

**Inventory of greenhouse gases emissions by sources and removals by sinks in the
Republic of Macedonia**

EXECUTIVE SUMMARY

July 2002

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Introduction

This publication is a result of a several months of analysis and cooperation between the experts group from the Center for energy, informatics and materials within Macedonian Academy of Sciences and Arts, and the Ministry of Environment and Physical Planning, related to preparation of the national inventory of greenhouse gas emissions by sources and removals by sinks. The inventory, which is the first of its type in the country, is a part of the First National Communication of the Republic of Macedonia, obligation of the country to the United Nations Framework Convention on Climate Change. The Republic of Macedonia ratified the UN Framework Convention on December 04, 1997 (Official Gazette – International agreements 61/97), and became party to the Convention on April 28, 1998. Preparation of the national communication was conducted thanks to the Global Environment Facility's (GEF) grant under the auspices of the project of the Macedonian Government and UNDP/GEF "Enabling Macedonia to Prepare its First National Communication in Response to Its Commitments to the UNFCCC".

The inventory is prepared according to IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 1996), with consideration of the three main GHGs: carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). The investigations were conducted by three working teams: the first team dealt with the energy sector, the second team focused on the industrial processes and waste sectors, and the third team worked on the agriculture and land use change and forestry sectors. The sufficiency and applicability of the existing annual and monthly publications of the State Statistical Office were checked for each sector. Complete and high quality input data concerning the economy activities in the country were provided, to remove all initial uncertainties. The correlation factors which determine the quality of the processes were mostly taken as prescribed by the methodology. Within all sectors, the annual reports of the State Statistical Office were main information sources, although for the waste and agriculture sectors (where lack and uncertainty of data were prevalent) other sources and local experts had to be extensively consulted.

Special treatment was applied to the energy sector, considering the complexity of this sector and its contribution to the total emissions with about 70%. The analyses were performed according to the type of final energy used: electricity production, heat production and transformation of mechanical energy for transport. Furthermore, separate detailed analyses were made for solid, liquid and gaseous fuels. The approach ensured the quality of input data for annual fuels demand determined by the structure and type of consumers. In addition, this approach is fully compatible with the longstanding practice of data collection in Macedonia.

The results of the GHG emissions calculations are presented according to the sectoral and subsectoral division in the IPCC methodology. At the end of this publication, an integral overview of GHG emissions in tables and figures for all sectors and all years of the period 1990-1998 is presented. It is worth pointing out the excellent matching (in range of 0.2%) of the results for the energy sector for all years obtained by the reference and by the sectoral approaches, being an indicator of high quality approach and accuracy in the calculations.

1. Inventory of GHG emissions from the energy sector

The preparation of input data for the energy sector was divided into categories according to the final energy used: electricity, heat energy and mechanical energy for transport. Within each of these three categories further division by fuel types (solid, liquid and gaseous) was made. The results, i.e. GHG emissions are presented following the sectors and subsectors definition subscribed by IPCC methodology.

1.1. Fuels used for electricity production

The review of the conversion and emission factors suggested by the IPCC methodology showed that the factors for the liquid and gaseous fuels are suitable for Macedonia and can be applied without modifications, while for the solid fuels they should be calculated taking into account the local conditions. There are two types of lignite used in the thermal power plants Bitola and Oslomej, while in the IPCC methodology only one type of lignite is defined. For that reason, parameters for equivalent lignite had to be calculated, i.e. equivalent heating value H_e , equivalent carbon content p_e and emission factor C_e for the total lignite consumption $A_e = A_1 + A_2$. The calculated values are presented in the table 1.1.1.

Table 1.1.1. Lignite consumption, heating values and emission factors

Year	Bitola A_1 [kt]	Oslomej A_2 [kt]	$A_1 + A_2$ [kt]	Bitola H_1 [TJ/kt]	Oslomej H_2 [TJ/kt]	H_e [TJ/kt]	Bitola p_1 [%]	Oslomej p_2 [%]	p_e [%]	C_e [t C/TJ]
1990	6,111	998	7,109	8,619	7,384	8,446	23.31	20.66	22.94	27.160
1991	5,810	787	6,597	8,443	6,927	8,262	23.31	20.66	22.99	27.830
1992	5,630	779	6,409	8,147	7,111	8,021	23.31	20.66	22.99	28.659
1993	5,863	712	6,575	8,114	7,821	8,082	23.31	20.66	23.02	28.486
1994	5,876	1,100	6,976	8,018	7,932	8,004	23.31	20.66	22.89	28.599
1995	6,058	1,170	7,228	7,824	7,750	7,812	23.31	20.66	22.88	29.290
1996	6,271	641	6,912	7,562	7,476	7,554	23.31	20.66	23.06	30.532
1997	6,368	1,046	7,414	7,831	7,597	7,798	23.31	20.66	22.94	29.413
1998	6,793	1,256	8,049	7,570	7,348	7,535	23.31	20.66	22.90	30.385

1.2. Fuels used for heat production

The estimates of the quantities of different primary-energy sources consumption for heat production over the analyzed period are based on some published and unpublished documents, as well as on experts' investigations. The evaluation of different primary-energy sources consumption over the analyzed period is shown in the table 1.2.1, where the liquid fuel consumption is given by subsectors, while fossil fuels consumption is summarized.

For calculation of GHG emissions, conversion and emissions factors subscribed by the IPCC methodology were used.

Inventory of GHG emissions from the energy sector

Table 1.2.1. Primary energy sources consumption [kt] for heat production

Year	Energy industries			Manufacturing industries and construction			Commercial/ Institutional & Residential			Agriculture/ Forestry/ Fishing			All sectors
	Resid. fuel oil	Gas/ Diesel oil	LPG	Resid. fuel oil	Gas/ Diesel oil	LPG	Resid. fuel oil	Gas/ Diesel oil	LPG	Resid. fuel oil	Gas/ Diesel oil	LPG	Solid fossil fuels
1990	113.2	0.0	0.0	202.8	44.6	31.0	87.9	31.1	13.1	46.2	25.3	6.0	190.0
1991	108.2	0.0	0.0	193.7	41.9	26.0	84.0	29.3	11.0	44.1	23.8	5.0	160.0
1992	100.6	0.0	0.0	180.2	35.3	18.0	78.1	24.6	7.6	41.0	20.1	3.5	174.0
1993	94.3	0.0	0.0	169.0	49.4	14.2	73.3	34.5	6.0	38.5	28.1	2.7	175.0
1994	66.9	0.0	0.0	119.9	43.7	9.9	52.0	30.5	4.2	27.3	24.8	1.9	148.0
1995	69.2	0.0	0.0	123.9	43.2	9.9	53.7	30.2	4.2	28.2	24.6	1.9	144.0
1996	74.2	0.0	0.0	132.9	45.9	9.9	57.6	32.0	4.2	30.3	26.1	1.9	109.0
1997	77.7	0.0	0.0	139.2	48.5	11.8	60.4	33.9	5.0	31.7	27.6	2.3	117.0
1998	76.5	0.0	0.0	137.0	52.1	14.9	59.4	36.3	6.3	31.2	29.6	2.9	142.0

1.3. Fuels used for transport

The estimates of GHG emissions from the transport sector were performed for each transport mode, as well as for each type of fuel.

The consumption of different types of fuel in the transport sector is given in the table 1.3.1. A different approach was applied to air transport, basing the calculations on the annual number of take-offs and landings at the airports in Skopje and Ohrid, and on the average consumption of fuel per take-off/landing per airplane. Considering the types of aircraft that fly from these airports, it is estimated that the average consumption of jet kerosene per take-off is roughly 400 kg, and per landing 300 kg per aircraft. These data, combined with the number of operations at both Macedonian airports, lead to the estimates given in column related to air transport in the table 1.3.1.

Table 1.3.1. Fuel consumption [kt] in the transport

Year	Road			Air [?]	Rail	Water	
	Gasoline	Gas/Diesel Oil	LPG	Jet Kerosene	Gas/Diesel Oil	Gasoline	Gas/Diesel Oil
1990	161.00	152.00	0.00	1.32	7.00	0.30	0.06
1991	163.00	143.12	0.00	2.66	6.88	0.30	0.06
1992	132.00	121.41	0.00	3.12	4.59	0.30	0.06
1993	182.00	178.00	0.00	4.17	3.92	0.30	0.06
1994	176.00	154.00	0.00	3.99	3.51	0.30	0.06
1995	171.00	153.00	0.00	4.40	3.86	0.30	0.06
1996	175.00	162.00	0.01	3.98	3.70	0.30	0.06
1997	163.00	171.00	0.27	3.59	3.91	0.30	0.06
1998	164.00	187.00	0.65	4.05	3.80	0.30	0.06

[?] Fuel consumption when taking-off and landing (military flights of KFOR and Army of Republic of Macedonia are excluded due to lack of data)

1.4. GHG emissions from the energy sector

The table 1.4.1 presents CO₂ emission from the energy sector for both approaches, reference (global) and sectoral. The discrepancy of the results is less than 0.2% for all years, which indicates accuracy in calculations.

Table 1.4.1. CO₂ emissions from the energy sector

Year	CO ₂ [kt]		Difference [%]
	Reference approach	Sectoral approach	
1990	8,767.19	8,769.97	0.03
1991	8,229.68	8,234.05	0.05
1992	7,721.37	7,727.43	0.07
1993	8,214.27	8,227.08	0.14
1994	8,007.50	8,016.40	0.10
1995	8,235.36	8,244.53	0.10
1996	8,147.16	8,160.77	0.15
1997	8,579.70	8,591.50	0.13
1998	9,172.84	9,189.06	0.17

CO₂, CH₄, N₂O and CO₂-eq emissions are presented numerically in table 1.4.2 and graphically in figure 1.4.1.

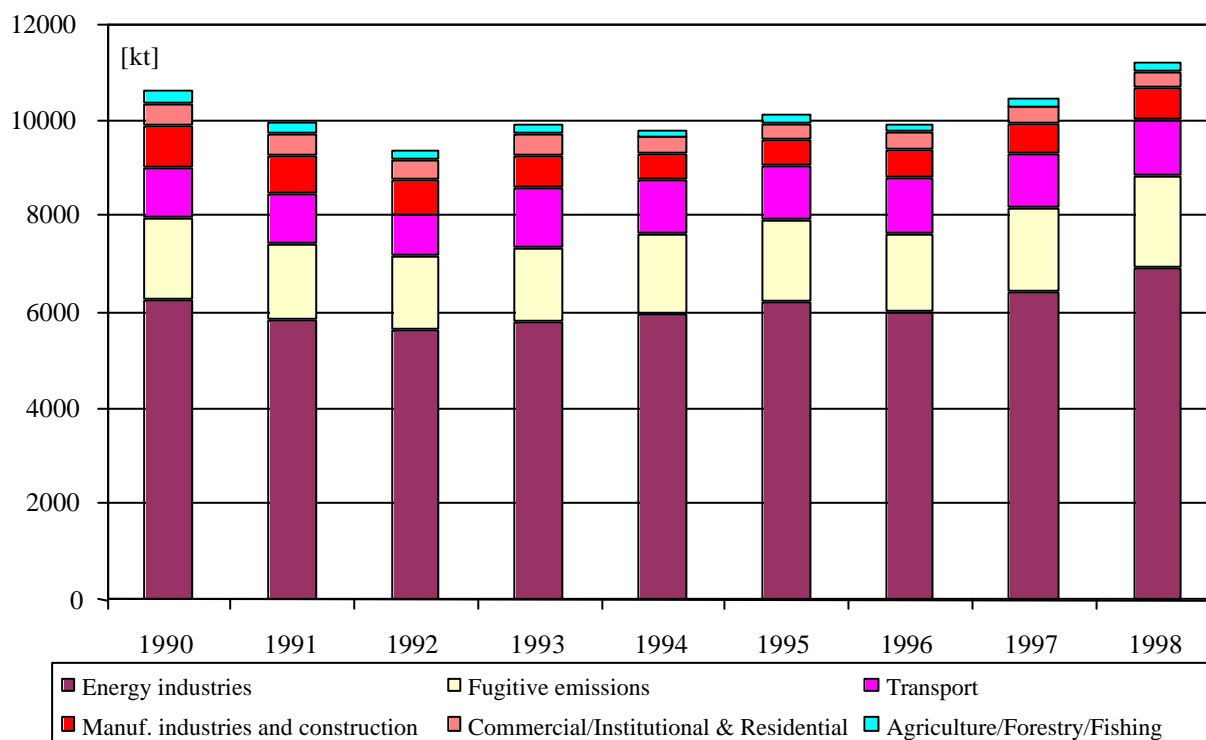


Figure 1.4.1. Contribution of energy subsectors to total CO₂-eq emissions

Inventory of GHG emissions from the energy sector

Table 1.4.2. GHG emissions [kt] from the energy sector

	Subsector	1990	1991	1992	1993	1994	1995	1996	1997	1998
CO ₂	Energy industries	6,208.28	5,783.52	5,603.62	5,729.65	5,943.99	6,155.81	5,956.81	6,349.69	6,857.25
	Transport	1,048.48	1,026.04	854.50	1,201.63	1,089.85	1,088.20	1,138.08	1,115.45	1,176.44
	Manufacturing industries and construction	864.68	814.02	727.67	727.06	544.86	556.25	592.62	626.21	639.93
	Commercial/Institutional & Residential	408.31	384.16	341.35	352.97	269.23	273.69	291.61	308.23	316.95
	Agriculture/Forestry/Fishing	240.21	226.31	200.28	215.77	168.48	170.57	181.65	191.92	198.49
	Total	8,769.97	8,234.05	7,727.43	8,227.08	8,016.41	8,244.53	8,160.77	8,591.49	9,189.07
CH ₄	Energy industries	0.074	0.068	0.064	0.065	0.064	0.065	0.061	0.067	0.070
	Fugitive emissions	81.019	75.188	73.046	74.937	79.500	82.375	78.776	84.493	91.726
	Transport	0.179	0.179	0.146	0.203	0.192	0.188	0.193	0.184	0.189
	Manufacturing industries and construction	0.023	0.022	0.019	0.019	0.015	0.015	0.016	0.017	0.017
	Commercial/Institutional & Residential	3.362	3.281	3.452	3.488	3.175	2.989	2.836	1.906	1.960
	Agriculture/Forestry/Fishing	0.016	0.015	0.013	0.014	0.011	0.011	0.012	0.013	0.013
	Total	84.674	78.752	76.741	78.726	82.957	85.643	81.894	86.681	93.975
N ₂ O	Energy industries	0.087	0.079	0.074	0.077	0.080	0.081	0.075	0.083	0.087
	Transport	0.010	0.010	0.008	0.011	0.010	0.010	0.011	0.011	0.011
	Manufacturing industries and construction	0.007	0.007	0.006	0.006	0.004	0.004	0.005	0.005	0.005
	Commercial/Institutional & Residential	0.047	0.046	0.048	0.049	0.044	0.042	0.040	0.027	0.028
	Agriculture/Forestry/Fishing	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.002	0.002
	Total	0.153	0.143	0.138	0.144	0.140	0.139	0.132	0.127	0.133
CO ₂ -eq	Energy industries	6,236.73	5,809.40	5,628.02	5,754.77	5,970.06	6,182.19	5,981.31	6,376.77	6,885.61
	Fugitive emissions	1,701.41	1,578.94	1,533.98	1,573.68	1,669.50	1,729.87	1,654.29	1,774.36	1,926.25
	Transport	1,055.28	1,032.78	860.10	1,209.43	1,097.04	1,095.38	1,145.57	1,122.59	1,183.86
	Manufacturing industries and construction	867.33	816.51	729.89	729.27	546.52	557.94	594.42	628.12	641.89
	Commercial/Institutional & Residential	493.60	467.37	428.77	441.31	349.55	349.35	363.46	356.73	366.83
	Agriculture/Forestry/Fishing	241.15	227.20	201.06	216.61	169.14	171.24	182.36	192.67	199.27
	Total	10,595.51	9,932.20	9,381.81	9,925.08	9,801.81	10,085.98	9,921.41	10,451.24	11,203.71

2. Inventory of GHG emissions from the industrial processes sector

The industrial processes sector is divided in the following three subsectors: mineral production, chemical processes and metal production. Annual production by items within each subsector is presented in the table 2.1. The corresponding GHG emissions together with equivalent CO₂ emissions are given in the table 2.2 and graphically presented in the figure 2.1

2.1. GHG emissions from mineral production

In this subsector dominant are CO₂ emissions from production and use of cement, lime, limestone-dolomit and natrium carbonate.

When calculating the CO₂ emissions, input data are the annual amounts of the above items.

2.2. GHG emissions from chemical processes

The input data used for calculation of GHG emissions from this subsector are the annual production of ammonia, calcium carbide, adipic acid, carbon black, methanol and coke.

2.3. GHG emissions from metal production

The input data for calculation of GHG emissions from this subsector are the annual production of iron and steel, ferronickel, ferroalloys and non-ferro metals.

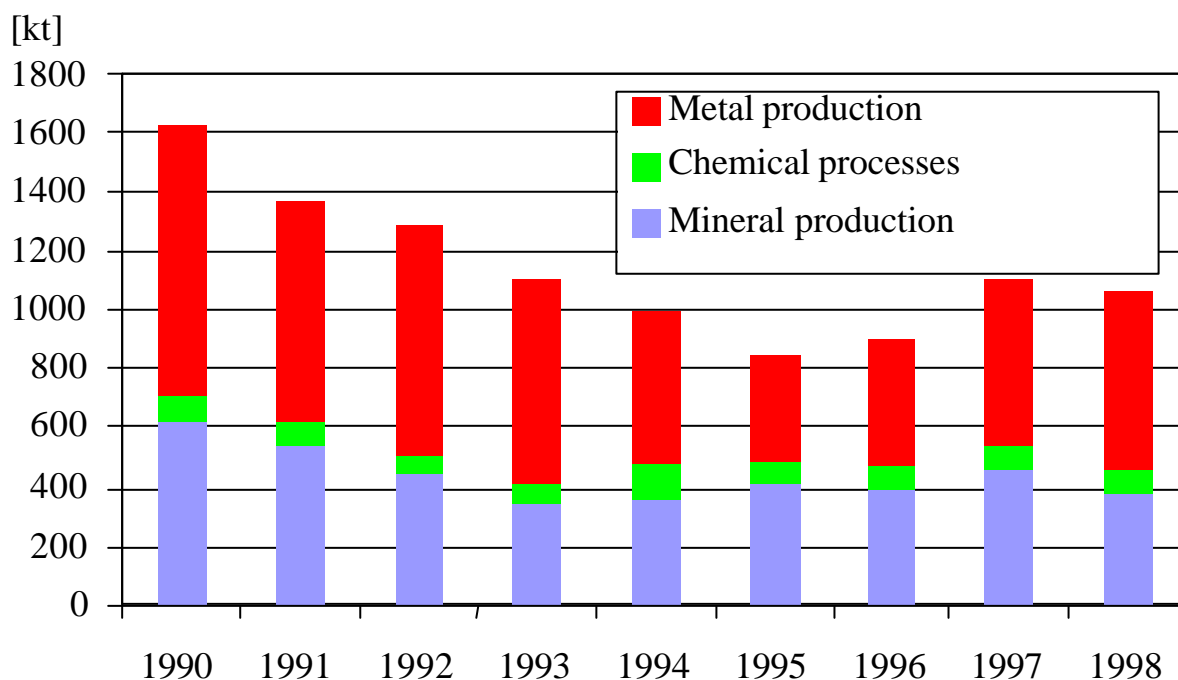


Figure 2.1. CO₂-eq emissions from the industrial processes sector

Inventory of GHG emissions from the industrial processes sector

Table 2.1. Amounts of industrial products [kt]

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998
Mineral production									
Cement	639.02	605.74	516.05	499.09	486.45	523.50	490.86	610.76	461.20
Lime	37.45	29.19	33.87	24.90	14.10	12.36	9.71	4.34	0.96
Limestone-dolomite	123.17	122.73	110.55	68.89	98.81	97.24	77.03	81.96	76.43
Sodium carbonate	6.46	5.15	4.56	4.37	5.82	8.25	3.72	3.92	3.68
Chemical processes									
Ammonia	7.95	7.31	7.18	7.74	6.08	4.93	6.60	5.14	6.99
Calcium carbide	3.01	2.61	2.03	2.28	1.95	2.68	2.52	2.20	1.94
Adipic acid	0.76	0.77	0.48	0.59	1.10	0.55	0.57	0.68	0.73
Carbon black	0.75	0.53	0.08	0.03	0.05	0.00	0.01	0.00	0.00
Methanol	0.00	4.44	4.96	2.80	2.61	3.97	1.10	1.23	1.23
Coke	0.14	0.00	0.01	0.08	0.05	0.07	0.03	0.01	0.01
Metal production									
Iron and steel	358.70	237.63	212.69	159.05	85.64	58.57	54.90	72.44	72.45
Ferrosilicon (75%)	51.81	49.63	51.56	47.16	44.54	50.34	47.11	53.80	61.17
Silicon metal	0.76	3.91	6.79	8.19	7.14	2.46	4.43	5.14	0.00
Ferromanganese	11.29	6.48	15.03	6.29	0.13	3.47	16.43	2.00	4.23
Silicon manganese	12.04	11.30	23.14	6.00	3.18	7.10	17.03	18.78	36.69
Ferrochromium	5.09	3.36	3.96	4.37	3.28	3.95	3.78	1.06	0.00
Zinc (Zn,Ag,Cd,Pb)	34.15	37.53	42.36	53.72	45.02	12.20	21.40	50.03	48.57

Inventory of GHG emissions from the industrial processes sector

Table 2.2. GHG emissions [kt] from the industrial processes sector

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998
Mineral production	624.54	538.25	441.17	343.83	360.44	420.22	399.84	457.34	378.27
Cement (CO ₂)	318.55	301.95	257.25	248.79	242.49	260.96	244.69	304.46	229.90
Lime (CO ₂)	29.59	23.06	26.75	19.67	11.13	9.76	7.66	3.43	0.76
Limestone-dolomite (CO ₂)	273.72	211.10	155.28	73.56	104.41	146.08	145.95	147.82	146.08
Sodium carbonate (CO ₂)	2.68	2.14	1.89	1.81	2.41	3.42	1.54	1.63	1.53
Chemical processes									
Ammonia (CO ₂)	11.92	10.95	10.77	11.61	9.11	7.39	9.89	7.70	10.48
Calcium carbide (CO ₂)	5.60	4.86	3.77	4.23	3.62	4.98	4.68	4.09	3.60
Adipic acid (N ₂ O)	0.23	0.23	0.14	0.17	0.33	0.16	0.17	0.20	0.22
Other chemicals (CH ₄)	0.008	0.014	0.010	0.005	0.005	0.007	0.002	0.002	0.002
Metal production	919.78	745.12	780.51	690.21	515.63	364.35	427.48	569.41	602.94
Iron and steel (CO ₂)	538.05	356.44	319.03	238.57	128.46	87.84	82.34	108.65	108.67
Ferroalloys (CO ₂)	250.27	244.18	298.40	244.84	213.86	229.56	262.77	268.15	307.29
Zinc (Zn,Ag,Cd,Pb) (CO ₂)	131.46	144.50	163.08	206.80	173.31	46.95	82.37	192.61	186.98
Mineral production (CO₂-eq.)	624.54	538.27	441.19	343.84	360.46	420.23	399.86	457.36	378.28
Chemical processes (CO₂-eq.)	88.01	88.02	59.50	70.47	115.43	63.23	67.45	74.72	82.40
CO ₂	17.53	15.82	14.54	15.85	12.73	12.38	14.58	11.8	14.09
CO ₂ -eq. of CH ₄	0.17	0.31	0.23	0.13	0.12	0.17	0.05	0.05	0.05
CO ₂ -eq. of N ₂ O	70.31	71.89	44.73	54.50	102.58	50.69	52.82	62.87	68.26
Metal production (CO₂-eq.)	919.79	745.13	780.53	690.22	515.65	364.37	427.5	569.44	602.95
Total (CO₂-eq.)	1,632.34	1,371.42	1,281.22	1,104.53	991.55	847.84	894.82	1,101.52	1,063.63

3. Inventory of GHG emissions from the agriculture sector

The agriculture sector is divided in the following four subsectors: enteric fermentation, manure management, rice fields and agricultural soils. The GHG emissions from this sector are mainly CH₄ and N₂O emissions.

3.1. GHG emissions from enteric fermentation

In this subsector CH₄ emissions are dominant, and depend on the number of animals (table 3.1.1). The emission factors are assumed to be constant over the whole analyzed period.

Table 3.1.1. Number of animals [in 1000's] in the period 1990 - 1998

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998
Dairy Cattle	165.0	163.7	164.6	165.3	165.8	166.4	175.6	177.4	165.6
Non-dairy Cattle	119.0	117.1	119.2	113.9	114.5	115.8	117.7	117.1	101.0
Buffalo	2.0	1.5	1.2	1.1	1.0	1.0	1.0	1.0	0.9
Sheep	2,297.0	2,250.5	2,351.4	2,458.6	2,466.1	2,319.9	1,813.9	1,631.0	1,315.2
Goats	214.0	214.0	214.0	214.0	214.0	214.0	214.0	214.0	214.0
Horses	66.0	65.2	64.6	61.7	61.8	61.7	66.5	65.9	59.8
Mules & Asses	49.4	49.4	47.4	49.4	49.4	49.4	49.4	49.4	49.4
Swine	179.0	171.0	173.0	184.9	171.6	175.1	192.4	184.3	196.8
Poultry	5,729.0	4,562.5	4,297.4	4,392.7	4,685.0	4,879.9	3,360.8	3,274.6	3,338.8

3.2. GHG emissions from manure management

This subsector counts for CH₄ and N₂O emissions. The following are manure management systems in Macedonia: solid storage and drylot, pasture range and paddock and other type.

Within this subsector, CH₄ and N₂O emissions depend on the number and type of animals in the manure management system.

3.3. GHG emission from flooded rice fields

The GHG emissions from this subsector are all CH₄ emissions. The input data is the area of intermittently flooded rice fields since the rice fields in Macedonia are of that type.

The CH₄ emissions from this subsector are so small, that can be neglected compared to emissions from the other subsectors.

3.4. GHG emission from agricultural soils

The GHG emissions from this subsector are merely N₂O emissions. The most significant are the direct N₂O emissions from soil, dependent on the amount of nitrogen input of different sources (table 3.4.1). Nitrogen from crop residues also contributes to the total N₂O emissions. The input data within this subsector are production of non-fixing crops, as well as production of pulses and soybeans.

Emission factors are assumed constant for the whole analyzed period. Direct N₂O emissions depend on the cultivated area, which also has not been changing over the analyzed period.

Inventory of GHG emissions from the agriculture sector

Table 3.4.1. Amounts of nitrogen (N) input [kt] of different sources

Type of N input to soil	1990	1991	1992	1993	1994	1995	1996	1997	1998
Synthetic fertilizer	27.3	19.4	22.4	18.5	17.8	14.8	15.7	11.0	14.7
Animal waste	34.6	13.2	33.3	34.4	35.7	34.5	13.2	28.2	24.6
N-fixing crops	5.7	7.1	3.3	5.4	5.7	6.0	6.0	6.6	6.6
Crop residue	12.7	19.2	17.5	13.6	16.7	18.4	15.8	16.8	17.1

3.5. Equivalent emissions from the agriculture sector

Summarized, annual GHG emissions from all subsectors are given in table 3.5.1. and graphically presented in figure 3.5.1. The agriculture sector does not count for significant emissions of NO_x, CO, NMVOC.

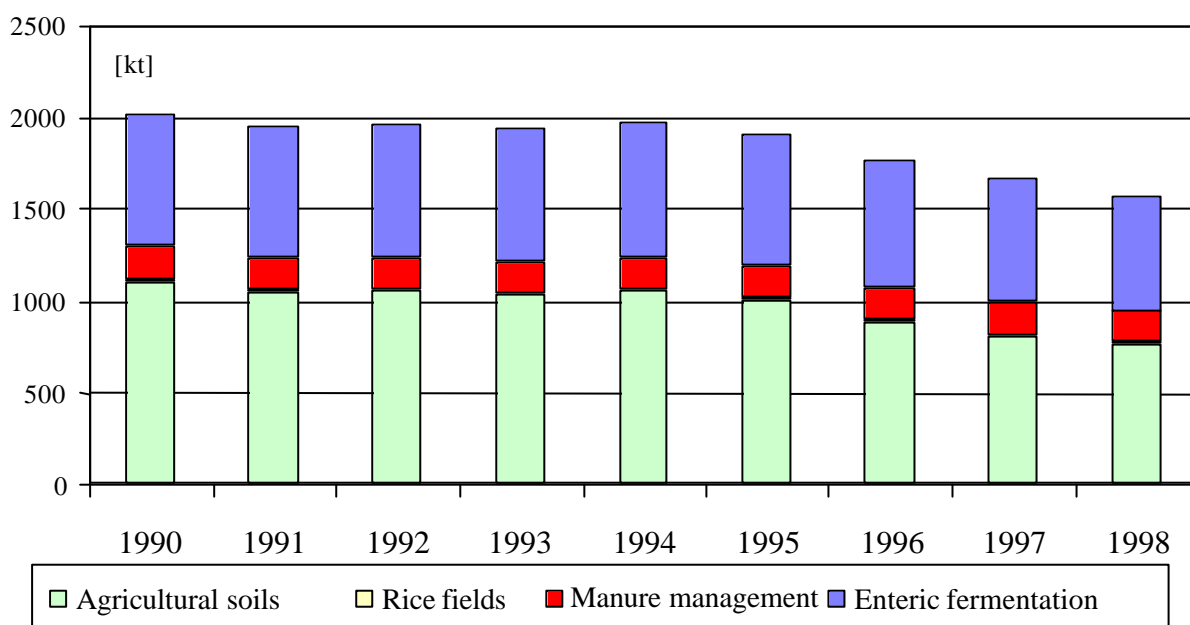


Figure 3.5.1. CO₂-eq emissions from the agriculture sector

Inventory of GHG emissions from the agriculture sector

Table 3.5.1. GHG emissions [kt] from the agriculture sector

	Subsector	1990	1991	1992	1993	1994	1995	1996	1997	1998
CH₄	Enteric fermentation	34.67	34.06	34.73	34.98	35.08	34.47	32.89	32.07	30.19
	Manure management	3.02	2.87	2.88	2.92	2.90	2.92	2.89	2.84	2.76
	Rice fields	0.45	0.43	0.42	0.26	0.09	0.06	0.21	0.26	0.22
	Agricultural soils									
	Total	38.14	37.36	38.03	38.16	38.07	37.45	35.99	35.17	33.17
N₂O	Enteric fermentation									
	Manure management	0.38	0.37	0.35	0.35	0.37	0.37	0.38	0.38	2.49
	Rice fields									
	Agricultural soils	3.57	3.40	3.42	3.33	3.43	3.26	2.88	2.61	0.35
	Total	3.95	3.77	3.77	3.68	3.80	3.63	3.26	2.99	2.84
CO₂-eq	Enteric fermentation	728.07	715.26	729.33	734.58	736.68	723.87	690.69	673.47	633.99
	Manure management	181.22	174.97	168.98	169.82	175.60	176.02	178.49	177.44	166.46
	Rice fields	9.45	9.03	8.82	5.46	1.89	1.26	4.41	5.46	4.62
	Agricultural soils	1,106.70	1,054.00	1,060.20	1,032.30	1,063.30	1,010.60	892.8	809.10	771.90
	Total	2,025.44	1,953.26	1,967.33	1,942.16	1,977.47	1,911.75	1,766.39	1,665.47	1,576.97

4. Inventory of GHG emissions from the land use change and forestry (LUCF) sector

GHG absorption and emissions from this sector are result of two processes, namely: changes in biomass stocks and forest and grassland conversion.

4.1. Changes in biomass stocks

Input values for calculation of changes in biomass stocks, annual biomass increment and total carbon uptake increment are the area of forest/biomass stocks and the annual growth rate. Carbon fraction of dry matter is taken constant, equal to 0.5, being the same value for each type of trees, for all years of the analyzed period.

For estimation of total biomass removed, input data taken into account are the following: commercial harvest, total traditional fuelwood and other wood consumed. Biomass conversion/expansion ratios are calculated for each type of harvest categories, for all years of the analyzed period.

The results for the balance between absorption and emission are presented in table 4.1.1.

Table 4.1.1. CO₂ absorption and emission from changes in biomass stocks

Year	Absorption [kt C]	Emission [kt C]	Absorption - emission [kt C]	Absorption - emission Conversion to CO ₂ [kt]
1990	820.45	415.37	405.08	1,485.28
1991	851.38	414.08	437.30	1,603.44
1992	867.20	413.96	453.24	1,661.86
1993	867.94	405.21	462.73	1,696.69
1994	868.92	389.52	479.40	1,757.80
1995	863.09	371.05	492.04	1,804.16
1996	845.17	359.29	485.88	1,781.57
1997	855.03	254.11	600.92	2,203.36
1998	875.61	264.01	611.60	2,242.52

4.2. Forest and grassland conversion

Forest and grassland conversion causes loss of biomass which is calculated using the following input data: annually converted area, and amounts of biomass before and after the conversion. In addition, when estimating CO₂ emissions, the amounts of the released carbon by on-site and off-site burning were taken into account. The summarized results for CO₂ emissions from forest and grassland conversion are given in the table 4.2.1. The total carbon released is taken as a sum of carbon released by burning and delayed emissions from decay.

Table 4.2.1. CO₂ emissions from forest and grassland conversion

Year	Carbon emissions [kt C]	CO ₂ emissions (kt CO ₂)
1990	22.81	83.64
1991	1.77	6.48
1992	37.18	136.31
1993	57.11	209.41
1994	22.97	84.22
1995	0.42	1.52
1996	3.88	14.24
1997	14.00	51.32
1998	7.48	27.44

4.3. GHG absorption and emissions from the LUCF sector

The annual amount of the released CO₂ by burning slightly reduces the amount of absorbed CO₂ by the forests. The balance is presented in table 4.3.1, while graphically the trends are displayed in figure 4.3.1. It should be noted that, in spite of its relatively low value, the absorption of CO₂ by the soil is counted within the balance.

Table 4.3.1. CO₂ [kt] from the LUCF sector

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998
Biomass (abs.)	1,485	1,603	1,662	1,697	1,758	1,804	1,782	2,203	2,243
Soils (abs.)	62	62	62	62	62	62	62	62	62
Burning and conv. (emiss.)	84	6	136	209	84	2	14	51	27
Abs. Emiss.	1,463	1,659	1,588	1,550	1,736	1,864	1,830	2,214	2,278

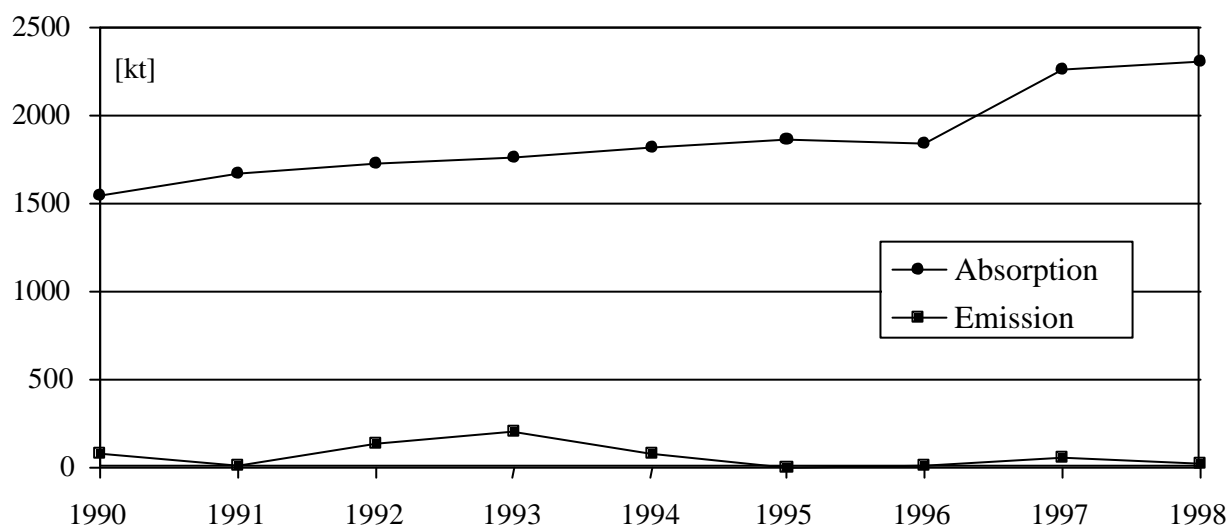


Figure 4.3.1. CO₂ from the LUCF sector

5. Inventory of GHG emissions from the waste sector

GHG emissions from the waste sector include mainly CH₄ emissions. In addition, this sector is accountable for N₂O emissions from human sewage.

5.1. CH₄ emissions from solid waste disposal sites

For estimation of CH₄ emissions from solid waste disposal sites (SWDSs) the following input data are used: total municipal solid waste (MSW) disposed to SWDSs, CH₄ correction factor (MCF), fraction of degradable organic component (DOC) in MSW, fraction of DOC which actually degrades, fraction of carbon released as CH₄, conversion ratio, recovered CH₄ per year and CH₄ oxidation correction factor.

To estimate the total annual MSW disposed to SWDSs, the number of population whose waste goes to SWDSs (total persons) and the MSW disposal rate are needed. The weighted average MCF depends on proportion of waste which goes to each type of SWDSs (managed, unmanaged-deep, and unmanaged-shallow) and MCF corresponding to each type of SWDSs.

5.2 CH₄ emissions from residential/commercial wastewater and sludge

For estimation of residential/commercial wastewater and sludge the following input data are used: annual population, DOC and fraction of DOC removed as sludge.

To calculate the emission factors for wastewater/sludge in this subsector, values for fraction of wastewater/sludge treated by both types of handling systems - aerobic and anaerobic, are considered.

The calculated data for the above mentioned waste with emission factors are presented in table 5.2.1.

Table 5.2.1. Input data for residential/commercial wastewater and sludge

Year	Residen./Commerc. wastewater [kt BOD]	Residen./Commerc. sludge [kt BOD]	Fraction of wastewater treated aerobically	Emission factor (kgCH ₄ /kgBOD)
1990	35.160	1.850	0.60	0.10
1991	35.351	1.860	0.60	0.10
1992	35.646	1.876	0.65	0.09
1993	35.819	1.885	0.65	0.09
1994	33.583	1.767	0.70	0.08
1995	34.085	1.794	0.70	0.08
1996	34.380	1.809	0.75	0.06
1997	34.623	1.822	0.75	0.06
1998	34.814	1.832	0.75	0.06

5.3. CH₄ emissions from industrial wastewater and sludge

For estimation of CH₄ emissions from industrial wastewater and sludge, total wastewater and sludge from industrial sources are calculated. Input values for these calculations are total industrial output of: fertilizer, food and beverage, paper and pulp, petrochemicals and rubber. The table 5.3.1 summarizes the relevant data for this subsector.

Inventory of GHG emissions from the waste sector

Table 5.3.1. Input data for estimation of CH₄ emissions from industrial wastewater and sludge

Year	Total industrial output [kt]					Wastewater [kt COD]	Sludge [kt COD]
	Fertilizer	Food and Beverage	Paper and Pulp	Petrochemicals	Rubber		
1990	99.873	306.220	12.697	1,172.740	3.627	52.299	4.174
1991	79.246	340.487	14.581	909.006	3.326	55.742	4.282
1992	65.470	320.365	12.962	545.079	3.276	50.331	3.745
1993	64.989	257.519	16.654	969.283	2.997	46.050	3.838
1994	68.827	287.799	13.456	157.470	2.139	58.946	3.966
1995	45.762	259.701	13.456	109.958	1.154	30.711	2.543
1996	53.596	380.691	7.489	655.495	881	65.391	3.853
1997	45.677	471.943	7.035	348.891	719	55.547	3.191
1998	54.677	451.078	9.315	714.518	701	100.256	6.739

Emission factors not taken from the IPCC methodology are particularly analysed and determined.

5.4 N₂O emissions from human sewage

The required input data in this subsector are: number of population, per capita protein consumption, fraction of nitrogen in proteins and emission factors.

5.5 Summarized GHG emissions from the waste sector

First part of the table 5.5.1 contains CH₄ and N₂O emissions from the waste sector. Second part of the table gives the emissions expressed in CO₂-eq, which are also presented graphically in figure 5.5.1.

Table 5.5.1. GHG emissions [kt] from the waste sector

		1990	1991	1992	1993	1994	1995	1996	1997	1998
CH ₄	Solid waste	43.9	45.2	45.6	45.8	43.4	44.6	45.4	45.8	46.0
	Residen./Commerc. wastewater and sludge	3.6	3.6	3.2	3.2	2.6	2.7	2.2	2.3	2.3
	Industrial wastewater and sludge	1.4	1.5	1.4	1.3	1.6	0.8	1.7	1.5	2.7
	Total	48.9	50.3	50.1	50.3	47.6	48.0	49.4	49.5	51.0
N ₂ O	Human sewage	0.5	0.5	0.5	0.5	0.4	0.5	0.5	0.5	0.5
CO ₂ -eq	Solid waste	922.1	948.8	956.8	961.4	911.4	935.6	954.2	961.0	966.2
	Residen./Commerc. wastewater and sludge	75.8	76.2	67.4	67.8	54.8	55.7	47.0	47.5	47.7
	Industrial wastewater and sludge	29.6	31.5	28.4	26.3	33.0	17.4	36.3	30.9	56.1
	Human sewage	142.6	145.7	145.7	145.7	136.4	139.5	139.5	142.6	142.6
	Total	1,170.1	1,202.2	1,198.2	1,201.2	1,135.6	1,148.1	1,177.1	1,181.9	1,212.6

Inventory of GHG emissions from the waste sector

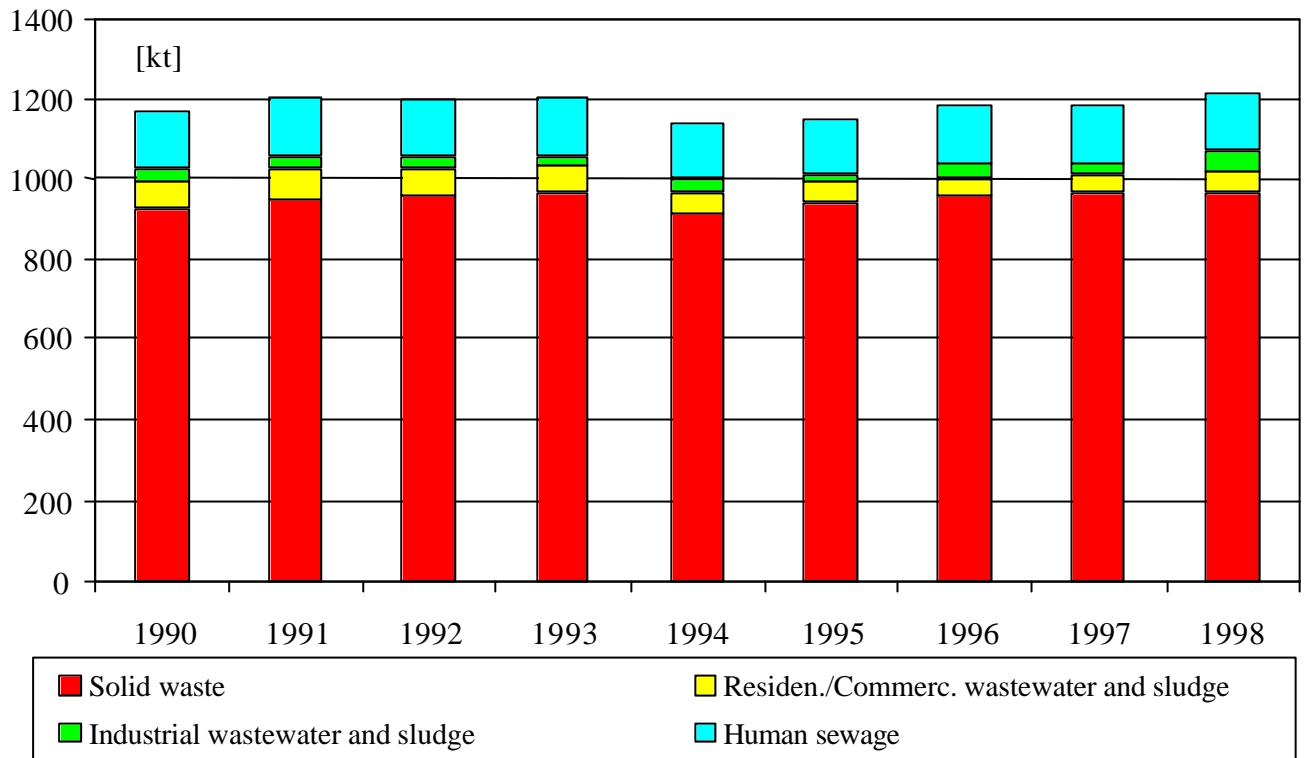


Figure 5.5.1. CO₂-eq emissions from the waste sector

6. Integral results

In the previous chapters of this report, the process of data collection and the determination of conversion and emission factors for each sector defined within IPCC methodology were elaborated. Accordingly, the corresponding results of GHG emissions calculations for the sectors and subsectors were presented.

In this chapter the intensity of total GHG emissions is presented, with sectors ranked in accordance with their contribution to total emissions.

The first part of the table 6.1 contains the amounts of GHG emissions for each sector separately, as well as the total emissions for the period 1990 - 1998. The second part of the table 6.1. presents the absolute and percental values of CO₂-equivalent emissions for all sectors. These values are also graphically displayed in figure 6.1.

As it can be seen in figure 6.1, GHG emissions exhibit decreasing trends within the industrial processes (by 35%) and agriculture (by 22%) sectors over the analysed period, while in the LUCF sector the emissions are oscillating and in the waste sector they are invariable. An increase in the GHG emissions occurred only in the energy sector (by 6%). Comparatively, the share of the energy sector in the total GHG emissions is particularly high (almost 3/4), followed by the agriculture, waste, and industrial processes sectors (amounting to 10%, 8% and 7%, respectively), while the contribution of the LUCF sector is less than 2%. The decreasing trend of GHG emissions from the industrial process and agriculture sectors is due to the reduction of activities within the national economy over the observed period.

The obtained results constitute a basic input for the follow-up GHG abatement analysis.

Integral results

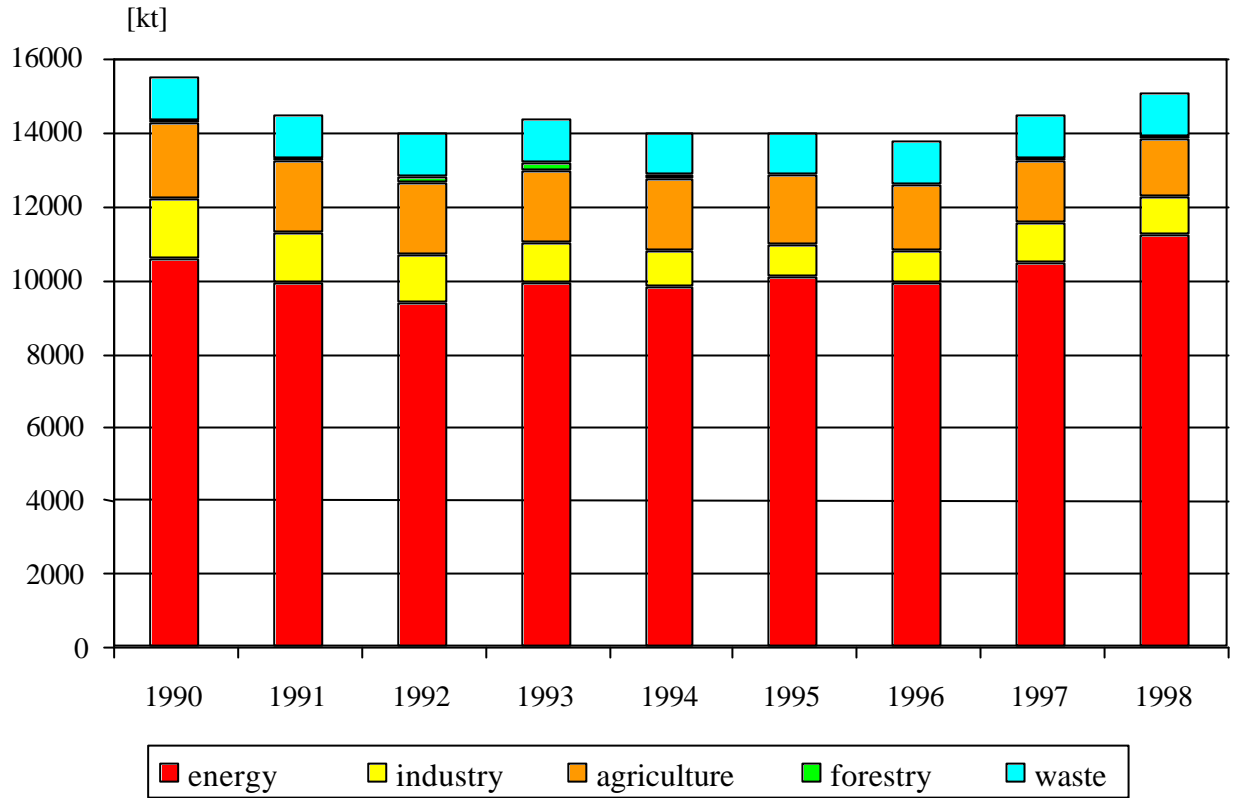


Figure 6.1. CO₂-eq emissions by sectors

Integral results

Table 6.1. GHG emissions [kt] by sectors

	Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998
CO ₂	Energy	8,769.96	8,234.05	7,727.42	8,227.08	8,016.41	8,244.52	8,160.77	8,591.50	9,189.06
	Industrial processes	1,561.86	1,299.22	1,236.26	1,049.91	888.84	796.98	841.94	1,038.60	995.32
	Agriculture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Forestry	83.64	6.48	136.31	209.41	84.22	1.52	14.24	51.32	27.44
	Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	10,415.46	9,539.75	9,099.99	9,486.40	8,989.47	9,043.02	9,016.95	9,681.42	10,211.82
CH ₄	Energy	84.67	78.75	76.74	78.73	82.96	85.64	81.89	86.68	93.98
	Industrial processes	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
	Agriculture	38.14	37.36	38.03	38.16	38.07	37.45	35.99	35.17	33.17
	Forestry	0.23	0.02	0.37	0.57	0.23	0	0.04	0.14	0.07
	Waste	48.93	50.31	50.12	50.26	47.58	48.03	49.41	49.49	50.95
	Total	171.98	166.46	165.27	167.72	168.84	171.13	167.34	171.48	178.17
N ₂ O	Energy	0.15	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13
	Industrial processes	0.23	0.23	0.14	0.18	0.33	0.16	0.17	0.20	0.22
	Agriculture	3.95	3.77	3.77	3.68	3.8	3.63	3.26	2.99	2.84
	Forestry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Waste	0.46	0.47	0.47	0.47	0.44	0.45	0.45	0.46	0.46
	Total	4.79	4.61	4.52	4.47	4.71	4.38	4.01	3.78	3.65
CO ₂ -eq	Energy	10,595.51	9,932.20	9,381.81	9,925.08	9,801.81	10,085.98	9,921.41	10,451.24	11,203.71
	Industrial processes	1,632.34	1,371.42	1,281.22	1,104.53	991.55	847.84	894.82	1,101.52	1,063.63
	Agriculture	2,025.44	1,953.26	1,967.33	1,942.16	1,977.47	1,911.75	1,766.39	1,665.47	1,576.97
	Forestry	88.47	6.90	144.08	221.38	89.05	1.52	15.08	54.26	28.91
	Waste	1,170.13	1,202.21	1,198.22	1,201.16	1,135.58	1,148.13	1,177.11	1,181.89	1,212.55
	Total	15,511.89	14,465.99	13,972.66	14,394.31	13,995.46	13,995.22	13,774.81	14,454.38	15,085.77
CO ₂ -eq [%]	Energy	68.31	68.66	67.14	68.95	70.04	72.07	72.03	72.31	74.27
	Industrial processes	10.52	9.48	9.17	7.67	7.08	6.06	6.50	7.62	7.05
	Agriculture	13.06	13.50	14.08	13.49	14.13	13.66	12.82	11.52	10.45
	Forestry	0.57	0.05	1.03	1.54	0.64	0.01	0.11	0.38	0.19
	Waste	7.54	8.31	8.58	8.34	8.11	8.20	8.55	8.18	8.04
	Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

List of abbreviations

GHG	Greenhouse gases
IPCC	Intergovernmental Panel on Climate Change
CO ₂	Carbon dioxide
CH ₄	Methane
N ₂ O	Nitrous oxide
A ₁ (kt)	Lignite consumption of Bitola thermal power plant
A ₂ (kt)	Lignite consumption of Oslomej thermal power plant
H ₁ (TJ/kt)	Heating value of the lignite of Bitola thermal power plant
H ₂ (TJ/kt)	Heating value of the lignite of Oslomej thermal power plant
H _e (TJ/kt)	Heating value of the equivalent lignite
p ₁ (%)	Carbon content of the lignite of Bitola thermal power plant
p ₂ (%)	Carbon content of the lignite of Oslomej thermal power plant
p _e (%)	Carbon content of the equivalent lignite
C _e (t C/TJ)	Emission factor of the equivalent lignite
LPG	Liquid Petroleum Gas
CO ₂ -eq (kt)	Amount of CO ₂ with greenhouse effect equivalent to unit of amount of CO ₂ , CH ₄ and N ₂ O. 1 kt CO ₂ corresponds to 1 kt CO ₂ -eq, 1 kt CH ₄ corresponds to 21 kt CO ₂ -eq, 1 kt N ₂ O corresponds to 310 kt CO ₂ -eq.
NM VOC	Non-Methane Volatile Organic Compounds
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand