO
G. Other	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NA,NE**		**348,22**				**348,22**
4. Agriculture		**15 142,71**	**19 548,64**				**34 691,34**
A. Enteric Fermentation		14 299,08					14 299,08
B. Manure Management		764,24	3 935,18				4 699,42
C. Rice Cultivation		79,38					79,38
D. Agricultural Soils(3)		NA,NE	15 613,46				15 613,46
E. Prescribed Burning of Savannas		NA	NA				NA
F. Field Burning of Agricultural Residues		NA,NO	NA,NO				NA,NO
G. Other		NA	NA				NA
5. Land Use, Land-Use Change and Forestry(1)	**-37 342,21**	**11,20**	**5,44**				**-37 325,57**
A. Forest Land	-58 036,65	11,20	2,89				-58 022,55
B. Cropland	38 371,43	NA,NE	NA,NE				38 371,43
C. Grassland	-16 541,27	NA,NE	NA,NE				-16 541,27
D. Wetlands	-21,91	NE	2,54				-19,37
E. Settlements	-1 113,81	NE	NE				-1 113,81
F. Other Land	NA,NE,NO	NE,NO	NE,NO				NA,NE,NO
G. Other		NE	NE				NE
6. Waste	**IE,NA,NO**	**7 592,83**	**1 078,80**				**8 671,63**
A. Solid Waste Disposal on Land	NA,NO	6 056,86					6 056,86
B. Waste-water Handling		1 535,97	1 078,80				2 614,77
C. Waste Incineration	IE	NO	IE				IE,NO
D. Other	NA	NA	NA				NA
7. Other *(as specified in Summary 1.A)*	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Memo Items: (4)							
International Bunkers	218,63	0,61	0,54				219,78
Aviation	NE	NE	NE				NE
Marine	218,63	0,61	0,54				219,78
Multilateral Operations	**NE**	**NE**	**NE**				**NE**
CO_2 Emissions from Biomass	**2 539,66**						**2 539,66**

Total CO_2 Equivalent Emissions without Land Use, Land-Use Change and Forestry (5)	400 479,36
Total CO_2 Equivalent Emissions with Land Use, Land-Use Change and Forestry (5)	363 153,79

Table A8.14. GHG emissions in 2003

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 [(1)]	CH_4	N_2O	HFCs [(2)]	PFCs [(2)]	SF_6 [(2)]	Total
	CO_2 equivalent (Gg)						
Total (Net Emissions) [(1)]	**281 319,41**	**74 524,70**	**20 892,24**	**NA,NE,NO**	**66,49**	**NA,NE,NO**	**376 802,83**
1. Energy	**233 833,95**	**52 853,26**	**551,93**				**287 239,13**
A. Fuel Combustion (Sectoral Approach)	233 797,55	757,54	551,81				235 106,89
1. Energy Industries	107 696,29	43,62	298,78				108 038,69
2. Manufacturing Industries and Construction	45 583,53	67,88	55,74				45 707,15
3. Transport	36 301,04	96,26	102,32				36 499,63
4. Other Sectors	42 543,94	546,90	90,29				43 181,13
5. Other	1 672,74	2,88	4,67				1 680,29
B. Fugitive Emissions from Fuels	36,40	52 095,72	0,12				52 132,24
1. Solid Fuels	NA,NE	29 029,83	NA,NE				29 029,83
2. Oil and Natural Gas	36,40	23 065,88	0,12				23 102,40
2. Industrial Processes	**86 708,86**	**808,87**	**1 998,90**	**NA,NE,NO**	**66,49**	**NA,NE,NO**	**89 583,13**
A. Mineral Products	14 049,03	NE	NE				14 049,03
B. Chemical Industry	11 592,00	31,91	1 998,90	NO	NO	NO	13 622,82
C. Metal Production	61 067,84	776,96	NE	NE,NO	66,49	NE,NO	61 911,28
D. Other Production	NO						NO
E. Production of Halocarbons and SF_6				NA,NE	NA	NA	NA,NE
F. Consumption of Halocarbons and SF_6 [(2)]				NE,NO	NE,NO	NE,NO	NE,NO
G. Other	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NA,NE**		**345,45**				**345,45**
4. Agriculture		**13 159,44**	**16 941,14**				**30 100,59**
A. Enteric Fermentation		12 449,25					12 449,25
B. Manure Management		616,11	3 427,02				4 043,14
C. Rice Cultivation		94,08					94,08
D. Agricultural Soils[(3)]		NA,NE	13 514,12				13 514,12
E. Prescribed Burning of Savannas		NA	NA				NA
F. Field Burning of Agricultural Residues		NA,NO	NA,NO				NA,NO
G. Other		NA	NA				NA
5. Land Use, Land-Use Change and Forestry[(1)]	**-39 223,40**	**5,62**	**3,91**				**-39 213,87**
A. Forest Land	-56 891,92	5,62	1,45				-56 884,84
B. Cropland	37 088,61	NA,NE	NA,NE				37 088,61
C. Grassland	-17 782,81	NA,NE	NA,NE				-17 782,81
D. Wetlands	-30,36	NE	2,46				-27,90
E. Settlements	-1 606,92	NE	NE				-1 606,92
F. Other Land	NA,NE,NO	NE,NO	NE,NO				NA,NE,NO
G. Other		NE	NE				NE
6. Waste	**IE,NA,NO**	**7 697,51**	**1 050,90**				**8 748,41**
A. Solid Waste Disposal on Land	NA,NO	6 167,87					6 167,87
B. Waste-water Handling		1 529,63	1 050,90				2 580,53
C. Waste Incineration	IE	NO	IE				IE,NO
D. Other	NA	NA	NA				NA
7. Other ***(as specified in Summary 1.A)***	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Memo Items: [(4)]							
International Bunkers	154,52	0,44	0,39				155,34
Aviation	NE	NE	NE				NE
Marine	154,52	0,44	0,39				155,34
Multilateral Operations	**NE**	**NE**	**NE**				**NE**
CO_2 Emissions from Biomass	**2 757,51**						**2 757,51**

Total CO_2 Equivalent Emissions without Land Use, Land-Use Change and Forestry [(5)]	416 016,71
Total CO_2 Equivalent Emissions with Land Use, Land-Use Change and Forestry [(5)]	376 802,83

Table A8.15. GHG emissions in 2004

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 [1]	CH_4	N_2O	HFCs [2]	PFCs [2]	SF_6 [2]	Total
	CO_2 equivalent (Gg)						
Total (Net Emissions) [1]	**284 800,02**	**74 113,56**	**22 279,66**	**IE,NA,NE,NO**	**80,44**	**IE,NA,NE,NO**	**381 273,68**
1. Energy	**228 679,48**	**53 244,92**	**526,22**				**282 450,62**
A. Fuel Combustion (Sectoral Approach)	228 642,25	757,43	526,09				229 925,77
1. Energy Industries	100 150,15	42,08	272,37				100 464,59
2. Manufacturing Industries and Construction	47 055,87	71,56	57,83				47 185,25
3. Transport	37 473,88	100,12	105,85				37 679,85
4. Other Sectors	42 446,98	540,88	86,03				43 073,90
5. Other	1 515,37	2,80	4,02				1 522,18
B. Fugitive Emissions from Fuels	37,23	52 487,49	0,13				52 524,85
1. Solid Fuels	NA,NE	29 232,65	NA,NE				29 232,65
2. Oil and Natural Gas	37,23	23 254,83	0,13				23 292,19
2. Industrial Processes	**88 262,36**	**852,35**	**2 155,03**	**IE,NA,NE,NO**	**80,44**	**IE,NA,NE,NO**	**91 350,18**
A. Mineral Products	15 280,17	NE	NE				15 280,17
B. Chemical Industry	11 563,43	35,89	2 155,03	IE,NO	IE,NO	IE,NO	13 754,36
C. Metal Production	61 418,76	816,46	NE	NE,NO	80,44	NE,NO	62 315,65
D. Other Production	NE						NE
E. Production of Halocarbons and SF_6				NA,NE	NA	NA	NA,NE
F. Consumption of Halocarbons and SF_6 [2]				NE,NO	NE,NO	NE,NO	NE,NO
G. Other	NA	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**NA,NE**		**342,97**				**342,97**
4. Agriculture		**12 237,89**	**18 179,45**				**30 417,33**
A. Enteric Fermentation		11 580,61					11 580,61
B. Manure Management		567,81	3 104,92				3 672,73
C. Rice Cultivation		89,46					89,46
D. Agricultural Soils[3]		NA,NE	15 074,53				15 074,53
E. Prescribed Burning of Savannas		NA	NA				NA
F. Field Burning of Agricultural Residues		NA,NO	NA,NO				NA,NO
G. Other		NA	NA				NA
5. Land Use, Land-Use Change and Forestry[1]	**-32 141,82**	**0,88**	**3,38**				**-32 137,56**
A. Forest Land	-55 602,26	0,88	0,23				-55 601,15
B. Cropland	38 471,36	NA,NE	NA,NE				38 471,36
C. Grassland	-13 800,66	NA,NE	NA,NE				-13 800,66
D. Wetlands	429,40	NE	3,16				432,55
E. Settlements	-1 639,66	NE	NE				-1 639,66
F. Other Land	NA,NE,NO	NE,NO	NE,NO				NA,NE,NO
G. Other		NE	NE				NE
6. Waste	**IE,NA,NO**	**7 777,53**	**1 072,60**				**8 850,13**
A. Solid Waste Disposal on Land	NA,NO	6 256,03					6 256,03
B. Waste-water Handling		1 521,50	1 072,60				2 594,10
C. Waste Incineration	IE	IE	IE				IE
D. Other	NA	NA	NA				NA
7. Other *(as specified in Summary 1.A)*	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Memo Items: [4]							
International Bunkers	186,62	0,52	0,46				187,61
Aviation	NE	NE	NE				NE
Marine	186,62	0,52	0,46				187,61
Multilateral Operations	**NE**	**NE**	**NE**				**NE**
CO_2 Emissions from Biomass	**2 518,03**						**2 518,03**

Total CO_2 Equivalent Emissions without Land Use, Land-Use Change and Forestry [5]	413 411,24
Total CO_2 Equivalent Emissions with Land Use, Land-Use Change and Forestry [5]	381 273,68

Table A8.16. Emission in sector «Energy» in 1990

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	NO_X	CO	NMVOC	SO_2
				(Gg)			
Total Energy	595 371,78	4 317,18	5,08	2 131,43	6 047,49	1 020,26	5 108,01
A. Fuel Combustion Activities (Sectoral Approach)	595 318,49	190,70	5,08	2 131,43	6 047,49	1 020,26	IE,NA,NE,NO
1. Energy Industries	271 267,11	5,54	2,14	778,34	82,25	19,95	IE
a. Public Electricity and Heat Production	271 267,11	5,54	2,14	778,34	82,25	19,95	IE
b. Petroleum Refining	IE	IE,NO	IE,NO	IE	IE	IE	IE
c. Manufacture of Solid Fuels and Other Energy Industries	IE	IE	IE	IE	IE	IE	IE
2. Manufacturing Industries and Construction	143 311,33	11,35	1,03	427,58	110,40	17,46	IE,NE
a. Iron and Steel	40 541,01	4,54	0,36	139,66	46,49	6,75	NE
b. Non-Ferrous Metals	1 086,02	0,06	0,01	3,05	0,66	0,12	NE
c. Chemicals	4 020,40	0,34	0,03	12,69	3,61	0,55	NE
d. Pulp, Paper and Print	160,79	0,02	0,00	0,48	0,37	0,03	NE
e. Food Processing, Beverages and Tobacco	5 811,17	0,32	0,05	15,73	4,48	0,60	NE
f. Other *(as specified in table 1.A(a) sheet 2)*	91 691,94	6,07	0,58	255,96	54,80	9,41	IE
Other non-specified	91 691,94	6,07	0,58	255,96	54,80	9,41	IE
3. Transport	89 330,85	13,99	0,82	828,30	4 434,80	837,88	IE,NE,NO
a. Civil Aviation	2 973,89	0,02	0,08	NE	NE	NE	NE
b. Road Transportation	46 345,94	10,18	0,39	444,02	3 366,87	633,15	IE
c. Railways	3 826,93	0,27	0,03	61,90	49,69	9,92	IE
d. Navigation	2 563,69	0,17	0,02	21,94	14,62	2,92	IE
e. Other Transportation *(as specified in table 1.A(a) sheet 3)*	33 620,40	3,34	0,30	300,44	1 003,61	191,89	IE,NO
Pipeline transport	6 606,13	0,12	0,07	17,67	2,36	0,59	NO
Off-road vehicles and other machinery	1 988,21	0,22	0,02	20,88	65,63	12,58	IE
Agriculture	19 656,89	2,63	0,16	201,66	861,10	163,82	IE
Other non-specified	5 369,16	0,38	0,05	60,23	74,53	14,90	IE
4. Other Sectors	91 409,20	159,83	1,10	97,21	1 420,04	144,97	IE
a. Commercial/Institutional	22 860,71	3,77	0,25	24,11	313,40	31,93	IE
b. Residential	64 831,88	153,17	0,82	68,68	1 087,11	110,95	IE
c. Agriculture/Forestry/Fisheries	3 716,61	2,89	0,03	4,43	19,53	2,09	IE
5. Other *(as specified in table 1.A(a) sheet 4)*	NA,NO	NA,NO	NA,NO	NA,NE	NA,NE	NA,NE	NA,NE
a. Stationary	NO	NO	NO	NE	NE	NE	NE
Other non-specified	NO	NO	NO	NE	NE	NE	NE
b. Mobile	NA	NA	NA	NA	NA	NA	NA
B. Fugitive Emissions from Fuels	53,28	4 126,48	0,00	NA,NE	NA,NE	NA,NE	NA,NE
1. Solid Fuels	NA,NE	2 637,92	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE
a. Coal Mining and Handling	NE	2 637,92	NE	NE	NE	NE	
b. Solid Fuel Transformation	NE	NE	NE	NE	NE	NE	NE
c. Other *(as specified in table 1.B.1)*	NA	NA	NA	NA	NA	NA	NA
2. Oil and Natural Gas	53,28	1 488,56	0,00	NA,NE	NA,NE	NA,NE	NA,NE
a. Oil	0,06	4,65	NE	NE	NE	NE	NE
b. Natural Gas	2,67	1 483,59				NE	NE
c. Venting and Flaring	50,55	0,31	0,00	NE	NE	NE	NE
Venting	NE	NE				NE	NE
Flaring	50,55	0,31	0,00	NE	NE	NE	NE
d. Other *(as specified in table 1.B.2)*	NA	NA	NA	NA	NA	NA	NA
Memo Items: [(1)]							
International Bunkers	3 563,80	0,47	0,03	30,04	20,03	4,01	NE
Aviation	NE	NE	NE	NE	NE	NE	NE
Marine	3 563,80	0,47	0,03	30,04	20,03	4,01	NE
Multilateral Operations	NE	NE	NE	NE	NE	NE	NE
CO_2 Emissions from Biomass	3 658,85						

Table A8.17. Emission in sector «Industrial processes» in 1990

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	HFCs[1]		PFCs[1]		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)				(Gg)					
Total Industrial Processes	123 995,16	62,35	8,52	NA,NE,NO	NA,NE,NO	IE,NA,NE,NO	203,23	NA,NE,NO	NA,NE,NO	30,96	115,56	874,79	190,04
A. Mineral Products	25 208,66	NE	NE							0,20	0,08	671,75	7,11
1. Cement Production	9 287,20												6,82
2. Lime Production	5 671,15												
3. Limestone and Dolomite Use	9 882,54												
4. Soda Ash Production and Use	367,77												
5. Asphalt Roofing	NE										0,00	0,00	
6. Road Paving with Asphalt	NE									0,20	0,08	669,75	0,29
7. Other *(as specified in table 2(I)A-G)*	IE	NE	NE							NO	NO	2,00	NO
Glass Production	IE	NE	NE							NO	NO	2,00	NO
B. Chemical Industry	14 147,72	4,58	8,52	NO	NO	NO	NO	NO	NO	24,88	43,67	38,28	88,64
1. Ammonia Production	14 107,58	NE	NE							NO	39,03	23,22	0,15
2. Nitric Acid Production			3,56							24,30			
3. Adipic Acid Production	NE		4,96							0,48	2,03	2,56	
4. Carbide Production	40,13	NE,NO								NE	NO	NO	NO
5. Other *(as specified in table 2(I)A-G)*	IE,NE	4,58	NE,NO	NO	NA,NO	NO	NA,NO	NO	NO	0,10	2,60	12,50	88,49
Carbon Black		2,86								0,10	2,60	10,42	0,81
Ethylene	NE	0,45	NE									0,62	
Dichloroethylene		NO											
Styrene		NO										NO	
Methanol		1,27											
Propylene	NE	NE	NE	NO	NO	NO	NO	NO	NO	NO	NO	0,30	NO
Polystyrene	NE	NE	NE	NO	NO	NO	NO	NO	NO	NO	NO	0,74	NO
Sulphuric acid production	NE	NE	NE	NO	NO	NO	NO	NO	NO	NO	NO	NO	87,69
Coke	IE	IE	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Phtalic Anhydride	NE	NE	NE	NO	NO	NO	NO	NO	NO	NO	NO	0,42	NO
C. Metal Production	84 638,78	57,77	NE	NO	NE,NO	IE,NO	203,23	NO	NE,NO	5,72	71,23	6,07	93,57
1. Iron and Steel Production	80 459,16	57,77								5,52	58,46	6,07	92,22
2. Ferroalloys Production	IE	IE								IE	IE	IE	IE
3. Aluminium Production	IE	IE					IE			IE	IE	IE	IE
4. SF_6 Used in Aluminium and Magnesium Foundries								NO	NE				
5. Other *(as specified in table 2(I)A-G)*	4 179,62	NE	NE	NO	NA,NE	NO	203,23	NO	NO	0,20	12,77	NO	1,34
Aluminium and Ferroalloys Production	4 179,62	NE	NE	NO	NE	NO	203,23	NO	NO	0,20	12,77	NO	1,34
D. Other Production	NO									0,16	0,58	158,68	0,73
1. Pulp and Paper										0,16	0,58	0,38	0,73
2. Food and Drink[2]	NE											158,30	
E. Production of Halocarbons and SF_6					NA,NE		NA		NA				
1. By-product Emissions					NA,NE		NA		NA				
Production of HCFC-22					NE								
Other					NA		NA		NA				
2. Fugitive Emissions					NA		NA		NA				
3. Other *(as specified in table 2(II))*					NA		NA		NA				
F. Consumption of Halocarbons and SF_6				NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO				
1. Refrigeration and Air Conditioning Equipment				NO	NO	NE	NO	NE	NO				
2. Foam Blowing				NE	NE	NE	NE	NE	NE				
3. Fire Extinguishers				NE	NE	NE	NE	NE	NE				
4. Aerosols/ Metered Dose Inhalers				NE	NE	NE	NE	NE	NE				
5. Solvents				NE	NE	NE	NE	NE	NE				
6. Other applications using ODS[3] substitutes				NO	NO	NO	NO	NO	NO				
7. Semiconductor Manufacture				NO	NO	NO	NO	NO	NO				
8. Electrical Equipment				NO	NO	NO	NO	NO	NO				
9. Other *(as specified in table 2(II)*				NO	NE	NO	NE	NO	NO				
Other non-specified				NO	NE	NO	NE	NO	NO				
G. Other *(as specified in tables 2(I).A-G and 2(II))*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table A8.18. Emission in sector «Solvent and Other Products Use» in 1990

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	N_2O	NMVOC
	(Gg)		
Total Solvent and Other Product Use	NA,NE	1,22	346,12
A. Paint Application	NE		225,82
B. Degreasing and Dry Cleaning	NE	NE	18,41
C. Chemical Products, Manufacture and Processing	**NE**		101,89
D. Other	NA	1,22	NA
1. Use of N_2O for Anaesthesia		1,22	
2. N_2O from Fire Extinguishers		NE	
3. N_2O from Aerosol Cans		NE	
4. Other Use of N_2O		NE	
5. Other *(as specified in table 3.A-D)*	NA	NA	NA

Table A8.19. Emission in sector «Agriculture» in 1990

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CH_4	N_2O	NO_x	CO	NMVOC
	(Gg)				
Total Agriculture	**2 517,90**	156,39	NA,NO	NA,NO	NA,NE,NO
A. Enteric Fermentation	1 641,95				
1. Cattle [1]	1 533,74				
Option A:					
Dairy Cattle	IE				
Non-Dairy Cattle	IE				
Option B:					
Mature Dairy Cattle	908,42				
Mature Non-Dairy Cattle	408,96				
Young Cattle	216,36				
2. Buffalo	NE				
3. Sheep	63,17				
4. Goats	2,61				
5. Camels and Llamas	NE				
6. Horses	13,29				
7. Mules and Asses	NE				
8. Swine	29,14				
9. Poultry	NE				
10. Other *(as specified in table 4.A)*	NO				
Other non-specified	NO				
B. Manure Management	867,64	25,46			NE,NO
1. Cattle [1]	690,23				
Option A:					
Dairy Cattle	IE				
Non-Dairy Cattle	IE				
Option B:					
Mature Dairy Cattle	457,86				
Mature Non-Dairy Cattle	183,06				
Young Cattle	49,31				
2. Buffalo	NE				
3. Sheep	1,50				
4. Goats	0,06				
5. Camels and Llamas	NE				
6. Horses	1,03				
7. Mules and Asses	NE				
8. Swine	166,84				
9. Poultry	7,99				
10. Other livestock *(as specified in table 4.B(a))*	NO				
Other non-specified	NO				

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CH_4	N_2O	NO_x	CO	NMVOC
	(Gg)				
B. Manure Management (continued)					
11. Anaerobic Lagoons		0,39			NE
12. Liquid Systems		NO			NO
13. Solid Storage and Dry Lot		24,51			NO
14. Other AWMS		0,56			NE
C. Rice Cultivation	8,31				**NA,NE**
1. Irrigated	8,31				NE
2. Rainfed	NO				NE
3. Deep Water	NO				NE
4. Other *(as specified in table 4.C)*	NA				NA
D. Agricultural Soils [(2)]	NA,NE	130,92			NA,NE
1. Direct Soil Emissions	NE	69,26			NE
2. Pasture, Range and Paddock Manure [(3)]		19,15			NE
3. Indirect Emissions	NE	42,50			NE
4. Other *(as specified in table 4.D)*	NA	NA			NA
E. Prescribed Burning of Savannas	NA	NA	NO	NO	NO
F. Field Burning of Agricultural Residues	NA,NO	NA,NO	NO	NO	NO
1 . Cereals	NO	NO	NE	NE	NO
2. Pulses	NA,NO	NA,NO	NE	NE	NO
3 . Tubers and Roots	NO	NO	NE	NE	NO
4 . Sugar Cane	NO	NO	NE	NE	NO
5 . Other *(as specified in table 4.F)*	NO	NO	NE	NE	NO
Other non-specified	NO	NO	NE	NE	NO
G. Other *(please specify)*	**NA**	**NA**	**NA**	**NA**	**NA**

Table A8.20. Emission/sink in sector «Land-Use, Land-Use Change and Forestry» in 1990

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/ removals[(1), (2)]	CH_4	N_2O	NO_x	CO
	(Gg)				
Total Land-Use Categories	**-33 839,16**	**0,40**	**0,03**	**0,10**	**3,50**
A. Forest Land	**-55 408,31**	**0,40**	**0,01**	**0,10**	**3,50**
1. Forest Land remaining Forest Land	-54 011,60	0,40	0,01	0,10	3,50
2. Land converted to Forest Land	-1 396,71	NE	NE	NE	NE
B. Cropland	**28 948,54**	**NA,NE**	**NA,NE**	**NE**	**NE**
1. Cropland remaining Cropland	25 920,31	NA	NA	NE	NE
2. Land converted to Cropland	-21,28	NE	NA,NE	NE	NE
C. Grassland	**-9 046,72**	**NA,NE**	**NA,NE**	**NE**	**NE**
1. Grassland remaining Grassland	-4 528,34	NA,NE	NA,NE	NE	NE
2. Land converted to Grassland	-4 518,38	NE	NE	NE	NE
D. Wetlands	**1 383,64**	**NE**	**0,02**	**NE**	**NE**
1. Wetlands remaining Wetlands [(3)]	-129,47	NE	NE	NE	NE
2. Land converted to Wetlands	1 513,11	NE	NE	NE	NE
E. Settlements	**283,69**	**NE**	**NE**	**NE**	**NE**
1. Settlements remaining Settlements [(3)]	-632,99	NE	NE	NE	NE
2. Land converted to Settlements	916,68	NE	NE	NE	NE
F. Other Land	**NA,NE,NO**	**NE,NO**	**NE,NO**	**NE,NO**	**NE,NO**
1. Other Land remaining Other Land [(4)]		NO	NO	NO	NO
2. Land converted to Other Land	NA,NE,NO	NE	NE	NE	NE
G. Other *(please specify)* [(5)]	**NE**	**NE**	**NE**	**NE**	**NE**
Harvested Wood Products [(6)]	NE	NE	NE	NE	NE
Information items[(7)]					
Forest Land converted to other Land-Use Categories	NE	NE	NE	NE	NE
Grassland converted to other Land-Use Categories	NE	NE	NE	NE	NE

Table A8.21. Emission in sector «Waste» in 1990

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 [1]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
	(Gg)						
Total Waste	**IE,NA,NO**	**300,78**	**5,02**	**NA,NO**	**NA,NO**	**NA,NO**	**NA,NO**
A. Solid Waste Disposal on Land	**NA,NO**	**224,61**		**NA,NO**	**NA,NO**	**NA,NO**	
1. Managed Waste Disposal on Land	NO	NA		NO	NO	NO	
2. Unmanaged Waste Disposal Sites	NO	224,61		NO	NO	NO	
3. Other *(as specified in table 6.A)*	NA	NA		NA	NA	NA	
B. Waste Water Handling		**76,17**	**5,02**	**NA,NO**	**NA,NO**	**NA,NO**	
1. Industrial Wastewater		4,28	NE	NO	NO	NO	
2. Domestic and Commercial Waste Water		71,89	5,02	NO	NO	NO	
3. Other *(as specified in table 6.B)*		NA	NA	NA	NA	NA	
C. Waste Incineration	**IE**	**NO**	**IE**	**NO**	**NO**	**NO**	**NO**
D. Other *(please specify)*	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Table A8.22. Emission in sector «Energy» in 2004

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	NO_X	CO	NMVOC	SO_2
				(Gg)			
Total Energy	228 679,48	2 535,47	1,70	718,39	1 030,57	172,09	1 283,67
A. Fuel Combustion Activities (Sectoral Approach)	228 642,25	36,07	1,70	718,39	1 030,57	172,09	1 283,67
1. Energy Industries	100 150,15	2,00	0,88	294,07	34,32	7,55	859,24
a. Public Electricity and Heat Production	88 921,70	1,29	0,82	261,30	25,58	6,21	767,35
b. Petroleum Refining	2 377,13	0,14	0,01	5,96	1,17	0,21	2,77
c. Manufacture of Solid Fuels and Other Energy Industries	8 851,32	0,57	0,05	26,80	7,56	1,13	89,12
2. Manufacturing Industries and Construction	47 055,87	3,41	0,19	128,98	34,79	5,41	138,39
a. Iron and Steel	21 388,58	1,88	0,08	59,82	14,84	2,35	79,28
b. Non-Ferrous Metals	1 752,87	0,07	0,01	4,74	0,80	0,17	5,36
c. Chemicals	4 660,38	0,19	0,01	11,90	2,19	0,43	0,56
d. Pulp, Paper and Print	501,56	0,02	0,00	1,33	0,28	0,05	0,20
e. Food Processing, Beverages and Tobacco	5 558,89	0,20	0,03	15,34	3,34	0,58	11,43
f. Other *(as specified in table 1.A(a) sheet 2)*	13 193,59	1,06	0,06	35,86	13,34	1,83	41,57
Other non-specified	13 193,59	1,06	0,06	35,86	13,34	1,83	41,57
3. Transport	37 473,88	4,77	0,34	242,57	668,64	127,44	39,23
a. Civil Aviation	276,32	0,00	0,01	1,17	0,39	0,20	0,55
b. Road Transportation	20 733,49	4,11	0,17	114,67	566,94	106,94	26,26
c. Railways	820,99	0,06	0,01	13,44	11,20	2,24	1,58
d. Navigation	251,80	0,03	0,00	5,17	3,45	0,69	0,81
e. Other Transportation *(as specified in table 1.A(a) sheet 3)*	15 391,28	0,57	0,15	108,12	86,66	17,37	10,04
Pipeline transport	10 055,99	0,18	0,11	26,89	3,59	0,90	NO
Off-road vehicles and other machinery	1 186,79	0,10	0,01	12,74	26,00	5,06	2,29
Agriculture	4 148,50	0,29	0,03	68,49	57,07	11,41	7,75
Other non-specified	NO	NO	NO	NO	NO	NO	NO
4. Other Sectors	42 446,98	25,76	0,28	49,13	283,32	30,63	229,48
a. Commercial/Institutional	5 785,78	0,96	0,06	11,47	47,91	5,11	72,39
b. Residential	35 509,85	24,33	0,21	34,72	225,94	24,46	150,96
c. Agriculture/Forestry/Fisheries	1 151,35	0,47	0,02	2,94	9,47	1,05	6,12
5. Other *(as specified in table 1.A(a) sheet 4)*	1 515,37	0,13	0,01	3,64	9,50	1,07	17,32
a. Stationary	1 515,37	0,13	0,01	3,64	9,50	1,07	17,32
Other non-specified	1 515,37	0,13	0,01	3,64	9,50	1,07	17,32
b. Mobile	NA	NA	NA	NA	NA	NA	NA
B. Fugitive Emissions from Fuels	37,23	2 499,40	0,00	NA,NE	NA,NE	NA,NE	NA,NE
1. Solid Fuels	NA,NE	1 392,03	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE
a. Coal Mining and Handling	NE	1 392,03	NE	NE	NE	NE	
b. Solid Fuel Transformation	NE	NE	NE	NE	NE	NE	NE
c. Other *(as specified in table 1.B.1)*	NA	NA	NA	NA	NA	NA	NA
2. Oil and Natural Gas	37,23	1 107,37	0,00	NA,NE	NA,NE	NA,NE	NA,NE
a. Oil	0,03	2,27	NE	NE	NE	NE	NE
b. Natural Gas	1,86	1 104,89				NE	NE
c. Venting and Flaring	35,33	0,22	0,00	NE	NE	NE	NE
Venting	NE	NE				NE	NE
Flaring	35,33	0,22	0,00	NE	NE	NE	NE
d. Other *(as specified in table 1.B.2)*	NA	NA	NA	NA	NA	NA	NA
Memo Items: (1)							
International Bunkers	186,62	0,02	0,00	3,75	2,50	0,50	0,58
Aviation	NE	NE	NE	NE	NE	NE	NE
Marine	186,62	0,02	0,00	3,75	2,50	0,50	0,58
Multilateral Operations	NE	NE	NE	NE	NE	NE	NE
CO_2 Emissions from Biomass	2 518,03						

Table A8.23. Emission in sector «Industrial processes» in 2004

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	HFCs[1]		PFCs[1]		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)				(Gg)					
Total Industrial Processes	88 262,36	40,59	6,95	NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	80,44	IE,NA,NE,NO	IE,NA,NE,NO	18,09	96,03	230,75	94,14
A. Mineral Products	15 280,17	NE	NE							0,03	0,01	104,07	3,24
1. Cement Production	3 777,10												3,19
2. Lime Production	3 426,92												
3. Limestone and Dolomite Use	7 904,01												
4. Soda Ash Production and Use	172,14												
5. Asphalt Roofing	NE										0,00	0,00	
6. Road Paving with Asphalt	NE									0,03	0,01	103,68	0,04
7. Other *(as specified in table 2(I)A-G)*	IE	NE	NE							NO	NO	0,39	NO
Glass Production	IE	NE	NE							NO	NO	0,39	NO
B. Chemical Industry	11 563,43	1,71	6,95	NO	IE,NO	NO	IE,NO	IE,NO	IE,NO	13,86	40,80	29,76	25,39
1. Ammonia Production	11 541,19	NE	NE							NO	37,75	22,46	0,14
2. Nitric Acid Production			1,96							13,34			
3. Adipic Acid Production	NE		5,00							0,48	2,05	2,58	
4. Carbide Production	22,24	NE,NO								NO	NO	NO	NO
5. Other *(as specified in table 2(I)A-G)*	IE,NE	1,71	NE,NO	NO	IE,NA,NO	NO	IE,NA,NO	IE,NO	IE,NO	0,04	1,00	4,72	25,24
Carbon Black		1,10								0,04	1,00	4,01	0,31
Ethylene	NE	0,23	NE									0,33	
Dichloroethylene		NO											
Styrene		NO										NO	
Methanol		0,37											
Propylene	NE	NE	NE	NO	NO	NO	NO	NO	NO	NO	NO	0,15	NO
Polystyrene	NE	NE	NE	NO	NO	NO	NO	NO	NO	NO	NO	0,16	NO
Sulphuric acid production	NE	NE	NE	NO	NO	NO	NO	NO	NO	NO	NO	NO	24,93
Coke	IE	IE	NO	NO	IE	NO	IE	IE	IE	IE	IE	IE	IE
Phtalic Anhydride	NE	NE	NE	NO	NO	NO	NO	NO	NO	NO	NO	0,08	NO
C. Metal Production	61 418,76	38,88	NE	NO	NE,NO	IE,NO	80,44	NO	NE,NO	4,14	55,00	4,26	65,24
1. Iron and Steel Production	58 476,11	38,88								3,90	40,31	4,26	63,70
2. Ferroalloys Production	IE	IE								IE	IE	IE	IE
3. Aluminium Production	IE	IE					IE			IE	IE	IE	IE
4. SF_6 Used in Aluminium and Magnesium Foundries								NO	NE				
5. Other *(as specified in table 2(I)A-G)*	2 942,66	NE	NE	NO	NA,NE	NO	80,44	NO	NO	0,23	14,69	NO	1,54
Aluminium and Ferroalloys Production	2 942,66	NE	NE	NO	NE	NO	80,44	NO	NO	0,23	14,69	NO	1,54
D. Other Production	NE									0,06	0,22	92,66	0,28
1. Pulp and Paper										0,06	0,22	0,15	0,28
2. Food and Drink[2]	NE											92,51	
E. Production of Halocarbons and SF_6					NA,NE		NA		NA				
1. By-product Emissions					NA,NE		NA		NA				
Production of HCFC-22					NE								
Other					NA		NA		NA				
2. Fugitive Emissions					NA		NA		NA				
3. Other *(as specified in table 2(II))*					NA		NA		NA				
F. Consumption of Halocarbons and SF_6				NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO				
1. Refrigeration and Air Conditioning Equipment				NO	NO	NO	NO	NO	NO				
2. Foam Blowing				NE	NE	NE	NE	NE	NE				
3. Fire Extinguishers				NE	NE	NE	NE	NE	NE				
4. Aerosols/ Metered Dose Inhalers				NE	NE	NE	NE	NE	NE				
5. Solvents				NE	NE	NE	NE	NE	NE				
6. Other applications using ODS[3] substitutes				NO	NO	NO	NO	NO	NO				
7. Semiconductor Manufacture				NO	NO	NO	NO	NO	NO				
8. Electrical Equipment				NO	NO	NO	NO	NO	NO				
9. Other *(as specified in table 2(II)*				NO	NE	NO	NE	NO	NO				
Other non-specified				NO	NE	NO	NE	NO	NO				
G. Other *(as specified in tables 2(I).A-G and 2(II))*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table A8.24. Emission in sector «Solvent and Other Products Use» in 2004

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	N_2O	NMVOC
	(Gg)		
Total Solvent and Other Product Use	NA,NE	1,11	113,20
A. Paint Application	NE		66,19
B. Degreasing and Dry Cleaning	NE	NE	7,25
C. Chemical Products, Manufacture and Processing	**NE**		39,76
D. Other	NA	1,11	NA
1. Use of N_2O for Anaesthesia		1,11	
2. N_2O from Fire Extinguishers		NE	
3. N_2O from Aerosol Cans		NE	
4. Other Use of N_2O		NE	
5. Other *(as specified in table 3.A-D)*	NA	NA	NA

Table A8.25. Emission in sector «Agriculture» in 2004

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CH_4	N_2O	NO_x	CO	NMVOC
	(Gg)				
Total Agriculture	**582,76**	58,64	NA,NE,NO	NA,NE,NO	NA,NE,NO
A. Enteric Fermentation	551,46				
1. Cattle [1]	519,65				
Option A:					
Dairy Cattle	IE				
Non-Dairy Cattle	IE				
Option B:					
Mature Dairy Cattle	399,11				
Mature Non-Dairy Cattle	82,80				
Young Cattle	37,74				
2. Buffalo	NE				
3. Sheep	7,00				
4. Goats	4,47				
5. Camels and Llamas	NE				
6. Horses	10,64				
7. Mules and Asses	NE				
8. Swine	9,70				
9. Poultry	NE				
10. Other *(as specified in table 4.A)*	NO				
Other non-specified	NO				
B. Manure Management	27,04	10,02			NE,NO
1. Cattle [1]	15,87				
Option A:					
Dairy Cattle	IE				
Non-Dairy Cattle	IE				
Option B:					
Mature Dairy Cattle	13,06				
Mature Non-Dairy Cattle	2,19				
Young Cattle	0,62				
2. Buffalo	NE				
3. Sheep	0,17				
4. Goats	0,11				
5. Camels and Llamas	NE				
6. Horses	0,82				
7. Mules and Asses	NE				
8. Swine	5,15				
9. Poultry	4,93				
10. Other livestock *(as specified in table 4.B(a))*	NO				
Other non-specified	NO				

Table A8.26. Emission in sector «Agriculture» in 2004 (continue)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CH_4	N_2O	NO_x	CO	NMVOC
	(Gg)				
B. Manure Management (continued)					
11. Anaerobic Lagoons		0,00			NE
12. Liquid Systems		NO			NO
13. Solid Storage and Dry Lot		9,90			NO
14. Other AWMS		0,11			NE
C. Rice Cultivation	4,26				**NA,NE**
1. Irrigated	4,26				NE
2. Rainfed	NO				NE
3. Deep Water	NO				NE
4. Other *(as specified in table 4.C)*	NA				NA
D. Agricultural Soils [2]	NA,NE	48,63			NA,NE
1. Direct Soil Emissions	NE	28,63			NE
2. Pasture, Range and Paddock Manure [3]		8,41			NE
3. Indirect Emissions	NE	11,59			NE
4. Other *(as specified in table 4.D)*	NA	NA			NA
E. Prescribed Burning of Savannas	NA	NA	NO	NO	NO
F. Field Burning of Agricultural Residues	NA,NO	NA,NO	NE	NE	NO
1 . Cereals	NO	NO	NE	NE	NO
2. Pulses	NA,NO	NA,NO	NE	NE	NO
3 . Tubers and Roots	NO	NO	NE	NE	NO
4 . Sugar Cane	NO	NO	NE	NE	NO
5 . Other *(as specified in table 4.F)*	NO	NO	NE	NE	NO
Other non-specified	NO	NO	NE	NE	NO
G. Other *(please specify)*	**NA**	**NA**	**NA**	**NA**	**NA**

Table A8.27. Emission/sink in sector «Land-Use, Land-Use Change and Forestry» in 2004

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/ removals[(1), (2)]	CH_4	N_2O	NO_x	CO
	(Gg)				
Total Land-Use Categories	**-32 141,82**	**0,04**	**0,01**	**0,01**	**0,37**
A. Forest Land	**-55 602,26**	**0,04**	**0,00**	**0,01**	**0,37**
1. Forest Land remaining Forest Land	-47 049,59	0,04	0,00	0,01	0,37
2. Land converted to Forest Land	-8 552,67	NE	NE	NE	NE
B. Cropland	**38 471,36**	**NA,NE**	**NA,NE**	**NE**	**NE**
1. Cropland remaining Cropland	38 397,06	NA	NA	NE	NE
2. Land converted to Cropland	-23,73	NE	NA,NE	NE	NE
C. Grassland	**-13 800,66**	**NA,NE**	**NA,NE**	**NE**	**NE**
1. Grassland remaining Grassland	-13 800,66	NA,NE	NA,NE	NE	NE
2. Land converted to Grassland	NA,NE,NO	NE	NE	NE	NE
D. Wetlands	**429,40**	**NE**	**0,01**	**NE**	**NE**
1. Wetlands remaining Wetlands [(3)]	-36,30	NE	NE	NE	NE
2. Land converted to Wetlands	465,70	NE	NE	NE	NE
E. Settlements	**-1 639,66**	**NE**	**NE**	**NE**	**NE**
1. Settlements remaining Settlements [(3)]	-1 639,66	NE	NE	NE	NE
2. Land converted to Settlements	NA	NE	NE	NE	NE
F. Other Land	**NA,NE,NO**	**NE,NO**	**NE,NO**	**NE,NO**	**NE,NO**
1. Other Land remaining Other Land [(4)]		NO	NO	NO	NO
2. Land converted to Other Land	NA,NE,NO	NE	NE	NE	NE
G. Other *(please specify)* [(5)]	**NE**	**NE**	**NE**	**NE**	**NE**
Harvested Wood Products [(6)]	NE	NE	NE	NE	NE
Information items[(7)]					
Forest Land converted to other Land-Use Categories	NE	NE	NE	NE	NE
Grassland converted to other Land-Use Categories	NE	NE	NE	NE	NE

Table A8.28. Emission in sector «Waste» in 2004

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 (1)	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
	(Gg)						
Total Waste	**IE,NA,NO**	**370,36**	**3,46**	**NA,NO**	**NA,NO**	**NA,NO**	**NA,NO**
A. Solid Waste Disposal on Land	**NA,NO**	**297,91**		**NA,NO**	**NA,NO**	**NA,NO**	
1. Managed Waste Disposal on Land	NO	NA		NO	NO	NO	
2. Unmanaged Waste Disposal Sites	NO	297,91		NO	NO	NO	
3. Other *(as specified in table 6.A)*	NA	NA		NA	NA	NA	
B. Waste Water Handling		**72,45**	**3,46**	**NA,NO**	**NA,NO**	**NA,NO**	
1. Industrial Wastewater		1,19	NE	NO	NO	NO	
2. Domestic and Commercial Waste Water		71,26	3,46	NO	NO	NO	
3. Other *(as specified in table 6.B)*		NA	NA	NA	NA	NA	
C. Waste Incineration	**IE**	**IE**	**IE**	**NO**	**NO**	**NO**	**NO**
D. Other *(please specify)*	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**