

NATIONAL INVENTORY REPORT 2008 OF THE SLOVAK REPUBLIC

GREENHOUSE GAS EMISSION INVENTORY 1990–2006
SUBMISSION UNDER THE UNFCCC AND VOLUNTARY
SUBMISSION UNDER THE KYOTO PROTOCOL

BRATISLAVA 2008

The National Inventory Report was prepared in accordance with UNFCCC related to *FCCC/CP/2002/8* from March 28 2003 – UN FCCC Guidelines on Reporting and Review and in accordance with Decision No 280/2004/EC of the European Parliament and of the Council of 11 February 2004.

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National Inventory Report of the Slovak Republic (NIR) under the UNFCCC (United Nations Framework Convention on Climate Change) and the Kyoto Protocol (voluntary reporting in accordance with decision 15/CMP.1) contains the following parts:

Part 1: National greenhouse gas emission inventory report of the Slovak Republic 1990–2006 (NIR) prepared using the reporting guidelines (UNFCCC 2006) and relevant parts of the Guidelines for the preparation of the information required under Article 7 of the Kyoto Protocol (Kyoto Protocol 2005). IPCC and other methods applied in the calculation of the emissions are described, as well as changes to the previous submission. Several summarising tables and graphs of the emission data and emission trends for the years 1990–2006 are included. Annex 1 – The list of cooperating organizations and experts, Annex 2 – The key sources and uncertainty analyses for the most recent inventory year 2006 and the base year 1990 and Annex 3 – The list of emission factors used in the energy sector, sectoral approach.

Part 2: CRF (Common Reporting Format) data tables of the Slovak Republic's greenhouse gas emissions for the years 1990–2006. The CFR tables are compiled with the latest UNFCCC CRF Reporter software (version 3.2.2), xml file with the databases, country specific variables and unit's lists.

Since the submission of the Slovak Republic's initial report under the Kyoto Protocol to the UNFCCC secretariat on 4 October 2006, several changes have occurred in the national system or registries. These are presented in chapter 1.2. Information on emissions and removals related to Article 3, paragraphs 3 and 4, as well as on Article 3, paragraph 14 will be included in the inventory submissions from the year 2010 onwards.

The main methodological improvements and changes since the inventory submission in 2007 are listed in Chapter 9.

Slovak Hydrometeorological Institute (Stanislava Nebusova, Zuzana Elenicova, Katarina Spisakova, Jozef Uhlik, Janka Szemesova), Profing (Jan Judak), Ecosys (Jiri Balajka), Forestry Research Institute Zvolen (Jozef Mindas), the Transportation Research Institute Zilina (Ivan Breziansky, Jozef Pinter), the Slovak Agricultural University Nitra (Bernard Siska), the Slovak Technical University Bratislava (Vladimir Danielik), Faculty of Mathematics, Physics & Informatics Bratislava (Martin Gera), Slovak Energy Agency, Slovak cooling and air conditions association (Peter Tomlein), SPIRIT Information Systems (Jozef Skakala) and veQ s.r.o. (Juraj Farkas) are involved in the process of development and have made the inventory calculations, as well as the description of the methodologies and other information included in the national inventory report.

Slovak Hydrometeorological Institute – Department of Emission is the Single National Entity with the overall responsibility of the compilation and finalisation of inventory reports and their submission to the UNFCCC Secretariat and the European Commission according the official journal: Vestník, Ministry of Environment, XV, 3, 2007, page 19. Slovak Hydrometeorological Institute – Department of Emission is the coordinator of the National Inventory system.

All relevant documents have to be approved by National Focal Point to the UNFCCC – Ministry of Environment – Department of Climate Change and the Emission Trading, Dr. Helena Princova (email: princova.helena@enviro.gov.sk)

The Slovak inventory report as well as the CRF tables and other relevant documents can be downloaded from the address: www.ghg-inventory.gov.sk.

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Annex 1: The list of sectoral cooperation in the frame of National inventory system in 2006

Annex 2: The Key Source Analysis and Uncertainty Management in the SR in 2006

Annex 3: The List of Emission Factors Used in Sectoral Approach in 2006

EXECUTIVE SUMMARY

This chapter includes a brief summary of the National Inventory Report of the Slovak Republic 2005 as a part of official GHG inventory submission 2007 to the UNFCCC.

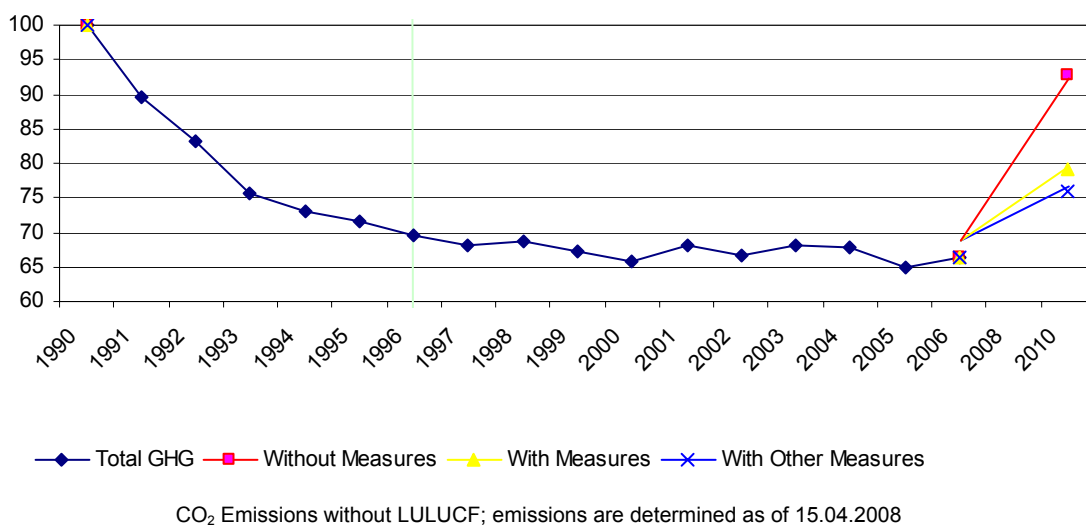
ES.1 Introduction

Climate change, caused by increasing anthropogenic emission of greenhouse gases, represents the most serious environmental issue in the history of humankind. The most important anthropogenic greenhouse gases are carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O). Other greenhouse gases included in GHGs inventory are halogenated hydrocarbons (PFCs, HFCs) and SF₆, which are not controlled by the Montreal Protocol. Photochemical active gases such as carbon monoxide (CO), nitrogen oxides (NO_x) and non-methane volatile organic hydrocarbons (NM VOCs) are not greenhouse gases, but they contribute indirectly to the greenhouse effect in the atmosphere. These have generally referred to as ozone precursors because they affect the creation and destruction of ozone in the troposphere. Precursors of sulphates - sulphur dioxide (SO₂) and aerosol - reduce the greenhouse effect.

The unfavourable development and balance of GHG emission generation since 1992 have created a demand to adopt an additional and effective instrument that would involve the participation of developing countries. In 1997, the parties of the Convention agreed to endorse the Kyoto Protocol (KP) that defines reduction objectives and instruments to achieve them for countries of the Annex I to the Convention. Developed countries defined in Annex B of the KP should reduce individually or together emissions of six GHG (CO₂, CH₄, N₂O, HFCs, PFCs and SF₆) on average by 5.2 % from the level of the year 1990 during the first commitment period 2008–2012. The Slovak Republic, as a member states of the EU (the EU commitment was adopted in the form of so-called burden sharing agreement) committed to an 8 % reduction of emissions compared to the base year 1990. The Slovak Republic and the EU countries ratified the Kyoto Protocol on May 31, 2002.¹

Total GHG emissions without LULUCF in the EU-27 were 7.9 % below the base year in 2005. By 2010, total EU-27 greenhouse gas emissions are projected to be 7.5 % lower than in 1990. The new member states (EU-10) reduced together the GHG emissions in average about 28 % in the 1990–2006 period without LULUCF. The main reason for this important emission reducing is above all the strong although temporary decreasing of the economy activities, following restructuring of the economy joined with the implementing of new, more effective technologies, reducing the share of the intensive energy industry and increasing the share of services in the GDP generation. The important exception is transport (mostly road transport), with the increasing of emissions. The continuous pressure is made in the field of the formulating the effective strategy and policy for the further reducing the emissions. (Figure ES. 1)

¹ Kyoto Protocol came into force on February 14, 2005

Figure ES. 1: GHG emission trends compared with the Kyoto target (%)

ES.2 National Circumstances

The Slovak Ministry of the Environment (www.enviro.gov.sk) is responsible for national environmental policy including climate change and air protection issues. It has the responsibility to develop acts, and amendments to existing legislation. Legislation proposals are commented by all ministries and other relevant bodies. Following the commenting process, proposed acts are negotiated in the Legislative Council of the Government, approved by the Government, and finally by the Parliament.

Supporting institutions founded by the Ministry of Environment play an important role. These include the Slovak Hydrometeorological Institute (www.shmu.sk), the Water Research Institute, and the Slovak Environmental Agency. Academic and research institutions (i.e. the Ecology and Forestry Research Agency Zvolen, the Transportation Research Institute Zilina, the Slovak Agricultural University Nitra, the Slovak Technical University Bratislava, Faculty of Mathematics, Physics & Informatics, Comenius University Bratislava, and the Slovak Academy of Science), non-governmental organizations, and associations of interested groups (the SEA - the Slovak Energy Agency, PROFING – energy consulting company, SZCHKT – Association for Air Conditioning and Cooling Technique, Detox – solvent use, SPIRIT – information systems, Ecosys – consulting company for projections in energetic) are involved in the process of development and implementation of policy and measures aimed to mitigate climate change impacts.

According to the global climatologic classification, the Slovak Republic is in the mild climate zone category with precipitation uniformly distributed over the whole year. The Atlantic Ocean impacts the west part of SR, a continental influence is typical for east part. A regular rotation of four seasons and variable weather throughout the year are typical for this country.

The Slovak Republic has 5.39 mills. inhabitants (as of 31.12.2007). The average population density is 110 inhabitants/km². The population is concentrated in the cities in the lowlands and the main basins. Mountains areas are randomly populated. In the Slovak Republic, there are 47.8 % of inhabitants are economically active. The largest city is Bratislava with 425 155 inhabitants (as 31.12.2006). It is the capital of the Slovak Republic.

Since 2000, macroeconomic development of the Slovak Republic has been influenced by implementation of measures with respect to the preparation of the country for EU membership. Among the most important measures were the removal of price distortions, changes in indirect taxes, and reconciliation of public financing mechanisms. In 2001, the growth in GDP reached 3.3 %. In 2003, the Slovak economy continued its positive development, when the growth of gross domestic product (GDP) at

constant prices reached 6.0 %, which is a comparable to the growth of the most developed economies in transition and a double that of the EU27 countries.

ES.3 Overview of Source and Sink

The GHG emissions presented in the National Inventory Report 2008 were updated and converted using the newest available methods, national conditions and data published by the Slovak Statistical Office. Total GHG emissions represented 48 902.42 Gg in 2006 (without LULUCF). This represents a reduction by 33.6 % in comparison with the reference year 1990. In comparison with 2005, the emissions decreased by 1.5 %. Total GHG emissions in the SR are stable or slightly increasing due to recovery of economic activities, increase in transport category and expected increase in actual emissions of F-gases (mainly HFCs and SF₆). Total GHG emissions including LULUCF sector are peaked and exceeded 1998. Significant changes are expected according the revisions of the NEIS database (new fuel's catalogue) and trying to keep consistency with European Trade System (ETS) and changes in balance methodology in sector AFOLU were applied. The Table ES. 1 shows the aggregated GHG emissions. In the period 1990–2006, the total greenhouse gas emissions in the Slovak Republic did not exceed the level of the year 1990 (Figure ES. 1). The national total emissions determined as of April 15, 2008 are shown below.

Table ES. 1: The total anthropogenic greenhouse gas emissions (Tg of CO₂ eq.)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Net CO ₂	59.43	52.02	47.78	43.41	42.12	41.22	39.95	39.92	39.98	39.59	37.79	36.42	34.73	36.53	36.81	39.83	36.93
CO ₂ *	61.84	55.53	51.93	47.69	45.44	43.92	42.37	41.33	41.92	41.23	40.20	41.64	39.97	41.36	41.07	40.70	39.98
CH ₄	5.40	5.15	4.85	4.47	4.45	4.64	4.58	4.63	4.86	5.07	4.68	4.73	5.33	4.96	4.93	4.63	4.63
N ₂ O	6.17	4.97	4.15	3.51	3.85	4.08	4.21	4.10	3.70	3.25	3.52	3.72	3.68	3.72	3.82	3.79	4.04
HFCs	NA,NO	NA,NO	NA,NO	NA,NO	0.00	0.02	0.04	0.06	0.04	0.07	0.08	0.08	0.10	0.13	0.15	0.17	0.20
PFCs	0.27	0.27	0.25	0.16	0.13	0.11	0.03	0.03	0.03	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.04
SF ₆	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
GHG	71.29	62.41	57.05	51.55	50.58	50.11	48.83	48.78	48.64	48.03	46.11	44.99	43.89	45.39	45.77	48.48	45.87
GHG*	73.68	65.91	61.19	55.83	53.88	52.79	51.24	50.16	50.57	49.65	48.50	50.20	49.11	50.21	50.00	49.33	48.90

* Total aggregated GHGs emission without LULUCF, emissions are determined as of 15.04.2008

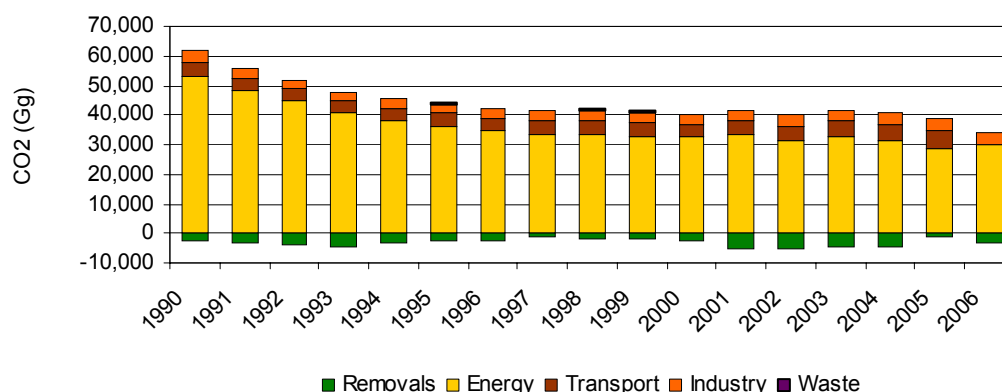
ES.4 CO₂ Emissions

A most important anthropogenic source of CO₂ emissions in the atmosphere is combustion and transformation of fossil fuels, which account for about 95 % of the total CO₂ emissions in the SR (Table ES. 2). A calculation of CO₂ emissions is based on energy statistical data when the IPCC sectoral method (sectoral approach) was applied. In addition, carbon dioxide arises during technological process of cement, lime, magnesite production and using of limestone. The balance includes also the production of coke, iron and steel, as well as CO₂ emissions arising during aluminium and ammonia production. Emission factors, estimated on the carbon content in fuels, were used. Carbon dioxide enters the atmosphere via the conversion of grasslands and forest areas into agricultural land, and forest fires. (Figure ES. 2)

Table ES. 2: The total CO₂ emissions by sectors (Tg)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Energy	53.04	48.36	45.07	41.13	38.37	36.43	34.82	33.53	33.14	32.53	32.45	33.23	31.40	32.97	31.60	30.35	30.04
Transport	4.89	4.12	3.79	3.77	4.01	4.26	4.31	4.48	4.76	4.66	4.18	4.75	4.89	5.00	5.27	6.21	5.80
Industry	3.84	2.97	3.01	2.72	2.99	3.16	3.17	3.26	3.92	3.98	3.50	3.61	3.65	3.36	4.16	4.12	4.12
Removals	-2.41	-3.51	-4.15	-4.28	-3.32	-2.70	-2.42	-1.40	-1.94	-1.64	-2.40	-5.23	-5.24	-4.83	-4.25	-0.88	-3.05
Waste	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.05	0.10	0.07	0.07	0.06	0.04	0.03	0.03	0.01	0.02
Total CO ₂ *	59.43	52.02	47.78	43.41	42.12	41.22	39.95	39.92	39.98	39.59	37.79	36.42	34.73	36.53	36.81	39.83	36.94

*Total CO₂ with LULUCF, emissions are determined as of 15.04.2008, emissions in Tg.

Figure ES. 2: Share of individual sector on CO₂ emissions (Gg) in 1990–2006

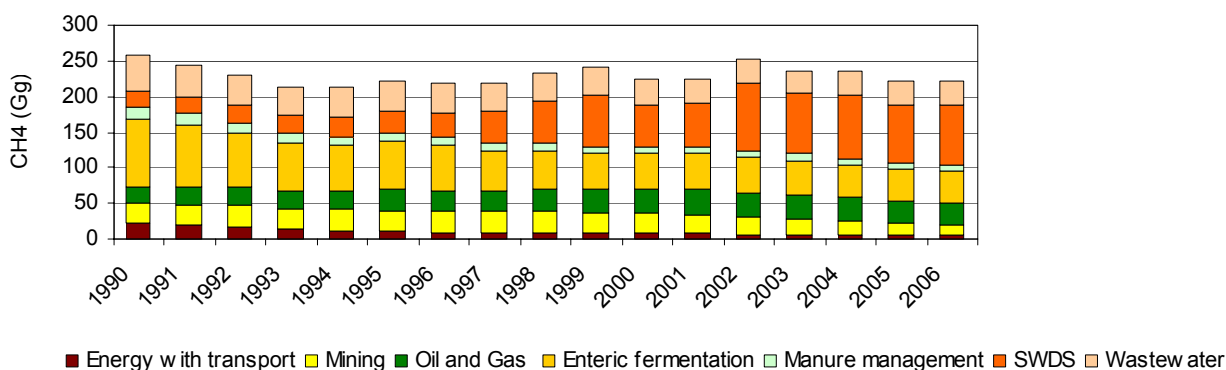
ES.5 CH₄ Emissions

Agriculture, large-scale beef cattle and pig breeding, are major sources of methane on the Slovak territory (Table ES. 3). The CH₄ does arise as the direct product of the metabolism in herbivores and as the product of organic degradation in animal excrement. Calculations of emissions for the Slovak Republic are based on the data listed in the Statistical yearbook of the Slovak Republic (Statistical yearbook, 2006) and the Green Report of the Slovak Ministry of Agriculture (Green Report, 2006). Leaks of natural gas in the distribution networks are a very important source of methane. Methane is also leaking into the atmosphere from brown coal mining and biomass burning. In addition, municipal waste dumps and sewage (predominantly septic tanks) are also important methane sources. Methane arises without the direct access of oxygen (Figure ES. 3).

Table ES. 3: The total CH₄ emissions by sectors (Tg)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Energy with transport	22.28	18.98	17.67	14.31	11.98	10.77	8.83	7.44	7.98	7.28	8.01	7.57	5.62	5.65	5.16	5.07	5.04
Mining	27.20	28.83	29.93	28.61	29.91	29.70	30.08	30.61	31.17	29.50	28.82	26.33	25.69	21.11	19.77	16.17	14.67
Oil and Gas	24.45	24.97	24.24	25.09	26.58	29.13	29.73	29.98	32.01	31.99	34.06	34.86	33.74	35.93	34.32	31.96	32.13
Enteric fermentation	94.77	86.89	76.41	66.09	62.39	66.90	62.67	56.10	52.91	50.78	49.93	51.44	49.78	47.65	44.22	44.91	44.21
Manure management	17.56	16.32	14.82	13.62	12.91	13.25	12.60	11.56	10.21	9.87	9.52	9.63	9.74	9.26	7.84	7.66	7.49
SWDS	22.37	23.45	24.16	24.89	27.75	30.85	33.81	44.10	58.01	72.24	57.47	59.93	93.52	84.22	91.00	81.81	83.85
Wastewater	48.19	45.52	43.69	40.04	40.36	40.38	40.04	40.31	39.11	39.64	35.09	35.42	35.50	32.11	32.05	32.68	32.72
Total CH₄	256.9	245.1	231.0	212.8	212.0	221.2	217.9	220.3	231.6	241.5	223.1	225.4	253.8	236.1	234.6	220.4	220.4

*Total CH₄ emissions without LULUCF are determined as of 15.04.2008, emissions in Tg.

Figure ES. 3: Share of individual sector on CH₄ emissions (Gg) in 1990–2006

ES.6 N₂O Emissions

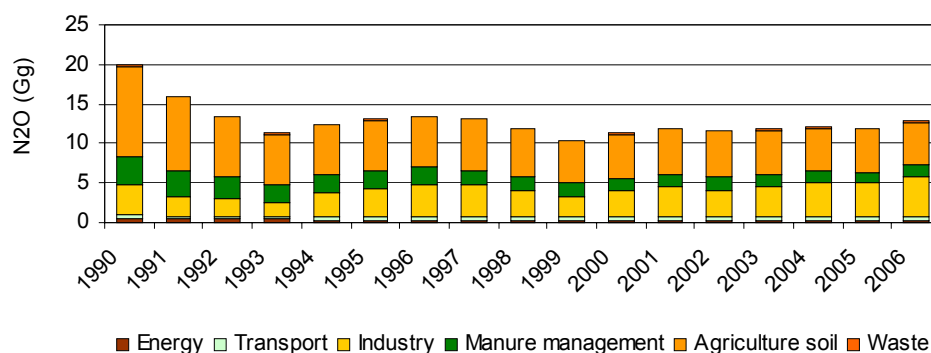
In comparison with other greenhouse gases, the mechanism of N₂O emissions and sinks develops from the nitrogen cycle in the atmosphere and their quantification is rather difficult (Table ES. 4). Global anthropogenic emission is estimated to be 3–7 billion tons of nitrogen per year. Natural sources are approximately twice as large as anthropogenic ones. The primary sources of N₂O in the Slovak Republic are agriculture, waste treatment and N₂O from combustion of fuels (energy and transport) (Figure ES. 4).

Table ES. 4 The total N₂O emissions by sectors (Tg)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Energy	0.583	0.499	0.445	0.390	0.348	0.320	0.295	0.279	0.276	0.271	0.275	0.283	0.269	0.288	0.276	0.266	0.274
Transport	0.394	0.320	0.283	0.267	0.287	0.326	0.355	0.390	0.432	0.445	0.415	0.492	0.488	0.514	0.518	0.611	0.570
Industry	3.706	2.570	2.295	1.774	3.164	3.632	4.242	4.014	3.413	2.564	3.331	3.768	3.370	3.730	4.264	4.134	5.050
Manure management	3.531	3.204	2.763	2.396	2.244	2.359	2.182	1.998	1.765	1.682	1.645	1.594	1.575	1.529	1.426	1.376	1.337
Agricultural soils	11.555	9.279	7.480	6.366	6.258	6.368	6.323	6.400	5.919	5.397	5.561	5.656	5.835	5.621	5.456	5.448	5.362
Waste	0.090	0.090	0.075	0.066	0.066	0.068	0.071	0.069	0.075	0.067	0.061	0.095	0.147	0.120	0.119	0.117	0.171
Total N₂O	19.91	16.02	13.40	11.31	12.42	13.17	13.57	13.24	11.95	10.50	11.35	11.98	11.87	11.99	12.32	12.23	13.03

*Total N₂O emissions without LULUCF are determined as of 15.04.2008, emissions in Tg.

Figure ES. 4: Share of individual sectors in N₂O emissions (Gg) in 1990–2006



ES.7 HFCs, PFCs and SF₆ Emissions

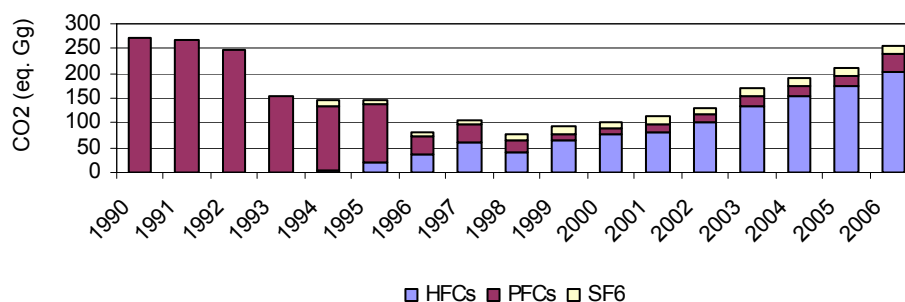
The first inventory of these substances² was executed in 1995. HFCs, PFCs and SF₆ are not produced in the SR, only data on consumption of these substances are available (Table ES. 5). They are used as coolants, extinguishing agents, blowing agents for PUR, in aerosol products and as insulating gases (SF₆). (Figure ES. 5)

Table ES. 5 The total HFCs, PFCs and SF₆ emissions by sectors (Gg)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
HFCs	0	0	0	0	2.9091	22.153	37.591	61.197	40.997	65.19	75.783	82.795	103.1	133.16	154.43	174.65	202.16
PFCs	271.37	266.94	248.42	155.42	132.06	114.32	34.512	34.617	25.404	13.602	11.647	15.593	13.747	21.651	19.91	20.252	35.822
SF ₆	0.0306	0.0329	0.0382	0.065	9.2679	9.9084	10.759	11.34	12.242	12.687	13.254	13.842	14.779	15.389	15.888	16.613	17.152
Total F-gases	271.4	267.0	248.5	155.5	144.2	146.4	82.9	107.2	78.6	91.5	100.7	112.2	131.6	170.2	190.2	211.5	255.1

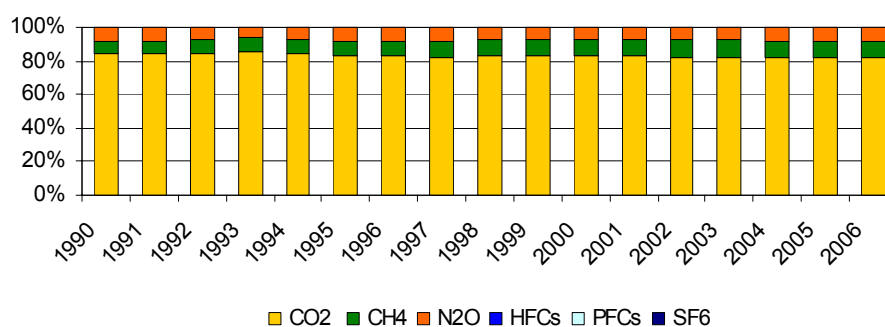
*Total HFCs, PFCs and SF₆ emissions are determined as of 15.04.2008, emissions in Gg.

² The utilisation of „F-gases“ (they are not covered by the UN Convention) in the SR is regulated in compliance with the Montreal Protocol and its appendices. Since 1986, the total consumption of controlled substances has been decreasing. Freons in cooling systems are successively being replaced by perfluorocarbons, so it can be assumed that consumption of these substances will increase several times following the year 1996.

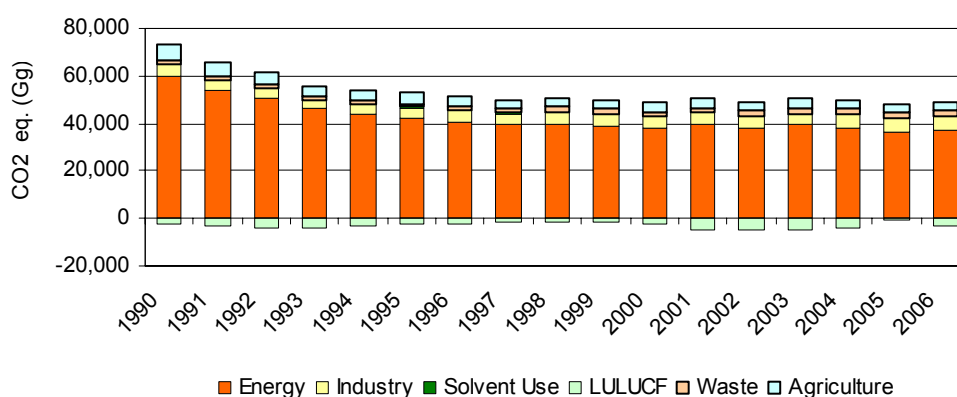
Figure ES. 5: Share of individual F-gases emissions (Gg of CO₂ eq.) in 1990–2006

ES.8 Aggregated Emissions

These are the emissions of greenhouse gases recalculated via GWP100 (Global Warming Potential)³ on the CO₂ equivalent (Figure ES. 6). Expressed as the CO₂ equivalent, carbon dioxide emissions contributed by almost 82 % to the total emissions, CH₄ (GWP = 21) emissions by about 9.5 %, N₂O (GWP = 310) emissions by about 8 % and the contribution of F-gases is below 1 % (Figure ES. 7).

Figure ES. 6: The aggregated emissions of greenhouse gases by gases in 1990–2006 in percent

Emissions without LULUCF in CO₂ equivalents; emissions are determined as of 15.04.2008

Figure ES. 7: The aggregated emissions of greenhouse gases by sectors in 1990–2006

Emissions without LULUCF in CO₂ equivalents; emissions are determined as of 15.04.2008

³ According to the currently valid Convention, the emission reduction expressed in CO₂ equivalent should be reported

ES.9 Indirect Greenhouse Gases

A major source of SO₂, NO_x and CO emissions is power and heat generation. A contribution of transport to NO_x and CO emissions is still growing. Metallurgy is an important source of CO emissions. Emissions of NM VOC are regularly estimated in the framework of the National Program of NM VOC Emissions Reduction in the SR. In the frame of this Program were revised emission factors for asphalt paving and residential plants combustion (total emission's decrease in 1990 about 45 %). The year 1990 was used as a starting point and updating was carried out for the years 1990, 1993, 1996–1999, 2005. A major source of NM VOC emissions come from the use of solvents, transport, refinery/storage and transport of crude oil and petrol. The categories of emission sources in National Emission Inventory System (NEIS) are based on Air Pollution Act (478/2002) and they do not correspond exactly to the structure of sources to CRF requirements. Therefore, it is impossible to provide information on emissions and emission factors according to the classification requested in standard tables (Table ES. 6).

Table ES. 6: The anthropogenic emissions of NO_x, CO, NM VOC and SO₂ (Gg) in 1990–2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CO	505.0	482.0	441.0	452.0	427.0	416.0	359.0	359.0	342.0	330.0	312.9	315.1	292.3	308.2	309.8	299.4	289.8
Stationary	345.0	335.0	296.0	297.0	268.0	255.0	204.0	201.0	183.0	180.0	185.2	175.6	165.1	184.2	189.6	181.4	192.9
Transport	154.0	142.0	141.0	151.0	155.0	157.0	151.0	153.0	154.0	145.0	121.9	133.6	121.3	117.5	113.1	108.7	88.4
Other*	6.0	5.0	4.0	4.0	4.0	4.0	4.0	5.0	5.0	5.0	5.9	5.9	5.9	6.5	7.1	9.4	8.5
NO_x	222.0	201.0	188.0	180.0	170.0	178.0	135.0	127.0	133.0	121.0	109.2	108.7	101.1	98.1	98.1	98.0	86.6
Stationary	165.0	154.0	144.0	138.0	126.0	133.0	90.0	82.0	87.0	78.0	70.3	67.6	59.7	58.4	56.5	55.4	51.8
Transport	57.0	47.0	44.0	42.0	44.0	45.0	45.0	45.0	46.0	43.0	38.3	40.6	40.9	39.1	40.9	41.8	33.8
Other*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5	0.6	0.6	0.8	1.0
NM VOC	136.6	136.6	136.6	111.2	111.2	105.2	103.2	93.4	90.5	83.6	78.8	81.6	77.1	81.2	82.8	78.9	78.4
Energy	14.0	14.0	14.0	12.6	12.6	10.7	11.1	9.5	9.6	9.0	8.7	9.3	7.9	8.4	9.9	12.8	12.2
Industry	8.8	8.8	8.8	5.9	5.9	2.8	2.7	2.7	1.6	1.5	1.4	1.3	1.4	1.7	1.7	1.6	1.6
Transport	33.6	33.6	33.6	30.9	30.9	33.0	31.8	32.0	31.9	29.1	25.0	26.6	23.8	26.0	24.7	18.7	15.4
Crude Oil	27.1	27.1	27.1	21.8	21.8	16.8	17.2	17.8	14.5	13.8	13.3	13.2	12.4	12.9	13.1	11.9	10.532
Solvent Use	48.0	48.0	48.0	38.3	38.3	41.2	39.8	30.8	32.3	29.5	29.8	30.6	30.9	31.6	32.7	33.2	38.0
Agriculture	0.7	0.7	0.7	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Waste	4.5	4.5	4.5	1.3	1.3	0.3	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2
SO₂	526.0	445.0	390.0	328.0	245.0	246.0	231.0	205.0	184.0	173.0	127.0	131.2	103.3	106.1	96.9	89.0	87.8
Stationary	523.0	442.0	388.0	326.0	243.0	244.0	228.0	202.0	181.0	172.0	126.1	130.2	102.5	105.3	96.0	88.8	87.5
Transport	2.7	2.7	1.8	1.8	1.8	1.8	2.9	2.9	2.9	0.9	0.9	0.9	0.8	0.8	0.9	0.2	0.2
Other*	0.30	0.30	0.20	0.20	0.20	0.20	0.10	0.10	0.10	0.07	0.02	0.01	0.02	0.03	0.01	0.00	0.00

*Biomass burning and forest fires, emissions are determined as of 15.04.2008

1 INTRODUCTION

1.1 Background Information on GHG Inventories and Climate Change

Global climate change due to the anthropogenic emission of greenhouse gases is the most important environmental problem in the history of humankind. The instrument to tackle the problem of climate change is the UN Framework Convention on Climate Change adopted in 1992. The aim of the Convention is to stabilize atmospheric concentrations of greenhouse gases to a safe level. Currently, there are 185 countries or international communities, including the Slovak Republic, and the EU that are parties to the Convention. The Convention requires the adoption of measures that aim to reduce the GHG emission to the level of the year 1990.

The framework Convention on Climate Change (UN FCCC) - the basic international legal instrument to protect global climate was adopted at the UN Conference on the environment and sustainable development (Rio de Janeiro, 1992). The final goal of the Convention is to achieve stabilisation of greenhouse gas concentrations in the atmosphere at a level that has not yet developed any dangerous interference in the climate system.

In the Slovak Republic, the Convention came into force on November 23, 1994. The SR accepted all the commitments of the Convention, including reduction of the greenhouse gas emissions by 2000 to the 1990 level. One of the commitments, resulting from the Convention, is to provide a regularly greenhouse gas emission inventory.

The Kyoto Protocol, adopted by consensus at the third session of the Conference of the Parties (COP-3) in Kyoto, December 1997, enforced the international responsibility for the climate change. The all Annex I countries, which ratified the Kyoto Protocol, formally defined their reduction targets in articles of the KP. The Kyoto Protocol came into force on February 16, 2005 after compliance of requirement determined in Article 25, paragraph 1; it means after signing of more than one-half Annex I countries, that representing of minimum 55 % of total CO₂ emissions of Annex I countries in 1990 (the signature of the Russian Federation ensured the majority). The Slovak Republic and the most countries of Central and East Europe agreed to reduce base year level of all six GHG emissions by 8 % during period 2008–2012. As of June 6th, 2007, 174 countries and one regional integration organisation (the European Community) had ratified, accepted, approved or acceded to the Kyoto Protocol. A meeting of the commitments gains high priority in the EU.

In the context of joining of the Slovak Republic the European Union (May 1st, 2004), raised the new requirements for legislative implementation in the field of air protection. The European Union considers the area of climate change for the one of the four environmental priorities.⁴ The Slovak Republic submits the data about GHG emissions in the relevant extend to the January 15, annually, according the Decision No 280/2004/EC of the European Parliament and of the Council concerning a Mechanism for Monitoring Community GHG emissions and for implementing the Kyoto Protocol.⁵ The ground for the implementing of the Decision were the following criteria:

1. Monitoring of the all anthropogenic emissions of GHGs in the EU member states,
2. Ensure the progress in the fulfilling the reduction targets UNFCCC and the Kyoto Protocol,
3. Implement Convention and Kyoto Protocol in the view of the national programs, GHGs inventory, national system and register EU and the member states,

Ensure completeness, transparency, consistency, accuracy, comparability and the timing in the EC reporting. The unfavorable development and balance of GHG emissions generation since 1992 have created a need to adopt an additional and effective instrument. In 1997, the parties of the Convention

⁴ *New environmental action program: Environment 2010 Our Future, Our Choice*

⁵ *OJ L 49, 19.2.2004, p. 1.*

agreed to endorse the Kyoto Protocol (KP) that defines reduction targets for countries of the Annex I to the Convention. Developed countries defined in Annex B of the Kyoto Protocol should individually or together reduce emissions of six GHG on average by 5.2 % from the level of the year 1990 during the first commitment period 2008–2012. The reduction target of the Slovak Republic is 8 % reduction of emissions compared to the base year 1990. The Kyoto Protocol has generally extended the options of the countries to choose the way and the instruments that are most appropriate for achievement of their reduction targets, taking into account the specific circumstances of the country. The common feature of new mechanisms is the effort to achieve the maximum reduction potential in the most effective way. The Slovak Republic and the EU countries ratified the Kyoto Protocol on May 31, 2002.⁶

The greenhouse effect of the atmosphere is a similar effect to that which may be observed in greenhouses, however the function of glass in the atmosphere is taken over by the "greenhouse gases" (international abbreviation GHGs). Short wave solar radiation is transmitted freely through the greenhouse gases, falling to the earth's surface and heating it. Long wave (infrared) radiation, emitted by the earth's surface, is caught by these gases in a major way and partly reemitted towards the earth's surface. Because of this effect, the average temperature of the surface atmosphere is 33°C warmer than it would be without the greenhouse gases. Finally, this enables the life on our planet.

The most important greenhouse gas in the atmosphere is water vapour (H₂O), which is responsible for approximately two thirds of the total greenhouse effect. Its content in the atmosphere is not directly affected by human activity, in principle it is determined by the natural water cycle, expressed in a very simple way, as the difference between evaporation and precipitation. Carbon dioxide (CO₂) contributes to the greenhouse effect 30 %, methane (CH₄), nitrous oxide (N₂O) and ozone (O₃), all three together 3 %. The group of synthetic (artificial) substances - chlorofluorocarbons (CFCs), their substitutes, hydrofluorocarbons (HFCs) and others such as fluorocarbons (PFCs) and SF₆, also belong to the greenhouse gases. There are other photochemical active gases as well, such as carbon monoxide (CO), oxides of nitrogen (NO_x) and non-methane organic compounds (NM VOC), which do not belong to the greenhouse gases, but contribute indirectly to the greenhouse effect of the atmosphere. They are registered together as the precursors of ozone in the atmosphere, as they influence the formation and disintegration of ozone in the atmosphere.

Whilst mentioning the emissions of greenhouse gases, we must also include CO₂, CH₄, N₂O and F-gases, as they are defined in the Kyoto Protocol. Though they belong to natural components of the ambient air, their present content in the atmosphere is significantly affected by human activity. The growth in concentrations of greenhouse gases in the atmosphere (caused by anthropogenic emission) leads to the strengthening of the greenhouse gas effect and thus to the additional warming of the atmosphere. Concentrations of greenhouse gases in the atmosphere are formed by the difference between their emission (release into the atmosphere) and sink. It follows then that the increase of their content in the atmosphere operates by two mechanisms:

- Emissions into the atmosphere;
- Weakening of natural sink mechanisms.

Globally (Climate Change, 1995) the annual anthropogenic emission of carbon dioxide ranges between 4–8 billion tons of carbon (about 4t of CO₂ per capita in the globe). The most important source of "new" carbon dioxide is presented by the fossil fuel combustion and cement production. The CO₂ is also released from the soil (deforestation, forest fires and conversion of grasslands into agricultural soil), but this contribution is more difficult to quantify. Carbon dioxide is very stable in the atmosphere; its residence time is tens of years (60–200 yrs.) and is removed from the atmosphere by a complex of natural sink mechanisms. It is expected that 40 % of carbon dioxide presently emitted be absorbed by the oceans. Photosynthesis by vegetation and sea plankton is a further important sink mechanism, though only a transitional one, because after the death (eating) of a plant, carbon dioxide is released again. The level of methane in the ambient air is affected by human activity in more ways. Land

⁶ Kyoto Protocol came into force on February 14., 2005

transformation into an agricultural one (mainly rice fields), animal husbandry, coal mining, natural gas mining, its transport and use as well as the biomass burning are all anthropogenic activities. The natural methane sources are not yet fully investigated and thus the role of methane in the climate change mechanism is not quite clear. As distinct from CO₂, the disintegration of methane in the atmosphere is via chemical reactions (by OH radical). Residence time of methane in the atmosphere is 10–12 years. At present, the annual total anthropogenic methane emission is said to be approximately 0.4 billion tons, emission from natural sources is about 0.16 billion tons (IPCC7 1995). PFCs, HCFCs, HFCs (perfluorocarbons, hydrochlorofluorocarbons, hydrofluorocarbons, etc.) and SF₆ are entering the atmosphere only because of human activity. They are used as carrier gases for sprays, fillings in cooling and extinguishing systems, as insulating substances, as solvents at the production of semi-conductors etc. Apart from the fact that they attack atmospheric ozone, they are very "high-powered" inert greenhouse gases having a residence time e.g. perfluoromethane (CF₄) of 50 000 years. It means that even minor emissions have a great negative effect. The ground level ozone concentrations are growing as a consequence of CO, NO_x and NM VOC emissions. They have very important source in exhaust gases, fossil fuel combustion and as far as NM VOCs are considered, the use of solvents, as well. N₂O enters the atmosphere from several small sources. The most important source does seem to be the emission from soil (nitrogen surpluses because of intensive fertilising and inconvenient agriculture-technical procedures). Fuel combustion, some industrial technologies, large-scale livestock breeding and sewage are the sources of N₂O emissions. Global anthropogenic emission is estimated to be 3–7 million tons of nitrogen per year. Natural sources are approximately twice as large as anthropogenic ones. The N₂O is disintegrated mainly photo chemically in the stratosphere.

According to the emission inventory of January, 2008, the Slovak Republic has achieved a reduction of total anthropogenic emissions of greenhouse gasses expressed as CO₂ equivalent, of approximately 34 % without LULUCF compared the base year 1990. This achievement is the result of several processes and factors, mainly:

- higher share of services in the generation of the GDP;
- higher share of gas fuels in the primary energy resources consumption;
- restructuring of industries;
- gradual decrease in energy demands in certain heavy energy demanding sectors (except for metallurgy);
- and the impact of air protection legislative measures influencing directly or indirectly the generation of greenhouse gas emissions.

A comparison of the GDP trend with the trend of aggregate emissions of greenhouse gasses (Figure 1. 1) shows that the SR is one of few countries where the trend of emissions is decoupled from the GDP increase. However, by international comparison, the generation of greenhouse gasses per capita still remains one of the highest in the Europe (Table 1.1).

Without introduction of effective measures SR will contribute to further increase of GHG emissions due to anticipated growth of the GDP and recovery of economic activities. Therefore, the investment strategy to tackle GHG emissions is one of the most important objectives.

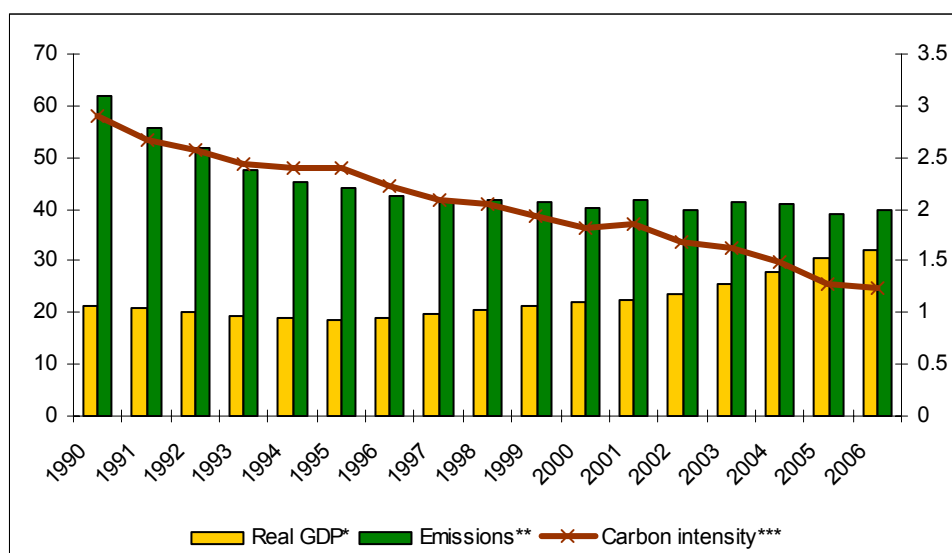
In May 2004, the Slovak Republic joined the European Union. Relevant European legislation is expected to have additional positive direct and indirect effects to reduction of GHG emissions, mainly in the energy sector. The introduction of emission trading scheme will allow for the implementation of further reduction measures.

⁷ *Intergovernmental panel was established in 1988 commonly by ECE (UNEP) and World Meteorological Organisation (WMO). Its task is to reach the authoritative international consensus in the scientific opinions on climate change. The working groups of IPCC prepare regular updated information for COP, where the latest knowledge in association with the global warming is included.*

Table 1.1: Carbon intensity per GDP in the Slovak Republic

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Real GDP*	21.385	20.746	20.126	19.525	18.942	18.376	19.067	19.784	20.527	21.299	22.100	22.400	23.700	25.400	27.700	30.500	32.269
Emissions**	61.838	55.527	51.933	47.695	45.437	43.917	42.372	41.327	41.921	41.230	40.195	41.642	39.972	41.359	41.065	40.704	39.984
Carbon intensity***	2.892	2.676	2.580	2.443	2.399	2.390	2.222	2.089	2.042	1.936	1.819	1.859	1.687	1.628	1.483	1.335	1.239

The values are absolute, *in billion Euro in year 2000, **Tg of CO₂ emissions without LULUCF, ***Tg of CO₂/billions Euro 2000

Figure 1. 1: Comparison of CO₂ emissions per GDP (carbon intensity)

1.2 Institutional Arrangement

The Slovak Ministry of the Environment (MoE) (www.enviro.gov.sk) is responsible for national environmental policy including climate change and air protection issues as a National Focal Point. It has the responsibility to develop acts, and amendments to existing legislation. All ministries and other relevant bodies comment legislation proposals. Following the commenting process, proposed acts are negotiated in the Legislative Council of the Government, approved by the Government, and finally by the Parliament. The Ministry of the Environment cooperates with other ministries, such as Ministry of Economy, the Ministry of Agriculture, the Ministry of Finance, the Ministry of Transport, Posts and Telecommunications, and the Ministry of Construction and Regional Development.

District and regional environmental offices are decision-making bodies according to the Act 525/2003 Coll. These are located at 8 regional and 46 district administration offices. Inspection and enforcement activities are carried out by the 4 inspectorates of the Slovak Environmental Inspection. According to the Act 478/2002 Coll. on Air Protection, competencies and decision-making process on large, medium and small pollution sources are given to regional, district levels and municipalities.

The Act 572/2004 Coll. on Trading with Emission Quotas is the first legal instrument directly oriented towards control of GHG emissions. According to this Act, competencies with respect to trading of emission quotas are given to the Ministry of the Environment, regional and district environmental offices.

The official publication about National inventory system for GHG emissions and projection under Article 5 of the Kyoto Protocol was published in the official journal of Ministry of Environment of the Slovak Republic <http://www.enviro.gov.sk/servlets/files/16715>.⁸

Supporting institutions founded by the Ministry of Environment play an important role. These include the Slovak Hydrometeorological Institute (SHMI) (www.shmu.sk), the Water Research Institute, and the Slovak Environmental Agency. Academic and research institutions (i.e. the Forestry Research Institute Zvolen, the Transportation Research Institute Zilina, the Slovak Agricultural University Nitra, the Slovak Technical University Bratislava, Faculty of Mathematics, Physics & Informatics, Bratislava, and the Slovak Academy of Science), non-governmental organizations, and associations of interested groups (the Slovak Energy Agency, PROFING, EFRA Zvolen, SZCHKT, Detox, SPIRIT, Ecosys, veQ s.r.o.) are involved in the process of development and implementation of policy and measures aimed to mitigate climate change impacts.

National emission inventories are compiled on contractual bases annually, in cooperation with external consultants, NGOs, scientific institutes and universities (Profing – company for energy research, Agricultural University, Research Institute for Transport, Chemical Technical University, Forestry Research Institute, Association for cooling and air condition technique, Central register for waste and wastewater etc.). Complete list of sectoral experts and institution is included in Annex 1.

The SHMI is up to that developing and maintaining a National Emission Inventory System (NEIS) - database of stationary sources to follow development of emissions of SO₂, NO_x, CO at regional level and to fulfil reporting commitments of national and EU Directives (http://www.spirit.sk/ie_home.html). The NEIS software product is constructed as a multi-module system, corresponding fully to the requirements of current legislation. The NEIS database contains also some technical information about sources like fuel consumption and use for estimation of sectoral approach.

The SHMI is annually updating the incoming information and activity data with the corresponding statistical information from Statistic Office of the SR and other national statistics.

Setting up a National Inventory System of emissions in compliance with the Kyoto Protocol and Council Decision 280/2004/EC is the priority of capacity development in the Slovak Republic at all levels identified also as a middle-term objective (2003–2007) of the Strategy of SR. The basic characteristics of the capacity building the NIS are follows:

- to define a National Inventory System (institutions, competences), which will group the experts from all sectors according to IPCC (NFP, SNE, scientific institutions, universities, research institutes, private sector, non-governmental organisations, Statistic Office...);
- to establish an independent working unit entitled the Single National Entity (SNE – according to a COP recommendation), which will coordinate the NIS and have competencies and responsibilities stipulated by law. The SNE will be controlled directly by NFP (MŽP SR), including financial resources;
- the SNE should interlink all stakeholders at the horizontal level with regard to expert, financial, legal and information issues. The SNE should also be responsible for achieving the commitments under the UNFCCC and KP in the field of reporting, assessment and providing information to all stakeholders, administration of national databases (NEIS, IPPC – air, NEC directive, EPER), implementation of QA/QC process, accreditation and certification, organisation of „cross-country“ meetings and communication with international organisations;
- to appoint experts or organisations for each IPCC sector or gas, and explicitly determine their responsibilities; to appoint a team for the work on national communications, modelling and projections of emissions (RAINS, CAFE) in the sense of keeping consistency, reproducibility and transparency;

⁸ Vestník, Ministry of Environment, XV, 3, 2007, page 19: National inventory system of the Slovak republic for the GHG emissions and sinks under the Article 5, of the Kyoto Protocol

- to obtain dedicated continuous finances from the State budget for achieving the commitments under the UNFCCC and KP on annual basis and in a sufficient amount (according to actual needs and analysis);
- to determine the competencies of the NIS and the operators of polluting sources, with regard to the dissemination of information.

Actually is in place (already prepared first version of web application in test procedure) project of the Slovak Ministry of the Environment aimed at proposal of national integrated system of inventory and projections of GHG emissions. The project will be carried out in two phases – after the first phase focused on methodological and organisational aspects (middle 2007) will in the second one the project aimed at proposal and implementation of required QA/QC parameters and procedures for GHG emission inventory (20/CP.7 KP) (2007–2008). The results from the first phase of the project are expected to be fully covered all sources and methodologies applied in the inventory process. The web application and registered domain www.ghg-invetory.gov.sk will be on the two levels: for the public and expert access (with the password). The pilot version runs from March 2007. The requirements for sustainable archiving will be fulfill.

1.3 Process of Inventory Preparation

The process of greenhouse gases inventory according the UNFCCC requirements is realized in the Slovak Republic from 1995, from 2000 in the CRF. Next year inventory will be provided in the new CRF Reporter program for the whole time series 1990–2005 according to the COPs Decisions (18/CP.8 about reporting and 13/CP.9 about reporting in the LULUCF sector). Climate Change and Emission Trading Department at the Ministry of the Environment of the Slovak Republic is the national focal point to the UNFCCC. MoE is granting and supervising development and maintenance of national emission inventories on annual bases. The complete CRF with the emission inventory are reported to the Secretariat of the UN FCCC by 15 of April annually. After review process from the external expert is published Centralized Review on the web page.

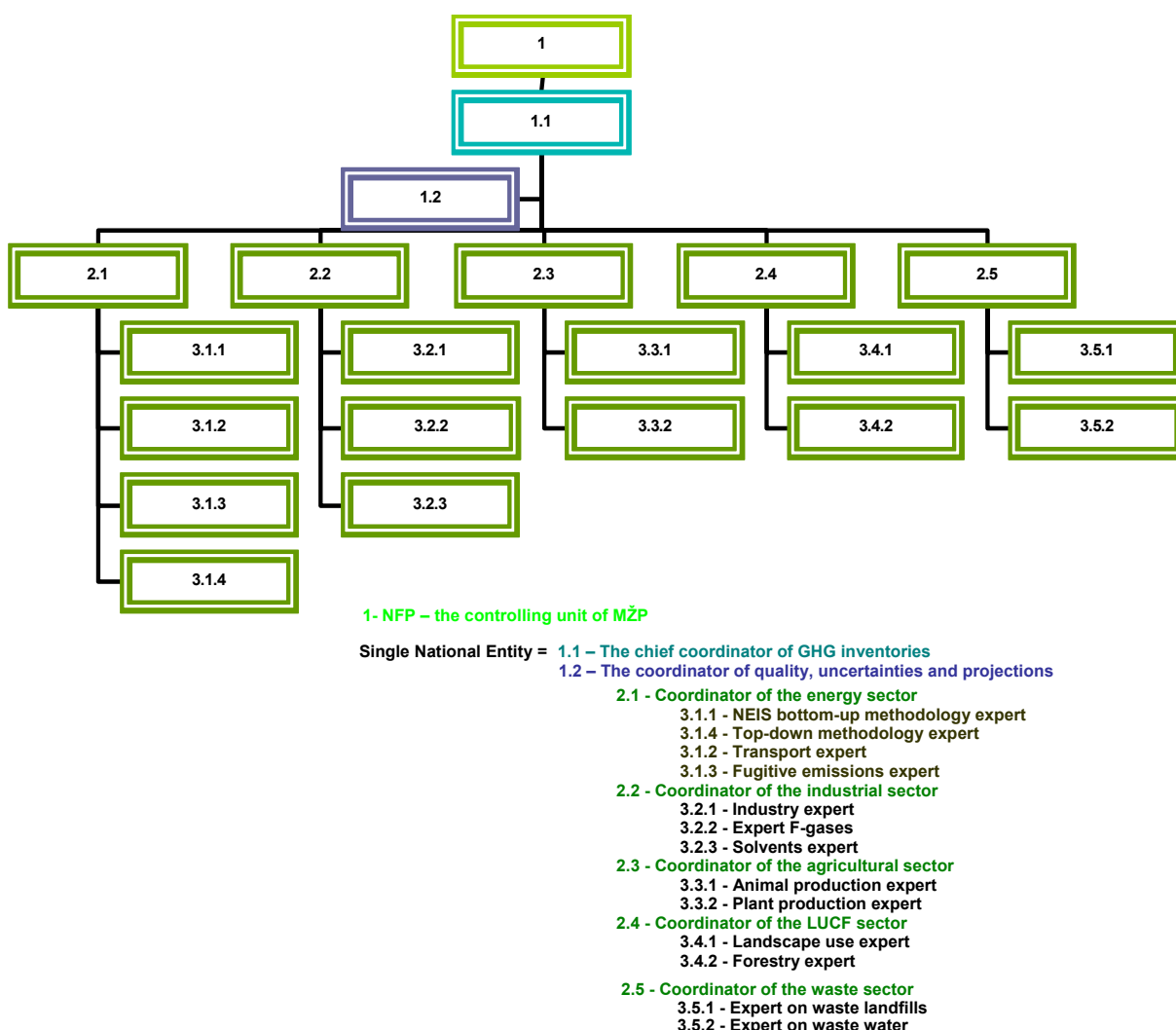
The emissions of GHGs in the Slovak Republic were estimated in compliance with the methods provided in IPCC 1996 Revised Guidelines, IPCC Good Practice Guidelines for LULUCF (2003) and IPCC Good Practice Guidance and Uncertainty Management in National GHG Inventories (GPG 2000); CORINAIR (2003), COPERT III (2002) and the national methodology in important categories. In accordance of these methodologies are used the emission factors: IPCC default, national specific, from literature. The emission balance is reported in the seven basic IPCC sectors (Annex I, KP), spits into the subsectors:

- Energy (Combustion processes, Transport, Fugitive emissions)
- Industrial Processes (Industrial technologies, F-gases)
- Solvents and Solvent Use
- Agriculture
- Land Use, Land Use Change and Forestry
- Waste
- The inventory process has not been certified (for example according to ISO 9001) and the quality system (QA/QC) has not been implemented. The quality system according to IPCC requires:
 - Transparency (is kept, NIRs);
 - Consistency (good, re-calculations since 1990 in case of change);
 - Comparability (default EFs according to IPCC, in case of absence EFs comparison with the the Czech Republic);
 - Completeness (expert estimation about 95 %), accuracy (not yet sufficiently assessed);
 - Use of good practice (according to the Good Practice Guidance, 2000 and 2003).

The uncertainties of emission factors are not assessed consistently and usually expert estimates are used. Even though there are not available any focused programs for improving quality of the emission data at the present time, the considerable effort and the financial instruments are spent for the building of the National Inventory System according to the Article 5 of the KP and the Decision 20/CP.7 COP, annually.

The proposed organisational structure (Figure 1. 2) can be easily extended to include the inventory obligations for other pollutants (basic pollutants, ammonia, volatile organic matters, POPs, heavy metals and solid particles) within the framework of the international conventions and the EU directives (CLRTAP, NECD, IPPC and e-PRTR). This proposal will have to be discussed in the future, as the EU plans to interlink the reporting under the conventions into one system in order to simplify and streamline the reported data sets.

Figure 1. 2: The organisational structure of the National Inventory System in the SR

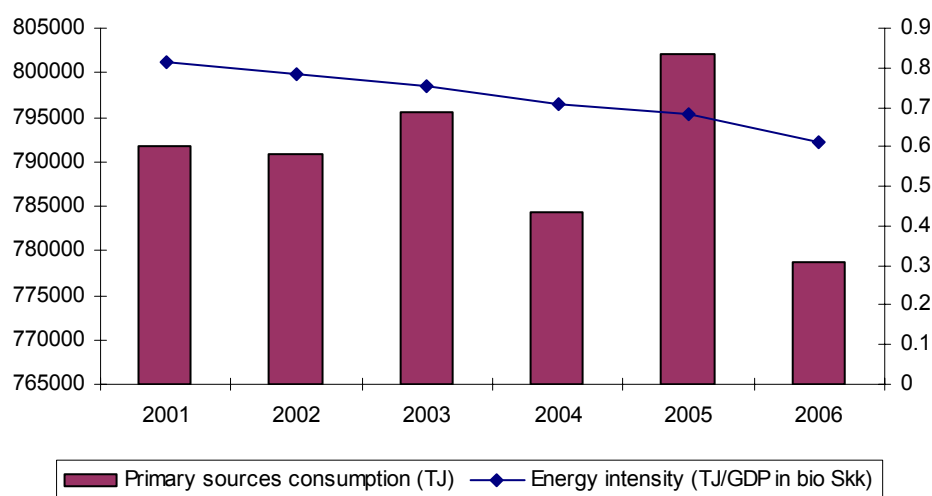


1.4 General Description of Methodologies and Data Sources

Energy sector – category energy industry

In 2006, the energy sector reached a 2.5 % share on the total GDP (according statistical information of Ministry of Finance). Energy intensity calculated on purchasing power is gradually decreasing, and was 1.9 times higher than the average recorded in the EU. The reason is a high proportion of heavy-energy-demanded industry contributing to the GD (Figure 1. 3).

Figure 1. 3: Development of Primary sources consumption (TJ) per GDP (billions Skk 2000) and energy intensity in the SR



Two IPCC methods are prescribed for the determination of emissions from fuel combustion of stationary sources. The Statistic Office of SR inserts National energy balance every year, which is base for calculation of reference approach (RA) (top down). The reference approach determines the apparent consumption of individual types of fuels (primary, secondary and biomass) for which inventory is prepared. The sectoral approach (SA) (bottom up) is based on National Emission Inventory System (NEIS), the database of stationary sources, which collects the data of fuels consumption from the major sources of air pollution in the Slovak Republic. Reference and sectoral approach are estimated on fully independent data sets, whereby obtained differences are negligible. The difference between the top down and the bottom up energy balance estimates the uncertainty level. The Slovak Republic is using reference approach as a national total emission estimate of CO₂, while consistent data series since 1990 exist only for this approach. The carbon emission factors (t C/TJ) are estimated for individual fuels type based on international methodology (IPCC, OECD, IAEA) and national measurements (expert judgment). The revision will impact fuels base, NCV and emission factors in accordance with the new inputs from operators of the most important plants and national legislation requirements. The revision was started in previous year and will be developed in co-operation with the Profing Ltd. company.

For preparation of emission inventory in energy sector was used the IPCC Tier 1 and 2 methodologies.

Energy sector – category transport

The transportation sector is in the last years not negligible source of emissions of all GHGs and indirect pollutants too. The emissions from this sector have increasing tendency every year and are the key source in level and trend assessment for calculation of uncertainty management. The emissions from road transport were calculated by using COPERT III method. The emissions from international bunkers from aviation were improved in the last year and the expert's judgment was used in this estimation.

Energy sector – category fugitive emissions

The important source of methane emissions in national GHGs inventory are fugitive emissions from coal mining & handling and oil & natural gas distribution as a key sources categories in uncertainty estimation. The Slovak inventory team in co-operation with Profing, Ltd. provided the revision of emissions and emission factors for underground mining and handling during the previous inventory year 2004 due to inconsistent emission factors. These ones used until now were suitable mainly for hard coal underground mines. The important reason for this opinion is an occurrence of brown coal underground mines with mainly non-gaseous system. Emission factors according to the IEA – CIAB – the published values for mining were assigned according to the depth of the mines. The fugitive emissions from transport and distribution of NG were calculated using new emissions factor refined EF (CH₄) for tier 1, based on North America data - IPCC Good Practice Guidelines, Table 2–16. The fugitive emissions of methane were recalculated from transport and distribution of natural gas activities.

Industrial processes sector – category industry

The industrial sector is a source of CO₂, CH₄, N₂O, NO_x, CO, NM VOC, SO₂, CF₄, C₂F₆, and SF₆ pollution. Even though the emissions of CO₂ and N₂O are reported in this sector only, because of problematic estimation of this emissions and hard separation of industrial sources and fuel combustion sources from each other in industrial processes. The emissions of CO₂ occurring by manufacture of glass, ammonium production and iron & steel production are included in the sectoral approach for energy sector – manufacturing industries and in the reference approach in the balance of fossil fuel combustion. The situation is complicated by the confidentiality aspects of adopted legislation (which is like protecting the large installations against the publicity of activity data). The national EFs are available only for several industrial processes (cement and lime production, limestone and dolomite use and the magnesite production).

Industrial processes sector – category F-gases

An evaluation of sent and processed data on the sources and emissions of the substances in the Slovak Republic is realized on the base of recommended emission factors corrected according to the received data by the IPCC Methodology (IPCC, 1996).

Solvent and other product use sector

The emissions of NM VOC from this source category are estimated based on CORINAIR methodology since 1990 (CORINAIR, 2003). The N₂O emissions were estimated from 2001, according the internal statistics of distributors for medicinal and food purposes.

Agriculture sector

The sources of N₂O and CH₄ emissions from agriculture are analyzed according to IPCC Methodology (IPCC, 1996), when principles of Good Practice (IPCC, 2000) in GHGs inventory in agriculture (1999) were taking account. The basic sources of data used for evaluations of emissions in this study were published in (Statistical yearbook, 1990–2005, Green Report, 1998–2005).

LULUCF sector

According to the COP Decision 13/CP.9 for reporting in LULUCF sector was adopted new methodology and reporting tables. GHG emissions and sinks were recalculated for the time series 1990–2003 in the consistency with new requirements.

Results of calculations were obtained by using the IPCC Methodology (IPCC, 2003) and the national data on wood volume increments for individual forest tree species, and results of a roundwood harvest inventory.

Waste sector

Production of CH₄ and N₂O emissions from waste disposal and wastewater treatment activities is balanced. The IPCC methodology and Good Practice Guidelines were used to estimate of methane emissions from waste and wastewater treatment. Emissions of nitrous oxide from wastewater were calculated by using IPCC and ISI methodologies. Database of Centre of Waste Service and Environmental Management in Bratislava and database of Wastewater on the SHMU have been used as a source of input data GHG emissions from the waste sector are the key source and concerning to the actual EFs there are estimated with the high uncertainty level.

Emissions of methane from SWDS were estimated with the Tier 2 methodology (First Order Decay = FOD) according the advises of the ERT and European Commission. All time series were recalculated from 1960 and the complete methodology approach was changed.

1.5 Description of Key Sources

To reduce uncertainty in emission inventory is important to recognise the key source categories. It is necessary to know that a key source category is one that is prioritized within the National Inventory System because its estimate has a significant influence on a country's total inventory of greenhouse gases in terms of the absolute level of emissions, the trend in emissions, or both.

The key source categories by level assessment and trend assessment were chosen those, whose cumulative contribution is less than 95 % and are enclosed to this National Inventory Report 2006 followed the Good Practice Guidance (IPCC, 2000 and 2003). The Slovak Republic determined in year 2006 11 key source categories by level assessment with LULUCF and 17 key source categories without LULUCF (Table 1. 3). The SR determined in year 2006 11 key source categories by trend assessment with LULUCF) and 17 key source categories without LULUCF (Table 1. 3). The most important key source categories in the SR are fuel combustion, road transport and the emissions of N₂O from agricultural soil and methane emissions from SWDS etc. The identification includes all reported greenhouse gases CO₂, CH₄, N₂O, HFCs, PFCs and SF₆ and all IPCC source categories with or without LULUCF.

The presented key source analysis was performed by SHMI with data for greenhouse gas emissions of the submission 2008 to the EC (280/2004/EC) and comprises a level assessment for years 1990 and 2000–2006 and a trend assessment for the trend of the years 1990 (1995) to 2006.

The method used to identify key source categories follows the Tier 1 method – quantitative approach described in the IPCC Good Practice Guidance 2000 (Chapter 7 Methodological Choice and Recalculation). The identification of key source categories has following steps:

- Identifying source categories;
- Level Assessment;
- Trend Assessment.

Level of disaggregating and identification of key source categories was chosen according those source categories that have been estimated using the same methodology and the same emission factor. In this way the following categories and sub-sectors were chosen expressed in CO₂ equivalent emissions for the years 1990 (1995) to 2006.

Level Assessment

For the level assessment the contribution of GHG emissions (expressed in CO₂ equivalent emissions) of each relevant source category to national total emissions was calculated. The calculation was performed for the years 1990 or 1995 for to 2006 according to Equation 7.1 of the GPG 2000. Then the sources were ranked in descending order of magnitude according to the results of the level assessment and finally a cumulative total was calculated.

Trend Assessment

The trend assessment identifies source categories that have a different trend from the trend of the overall inventory. As differences in trends are more significant at the overall inventory level for larger source categories, the result of the trend difference is weighted according to the source's level assessment. For the trend assessment, emissions of the years 2006 were compared with base year emissions (1990 or 1995 for F-gases), resulting in eight calculations. The calculation was performed according to Equation 7.2 of the GPG 2000. The results were ranked in descending order of magnitude and a cumulative total was calculated. (Annex 2)

Key Source Analysis for Base Year 1990

The level key source analysis for base year was evaluated by Tier 1 methodology with and without LULUCF. The Slovak Republic determined in year 1990 9 key source categories by level assessment with LULUCF and 14 key sources without LULUCF.

1.6 QA/QC Procedure

The Slovak Hydrometeorological Institute is a company which has build and introduced the quality management system according the requirements of the EN ISO 9001:2000 standard of conformity for the following activities:

- Monitoring of the determinants characterising the state of air and waters on the Slovak territory;
- Assessment, archiving and interpretation of data and information on the state and regime of air and waters;
- Providing data and information on the state and regime air and waters;
- Study and description of the atmosphere and hydrosphere phenomena;
- Education and training within the activity of institute.

Sectoral experts apply the QA/QC methodology to our conditions, collect data from providers and process emission inventory for a given sector – they provide partial reports with information on quality and reliability of data on activities and emissions. These partial conclusions serve as a basis to estimate total uncertainties in emission inventories by a coordinator for uncertainties for all sectors. In some cases Tier 2 – Monte Carlo methodology (wastes, energy) which requires detailed review of quality of each input parameter, works out uncertainty analysis. Complete emission inventories of greenhouse gases are subject to critical review by independent experts from the Czech Republic.

There are a number of sub-processes and feedbacks in working out an inventory. Inventory in a given sector is divided to partial methodologies (e.g. „Reference approach“ and „Sectoral approach“ in the energy sector). It is further divided to processing by categories and gases (transport, F-gases).

Data are provided in particular by Statistical Office, National Emission Information System – NEIS, operated by SHMU and individual questionnaires of national experts through which some data are acquired directly from legal entities. Relatively large collection and validation of data on air pollution sources via bottom-up approach are carried out in the framework of the National Emission Information System (NEIS). Since 2000, this system has included a large database of data from approximately 10 thousand sources and on 120 pollutants. This system serves primarily to the needs of implementation of air protection legislation (Act 478/2002 on air protection, Act 401/1998 on charges for air pollution, Act 245/2003 on integrated pollution prevention and control, Decree of the MŽP SR 61/2004 laying down requirements for keeping operational records on stationary resources and others). NEIS is a source of data on activities serving to estimate greenhouse gas emissions in particular in the energy and industry sectors. However, it will be a difficult task for the future to work out functions of NEIS so that it can provide data for inventory and projections of greenhouse gases and so that the data provided by NEIS and the data provided within the CRF inventory to the UNFCCC or data used in NAP for greenhouse gas trading are consistent.

National expert responsible for inventory compilation collects partial reports, controls, and comments and publishes in the national report.

National expert fills in the database of a used programme module „CRF Reporter“ and provides these data to the UNFCCC and to the European Commission.

Extent and requirements for quality management system (QMS) have already been defined, practical application is expected in a short time after completing necessary steps in the area of organisational arrangements and data archiving system. At present a project was completed which was aimed at providing software to archive methodological procedures, database of input and output data in particular IPCC sectors, including the publishing of information in accordance with requirements of 20/CP.7 (obligation to establish and operate postal and electronic address and internet page of a national unit for emission inventories SNE). The emission estimates elaborated for individual sectors by external consultants are controlled and recalculated at the DoAQ on the SHMI. Activity data for major sources are compared with national statistics and with previous year's submitted data (e.g. change in fuel base, respectively fuel quality characters, technology, separation technique, etc.) A quality management system (QMS) has been designed to achieve the objectives of good practice guidance, namely to improve transparency, consistency, comparability, completeness and confidence in national inventories of emissions estimates.

Energy balance from energy statistics is compared with summary fuel consumption reported by sources. Fuel consumption in transport based on fuels sold is compared with the model results. External reviewers (from the Czech Republic) are regularly invited to comment the inventory results. Control procedures are continuously developed and built in to the National Inventory System. Structural changes of the current NIS, in accordance with the new air protection act (transposition of EU air pollution legislation), is ongoing process. Harmonisation of all pollutant inventories and ISO9001 are introducing. In accordance with these requirements the inventory results for the year N are completed to the 31 December (N+1) and the inventory results of the basic pollutants for the year N are completed to the 15 January (N+2) draft and 15 April (N+2) final version.

SNE still tries to improve quality of greenhouse gas emission inventory according to the IPCC Good Practise Guidelines 2000 and IPCC GPG in LULUCF 2005 in accordance with principles of consistency, transparency, comparability, accuracy and in the framework of QA/QC. A draft to improve quality of process of estimating emissions in particular sector is worked out each year. The waste sector – solid municipal waste landfills – was reassessed and recalculated in accordance with the methodology FOD, approach Tier 2. Default parameters have also been reassessed or replaced with national data. A plan for revision of emission factors for solid and liquid fuels in the energy sector has been prepared. The solvent sector was assessed since 1997 when information from individual operators became available. Time for the solvent sector is planned to be added in a near future.

Table 1.2: Results of key source analysis in trend and level assessment with LULUCF, year 2006

Source Category Analysis Summary (2006 GHGs Inventory)			
Quantitative Method Used: TIER 1 with LULUCF			
ENERGY SECTOR	GHG	Key Source	Criteria
1.A.1 Energy Industries	CO ₂	yes	Level, Trend
1.A.1 Energy Industries	CH ₄	no	
1.A.1 Energy Industries	N ₂ O	no	
1.A.2 Manufacturing Industries and Construction	CO ₂	yes	Level, Trend
1.A.2 Manufacturing Industries and Construction	CH ₄	no	
1.A.2 Manufacturing Industries and Construction	N ₂ O	no	
1.A.4 Other sector	CO ₂	yes	Level, Trend
1.A.4 Other sector	CH ₄	no	
1.A.4 Other sector	N ₂ O	no	
1.A.3.a Transport - Civil Aviation	CO ₂	no	
1.A.3.a Transport - Civil Aviation	N ₂ O	no	
1.A.3.b Transport - Road Transportation	CO ₂	yes	Level, Trend
1.A.3.b Transport - Road Transportation	CH ₄	no	
1.A.3.b Transport - Road Transportation	N ₂ O	no	
1.A.3.c Transport - Railways	CO ₂	no	
1.A.3.c Transport - Railways	CH ₄	no	
1.A.3.c Transport - Railways	N ₂ O	no	
1.A.3.d Transport - Navigation	CO ₂	no	
1.A.3.d Transport - Navigation	CH ₄	no	
1.A.3.d Transport - Navigation	N ₂ O	no	
1.A.5.a Other non-specified	CO ₂	yes	Level, Trend
1.A.5.a Other non-specified	CH ₄	no	
1.A.5.a Other non-specified	N ₂ O	no	
1.B.1.a Coal Mining and Handling	CH ₄	yes	Trend
1.B.1.b Fugitive Emission from Oil, Natural Gas and Other	CH ₄	yes	Trend
INDUSTRIAL SECTOR	GHG	Key Source	Criteria
2(I).A.1 Cement Production	CO ₂	yes	Level, Trend
2(I).A.2 Lime Production	CO ₂	yes	Level, Trend
2(I).A.3 Limestone and Dolomite Use	CO ₂	no	
2(I).A.7 Magnesite Use	CO ₂	no	
2(I).B.2 Nitric Acid Production	N ₂ O	yes	Level, Trend
2(I).C.1 Iron and Steel Production	CO ₂	no	
2(I).C.3 Aluminium Production	CO ₂	no	
2(I).C.3 Aluminium Production	PFCs	no	
2(I).F HFCs emissions	HFCs	no	
2(I).F SF ₆ emissions	SF ₆	no	
SOLVENT SECTOR	GHG	Key Source	Criteria
3.D Other Solvent Use	N ₂ O	no	
AGRICULTURE SECTOR	GHG	Key Source	Criteria
4.A Enteric Fermentation	CH ₄	yes	Level, Trend
4.B Manure Management	CH ₄	no	
4.B Manure Management	N ₂ O	no	
4.D Agricultural Soils	N ₂ O	yes	Level, Trend
LULUCF SECTOR	GHG	Key Source	Criteria
5.A Forest Land	CO ₂	no	
5.A Forest Land	CH ₄	no	
5.A Forest Land	N ₂ O	no	
5.B Cropland	CO ₂	no	
5.C Grassland	CO ₂	no	
5.F Other Land	CO ₂	no	
WASTE SECTOR	GHG	Key Source	Criteria
6.A Solid Waste Disposal on Land	CH ₄	yes	Level, Trend
6.B Wastewater Handling	CH ₄	no	
6.B Wastewater Handling	N ₂ O	no	

Table 1. 3: Results of key source analysis in trend and level assessment without LULUCF, year 2006

Source Category Analysis Summary (2006 GHGs Inventory)			
Quantitative Method Used: TIER 1 without LULUCF			
ENERGY SECTOR	GHG	Key Source	Criteria
1.A.1 Energy Industries	CO ₂	yes	Level, Trend
1.A.1 Energy Industries	CH ₄	no	
1.A.1 Energy Industries	N ₂ O	no	
1.A.2 Manufacturing Industries and Construction	CO ₂	yes	Level, Trend
1.A.2 Manufacturing Industries and Construction	CH ₄	no	
1.A.2 Manufacturing Industries and Construction	N ₂ O	no	
1.A.4 Other sector	CO ₂	yes	Level, Trend
1.A.4 Other sector	CH ₄	no	
1.A.4 Other sector	N ₂ O	no	
1.A.3.a Transport - Civil Aviation	CO ₂	no	
1.A.3.a Transport - Civil Aviation	N ₂ O	no	
1.A.3.b Transport - Road Transportation	CO ₂	yes	Level, Trend
1.A.3.b Transport - Road Transportation	CH ₄	no	
1.A.3.b Transport - Road Transportation	N ₂ O	no	
1.A.3.c Transport - Railways	CO ₂	no	
1.A.3.c Transport - Railways	CH ₄	no	
1.A.3.c Transport - Railways	N ₂ O	no	
1.A.3.d Transport - Navigation	CO ₂	no	
1.A.3.d Transport - Navigation	CH ₄	no	
1.A.3.d Transport - Navigation	N ₂ O	no	
1.A.5.a Other non-specified	CO ₂	yes	Level, Trend
1.A.5.a Other non-specified	CH ₄	no	
1.A.5.a Other non-specified	N ₂ O	no	
1.B.1.a Coal Mining and Handling	CH ₄	yes	Level, Trend
1.B.1.b Fugitive Emission from Oil, Natural Gas and Other	CH ₄	yes	Level, Trend
INDUSTRIAL SECTOR	GHG	Key Source	Criteria
2(I).A.1 Cement Production	CO ₂	yes	Level, Trend
2(I).A.2 Lime Production	CO ₂	yes	Level, Trend
2(I).A.3 Limestone and Dolomite Use	CO ₂	yes	Level, Trend
2(I).A.7 Magnesite Use	CO ₂	yes	Level, Trend
2(I).B.2 Nitric Acid Production	N ₂ O	yes	Level, Trend
2(I).C.1 Iron and Steel Production	CO ₂	yes	Level, Trend
2(I).C.3 Aluminium Production	CO ₂	yes	Level, Trend
2(I).C.3 Aluminium Production	PFCs	no	
2(I).F HFCs emissions	HFCs	no	
2(I).F SF ₆ emissions	SF ₆	no	
SOLVENT SECTOR	GHG	Key Source	Criteria
3.D Other Solvent Use	N ₂ O	no	
AGRICULTURE SECTOR	GHG	Key Source	Criteria
4.A Enteric Fermentation	CH ₄	yes	Level, Trend
4.B Manure Management	CH ₄	no	
4.B Manure Management	N ₂ O	no	
4.D Agricultural Soils	N ₂ O	yes	Level, Trend
WASTE SECTOR	GHG	Key Source	Criteria
6.A Solid Waste Disposal on Land	CH ₄	yes	Level, Trend
6.B Wastewater Handling	CH ₄	yes	Level, Trend
6.B Wastewater Handling	N ₂ O	no	

1.7 General Uncertainty Evaluation

The uncertainty of estimation of CO₂ emissions is mainly caused by uncertainty of statistical data on consumption. Another source of uncertainty is the applied default emission factors. An additional error in calculation of the other greenhouse gas emissions may occur because of less exact methods and it cannot be estimated. Quantification of emission's uncertainty by level and trend assessment was calculated by using Tier 1 method published in Good Practice Guidance (IPCC, 2000). Even though the Tier 1 uncertainty analysis were estimated the uncertainties to be 12.7 % by level assessment and 7.8 % by trend assessment (Annex 2).

The calculation uncertainty by using the more sophisticated Tier 2 - Monte Carlo method is evaluated second year by cooperation with the external expert from Faculty of Mathematics, Physics & Informatics Mr. Martin Gera.

According to the most recent results, the research article "Emission Estimation of the Solid Waste Disposal Sites According to the Uncertainty Analysis Methodology" was published⁹ in the official journal. The main topic of this article was to eliminate uncertainty of methane emissions produced by solid waste disposal sites. From our analyses seems that uncertainty of emissions are strongly dependent to the PDF's setting. These features were identified by simplest linear analyses of uncertainty of total emissions and in the second case with changing PDF's setting. The data accuracy play important role to the total uncertainty. PDFs selection in the case of symmetry uncertainty has no significant influence to the total uncertainty. Increasing of partial uncertainties for input factors multiple total uncertainties in the symmetrical cases. In the case of asymmetry, total uncertainty could be smaller than uncertainties of single input parameters. This approach shows that more important feature which has strongest influence to the total uncertainty is asymmetry allowance. The essential result from our study is fact that total uncertainty was reduced comparable to IPCC default recommended value. This value is 50 % for total methane emissions from SWDS. This default uncertainty is applicable to the Tier 1 default method. From this value in the Tier 1, the key sources are identified by categories magnitude, which adds up to over 95% of the total emissions or emission trend. In Tier 2 the 90 % of the level or trend uncertainties are also taken for the key sources specification. Specification and identification of the key sources are important for economy and government institutions to obtain overview of emissions unload. During the uncertainty computation the emitting of CH₄ from underlayer and many other factor as meteorological condition, managing of sites are included. These dependences are expressed in FOD model, which was solved by Monte Carlo simulation. Spreading of emission uncertainty during the analyzed period was obtained. From the computed result precision increasing of emissions are observed. In spite of high inaccuracy on the input data in the beginning of the examined period (this uncertainty has influence to the current uncertainty) the relative valuable result are obtained (Figure 1. 4).

The Monte Carlo method is based on the generation of multiple trials to determine the expected value of a random value. In case of the SR this method is uncertainties combination of probability distribution functions for activity data (AD) and emission factors (EFs). Total emissions are computed as combination of random numbers for appropriate distribution function for assigned greenhouses gases. The advantage of this method is asymmetry allowance to the statistical distribution. This is useful for data manipulation, in the case, when proper input data quality is provided. For this reasons the software package, which works with probabilistic distribution and their combination, was developed. With help of AuvTool software, they create useful tools for uncertainties estimation. In developed packages the next statistical distributions are supported.¹⁰

For specification of probability distribution of AD and EF there are variety of inputs. For two parameters distributions the mean value and values represented 95 % confidence interval are directly expressed. There are few ways how insert these values, one can do it with direct values, or with

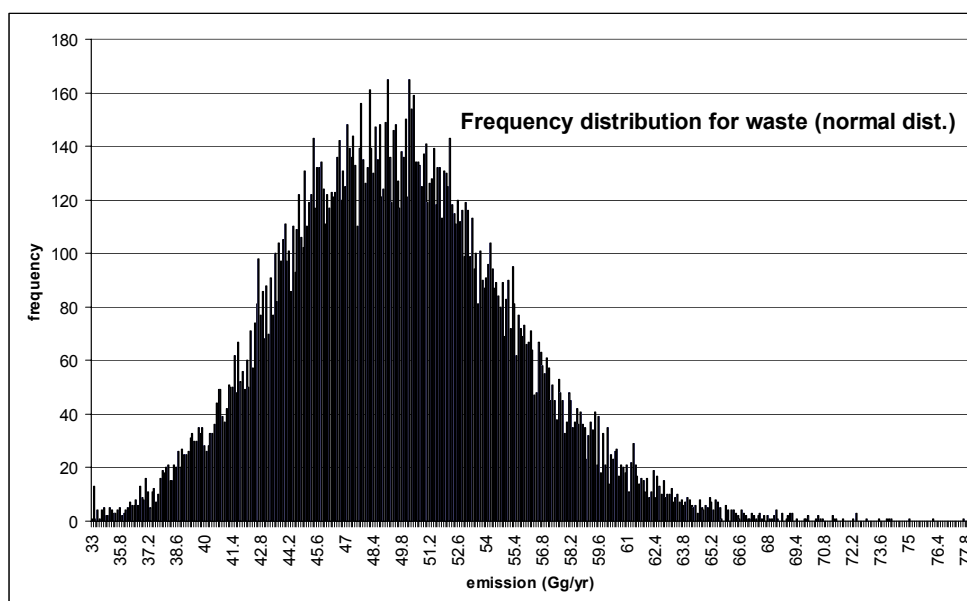
⁹ J. Szemesova, M. Gera: *Contributions to Geophysics & Geodesy*, 37/3, 2007

¹⁰ Gumbel, Exponential, Weibull, Lognormal, Uniform, Triangular, Beta, Binomial, Neg_binomial, Chisq, Nc_chisq, F, Nc_F, Gamma, T, Nc_T, Normal and Poisson.

relative, eventually with percent values. For three parameters distribution there is place for tuning 95 % confidence interval (to be close with expert opinion).

From mathematical or better say from statistical point of view, there are no difficulties with formulas computation. After sector expert consultation, how one can expect, the most difficult parts is model initialization (input data for developed software). Chosen of the appropriate distribution function triggers for AD and EF some difficulties, mainly in the case of the absence of the direct measured data. These procedures consume a majority of exerted effort.

Figure 1. 4: Total emission of CH₄ for the year 2005 for normal parameters distribution with 10 % uncertainties for all parameters



1.8 General Assessment of the Completeness

The Slovak Republic is reported in its CRF 2006 submission 2008 gases or source/sink categories as not estimated (NE) and categories, whose are reported as included elsewhere (IE) are explained in Tables 9(a) CRF. The additional GHG emissions are not reported. In some categories (waste incineration, off-road transport, wastewater or solvent use sector) are not consistent the data from the base year caused by lack of input data and resources, but the SHMI in cooperation with MoE is doing number of steps for improving the actual status in inventory completeness. The description of the actual situation in completeness is provided in CRF Table 9. All sources and sinks included in the IPCC Guidelines are covered in the inventory year 2005. No additional sources and sinks have been identified. Both direct GHGs as well as precursor gases are covered by the SR inventory. The geographic coverage is complete; all territory of the Slovak Republic is covered by the inventory. The sources and sinks not considered in the inventory but included in the IPCC Guidelines are clearly indicated, the reasons for such exclusion are explained. In addition, the notation keys presented below are used to fill in the blanks in all the tables in the CRF. Notation keys used in the NIR are consistent with those reported in the CRF. Notation keys are used according to the UNFCCC guidelines on reporting and review (FCCC/CP/2002/8).

Sector energy – sectoral approach for the sub-categories for the period 1991–1999, the key notes (IE) for non-GHGs gases (SO₂, NO_x and CO) indicate that the emissions are included in the main categories.

Solvent use – emissions of CO₂ were not estimated (NE), lack of appropriate methodology. The expert estimation will be performed for the next submission.

2 TRENDS IN GREENHOUSE GAS EMISSIONS

2.1 Emission Trends for Aggregated GHG Emissions

The major indicator of emissions trend in the last years is the comparison of GDP and per capita emissions. Main reasons for decoupling of GHG emissions from GDP growth in the last period are:

- higher share of gas fuels in the total primary energy consumption,
- ongoing privatization and restructuring of industries,
- slightly increasing share of services on the total GDP,
- regulation and implementation of energy saving measures in the heavy energy demanding sectors,
- positive indirect impact of air protection regulatory measures (fuel switching towards less carbon intensive fuels).

While indicator of carbon intensity can be changed much more rapidly in situation of high dynamic of economic growth, GHG per capita is different case where you can get very impressive results even without measures, just by higher population growth rate - and this is not the case of the Slovak Republic just now. It will take much longer time to change numerator by impact of new technologies implementation namely in combination with high dynamic of development in the energy intensive industries. Development of GHG/cap indicators in period 1990–2006 is given in Table 2. 1.

Table 2. 1: The Indicators of per capita trend 1990–2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Populations	5,298	5,283	5,307	5,325	5,347	5,364	5,374	5,383	5,391	5,395	5,401	5,380	5,379	5,379	5,383	5,387	5,394
Total GHGs	73,679	65,906	61,186	55,826	53,884	52,791	51,239	50,163	50,567	49,646	48,500	50,203	49,112	50,205	49,999	49,333	48,902
Per capita	13.91	12.47	11.53	10.48	10.08	9.84	9.53	9.32	9.38	9.20	8.98	9.33	9.13	9.33	9.29	9.16	9.07

In accordance with the generally expected results, the aggregated emission of GHGs in year 2006 moderate decreased comparable to the previous inventory year 2005 about more than 370 Gg excluding LULUCF, it means approximately 1 %. With the including the sector LULUCF the net aggregated emissions in 2006 inventory year decreased comparable to previous year 2005 about 2 600 Gg it means more than 5 %. The reason is in increasing the sinks in LULUCF sector, as has been expected in the projections last year. After period of decreasing according the natural catastrophe in the large part of forest in the end of 2004 in High Tatra Mountains, the forest was destroyed, the new reconstruction of forest took place.

There is the significant decreasing of aggregated emission against the base year (1990) about approximately 25 000 Gg it means the decreasing about more than 33.6 % without LULUCF and more than 35 % with LULUCF sector.

The total national emission in the current inventory year 2006 was estimated to be 48 902.42 Gg of CO₂ eq. without LULUCF sector and the net GHG emission was 45 873.70 Gg including the sinks from LULUCF. The Slovak Republic reported the national emission from energy sector based on sectoral approach data in 2006 to be 37 187.34 Gg CO₂ equivalent including the transport emissions (6 001.74 Gg of CO₂ eq.), which represent decrease compare the base year by about 38 % and also decrease in the transport sub-sector against previous year 2005.

The total emissions from industrial processes sector in 2006 were estimated to be 5 945.69 Gg of CO₂ eq. This is increase compare the base year by about 13 %, but also increase compare to previous year about more than 5 %. The numbers were changed because the recalculation of all time series in the nitric acid production. Intensive growing of the industry production causes the increasing of emissions.

The total emissions from sector of solvent use were estimated to be 82.43 Gg of CO₂ eq. this is decreasing comparable to previous year about 5 %. The time series is now complete, the period 1990–1993 (before the SR formation) is not sufficiently covered by statistical data (lack of the national statistics data) and the constant expert judgment values for this period was used. The comparison with the base year is now possible, the increasing in more than 380 %.

The emissions from agriculture sector were estimated to be 3 162.32 Gg of CO₂ eq. It is decrease compare the base year by about 55 % and minor decrease comparable to the previous year. The agriculture sector is the most decreasing sector comparable to the base year 1990.

The total emissions and sinks from LULUCF sector were estimated to be –3 028.72 Gg of CO₂ eq., the whole time series 1990–2006 were recalculated according the new methodology¹¹ and those emissions and sinks were included into the submission. The estimation of emissions and sinks in the LULUCF sector are complicated to explain with the consistent time series.

The emissions from waste sector were estimated to be 2 527.90 Gg of CO₂ eq. The decrease comparable to the previous inventory year is minor, but comparable to the base year no decrease was registered, because of including the waste incineration from base year and other waste treatment activities. The methodology changes and the complete time series reconstruction was caused the increasing the waste sector emissions by 60 %, but this is expected trend.

A major share of aggregated emission covers the energy sector by about 76 %, the industrial processes sector covers about 12.2 %, the solvent use sector about 0.2 %, the agriculture sector about 7.6 % and the waste sector about 5.2 % (Figure 2. 1). The major share of aggregated emission covers CO₂ emissions by about 81.8 %, CH₄ emissions by about 9.5 %, N₂O emissions by about 8.3 % and F-gases emissions by about 0.4 % (Figure 2. 2).

Figure 2. 1:

The aggregated GHG emissions by sectors in 2006

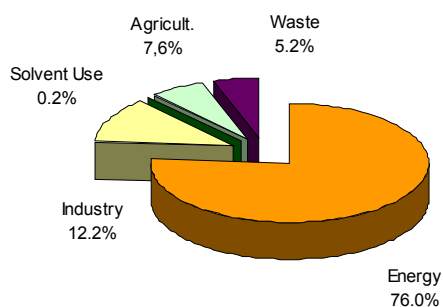
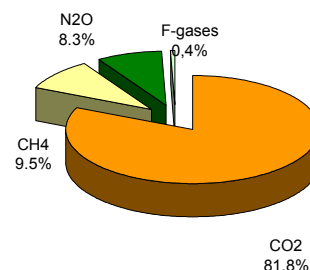


Figure 2. 2:

The aggregated GHG emissions by gases in 2006



2.2 Emission Trend by Gas

The total anthropogenic emissions of carbon dioxide decreased relating to the base year (1990) by about 35 % without LULUCF and represented in current year 39 984.02 Gg of CO₂ without LULUCF sector. Comparable to the previous inventory year, the decreasing is about 800 Gg of CO₂.

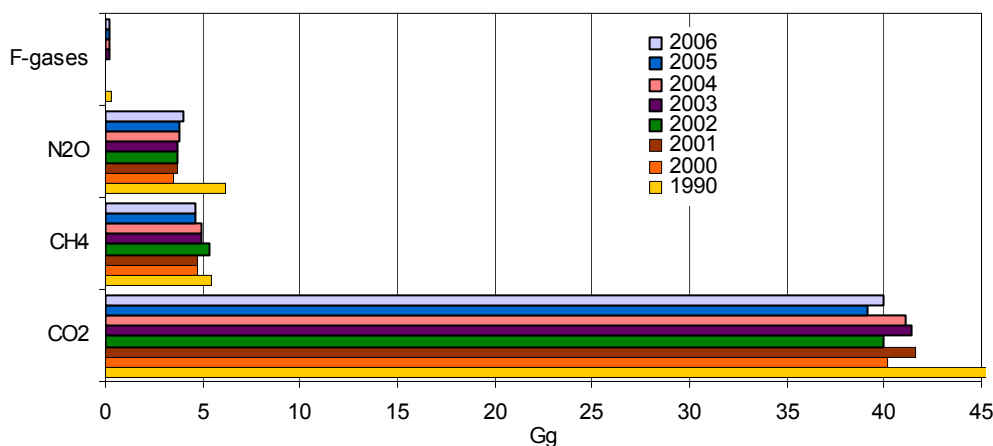
The total anthropogenic emissions of methane reached in the 2006 almost 4 627.49 Gg of CO₂ equivalent without LULUCF and the trend is relative stable during the last years.

¹¹ IPCC 2003 Good Practice Guidelines for LULUCF

The total emissions of N₂O increased relating the previous year to 4 039.04 Gg of CO₂ equivalent without LULUCF and decreased relating the base year about 35 %. The trend is slightly increasing during last years.

The total emissions of F-gases represented 255.14 Gg and are increased comparable with the previous year's inventory by about 60 Gg, but beside the base year (1990) shows a more than 34 % decreasing, caused by decreasing a consumption of perfluorocarbons (Figure 2. 3).

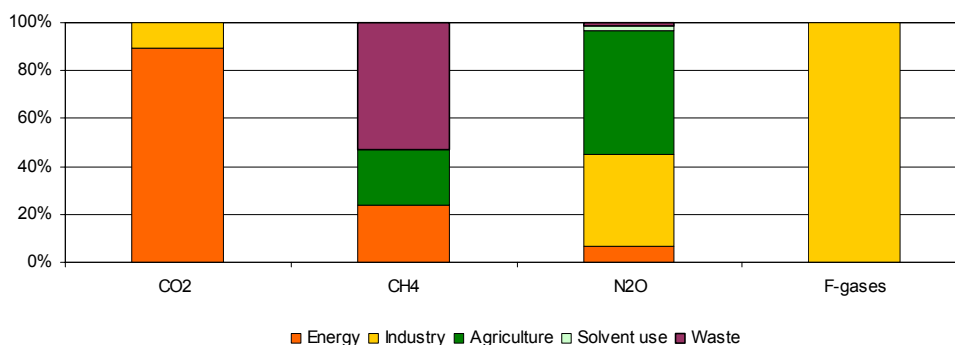
Figure 2. 3: The emission trends by gas for the recalculated years 1990, 2000–2006



2.3 Emission Trend by Source

The major share of CO₂ emissions is from energy sector (fuel combustion, transport) with more than 90 % from the total carbon dioxide emissions in last 2006 inventory. More than 42 % of CH₄ emissions produces waste sector (SWDS), more than 21 % of N₂O emissions produces agriculture sector (fermentation) and 100 % F-gases emissions come from industrial processes sector as depicted on Figure 2. 4.

Figure 2. 4: The emission trends by source in 2006



2.4 Emission Trends for Indirect GHGs and SO₂

The total anthropogenic emission of NO_x was estimated to 96.56 Gg and the major share was produced by energy sector. The total emission of CO was estimated to 289.81 Gg and the major share of emissions was produced by energy sector. The emission of NM VOC was estimated to 78.40 Gg

per year 2006 and the major share was produced by energy sector, industrial processes sector and solvent-use sector. The emissions of SO₂ were estimated to 87.85 Gg per year 2006 and the major share of emissions was produced by energy sector. Emissions of all indirect GHG and SO₂ have decreasing character since 1990 because the air quality management programs.

Although air quality management programs are focused on limitation of basic pollutants, they contribute to decrease GHG emissions in relatively high share. There are actually 18 air quality management areas in 2 agglomerations and 8 specially followed zones due to air quality in the Slovak Republic at present. Exceeding of daily limit value for sulphur dioxide has occurred in the district of Prievidza, exceeding of limit values for nitrogen oxide has occurred in Bratislava – capital of the SR. Both areas belong to the air quality management areas. For all these areas have been developed programs on air quality management with clearly specified measures for individual sources to improve local air quality. All programs are published at the internet web page of the Ministry of the Environment (www.enviro.gov.sk). In addition, an action plans containing short time measures.

Programs and plans were developed according to the Act No. 478/2002 on Air Protection as amended and Decree of the Ministry of Environment of the Slovak Republic No. 705/2002 on air quality. EU directives 1999/96/ES 2002/3/ES, 1999/30/ES and 2000/69/ES were transposed by this act and decree.

3 ENERGY SECTOR

3.1 Fuel Combustion Activities

3.1.1 Energy Industry

Fossil fuels combustion in the energy and industry sectors is the most important source of emissions in SR - up to 75–80 %. It is especially public energy providing for power and heat supplying, industrial energy - energy production for technological processes and last but not least district heating - heat supply for block of flats and dwelling houses, public equipment and services, objects of non-productive sphere.

Methodology and Activity Data

Two IPCC methods are prescribed for the determination of emissions from fuel combustion of stationary sources. The Statistic Office of the SR inserts National energy balance every year, which is base for calculation of reference approach (RA) (top down). Profing Ltd. Bratislava (the company for energetic research) executed the preparation of preliminary energy balance based on published materials from Statistic Office. Profing Ltd. Bratislava namely director Dr. Jan Judak is the sectoral expert for energy and the external consultant for energetic questions in the Slovak national inventory system. He is responsible for preparation of reference approach balance, the fugitives emissions balance from mines, oil and gas industry. The reference approach determines the apparent consumption of individual types of fuels (primary, secondary and biomass) for which inventory is prepared. This information is available in energy (TJ) and mass (Gg) units

Sectoral approach

The following sub-sectors of the IPCC categories according 1996 Guidelines are relevant for the Slovak Republic in sectoral approach methodology:

1.A.1	Energy industry
1.A.1.a	Public Electricity and Heat Production
1.A.1.b	Petroleum Refining
1.A.1.c	Manufacture of Solid Fuels and Other Energy Industries
1.A.2	Manufacturing Industries and Construction
1.A.2.a	Iron and Steel
1.A.2.b	Non-Ferrous Metals
1.A.2.c	Chemicals
1.A.2.d	Pulp, Paper and Print
1.A.2.e	Food Processing, Beverages and Tobacco
1.A.2.f	Other
1.A.4	Other Sectors
1.A.4.a	Commercial/Institutional
1.A.4.b	Residential
1.A.4.c	Agriculture/Forestry/Fisheries
1.A.5	Other
1.A.5.a	Stationary

The sectoral approach (SA) (bottom up) is based on National Emission Information System (NEIS), the database of stationary sources, which collects the data of fuels consumption from the major sources of air pollution in the Slovak Republic. These data are available in consistent series only from year 2000, when the system NEIS was put in operation and replaced the old system EAPSI (Emission and Air Pollution Source Inventory). These two systems are comparable only on national level. Comparison of the individual parts of EAPSI (EAPSI 1 and EAPSI 2) with the NEIS module (large, medium-size sources), respectively comparison of individual sources in both systems is difficult. According to the Act 134/1992 as amended, the district offices are obliged to elaborate yearly reports about operational characteristics of air pollution sources in their district and provide them electronically (in the NEIS BU format) for the next processing to an SHMI. The SHMI is an

organization accredited by the Ministry of Environment with managing of central database NEIS CU and providing the processes of data on the national level (Bulletin MoE No 6/2000). The first collection and processing of data in module NEIS was realized in 2001 on SHMI, Department of Air Quality. New system contained 843 large point sources from 79 the NEIS BU district databases in 2005. As the sources of 5 MW and above were included to the evidence of large point sources in the EAPSI system, the comparison of numbers of sources in both systems is difficult. In year 2005 system NEIS registered 12 082 medium sources of the heating output of 0.2–5 MW. The emission balances in 2000–2005 were processed in the NEIS CU module by the same calculation as done up to 1997. The input data (fuel amounts, according to the types, sold for households and retail consumers, and quality marks) necessary for the emission balance were collected from Regional Offices in NEIS BU module (Figure 3. 1). The sources below 0.2 MW are qualified as small sources and emissions balance proceed in NEIS CU module is based on the statistical data about sale of solid fuels for households and small consumers according the Directive MoE SR No. 53/2004. The statistic is completed by the consumption of natural gas for inhabitants (from evidence of the Slovak Gas Industry Ltd. www.spp.sk) and correspondent emission factors.

In the context of special revision of the qualitative characterisation of solid fuels (in accordance with the valid legislation and technical standard 2008 of MoE), the emission of wood were included in the inventory first time and the time series from 1990 was estimated. The major changes were occurred in the context of the revision the codebook of fuels in accordance with the actual legislation (706/2002 MoE SR, 129/2002 MoE SR about the Catalogue of Waste and Directive 200/76/EC about Waste Incineration). (www.spirit.sk, www.air.sk)

Activity data included in each category were collected from the NEIS, according the national methodology, the production type of the operators and the complete analysis of the production activities in the included installations. The activity data for the actual year are providing in the mass unit (thousand of m³ or tones) with the corresponding calorific values (GJ/thous.m³ or GJ/t). The characterizations of the fuel provide operators through the NEIS. Operators are under the state control and guarantee the quality assurance and control of the data. The calorific values of the fuel's type are announced annually by Statistical Office. If the operator uses the plant specific calorific values, have obligation to prove the measurements to the NEIS database.

A consumption of biomass is not included in the total CO₂ emission balance, but is provided.

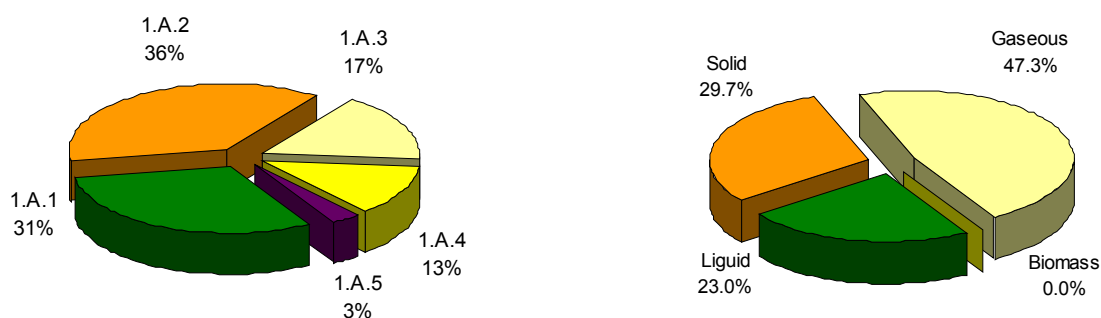
According the quantity and calorific values the sectoral expert completes the calculation of the quantity the fuel's type in the energy unit (TJ). For each fuel's type the default or national emission factor is used and the correspondent emissions of CO₂, CH₄ and N₂O are calculated. The emission factors for the non-CO₂ are default (IPCC), most of the CO₂ emission factors are default, but the Emission Trading Scheme will improve the proportion between national and default EFs to the using of the national EFs, mostly plant specific. The example is described for natural gas.

The energy balance "bottom up" using the IPCC (IPCC, 1996) detail method Tier 2 and national or IPCC default emission factors for each fuel category and each IPCC category.

Recalculation of the methodology in category of fuels in sectoral approach

The following revision and recalculation of sectoral approach between 2000 and 2006 was necessary. The changes are based on the different distribution of fuels inside of IPCC categories and excluding or including the fuels consider as waste into the category 6.C – waste incineration. The fuels from the category other fuel were reallocated to the corresponding categories according the official statistical data. The category other fuel consist from the data about waste incineration with the energy use. This type of combustion was evaluated for this submission for the first time in the accordance with the revision of the waste sector.

Figure 3. 1: A distribution of emissions CO₂ eq. in type of fuels in SA in 2006 IPCC 1.A sub-sector and according the fuel types



The recalculated emission trend for CO₂ and N₂O emissions from waste incineration with energy use was reported in the category 1.A.1a – Energy Industries (other fuel). The real data based on statistical information are known from 1993, after separation of the Slovak Republic. The values from 1990–1992 were estimated according expert judgment from sectoral expert for waste sector, Mr. Juraj Farkas. The emissions of methane are not relevant for this type of incineration Table 3. 1.

Table 3. 1: The trend of recalculated emissions from waste incineration with energy use

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CO ₂ (Gg)	30.000	43.000	43.000	47.901	41.686	39.097	38.320	41.583	47.642	45.052	53.856	33.919	40.392	41.945	47.642	47.383	49.130
N ₂ O (Gg)	0.0030	0.0046	0.0046	0.0046	0.0035	0.0031	0.0031	0.0033	0.0039	0.0036	0.0043	0.0027	0.0032	0.0033	0.0032	0.0023	0.0024

Reference approach

Upper level of emissions and sinks of CO₂ from fuel use is determined by using of summary inventory data of the Slovak Republic in form of so-called reference approach table 1.A(b) (this table provides for data of fuel consumption by type of fuel, their low heating values, emission factors and share of oxidation). This method is called also the top down or the upstream method and is characterized with minimum requirements on input data. The reference approach provides only aggregate estimates of emissions by fuel type distinguishing between primary and secondary fuels. The aggregate nature of the reference approach estimates means that stationary combustion emissions cannot be distinguished from mobile combustion emissions. The method is applied also as the quickest control and confirmation method. It is necessary to state, that this method doesn't involve so called fugitive emissions, i.e. uncontrolled emissions from mining and post-mining treatment, from transport and other use of fuels.

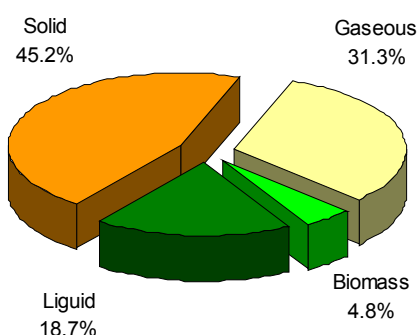
The reference approach estimates of direct CO₂ emissions from following groups of the fuels combusted in whole energy sector:

- Liquid fuels
 - Primary Fuels* - Crude Oil, Orimulsion Natural, Gas Liquids;
 - Secondary Fuels* – Gasoline, Jet Kerosene, Other Kerosene, Shale Oil, Gas/Diesel Oil, Residual Fuel Oil, LPG, Ethane, Naphtha, Bitumen, Lubricants, Petroleum Coke, Refinery Feedstocks, Other Oil;
- Solid fuels
 - Primary Fuels* – Anthracite, Coking Coal, Other Bit. Coal, Sub-bit. Coal, Lignite, Oil Shale Peat;
 - Secondary Fuels* - BKB & Patent Fuel, Coke Oven/Gas Coke;
- Gaseous fuels
 - Primary Fuels* – Natural Gas;
- Fuels used as feed stocks type – Naphtha, Lubricants, Bitumen, Coal Oils and Tars (from Coking Coal), Natural Gas, Gas/Diesel Oil, LPG, Butane, Ethane, Plastics;
- Information Entries - Solid Biomass, Liquid Biomass, Gas Biomass.

The main of fuel categories (liquid, solid and gaseous) contained all types of fuels used. In the different fuel's type can be included more than one fuel. This methodology is based on the national statistic methodology and international standard, independent from the emission inventory, but followed the IPCC 1996 Guidelines and IPCC 2000 GPG.

Using the IPCC methodology (IPCC, 1996), the quantity of residual carbon from combustion which stayed in products (carbon fixed in tar and tar's oils occurring by carbonisation and in petrochemical oil products such as polyethylene, polypropylene, asphalts and lubricants etc., carbon bound in fertilisers) was estimated. The total amount of carbon stored in products in 2006 was determined to 1 010 Gg of carbon. The method of determination is based on plant specific information and expert's judgment (Profing Ltd.) and the balanced items are less significant from the viewpoint of total (Figure 3. 2).

Figure 3. 2: A distribution of CO₂ emissions in type of fuels in RA in 2006



Emission Factors in SA

The carbon emission factors (t C/TJ) are estimated for individual fuels type based on international methodology (IPCC, OECD, IAEA) and national measurements (expert judgment, Profing Ltd., sectoral expert). The national emission factors for CO₂ are in use for this time, for natural gas from year 2000, for coal from 2000, for brown coal according the source (Slovak, Ukraine, Czech Republic) from 2000, for coke from 2000 and for coke gas from 2000. The revised emission factors are depending on net calorific values and slightly vary from year to year and across IPCC categories. The emission factors for natural gas and other most important fuels are based on precious measurements and calculation published every month by Slovak Gas Industry Ltd, Slovak Energy Industry Ltd. and U.S. Steel company for iron and steel production. These EFs are in use for installations joined in the Emission Trading Scheme and for the requirements of the Ministry of Environment of SR (Table 3. 2).

The conversion factors (TJ/Unit) are calculated every year from statistical data and little various annually. The variations depend on fuels characteristics, which are published by Statistic yearbook annually. The carbon emission factors (t C/TJ) are estimated for individual fuels type based on international methodology (IPCC, OECD, IAEA) and national measurements (expert judgment, Profing, 2003).

Carbon emission factors are estimated from known fuel composition and accessible average low heating values of the most applied fuels. Carbon emission factors may vary considerably both among and within primary fuel types.

Table 3. 2: The previous and the revised EFs for important fuels

SUBMISSION	EF	FUEL	VALUE	UNIT	VALUE	UNIT	CATEGORY
2007	CO2	Coal	91.92	tCO2/TJ	25.0691	tC/TJ	all
2008	CO2	Coal	97.16-94.48	tCO2/TJ	25.7429	tC/TJ	vary
2007	CO2	Coke	104.64	tCO2/TJ	28.54	tC/TJ	all
2008	CO2	Coke	110.22	tCO2/TJ	30.08	tC/TJ	all
2007	CO2	Brown coal	94.15	tCO2/TJ	25.68	tC/TJ	all
2008	CO2	Brown coal	97.05-104.65	tCO2/TJ	28.56	tC/TJ	vary
2007	CO2	Natural gas	55.18	tCO2/TJ	15.05	tC/TJ	all
2008	CO2	Natural gas	55.25	tCO2/TJ	15.08	tC/TJ	all
2007	CO2	Coke gas	47.36	tCO2/TJ	12.92	tC/TJ	all
2008	CO2	Coke gas	42.31	tCO2/TJ	11.55	tC/TJ	all

For natural gas, the carbon emission factor depends on the composition of the gas, which in its delivered state, is primarily methane, but can include small quantities of ethane, propane, butane, and heavier hydrocarbons. Natural gas flared at the production site will usually be "wet", i.e., containing far larger amounts of non-methane hydrocarbons. The carbon emission factor will be correspondingly different. The emission factors for natural gas (Russian) in the Slovak Republic are based on precisely measurements and calculation published every month by the Slovak Gas Industry since 1 January 2000. These EFs are in use for installations covered by the European Trading Scheme (ETS) and for the requirements of the Ministry of Environment of SR in the present and are published on the website <http://www.spp.sk/Archiv/Slovak/zlozenie%20plynu2006SK.pdf>. These EFs are in use for installations joined in the ETS and for the requirements of the Ministry of Environment (Table 3. 3).

Table 3. 3: EF CO₂ and NCV for NG [15°C; 101,325 kPa]

Year 2006	Natural gas [mol %]	NCV	EF [CO ₂]									
Month	CH ₄	C ₂ H ₆	C ₃ H ₈	i-C ₄ H ₁₀	n-C ₄ H ₁₀	i-C ₅ H ₁₂	n-C ₅ H ₁₂	C ₆ H ₁₄	CO ₂	N ₂	MJ/m ³	tCO ₂ /TJ
I.	97.19	1.20	0.38	0.05	0.07	0.01	0.01	0.01	0.21	0.87	34.30	55.25
II.	97.43	1.07	0.34	0.05	0.06	0.01	0.01	0.01	0.17	0.85	34.26	55.20
III.	97.65	0.96	0.31	0.05	0.05	0.01	0.01	0.01	0.13	0.83	34.22	55.15
IV.	97.78	0.89	0.29	0.05	0.05	0.01	0.01	0.01	0.10	0.81	34.21	55.12
V.	97.86	0.84	0.29	0.05	0.05	0.01	0.01	0.01	0.07	0.81	34.20	55.11
VI.	97.29	1.17	0.36	0.05	0.06	0.01	0.01	0.01	0.17	0.87	34.30	55.21
VII.	97.07	1.28	0.41	0.06	0.07	0.01	0.01	0.01	0.20	0.88	34.36	55.26
VIII.	97.95	0.79	0.29	0.05	0.05	0.01	0.01	0.01	0.05	0.79	34.20	55.09
IX.	97.84	0.87	0.30	0.05	0.05	0.01	0.01	0.01	0.06	0.80	34.23	55.11
X.	97.61	1.00	0.33	0.05	0.06	0.01	0.01	0.01	0.10	0.83	34.26	55.15
XI.	97.16	1.22	0.39	0.05	0.07	0.01	0.01	0.01	0.21	0.86	34.31	55.26
XII.	97.14	1.24	0.38	0.06	0.06	0.01	0.01	0.01	0.22	0.87	34.31	55.25
Average	97.50	1.04	0.34	0.05	0.06	0.01	0.01	0.01	0.14	0.84	34.26	55.18

Carbon content per unit of energy is usually less for light refined products such as gasoline than for heavier products such as residual fuel oil (Table 3. 4).

The problem identified by ERT was inconsistency between EF for natural gas before and after year 2000. Before 1 of January 2000 SR hasn't enough information and detailed analyses about the NG composition and therefore energy sectoral expert used default EF from IPCC guidelines (56.10 t/TJ) for the time series 1990–1999. The ERT considered this approach not consistent with IPCC GPG 2000 and invited to revise EF using extrapolation method based on national data after 2000 (Table 3. 5).

Calculated extrapolated values were used for calculation of carbon emission factors for natural gas, used in reference approach, too (Table 3. 6).

Table 3. 4 The parameters of the natural gas published by Slovak Gas Industry on-line (www.spp.sk)

Year		2000	2001	2002	2003	2004	2005	2006
Content of natural gas	CH ₄					97.69	97.50	
	C ₂ H ₆					0.95	1.04	
	C ₃ H ₈	97.14	97.37	97.42	97.57	0.29	0.34	97.13
	i-C ₄ H ₁₀	1.13	1.03	1.03	0.96	0.05	0.05	1.25
	n-C ₄ H ₁₀	0.37	0.32	0.32	0.31	0.01	0.01	0.39
	i-C ₅ H ₁₂	0.05	0.04	0.04	0.05	0.01	0.01	0.06
	n-C ₅ H ₁₂	0.07	0.06	0.06	0.06	0.01	0.01	0.07
	C ₆ H ₁₄	0.01	0.01	0.01	0.01	0.12	0.14	0.01
	CO ₂	0.01	0.01	0.01	0.01	0.82	0.84	0.01
	N ₂	0.02	0.01	0.01	0.01			0.01
		0.27	0.23	0.21	0.15			0.22
		0.93	0.92	0.89	0.87			0.85
Qv. 15°C (MJ/m ³)		34.25	34.18	34.21	34.21	34.22	34.26	34.31
Inhalt C (t C/TJ)		15.09	15.07	15.06	15.06	15.05	15.05	15.08
EF CO ₂ (t CO ₂ /TJ)		55.28	55.22	55.19	55.16	55.13	55.18	55.25
Oxidation factor		0.995	0.995	0.995	0.995	0.995	0.995	0.995
EF CO ₂ OF calculated (t CO ₂ /TJ)		55.00	54.94	54.91	54.89	54.85	54.90	54.97

Table 3. 5: Table of the revised CO₂ emission factors for natural gas used in sectoral approach

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
EF t/TJ	55.47	55.45	55.42	55.4	55.38	55.36	55.34	55.31	55.29	55.27	55.28	55.22	55.19	55.16	55.13	55.18	55.25
extrapolated values											real national data						

Table 3. 6: Table of the revised carbon emission factors for natural gas used in reference approach

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
EF t/TJ	15.54	15.47	15.4	15.35	15.29	15.25	15.2	15.17	15.13	15.11	15.09	15.07	15.06	15.06	15.05	15.06	15.08
extrapolated values											real national data						

For the extrapolation two methodological functions were provided (linear and polynomic), as a most appropriate the linear extrapolation was chosen in the calculation of EFs 1990–1999.

Slovak inventory team would like to follow recommendation in this agenda and accept changes in emission factors for natural gas, made recalculations in the sectoral approach for 1990 and 2004 and in reference approach for 1990–2006. The next step will be re-distribution of the sectoral approach to the sub-categories according national industrial activities in the category 1.A.2f.

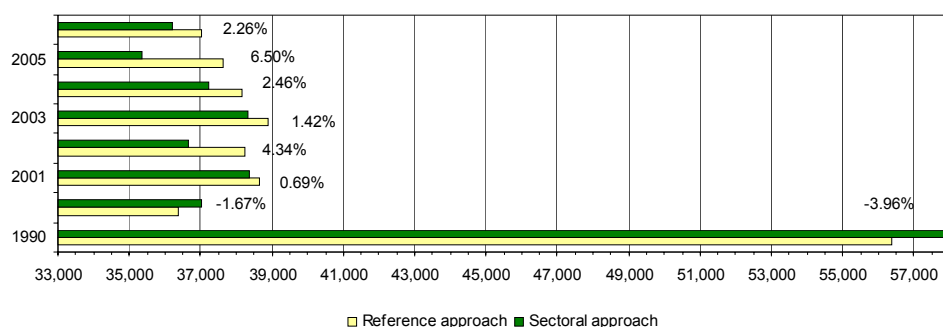
Emissions

The complete time series of CO₂, CH₄ and N₂O emissions for reference and sectoral approach from base year were estimated and the differences are summarized in the Table 3. 7. The higher difference between sectoral and reference approach in the older submissions is caused by the complicated situation in the national database NEIS, changes in the legislation in air protection and different classification of fuels' type in statistical collection of data and national legislation in large combustion plants and other stationary sources. The recalculated sectoral approach, where the fuel consumption was reallocated into the categories for the years 1991–1999 according expert judgment. The revised EFs for the natural gas, coal, brown coal, coke and coke gas were used.

The total anthropogenic emission of carbon dioxide from energy sector, fuel combustion was estimated in the inventory year 2006 to be 35 837 Gg as a national total CO₂ emissions (Figure 3. 3).

Table 3. 7 The sectoral and reference approaches for the recalculated years 1990–2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Sectoral approach (CO ₂ Gg)	57.93	52.49	48.86	44.91	42.38	40.69	39.14	38.01	37.90	37.18	36.63	37.98	36.29	37.97	36.88	36.57	35.84
Reference approach (CO ₂ Gg)	56.38	49.72	44.94	42.86	39.74	40.88	41.38	41.48	39.68	38.56	36.39	38.65	38.23	38.88	38.15	37.64	37.04
Difference in %	-2.68	-5.27	-8.02	-4.56	-6.24	0.47	5.73	9.11	4.70	3.71	-0.64	1.75	5.37	2.40	3.45	2.95	3.35

Figure 3. 3: A comparisons of SA and RA in 1990, 2000–2006

Reference and sectoral approach are estimated on fully independent data sets, whereby obtained differences are negligible. The difference between the top down and the bottom up energy balance was calculated to be 3.35 %. The differences in fuel consumption between these two approaches can be caused by using average NCVs (net calorific values) in reference approach and fuel specific NCVs in sectoral approach. In the sectoral approach, the quantities of fuels used in blast furnace (IPCC category 1.A.2a – solid fuels and gaseous fuels) were excluded from energy balance and the quantities of residual carbon from combustion which stayed in products were excluded from energy balance (IPCC categories 1.A.1c – other fuels and 1.A.2c – liquid and gaseous fuels). Since 1990, the total fuel combustion decreased significantly and the share of natural gas as an alternatively fuel type increased. After the medium increase of solid fuels in 2001, the slightly decreasing in 2002–2005 was appeared in energy balance. The balance of solid fuels consumption is complicated with the calculation of the stock change. The Statistic Office of the SR updates the fuel's categories and methodology for stock fuel annually. Therefore, it is a problematic situation with providing the consistent data series in last year's inventories in reference approach. The quality of data used for bottom-up approach is higher, because this data are checked more time (by the operators, by providers of NEIS database, by sectoral expert and by inventory unit).

Recalculation and Time Series

According the recommendations of the ERT from the in-depth review from last year 2007 several recalculations were implemented in the inventory of energy sector – sectoral approach and reference approach.

1. Recalculation based on improvement of methodology for allocation the fuel into the categories (solid, liquid, gaseous, biomass and other). For the bottom-up analysis of fuel consumption, the Slovak NIS uses National Emission Information System database for the stationary sources of air pollution. The database covers all operators and sources, where the fuel is combusted and has evidence about all characteristics of fuels (weight, type, NCV, density, origin and other parameters). Reporting of these data and other relevant information is require based on national legislative (Act 478/2002 on air protection, Act 401/1998 on charges for air pollution, Act 245/2003 on integrated pollution prevention and control, Decree of the MŽP SR 61/2004 laying down requirements for keeping operational records on stationary resources and others). Several changes in the other fuel category were included into waste and biomass according the implementation of new legal documents: Regulation of MŽP SR No. 706/2002, Regulation of MŽP SR No. 129/2004, amended Regulation MŽP SR 284/2001 to established catalogue of the waste and Directive No. 200/76/EC

about waste incineration. The allocation and the list of reporting fuels are also based on the annually announced official decree and all official requirements are regularly implemented into the database NEIS. The changes are only in allocation in-between categories in sectoral approach and do not influence the total energy consumption.

- The category other fuel now includes only the waste incineration from 1990 with energy use.
 - The category liquid includes following fuel's type: propane-butane, diesel oil, refinery gas, heavy heating oil, light heating oil and other liquid.
 - The category of solid includes following fuel's type: lignite, coal, coke, brown coke (several types according origin), other solid and briquettes.
 - The category gaseous includes following fuel's type: Natural gas, coke gas, refinery gas, coke-oven gas and other gaseous.
 - The category of biomass includes following fuel's type: biogas and wood.
2. Recalculation based on improvement of the splitting-up the sectoral approach in 1991–1999. The splitting was required in the final report of the in-depth review conclusion and it was mostly technical problem with the comparability of the database systems before and after 2000. The changes in the sectoral approach are not important and the total amount of the emissions in the categories remained constant. The splitting was performed manually by selection the important sources and statistical evaluation.
 3. Recalculation based on the revision of emission factors for the important fuels (see Table 3.2). The national EF for coal, brown coal, natural gas, coke and coke gas were treated in comparison of ETS values and according the allocation of source in to the categories of installation, the NCV of fuels and origin. The brown coal from Czech Republic has higher EF, because of higher quality and purity. This approach has a significant influence to the total CO₂ emissions from the base year in energy sector – sectoral approach.
 4. Recalculation in years 2002-2006 in category 1A2a - Iron&Steel Production not appropriately quantity of blast furnace gas was excluding from balance of gaseous fuel according the assumption of avoiding double counting. This fuel is including in the coke coal and blast furnace coal (primary fuels) and in the reason of avoiding double counting is excluding also with other secondary fuels. In 2005 there was a significant increase of blast furnace gas and coke gas, so it will also significantly lower gaseous fuels after excluding. We were checked it with US Steel company and the error in estimation was eliminated. The CO₂ emissions increased from 2 614 Gg to 4 212 Gg.

The results according energy categories are summarized in the table (Table 3. 8) below.

Table 3. 8: Table of recalculation changes in the main energy categories in CO₂ equivalents (Gg) emissions

Year of sub.	Category	1A1	1A2	1A4	1A5
1990 (2007)		15 717.58	24 125.89	10 949.94	1 683.31
1990 (2008)		16 031.74	24 418.18	11 337.70	1 878.11
Differences in %		1.96	1.20	3.42	10.37
2005 (2007)		11 274.97	12 253.72	4 845.13	1 430.97
2005 (2008)		11 827.40	12 169.77	4 924.13	1 431.42
Differences in %		1.16	-0.69	0.17	0.001

Key Source and Uncertainties

The emissions of CO₂ from these categories (liquid, solid and gaseous fuel's combustion) are the most important key sources and they have a decisive effect on the level and trend uncertainty management (Annex 2). The emission balance of other GHGs (CH₄, N₂O) from 1.A.1-5 IPCC categories was

estimated by using IPCC methodology (IPCC, 1996) and default emission factors in like manner as previous year. These categories are not key source.

3.1.2 Road Transport

Aim of the transport category is the emission check of basic pollutants (CO, NO_x, SO₂) and solid particles - TSP, PM₁₀, PM_{2.5}, NM VOC emissions and heavy metals, emissions of persistent organic substances (POPs) and greenhouse gases (GHG) produced by road transport in the Slovak Republic in year 2006. Balance of pollutant and heavy metal emissions is evaluated according EMEP/CORINAIR methodology and using COPERT III computer program. The emission inventory of road transport in 2006 included also the emissions from light and heavy-duty vehicles, buses operated by CNG (Compressed Natural Gas) for 2000–2006. This emission is not key source. The input parameters are known only from 2000. It is assumed, that before year 2000 the use of CNG was negligible. The emissions from this sector have increasing tendency every year and are the key source in level and trend assessment for calculation of uncertainty management (Annex 2).

Methodology and Activity Data

The based methodology of GHGs in the road transport is computer program COPERT III, with the desegregation into the 6 base categories and 83 subcategories from the operation of road vehicles in the agglomeration, road and highway traffic mode. This methodology uses for the calculation of emissions the technical parameters about types of vehicles and the country characteristic. For example the composition of car fleet, age of the cars, the parameters of operation and fuels or climate conditions. The estimation is provided in the five main types of the input data:

- Total fuel consumption;
- Composition of vehicles fleet;
- Driving mode;
- Emission factors;
- Others.

Based on these input parameters and additional information (age of automobiles) is possible to estimate emissions.

The important information about import, production, distribution and sale of the gasoline and diesel oil were received from producer of fuels – Slovnaft Ltd. Bratislava and Petrochema Ltd. Dubová, from the Customs Directory SR, Statistic Office of the SR. The data about distribution and sale of gaseous fuels – LPG and CNG – were obtained from the exclusive dealers and Slovak Gas Industry Ltd. All materials are in the Slovak language and are official.

Emission Factors

The emission factors for the group of pollutants such as CO₂, SO₂, N₂O, NH₃, PM and partially also CH₄ is possible to obtain with the simply formula between driving mode and consumed fuel. This value is constant for the different vehicles categories. Emission factors are automatically calculated by COPERT III based on input parameters – average speed, quality of fuel, age of vehicles, weight of vehicles, and volume of cylinders.

Emissions

The share of emission estimation of GHGs from road transport in 2006 is presented on the Figure 3. 4 and in the Table 3. 9 in the classification of the based group of vehicles fleet, according the structure of COPERT III. The total aggregated emissions from road transport reached in 2006–5 859.19 Gg of CO₂ eq. The major share belongs to the duty vehicles and passenger cars. Table 3. 9: is completed with the information about share of emissions to the operations: city, road and highway traffic.

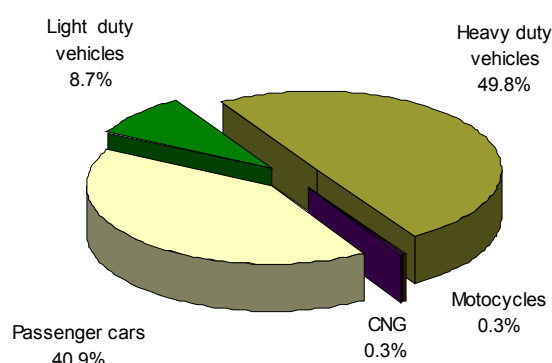
Figure 3. 4: A share of individual vehicles in road transport in 2006 according the emissions in CO₂ eq.

Table 3. 9: The results in GHGs emission balance in 2006 in the road transport

Category of road vehicles	Emissions GHG in 2006 [t]			Category of road vehicles	Emissions GHG in 2006 [t]		
	CO ₂	CH ₄	N ₂ O		CO ₂	CH ₄	N ₂ O
Passenger cars	2 278 307	732	339	Heavy duty vehicles	2 872 238	217	140
gasoline < 1.4 l	1 042 095	449	163	gasoline > 3.5 t	0	0	0
gasoline 1.4 l–2.0 l	648 695	211	95	diesel 3.5–7.5 t	559 274	59	48
gasoline > 2.0 l	121 013	34	14	diesel 7.5–16 t	454 120	26	24
diesel < 2.0 l	303 299	11	49	diesel 16–32 t	1 300 818	89	49
diesel > 2.0 l	71 914	3	11	diesel > 32 t	181 707	6	5
LPG	90 935	24	7	City buses	199 108	21	7
Two stroke engine	356	0	0	Long-line buses	177 211	16	7
Light duty vehicles	496 992	30	40	Vehicles on CNG	12 675	127	0.4
gasoline < 3.5 t	165 474	23	18	Motorcycles	14 270	22	0
diesel < 3.5 t	331 518	7	22	< 50 cm ³	4 559	4	
				Two stroke engine > 50 cm ³	6 136	11	
				Four stroke engine < 250 cm ³	257	2	
				Four stroke engine 250–750	613	2	
				Four stroke engine > 750 cm ³	985	3	
				Sum in the SR	5 674 482	1 128	519
Traffic				Emissions GHG [t] in 2006			
				CO₂	CH₄	N₂O	
City				2 455 633	865	255	
Road				2 279 060	210	175	
Highway				939 789	53	89	
Sum in the SR				5 674 482	1 128	519	

Recalculation and Time Series

No recalculations were provided. The time series is complete estimated by COPERT III.

Trends in Emissions and Fuels

The trend in the production of the CO₂ and N₂O emissions from road transport correspond with the consumption of the fuels. The emission factors are constant during the time series. The development of the Slovak economy is accompanied with the increasing of the road transport and the fuel consumption (mostly diesel). For the CH₄ emissions are primary important the vehicles alteration for the vehicles with better environmental and energetic parameters (mostly personal cars with catalyzes). The conclusion is slightly decreasing of the emission production comparable to the previous year 2005. This result is caused by decreasing of the fuels consumption (Gasoline –10.6 %, Diesel –4.5 %) in the road transport and the important process of renovation the car fleet with the modern lower-emission

production engines and environmentally friendly parameters. The elimination of the negative influences in the road transport is continuing with the increasing LPG and CNG vehicles (mostly buses and duty vehicles).

3.1.3 Non-Road Transport

The emissions from this sector included the civil aviation, navigation and railways sources of pollution in the Slovak Republic in year 2006. The emissions from road and non-road transport were calculated by using default method and the consistent data series from 1990 were determined by SHMI in co-operation with external experts Dr. J. Breziansky and Mr. J. Pinter from Research Institute of Transport in Zilina.

The emissions of GHGs from the consumption of the fuels in the civil aviation, navigation and railways transport were estimated by CORINAIR methodology (CORINAIR, 2003). The emissions from civil aviation transport were estimated according the consumption of fuel and expert judgment in the splitting to the domestic and international flights. The emissions from inland shipping are included into the international bunkers.

Methodology and Activity Data

Railways – the mobile sources of pollution in the railways transport included vehicles of the motor traction the Railways Company, Ltd. of the SR (RC SR). This motor traction is divided into the two basic groups of vehicles: motor locomotives (Traction 70) and motor wagons (Traction 80). The operation of the motor traction is covered by four depots in the organization structure of the Railways Company, Ltd. from 2002 (Bratislava, Zvolen, Zilina and Kosice). This structure is respected in the emission inventory (Table 3. 10). The consumption of diesel oil for the motor traction in the SR was obtained from the statistic of the Railways Company, Ltd. for the whole time series (Table 3. 11).

Table 3. 10 The statistic information about the railways organisation structure in 2006 (Traction 70+80)

Statistic Data	Number					
Traction 70+80	Year run	Kosice	Zilina	Zvolen	Bratislava	Sum
CARGO+Public	Consumption					
	Consumption					
	[number]	226	115	184	185	710
	[km]	7,578,780	3,426,526	9,053,007	6,636,589	26,694,902
	[hrtkm]	543,190,000	226,798,000	2,272,540,000	882,714,000	3,925,242,000
	[l]	10,049,712	3,722,653	17,219,757	11,293,898	42,286,020
	[t]	8,442	3,127	14,465	9,487	35,520

Table 3. 11 The diesel oil consumption in the railways motor traction section according the RC SR

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Diesel oil (kt)	118.18	88.90	73.35	62.97	59.44	64.01	62.82	59.03	54.15	49.57	48.86	48.18	44.76	35.80	34.33	33.43	35.52

Navigation - The Slovak Republic was used Tier 1 methodology based on transportation model (fuel consumption by transit transport) for emission estimation of marine transport on Danube River, not occurring national shipping activity. According recommendations of ERT final findings and IPCC GPG 2000, the recalculation in category 1.A.3d – Navigation was provided, emission estimation based on fuel consumption and the international rule for inland shipping on the Danube river was evaluated.

Two relevant ports on Danube River take into consideration for the emission estimation in the Slovak inland international transport – Bratislava and Komarno. The activity data for the period 1994–2006 come from State Shipping Administration in the accordance periodical annual providing of statistical-processing information in the water transport. The activity data for the period 1990–1993 are not statistically documented and that why the expert estimation on the base of the navigation traffic on the

Danube River were performed. Emissions for the year 2000 were estimated to be negligible, because of increasing prices of diesel oil fuel in the Slovak Republic and decreasing prices of fuels in the neighbors' countries (market discrepancies).

Civil Aviation – The Slovak Republic was used Tier 1 methodology based on LTO cycles for emission estimation of aviation transport, not divided into national and international flights. According recommendations of ERT final findings and IPCC GPG 2000, the recalculation in category 1.A.3a – Civil aviation was provided emission estimation based on fuel consumption and the international rule for domestic and international flights based on expert judgment was evaluated.

The overall view of the sale the aviation fuels according type (aviation gasoline and jet kerosene) during 1990–2006 was revaluated. For the period 1994–2006 the data come directly from airport statistical processing information based on annual bases. The data for the period 1990–1993 about the sale of fuel are based on expert estimation according the real LTO cycles in the detached period.

Statistic methodology for the airport traffic is determined only by origin of air operator for domestic and international. It means, that no direct information about numbers of domestic and international operated flights are known for the period 1990–2006. The average splitting of consummated fuel was executed by expert estimation. Based on expert estimation about total fuel sale of jet kerosene was statement, that domestic consumption presents 10 % of the total and international 90 % from the total. The approximately opposite ration is applied in consumption of aviation gasoline: 90 % on domestic flights and 10 % on international flights.

Emission Factors and Emissions

Railways – in the balance of the GHGs emissions were made two fundamental changes in the values of emission factor for the motor traction. In the year 1994 and 2002 based on the legislative basis (regulation of the Ministry of Environment Nr. 144/2001) about the requirements of the fuel's quality. The emissions and the actual EFs are shown in the Table 3.12. The emissions are divided according the type of the railways operation (passenger, freight and service transport) from 1995.

Table 3. 12 The fuel consumption and the emissions in the 2006 in the railways

Traction 70+80	Diesel oil consumption		Emissions [t]		
	[l]	[t]	CO ₂	N ₂ O	CH ₄
Emission factors for the motor locomotives and wagons kg / t			3 188	1.37	0.19
Košice	10,049,712	8,442	26,912.30	11.57	1.60
Žilina	3,722,653	3,127	9,969.00	4.28	0.59
Zvolen	17,219,757	14,465	46,113.10	19.82	2.75
Bratislava	11,293,898	9,487	30,244.20	13.00	1.80
RC SR Sum (CARGO+Public)	42,286,020	35,520	113,238.60	48.66	6.75

Navigation – The GHG emissions from the diesel oil consumption sold in the Slovak Republic important ports Bratislava and Komarno was balanced in the period 1990–2006. Two variant were take into consideration:

Variant 1 on Table 3. 13 showed the emission balance using EFs for the different type of ships known in the time of estimation for diesel fuel – more realistic and recommended to use by sectoral expert (applied).

Varian B on Table 3.14 shows emission balance using the recent EFs for the different type of ships for diesel fuel – not recommended by sectoral expert because the quality of diesel oil was change during the period 1990–2006 (not applied).

Table 3. 13: Emission balance of GHGs from diesel oil sold for shipping companies in the SR between 1990–2006 based on historical EFs in that time

Year	Sold	Sold	Emissions [t]		
	Diesel oil [t]	Diesel oil [TJ]	CO ₂	N ₂ O	CH ₄
EF in kg/t Diesel oil			3 188	0.10	0.25
1990	20 500	871.25	65 354.00	2.05	5.13
1991	18 000	765.00	57 384.00	1.80	4.50
1992	17 000	722.50	54 196.00	1.70	4.25
1993	14 000	595.00	44 632.00	1.40	3.50
EF in kg/t Diesel oil			3 188	1.37	0.20
1994	13 387	568.95	42 677.76	18.34	2.68
1995	18 066	767.81	57 594.41	24.75	3.61
1996	15 390	654.08	49 063.32	21.08	3.08
1997	9 167	389.60	29 224.40	12.56	1.83
1998	12 813	544.54	40 847.84	17.55	2.56
1999	2 701	114.79	8 610.79	3.70	0.54
2000	0	0.00	0.00	0.00	0.00
2001	8 366	355.56	26 670.81	11.46	1.67
EF in kg/t Diesel oil			3 188	1.37	0.19
2002	9 027	383.66	28 778.71	12.37	1.72
2003	6 836	290.53	21 793.17	9.37	1.30
2004	2 661	113.09	8 483.17	3.65	0.51
2005	214	9.10	682.23	0.29	0.04
2006	9 569	406.68	126 743	54.47	7.55

Remarks: In red colour the expert estimation of diesel oil sale based on the developing of diesel fuel consumption on The Slovak part of Danube river.

Table 3. 14: Emission balance of GHGs from diesel oil sold for shipping companies in the SR between 1990–2006 based on recent EFs

Year	Sold Diesel oil [t]	Sold Diesel oil [TJ]	Emissions [t]		
			CO ₂	N ₂ O	CH ₄
EF in kg/t diesel oil			3,188	1.37	0.19
1990	20 500	871.25	65 354	28.09	3.90
1991	18 000	765.00	57 384	24.66	3.42
1992	17 000	722.50	54 196	23.29	3.23
1993	14 000	595.00	44 632	19.18	2.66
1994	13 387	568.95	42 678	18.34	2.54
1995	18 066	767.81	57 594	24.75	3.43
1996	15 390	654.08	49 063	21.08	2.92
1997	9 167	389.60	29 224	12.56	1.74
1998	12 813	544.54	40 848	17.55	2.43
1999	2 701	114.79	8 611	3.70	0.51
2000	0	0.00	0	0.00	0.00
2001	8 366	355.56	26 671	11.46	1.59
2002	9 027	383.66	28 779	12.37	1.72
2003	6 836	290.53	21 793	9.37	1.30
2004	2 661	113.09	8 483	3.65	0.51
2005	214	9.10	682	0.29	0.04
2006	9 569	406.68	126 743	54.47	7.55

Remarks: In red colour the expert estimation of diesel oil sale based on the developing of diesel fuel consumption on The Slovak part of Danube river.

The emission estimations shown in the Table 3.13 were included into the 1.C.1b – Marine (international bunkers), not included into national total GHG emissions.

Civil Aviation – the GHG emissions estimation was performed according the totals of sale fuels on the important The Slovak airports in the period 1990–2006 and the expert estimated consumption of the fuels to the national and international fuel consumption.

For the emissions estimation and balance of GHGs in the period 1990–2006 the mixed emission factors (Table 3. 15) were used for jet kerosene and aviation gasoline. The mixed emission factors determine average production of GHG emissions during all flight phases (LTO and flight).

According the presented starting information above and other relevant facts from the CORINAIR Emission Inventory Guidebook the following mixed emission factors were used (Table 3. 16).

Table 3. 15: Starting points for the mixed EFs estimation are depicted in the following table

Starting conditions for the estimation of mixed EFs for GHG emissions for Jet Kerosene		
Parameter	International Flights	Domestic Flights
Fuel	Jet Kerosene	
Representative Aircraft	B 737–500, (400,100)	EMB-120, Saab 340B
Average Flight Distance	1365 km	375 km
Average Flight Duration	1.75 hours	0.75 hours
Average Speed	780 km/hour	500 km/hour

Table 3. 16: Mixed emission factors for the GHG emissions balance in Air transport according fuel consumption

Mixed emission factors for the GHG emissions balance in Air transport according fuel consumption		
Parameter	Emission factor [g/kg fuel]	
	International Flights	Domestic Flights
GHGs	Jet Kerosene	
CO ₂	3150	3150
N ₂ O	0.104	0.35
CH ₄	0.05	0.25
GHGs	Aviation Gasoline	
CO ₂	3150	
N ₂ O	0.1	
CH ₄	1.9	

It is generally known, that in the period 1990–2006 the technological development of aircraft industry took place and emissions were decreasing from air traffic. The using of mixed EFs based on recent knowledge about parameters of aircraft can caused underestimating of emissions in the earlier period and base year, too. It is historically proved, that in the earlier 90-ties, the obsolete aircrafts were used. Because no relevant information from earlier period of estimating time series are known, the problem cannot be solved satisfactory.

Based input information used for the emission estimation from civil aviation are the numbers of realized LTO cycles during the year on the monitored airports following the types of aircrafts and the carrying capacity of the airports. The aircrafts are divided into the two weight categories into the 5.7 t and over 5.7 t. The innovated method is using the emission factors for the each aircraft type and weight category. The number of the LTO cycles in inventory year 2006 was 34 529 cycles. The total consumption of jet kerosene was 31 804.5 t (45 687 649 l) and the consumption of aviation gasoline was 182.10 t (246 082 l).

Recalculation and Time Series

Railways – the inter-annual increasing in 2005/2006 of the diesel oil consumption in motor traction of railways is only minor fluctuation in the trend of permanent decreasing (2004/2005 – 3.6 %, 2003/2004 – 4.5, 2001/2002 – 7.1 %, 2000/2001 – 0.98 %, 1999/2000 – 1.5 % and 1998/1999 – 8.5 %). The reduction of number of the realised operations in passenger and freight railways transport causes these decreasing. The Railways Company, Ltd. makes new economic and effective policy in the operation of the railway transport.

Navigation – the total reduction of all GHG emissions from navigation transport in 1990 was 100 % in comparison to the previous submission (2007). The results are summarized in Table 3. 17 and Table 3. 18. All emissions were considered to be international bunkers according to the character of shipping activity on Danube River in the SR. No recalculation in the submission 2008 focused to the base year or 2005 was provided.

Table 3. 17: The recalculation changes in the navigation transport in Gg in the 2007 submission

Year of sub.	Category	1A3d			Year of sub.	Category	1C		
		CO ₂	CH ₄	N ₂ O			CO ₂	CH ₄	N ₂ O
1990 (2006)		142.6078	0.0112	0.0613	1990 (2006)		NO	NO	NO
1990 (2007)		NO	NO	NO	1990 (2007)		65.3540	0.0051	0.0021
Differences in %		100.00	100.00	100.00	Differences in %		100.00	100.00	100.00
Differences in Gg		142.6078	0.0112	0.0613	Differences in Gg		65.3540	0.0051	0.0021

Table 3. 18: New estimated emissions in the 1990–2006 from international navigation transport in Gg

Emissions 1A3d International bunkers	Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
	CO ₂ (kt)	65.35	57.38	54.20	44.63	42.68	57.59	49.06	29.22	40.85	8.61	0.00	26.67	28.78	21.79	8.48	0.68	30.51
	CH ₄ (t)	5.13	4.50	4.25	3.50	2.68	3.61	3.08	1.83	2.56	0.54	0.00	1.67	1.72	1.30	0.51	0.04	13.11
	N ₂ O (t)	2.05	1.80	1.70	1.40	18.34	24.75	21.08	12.56	17.55	3.70	0.00	11.46	12.37	9.37	3.65	0.29	1.82

Civil Aviation – Total reduction of CO₂ emissions from aviation transport in 1990 was 84.76 % in comparison to the previous submission (2007). Total reduction of N₂O emissions from aviation transport in 1990 was 98.83 % in comparison to the previous submission (2007). Total increasing in methane emissions (100 %) was caused by estimation CH₄ emissions, using mixed EFs for different type of aircrafts and dividing the methane emissions from total voluntary organic compounds (VOC). The results in domestic and international aviation transport are summarized in the Table 3.17 and Table 3. 20 below. No recalculation in the submission 2008 focused to the base year or 2005 was provided.

Table 3. 19: Table of recalculation changes in the domestic and international aviation transport in Gg

Year of sub.	Category	1A3a			Year of sub.	Category	1C		
		CO ₂	CH ₄	N ₂ O			CO ₂	CH ₄	N ₂ O
1990 (2006)		50.77	NE	0.07	1990 (2006)		NE	NE	NE
1990 (2007)		7.74	0.001	0.0008	1990 (2007)		63.1037	0.0010	0.0021
Differences in %		84.76	100.00	98.83	Differences in %		100.00	100.00	100.00
Differences in Gg		43.03	0.001	0.07	Differences in Gg		63.1037	0.0010	0.0021

Table 3. 20: Table of new estimated emissions in the 1990–2006 from domestic and international transport

1A3a	Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
National airlines	CO ₂ (kt)	7.74	7.19	6.65	6.47	5.50	5.48	6.43	5.69	5.23	5.31	5.50	5.23	5.45	6.99	9.07	10.53	11.74
	CH ₄ (t)	1.00	0.93	0.86	0.86	0.71	0.69	0.79	0.70	0.63	0.65	0.73	0.72	0.76	0.87	0.95	1.11	1.20
	N ₂ O (t)	0.80	0.75	0.69	0.69	0.57	0.57	0.67	0.60	0.55	0.55	0.57	0.53	0.56	0.73	0.97	1.13	1.82
International airlines	CO ₂ (kt)	63.10	58.68	54.25	53.14	44.78	45.04	53.16	47.08	43.41	43.80	44.51	41.86	43.46	57.46	77.68	90.14	101.09
	CH ₄ (t)	1.05	0.98	0.90	0.90	0.75	0.75	0.88	0.78	0.72	0.72	0.74	0.70	0.73	0.95	1.26	1.47	1.64
	N ₂ O (t)	2.08	1.94	1.79	1.79	1.48	1.49	1.75	1.55	1.43	1.45	1.47	1.38	1.43	1.90	2.56	2.98	3.34

Against the previous year 2005 was in the emissions from civil aviation increasing development observed – about 12 % in the actual year 2006. This was caused by the increasing number of LTO cycles in all airports in the SR, mostly in Bratislava (28 % increasing). We are expected this trend also in the future. The trend of the aviation transport is influenced from 2002 by entering of the low-cost airlines. The aviation fuel consumption is influenced by price policy, there is a strong pressure of the airlines to buy fuel abroad, when the price on the Slovak airports is inconvenient comparable to other neighbour countries.

Key Source and Uncertainties

The increasing of quality of emission inventory from the transport depends closely on the decreasing and removing of the following uncertainties:

- The uncertainties joint with the COPERT III methodology;
- The uncertainties joint with the collection, preparation and application of the input data.

The important influence for the quality of calculated results by COPERT III has uncertainty of the following statistics information:

- Statistic information about consumption of the fuels;
- Allocation of the total number of vehicles into the all categories according the methodology;
- The average yearly overrun kilometres;
- The average speed in the traffic mode;
- The average temperatures;
- The beta-factor.

3.2 Fugitive Emissions from Fuels

The important source of methane emissions in national GHGs inventory are fugitive emissions from coal mining & handling and oil & natural gas distribution as a key sources categories in uncertainty estimation (Annex 2). In the 2006 are mined 2 206.3 kt of brown coal from domestic production, of it 110 kt of assorted coal for the habitants. The coal market is fully liberalized, the domestic production not covers all demand, because of 932 kt of brown coal were imported (mostly from Czech Republic). A total methane emission from underground coal mining in 2006 was estimated to be 14.67 Gg (13.34 Gg of CH₄ from underground coal mining and 1.33 Gg of CH₄ from post-mining activity) (Figure 3. 5). The Slovak inventory team with cooperation of Profing Ltd. was provided the revision of emissions and emission factors for underground coal mining and handling during the year 2006 because the emissions factors used until presence were suitable mainly for hard coal underground mines. The important reason for this opinion is an occurrence of brown coal underground mines with mainly non-gaseous system.

3.2.1 Coal Mining

Methodology and Activity Data

Total emission from fugitive sources in coal mining industry can be calculated by following formula: Emissions = underground mining emissions + post-mining activity emissions – recovery or flared methane. The most important activity data is the amount of mined brown coal (in the raw form). The fugitive methane emissions from underground coal mining and postmining activities in the Slovak Republic were estimated in accordance the three following steps of methodology:

Step A – Activity data. In the Slovak Republic are five localities of underground mines in operation. Data of coal production from single underground mines have been obtained from official sources – companies: HBP, a.s., Baňa Dolina, a.s. a Baňa Záhorie, a.s., and Ministry of Economy of SR and Statistic Office of the SR. The Table 3. 21 provides the values of coal production from 1993.

Table 3. 21: The total brown coal production in the SR during 1993–2006

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
	Brown coal (kt)													
Mining	3 614.3	3 744.8	3 759.1	3 840.1	3 914.2	3 951.0	3 806.5	3 649.3	3 424.0	3 401.0	3 075.2	2 951.9	2 511.2	2,206.3

Step B – Emission factors. For the calculation of fugitive methane emissions there were used the emission factors from following sources (Table 3.20):

- 1. IPCC Guidance for National Greenhouse Gas Inventories, Fugitive sources, 1.4 Methane Emissions from Coal Mining and Handling Activities;
- 2. IEA – CIAB Global Methane and the Coal Industry;⁵
- 3. EF(CH₄) specified of mines operator – HBP, a.s.

Table 3. 22: The EF_{CH₄} for coal mining a handling assigned to single mines in SR

Mine	Mine Nováky	Mine Nováky 6.ŤÚ	Mine Cígel'	Mine Cígel' 7.ŤÚ	Mine Handlová	Mine Handlová VŠ	Mine Dolina	Mine Záhorie
Depth of mine [m]	200	200	500	500	500–1500	500–1500	600	400
	EF _{CH₄} [m ³ /t]							
1. IPCC Guidance for National Greenhouse Gas Inventories								
IPCC mining tier1	10	10	10	10	10	10	10	10
IPCC post mining	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
2. IEA - CIAB Global Methane and the Coal Industry								
EF(CIAB) mining	6	6	13	13	13	13	13	13
IPCC post mining	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
3. EF _{CH₄} specified of the mines operator - HBP, a.s.								
Mining-measure	0.92	4.17	0.00	4.17	0.00	4.17	0.02	0.02
Post mining	0.39	0.46	0.00	0.46	0.00	0.46	0.01	0.01

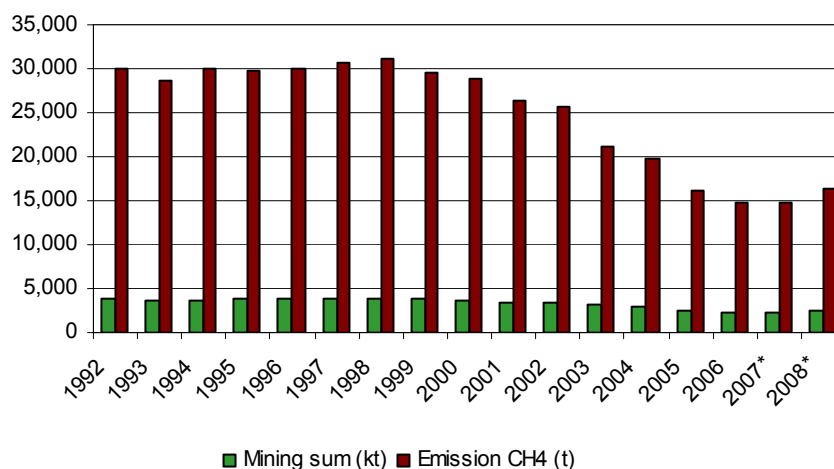
Step C – Recovery. For the calculation are used assumptions that fugitive methane emissions aren't use to electricity and heat production, and don't flare for reducing methane emissions from coal mining in the Slovak Republic.

Emission Factors and Emissions

Emission factors according to IPCC Guidance – for all mines have been used the identical values 10 m³ CH₄/t for coal mining and 0.9 m³ CH₄/t for post-mining. Both values are on the lower level of the suggested scale. Emission factors according to IEA – CIAB – the published values for mining were assigned according to the depth of the mines within 6 a 13 m³ CH₄/t and 0.9 m³ CH₄/t for post-mining activity. There were used the values on the lower level of the suggested scale as well as in the previous case. EF (CH₄) specified of the mines operator – HBP, a.s. on the base of measurement concentration values of the methane and amount of ventilation air data, were assigned to single mines according to suggestion of the operators. EF (CH₄) for post-mining have been used from IPCC Good Practice Guidance (IPCC, 2000), for mining without drainage, with known of gas amount – in the coal after mining is present 30 % of gas and for mines with pre-drainage, 10 % of gas (Figure 3. 5).

⁵ <http://spider.iea.org/ciab/>

Figure 3. 5: Trends in coal mining productivity and methane emissions from mining and post-mining activity in 1990–2008* (*with predictions)



The Figure 3. 6 below shows comparison of trends emissions CH_4 in SR in years 1992–2008, calculated according to emission factors of IPCC, IEA-CIAB methodology and EF (CH_4) HBP a.s. In the case of emissions calculation with using of IPCC emission factors, the trend of fugitive emissions CH_4 is declining in accordance to reduction of coal mining in the SR. Application EF (CH_4) specified of mines operator (HBP, a.s.) – trend of fugitive emissions CH_4 is increasing in contradiction with reduction of coal mining in SR. It is due to the moving of coal mining to parts of mines with coal containing more of gas. The fugitive methane emissions in the period 1990–2008 were calculated on the base of coal production from single underground mines, obtained from official sources – companies HBP, a.s., Baňa Dolina, a.s. a Baňa Záhorie, a.s., and Ministry of Economy of SR and Statistic Office of the SR. For the balance of the fugitive methane emissions from coal mining and post – mining in SR, we used the value, calculated according to the methodology IEA - CIAB Global Methane and the Coal Industry according to the depth of the mines (see Table 3. 22 point 2) as a best appropriated. Table 3. 23 presents recalculated fugitive emissions from coal mining and handling and the post-mining activities during 1990–2006.

Figure 3. 6: Comparison of trends emissions CH_4 in SR in years 1992–2008* (*with predictions)

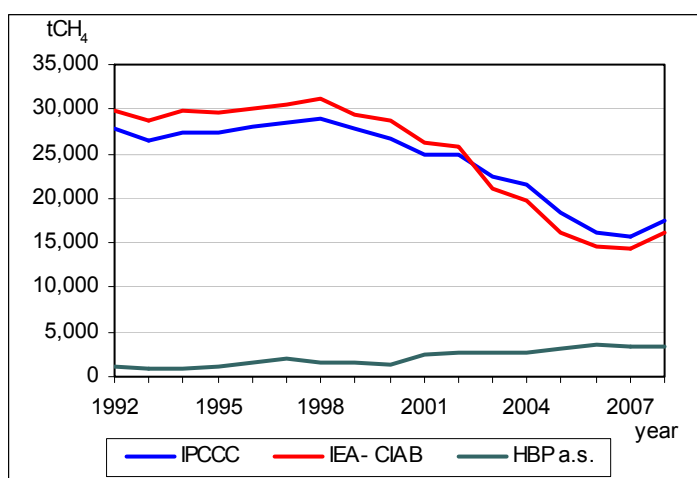


Table 3. 23: The total CH₄ fugitive emissions from mining and post-mining activities in the SR in 1990–2006

Year	1990	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
	Fugitive emissions of CH₄ (Gg)															
Mining	25.1	27.6	26.4	27.7	27.4	27.8	28.3	28.8	27.2	26.6	24.3	23.6	19.3	18.0	14.7	13.3
Post-mining	2.1	2.3	2.2	2.3	2.3	2.3	2.4	2.4	2.3	2.2	2.1	2.1	1.9	1.8	1.5	1.3
Total	27.2	29.9	28.6	29.9	29.7	30.1	30.6	31.2	29.5	28.8	26.3	25.7	21.1	19.8	16.2	14.7

Post-mining activity emissions represents the rest of gaseous methane present in the mined coal. This source of emission releases the methane into the atmosphere during the manipulation and storage of coal. The measurement of these emissions are not realised and the emission estimation must be done with the default emission factors. It is assumed, that 25–40 % of CH₄ is present into the coal. For the without drainage mines is recommended to use 30 % and for the pre-drainage mines the emission factor 10 %. The following Table 3. 24 presents the emission factors for the Slovak mines.

Table 3. 24: The post-mining EFs in the mines in the SR

Mines	Post-mining EF CH ₄	
	m ³ CH ₄ /t brown coal	kgCH ₄ /t brown coal
Mine Nováky	0.39	0.261
Mine Čígel'	0.00	Non-gaseous
Mine Čígel' 7.ŤÚ	0.46	0.308
Mine Handlová	0.00	Non-gaseous
Mine Handlová VŠ	0.46	0.308

Recalculation and Time Series

The important recalculation and changes in the emissions factors and methodology of estimation the emissions from underground coal mining and post-mining activities were provided in the previous submission 2006 and are described above. The whole time series were recalculated according these changes. No additional recalculation are needed. The time series is consistent and more suitable for the national conditions.

Key Source and Uncertainties

The amount of methane from underground mining is naturally variable. The direct measurements of the CH₄ emissions from the ventilated air are made with the ± 20 % accuracy with the dependence of the measurement's installation. The repeatability of the measurements increases accuracy up to ± 5 %. For the continual measurement is the uncertainty in the range of ± 10 –15 % for the two weeks repeating.

3.2.2 Oil and Natural Gas Production

Methodology and Activity Data

The production of oil and natural gas from domestic sources are negligible in the SR and the major share of these stocks comes from import. These categories are important key sources in level and trend assessment in uncertainty management (Annex 2). The total methane emissions represent 31.96 Gg in 2005 and were recalculated in the previous submission back to the base year because of estimation of emissions from venting and flaring.

The total CO₂ emissions in 2006 were 0.175 Gg and the estimation was based on the composition of natural gas and carbon content. The time series was completed from 1990.

The fugitive emissions CH₄ from transport and distribution of natural gas in SR have been calculated with IPCC default methodology from following activity data into the three steps:

Step A – Data of natural gas have been obtained from official sources – The Slovak Gas Industry, Ltd., Ministry of Economy of SR and Statistic Office of the SR (Table 3. 25).

Step B – For the calculation of fugitive methane emissions, there were used the emission factors from the following sources:

- 1. IPCC Guidance for National Greenhouse Gas Inventories, Reference manual, Fugitive sources, 1.9 Fugitive Emissions from Oil and Natural Gas Activities;
- 2. IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories 2.7 Fugitive Emissions from Oil and gas operation; The Table 3 in GPG gives of EF used for calculation.

Step C – Emissions from compression stations and pipelines were calculated on the base of gas leakages according to Slovak Gas Industry, Ltd. methodology.

Distribution losses of NG in SR are 1 944 809 m³ (15°C; 101.325 kPa) (1 290 t of CH₄) according to preliminary balances of gas fuels in year 2006 (Statistical office of SR). This value represented approximately 0.03 % of total NG consumption in SR.

Table 3. 25: The data in year 2006 – production, export and import NG in SR

SR	Natural gas [m ³]	Natural gas [PJ]
Indigenous production	194 000 000	7.368
Associated gas	16 000 000	0.608
Nonassociated gas	178 000 000	6.760
Stock changes	11 000 000	0.377
Gas vented	1 000 000	0.038
Gas flared	4 000 000	0.152
Export	570 000 000	20.694
Import	6 940 000 000	238.111
Inland consumption	6 575 000 000	225.161

The calculation of fugitive methane emissions from transport and distribution of NG in SR according to Slovak Gas Industry, Ltd. methodology (national approach) is based on the calculation of leakages of NG from the compression stations and from transport pipelines. There are four big compression stations (KS1 – Velke Kapusany, KS2 – Jablonov nad Tunov, KS3 – Velke Zlievce and KS4 – Ivanka pri Nitre) and three transport pipelines (ZLC Roznava, HPS Velky Krtis, ZLC Nitra) in the Slovak Republic. The estimation of the leakages from these facilities is 14 007 t of CH₄ (according the continual measurements). The distribution losses in the distribution pipelines were estimated according to the expert's judgment of the Slovak Gas Industry, Ltd. with the following methodology:

Distribution losses [kg CH₄] = 233 814 [m³ ZP] * 0.975 * (273.15/(273.15+15)) * 0.7176 = 155 t of CH₄.

Fugitive emission CH₄ from transit and distribution of NG = 14 007 + 155 = 14 162 t of CH₄.

An additional emissions are fugitive emissions from NG and oil production in SR = 1 607 – 4 188 t of CH₄ (calculated according to IPCC methodology – table 6). That is mean, that the total fugitive emissions of CH₄ from transit and distribution of NG + from NG and oil production in SR 15 769 – 18 350 of CH₄ according to the national methodology. This approach seems to be less quality, that the estimation with the applications new refined EF (CH₄) (high) for tier 1, based on North America data (IPCC). The national data from The Slovak Gas Industry, Ltd. are not available for the whole time series from 1990.

Emission Factors and Emissions

The fugitive emissions from transport and distribution of NG were calculated according using the new emissions factor refined EF (CH₄) for tier 1, based on North America data – IPCC Good Practice Guidelines, table 2–16 (max. level of emissions – 32 097 t CH₄). In the Table 3. 26 are presented of fugitive methane emissions for activities related to NG and Oil operations, calculated with applications new refined EF (CH₄) (high) for tier 1, based on North America data.

The results of the calculated fugitive methane emissions (Table 3. 27) show, that disaggregating of gas and oil industry to main- and sub-categories according to principles „good practice“ improved quality of balances. The results received from the calculation of methane emissions with applications new refined EF (CH₄) (high) for tier 1, based on North America data are the most real values. The trend of fugitive emissions CH₄ from transport and distribution of natural gas in SR is increasing. It is due to the expansion of the distributed system and growth of NG consumption in SR.

Table 3. 26: New refined EF (CH₄) for tier 1, based on the balance in North America

Category	Emission Type	EF (low)	EF (high)	Unit
NG production	fugitive	2.60E-03	2.90E-03	GgCH ₄ /mil.m ³ NG
	flaring	1.10E-05	1.10E-05	GgCH ₄ /mil.m ³ NG
NG processing	fugitive	6.90E-04	10.7E-04	GgCH ₄ /mil.m ³ NG
	flaring	1.30E-05	1.30E-05	GgCH ₄ /mil.m ³ NG
NG transmission	fugitive	2.10E-03	2.90E-03	GgCH ₄ /km of pipeline
	venting	0.80E-03	1.20E-03	GgCH ₄ /km of pipeline
NG storage	all	4.30E-04	42.0E-04	GgCH ₄ /mil.m ³ of withdraw. NG
NG distribution	all	5.20E-04	7.10E-04	GgCH ₄ /km of distributed mains
Oil production	fugitive	1.40E-03	1.50E-03	GgCH ₄ /mil.m ³ Oil
	venting	6.20E-05	27.0E-05	GgCH ₄ /mil.m ³ Oil
	flaring	0.50E-05	27.0E-05	GgCH ₄ /mil.m ³ Oil
Oil transportation	all	5.40E-06	5.40E-06	GgCH ₄ /mil.m ³ Oil – pipeline

Table 3. 27: Fugitive methane emissions calculated with applications new refined EF (CH₄)

Category	Quantity	Unit	EF(low)	EF(high)	CH ₄ (low)	CH ₄ (high)
			GgCH ₄ /mil.m ³ NG GgCH ₄ /km	GgCH ₄ /mil.m ³ NG GgCH ₄ /km	t CH ₄	t CH ₄
NG* production fugitive	194 000 000	m ³ ZP	2.60E-03	2.90E-03	662	662
NG* production flaring	194 000 000	m ³ ZP	1.10E-05	1.10E-05	53	53
NG processing fugitive	194 000 000	m ³ ZP	6.90E-04	1.07E-03	133.86	207.58
NG processing flaring	194 000 000	m ³ ZP	1.30E-05	1.30E-05	2.52	2.52
NG storage fugitive	11 000 000	m ³ ZP	4.30E-04	4.20E-03	4.73	46.20
NG transport fugitive	2 270	km	2.10E-03	2.90E-03	4 767.00	6 583.00
NG transport venting	2 270	km	8.00E-04	1.20E-03	1 816.00	2 724.00
NG distribution fugitive	30 566	km	5.20E-04	7.10E-04	15 894.32	21 701.86
Oil production fugitive	28 000	t	1.40E-03	1.50E-03	39.20	42.00
Oil production venting	28 000	t	6.20E-05	2.70E-04	1.74	7.56
Oil production flaring	28 000	t	5.00E-06	2.70E-04	0.14	7.56
Oil transport fugitive	11 145 449	t	5.40E-06	5.40E-06	60.19	60.19
Total					23 434.52	32 097.30

Note: NG* production – the values of fugitive and flaring methane emissions were calculated on base reported data of vented NG – 2.1 mil.m³ and flared NG – 1 mil.m³ (Statistic Office of the SR – 2006) These emissions are estimated to 30.72 t, total is 32 128.2 t.

Table 3. 28 presents recalculated fugitive emissions of methane from transport and distribution of natural gas activities during 1990–2006 according the IPCC Good Practice Guidelines, Table 2–16 methodology using the EF (high) (IPCC, 1996).

Table 3. 28: The total CH₄ fugitive emissions from transport and distribution of NG in the SR in 1990–2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Fugitive emissions of CH ₄ (Gg)																	
NG	24.45	24.97	24.24	25.09	26.58	29.13	29.73	29.98	32.01	31.99	34.06	34.86	33.74	35.93	34.32	31.96	32.13

Trend Consistency

The trend of fugitive emissions of CH₄ from transport and distribution of natural gas in the SR is increasing. It is due to the expansion of the distributed system and growth of NG consumption in SR.

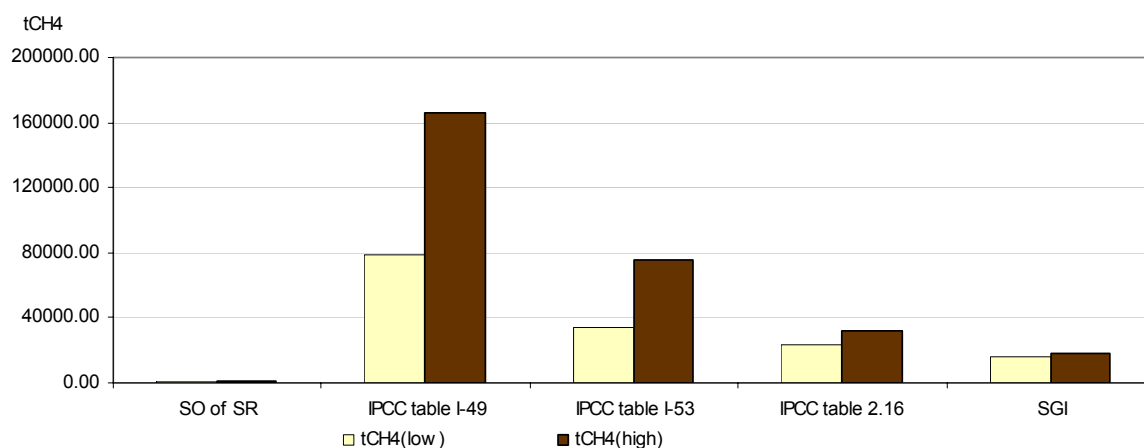
Except of the fugitive emissions CH₄ from transport and distribution of natural gas in SR were calculated CO₂ emissions on the base of natural gas composition. The average value of CO₂ content in natural gas in 2006 year was 0.1917 % mol.

The comparison between the methodologies used for calculation (national approach according the Slovak Gas Industry, Ltd. and IPCC) of the fugitive methane emissions from transport and distribution of natural gas in SR is shown on Figure 3. 7.

The application EFCH₄ – IPCC default EF CH₄ from oil and NG for regions of former USSR and Eastern Europe (IPCC Guidelines, Reference Manual Table I-49) gives too high results (78 364–165 926 t CH₄) and are approximately 3.3–5.2 times higher as the above-mentioned values. The estimate of the Statistical Office for distributed losses (1 290 t CH₄) is too low.

For the balance of the fugitive methane emissions from transport and distribution of natural gas in SR we recommend to use value, calculated using applications new refined EF CH₄ for tier 1, based on North America data - IPCC Good Practice Guidelines, Table 2–16 (max. level – 32 128 tCH₄)

Figure 3. 7: Comparison of the fugitive methane emissions calculated from IPCC factors and Slovak Gas Industry, Ltd. methodology



Recalculation and Time Series

Fugitive CO₂ emissions from 1.B.2 category – natural gas

The Slovak Republic made decision to re-evaluated CO₂ emissions from natural gas categories 1.B.2.B-d (production, processing, transmission, distribution, other leakage, venting and flaring and storage) according to the recommendations of ERT during in-country review. The emission factor for CO₂ fugitive emissions was estimated from the specific analytical measurements of natural gas

composition shown in the following Table 3. 29. The measurements are provided by accredited laboratories of The Slovak Gas Industry Company, Ltd.

Table 3. 29: The results from the analytical measurements due in accredited laboratories of Slovak Gas Industry company in the period 2000–2006

	Composition of Natural Gas [%]									
Year	CH ₄	C ₂ H ₆	C ₃ H ₈	i-C ₄ H ₁₀	n-C ₄ H ₁₀	i-C ₅ H ₁₂	n-C ₅ H ₁₂	C ₆ H ₁₄	CO ₂	N ₂
2000	97.14	1.13	0.37	0.05	0.07	0.01	0.01	0.02	0.27	0.93
2001	97.37	1.03	0.32	0.04	0.06	0.01	0.01	0.01	0.23	0.92
2002	97.42	1.03	0.32	0.04	0.06	0.01	0.01	0.01	0.21	0.89
2003	97.57	0.96	0.31	0.05	0.06	0.01	0.01	0.01	0.15	0.87
2004	97.69	0.95	0.29	0.05	0.05	0.01	0.01	0.01	0.12	0.82
2005	97.50	1.04	0.34	0.05	0.06	0.01	0.01	0.01	0.14	0.84
2006	97.22	1.18	0.37	0.05	0.06	0.01	0.01	0.01	0.19	0.85

According the activity and input data provided in the Table 3. 29, the calculation of so-called recalculation factor for estimation CO₂ emissions from natural gas treatment was evaluated to be 5.44 CO₂ in g per Gg of CH₄.

The N₂O emissions are not estimated (negligible) in the total content of natural gas and oil composition by flaring (measurements in the accredited laboratories).

The results are summarized in Table 3. 30 and Table 3. 31.

Table 3. 30: The recalculation changes in the fugitive emissions of natural gas in category 1B2 in Gg of CO₂

		1B2
Year of sub.	Category	CO ₂
1990 (2006)		NO
1990 (2007)		0,14568
Differences in %		100,00
Differences in Gg		0,14568

Table 3. 31: The new estimated CO₂ emissions in the 1990–2006 from fugitive emissions

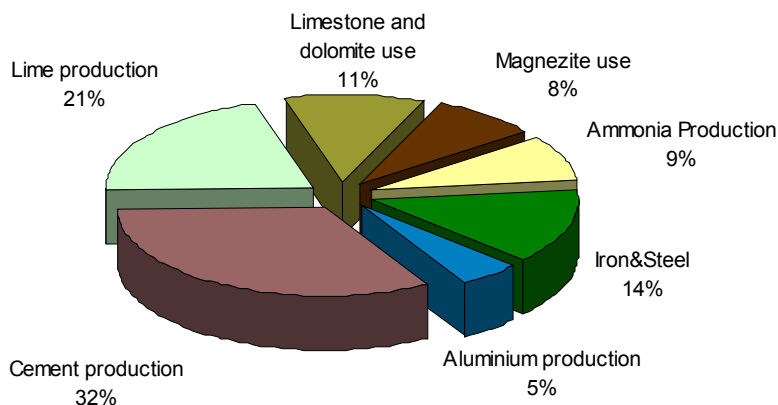
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CO ₂ (t)	145.7	132.6	128.8	133.2	141.2	154.7	157.9	159.2	170.0	169.9	180.9	185.2	179.3	190.9	182.4	169.7	174.7

4 INDUSTRIAL PROCESSES

The Industrial Processes sector in the Slovak Republic is a source of CO₂, CH₄, N₂O, NO_x, CO, NM VOC, SO₂, CF₄, C₂F₆, and SF₆ pollution. Even though the emissions of CO₂ and N₂O are reported in this sector only, because of problematic estimation of this emissions and hardly separation of industrial sources and fuel combustion sources each other in industrial processes. The emissions of CO₂ occurring by manufacture of glass, ammonium production and iron & steel production are included in sectoral approach of the energy sector – manufacturing industries and in the reference approach in the balance of fossil fuel combustion. The Faculty of Chemical and Food Technology of Slovak Technical University was took responsibility for preparation of this emission balance and followed the instructions of IPCC methodology and Good Practice Guidance (IPCC, 1996 and 2000). The information used in the report was obtained from different sources as well (Statistic Office of the SR, Ministry of Economy, Union of Slovak Chemical Industry, plant operators, producer etc). The obtained information was checked with the experience of the SHMI with monitored industrial technologies. The main attention was paid to the biggest sources of emissions of greenhouse gasses. This approach made it possible to obtain real picture on emissions in the Slovak Republic from industrial processes sector.

Whereas the N₂O emissions comes from the nitric acid production only (5.05 Gg of N₂O) (this category is key source by level and trend assessment), the cement, lime, limestone and dolomite use and iron & steel production are very important key sources of CO₂ emissions. Total anthropogenic emissions of CO₂ from this sector are 4 124.31 Gg and the major share comes from mineral production (3 013.57 Gg) (Figure 4. 1).

Figure 4. 1: The share of individual technologies in the industrial processes sector in 2006



4.1 Cement Production

Methodology and Activity Data

According to the IPCC Guidelines, it is a good practice that the amount of CO₂ emission is calculated from the mass of produced cement clink. However, in the Slovak Statistical Annual Report only mass of produced cement is published. Therefore, the emission factor of CO₂ has to be recalculated to the mass of produced cement. For this reason two values of emission factor of CO₂ are presented. One of them is related to the cement clink production, the other to the cement production.

Cement plants, where the cement clink is produced, are decisive for inventory of greenhouse gases. The CO₂ emissions originate at clink production. Production of cement from clink consists in milling the

clink with some solid additives. Therefore it is meaningful to balance just the clink production. Amount of produced cement is not important for greenhouse gases emissions.

As we stated above it is easy to estimate the production of CO₂ at the cement production because the chemical reactions are rather simple. Content of cement clink in cement varies in the range 67.3 % – 82.0 %. This value is known for every cement plant. The weighted average value of the clink content in the cement is calculated annually.

The content of CaO in the cement clink varies from 65.3 % to 69.7 %. The value of the weighted average is calculated to 67.11 % in 2006 and update annually. It follows with the estimation of the emission factor of CO₂ related to the cement clink.

Cement is produced by a high temperature reaction of calcium oxide (CaO) with silica (SiO₂) and with alumina (Al₂O₃). A source of calcium oxide is limestone (CaCO₃). As the cement clink is produced at the temperature of 1 450°C the reaction produces carbon dioxide. The other emissions originate from impurities in the raw material (SO₂).

The weighted average value of the clink content in the cement is 75.35 % in 2006. This value is known for every cement plant. According to the IPCC Methodology (IPCC, 1996) it is good practice, that amount of CO₂ emission is calculated from the mass of produced cement clink. However, in the Statistical yearbook (SY, 2006) there is only mass of produced cement available. Therefore, emission of CO₂ is calculated from the mass of produced cement.

The Slovak Republic is using Tier 1 methodology for CO₂ emissions estimation from cement production based on activity data of clinker production. The methodology is consistent from base year, but before 1996 no detail statistical information were available about clinker production from the operators nor Statistical Office. The estimation was made according the average calculation of CaO content in cement produced and average emission factor for amount of clinker was calculated. The background excel sheet is provided detail figures about clinker production in the SR from 1990.

Emission Factors and Emissions

It follows that the emission factor of CO₂ related to the cement clink is 526.82 kg CO₂ / 1 t of cement clink in 2006. The emission factor of CO₂ recalculated to the production of cement is 380.21 kg CO₂ / 1 t of cement (only the plants, where the clink is produced, are included). The total sum of cement production in the Slovak Republic was 3 587 420 t and total sum of cement clink production was 2 589 079 tons (Table 4. 1).

Table 4. 1: The comparison of EFs and emissions of CO₂ in 2001–2006

Year	2001	2002	2003	2004	2005	2006
Emission Factor of CO₂ [t/t of cement clink]	0.5016	0.5063	0.5157	0.5261	0.5243	0.5268
Emission Factor of CO₂ [t/t of cement]	0.38	0.3643	0.3862	0.3862	0.375	0.3802
Emission of CO₂ [Gg]	1,187.43	1,144.19	905.00	1,194.84	1,233.51	1,363.98

Key Source and Uncertainties

It should be mentioned that calculation of uncertainties according to Monte-Carlo method couldn't be done because of lack of necessary data. Thus, the uncertainties in mass of clink (2 %), composition of limestone (3 %), composition of clink (2 %) and mass of non-reacted limestone (5 %) were estimated according to GPG 2000 for each plant. It follows that uncertainty of EF (per clink) is 2.0 % and uncertainty of CO₂ emissions is 3.5 %.

4.2 Lime Production

Methodology and Activity Data

From a chemical point of view, lime is calcium oxide (CaO). It is produced by the thermal decomposition of limestone at the temperatures of 1 040°C–1 300°C. Carbon dioxide is produced according to the same reaction scheme as shown above in the case of cement production. According to the new data on average purity of lime, the purity of lime varies in the range 94–99 %. The weighted average value is 96.2 % with uncertainty 3.0 %.

Emission Factors and Emissions

The emission factor of CO₂ using the new data on purity of lime is 754.94 kg CO₂ per 1 ton of lime (0.785 × 0.966). In older inventories, the value 97 % was used (Table 4. 2).

Table 4. 2: The recalculated CO₂ emissions from lime production in the SR in 2000–2006

Year	2000	2001	2002	2003	2004	2005	2006
	(Gg)						
Lime Production	753.59	815.96	918.99	781.69	908.94	1,041.71	1,131.24
Emissions CO₂	539.57	584.22	657.99	573.17	672.16	785.83	854.02

Recalculation

In older inventories (since 2003) lime production from Carmeuse Vapenka Kosice was not included; the data on lime production were not supplied by the plant. However, in 2006 the older data from the plant were also obtained. The corrected data about lime production and CO₂ emissions in the period 2003–2005 were reported.

Key Source and Uncertainties

It should be mentioned that calculation of uncertainties according to Monte-Carlo method could not be done because of lack of necessary data. Thus, the uncertainties in mass of lime (2 %) and content of CaO in lime (2 %) were estimated according to the IPCC Good Practice Guidelines for each plant. It follows that uncertainty of EF (per clink) is 0.9 % and uncertainty of CO₂ emissions from lime production is 1.4 %.

4.3 Limestone and Dolomite Use

Methodology and Activity Data, Emission Factors and Emissions

At thermal decomposition or chemical reactions of limestone to clink carbon dioxide is produced. The maximum value of emission factor of CO₂ is 440 kg CO₂/1 t of consumed limestone, which is the recommended value according to the IPCC. However, the average content of CaCO₃ in raw material in the Slovak Republic is 97 %, therefore the emission factor CO₂ has to be lowered to 427 kg/1 t of consumed limestone (440 × 0.97). In this category the mass of consumed limestone in industrial processes except of cement and lime production is presented. The recalculated amounts from the previous submission of consumed limestone according to the sources and emissions of CO₂ are summarized in Table 4. 3: Total emission of CO₂ at limestone utilization in the period 2000–2006. The new data are correct while the previous ones were influenced by wrong methodology that yielded to high consumption of limestone at iron and steel production. (According to the information from the plant, instead of limestone consumption per iron ore the CO₂ emission per tone of pig iron was used in the older inventories. Therefore, the mass of the consumed limestone after our recalculation was more than two times higher.) The amount of CO₂ emissions is based on the consumption of limestone and dolomite at production of calcium carbide, glass and iron & steel.

Table 4. 3: Total emission of CO₂ at limestone utilization in the period 2000–2006

Year	2000	2001	2002	2003	2004	2005	2006
	(Gg)						
Limestone Use	403.83	386.88	361.73	374.71	615.95	471.19	454.96

It should be mentioned that consumption of iron ore decreased in the comparison with 2005. It follows that consumption of limestone decreased from this source as well (Table 4. 4).

Table 4. 4: Total emission of CO₂ and the emission factors of CO₂ at limestone utilization in 2006

Year	Consumption of limestone at				emission of CO ₂	emission factor of CO ₂
					[t]	[kg / t of limestone]
	iron and steel production	calcium carbide production	glass production			
	[t]	[t]	[t]	total [t]		
2006	840,707	151,857	72,907	1,065,471	454,956	427

Key Source and Uncertainties

It should be mentioned that calculation of uncertainties according to Monte-Carlo method couldn't be done because of lack of necessary data. Thus, the uncertainties in mass of used limestone and dolomite (2 %) and their composition (3 %) were estimated according to IPCC Good Practice Guidelines for each plant. It follows that uncertainty of EF (per clink) is 0.9 % and uncertainty of CO₂ emission is 4.1 %.

4.4 Magnesite Use

Methodology and Activity Data, Emission Factors and Emissions

At thermal decomposition of magnesite carbon dioxide is produced. Maximum emission factor of CO₂ is 522 kg CO₂/1 t of magnesite or after recalculating 1 092 kg CO₂/1 t of magnesite clink. Purity of magnesite in the SR varies mainly from 84 % to 94 %. The weighted average is 90.02 % and the emission factor of CO₂ is 983.05 kg CO₂ / 1 t of magnesite clink. Finally, all the necessary data on magnesite clink production are available. In Table 4. 5, the data on produced magnesite clink together with emission data of CO₂ are summarized.

Table 4. 5: Total emission of CO₂ at magnesite clink production in the period 2000–2006

Year	2000	2001	2002	2003	2004	2005	2006
	(Gg)						
Magnesite Clink	436.49	459.71	467.06	479.23	524.93	481.88	346.49
Emissions CO₂	409.82	431.63	438.52	449.95	499.67	476.00	340.62

Key Source and Uncertainties

It should be mentioned that calculation of uncertainties according to Monte-Carlo method couldn't be done because of lack of necessary data. Thus, the uncertainties in mass of produced magnesite clink (2 %, except of Slovmag production – 10 %) and it's content (3 %, except of Slovmag data – 10 %) were estimated according to IPCC GPG 2000 for each plant. It follows that uncertainty of EF (per clink) is 1.8 % and uncertainty of CO₂ emissions from production of magnesite clinker is 2.2 %.

4.5 Ammonia Production

Methodology and Activity Data, Emission Factors and Emissions

Ammonia is made from nitrogen and hydrogen by fine-tuned versions of the process developed by Haber, Nernst and Bosch. In principle, the reaction between hydrogen and nitrogen is easy. However, to get a respectable yield of ammonia in a chemical plant is necessary to use a catalyst and extreme pressure. For estimation of the greenhouse emissions from the production of ammonia was used the emission factors recommended by IPCC (1.5 t/t of ammonia). However, the emissions of CO₂ and CH₄ are included in energy sector in natural gas consumption (1.A.2c). The Table 4.6 shows the total consumption of natural gas by production of ammonia, total ammonia production in the SR in 2000–2006 and the emissions, which were included in the energy sector, but after recalculation the emissions are included in the industrial processes, category 2.B.1. The overall plant specific EF for the whole time series is 0.989 t CO₂/t produced ammonia (only one producer of ammonia is operated in the Slovak Republic. In 2006, Duslo a.s. produced 354 558 tons of ammonia. Based on data supplied by the plant 223 795 440 Nm³ (167 000 tons) of natural gas was consumed for ammonia production and 228 129 942 Nm³ (447 858 tons) of CO₂ resulted from that. However, 49 536 166 Nm³ (97 248 tons) of CO₂ was used for urea production. The rest of CO₂ (350 610 tons) escaped to the air. The presented data are based on the measurements in the plants, therefore the emission factor of CO₂ changed in comparison with the older inventories. Moreover, consumption of CO₂ for urea production is taken into account for the first time.

Table 4. 6: Total production of ammonia in the SR in 1990–2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
	(Gg)																
NG Consumption	169.56	165.61	162.12	97.45	166.69	180.77	193.91	193.07	171.59	171.45	189.82	193.96	188.40	166.59	192.13	186.55	167.00
Ammonia Produced	360.00	351.60	344.20	206.90	353.90	383.80	411.70	409.90	364.30	364.00	403.00	411.80	400.00	353.68	407.90	426.35	354.56
Emissions CO ₂	356.04	347.73	340.41	204.62	350.01	379.58	407.17	405.39	360.29	360.00	398.57	407.27	395.60	349.79	403.41	421.66	350.66

4.6 Nitric Acid Production

Methodology and Activity Data

In a world measure the nitric acid production consumes about 20 % of all ammonia produced. Nitric acid production in the Slovak Republic is an important source of N₂O emissions from industrial processes and key source category in level and trend assessment.

Emission Factors and Emissions

The emission factors of N₂O was presented as 5.43 kg N₂O / 1 t HNO₃ and 5.58 kg N₂O / 1 t HNO₃ until now. Direct measurements of N₂O emissions were realized in Duslo Sala in the period 2005–2006, the following EFs on the basis of Norsk Hydro since 1990 are correct 13 kg N₂O/1 t HNO₃ for atmospheric plant, 7 kg N₂O / 1 t HNO₃ for medium pressure and 9 kg N₂O / 1 t HNO₃ for high pressure plant. In Duslo Sala, out-dated atmospheric plant was closed in 2000. The medium-pressure plant in Duslo Sala was renewed in 1980s, thus EF was also assumed to be 7 kg/ 1 t of HNO₃. It is in agreement with the data presented by Norsk Hydro according to the IPCC Good Practice Guidance. It seems that discrepancy between previously and recently used EFs is based on the non-correct information about holding time of gasses at catalyst and temperature in reactor. KD1 in Duslo was last time improved in 70-ties, EF for "out-dated plants" according GPG 2000 10–19, in the lowest part (13 kg N₂O/1 t HNO₃). KD2 in Duslo was improved in 80-ties. It is very realistic, that now is EF higher than 7 kg N₂O/1 t HNO₃, but not enough evidences are available. According to the measured data EFs are: 7.3 and 10.332 kg N₂O / 1 t of HNO₃ for medium-pressure plant in 2005 and 2006, respectively; 9.2 and 9.02 kg N₂O / 1 t of HNO₃ for high-pressure plant in 2005 and 2006, respectively. The technology used in Chemko, a.s. is the same as in Duslo, a.s. (medium pressure plant). The production tech-

nology in Chemko was improved in 1994. Until 1994 the old value from Duslo can be used (before reconstruction) and after 1994 improved EF from Duslo was used.

Therefore the recalculation of emissions of N₂O was necessary on the basis of Norsk Hydro data since 1990. The following emission factor was used in 1990 based on weighted average: 8.95 kg N₂O/1 t HNO₃ for total amount of produced nitric acid. New, corrected data are presented in Table 4. 7. Emission of N₂O at nitric acid production in 2006 was 5.049 tons.

Table 4. 7: Table of new estimated N₂O emissions and weighted EFs in the 1990–2006 from nitric acid production

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
N ₂ O (Gg)	3.71	2.57	2.29	1.77	3.16	3.63	4.24	4.01	3.41	2.56	3.33	3.77	3.37	3.73	4.26	4.13	5.05
EF kg/t	9.25	8.51	8.24	7.59	8.77	9.1	9.49	9.52	9.04	8.36	8.18	8.11	8.34	8.2	8.12	8.3	8.95

Key Source and Uncertainties

It should be mentioned that calculation of uncertainties according to Monte-Carlo method couldn't be done because of lack of necessary data. Thus, the uncertainties in mass of produced nitric acid (2 %) and used EF (5 %) were estimated according to IPCC Good Practice Guidelines for each plant. It follows that uncertainty of EF is 3.4 % and uncertainty of N₂O emissions is 6.7 %.

Recalculation and Time Series

Total increasing of N₂O emissions from category 2.B.2 nitric acid production in 1990 was 129.67 % in comparison to the previous submission (2006). The results are summarized in Table 4. 8.

Table 4. 8: The recalculation changes in the nitric acid production in category 2B2 in Gg of N₂O

		2B2
Year of sub.	Category	N ₂ O
1990 (2006)		1,6395
1990 (2007)		3,7655
Differences in %		–129,67

4.7 Production of Calcium Carbide

Methodology and Activity Data

Calcium carbide (the correct chemical name of this compound is calcium acetylide) is produced in by the reaction of CaO and coke at submerged arc furnace. Recently this technology was modernized in order to decrease the emissions (in 1992) in the SR. The main component of released emissions is CO₂. Emission factors for CO₂ (0.76 t CO₂/t of CaC₂ at decomposition of limestone; 1.09 t CO₂/t of carbide at the reduction and 1.1 t CO₂/t of carbide at using of the product) were taken from the IPCC recommendation. Emissions of CO₂ emitted at decomposition of limestone are included in limestone and dolomite use in this inventory and emissions of CO₂ at the reduction are included in energy sector – consumption of coke (1.A.2b) and category limestone and dolomite use (2(I)A.3).

97 257 tons of CaC₂ (calcium carbide) was produced in the Slovak Republic in 2006. According to data supplied by NCHZ, a.s. Nováky, 57 624 tons of produced calcium carbide was exported from the SR. The rest was used for acetylene production. At this production no emission of CO₂ is released. The emissions of CO₂ at the reduction step are 106 010 tons.

4.8 Production of Metals

4.8.1 Iron and Steel Production

Methodology and Activity Data

Pig iron is produced by the reduction of iron ore by coke in a blast furnace, the main emission being CO₂. Limestone is added as an agent for slag formation. Pig iron contains about 4 % of carbon and in the next step; part of this carbon is oxidized. This process is accompanied by CO emissions most of which is burned to CO₂. Iron ore was processed to pig iron. The emissions of CO₂ from added limestone are included in consumption of limestone in this inventory (2(l)A.3). The mass of used coke is included in energy sector (1.A.2a).

Emission Factors and Emissions

In an open-hearth process the 4 836 492 tons of steel was produced, the emission factor for CO₂ being 116.5 kg CO₂/t of steel. This emission factor results from decreasing of carbon from pig iron (40 kg/t) to steel (2.5 kg/t). It should be noted that EF is lower than in 2005. Differences between each-year emission factors are caused by the different amounts of iron scrap added to the charge at steel making process. Differences between the emission factors are caused by different amounts of iron scrap added to charge at steel making process. For estimation of emission, recommended emission factors at steel processing were used. In older inventories, the emissions of CO₂ from coke production were included in iron and steel production as well. In this inventory new methodology was used. This methodology strictly copies the GPG 2000 – Tier 2 Method. However, there are not differences in CO₂ emissions whether the older or the new methodology is used. (Tier 2 in IPCC Guidelines – recommended method).

In order to summarize the data based on this new approach the emissions of CO₂ from steel production, which are not included in energy sector are presented in Table 4. 9 for the period 1990–2006.

Table 4. 9: Emissions of CO₂ from steel production for the period 1990–2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
	Emissions of CO ₂ (Gg)																
Steel production	420.26	373.28	348.38	378.24	392.99	378.47	344.56	362.53	365.80	403.56	415.36	442.72	484.18	535.15	539.82	506.00	563.65

Pig iron is not produced in other plants in the SR. Steel is produced also by Prakovská oceliarska spoločnosť, s.r.o. Prakovce (production of 1,180 tons of steel), by plant Metalurg (11,003 t of steel) and by ironworks Železiarne Podbrezová, a.s. (364,398 t of steel). 376,581 tons of steel was produced in these plants in 2006. Emissions of CO₂ from these plants originate only from energy production and thus they are not included in this report.

Key Source and Uncertainties

It should be mentioned that calculation of uncertainties according to Monte-Carlo method couldn't be done because of lack of necessary data. Thus, the uncertainties in mass of used coke (2 %), mass of used iron ore (2 %), mass of produced pig iron (2 %), mass of produced steel (2 %), contents of carbon in iron ore (5 %), in pig iron (25 %), in steel (25 %) and used default EF from coke (5 %) were estimated according to IPCC Good Practice Guidelines for each plant. It follows that uncertainty of EF is 5 % and uncertainty of CO₂ emissions is 5.4 %.

4.8.2 Ferroalloys Production

Methodology and Activity Data

Ferroalloys are produced in arc furnaces, submerged arc furnaces by the reduction of the mixture of iron ore, and added metal and/or metalloid (Si) oxides. In 2006, the production of ferroalloys in the Slovak Republic was as follows: 118 519 tons of ferroalloys based on Mn, 16 155 tons based on Si, ferroalloys based on Cr were not produced in 2006.

Emission Factors and Emissions

The emission factors for carbon dioxide were taken from the IPCC recommendation (1.6 t/t of ferroalloys based on Mn, 1.3 t/t of ferroalloys based on Cr and 5 t/t of ferroalloys based on Si). These emissions are softly overvalued because content of carbon in iron is neglected. However, without knowledge on composition of used iron ore and ferroalloys mass of emissions cannot be more exact. These emissions are included in energy sector (1.A.2a).

4.8.3 Aluminium Production

Methodology and Activity Data

Aluminium is produced by the electrolysis of alumina dissolved in cryolite-based melt ($t = 950^{\circ}\text{C}$). The main additions to cryolite (Na_3AlF_6) are aluminium fluoride (AlF_3) and CaF_2 . From the point of emissions view, the content of AlF_3 is of great interest. However, it should be also mentioned that the Slovak plant uses a modern technology in which most of the HF and other fluorides escaping from the electrolytic cells are absorbed and adsorbed on alumina, which is used subsequently in the electrolytic process. The anodes are made from graphite. Production of the so-called pre-baked anodes is made in a separate plant. As a result of that the emissions are much lower than in the so call Soederberg process. It may happen that at a special technological disturbance (the anode effect) the production of CF_4 and C_2F_6 can occur. Because of progress in process control this irregularity occur only 1–2 times in a month.

Emission Factors and Emissions

The emission factor for CO_2 was taken from the IPCC recommendation (1.5 t CO_2 /t of aluminium). The emission factors of PFC (CF_4 , C_2F_6) were calculated according to the Tabereaux's equation. According to the data from plants average current efficiency was 93.7 % in 2006, the number of the anode effects per pot day equals to 0.084 and their average duration was 2.51 min. It follows that the emission factors were 0.0305 kg CF_4 /1 t of aluminium and 0.00305 kg C_2F_6 /1 t of aluminium, respectively. In 2006, the number of anode effects significantly increased which resulted significantly in higher emission factors of PFC. In 2006, the Slovak aluminium company produced 158 289 t of aluminium. The EFs correspond to the most modern technology and they are summarized together with the total amounts of emissions in Table 4. 10.

Table 4. 10: An overview of emissions and EFs in aluminium production in 2006

	CO_2	CF_4	C_2F_6
Emission [t]	196 441	4.838	0.4838
Emission factor [kg/t]	1 241.026	0.0305	0.00305

Key Source and Uncertainties

It should be mentioned that calculation of uncertainties according to Monte-Carlo method couldn't be done because of lack of necessary data. Thus, the uncertainties in mass of produced aluminium (2 %), content of PFC in gas (3 %) measuring of CE (5 %), AE (5 %) and AED (5 %) were estimated according to IPCC Good Practice Guidelines for each plant. It follows that uncertainty of EFs of PFCs is 9.2 % and uncertainty of PFC emission is 9.4 %.

Consumption of SF_6 at the casting house

In 2006, SF_6 was not used in the Slovak Republic at casting. Thus, the consumption of SF_6 in 2006 was 0 kg.

4.9 Consumption of HFCs, PFCs and SF₆

F-Gases notion means the emissions of substances that, because of their effects, can be added to the greenhouse gases group. However, before COP3 in Kyoto they were not considered during the inventory and projection of GHGs. Following gases are considered to be new ones:

- HFCs – hydrofluorocarbons (23, 32, 41, 43, 125, 134, 134a, 152a, 143, 227ea, 236fa, 245ca);
- SF₆ – sulphur hexafluoride;
- PFCs – perfluorocarbons (CF₄, C₂F₆, C₃F₈, C₄F₁₀, C₄F₈, C₅F₁₂, C₆F₁₄, CF₃Br).

The aim is to evaluate the sources and emissions of selected substances in 2004. For given years the emissions are set based on list of sources, production or usage of these substances in the Slovak Republic and comments on accuracy of input and calculated data are given. Following procedure was engaged to reach the aim:

- An evaluation of the sources and emissions of selected substances in 1990–2005 based on acquired data from importers and users in 2006;
- An evaluation of the data storage in own tables and CRF tables according to IPCC methodology.

Methodology and Activity Data

For given years the emissions are set based on list of sources, production or usage of these substances in the Slovak Republic and comments on accuracy of input and calculated data are given. Good Practice Guidance documents for groups convened on the following sources:

- SF₆ emissions from electrical equipment and other sources;⁶
- Fluorinated carbon emissions⁷ from semiconductor manufacturing;
- HFCs emissions from refrigeration and air conditioning.

Good practice recommendations on seven sources of emissions of:

- Aerosols and metered dose inhalers;
- Solvent uses;
- Foams;
- Stationary refrigeration;
- Mobile air conditioning;
- Fire protection;
- Other applications.

The Revised 1996 IPCC Guidelines describe two tiers for estimating emissions from the use of OD substitutes:

- The advanced or actual method (Tier 2);
- The basic or potential method (Tier 1).⁸

Actual emission

The actual emission estimation method (Tier 2) accounts for the time lag between consumption and emissions.

⁶ SF₆ from other uses like sound-proof windows, medical purposes, military application, equipment used in accelerators, lasers and night vision goggles, car tires, sport shoes, balls, etc. are delayed for some years.

⁷ Including CF₄, C₂F₆, C₃F₈, C₄F₈, CHF₃, NF₃, SF₆.

⁸ Decision 2/CP.3 affirms that actual emissions should be used for the reporting of emissions to the UNFCCC, and that Parties should make every effort to develop the necessary sources of data.

Potential emission

The potential emission estimation method assumes that emissions occur during the year in which the chemical is produced or sold into a particular end-use sector.

Substances in question alone are not registered under the item of the Custom Tariff in the Slovak Republic. The 250 potential supplier, users and consumers of the substances in question are addressed on the base of the description of the substances with GWP. These potential consumers of the substances in question are yearly sent the letter authorised by the Ministry of Environment containing the tables. Data in these tables enable to determine the rate of emissions and new filling using the method of approximation. Received data are in case of doubt verified at sender and they are summarised in the tables according to the way of use. Tables used since 1990 are used for data storage in order to retain the continuity of observing the trends of sent data.

Evaluation of sent and processed data on the sources and emissions of the substances in the Slovak Republic is realized on the base of recommended emission factors corrected according to the received data by methodology IPCC (IPCC, 1996):

- In own Excel tables – evaluation according to sent data and IPCC methodology;
- In CRF IPCC tables – evaluation according to sent data and IPCC methodology.

Tables used in 1990–2005 are used also in 2006 for data storage in order to retain the continuity of observing the trends of sent data.

An assessment of direct and aggregated emissions of new gases is based on the approximation of the coolant consumption trend considering the up-to-date trend of PFCs and HFCs decrease and start of HFCs coolants use. Approximation is based on following analyses:

- Trend of decrease of CFCs and HFCs coolants in appliances fillings, supplies with certain rate of recycling of these coolants and taking into account operational emissions of coolants;
- An approximation of the trend of total consumption and emissions of halogenated coolants;
- An approximation of the trend of total consumption and emissions of particular halogenated coolants.

Conditions for the evaluation of retrospective and perspective of the trend of consumption of HFC were thus prepared using the total sums of purchased and cumulated of CFC, HCFC and HFC coolants.

The Revised 1996 IPCC Guidelines describe two tiers for estimating emissions, which occur during the year in which the chemical is produced or sold into a particular end-use sector. The bottom-up approach takes into account the time lag between consumption and emissions explicitly through emission factors. The top-down approach takes the time lag into account implicitly, by tracking the amount of virgin chemical consumed in a year that replaces emissions from the previous year. The basic approach we use is top down, but we follow the cumulative amount of substances and calculate emissions using emissions factors. We follow; compare the amount of substances used to substitute emissions calculated from:

- Top down approach;
- Cumulative amount of substances and emissions factors.

Emission Factors and Emissions

The lifetime of SF₆ is up to 3 200 years, GWP is up to 23 900 kg CO₂/kg, and it is used as an extinguishing medium in electronics, protection against explosion, isolation, sterilization, detection gas, alloying of Al and Mg, tobacco production. Beside that it is substitute for halons, 90 % of its use is devoted to the isolation in high and low voltage electric equipment because of higher safety level and dimension reducing, 10 % of its use is devoted to the surface treatment of metals and so on in the world. Up to thousands kg of SF₆ can be in one interrupter of high voltage. Highly toxic products originate at temperatures over 400°C. Alternatives at low voltage are vacuum and air. In last times, it was used in the older types of extinguishers and at aluminium production in the Slovak Republic. Today it is used especially as an isolating gas in high voltage switchgears, in high voltage switchers at

electricity distribution plant with supposed release 1 % of filling per year. A filling is dimension for 30 years without refilling. Since 1993, the SF₆ is used for anti noise and thermal isolation into windows. It is filled in close cycles practically without releases.

The perfluorocarbons are produced already 30 years. They are used in special heating and cooling. In electronics, they are used in gaseous state as a protection against explosion, isolation and detection gases. Further, they are used for cleansing, dissolving, fluorine etching of glass and as extinguishing media.

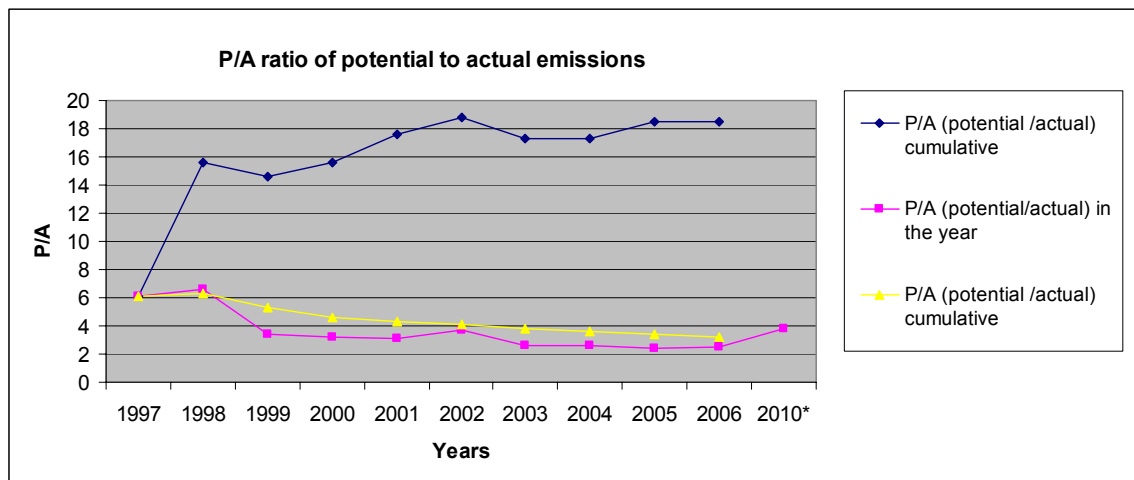
Because of expected prohibition of coolant R12 import, 700 tones of it was purchased in years 1993 and 1995. This amount is gradually consumed and coolant R12 was still available in 2001. Coolants consumption has decreased in the Slovak Republic comparing to 1990 by 60 %.

Up to the year 1998 the products designed for coolants R22, R134a and R404A were usually imported. Only in 1999 the indications of import of products containing coolants R407C and R410A are emerging. Because of the entry into force of the Act No. 76/1998 on the Protection of the Ozone Layer of the Earth on April 1, 1998, the year 1998 was the year of making the supplies of coolant R22. Consumption of alternative coolants R401A and R409A for R12 started to decrease in the year 2002. Coolants R407C and R410A shows the growth tendency since 1999. Coolant R134a shows continuing growth tendency mainly because of rising import of cars with AC. After 2011 we can expect slight decreasing of R134a consumption. The potential and real emissions in aluminium production were decreased in 1997, 1998 and mainly in 1999 comparing 1995 due to the new technologies of aluminium production. It can be significantly seen on the decreased P/A ratio in the year 1999 in the next graph. Since the year 2000 these emissions has not been already included to this part of inventory. A consumption of coolants and extinguishing media in 1998 has decreased because of decrease of investments in construction works in the Slovak Republic. But in the future mainly potential emissions will increase due to gradual substitution of CFC and HCFC coolants by HFC coolants, especially coolant R134a or coolants R125 and R143a as components in mixtures of coolants R 404A, R407C, R410 and so on. On the other hand, there is the decrease from aluminium production and extinguishing media. Increase of extinguishing media started in the year 2000 using not only HFC 227ea, but HFC 236fa as well. There are calculated only 1 % emissions from new extinguishing media. Today there are no emissions from foams, solvents and aerosols because these substances are not used for these purposes in the Slovak Republic. A usage of PFC solvents and extinguishing media will probably show its effect on emissions in the future (Table 4. 2).

In relation with the high reliability of the new cooling equipments with the content of HFCs, PFCs and SF₆ and progressive implementation of preventive service, the ratio of cumulative potential and actual emissions is still rising although in the years 2003/ 2004 and 2005/2006 was on the same level. The ratio of potential and actual emissions and as well of the cumulative potential and cumulative actual emissions is declining. It is because the actual emissions are rising adequately to the cumulative amount of these HFCs substances – substitutes of ODS.

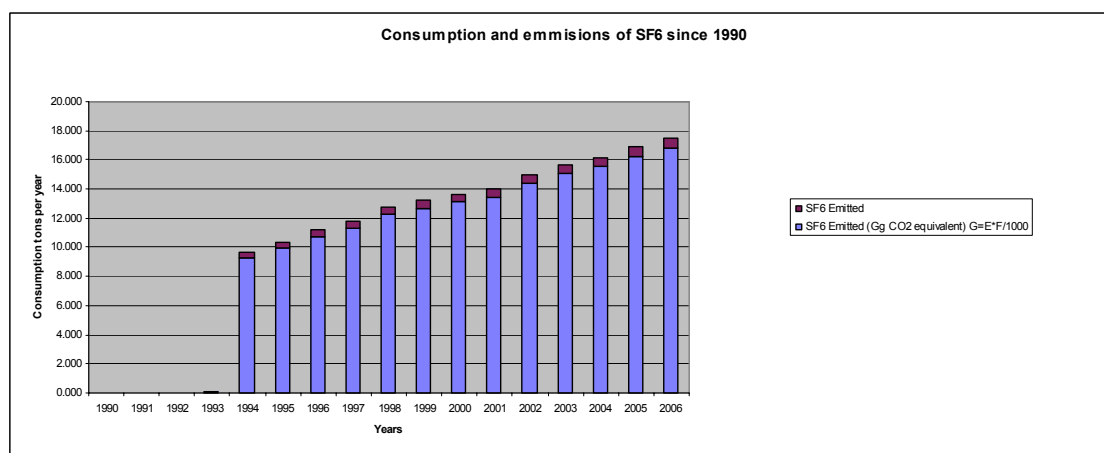
The above analysis shows that in the year 2006 was reached faster application of HFCs because the HCFCs applications have been completely abandoned in new installations by the Act n. 76/1998 Z.z. in version n. 408/2000 Z.z. in the year 2005. Decline of extinguishing media consumption is because they are very expensive and the investment to them is planned for a longer time.

Figure 4. 2: The ratio of potential to actual emissions P/A



Notices: Potential and actual emissions of PFC 14 and PFC116 – C_2F_6 Perfluorethane originates as a by-product during the aluminium production in Žiar nad Hronom. Since 2000 PFC 14 and PFC116 originated as a by-product during the aluminium production hasn't been included to the emissions of this part of inventory. There are calculated less than 1 % emissions from new extinguishing media (without consumption for extinguishing- no consumption was recorded in the last years).

Consumption of SF_6 is approximately at the same level. Technical solutions, which could substitute this gas, are still very expensive. Consumption of PFCs during etching is practically without emissions. In relation with the high reliability of the new cooling equipments with the content of HFCs, PFCs and SF_6 and progressive implementation of preventive service, the ratio of potential and actual emissions in the year 2003 and as well the ratio of the cumulative potential and actual emissions is declining. It is because the cumulative amount of these HFCs substances – substitutes of ODS is rising quicker as the actual emissions are declining. The saturation of this ratio we can expect only after the year 2010 (Figure 4.3).

Figure 4. 3: Consumption and emissions of SF_6 since 1990

Key Source and Uncertainties

Inventory of F-gases is complicated due to high number of substances HFCs, PFCs and SF_6 , totally 12 HFCs substances. They are components of different mixtures used in different more than 15 applications. Each application has its own development of consumption and trend of emission development. According to the IPCC GPG it is no sense to deal with uncertainties, which do not have fundamental influence to the total emissions. This should be taken into account in all numerous applications of different F-gases. That why in the coincidence with IPCC GPG the first step is the

quantifying of uncertainties and it is done by expert judgment due to this large extent of different applications and gases for potential and actual emissions.

Given substances are not solo (independently) documented under any of items in custom scale of rates (tariff). On the base of description of the F-gases with GWP in questionnaires, they are sent to potential importers, producers, users and consumers of given substances in SR. It means that we have lot of different data sources on the base of questionnaires.

Due to the links, relations in the questionnaire to other potential importers, producers, and that the most of the companies are presented in Catalogue of RAC companies and are the members or are trained by SZ CHKT. The SZ CHKT is authorized by Ministry of Environment for training and certification of personnel, or they are on the internet, participating on the exhibitions and so on, we can assume, that more then 90 % of potential companies were addressed. Addressed companies filled the questionnaires on the base of their documentation and so the reported data should correspond to the reality. With the reported data, these companies are confronted during the next two years. It should be enough for checking and correcting the wrong data. The data processed in this way we can consider as representative. During an inventory, we can assume nonsymmetrical error distribution in reported data in the range from -5 % to + 15 %. It means that we suppose data sooner underestimated as overestimated.

Similarly, uncertainness come out from the assessing of emission factor, which is gradually decreasing during the years 1994–2006 in the range from 17 to 8 % according to the application. The lowest emission factors are on the products completed in the factories mainly in domestic refrigerators, chillers and so on. Higher emission factors are in cooling circuits assembled on the place of application for example commercial, agricultural, industrial, transport refrigeration and so on. Given range of emission factors is overcome only in car air conditioning, where emission factor is expected over 20 %. From this assessment comes out that emission factor in all applications is in the range from 8 to 25 %. Assessment of uncertainties by expert judgment is considered for the development of potential and actual emissions. Potential emissions depended on preciseness and completeness of reported data is evaluated in the range from - 5 to 15 % and actual emissions in the range from 8 to 17 %. Both distributions are nonsymmetrical. In the case of potential emissions, we suppose that reported data are sooner underestimated and in the case of emission factor, we suppose in more applications trend to the lower emission factor. Potential emissions have correlation to economical development in the SR. Uncertainties in to the relation of potential emissions are dependent on time (years). Trend of development of potential emissions can have fluctuating mainly increasing tendency, which in the future will be decreasing due to implementation of alternative natural refrigerants. Nowadays the development is given mainly by the fact that HFCs substances are substituting CFCs and HCFCs substances excluded from usage by Montreal Protocol. Emission factors depend on time (years) and correlate with the technical and technological development and to the implementation of legal acts, technical standards and so on. Trend of the development of emission factor should have decreasing tendency.

If these assessments should be exactly statistically analyzed, it would be necessary to buy software for statistical analysis by the method of Monte Carlo and analyze probability distribution of inputs it means emission factors and the movement of substances in every application. Such work would be quite extensive and it would require higher financial costs. It is therefore necessary to consider whether such work in comparison with expert judgment, which is acceptable by GPG, will be adequate to the significance and the ratio of emissions in all or only chosen applications.

Method Monte Carlo requires sequence of steps during several years. It is a method, which only on the basement of gradually acquired experiences improves quality of inventory by gradual decreasing of uncertainties.

5 SOLVENT AND OTHER PRODUCT USE

This category includes the emissions of CO₂, N₂O and NM VOC (photochemical smog) from solvent and other product use according to the IPCC Guidelines. The emissions of CO₂ from these sources are not included in the Slovak emission inventory until now. The lack of relevant input sources and emission factors for CO₂ has the significant reason for the omission this source from the inventory. In other way, the CO₂ emissions might be ballast with the high uncertainty.

The primary attention in the 2008 submission in the solvent use sector inventory was put in to the N₂O emissions. The most important problem was to collect all available input data in a consistency manner. The statistical information are poor, so it was decided to request directly the producers, importers, distributors and users.

In the frame of National Program for Emission Reduction of Non-Methane Volatile Organic Compounds were estimated total NM VOC emissions from solvent and other products use with cooperation with Ministry of Environment, team of experts on the base of Directive 1999/13/EC and upon a close cooperation with producers in the Slovak Republic.

Methodology and Activity Data

The aim of N₂O emission inventory from solvent and other product use sector is in the medicine (anesthesia) and food use (aerosol cans). There is also the consumption of N₂O for the analytical purposes, but the gas is burned after the use, so this source is not included into the total inventory. The amounts are negligible. The activity data come from the three major distributors of N₂O liquid gas – Messer-Tatragas, Linde and SIAD companies. The methodology is very simple, because the source is not key one. We can suppose that the final emissions from these sources are equal to the consumed gas. The time series was reconstructed based on statistical data about production. The total numbers of used N₂O in the sector are showed in the Table 5. 1.

Table 5. 1: The consumption of N₂O for the period 1990–2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
	tons																
Medicine	55.00	55.00	55.00	55.00	54.23	99.98	107.16	86.82	68.33	70.61	64.96	80.99	76.22	73.35	70.61	65.65	59.77
Food	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.68	108.49	117.78	188.37	212.90	206.13
Total	55.00	55.00	55.00	55.00	54.23	99.98	107.16	86.82	68.33	70.61	64.96	96.67	184.71	191.13	258.98	278.55	265.90

1990–1993 - estimated on the basis of data supplied by Messer-Tatragas.

The estimation of NM VOC emissions was processed based on IPCC Methodology (IPCC, 1996) uses CORINAIR Methodology (CORINAIR, 2003) and SNAP classification. Inventory was carried out upon the base of data about production, import, export and selling of individual type of solvents. The estimation is divided into the four categories – paint application, degreasing and dry cleaning, chemical products, manufactured and processing and other (processing of vegetable fat and oil). The activity data according to the CORINAIR methodology are in the consistency form from 1990.

Emission Factors and Emissions

The emission factors for the consumption of N₂O for the medicine and food purposes are equal to the activity data, with the supposing, that all gas is evaporated into the atmosphere. The total emissions of N₂O in the solvent and other product use sector are 265.898 tons in 2006.

The total emissions of NM VOC from this category were 37.959 Gg per year 2006.

6 AGRICULTURE

6.1 Cross-cutting

The humankind activities in Agriculture sector significantly contribute to changes of concentration of some gases in atmosphere what consequently increase its greenhouse effect as well as acidity of environment. Despite of fact that water vapour and CO₂ are gases of the highest importance sharing greenhouse effect of the atmosphere, N₂O and CH₄ emitted in Agriculture sector are considered as the most important gases from the point of view of planning adaptive measures to reduce their influence on environment. Sources of N₂O and CH₄ emissions are analyzed according to revised IPCC Methodology (IPCC, 1996), when principles of Good Practice in GHGs inventory (IPCC, 2000) in agriculture were taking account. Some national data from research projects were utilized too. Some of N₂O, CH₄ and NH₃ emissions can be reduced if effective adaptation measures are accepted in agricultural practice. Effective measures were proposed for condition of the Slovak Republic in other studies (NC SR, 2005), shortage of data, especially on storage and application of manures, resulted in fact that emissions are evaluated on the level business as usual in this study. Methodology used in this study utilized also results of research institutions sharing nitrogen fluxes in condition of the Slovak Republic.

Emissions from burning of field residuals were not defined in this study because these forms of soil cultivation are prohibited by law in SR. Area of histosols on the territory of SR is only 4 893 ha and those soils are not cultivated due to landscape protection during last years. This source is not evaluated in the inventory.

As the most important gases emitted from agriculture are considered methane and nitrous oxide. Agriculture produces about 26 % of total methane and more than 67 % of total nitrous oxide emissions in the Slovak Republic (NC SR, 2005).

The Slovak Agricultural University in Nitra, namely Dr. B. Siska was took responsibility for inventory of emissions from Agriculture sector. Methodology used also results of research institutions sharing nitrogen fluxes in condition of the Slovak Republic. Basic sources of data used for evaluations of emissions were published in:

- Census of sowing areas of field crops in the SR;
- Annual census of domestic livestock in the SR;
- Green report of the SR 1998–2007, Ministry of Agriculture of the SR;
- Statistical Yearbook 1990–2007, Statistic Office of the SR.

6.2 Methane Emissions

6.2.1 Enteric Fermentation

Methodology and Activity Data

The cattle are among all domestic livestock the most important producer of methane due to its digestive tract, weight and relatively high number as compare with other population of livestock in the SR. Therefore, trends of total CH₄ emissions reflect first numbers of animals in this category. Numbers of animal dairy cows as well as other cattle have decreased by than half during evaluated period. Except for domestic livestock category the amount of emitted methane is influenced by some parameters within the category as age or weight of animal, amount of food and its quality, consumption of energy for basal metabolisms.

Methane emissions from enteric fermentation are dominant emissions from animal husbandry and from agriculture at all. The cattle produce more than 90 % of these emissions and dairy cattle give nearly half of emissions in the category. Less than 10 % of emissions produce other categories of domestic livestock. An intensification of animal husbandry increased also methane emissions on level

100 kg CH₄ per head per year. On the other hand, higher efficiency leads to decrease of numbers of dairy cattle and consequently decrease of total methane emissions from this category.

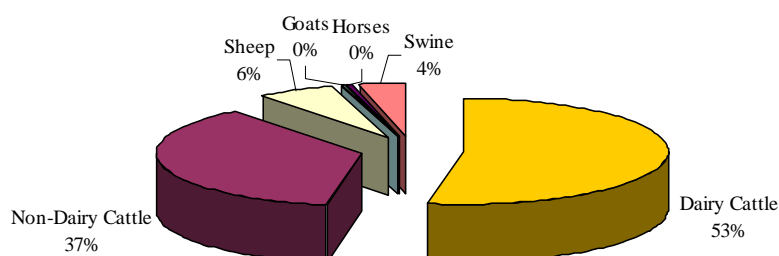
Methane emissions from enteric fermentation of dairy and non-dairy cattle are key source categories according level and trend assessment for the base year and for the 2004. The Slovak Republic used Tier 1 simple methodology based on numbers of animals and milk production for these categories. As the ERT was recalling for the revision of emissions factors for dairy cattle in enteric fermentation category based on milk production, sectoral expert for agriculture was decided to recalculate methodology for Tier 2 based on national data about animal number in detailed categories (for other non-dairy cattle) and more advance characteristic about feed and milk conditions for category dairy cattle. Detail input data are available from 1997 until present published in the Green reports of the SR (www.land.gov.sk) and verified by district offices statistical farm information (bottom-up approach).

Methane emissions from enteric fermentation for dairy cattle, non-dairy cattle and sheep are based on Tier 2 approach. The bottom-up regional input data about the number of animals, feeding situation, weight, milk production, average gross energy intake and other are available from 1997. The time series 1990–1996 was evaluated based on extrapolation methodology. The complete time series is consistent with the recommendations of the GPG 2000. The methane emissions from enteric fermentation for other animals (goats, horses, swine) are not significant and were estimated by Tier 1 methodology.

Emission Factors and Emissions

Total emissions of methane from enteric fermentation decreased from 94.77 Gg in year 1990 to 44.21 Gg in year 2006, what is decrease by more than 53 %. According to the projections, in 2012 decreasing numbers of dairy cattle (calculated according to milk productivity and limits of milk production for the SR) and numbers of sheep and goats will reduce emissions from this source on level 34.7 Gg per year what is less then one third of emissions of 1990 (Figure 6. 1).

Figure 6. 1: Methane emissions from enteric fermentation according to livestock categories in 2006



Emission factors for dairy cattle, non-dairy cattle and sheep were estimated based on milk production, average gross energy intake and are national specific. Methane emissions from enteric fermentation for dairy cattle reflect milk production during evaluated period of year given in Table 6.1. For the estimation of emission factor for methane emissions from enteric fermentation of dairy and non-dairy cattle, the extrapolation, linear function was used back to the base year 1990. For the estimation of emission factors for methane emissions of non-dairy cattle, the extrapolation, linear function was used back to the base year 1990. The time series of EFs is based on average gross energy intake (AGEI) and detailed cattle categories analysis. The emission factor for enteric fermentation was estimated according to milk productivity for each year by interpolation when for milk productivity 2 550 l the EF 81 kg CH₄ per head per year was used and for productivity 4 200 l was used the EF 100 kg CH₄ per head per year (Table 6. 1).

Table 6. 1: The milk production in kg per dairy cow in the SR for the period 1990–2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Milk production in kg per cow per day	6.34	6.86	7.38	7.91	8.43	8.95	9.48	9.65	10.65	10.94	11.99	12.43	13.07	13.32	13.45	14.24	15.60

Total emissions of methane from enteric fermentation for dairy cattle decreased from 40.37 Gg in year 1990 to 23.33 Gg in year 2006, what is decrease by more than 42 % (Table 6. 2). According to the projections, in 2012 decreasing numbers of dairy cattle (calculated according to milk productivity and limits of milk production for the SR) will reduce emissions from this source (Figure 6. 2).

Total emissions of methane from enteric fermentation for non-dairy cattle decreased from 45.44 Gg in year 1990 to 16.22 Gg in year 2006, what is decrease by about 64 % (Table 6.3, Figure 6. 3).

Table 6. 2: The new estimated CH₄ emissions and EFs in the 1990–2006 from enteric fermentation of dairy cattle based on milk production

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Milk Production (kg/day)	6.34	6.86	7.38	7.91	8.43	8.95	9.48	9.65	10.65	10.94	11.99	12.43	13.07	13.32	13.45	14.24	15.60
Emissions (Gg)	40.37	37.83	33.24	30.68	29.24	29.64	28.65	26.75	25.65	25.04	25.11	24.88	25.61	24.53	23.22	23.64	23.33
EF CH ₄ (kg/head)	73.53	75.51	77.49	79.48	81.46	83.44	85.42	86.35	90.26	91.37	92.58	95.98	98.56	99.79	100.12	102.97	106.69
	extrapolated values							real national data									

Figure 6. 2: The development of CH₄ emissions in Gg from enteric fermentation for dairy cattle according linear function calculation before 1997

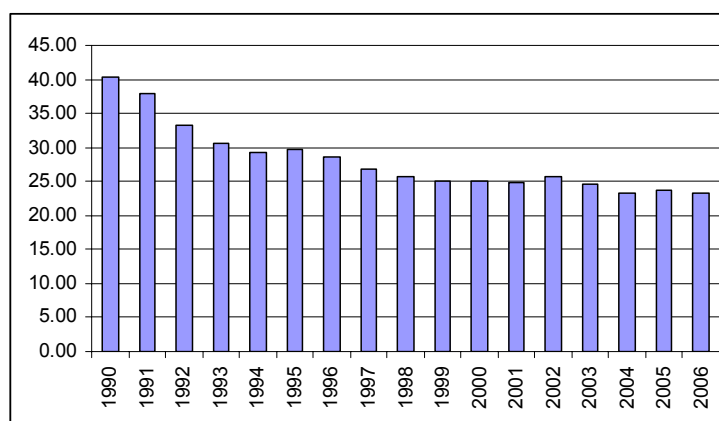
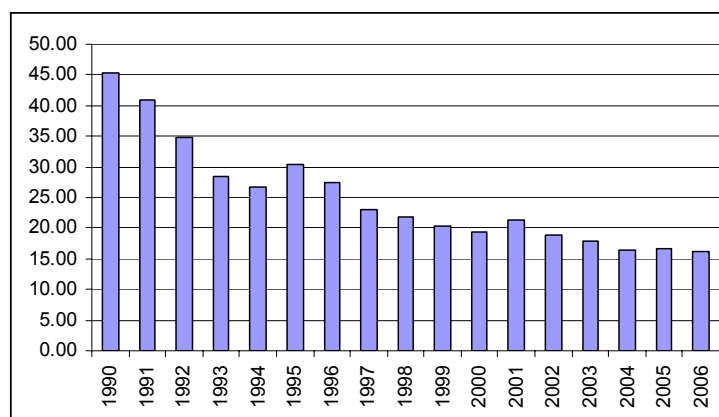


Table 6. 3: The new estimated CH₄ emissions and EFs in the 1990–2006 from enteric fermentation of non-dairy cattle based on average gross energy intake in MJ

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
AGEI (MJ)	122.03	123.05	124.06	125.08	126.09	127.11	128.12	131.4	130.2	130.2	131.39	133.65	130.91	135.86	134.32	140.81	140.81
Emissions (Gg)	45.44	40.81	34.85	28.54	26.59	30.42	27.39	22.99	21.84	20.25	19.38	21.41	18.96	18.01	16.37	16.69	16.22
EF CH ₄ (kg/head)	44.82	45.55	46.28	47.01	47.75	48.48	49.21	46.57	51.93	51.79	51.67	58.51	54.50	51.83	53.09	55.95	56.10
	extrapolated values							real national data									

Figure 6. 3: The development of CH₄ emissions in Gg from enteric fermentation for non-dairy cattle according linear function calculation before 1997



Recalculation and time series

Total decreasing of CH₄ emissions from category 1A1 enteric fermentation in 1990 was 10.14 % in Dairy and 11.34 % in Non-Dairy Cattle in comparison to the previous submission (2006). The results are summarized in Table 6. 4.

Table 6. 4: The recalculation changes in the CH₄ emissions from enteric fermentation of Cattle in category 1A1

		4A1 Dairy Cattle	4A1 Non-Dairy Cattle
Year of sub.	Category	CH ₄	
1990 (2006)		50.51	56.784
1990 (2007)		40.37	45.443
Differences in %		-25.12	-24.96
Differences in Gg		-10.14	-11.34

6.2.2 Manure Management

Methodology and Activity Data

In anaerobic conditions due to decomposition of manure, some methane is emitted too. These conditions can be found especially in large-scale farms (farms for dairy cattle, fattening pigs, poultry) (Figure 6. 4).

Emission Factors and Emissions

Methane emissions from this source decreased from 17.56 Gg in year 1990 to 7.49 Gg in 2006. Total methane emissions in 2006 from agricultural sector (animal husbandry) were 61.77 Gg. A trend of emissions during evaluated period is depicted on Figure 6. 5. Total CH₄ emissions (Table 6. 5) from manure management in agriculture decreased due to decrease of livestock numbers of all categories except for poultry. Extreme decrease of animals in category of pigs due to economical reason (low prices of meat on the market) was recorded last year in SR what consequently influenced methane emissions in category manure management. Emissions decreased by about 56 % in category manure management. Next decrease is supposed also in year 2007 and during period of years 2007–2012. Methane emissions can drop by about 10 % up to year 2012 because of next decrease of populations of cattle.

Figure 6. 4: Methane emissions from manure management according to livestock categories in 2006

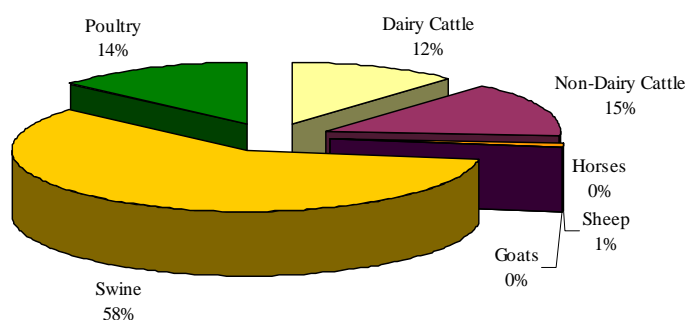


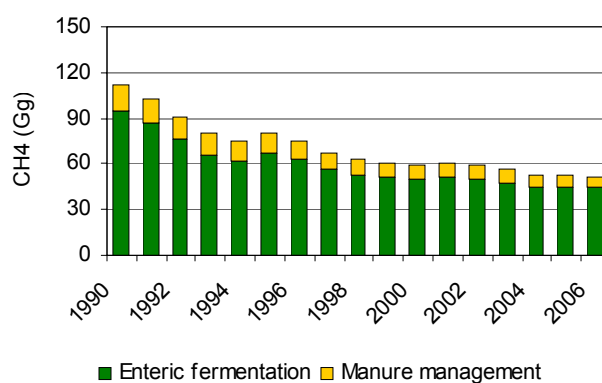
Table 6. 5: The total methane emissions in the SR for the period 1990–2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Emissions of CH ₄ (Gg)																	
Enteric Fermentation	94.77	86.89	76.41	66.09	62.39	66.90	62.67	56.10	52.91	50.78	49.93	51.44	49.78	47.65	44.22	44.91	44.21
Manure Management	17.56	16.32	14.82	13.62	12.91	13.25	12.60	11.56	10.21	9.87	9.52	9.63	9.74	9.26	7.84	7.66	7.49
Total	112.32	103.22	91.23	79.71	75.30	80.15	75.27	67.66	63.12	60.65	59.44	61.08	59.52	56.91	52.06	52.57	51.70

In future higher part of total methane emission will create emissions from animal excreta that are much more easy to manage, e.g. by proper storage, than emission from enteric fermentation.

Time Series

The methodology based on the national data was evaluated for the methane emission estimation in manure management. The national approach is based on the animal numbers per regions, calculation of the volatile solid excretion (VS) and methane conversion factor (MCF) as inputs to the formula for the estimation of national EFs. This approach will be use in the next submission.

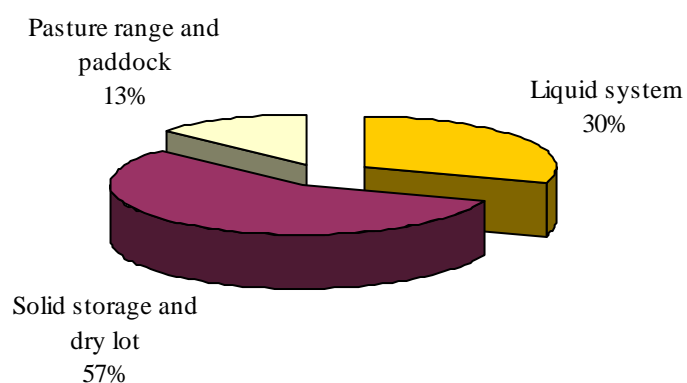
Figure 6. 5: The trend of CH₄ emissions in agriculture in 1990–2006

6.3 Nitrous Oxide Emissions

6.3.1 Manure Management

Methodology and Activity Data

Decreasing numbers of domestic livestock especially in categories pigs (as was mentioned above) and dairy cows also produced lower amount of nitrogen. Numbers of animals in category dairy cows start to be limited by milk quotation. Input of nitrogen from manure management in 2006 from this source was on level 1.337 Gg (Figure 6. 6).

Figure 6. 6: The N₂O emissions from manure management according to AWMS in 2006

Emission Factors and Emissions

Because domestic livestock produce different kind of nitrogen inputs (liquid or dry) into the ecosystem there is important also structure of domestic livestock (ratio of different categories of domestic livestock) from the point of view of direct emissions as well as emissions from AWMS. Except for it production of nitrogen per head per year also plays some role. There is used production of nitrogen in category cattle 90 kg per head per year in this study (according to IPCC, 1996). For dairy cows of productivity higher than 4 500 l there is also published amount 100 kg N per head per year (CORINAIR, 2003). There are also some differences in category other cattle, where for intensive animal husbandry are presented higher production of nitrogen (instead of 56 kg amount of 60 kg N pre head per year is recommended – Table 6. 6). Direct measurements of nitrogen produced by domestic livestock in the Czech Republic showed that real amounts could be much more higher than recommended values of produced nitrogen in methodologies what directly influence also N₂O emissions. The applied animal fertilizers lost the definite amount of nitrogen by volatilization and N-NO_x conversion, this amount for animal fertilizers is 20 %, its means that for the conversion of N to N₂O rest only 80 % of total amount applied synthetic fertilizers. For category manure management (especially sows and pigs) is the most often form of management solid and liquid system for storage of excreta in the Slovak Republic. For the sheep, horses and goats is characteristic management system - the pasture range in some period of year (mean is 200 days per year). Input of nitrogen oxide from manure management in 2006 from this source was on level 1.337 Gg and the total decreasing according to the base year is about 62 %.

Table 6. 6: The N production (kg/head/year) for different categories of domestic livestock (IPCC, 1996)

Livestock categories		N [kg]
Cattle	Dairy cows	100
	Non dairy cows	60
Pigs	Mean	20
	Sows*	36
	Piglets up to 50 kg	15
	Young sows over 50 kg	16
	Fattening pigs	14
Sheep, Goats		16
Poultry	Mean	0.6
	Laying hens	0.8
	Broilers	0.6
	Turkeys and ducks	2.0
Horses		25

*N production of piglets up to 20 kg is included in category sows

Knowledge on animal housing, pasture and production of manures and slurries was found on the base of questioners in the national paper. Some additional information was based on expert decision. Duration of pasture is limited by climatic conditions. According to methodology IPCC next Animal Waste Management Systems (AWMS) were recognized for evaluation in the Slovak Republic (Figure 6. 6):

- Liquid systems;
- Solid storage and dry lot;
- Pasture range and paddock

Solid storage of manure was found as the most frequent AMWS in condition of the Slovak Republic. Liquid storage of slurries is also frequently used especially in category pigs. For sheep, goats and horses is frequent housing on grasslands since April to October.

N₂O emissions from AWMS were based on analyses of housing systems on the territory of the Slovak Republic that was made by Research Institute of Animal Production in Nitra There was supposed that sheep, goats and horses can stay on pasture 200 days a year, 40 % of dairy cattle 150 days during

day only especially in mountainous regions. During winter period sheep and goats produce 9 % of waste as slurry and 91 % as manure (Brestenský et al., 1998).

Table 6. 7: The perceptual share of Animal Waste Management Systems (AWMS) in the Slovak Republic

Categories of domestic livestock		Liquid systems	Solid storage and dry lot	Pasture range and paddock
Cattle	Dairy cattle	5	75	20
	Other cattle	5	85	10
Sheep and goats		0	45	55
Pigs		80	20	0
Poultry	Laying hens	85	15	0
	Broilers	65	35	0
	Other poultry	45	15	40

There is possible to see some trends in use of animal housing and consequently animal waste management system. Ministry of Agriculture of the Slovak Republic is the second source of data on animal housing, pasture and production of manures and slurries. Values are given in table bellow and use as alternative source of data for calculation of emissions. Therefore calculations were done in two variants (Table 6. 9).

Recalculations and time series

Total N₂O emission estimation from Manure management was revised and no changes of methodology were necessary. Input data about nitrogen from pasture range and paddocks and inconsistencies were reevaluated and the correct information about $Frac_{GRAZ}$ were provided. No recalculation, no changes were made (Table 6. 8.).

Table 6. 8: The new estimated $Frac_{GRAZ}$ in the 1990–2006 in %

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
$Frac_{GRAZ}$	15.3	15.2	15.6	14.7	14.5	14.6	14.6	14.8	14.8	15.3	15.5	14.7	14.5	14.6	14.7	14.8	13.0

Table 6. 9: The trends in use of animal housing and consequently animal waste management system

Category	Total average annual N excretion	Manure management systems (Fraction of total annual excretion [%])							
(Sub-category)	(kg N/ animal* year)	Pasture/ Range/ Paddock	Daily spread	Solid storage	Dry lot	Liquid/ Slurry	Anaerobic lagoon	Open pits below anim. confinements	Anaerobic digester
Cattle total									
Dairy Cows	70.26	20		75		5			
Bulls	67.89			80		10		10	
Heifers	54.60	30		70					
Calves	14.31			100					
Cattle total beef									
Dairy Cows	67.53	80		20					
Sires	78.33	80		20					
Heifers	52.05	90		10					
Calves	19.38	90		10					
Pigs total dairy									
Sows	22.71			25		75			
Fattening Hogs	8.02			20		80			
Piglets	0.67			10		90			
Poultry total									
Hens (Layers)	0.89			10	5	85			
Broilers	0.30			30	5	65			
Turkey	1.31			50		50			
Ducks	0.88	60		40					
Gooses	0.94	60		40					
Horses	72.27	30		70					
Sheep total									
Milking ewes	10.86	40		60					
Others	6.21	50		50					
Goats total				100					
Milking She-goats	6.57	40		60					
Others	4.93	50		50					
Rabbits	0.91			100					
Others									

6.3.2 Direct N₂O Emissions from Cultivated Soils

The N₂O emissions from cultivated soils are of natural origin from microbial processes – nitrification and denitrification. The direct N₂O emissions from cultivated soils in sense of IPCC Methodology (IPCC, 1996) depend on nitrogen inputs: synthetic fertilizers, animal excreta, crop residuals, cultivation of histosols and N-symbiotic fixation of leguminous (Bouwman, 1990).

Methodology and Activity Data

A consumption of synthetic fertilizers decreased during last decade of 20th century, from 200.0 Gg in 1990 to 78.7 Gg in 2006. The synthetic fertilizers in year 2006 were applied on 60.7 % of area of arable soils and only on 62.3 % of sowing area of cereals. Especially sugar beet and fodder crops were short of nutrient during last decade of years in condition of the Slovak agriculture. Despite these facts consumption of synthetic fertilizers increased in 2004 and 2005 by about 10–12 % during last year as compare with year 2000 (Table 6. 10). Because of decreasing numbers of domestic livestock in some categories (producing still less nitrogen in wastes), this trend in consumption of nitrogen fertilizers should continue if the present level of yields of field crops is accepted (Green Report, 2005).

Table 6. 10: Total inputs of N (thousands of t) from mineral fertilizers applied in agriculture during years 1990–2005 with estimations up year 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Fertilisers (kt)	222.26	146.34	90.19	64.85	68.67	69.59	74.46	88.02	81.84	65.39	72.65	76.03	88.26	81.30	79.91	81.32	78.68
N-inputs (kt)	200.03	131.71	81.17	58.37	61.80	62.63	67.02	79.22	73.66	58.85	65.39	73.21	79.43	73.17	71.92	73.19	70.81
Emissions N ₂ O (Gg)	3.929	2.587	1.594	1.146	1.214	1.230	1.316	1.556	1.447	1.156	1.284	1.438	1.560	1.437	1.413	1.438	1.391

Emission Factors and Emissions

The applied synthetic fertilizers lost the definite amount of nitrogen by volatilization and N–NO_x conversion, this amount for synthetic fertilizers is 10 %, its means that for the conversion of N to N₂O rest only 90 % of total amount applied synthetic fertilizers (70.81 kt / year 2006). After using the IPCC default emission factor 0.0125 kg N₂O–N / kg N the total emissions of N₂O from using the synthetic fertilizers in 2006 were 1.391 Gg (0.885 Gg of N).

Methodology and Activity Data

The direct inputs of nitrogen slightly vary according to applied methodology. According to IPCC Methodology (IPCC, 1996) (Method A)⁹ higher inputs of nitrogen from animal excreta are calculated – in average higher by about 5 % as compared with detailed method (Method B).¹⁰ Since 1990 there was recorded decrease of nitrogen inputs from 171.4 Gg to 70.8 Gg in year 2006 – what represent more than half of original emissions. Because domestic livestock produce different kind of nitrogen inputs (liquid or dry) into the ecosystem there is important also structure of domestic livestock (ratio of different categories of domestic livestock) from the point of view of direct emissions as well as emissions from AWMS. Except for it production of nitrogen per head per year also plays some role. There is used production of nitrogen in category cattle 90 kg per head per year in this study (according to IPCC, 1996). For dairy cows of productivity higher than 4 500 l there is also published amount 100 kg N per head per year (CORINAIR, 2003). There are also some differences in category other cattle, where for intensive animal husbandry are presented higher production of nitrogen (instead of 56 kg amount of 60 kg of N pre head per year is recommended). Direct measurements of nitrogen produced by domestic livestock in Czech republic showed that real amounts could be much more higher than recommended values of produced nitrogen in methodologies what directly influence also N₂O emissions.

Based on data about management in 222 agriculture farms were performing the total analysis of manure production in the SR (Table 6. 11).

Table 6. 11: Housing of animals and production of liquid and solid manures in percent (Brestensky, 1998)

Category of domestic livestock		Animal Waste Management System		
		Production of slurries [%]	Production of manure [%]	Pasture [%]
Cattle	Dairy cows	5	75	20
	Non dairy cows	5	85	10
6.3.2.1.1 Pigs	Mean	76	24	0
	Fattening pigs	91	9	0
	Sows	41.6	58.4	0
Sheep and goats		4	41	55
Poultry	Mean	55.4	44.6	0
	Laying hens	2.2	97.8	0
	Broilers	98.2	1.8	0
	Turkeys and ducks	100	0	0
Horses		0	45	55

⁹ Method A: nitrogen input was calculated for animal categories of domestic livestock according to IPCC Methodology¹² cattle (dairy and others), pigs, sheep, goats, horses, and poultry, 1996

¹⁰ Method B: the more detailed values for calculation of N₂O emissions were used, when categories of domestic livestock per year for other cattle were supposed.

Emission Factors and Emissions

The calculated amount of nitrogen from animal waste applied on fields was 45.69 kt N (liquid and solid systems; $(1 - \text{Frac}_{\text{Fuel}} + \text{Frac}_{\text{Graz}} + \text{Frac}_{\text{Gasm}}) = 0.703$) and the total amount of N_2O emissions from animal excreta in 2006 were 0.872 Gg (0.555 Gg of N).

Introduction for crop residuals

Directly after incorporation of the crop residuals into the soil, the multilateral interactions between organic compounds and nutrients presented in the residuals with the mineral and organic components of soil take place. The knowledge of nutrient potential in crop residuals by crop rotation are mostly actual in the in the present requirements of biologicalisation in plant production.

Methodology and Activity Data

During 1986–1997 the crop and root residuals were observed from 29 crop species on three to seven different soil-climate sites in the Slovak Republic (partly on the small parcels production and partly on the large scale production). The sampling was provided according the plant specification (numbers of plants per hectare). The crop residuals were abstracted from the same field as root residuals directly after root take off. Crop residuals as well as symbiotic fixation depend according to applied methodology in this study on acreage of field crops and leguminous. Nitrogen input from crop residuals varies about value 180 000 t per year. Nitrogen in crop residuals according to categories of different crops were established on the base of results of field trial of Research Institute of Plant production (Jurcova, 2000). The details for estimation total input of nitrogen from residual crops are depicted in Table 6. 12 and were calculated according the growing areas of crops and vegetable.

The collection of experimental results and samplings were evaluated by statistical method using the polynomial regression.

Emission Factors and Emissions

The total growing area of crops (wheat, ray, barley, oat, maize, potato, sugar beet, oil plants, tobacco, vegetable, fodder crops, grassland and other) in 2005 were 1 137 250 ha and the direct inputs of nitrogen from crop residuals were 66 272 t per year 2006. The crops residuals from previous year were base for calculation of N_2O emissions (according the used methodology). The used emission factor 0.0125 kg N_2O -N / kg N is according the IPCC methodology (IPCC, 1996) and gives the total N_2O emissions from crops residuals in 2006 – 1.3018 Gg (0.828 Gg of N).

Table 6. 12: The Growing areas and total nitrogen amount of crops and leguminous in the SR

Crop		1990 [ha]	2002 [ha]	2003 [ha]	2004 [ha]	2005 [ha]	Average nutrient potential [N kg/ha]	2005 N [t]	2006 N [t]
Cereals	Wheat	418 158	405 800	306 900	367 800	349 105	53	19 493	15 835
	Ray	46 335	38 000	25 200	32 500	28 717	45	1 463	793
	Barley	190 634	194 700	269 300	222 000	184 519	45	9 990	6 666
	Oat	13 015	20 500	30 400	24 500	19 530	55	1 348	762
	Maize	150 731	140 400	146 000	147 800	151 006	39	5 764	7 146
potato		55 245	26 100	25 700	24 200	18 384	59	1 428	1 252
sugar beet		51 288	30 900	32 000	35 500	27 719	20	710	468
oil plants		70 906	201 600	208 900	196 700	250 397	107	21 047	27 544
tobacco		3 019	1 234	1 234	957	920	45	43	61
fodder crops		9 718	0	0	2 000	1 664	20	40	40
maize for silage		179 888	96 787	98 973	95 900	84 495	55	5 275	5 524

Results and Discussion

According to the actual results the content of mineral component in the crop residuals fluctuates mostly in dependence of genetic plant attributes and the level of agro technique, primary fertilizing. From the research results assumed, that the content of nitrogen can differ in the residuals by the same crop, content of nitrogen is higher in roots. Nitrogen content is fluctuated and is highest in the N-fixing crops. This is in accordance also with other authors.

The second factor besides nutrient content in plant is the weight of crop residuals and root residuals and this influence the nitrogen in soils, too. This is depending on the crop specification and harvesting practice. Statistically we can specify the potential content of nitrogen in kg per hectare in residuals. Besides the observation this potential we have studied the collection of 29 crops and the most common harvesting practices. Table 1 shows the statistical average of potential values of nitrogen inputs for the observed crops. Average nitrogen potential ranges between 19–298 kg per hectare.

Values in yellow fields were used for calculation in excel files directly. Stems and leaves are usually utilized as a fodder for domestic livestock. Missing are data on export of straw abroad. Except for it those values for grasslands, alfalfa, horse bean, maize for silage and clover include also a green part of crops (leaves and stems) utilized for animal feeding (in green fields). Therefore crop residuals are defined only as a part of plants – short stems and roots standing on the field – values in yellow area. According to Statistical Yearbook and Green Report of the Slovak Republic it is not possible to split fodder crops and grasslands into year subcategories (Table 6. 13).

Conclusion

Coefficients for the nutrient estimations and the model for the nutrient input into the soils from crop residuals have a high importance in nutrient balance and agricultural practice by sowing, cultivation and harvesting of effective plant production in agriculture.

Background of Information and Calculation

The first and second papers (Jurčová, Torma) estimated nitrogen amount applied into soils on the base of higher input of nitrogen fertilizers (both from synthetic and organic fertilizers) into agricultural soils. The analyses were based on results from field trials during years 1986–1997. Those inputs of nitrogen from crop residuals correspondent to common practice in Slovak agriculture.

The third source (Kováčik) used also experimental data from more recent field trials with respect to good practice rules in agriculture.

We decided to calculate nitrogen inputs from crop residual according to acreage of field crops for several reasons:

- We prefer use of national data from direct measurements instead of some default values;
- According to IPCC methodology the basic information on nitrogen input into soil from crop residuals are yields of field crops. Some crops suffer from winter frosts (oil seed rape, winter wheat, winter barley) and summer drought (sunflower and other) and they are not harvested and so not included into official statistics on crop yields. Anyway they are source of nitrogen in soils. If there is only crop yield taking into account they are not included into calculation of N₂O emissions. Therefore the acreage of field crops and national data about nitrogen content in crop residuals looks as more representative data for calculation procedure. Importance of crops is changing. Still more and more agricultural land is not utilized. Acreage of oil seed rape and sunflower increase, sugar beet, potato and fodder crops (alfalfa, clover, leguminous plants) decrease;
- Regional differences.

Table 6. 13: Nutrition potential in crop residuals in kg of nitrogen per hectare

Crops	kg N per hectare	Notice
Horse been	298	including stems and leaves
Chicken pea	201	including stems and leaves
Beans	192	including stems and leaves
Oil seed rape - spring form	166	including stems and leaves
Lens	163	including stems and leaves
Clover in mix in 2nd year	153	
Grasslands in 4th year	136	
Alfalafa in 4th year	133	
Soybeen	132	including stems and leaves
Corn	127	including stems and leaves
Alfalafa+grass in 3rd year	127	
Clover in 3rd year	127	
Alfalafa in 3rd year	126	
Grasslands in 3rd year	123	
Alfalafa+grass in 2nd year	122	
Alfalafa in 2nd year	120	
Clover in 2nd year	120	
Popper	115	including stems and leaves
Grasslands in 2nd year	113	
Peas	112	including stems and leaves
Sunflower	108	including stems and leaves
Oil seed rape - winter form	107	including stems and leaves
Mustard	91	including stems and leaves
Oat	89	including stems and leaves
Spring wheat	84	including stems and leaves
Triticale	80	including stems and leaves
Winter wheat	79	including stems and leaves
Winter ray	77	including stems and leaves
Linnet	67	
Winter barley	66	including stems and leaves
Spring barley	60	including stems and leaves
Potato	59	
Oat	55	
Maize for silage	55	
Triticale	54	
Winter wheat	53	
Spring wheat	52	
Peas	49	
Beans and cereals as fodder crop	46	
Tobacco	45	
Winter ray	45	
Spring barley	43	
Winter barley	45	
Corn	39	
Sugar beet	20	

Calculation Procedure

Nitrogen input from symbiotic fixation of leguminous plants was calculated according to their growing areas, when value $26 \text{ kg} \cdot \text{ha}^{-1}$ (Vostál, cit. in Bielek, 1998) per year was used for calculation according to equation:

$$F_{BN} = 26 \times SA_{BN} \quad [\text{kgN} \cdot \text{year}^{-1}]$$

Where: SA_{BN} – acreage of N-fixing crops

Calculation of crop residuals (including N-fixing crops) is based on national data on acreage of field crops and nitrogen content in crop residuals (Table 1) according to equation:

$$F_{CR} = CR_T \times SA_T \quad [\text{kgN} \cdot \text{year}^{-1}]$$

Where: CR_T = nitrogen content in crop residuals in category T [$\text{kgN} \cdot \text{ha}^{-1}$]

SA_T = acreage of crop in category T [ha]

Recalculation and Time Series

Total reduction of N_2O emissions from 4.D.1.3 Direct soil emissions – N-fixing Crops in 1990 was 31 % in comparison to the previous submission (2006). Total reduction of N_2O emissions from 4.D.1.4 - Direct soil emissions - Crop Residues in 1990 was 57 % in comparison to the previous submission (2006). The results are summarized in Table 6. 14 and Table 6. 15.

Table 6. 14: Recalculation changes in the direct soil emissions incorporated in soils in Gg

Year of sub.	4D1.3	N_2O	Year of sub.	4D1.4	N_2O
1990 (2006)		0.90375	1990 (2006)		2.76802
1990 (2007 – June)		0.61977	1990 (2007 – June)		1.19488
Differences in %		31.1	Differences in %		57.0
Differences in Gg		0.28	Differences in Gg		1.58

Table 6. 15: New estimated emissions in the 1990–2006 from direct soil emissions from crop and N-fixing crops residuals in Gg of N_2O , comparison of old and new estimated dataset

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
4D1.3 -old (Gg)	0.9	0.89	0.88	0.91	0.82	0.75	0.71	0.7	0.62	0.61	0.56	0.58	0.46	0.51	0.53		
4D1.3 -new (Gg)	0.62	0.61	0.61	0.63	0.57	0.51	0.46	0.42	0.37	0.35	0.34	0.31	0.29	0.28	0.28	0.28	0.31
Difference %	-31.1	-31.9	-30.5	-30.3	-30	-32.4	-34.6	-40.4	-40.3	-42.2	-38.5	-46.7	-37.6	-45.4	-47.1		
4D1.4 -old (Gg)	2.77	2.78	2.8	2.77	2.81	2.83	2.88	2.92	2.92	2.94	3.12	3.11	3.11	3.11	3.14		
4D1.4 -new (Gg)	1.19	1.21	1.23	1.17	1.19	1.23	1.29	1.28	1.29	1.28	1.33	1.29	1.31	1.33	1.31	1.31	1.30
Difference %	-57	-56.5	-56.1	-57.9	-57.8	-56.5	-55.3	-56.1	-55.7	-56.4	-57.4	-58.4	-57.9	-57.2	-58.2		

The activity data on crop residuals start from 1989 because the mineralization rate. It is supposed that crop residuals from one year are mostly source of N_2O emissions in following year. Scientist did this recommendation from department of plant nutrition and agro chemistry.

We use acreage instead of yield for several reasons:

- Missing statistics on yield of some fodder crops at the beginning of evaluated period,
- Some crops suffer from winter frosts (oil seed rape, winter wheat, winter barley) and summer drought (sunflower and other) and they are not harvested and so not included into official statistics on crop yields. Anyway they are source of nitrogen in soils. If there is only crop yield taking into account they are not included into calculation of N_2O emissions. Therefore the acreage of field crops and national data about nitrogen content in crop residuals looks as more representative data for calculation procedure,

- The differences between approaches were caused by excluding the permanent grasslands as well as soils not included into statistics. Those soils are not cultivated and fertilized and not sufficient data about nitrogen inputs and acreage are available.

Methodology and Activity Data

Nitrogen inputs from symbiotic fixation are of local importance and depend on acreage of leguminous plants. Total input of nitrogen into cultivated soils drastically decreased in the first half of 90' (from 760.0 Gg in 1990 to 500.0 Gg in 1995). During last years inputs of nitrogen into soils was stabilized on level 430.0 Gg per year.

Emission Factors and Emissions

For the conditions of the SR are the nitrogen inputs from symbiotic fixation in the range 20–30 kg/ha (Bielek 1998), but is enough reasons to accept an experimental value 26 kg N/ha. The details for estimation total input of nitrogen from N-fixing residual are in Table 6. 16 and were recalculated according the data obtained from direct measurement (Jurcova, 2000) in the conditions of the SR and recalculated to the growing areas of N-fixing crops and average harvest.

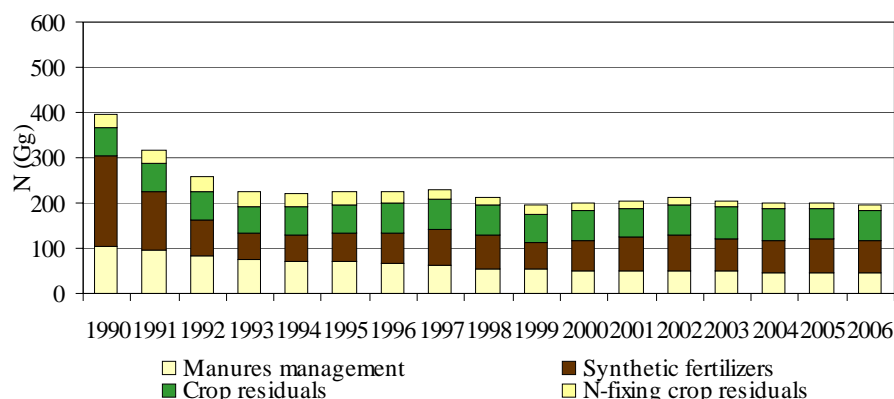
The total growing areas of N-fixing crops (peas, lens, beans, mix of fodder beans and cereals, soybeans, alfalfa, clover) in 2005 were 81 036 ha and the direct inputs of nitrogen from N-fixing crops were 15 885 t of N per year 2006. The crops residuals from previous year were base for calculation of N₂O emissions from N-fixing crops (according the used methodology). The used emission factor 0.0125 kg N₂O-N / kg N is according the IPCC methodology and gives the total N₂O emissions from N-fixing crops in 2006 – 0.3121 Gg (0.199 Gg of N) including biologic fixation.

Table 6. 16: The Growing areas and total nitrogen amount of N-fixing crops in the SR

Crop		1990 [ha]	2002 [ha]	2003 [ha]	2004 [ha]	2005 [ha]	Average nutrient potential [N kg/ha]	2005 N [t]	2006 N [t]
N-fixing crops	peas	28 446	4 899	5 385	6 134	5 185	112.0	39 931	8 607
	lens	2 579	942	1 383	975	676	163.0	6 822	1 637
	beans	2 272	720	743	676	678	192.0	4 735	2 008
	mix of fodder beans and cereals	9 571	2 527	3 000	2 200	0	134.0	24 068	0
	soybeans	5 474	10 983	8 510	10 898	12 036	132.0	37 490	50 432
	alfalfa	110 002	61 532	60 967	60 324	53 889	126.0	422 266	130 413
	clover	35 068	10 425	8 383	9 371	8 571	123.5	56 224	16 885

Biologic fixation from 81 036 ha of N-fixing crops were 2 809 t N per year 2006. The used emission factor 0.0125 kg N₂O-N / kg N is according the IPCC methodology and gives the total N₂O emissions from biologic fixation in 2006 – 0.055 Gg (0.035 Gg of N). The total N₂O emissions from N-fixing crops (residuals + biologic fixation) in 2006 were 0.312 Gg. A trend of direct N input in agricultural soils according to the sources during 1990–2006 is depicted on the Figure 6. 7.

Except for total nitrogen inputs into soils there are also found changes of importance of nitrogen sources. While the consumption of synthetic fertilizers as well as input of nitrogen from animal husbandry decreased crop residuals created relatively stable input of nitrogen (approximately 180.0 Gg). This fact document abnormal intake of nutrients from soils what can influence their fertility during next years. The 1.25 % of nitrogen from inputs defined above in sense of applied methodology creates direct N₂O emissions and so trends reflect their sources.

Figure 6. 7: The trend of direct N inputs in soils according to sources (SR 1990–2006)

6.3.3 Indirect N₂O Emissions

This part of N₂O emissions resulted from processes of atmospheric deposition of ammonia and NO_x, as well as due to transformation of nitrogen from leaching and runoff losses.

Methodology and Activity Data

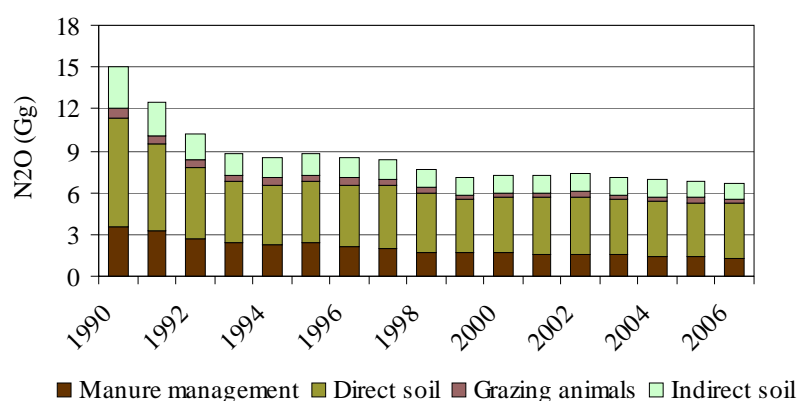
The indirect emissions decreased during evaluated period too because of their dependence on direct inputs of nitrogen that decreased too.

Emission Factors and Emissions

Mean value for leaching of nitrogen vary in range 7–10 kg per 1 ha per year (7 % of N-inputs) in condition of SR. Next nitrogen losses 5 – 10 (7 % of N-inputs) kg per ha per year are caused by soil erosion and runoff (Bielek 1998). Totally soils loss about 14 % of nitrogen input due to leaching, runoff and erosion in climatic condition of the Slovak Republic. Total indirect emissions of N₂O from atmospheric deposition create 352.83 tons per year 2006; the emissions of N₂O from nitrogen leaching and run-off are 833.83 tons per year 2006. The total indirect emissions in 2006 are 1.187 Gg with the reduction of 61 % compared to the 1990 year.

Trends and Recalculations of N₂O Emissions

Trends of the total N₂O emissions from agriculture sector reflect trends of direct emissions from cultivated soils, emissions from AWMS and indirect emission from leaching and deposition of ammonia and NO_x. After big decrease of N₂O emissions in the 1st half of 90's (from 15.1 Gg in 1990 to 8.7 Gg in 1995) the emissions stabilized on level 6.7 Gg per year (Figure 6. 8).

Figure 6. 8: The trend of N₂O emissions in agriculture in 1990–2006

The N₂O emissions from agriculture sector create about 49 % of total N₂O emissions in the SR. The total N₂O emissions in Agriculture sector are given by direct emissions from cultivated soils and animal husbandry and indirect emissions from leaching and nitrate depositions. The emission factors for calculation of direct N₂O emissions from agriculture sector, emissions from AWMS and indirect emissions from leaching were used according to Table 6. 17.

Table 6. 17: The EFs for the calculation of N₂O emissions from agriculture (IPCC, 1996)

EF ₁	Direct emissions - cultivated soils	0.0125 (0.0025–0.0225) kg N ₂ O - N/kg
EF ₃	AWMS - liquid storage	0.001 (0.001) kg N ₂ O - N/kg
	AWMS - dry storage	0.02 (0.005–0.03) kg N ₂ O - N/kg
	AWMS - pasture	0.02 (0.005–0.03) kg N ₂ O - N/kg
EF ₄	Indirect emissions – atmospheric deposition	0.01(0.002–0.02) kg N ₂ O-per kg emitted NH ₃ and NO _x
EF ₅	Indirect emissions - leaching	0.025 (0.002–0.12) kg N ₂ O - per kg of leaching N

Key Source and Uncertainties - Activity Data

Both for calculation GHG and ammonia emissions there are required data on number of domestic livestock according to categories and amount of applied fertilizers. Basic sources of data used for evaluations of emissions in this study were published in:

- Green Report of SR;
- Statistical yearbook.

Data published in Green Report of the SR (Green Report, 2007), as well as Statistical yearbook (Statistical yearbook, 2007) can differ slightly, especially if the number of animals in some category is very low. Round up or down if the numbers of domestic livestock are given in thousands of head can cause differences up to 3 %. However, differences are not of high importance.

Subcategories of domestic livestock can be estimated according to Annual census of domestic livestock. in the SR. Data from this publication are issued relatively soon after end of previous year but many times they are different as compare with data from Green Report or Statistical yearbook.

Productivity of different categories of domestic livestock varies in conditions of the Slovak Republic significantly in dependence on scale and production level of farm.

In conditions of the SR, both extensive and intensive farming system in animal husbandry can be found. The range of nitrogen production for dairy cows is in range 60–140 kg per head per year. Nitrogen inputs from animal excreta differ in dependence on used methodology and therefore two variants of calculation were applied in this study:

- Nitrogen input was calculated for animal categories of domestic livestock according to methodology (IPCC, 1996): cattle (dairy cattle – 90 kg of N per head and others with production of 56 N per head), pigs, sheep, goats, horses, poultry;
- More detailed values for calculation of NH₃ emissions were used, when categories of domestic livestock were separated according to weight to subcategories and production of 100 kg N per year for dairy cattle and 60 kg N for other cattle was supposed.

Nitrogen inputs can differ from calculations in range +10 %. Towards future, this mistake should be lower because the level of animal husbandry can be concentrated to relatively smaller number of producers and so it can be much easier to define production level of farms.

According to IPCC methodology (IPCC, 1996), there is next animal waste management systems (AMWS) observed in condition of the Slovak Republic:

- Liquid storage of animal excreta;
- Dry storage;
- Pasture.

Dry storage of animal excreta is the most frequent way of AWMS especially in category cattle. Production of slurries is typical for domestic livestock in category pig. Pasture is typical for sheep, goats, horses and part of cattle during spring, summer and autumn. N_2O emissions from AWMS were based on analyses of housing systems on the territory of the Slovak Republic that was made by Research Institute of Animal Production in Nitra (Brestenský, 1998). There was supposed that sheep, goats and horses can stay on pasture 200 days a year, 40 % of dairy cattle 150 days during day only. Results of analyses on animal waste management system were used for calculation of nitrogen input from animal husbandry into N-cycle. This analysis was based on questionnaire. 222 agricultural subjects were included (21.3 % of total amount of subjects in the SR) in this research. Those subjects cultivated 14.7 % of total agricultural land and 15.2 % of arable land. It is very probable that answers were received first of all from farmers were elements of good practice in agriculture started to apply. Storage of dry manures is probably more frequent then questionnaire showed and emissions from AWMS will be higher. For sheep, goats and horses is frequent housing on grasslands since April to October. Duration of grazing period can vary significantly in dependence on weather conditions in different part of the SR. There is not enough date for statistical evaluation but in this point can be found significant differences.

Applied amounts of synthetic fertilizers into cultivated soils are very low for last 15 years. Potential for volatilization of ammonia and emissions of N_2O can vary in very large range. The best information on NH_3 emission from cultivated soils in the SR can be reached on the base of applied nitrogen fertilizers. Emissions also depend on type of fertilizers, soil parameters (pH), meteorological conditions, time of application in relation to crop development. Applied nitrogen fertilizers were calculated on the base of FAO materials for the Slovak Republic (Bielek, 1998). Selection of emission coefficients reflect climatic and soil condition of the Slovak Republic, when climate in Central Europe was defined as a cool (ECOTEC, 1994) with prevailing acidic soils. ECOTEC coefficients are lower then those published by (Assman, 1992) or coefficients for non-defined climatic conditions (simple methodology). Emissions of ammonia from cultivated soil can be higher in dependence on used methodology by 6–20 %.

N inputs from symbiotic fixation of leguminous crops in condition of SR vary in range 20–30 $\text{kg} \cdot \text{ha}^{-1}$ (Bielek, 1998). As an average value can be accepted 26 $\text{kg} \cdot \text{ha}^{-1}$ (Vostál at all., cit. in Bielek, 1998). This value varies in range ± 20 % from the mean value. Data on production of nitrogen in excreta of domestic livestock are influenced by facts mentioned above (N production by domestic livestock and numbers of domestic livestock according to categories).

Nitrogen content in crop residuals as well as of their decomposition in soil significantly influences formation of yield in next years. National methodology for calculation of nitrogen inputs from crop residuals was used when nitrogen amount was calculated according to acreage of field crops and nitrogen content in different crops (Jurčová, 1998). The yield of field crops can vary in range ± 20 % year to year.

Key Source and Uncertainties - Emission Factors (default factors)

Uncertainties are defined by emission coefficients. For direct soil N_2O emissions calculated values from reality can differ in range 20–200 %, for N_2O from animal waste management system in range 25 – 150 %, for indirect N_2O emissions from NH_3 volatilization in range 20–200 % and for indirect N_2O emissions from leaching I range 10–500 %.

Great uncertainties are defined for N_2O and NH_3 emissions (especially from agricultural soils, foliar emissions and decomposition) and therefore presented results should be considered as preliminary. Direct measurements show that ammonia can volatilize in large range. There was found values in range 2 - 20 $\text{kg} \cdot \text{ha}^{-1}$ in winter wheat crop (Bielek, 1998). Volatilization is influenced by soil parameters, where e.g. haplic fluvisols emit less ammonia in the same climatic condition than other soils.

According to recommendation in IPCC, 2000 there are necessary also direct measurements gases emissions in agriculture. These data are absent in condition of the SR.

Emissions calculated according IPCC methodology are little bit higher values (by about 3 %) than emissions calculated by detailed methodology. This fact is caused by higher nitrogen inputs from animal husbandry calculated by IPCC methodology (IPCC, 1996). According to results reached by two methods we can conclude that calculation methods are relatively similar.

The highest uncertainties are observed on cultivated soils (soils with fertilizers). More exact data on NH_3 and N_2O emissions from cultivated soils is possible to reach by modelling e.g. by DNDC model. Today this kind of model is tested at the Department of Biometeorology and Hydrology at the Slovak Agricultural University in Nitra.

7 LAND USE, LAND USE CHANGE AND FORESTRY

7.1 Input Data

Forest and research institute in Zvolen namely Dr. J. Mindáš (external expert for SHMI) took responsibility for the inventory emission balance from LULUCF. Basic input data used for calculations of GHG emissions from forestry and land use change are showed in Table 7. 1. According to present knowledge, about 55–90 % (depending on tree species) of the total tree's biomass can be assumed stored in the stems. The density of wood (at dry weight) varies from 350 to 800 kg/m³. Using these data and a carbon content of 49.7 % for wood (other parts of trees 46.7–52.8 %, mean value 50 % was used). The total carbon stored in biomass of forest trees of 157.4 Tg C (1990) was estimated based on stemwood biomass data; conversion/expansion factors were estimated according to the experimental data for main forest tree species (Sebik, 1989). The average stock of carbon varies from 47.9 (Poplars) to 108.8 (Beech) tons of carbon per hectare.

Table 7. 1: Overview of land use input data according the new methodology in 1990–2006

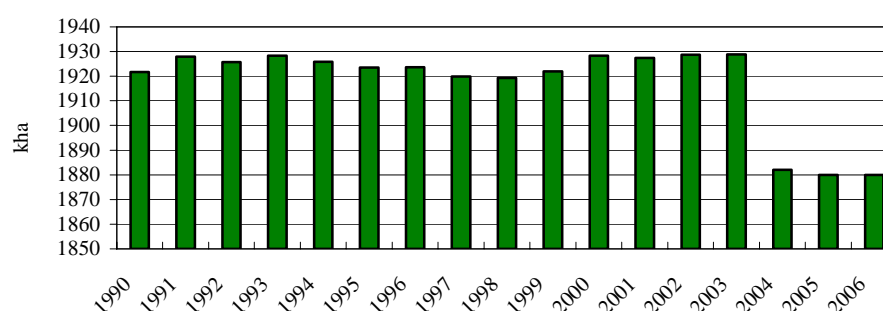
Area (kha)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Forest land	1,921.7	1,927.9	1,925.8	1,928.3	1,925.9	1,923.5	1,923.7	1,919.9	1,919.3	1,922.0	1,928.3	1,927.4	1,928.7	1,928.8	1,930.7	1,931.6	1,932.0
Cropland	1,509.0	1,509.0	1,486.0	1,482.0	1,482.0	1,483.0	1,475.0	1,482.5	1,480.0	1,460.6	1,450.5	1,449.1	1,441.0	1,430.2	1,425.0	1,423.1	1,409.7
Grassland	813.0	808.0	810.0	832.0	835.0	835.0	842.0	834.6	835.0	856.4	865.2	864.8	863.5	883.5	885.0	893.6	893.2
Wetland	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Settlements	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other	621.8	620.7	643.8	623.2	622.7	624.0	624.8	628.5	631.3	626.6	621.5	624.3	632.3	622.5	662.9	697.2	757.4

7.2 Forest Land

Methodology and Activity Data

Results of calculations were obtained by using the new LULUCF Methodology (IPCC, 2003) and national data on area of Forested land and land converted to the forest during the inventory year 2006. The Figure 7. 1 shows the activity data in ha per estimated time series 1990–2006.

Figure 7. 1: Development of total forest area – Forest land remaining Forest land

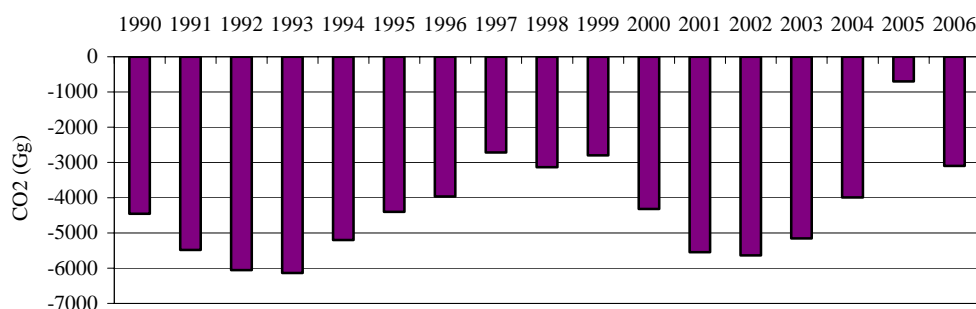


The total area of Forest land remaining the Forest land in 2006 remains 1 880 kha, the changes in the forest land were following Grassland converted to Forest land 23.00 kha and Other land converted to the Forest land 29.00 kha per 2006. Total forest area in 2006 was 1 932 kha, with the net carbon stock change into the soil per area 73.32 kg C/ha. The annual tree biomass increment per hectare (resulting from application of annual wood volume increment data and biomass conversion/expansion factor) varies from 1.3 to 5.7 t dm/ha. The total annual carbon increment in tree biomass is 4 201.4 kt C. The total annual carbon consumption from forest harvest in the Slovak forests is 702.93 kt C.

Emission Factors and Emissions

The carbon stock change in soil from the forest land per 2006 is $-3\,096.83$ Gg of CO_2 . It is necessary to mention that almost every forest on the area of the SR are managed, it means that total annually uptake on woody areas for last 100 years and the harvest from deforestation are included in this category. The summary results from this category are depicted on Figure 7. 2. Uptake of carbon into the biomass of forest trees is slightly increased from 1990 despite release of carbon in this category is highly fluctuated and is determining factor of final balance different. The category of fuel wood is connected to the energy sector (fuel combustion) where other gases are balanced. Total decreasing of the removals from the managed forest land in the SR comparable to the 1990 is more than 10 %.

Figure 7. 2: The CO_2 balance from managed forests – total Forest land during 1990–2006

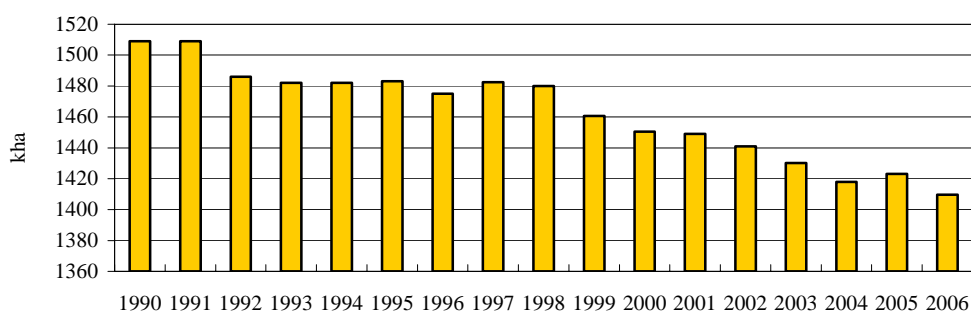


7.3 Cropland

Methodology and Activity Data

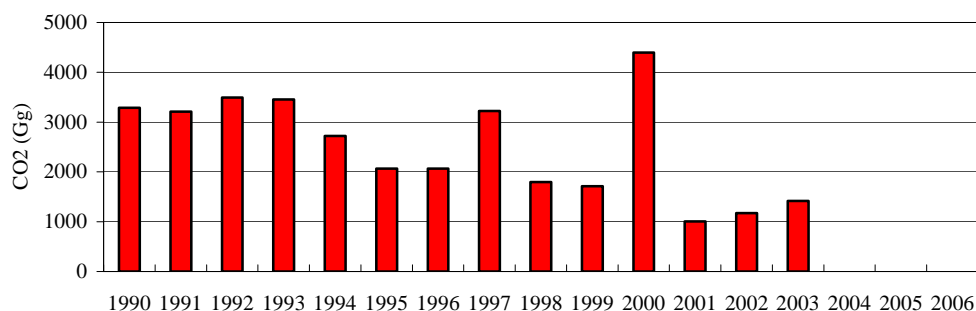
Results of recalculations were obtained by using the new LULUCF Methodology (IPCC, 2003) and national data on area of cropland and land converted to the cropland during the inventory year 2006. The Figure 7. 3 shows the activity data in kha per recalculated time series 1990–2006. The total area of cropland remaining cropland in 2006 was 1 409.7 kha per 2006. Total cropland area in 2006 was 1 409.7 kha.

Figure 7. 3: Development of total cropland – Cropland remaining Cropland in 1990–2006



Emission Factors and Emissions

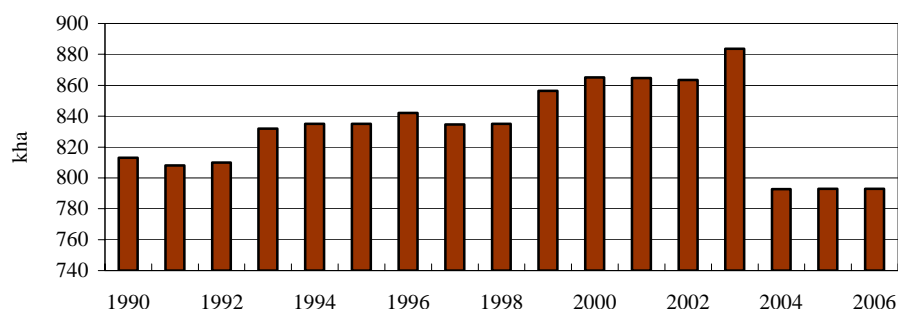
The carbon stock change in soil from the cropland per 2006 is 4.89 Gg of C. The total quantity of removed CO_2 in this subcategory is 1.08 Gg CO_2 . The summary results from this category are depicted on Figure 7.4. Total decreasing of the removals from the cropland in the SR comparable to the 1990 is more than 100 % caused by shifted from the positive emissions to the removals in 2006.

Figure 7. 4: The CO₂ balance from total Cropland during 1990–2006

7.4 Grassland

Methodology and Activity Data

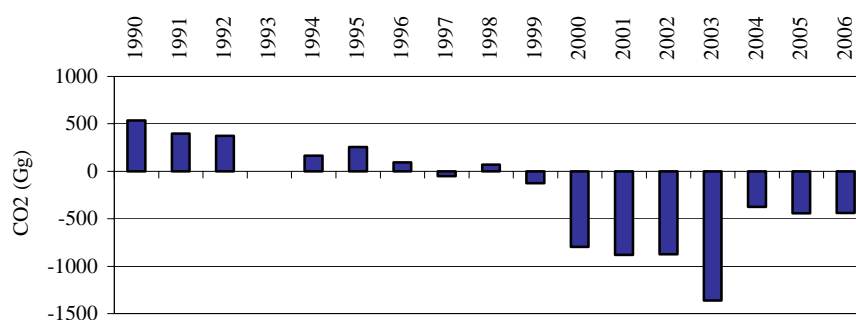
Results of recalculations were obtained by using the new LULUCF Methodology (IPCC, 2003) and national data on area of grassland and land converted to the grassland during the inventory year 2006. The Figure 7. 5 shows the activity data in ha per recalculated time series 1990–2006.

Figure 7. 5: Development of total grassland area – Grassland remaining Grassland in 1990–2006

The total area of grassland remaining grassland in 2006 was 792.8 kha, the changes in the grassland were following cropland converted to the grassland 73.5 kha per 2006 and other land converted to the grassland 26.7 kha per 2006. Total grassland in 2006 was 893.2 kha, with the net carbon stock change into the soil per area 134.8 kg C/ha.

Emission Factors and Emissions

The carbon stock change in soil from the Grassland per 2006 is 119.85 Gg of C. The total quantity of removed CO₂ in this subcategory is –439.45 Gg CO₂. The summary results from this category are depicted on Figure 7.6. Total decreasing of the removals from the cropland in the SR comparable to the 1990 is more than 100 % caused by shifted from the positive emissions to the removals in 2006.

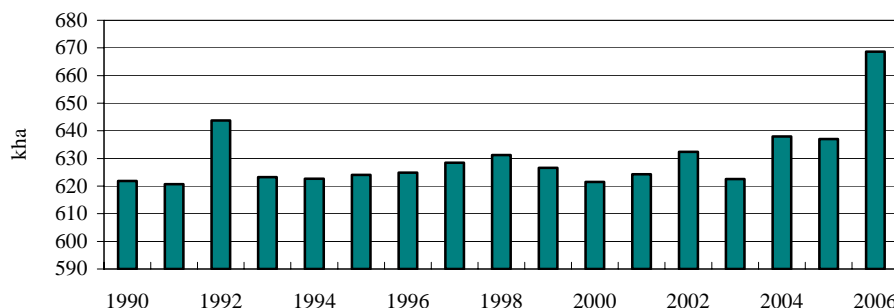
Figure 7. 6: The CO₂ balance from total Grassland during 1990–2006

7.5 Other Land

Methodology and Activity Data

Results of recalculations were obtained by using the new LULUCF Methodology (IPCC, 2003) and national data on area of other land and land converted to the other land during the inventory year 2006. The Figure 7. 7 shows the activity data in ha per recalculated time series 1990–2006.

Figure 7. 7: Development of total other land area – Other land remaining Other land in 1990–2006

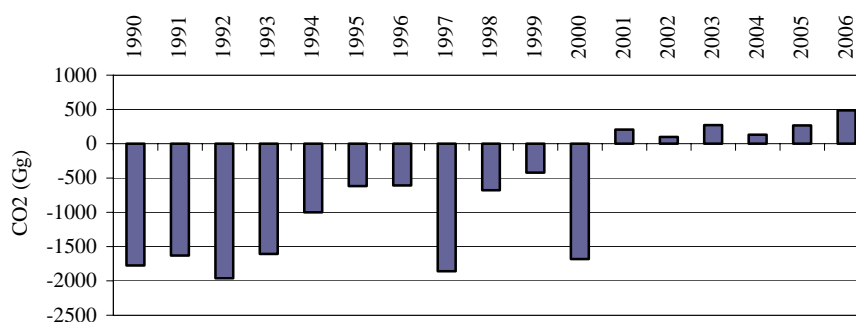


The total area of other land remaining other land in 2006 was 637.0 kha, the changes in the other land were following forest land converted to the other land 35 kha per 2006, Cropland converted to Other land 46.8 kha per 2006 and Grassland converted to Other land 7 kha per 2006. Total Other land in 2006 was 757.4 kha, with the net carbon stock change into the soil per area 26.6 kg C/ha.

Emission Factors and Emissions

The carbon stock change in soil from the other land per 2006 is –158.71 Gg of C. The total quantity of removed CO₂ in this subcategory is 484.40 Gg CO₂. The summary results from this category are depicted on Figure 7. 8.. Total decreasing of the removals from the Other land in the SR comparable to the 1990 is more than 100 % caused by shifted from the removals to the emissions in 2006.

Figure 7. 8: The CO₂ balance from total Other land during 1990–2006



7.6 Controlled Burning and Forest Fires

Activity data and emissions from controlled burning and forest fires are summarized in the following Table 7. 2. The input data come from the Statistic Office of the SR.

Table 7. 2: Forest fires and controlled burning of the forest in 1990–2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Biomass burned	t dm																
Control Burning	82.60	52.47	46.96	47.82	49.97	56.04	60.24	65.83	65.79	76.12	69.26	83.58	82.43	89.20	110.17	131.45	123.47
Forest Fires	4.79	1.94	10.56	11.57	1.41	1.39	3.50	1.88	0.50	0.45	1.41	0.49	0.50	2.46	2.07	2.12	1.92

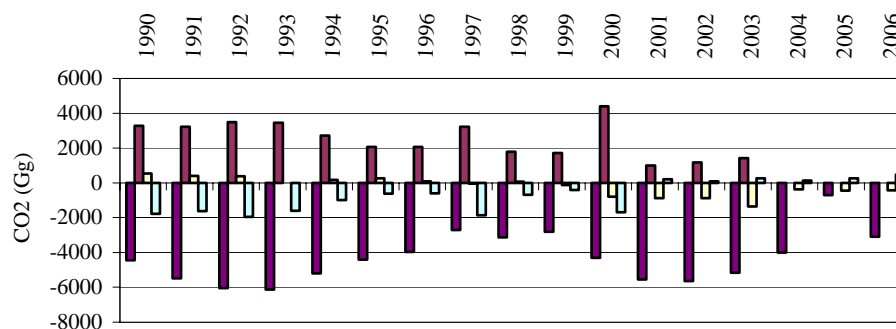
7.7 Total LULUCF

The total net emissions/removals of carbon dioxide represent –3 050.795 Gg due to Forest land (–3 096.83 Gg), Cropland (1.02 Gg), Grassland (–439.45 Gg) and Other land (484.40 Gg). Total amount of methane emission from LULUCF sector represents 0.9 Gg of CH₄ and total amount of N₂O is 0.0102 Gg. The emissions of other pollutant are from forest fire and controlled burning of forest. The NO_x emissions are 0.449 Gg and emissions of CO are 7.9 Gg in 2006. Summary results are presented on Figure 7. 9. The total removals from the LULUCF sector fluctuated between 1990 and 2006 (Table 7. 3).

Table 7. 3: The total CO₂ emissions and removals according categories during 1990–2006

Emissions (Gg)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Forest land	-4,454.0	-5,485.3	-6,056.3	-6,135.0	-5,205.5	-4,399.4	-3,968.5	-2,717.4	-3,130.1	-2,800.3	-4,318.4	-5,550.6	-5,641.2	-5,155.6	-3,995.4	-701.3	-3,096.8
Cropland	3,286.7	3,211.0	3,494.8	3,456.9	2,724.8	2,062.6	2,062.6	3,226.1	1,797.7	1,710.7	4,394.2	1,002.3	1,174.0	1,416.3	-14.2	1.1	1.1
Grassland	535.9	396.1	372.8	NO	163.1	256.3	93.2	-49.7	69.9	-126.5	-797.4	-880.4	-873.7	-1,363.2	-373.3	-441.7	-439.5
Wetland	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Settlements	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other	-1,775.1	-1,629.3	-1,962.4	-1,606.1	-998.9	-615.5	-609.0	-1,860.8	-677.0	-419.8	-1,681.9	203.6	98.0	269.3	131.9	264.5	484.4
Total net	-2,406.6	-3,507.5	-4,151.1	-4,284.2	-3,316.5	-2,696.0	-2,421.6	-1,401.8	-1,939.5	-1,635.9	-2,403.4	-5,225.1	-5,242.9	-4,833.2	-4,250.9	-877.3	-3,050.8

Figure 7. 9: The total CO₂ balance in LULUCF sector in 1990–2006



8 WASTE

8.1 Input Data

Juraj Farkas (Integrated Skills Ltd. – UK) as sectoral expert for waste assigned by the Department of Air Protection of the Ministry of Environment of the Slovak Republic by the letter dated 17th July 2006 under the national UNFCCC system, has signed agreement with the Slovak Hydrometeorological Institute on May 2, 2007 on preparing report evaluating „GHG Emissions from Waste Sector in 2006“.

The production of emission of CH₄ and N₂O are important by disposal waste and wastewater treatment. Disposal of wastes and handling of wastewater results in production of greenhouse gases emissions. An estimation of the following emissions in 2006 is presented:

- Solid Waste Disposal Sites (4A)
- Wastewater Handling (4B)
- Waste Incineration and open Burning (4C)
- Biological Treatment of Solid Waste (4D)

The IPCC Methodology (IPCC, 1996) and Good Practice Guidelines (IPCC, 2000) were used by estimation of methane emissions from waste and wastewater. The emissions of nitrous oxide from wastewater were calculated by using IPCC and ISI methodologies. As a source of input data were used the database of Centre of Waste Service and Environmental Management in Bratislava and database of wastewater on the SHMI. Other necessary input were obtained from publications (Statistical yearbook, 2007, Green Report, 2007).

Improvements

The following major improvements were applied to emission estimations:

- The IPCC 2006 Guidelines were used as the basis for emission estimation for the first time,
- For disposal and incineration of ISW the emission assessment is based on individual waste streams, not on the total amount of ISW,
- Emissions from composting were estimated,
- Recovery of methane from MSW disposal was included into the balance,
- Sewage sludge and clinical waste emissions from incineration were assessed separately.

8.2 Solid Waste Disposal Sites

The emissions from solid waste disposal sites (SWDS) are the main emissions of the waste sector. The methane emissions are estimated separately for municipal solid waste (MSW) and industrial solid waste (ISW).

8.2.1 Disposal of Municipal Solid Waste

Methodology and Activity Data

On July 1, 2001 was taken in force new legislative regulation about SWDS in accordance the harmonisation with EU legislative. The relevant Act No. 223/2001, Decree of Ministry of Environment No. 283/2001 contains new regulation of limitation of SWDS, disposal with waste gases and monitoring of waste disposal. The gases produced in solid waste disposal sites, particularly CH₄, can be a local environmental hazard if precautions are not taken to prevent uncontrolled emissions or migration into surrounding land. Landfill gas is known to be produced both in managed “landfill” and “open dump” sites. Both are considered here as solid waste disposal sites (SWDSs). Either gas can migrate from SWDSs laterally or by venting to atmosphere, causing vegetation damage and unpleasant odours at

low concentrations, while at concentrations of 5–15 % in air, the gas may form explosive mixtures. It will then describe two methodologies for estimating CH₄ emissions from SWDSs. One of these methods is a default base method, which all countries can use to estimate CH₄ emissions from different types of SWDSs. It is recommended that countries, which have adequate data, also estimate their emissions using the second method presented.

A number of methods are used to estimate CH₄ emissions from solid waste disposal sites. These methods vary widely, not only in the assumptions that they make, but also in their complexity, and for data they require. Some very complex models are concerned with movement of CH₄ and other gases through individual disposal sites; however, these models cannot be applied to site populations and therefore will not be considered further here.

The Figure 3.1 in the IPCC Guidelines 2006 presents a decision tree for CH₄ emissions from waste disposal. The following table presents answers, relevant to situation in MSW disposal in the SR. Tier 2 – Estimate emissions using the IPCC FOD method with default parameters and good quality country-specific activity data were selected as appropriate method. Comparing the situation abroad with the situation in the SR, several differences can be identified:

- Most countries are using site-specific data. The methane emissions are calculated for each SWDS (or group of SWDS) separately and then the results are summed to obtain national methane emissions estimations. This approach is not yet possible in the SR, because collected data on MSW do not include the needed characterisation of SWDS;
- Historical data on MSW management and disposal are more detailed than data available in the SR;
- Data on MSW fractions are collected in more systematic and regular way than is the practice in the SR.

As the most appropriate approach was selected the second version of FOD method, as it is defined in the IPCC Good Practice Guidance. This decision is supported by following reasons:

- Parameters used are better defined and allow direct comparison with the Tier 1 method;
- Some of the parameters used are defined as time-variables. This allows modelling of the waste sector transformation in the SR in the period 1992–2000;
- Structure of required input data better corresponds with MSW data available for the SR (data for the use of multiphase method are not available).

A small, but important change is done to better reflect the significant improvement of SWDSs practice in the period 1992–2000. The MCF is not depending on the year when MSW was disposed, but on the year when the inventory (estimation of methane emission) was done. The original IPCC equation here MCF is depending on the year when MSW was disposed follows the idea that landfill operation practice does not change with time. This is in contradiction to the situation in the SR, where within a relatively short time disposal practices changed toward controlled landfilling. Compacting and covering of waste was introduced and this, to our opinion, caused increased generation of methane. However, this period of modernising of disposal practice in the SR requires further investigation.

The Slovak technical standard STN 83 8108 Landfilling – Landfill gas recommends the following equation for estimation of landfill gas generation per ton of waste:

Estimation of landfill gas generation according to STN:

$$G_t = 1.868 \cdot C_O \cdot (0.014 \cdot \bar{\delta} + 0.28) (1 - 10^{-kt})$$

Where:

- G_t = landfill gas generation per year (m³/t)
- C_O = organic carbon in waste (recommended 150–200 kg/t)
- $\bar{\delta}$ = temperature (recommended 20–40°C)
- k = decay parameter (recommended 0.03–0.06)
- t = time (years).

Activity Data and Other Parameters

The IPPC methodologies encourage the use of locally based parameters, which reflect local level and conditions of MSW disposal. FOD method parameters (this includes Tier 1 parameters, because they are used in FOD method) were reviewed with the aim to identify parameters specific to MSW management in the SR. Parameters currently used for methane emission estimation in the Slovak Republic were critically reviewed and additional data were collected to support proposed changes in these parameters.

A brief overview of Slovak waste management milestones (Table 8. 1) was prepared as an introduction to the discussion on parameters and activity data. These milestones were selected to provide support to the arguments why and how parameters and activity data were proposed or modified.

Table 8. 1: Milestones of waste management in the Slovak Republic

Year	Milestone
1960	Estimation of MSW generation in Slovak Republic (565 Gg)
1970	Estimation of MSW generation in Slovak Republic (665 Gg)
1977	MSW incinerator put in operation in Bratislava
1980	Analysis of MSW fractions in Bratislava and Kosice
1989	MSW incinerator put in operation in Kosice
1991	First waste legislation adopted
1992	Start of regular recording of waste data
1992	A.S.A. started operation in Slovak Republic (serving ca. 10% of population in 2006)
1995	Marius Pedersen started operation in Slovak Republic (serving about 20% of population in 2006)
2000	Operation of SWDS non-complying with legislation ended
2000	Reconstruction of MSW incinerator in Bratislava
2001	Waste legislation update, approximation to EU waste law started
2002	EU waste classification system adopted
2003	IPPC Directive implemented in Slovak Republic
2004	Slovak Republic joining EU, Transposition of EU waste law to Slovak legal system

The Statistical Office published information on MSW generation in 2006. The model for estimation of methane emissions from SWDS was updated. The data on landfill gas flaring¹² were identified and can be now included into the model for estimation of methane emissions from SWDSs in the Slovak Republic. The following amounts of landfill gas were flared (Table 8. 2).

Currently two landfills have installed flaring systems, in both cases the landfill gas collection and flaring system was installed by company Terrasystems within a carbon trading scheme. The company wants to include another four landfills, resulting in expected savings of ca. 550 000 tons of CO₂ in the period 2008–2012. The annual saving can be estimated to 110 Gg CO₂ or 5 Gg CH₄ or nearly 10 % decrease of methane emissions from MSW landfills in the SR.

Table 8. 2: Methane recovery from SWDS in the SR

Year	Total recovered methane (Gg/year)
2003 and before	0
2004	0.03
2005	0.45
2006	0.79

¹² Energetické využitie skládkového plynu Juraj Klukan, H+W Service, spol. s.r.o. Bratislava, 2006

Methane Correction Factor

The methane correction factor (MCF) describes the way how MSW is managed on site, this factor is individual for each landfill. The currently available data do not allow a site-by-site approach.

But, with the adoption of the first Waste Act a period of re-direction of MSW stream from old non-complying SWDSs to controlled EU-standard landfills was enforced by the Slovak Ministry of Environment. Thus, the following hypothesis is proposed:

- Before 1992 all MSW was disposed to SWDSs on which very little or no data exist = IPCC category uncategorised sites;
- Since 2000 all MSW is disposed to managed landfills = IPCC category managed sites;
- Period 1993–1999 is a period of transition when managed sites were gradually developed = linear growth of MCF.

Of course, there is a risk that managed sites existed before 1992 or uncategorised sites were still in (illegal) operation after 2000, but there is no available evidence to reject the hypothesis above. MCF(x) for year 2006 was 1 fraction.

Degradable Organic Carbon

An analysis of existing data on MSW fractions in the Slovak republic was done to verify the value of DOC. The MSW composition data cover different target areas (national, regional, municipal, sub-urban) and are from various years (in general 1997–2006) but the following calculations are aimed more on presenting a DOC calculation method to be used in future when better data are available.

The data used can not be fully verified, and the methodology of MSW composition analysis is not known for some data, but they are quoted in official documents of the Slovak Ministry of Environment.

The GPG 2000 presents IPCC default DOC values for paper, textile, garden and park waste, food waste and wood and straw. It is assumed, that the remaining MSW has DOC values equal or very close to 0, thus not influencing methane generation balance. These default DOC values were used to calculate site-specific DOC values using the following equation, a modification of Equation 2 from Revised 1996 IPCC Guidelines:

$$\text{DOC} = 0.4 (A) + 0.16 (B) + 0.30 (C)$$

Where

- A = paper and textile fraction of MSW;
- B = biowaste (combined food waste and garden and park waste);
- C = wood and straw.

The following Table 8. 3 shows results of MSW composition analysis for various towns and villages in the SR and calculated DOC values. These data should be understood as informative, because the method of analysis is not known in all cases.

Table 8. 3: The DOC based on individual MSW analyses

Location	Paper, textile	Bio waste	Wood	DOC
D. Streda	18.50%	28.20%	1.30%	0.12
Presov	15.00%	44.50%	2.10%	0.14
Poprad	20.90%	45.40%	1.80%	0.16
Humenne	17.70%	25.20%	2.20%	0.12
Košice	24.00%	45.00%		0.17
Prievidza	10.50%	36.00%		0.1
Brezno	14.00%	31.00%		0.11
Cifare	11.60%	28.30%		0.09
Kálna n/H	17.80%	31.30%		0.12
Levice	23.00%	24.90%		0.13
Nitra	11.10%	31.50%	18.60%	0.15
Trebišov	8.00%	51.00%		0.11

The average DOC value is 0.12 Gg C/Gg MSW. This is very close to the DOC value used in the SR for estimation of methane emissions from SWDSs. Also, MSW composition data by type of dwellings and by type of heating published in Czech Republic in 2003 were processed to verify the DOC values with following results (Table 8. 4 and Table 8. 5).

Table 8. 4: The DOC based on type of dwelling

MSW fraction	C1	C2	S	V
Paper and textile	28.30%	28.80%	30.70%	9.80%
Biowaste	18.20%	19.60%	17.30%	6.30%
DOC	0.14	0.14	0.15	0.05

Note: C1 apartment blocs, large towns population over 80 000 and centralised heat supply, C2 apartment blocs, smaller towns population 20–80 000 and centralised heat supply, S mixed housing of towns, mixed heating systems, V rural housing, family houses and local heating with solid fuels.

Table 8. 5: The DOC based on type of heating

Households with:	- gas heating		- solid fuel heating	
	Range	Average	Range	Average
Paper and textile	15.5 % - 30.5 %	24.0 %	1.8 % - 19.9 %	11.3 %
Kitchen waste	26.2 % - 72.2 %	47.8 %	14.5 % - 45.5 %	32.5 %
DOC	0.10 - 0.23	0.17	0.03 - 0.15	0.09

The DOC values in Table 8. 4 and Table 8. 5 indicate significant dependence of DOC on type of heating. Using formula below indicative historical DOC values can be estimated from statistical data on housing quality – these are shown in the Table 8. 6.

$$DOC_{(X)} = DOC_{CH} \cdot HCH_{(X)} + DOC_{SF} \cdot (1-HCH_{(X)})$$

Where:

- $DOC_{(X)}$ = DOC value in the year X;
- DOC_{CH} = Average DOC value for households with central heating / gas heating;
- DOC_{SF} = Average DOC value for households with solid fuel heating;
- $HCH_{(X)}$ = Share of households with central heating / gas heating in the year X.

The remaining DOC data were interpolated using linear regression.

Table 8. 6: The Estimation of historical DOC data

Year	Households with central heating		
	DOC by Table 8. 4	DOC by Table 8. 5	
1961	7.4 %	0.06	0.08
1970	23.6 %	0.07	0.09
1980	46.2 %	0.09	0.10
1991	74.7 %	0.12	0.11
2001	76.3 %	0.12	0.11

Oxidation Factor

Well-managed SWDS use 0.1 for oxidation factor. The current situation of MSW disposal in the SR has improved significantly, according to the waste legislation only well-managed landfills can be operated. This provides the argument that the Slovak Republic should not use the IPCC default zero for this parameter. On the other hand, there are still old SWDS which were not properly built nor operated. The OX value is considered a time-variable, although this is not stated in the IPCC documents. Currently we are using for the 2006 the OX = 0.05 fraction.

Methane Generation Potential

The methane generation potential is calculated using values proposed in Table 8. 7 and Table 8. 8. The methane generation potential is also a time-variable, as its value depends on time-variable parameters.

Methane Generation Constant

The methane generation constant depends mainly on moisture, for areas with rainfall over 500 mm/yr the recommended value is 0.065. The rainfall was in the last 10 years over 500 mm/yr.

Overview of Constant Parameters

The following parameters are proposed as constant for estimation of methane emissions from SWDS:

Table 8. 7: The proposed parameters as a constant

Parameter	Value	Note
Fraction dissimilated DOC (DOC_F)	0.6	IPCC default value, no national data available
Fraction of methane in landfill gas (F)	0.5	IPCC default value, national data not representative
Methane recovery (R)	0	No methane recovery in the SR
Methane generation rate constant (k)	0.065	Not sufficient data for use of multiphase model

Overview of Time-variable Parameters

The following parameters are proposed as time-variable for estimation of methane emissions from SWDS:

Table 8. 8: The proposed parameters as a time- variable

Parameter	Range	Note
Methane correction factor (MCF)	0.6 - 1	Constant in 1960 – 1992 (no data), linear increase 1993 – 2000, constant from 2001
Degradable Organic Carbon (DOC)	0.06 – 0.12	Linear increase in 1960 – 1991. constant after 1991
Oxidation factor (OX)	0 – 0.05	Zero till 2000, 0.05 from 2001
Methane generation potential (L_0)	0.014 – 0.048	Function of DOC

Activity data used for estimation of methane emissions from SWDS are the following:

- Length of data timeline;
- Total MSW generated;
- Fraction of MSW landfilled;
- Length of data timeline.

The Statistical office of the Slovak Republic publishes data on MSW generation and disposal since 1992. Although this creates a timeline of 15 years, this is not sufficient for the use of FOD method. A longer timeline of data is needed. There are several possibilities how to estimate the needed length of data timeline:

- The Waste Act requires monitoring of a landfill at least for 30–50 years (approximately period when all biodegradable components in MSW should decompose);
- The methane generation constant for slower decay rates ($k = 0.03$) means a half life of about 23 years;

- The latest available estimation on MSW in the Slovak Republic dates back to 1960;
- Statistical data on housing (needed for estimation of DOC(X)) are available from 1961.

Therefore it was decided to generate a MSW data from 1960, i.e. for 46 years.

Total MSW Generated

The data on MSW were analysed and processed to obtain the possibly most realistic view on the historical MSW data.

Reliability of Existing Data

Analysis of MSW generation data shows, that there is recorded a huge difference in MSW generation in years 1992–94, comparing to the data 1995–2005. This can be explained by a “learning period” when waste generators getting familiar with the new system of data recording. Therefore it is proposed to exclude these “inflated” data from estimation of methane emissions and replace them by interpolated data, as explained in the following. It may be interesting that similar, but smaller “inflation” of data appears also in the period 2002–2005, when EU waste classification system was introduced.

Interpolation of Non-existing Data

Latest indication on MSW generation in the Slovak Republic was found for 1960 and 1970. Since 1992, data from annual monitoring are available. Annual MSW generation was interpolated from these data using following equation:

$$MSWT_i = Pop_i ((MSWC_2 - MSWC_1) / (Year_2 - Year_1) + MSWC_{i-1})$$

Where:

- i = Year, for which MSW generation is interpolated;
- $MSWT_i$ = Total MSW generated in the year i ;
- Pop_i = population in the year i ;
- $MSWC_2$ = MSW per capita in the Year 2;
- $MSWC_1$ = MSW per capita in the Year 1;
- $MSWC_{i-1}$ = MSW per capita in the previous year;
- Year 2 = last year of the period for which data are interpolated;
- Year 1 = first year of the period for which data are interpolated.

It is hard to expect that further research will result in more exact data on MSW generation in past (before 1989) as the practise of MSW generation estimation in that time was based on number of kilometres driven by a collection vehicle. These data were often considerably exaggerated.

Fraction of MSW Landfilled

When assessing the amount of MSW disposed to SWDSs, the key factor to the MSW management practice in the Slovak Republic is operation of two MSW incinerators in Bratislava and Kosice.

These two incinerators burned in average 150 Gg MSW per year in the period 1993–2004 (BA 100 Gg/yr, KE 50Gg/yr). It is assumed that this amount of MSW was burned since they were put in operation. Thus, the input values for fraction of MSW landfills can be divided into three periods:

- 1960–1976 1 - All waste disposed to SWDS;
- 1977–1994 0.9 - MSW Incinerators in operation;
- 1995–2005 Real data on MSW disposed were used.

The activity data used for estimation of methane emissions from MSW disposed to SWDSs are shown in the Table 8. 10 – MSW activity data. Average MSW values for the period 1995–2005 are in the following Table 8. 9: :

Table 8. 9: The MSW typical values for the Slovak Republic 1995–2006

MSW generation:	268	kg MSW/cap/yr
	0.73	kg MSW/cap/day
Fraction of MSW disposed to SWDS:	0.82	
MSW disposal rate:	0.6	kg MSW/cap/day

Emission Factors and Emissions

Due to proposed changes to parameters, recalculation of estimation of emissions from SWDS in the SR was done for the time period 1990–2006 for both Tier 1 and Tier 2 methodologies, year 200ž only with Tier 2 FOD methodology. The input parameters are collected in the Table 8. 10.

Table 8. 10: MSW disposed to SWDS – Activity data during 1960–2006

Year	Population	MSW T(X) (Gg/yr)			MSW L(X) (Gg/yr)		NOTE
		Original	Modified	MSWE	Original	Modified	
1960	3,994,270	565	565	1	565	565	Tölgyessy&Patrik
1961	4,191,977	595	595	1	595	595	
1962	4,238,056	604	604	1	604	604	
1963	4,282,865	613	613	1	613	613	
1964	4,327,949	622	622	1	622	622	
1965	4,373,595	630	630	1	630	630	
1966	4,413,853	639	639	1	639	639	
1967	4,450,880	646	646	1	646	646	
1968	4,483,656	654	654	1	654	654	
1969	4,518,773	661	661	1	661	661	
1970	4,528,459	665	665	1	665	665	Tölgyessy&Patrik
1971	4,559,341	692	692	1	692	692	
1972	4,596,330	719	719	1	719	719	
1973	4,640,673	749	749	1	749	749	
1974	4,691,014	780	780	1	780	780	
1975	4,739,301	811	811	1	811	811	
1976	4,789,452	843	843	1	843	843	
1977	4,840,819	875	875	0.9	788	788	
1978	4,891,673	908	908	0.9	817	817	
1979	4,940,223	941	941	0.9	847	847	
1980	4,984,331	973	973	0.9	876	876	Interpolated
1981	5,017,032	1,004	1,004	0.9	904	904	
1982	5,054,770	1,036	1,036	0.9	933	933	
1983	5,091,537	1,068	1,068	0.9	962	962	
1984	5,127,719	1,101	1,101	0.9	991	991	
1985	5,161,789	1,133	1,133	0.9	1,020	1,020	
1986	5,192,789	1,165	1,165	0.9	1,049	1,049	
1987	5,223,609	1,197	1,197	0.9	1,078	1,078	
1988	5,251,120	1,229	1,229	0.9	1,106	1,106	
1989	5,276,186	1,260	1,260	0.9	1,134	1,134	
1990	5,297,774	1,291	1,291	0.9	1,162	1,162	Interpolated
1991	5,283,404	1,313	1,313	0.9	1,182	1,182	
1992	5,306,539	2,461	1,345	0.9	2,247	1,210	
1993	5,324,632	2,331	1,375	0.9	2,025	1,238	
1994	5,347,307	1,909	1,407	0.9	1,709	1,266	
1995	5,363,676	1,570	1,570	0.86	1,347	1,347	
1996	5,373,793	1,458	1,458	0.86	1,249	1,249	
1997	5,383,233	1,451	1,451	0.83	1,206	1,206	
1998	5,390,866	1,366	1,366	0.81	1,113	1,113	
1999	5,395,324	1,380	1,380	0.82	1,134	1,134	
2000	5,400,679	1,339	1,339	0.79	1,056	1,056	Statistical office data hold
2001	5,379,780	1,258	1,258	0.83	1,049	1,049	
2002	5,378,809	1,524	1,524	0.78	1,192	1,192	
2003	5,378,950	1,599	1,599	0.79	1,256	1,256	
2004	5,382,574	1,475	1,475	0.81	1,195	1,195	
2005	5,387,285	1,468	1,468	0.78	1,145	1,145	
2006	5,393,640	1,260	1,260	0.79	1,260	1,260	

COHEM estimation

The basic difference in results calculated using Tier 1 methodology is, that the set of default parameters includes $DOC_F = 0.77$ but proposed parameters use $DOC_F = 0.6$. This explains lower emissions estimated using proposed parameters in the period 1990–1994. Faster growth of methane emissions is caused by increase of MCF in period 1993–2000 (changing from 0.6 to 1).

The estimation of methane emissions from SWDSs using FOD method were calculated using a spreadsheet model. Results are presented as cumulative diagram (Figure 8. 1), which shows contribution of emissions from MSW disposed each year and covers the entire period 1960–2006 and as a bar chart showing total emissions for the period 1990–2006.

According to the used model for estimation of methane emissions from MSW disposed to SWDSs the total emissions reached 47.25 Gg/yr in 2006. Values and parameters were used for emission estimations according to Tier 2 FOD methodology. The cumulative diagram shows fast increase of methane emissions in the period 1994–2002, this can be explained as a reaction to the improvement of MSW disposal practices in the period 1992–2000 (Table 8. 11) and (Figure 8. 1). The methane emissions, estimated using the Tier 2 methodology, are lower than those estimated by the Tier 1 methodology. Also, the results of Tier 2 estimation create a smoother line than Tier 1 results as year-to-year changes in amount of disposed MSW are spread in form of emissions to more years. The following figure compares the methane emissions in the period 1990–2006. In both cases modified activity data and proposed parameters were used (Figure 8. 2 and Figure 8. 3).

Figure 8. 1: Methane emissions from SWDS according Tier 2 methodology

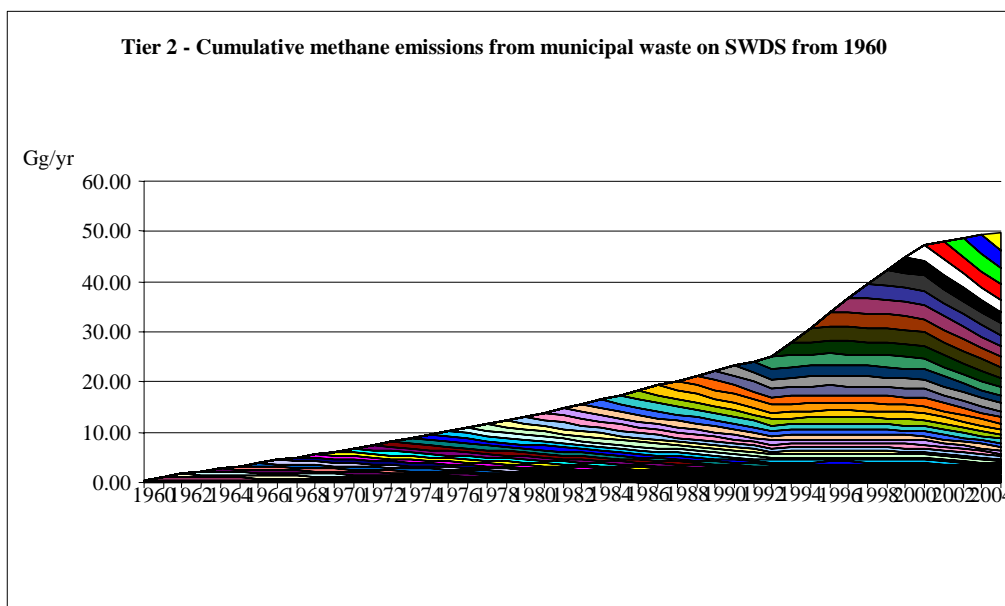


Figure 8. 2: Methane emissions from SWDS in the period 1990–2006

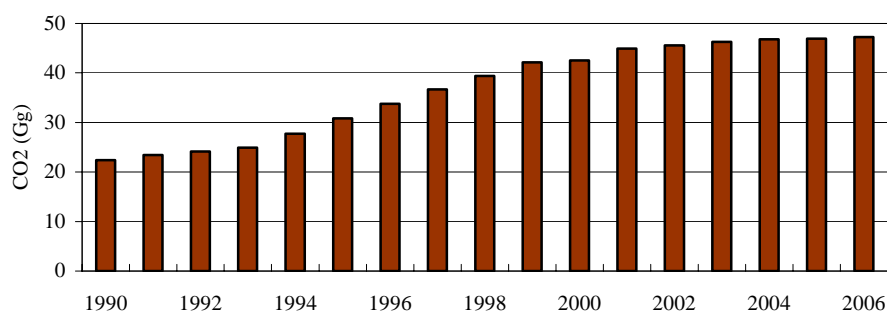
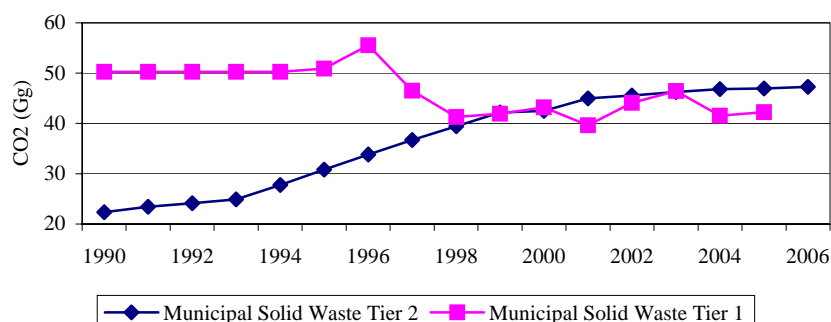


Figure 8. 3: The comparison of Tier 1 and Tier 2 methodology during 1990–2005 (2006)



When comparing the results obtained by the Tier 1 and Tier 2 methods, the basic difference between these methods must be kept in mind:

- Tier 1 method assumes that all methane is emitted “at once” and not only activity data but also parameters reflect the situation in the year of MSW disposal;
- Tier 2 method assumes, that methane is emitted “continuously” and current emissions are influenced by the past emissions.
- This difference in approach to emission estimation can be negligible in countries with long history in controlled MSW disposal, but in countries which recently significantly changed their waste management practices (like the SR) this creates additional uncertainties.

Table 8. 11: The recalculated methane emissions from municipal SWDS during 1990–2006

Year	MSWL	MCF	DOC	L0	OX	Rec	CH4 (Gg)
1990	1 162	0.6	0.12	0.028	0	0	22.37
1991	1 182	0.6	0.12	0.029	0	0	23.45
1992	1 210	0.6	0.12	0.029	0	0	24.16
1993	1 238	0.6	0.12	0.029	0	0	24.89
1994	1 266	0.65	0.12	0.031	0	0	27.75
1995	1 347	0.7	0.12	0.034	0	0	30.85
1996	1 249	0.75	0.12	0.036	0	0	33.81
1997	1 206	0.8	0.12	0.038	0	0	36.7
1998	1 113	0.85	0.12	0.041	0	0	39.4
1999	1 134	0.9	0.12	0.043	0	0	42.18
2000	1 056	0.95	0.12	0.046	0.05	0	42.51
2001	1 049	1	0.12	0.048	0.05	0	44.94
2002	1 192	1	0.12	0.048	0.05	0	45.54
2003	1 256	1	0.12	0.048	0.05	0	46.27
2004	1 195	1	0.12	0.048	0.05	0	46.79
2005	1 142	1	0.12	0.048	0.05	0	46.94
2006	1 260	1	0.12	0.048	0.05	0	47.25

8.2.2 Disposal of Industrial and Other Waste Streams

The Figure 3.1 in GL2006 presents a decision tree for CH₄ emissions from waste disposal. The following table presents answers, relevant to situation in ISW disposal in The the Slovak Republic.

ISW - CH4 decision tree	
Question	Answer
Are good quality country-specific activity data on historical and current waste disposal available?	NO
Is solid waste disposal on land a key category?	NO
Tier 1:	
Estimate Emissions using the IPCC FOD method with default data to fill in missing country-specific data.	
BUT	
Tier 0 used, see the text below	

The “Tier 0” methodology is still considered as the most appropriate method for estimation of methane emissions from ISW disposal to SWDSs in the SR. The key problem is the unavailability of a consistent time series needed for Tier 2. The option of estimating amount of ISW from GDP (Tier 1) is not suitable, as there were/are too many changes (political, technological, ownership) significantly influencing ISW management. The number of companies producing larger amounts of waste is relatively small, thus fluctuations in their production and/or waste generation strongly influence ISW balance in the Slovak Republic.

Methodology and Activity Data

The Equation 1 from Revised 1996 IPCC Guidelines is used.

$$E_{CH_4} = (ISW_{Li} * MCF * DOC_i * DOC_F * F * 16/12 - R) * (1 - OX)$$

Where

- ISW_{Li} sum of industrial solid waste streams disposed to solid waste disposal sites with DOC_i (Gg/yr),
- MCF methane correction factor (fraction),
- DOC_i degradable organic carbon (fraction),
- DOC_F fraction DOC dissimilated,
- F fraction of CH_4 in landfill gas (default is 0.5),
- R recovered CH_4 (Gg/yr),
- OX oxidation factor (fraction – default is 0).

Not the total amount of landfilled ISW was used as input for the equation above, but only selected waste streams with $DOC > 0$. This can be expressed by the equation

$$ISW_{Li} = \sum (G_k)$$

Where

- G_k is the amount of ISW landfilled of the waste group k in waste classification system.

The default IPCC parameters listed in IPCC Guidelines 2006 were used for estimation of methane from ISW disposed to solid waste disposal sites. These parameters are discussed in detail in the report¹³ prepared last year. This chapter is focusing only on specific issues related to ISW disposal in The Slovak Republic.

Degradable Organic Carbon

The default DOC values were assigned to individual groups of waste, defined in the old and new classification systems (Table 8. 12).

Table 8. 12: Default DOC values for major waste streams

Default DOC values for major waste streams		
	Waste Stream	DOC (fraction by weight)
A	Paper and textiles	0.4
B	Garden and park waste, other (non-food) organic putrescibles	0.17
C	Food waste	0.15
D	Wood and straw waste (excluding lignin C)	0.3

¹³ Methane Emissions from Solid Waste Disposal Sites, 2006

Methane Correction Factors

The Table 8. 13 shows SWDS classification and related methane correction factors.

Table 8. 13: SWDS related methane correction factors

SWDS classification and methane correction factors (MCF)	
Type of Site	MCF Default Values
Managed – anaerobic	1
Managed – semi-aerobic	0.5
Unmanaged 3 – deep (>5 m waste) and /or high water table	0.8
Unmanaged 4 – shallow (<5 m waste)	0.4
Uncategorised SWDS	0.6

This parameter is used in the same manner as for MSW landfills, because co-disposal of MSW and ISW ended with the entry of the SR to the EU (2004). The following hypothesis is used:

- Before 1992 all ISW was disposed to SWDSs on which very little or no data exist = IPCC category uncategorised sites,
- Since 2000 all ISW is disposed to managed landfills = IPCC category managed anaerobic sites,
- Period 1993–1999 is a period of transition when managed sites were gradually developed = linear growth of MCF.

Other Parameters

Recommended IPCC default values are used for the remaining parameters DOC_F (0.5) F (0.5), R (0) and OX (0.1).

Activity Data

The structure of data collected by the Statistical Office allowed identification of waste streams which contain mainly biodegradable carbon. The default DOC values were assigned to these waste streams and the resulting are in Table 8. 14.

Table 8. 14: Activity data for the industrial solid waste disposal sites in 1997–2006

ISW disposed to SWDSs (Gg/y)						
Year	Total ISW	Biodegradable ISW	Paper, textile	Wood, straw	Non-food waste	Food waste
DOC			0.4	0.3	0.17	0.15
1997	3085	115	38	25	28	24
1998	2861	372	31	28	54	260
1999	2642	525	49	69	88	319
2000	2313	222	48	17	108	49
2001	2470	220	43	16	75	86
2002	2915	813		70	683	60
2003	3322	612		74	538	
2004	4262	666		125	541	
2005	2888	553		76	477	
2006	5646	625		41	584	

Emissions

The resulting methane emissions from ISW disposal to SWDSs are shown in the following Table 8. 15:

Table 8. 15: Methane emissions from ISW disposed to SWDS

Methane emissions from ISW disposed to SWDS	
Year	CH ₄ (Gg/y)
1990	15
1991	15
1992	15
1993	15
1994	15
1995	15
1996	15
1997	7.4
1998	18.6
1999	30
2000	15
2001	15
<hr style="border-top: 1px dashed black;"/>	
2002	48
2003	38
2004	44.2
2005	34.9
2006	36.6

Note: Dashed line indicates change of waste classification, data from 1990–1996 are extrapolated

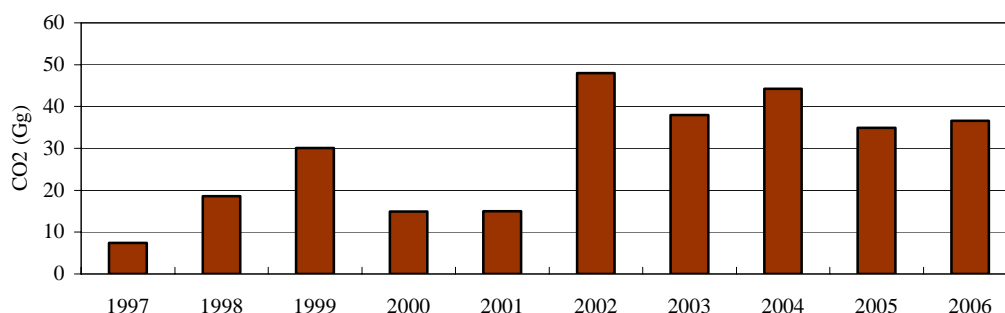
Extrapolation to 1990

The extrapolation of emissions from ISW disposal is not supported by sufficient information and should be understood as informational only from following reasons:

- The system of waste classification has changes in 2002, this is splitting the available data to two non-compatible sets each covering 5 years,
- ISW data are published only since 1997, previous data are not reliable and not compatible with current data,
- The waste management practice has changed significantly in the period 1990–2000 towards controlled landfilling,
- The political system has changed in 1989 and economic transformation started in 1990, the following decade is full of economic turbulences, closing of old factories and starting of new enterprises.

The estimation on methane emissions from disposal of waste to SWDS leads to following conclusions:

- The change of waste classification has little impact on data on disposed MSW, thus extrapolation of data back to 1990 can be done (FOD method is used),
- Methane emissions from MSW, after significant increase due to changes in landfilling practice are stable, growing less than 1 % per year since 2002,
- The change of waste classification in ISW leads to significant change in emission estimation (old system average = 17.2, new system average = 40.3). Thus, there are not sufficient data for extrapolation back to 1990,
- A new approach, based on assessment of DOC content in individual waste streams (categories of EWC) was used to improve the results (Figure 8. 4).

Figure 8. 4: The new recalculated emissions of methane from ISW in 1997–2006

8.3 Emissions of CH₄ from Wastewater

Methodology and Activity Data

Methane emissions from wastewater handling should be calculated for two different wastewater and resulting sludge types:

- Domestic wastewater;
- Industrial wastewater;
- Domestic sludge;
- Industrial sludge.

For each category, the method for estimating CH₄ emissions from wastewater handling requires three basic steps:

- Determine the total amount of organic material in the wastewater produced for each wastewater handling system. The principal factor in determining the CH₄ generation potential of wastewater is the amount of degradable organic material of the wastewater. The most common parameters used to measure the degradable organic component (DC) of the wastewater are the BOD (Biochemical Oxygen Demand – 5 days) and COD (Chemical Oxygen Demand). Data permitting, COD is the recommended parameter for estimating the DC of wastewater. The DC indicator, usually indicated in units of mass DC per unit volume (e.g., kg COD per m³ wastewater) is multiplied by the volume of the source of wastewater (e.g., industry or domestic) to estimate the total amount of organic wastewater produced;
- Estimate emissions factors for each wastewater handling system in kg CH₄ per kg DC. The emissions factors depend on the fraction of wastewater managed by each wastewater handling method, maximum CH₄ producing capacity of the wastewater, and the characteristics of the wastewater handling process (principally, the degree to which it is anaerobic);
- Multiply the emissions factor for each wastewater handling system by the total amount of organic material in the wastewater produced for each system, and sum across the wastewater system to estimate total CH₄ emissions.

The organic content of the wastewater stream and the volume of wastewater drive the greenhouse gas (GHG) generation potential of the wastewater. For the categories of wastewater types defined (domestic and industrial), the following is the method for estimating the total organic wastewater (TOW):

Domestic Wastewater - data needed are:

- Degradable organic component (DC) indicator in kg DC per 1 000 persons per year. For domestic wastewater and sludge, BOD is the recommended DC indicator. Although COD is considered a more appropriate indicator for the organic component of the waste, BOD is the more frequently reported indicator for domestic wastewater. Consequently, the use of BOD estimates will result in more precise calculations than when COD is used;

- Country population in thousands (developing countries may choose to estimate wastewater and sludge handling emissions based only on the urban population of the country if wastes produced in rural areas decompose in an aerobic environment;
- Fraction of BOD removed as sludge.

Industrial wastewater - data needed are:

- Degradable organic component (DC) indicator in kg DC per m³ of industrial wastewater/sludge produced per unit product. For industrial wastewater and sludge streams COD is the appropriate DC indicator. Data on COD values should be available in most countries. It is recommended that country-specific information, if available, be used;
- Wastewater produced per unit product by industry in m³/tonne of product;
- Total industrial output in tones per year;
- Fraction of COD removed as sludge.

For estimation of methane emissions from wastewater handling input data has been achieved from official documents such are Statistical yearbook, Green Report of Ministry of Soil Management and from the database of waste waters, which is administrated by the Slovak Hydrometeorological Institute.

The database consists of information on amount of wastewaters, which are produced and discharged pollution, type of treatment process applied, etc.

In the Table 8. 16 and Table 8. 17: are data used for calculation of methane emissions from domestic organic wastewater and industrial wastewater and sludge.

Table 8. 16: Data used for calculation of methane emissions from domestic wastewater and sludge

Parameter	Amount	Unit	Data Source
P	5 393 640	persons	Statistical authority SR, year 2006
D _{dom}	18 250	Kg BOD/1000 persons/yr	IPCC, one person produces 50 g BOD for day
DS _{dom}	0.5	kg CH ₄ /kg BOD	Appraisal value
B _{oi}	0.6	kg CH ₄ /kg BOD	IPCC default 0.6
B _{oj}	0.6	kg CH ₄ /kg BOD	IPCC default 0.6
WS _{ix}	¹⁾		Appraisal value - according to percentage of population connected to the sewerage system - Green report
SS _{iy}	¹⁾		Appraisal value - according to percentage of population connected to the sewerage system - Green report
MCF _x	¹⁾		Appraisal value - according information about type of wastewater treating
MCF _y	¹⁾		Appraisal value - according information about type sludge handling system
MR	¹⁾	kg CH ₄	Appraisal value - (20 % of methane emissions are recovered or flared)

¹⁾ values are the tables in IPCC format were are in annex (worksheet 6.2 – sheet 2, 3)

Table 8. 17: Data used for calculation of methane emissions from industrial wastewater and sludge

Parameter	Amount	Unit	Data Source
TOW _{ind}	¹⁾ kg COD/yr		Database of Hydrometeorological institute (50 % of COD was removed as a sludge)
TOS _{ind}	¹⁾ kg COD/yr		Database of Hydrometeorological institute (50 % of COD was removed as a sludge)
DS _{ind}	0.5		Appraisal value
B _{oi}	0.25 kg CH ₄ /kg COD		IPCC default 0.25
B _{oj}	0.25 kg CH ₄ /kg COD		IPCC default 0.25
WS _{ix}	²⁾		Appraisal value - according information about type of wastewater treating
SS _{jy}	²⁾		Appraisal value - according information about type sludge handling system
MCF _x	²⁾		Appraisal value - according information about type of wastewater treating
MCF _y	²⁾		Appraisal value - according information about type sludge handling system
MR	0 kg CH ₄		No data available, IPCC default 0

¹⁾ values for industrial sources are the table in IPPC format were are in annex (worksheet 6.3 – sheet 2,3)

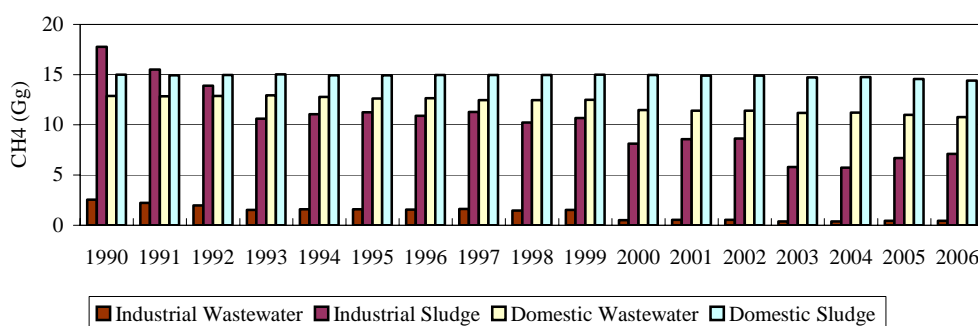
²⁾ values are the tables in IPPC format were are in annex (worksheet 6.3 – sheet 2,3,4)

Parameters WS_{ix} a SS_{jy} for domestic wastewater are appraised from information about percentage of population connected in sewage system. In the year 2006 is 58 % of population connected in sewerage system and domestic wastewater is handled in aerobic treatment facilities and lagoons. The 42 % of population collect domestic wastewater in sewer systems as septic tanks or latrines. The situation is similar like in the year 2005. In the future is planed more investment for build sewerage systems and improved wastewater treatment. Then the percentage of population connected in sewage system will increased.

Data used for calculation of methane emissions from industrial wastewater and sludge are from database, which contains information of, produced COD. Information about sludge handling is obtained from producers. Same data are not used in calculation for example big industry as Slovnaft burned all produced sludge, this sludge produce not methane emissions. Also aren't used industrial sources were produces only sewage wastewater and handling this wastewater with aerobic treatment facilities. These sources are relevant for calculation methane emissions. In comparison in year 2005 COD produced in all industry is little increased about 6 %.

Emission Factors and Emissions

The total emissions of methane in 2006 from wastewater are 32.75 Gg. The industrial wastewater represents 0.40 Gg of CH₄, the domestic and commercial 10.78 Gg of CH₄. The industrial sludge produces 7.10 Gg of CH₄ emissions and 14.39 Gg of CH₄ are from domestic and commercial sludge (Figure 8. 5).

Figure 8. 5: Total methane emissions from wastewater in 1990–2006

Recalculations and Time Series

The Slovak Republic is provided and reviewed during in-country review before the ERT new recalculated inventory of methane emissions from solid waste disposal sites 6.A category. It is important to say, that data needed for methane emission estimation from waste disposed to SWDS, especially those needed for defining national-based parameters, are not collected directly and IPCC default values or expert estimates must be used. This situation has impact on the level of uncertainty of total methane emission estimation from the waste management. The methane emissions from MSW disposed to SWDS are estimated using the Tier 2 method, as the data on disposed MSW are available for the current and previous years. Recalculation and revaluation of methodology in industrial waste disposal was provided, the consistent time series from 1997 is now available. The results are summarized in Table 8. 11 and Table 8. 15.

8.4 Emissions of N₂O from Wastewater

Methodology and Activity Data

For calculation, emissions of nitrous oxide are used two methods: IPCC and ISI. IPCC method use consumption of proteins for one person. Used parameters are in the Table 8. 18.

Table 8. 18: Parameters for calculation of emissions nitrous oxide for domestic wastewater – IPCC

Parameter	Amount	Unit	Data Source
Proteins	33 kg /person/yr		Statistical Office SR 2006, Is known only one amount from year 1999, but this information isn't changed
PO	5 393 640 persons		Statistical Office SR 2006
EF ₆	0.01 kg N ₂ O-N/kg N in domestic wastewater		IPCC default 0.01
Frac _{NPR}	0.16 0,16 kg N/kg proteins		IPCC default 0.16

ISI method expects that wastewater treatment plant where aren't biological nitrification haven't emission of N₂O. For calculation N₂O, we used only data for treatment plant where biological nitrification is and denitrification. Number of this type of treatment for domestic and industrial wastewater are increased, therefore this emission of N₂O in the future will increase also. In the calculation are used only data for treatment plant where is c in this case k_{denit} we can eliminate. Population we can exchange with population of equivalents, calculated from COD in the inlet in wastewater treatment and production of BOD for one person (0.05 kg/person/day) (Table 8. 19, Table 8. 20).

Table 8. 19: The parameters for calculation of emissions nitrous oxide for domestic wastewater – ISI

Parameter	Amount	Unit	Data Source
EO		persons	Calculated like : BOD in inlet of treatment plant/production of BOD for one person – 0.05 kg/person/day
(N) _{sp}	4 kg/person/day		ISI default 4
k _{N2O}	0.0165 kg N ₂ O-N/kg N in domestic wastewater		ISI default 0.009-0.024 kg N ₂ O-N/kg N, medial value are used 0.0165 kg N ₂ O-N/kg N
K _{diss}	0.65		IPCC default 0.5-0.8, medial value are used 0.65

Table 8. 20: The parameters for calculation of emissions nitrous oxide for industrial wastewater – ISI

Parameter	Amount	Unit	Data Source
mn _i		[m ³ /day]	Data for individual wastewater plant – database SHMU
(N) _i		[mg/l]	Data for individual wastewater plant – database SHMU
k _{N2O}	0.0165 kg N ₂ O-N/kg N in domestic wastewater		ISI default 0.009-0.024 kg N ₂ O-N/kg N, medial value are used 0.0165 kg N ₂ O-N/kg N
K _{diss}	0.65		IPCC default 0.5-0.8, medial value are used 0.65

Emission Factors and Emissions

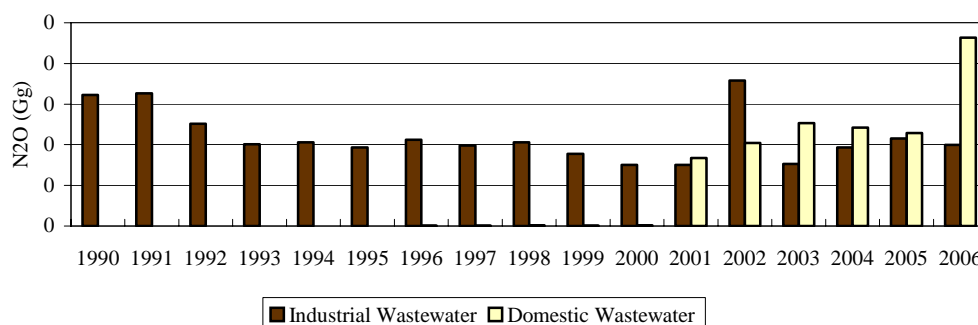
Since N₂O emissions from human sewage are closely linked to the agricultural N cycle, the method is further discussed in the Agricultural Chapter (on indirect N₂O emissions from nitrogen used in agriculture).

The emissions of nitrous oxide from wastewater management were estimated by two methods: IPCC (IPCC, 1996) and ISI (ISI, 1993) and the results are showed in Table 8. 21. The total N₂O emissions from wastewaters handling in 2006 – IPCC, ISI

Table 8. 21: The N₂O emissions from wastewater management

Method	N ₂ O emit from domestic wastewater [t/yr]	N ₂ O emit from industrial wastewater [t/yr]	Emissions of N ₂ O [t/yr]
IPCC 1996	-	-	450.39
ISI	92.81	39.97	132.78

For calculation of nitrous oxide emissions IPCC and ISI method was used. Based on IPCC method is calculation of nitrous oxide emissions from consumptions of proteins. ISI method used calculation from treatment domestic wastewater and industrial wastewater. Future predicts that number of wastewater treatment plants where is biological nitrification and denitrification will be rise. IPCC method gives the same results because, the consumptions of protein is stable. This method is take in account wastewater handling. Results are assumed in the .

Figure 8. 6: The comparison of N₂O emissions from wastewater treatment in 1990–2006

8.5 Incineration and Open Burning of Waste

Incineration of waste produces mainly emissions of CO₂, N₂O and CH₄. Emissions of CO₂ from waste incineration are significantly greater than N₂O emissions. Methane emissions are observed during open burning of waste or inefficient (incomplete) incineration of waste. Currently, waste incineration is more common in developed countries, although it is common for both developed and developing countries to incinerate clinical waste. Open burning of waste occurs in developing countries or in countries where this method is traditional.

Methodology and Activity Data

The methodology described here is fully based on IPCC Guidelines 2006 and applies to incineration with and without energy recovery and to open burning of waste. Emissions from waste incineration without energy recovery and open burning of waste are reported in the waste sector, while emissions from incineration with energy recovery are reported in the energy sector. For reasons of completeness, first all emissions are estimated and then those without energy recovery are included into results.

Five waste streams are defined, which differ in their content of fossil fuel carbon, thus have different emission potential. These are:

- Municipal solid waste (MSW)
- Industrial waste (ISW)
- Hazardous waste (HW)
- Clinical waste (CW)
- Sewage sludge (SS)

Situation in the SR

Incineration of waste is an accepted practice in the Slovak Republic. It is regulated in accordance with EU waste legislation. The number of facilities incinerating waste is decreasing in general. This does not mean that less waste is thermally treated, but small old facilities are replaced by modern, bigger ones. Also, the large facilities are undergoing reconstruction and modernisation, aimed on improvement of environmental standards to comply with EU requirements. These two facts are introducing significant uncertainty into estimation of GHG emissions from incineration (Table 8. 22).

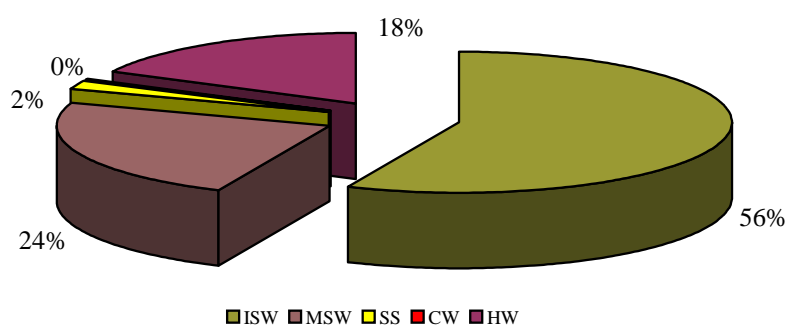
An estimation of share of individual incinerated waste types was done, based on the total amounts incinerated in 2006, with the following result in Figure 8. 7.

Statistical (quantitative) data on incineration are published annually. Data on situation in this sector (qualitative) data are updated once in four/five years, when a new National Waste Management Plan is published.

Table 8. 22: The number of incineration facilities in the SR

Number of facilities incinerating waste in Slovakia				
End of year	MSW	ISW	CW	Co-incineration
2006	2	15	18	5
2005	2	15	18	5
2004	2	18	22	3
2003	2	19	23	3
2002	2	21	25	3
2001	2	28	37	-
1996	4	37	39	-

Figure 8. 7: Distribution of incinerated waste in the Slovak Republic



Municipal Solid Waste Incineration (MSW)

The Statistical Office of the Slovak Republic publishes the amount of incinerated MSW since 1993. The data on incineration of MSW for Bratislava region were used as MSW incinerated in Bratislava MSW incinerator, similar approach was used for Kosice. Although there are available data directly from each incinerator, the requirement to work with one consistent set of data got a priority. Also, although there is identification of “incineration with energy recovery” and “incineration without energy recovery”, these categories do not seem to be correctly used. The information from MSW incinerator operators were used for indication of proper option. The change of waste classification in 2002 does not seem to have impact on recorded amounts of incinerated MSW (Table 8. 23).

Table 8. 23: Amount of MSW incinerated in the SR during 1993–2006

Amount of MSW incinerated in Slovakia (Gg/year)				
Year	Total	Bratislava incinerator	Kosice incinerator	Other incineration
1993	185	110	45	30
1994	161	109	44	8
1995	151	96	52	3
1996	148	99	46	3
1997	161	114	43	4
1998	184	112	64	7
1999	174	110	61	3
2000	208	117	88	3
2001	131	72	56	3
2002	156	90	64	2
2003	162	95	66	1
2004	184	116	67	1
2005	183	125	56	2
2006	190	128	58	4

Note: Dashed line indicates change of waste classification

The MSW Incinerator in Bratislava

The MSW incinerator in Bratislava was put in operation in 1977 and significantly reconstructed in the period 2000–2004. Installed capacity is 130 Gg/y, the incinerator can be characterised as continuously operated stoker, generated heat is used for production of steam and electric energy. The incinerated amounts are shown in the table above. The operator of the incinerator is OLO – a waste management company servicing Bratislava.

The MSW Incinerator in Kosice

The MSW incinerator in Kosice was put in operation in 1991, after more than 10 years of construction. The emissions exceeded standards and the plant operated in “testing operation” and based “exceptions” from environmental law. The situation has stabilised after entry of foreign investor and creation of company KOSIT, which initiated reconstruction of the plant in 2004. The availability of emission monitoring data (before and after reconstruction of this MSW incinerator) allows documenting the importance on modernisation and impact on estimation of emissions (Table 8. 24).

Table 8. 24: Air emissions from MSW incinerators – comparison before and after reconstruction

Air emissions from MSW incinerator in Slovakia		
Parameter (all data in t/y)	Air emissions in 2004 (Before reconstruction)	Air emissions in 2006 (After reconstruction)
Amount of incinerated waste	43 444	72 607
Solid particulates	13.05	0.67
SO ₂	45.02	2.45
NO _x	48.86	55.93
CO	41.85	8.39
HCl	7.16	3.50
HF	0.70	0.10
Hg+Cd+Tl	0.11	0.01
Pb+Cu+Mn+As+Ni+Cr+Co+Sb+V	8.24	0.04

Industrial Solid Waste Incineration

From the total of 37 ISW incinerators only a few have installed capacity exceeding 1 ton per hour. These are located in following companies:

- Duslo a.s. Sala, operating rotary kiln and fluid bed furnace (5 ton/hour)
- Petrochema a.s. Dubova – two rotary kilns (5.5 ton/hour)
- Slovnaft a.s. Bratislava – rotary kiln and chamber furnace (3.5 ton/hour)
- Helpeco s.r.o Povazska Bystrica – rotary kiln (1 ton/hour)

The remaining 30 facilities are smaller unit, mostly various versions of HOVAL, rotary kilns or chamber furnaces. Very few of these units comply with EU environmental requirements, thus have to be modernised (equipped with air pollution control) or decommissioned. There is growing interest of cement industries to incinerate waste with high calorific value, but the Statistical Office does not monitor this type of waste treatment. The company Ecorec processes about 25 000 tons of waste annually – this is about 6 % of all ISW incinerated. The data on incinerated ISW is published in a detailed structure – by Chapters of the European Waste Catalogue¹⁴. This allowed identifying waste streams in which is significant share of fossil carbon for estimation of CO₂ emissions. Results of this division are shown in the Table 8. 25. Industrial solid waste is recorded by Statistical Office since 1997 and only since 2002 the statistical office provides information on “incineration with energy recovery” and “incineration without energy recovery”. The analysis of the data allow to make a conclusion, that

¹⁴ Commission Decision 2000/532/EC of 3 May 2000 establishing a list of hazardous waste

about 20 % of total ISW is incinerated without energy recovery and this means that about 35 % of “fossil carbon rich” waste is incinerated without energy recovery. Also, further comparison of “fossil carbon rich” waste streams destined for incineration results in conclusion, that industrial solid waste and hazardous waste are nearly identical (or there is very little non-hazardous industrial “fossil carbon rich” waste incinerated), thus in the further the terms “incinerated hazardous waste” and incinerated ISW” define the same waste.

Table 8. 25: Amount of ISW incinerated in the SR during 1997–2006

Amount of industrial waste incinerated in Slovakia (Gg/yr)		
Year	Total ISW	C fossil-rich Waste
1997	220	91
1998	401	87
1999	282	65
2000	278	61
2001	226	67
2002	465	66
2003	638	57
2004	312	42
2005	407	20
2006	452	43

Note: Dashed line indicates change of waste classification

Hospital Waste Incineration

Incineration of hospital waste is a sector undergoing the most significant changes, but also it is the least known sector. The statistical information shows the following amounts of reported generation, estimated generation and reported incineration waste from the waste sector. The growing amount of incinerated clinical waste does not mean that more waste is incinerated, but the improvement of reporting. This is documented in the Table 8. 26, where the waste reported as generated clinical waste in fact includes also large amounts of waste from non-healthcare activities in hospitals (e.g. food waste, green waste, garage waste). This sector seems to be significantly affected by the change of waste classification in 2002, as the reported incinerated waste increased more than 10-times. The data reported after 2002 seem to be more realistic numbers, as typically 10–20 % of clinical waste requires incineration. However, the share of hospital waste of the total waste incinerated is insignificant and not affecting the overall balance.

Table 8. 26: Amount of CW incinerated in the SR during 1997–2005

Clinical waste generation in Slovakia (Gg/y)			
Year	Reported CW Generation	Estimated CW Generation	Reported CW Incineration
1997	279.0	28.7	0.7
1998	102.0	28.3	0.5
1999	11.0	24.9	0.2
2000	10.5	24.7	0.2
2001	1.8	24.0	0.1
2002	2.4	22.3	0.1
2003	143.0	20.9	1.6
2004	76.0	21.0	2.2
2005	68.0	20.4	2.9
2006			

Note: Estimated CW generation (Gg/yr) = number of beds in health sector * occupancy * typical daily waste generation per bed (kg) * 365 / 1 000 000. Dashed line indicates change of waste classification. No data for 2006 available.

Sewage Sludge Incineration

Only two incinerators incinerate sewage sludge in the SR, in both cases it is sludge from industrial waste water treatment. The oil refinery Slovnaft a.s. Bratislava has developed specialised incinerator for burning sewage sludge for company owned waste water treatment plant in 1986. This facility was significantly improved during reconstruction in 2006. The operational capacity of the incinerator is 24.5 Gg/y of dewatered sludge (20 % dry mass). The actually incinerated amount of sludge was 13.875 Gg/y in 2006. The incinerator is a stacked furnace type, designed to operate continuously. There is no energy recovery. The chemical factory Duslo a.s. Sala operates a fluidised bed furnace, incinerating (except other waste) about 1.7 Gg/y of sewage sludge. This furnace was put in operation in 1985 and was reconstructed in 2006. The heat is used for generation of steam.

Open Burning of Waste and CH₄ Emissions from Incineration

Open burning of waste is considered illegal in the Slovak Republic, thus it is not included in emission estimation. Also, methane emissions from waste incineration are not estimated in this report, as they are considered negligible, understanding the situation in waste incineration in the SR.

Emission Factors and Emissions of CO₂

Consistent with the general IPCC guidelines, only CO₂ emissions resulting from the incineration of carbon in waste of fossil origin (e.g. plastics, certain textiles, rubber, liquid solvents, and waste oil) should be included in emissions estimates. The carbon fraction that is derived from biomass materials (e.g. paper, food waste, and wooden material) is not included. The following table presents answers, relevant to situation in the Slovak Republic (Table 8. 27).

Table 8. 27: The decision tree for estimation of methodology in the SR

CO ₂ decision tree	
Question	Answer
Are plant-specific data and/or data for different management practices available?	NO
Are country-specific data on waste generation, composition and management practices available?	YES
Are country-specific data on emission factors for waste management practices available?	NO
Tier 2a:	
Estimate CO₂ emissions using country-specific data and default emission factors.	

Tier 2a Methodology

The Tier 2a methodology for estimation of CO₂ emissions from waste incineration and open burning is using the same equation as the Tier 1 approach but is based on country-specific data regarding waste generation, composition and management practices. The equation 5.1 from IPCC Guidelines 2006 for CO₂ emission estimation (E_{CO_2}) is recommended for estimation of CO₂ emissions in cases when composition of waste is uniform or now known:

$$E_{CO_2} = \sum (SW_i * dm_i * CF_i * FCF_i * OF_i) * 44/12$$

where:

- SW_i total amount of solid waste of type i (wet weight) incinerated or open-burned, Gg/yr
- dm_i dry matter content in the waste (wet weight) incinerated or open-burned, (fraction)
- CF_i fraction of carbon in the dry matter (total carbon content), (fraction)
- FCF_i fraction of fossil carbon in the total carbon, (fraction)
- OF_i oxidation factor, (fraction)
- 44/12 conversion factor from C to CO₂
- i type of waste incinerated/open-burned

In case of MSW incineration, where the waste composition is known, the equation 5.2 from IPCC Guidelines 2006 should be used:

$$E_{CO_2} = MSW * \sum (WF_j * dm_j * CF_j * FCF_j * OF_j) * 44/12$$

where:

- E_{CO_2} CO₂ emissions in inventory year, Gg/yr
 MSW total amount of municipal solid waste as wet weight incinerated or open-burned, Gg/yr
 WF_j fraction of waste type/material of component j in the MSW (as wet weight incinerated or openburned)
 dm_j dry matter content in the component j of the MSW incinerated or open-burned, (fraction)
 CF_j fraction of carbon in the dry matter (i.e., carbon content) of component j
 FCF_j fraction of fossil carbon in the total carbon of component j
 OF_j oxidation factor, (fraction)
 44/12 conversion factor from C to CO₂
 j component of the MSW incinerated/open-burned such as paper/cardboard, textiles, food waste, wood, garden (yard) and park waste, disposable nappies, rubber and leather, plastics, metal, glass, other inert waste.

Parameters

The IPCC Guidelines 2006 provides default IPCC values (Table 8. 28 and Table 8. 29) for estimation of CO₂ emissions from incineration and these are shown in the following tables. These will be used for estimation of CO₂ EF from incineration, in accordance with the Tier 2a methodology.

Table 8. 28: The IPCC default data for CO₂ EF

IPCC Default data for CO ₂ emission factors for incineration			
	Dry matter content (% of wet weight)	Total carbon (% of dry weight)	Fossil carbon (% of total carbon)
Industrial Waste	NA	50	90
Clinical Waste	NA	60	40
Sewage Sludge	NA	40 – 50	0
Fossil liquid waste	NA	80	100

Table 8. 29: IPCC input parameters

IPCC default dry matter content, total carbon content and fossil carbon fraction of different MSW components					
MSW component	Dry matter content (%) wet weight)	Total carbon content (% of dry weight)		Fossil carbon fraction (% of total carbon)	
	Default	Default	Range	Default	Range
Paper/cardboard	90	46	42- 50	1	0 – 5
Textiles	80	50	25- 50	20	0 – 50
Food waste	40	38	20 - 50	-	-
Wood	85	50	46- 54	-	-
Garden and park waste	40	49	45- 55	0	0
Nappies	40	70	54 - 90	10	10
Rubber and Leather	84	67	67	20	20
Plastics	100	75	67- 85	100	95 – 100
Metal, glass, inert waste	100 (>90)	NA (<3)	NA (<5)	NA (100)	50 – 100

Table 8. 30: Municipal solid waste parameters in the SR

MSW composition				
MSW fractions	SR	2000	Bratislava 1993	Kosice 1995
Food & Garden waste		38.00%	36.70%	44.50%
Paper		13.00%	15.50%	20.00%
Glass		8.00%	5.80%	10.00%
Plastics		7.00%	7.00%	8.00%
Textiles		-	5.10%	4.00%
Metals		3.00%	-	4.50%
Leather, rubber		-	-	3.00%
Hazardous waste		1.00%	0.20%	1.00%
Residues / mineralised		30.00%	29.70%	4.00%

For estimation of CO₂ emissions from MSW incineration the activity data from Table 8. 23, IPCC default parameters and the Slovak specific parameters on waste composition were used. The oxidation factor is considered 100 %. The results are shown in the following Table 8. 31. The results indicate that CO₂ emissions from MSW incineration do not change significantly with time, the main impacts causing variations include:

- Changes in waste data reporting methodology
- Reconstruction of incinerators (period 2001–2003)

This conclusion was used for extrapolation of CO₂ emissions from MSW incineration back to the year 1990 keeping in mind that the Kosice incinerator was put in operation in 1991. These extrapolated data are calculated as average of emission data prior to incinerator reconstruction in 2000.

Table 8. 31: CO₂ emissions from MSW incineration during 1990–2006

CO ₂ emissions from MSW incineration (Gg/yr)		
Year	MSW incinerated	CO ₂ emissions
1990		30
1991		43
1992		43
1993	185	47.9
1994	161	41.69
1995	151	39.1
1996	148	38.32
1997	161	41.69
1998	184	47.64
1999	174	45.05
2000	208	53.86
2001	131	33.92
2002	156	40.39
2003	162	41.95
2004	184	47.64
2005	183	47.38
2006	190	49.13

Note: Dashed line indicates change of waste classification
Extrapolated data are shown in italics

Estimation of Emissions from ISW Incineration

The CO₂ emissions from industrial solid waste incineration were obtained using activity data from the Table 8. 25 and default IPCC parameters from Table 8. 29. The dry matter content of ISW was

estimated to 90 % of wet weight. The oxidation factor was estimated to 90 %, to compensate for old incinerators. The following results were obtained (Table 8. 32).

Table 8. 32: CO₂ emissions from ISW incineration during 1990–2006

CO ₂ emissions from ISW incineration				
Year	ICW incinerated		CO ₂ emissions	
	Total	C fossil rich	Total	No energy rec.
1990	280.7	128.2	190.4	66.7
1991	280.7	128.2	190.4	66.7
1992	280.7	128.2	190.4	66.7
1993	280.7	128.2	190.4	66.7
1994	280.7	128.2	190.4	66.7
1995	280.7	128.2	190.4	66.7
1996	280.7	128.2	190.4	66.7
1997	219.6	92.5	137.3	48.1
1998	400.9	185.6	275.6	96.5
1999	279	128.7	191.1	66.9
2000	278.3	128.1	190.2	66.6
2001	225.5	106.4	158	55.3
2002	465	75.9	112.6	39.4
2003	637.8	63.3	94	32.9
2004	311.7	49	72.7	25.4
2005	405.4	24.1	35.8	12.5
2006	452.5	43.3	63.3	22.5

Note: Dashed line indicates change of waste classification
Extrapolated data are shown in italics

Although the total amount of incinerated ISW seems to be stable, the share of waste streams rich on fossil carbon is decreasing.

Estimation of Emissions from Sewage Sludge Incineration

Sewage sludge does not contain fossil carbon thus there are no CO₂ emissions to estimate.

Estimation of Emissions from Clinical Waste Incineration

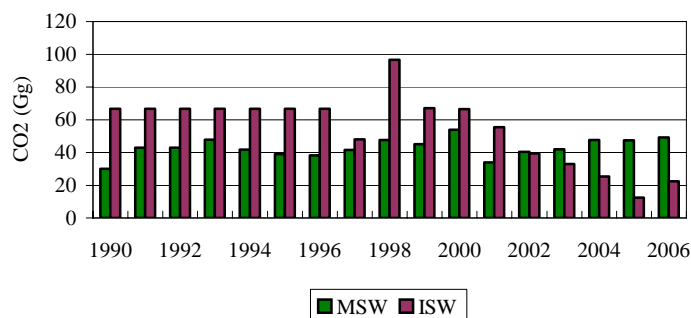
The share of incinerated clinical waste is small and there are no reliable data. CO₂ emissions from clinical waste incineration are included in the ISW incineration data.

Summary on CO₂ Emissions

The estimation of CO₂ emissions from waste incineration is summarised here (Figure 8. 8):

- MSW incineration generates CO₂ emissions, but gained heat is used for steam and electricity generation. Thus, MSW incineration does not affect GHG balance of the Waste Sector, but the result can be used in energy sector.
- ISW incineration generates CO₂ emissions, but only about 20 % of ISW is incinerated without energy recovery. Thus, ISW incineration does affect GHG balance of the waste sector.
- Sewage sludge is not considered as a CO₂ source as it does not contain fossil carbon
- Clinical waste incineration is small and there are not sufficiently reliable data. It is assumed, that the emissions from CW incineration are included in ISW incineration data.

No new incinerators were put in operation after the base year (1990), thus it can be expected that incinerated amounts of waste are stable – extrapolation was done as average of 1997–2000 data. (The only exception is MSW incinerator in Kosice, this was included in the balance).

Figure 8. 8: The CO₂ emissions from waste incineration in the SR during 1990–2006**Emission Factors and Emissions of N₂O**

Nitrous oxide is emitted in combustion processes at relatively low combustion temperatures between 500 and 950 °C. Other important factors affecting the emissions are the type of air pollution control device, type and nitrogen content of the waste and the fraction of excess air.

Although N₂O emissions are not directly monitored, the results of NO_x (as NO₂) monitoring is generally available and it is used in this chapter as verification tool (emissions of N₂O must not be higher than those of NO₂) (Table 8. 33).

Table 8. 33: The decision tree for estimation of methodology in the SR

N ₂ O decision tree		
Question	Answer	Comments
Is waste incinerated in the country?	YES	2 MSW incinerators Medical waste incineration Industrial waste incineration 2 sewage sludge incinerator
Are waste incineration data available by waste type?	YES	But changes in data collection methodology do not allow preparation of consistent time series for more than five years
Are measurement data available for Emission factors?	NO	Statistics report NO _x
Are country-specific emission factors available for N ₂ O?	NO	No research in this area
Estimate N ₂ O emissions from each waste type using IPCC default emission factors		

Tier 1 Methodology

The formula for estimation of emissions is based on multiplying the incinerated waste stream amount by emission factor specific for that waste stream. The equation shown in GPG was used for estimation of N₂O emissions from incineration.

$$E_{N_2O} = \sum (IW_i * EF_i) * 10^{-6}$$

where:

- E_{N_2O} Total emissions of N₂O (Gg/yr)
 IW_i Total amount of incinerated waste stream i (Gg/yr)
 EF_i Aggregate emission factor for the waste stream i (kg/Gg)
 10^{-6} Conversion from kg to Gg

Additionally, it is recommend as *good practice* to estimate the indirect N₂O emissions using the guidance in Chapter 7 Ozone Precursors, SO₂ and Indirect Emissions of Volume 1, in case that the NO_x emissions from incineration are known, according to the following formula:

$$E_{N_2O} = (NO_x-N + NH_3-N) * EF_4 * 44/28$$

where:

- E_{N_2O} N₂O from atmospheric deposition of N from NO_x and NH₃ emissions in Gg
 NO_x-N Nitrogen content of NO_x emissions from source i assuming that NO_x is reported in NO₂ equivalents (Gg NO_x-N or Gg NO₂ • 14/46)
 NH_3-N Nitrogen content of NH₃ emissions (Gg NH₃-N or Gg NH₃ • 14/17)
 EF_4 Emission factor for N₂O emissions from atmospheric deposition of N on soils and water surfaces (kg N₂O-N/kg NH₃-N or NO_x-N emitted). Default IPCC value = 0.01 (range 0.002–0.05)

IPCC Default Parameters

The following default N₂O emission factors (wet weight) were selected from the IPCC Guidelines 2006, Table 5.6. The selection is based on incinerated waste types and technologies used. Waste amounts are normally given as wet weight in the Slovak Republic (Table 8. 34).

Although the GL2006 recommend using emission factor 50 for MSW, quotations from Europe indicate different values in Table 8. 35.

Table 8. 34: IPCC default parameters for emission factors

IPCC Default N ₂ O emission factors (wet weight)		
Type of waste	Technology	Emission factor (g N ₂ O / t waste)
MSW	Continuous inc.	50
Industrial waste	All types	100
Sewage Sludge	All types	900

Table 8. 35: N₂O Emission factors for incineration

Additional N ₂ O emission factors		
Country	Source	Emission factor (g N ₂ O / t waste)
Germany		8
Netherlands		20
Austria	GL2006	12
Germany		5.5 – 66
UK	GPG2003	5.5 – 11 (max 30)

Slovakia Specific Activity Data and Parameters for MSW

The activity data on incinerated waste amounts are listed in Table 8. 36 and Table 8. 37. Additionally some NO_x emissions were identified for MSW incineration.

Table 8. 36: NO_x emissions from Bratislava MSW incinerator

NO _x emissions from Bratislava MSW Incinerator			
Year	Incinerated MSW (t/y)	NO _x emissions (t/y)	EF g NO _x /t MSW
2002	86 874	110.1	1267
2003	102 363	155.5	1519
2004	119 517	177.1	1482
2005	136 465	164.7	1207
2006	137 988	107.3	778

Table 8. 37: NO_x emissions from Kosice MSW incinerator

NO _x emissions from Kosice MSW Incinerator			
Year	Incinerated MSW (t/y)	NO _x emissions (t/y)	EF g NO _x /t MSW
2004	43 444	48.86	1125
2005	73 665	57.66	782
2006	72 607	55.93	770

It should be noted, that the reconstruction of both incinerators leads to significant decrease of EF_{NO_x} by ca 40 %. Also, there is one information on ISW incineration (includes incineration of sewage sludge). Obtaining information on NO_x emissions from ISW is more difficult, as companies publish their emission data as one bulk number for all emission sources within a company (Table 8. 38).

Table 8. 38: The NO_x emissions from Duslo a.s. MSW incineration

NO _x emissions from Duslo a.s. MSW Incinerator			
Year	Incinerated ISW (t/y)	NO _x emissions (t/y)	EF g NO _x /t ISW
2006	6200	34	5445

The N₂O emissions from MSW incineration were estimated using both methods presented upper. First a test comparing both methods was done (Table 8. 39).

Table 8. 39: Comparing estimation of N₂O emission from Bratislava MSW

Comparing estimation of N ₂ O emission from Bratislava MSW incinerator				
Year	MSW (t/y)	Deposition	N ₂ O emissions (Gg/y)	
			Default EF (50)	Europe EF (20)
2002	86874	0.0005	0.0043	0.0017
2003	102363	0.0007	0.0051	0.002
2004	119517	0.0008	0.006	0.0024
2005	136465	0.0008	0.0068	0.0027
2006	137988	0.0005	0.0069	0.0028

The column Deposition shows N₂O emissions estimated from actual NO_x emissions by using default EF₄ = 0.01. The next column shows estimation of NO_x emissions, but the results are eight-times higher than in the previous column and do not reflect the decrease of emissions as a result of plant reconstruction. Further review of available NO_x emission factors resulted in formulation of two hypotheses:

1. Emission factors observed in Germany and Austria may be more suitable for the Slovak Republic, as many Slovak incinerators are of German origin
2. Emission factors for reconstructed plants should be decreased, it is expected that the decrease of EF for NO_x (before and after reconstruction) is the same as for N₂O

Thus, the calculation was repeated with the EF=20 kg N₂O/t MSW and the new results are 3 times bigger than the estimate obtained in Deposition calculation, which is within the range of the EF (0.002 – 0.05). For estimation for MSW most probably incinerated in smaller units, the EF=50 was used.

Table 8. 40: The final estimation of N₂O emissions from MSW incineration

Estimation of N ₂ O emissions from MSW incineration				
Year	Bratislava incinerator (20)	Kosice incinerator (20)	Rest (50)	N ₂ O emissions (Gg/y)
1990	110	0		0.003
1991	110	45		0.0046
1992	110	45		0.0046
1993	110	45	30	0.0046
1994	109	44	8	0.0035
1995	96	52	3	0.0031
1996	99	46	3	0.0031
1997	114	43	4	0.0033
1998	112	64	7	0.0039
1999	110	61	3	0.0036
2000	117	88	3	0.0043
2001	72	56	3	0.0027
2002	90	64	2	0.0032
2003	95	66	1	0.0033
2004	116	67	1	0.0032
2005	125	56	2	0.0023
2006	128	58	4	0.0024

Notes: Number in parenthesis indicates EF used in that columns. Numbers in bold indicate use of EF reduced by 40 % (12 instead of 20). Dashed line indicates change in waste classification. Numbers in italics indicate extrapolated data

Estimation of Emissions from ISW Incineration

Activity data on ISW and SS incineration from Table 8. 25 were used. It is assumed, that the total amount of incinerated sewage sludge (SS) was/is 15 Gg/year and resulting emissions are 0.0135 Gg N₂O/year. The default IPCC parameters were used and the results are shown in the following Table 8. 41).

Table 8. 41: Estimation of N₂O from ISW during 1990–2006

Estimation of N ₂ O emissions from ISW incineration (Gg/y)			
Year	ISW incinerated	Total N ₂ O from ISW	N ₂ O from ISW, no energy recovery
1990	250	0.026	0.0052
1991	250	0.026	0.0052
1992	250	0.026	0.0052
1993	250	0.026	0.0052
1994	250	0.026	0.0052
1995	250	0.026	0.0052
1996	250	0.026	0.0052
1997	200	0.02	0.004
1998	381	0.038	0.0076
1999	259	0.026	0.0052
2000	258	0.026	0.0052
2001	206	0.021	0.0041
2002	445	0.045	0.0089
2003	618	0.062	0.0124
2004	292	0.029	0.0058
2005	385	0.039	0.0077
2006	452	0.044	0.0087

Estimation of Emissions from Clinical Waste Incineration

It is not expected, that incineration of clinical waste leads to emissions influencing the N₂O balance of the waste sector.

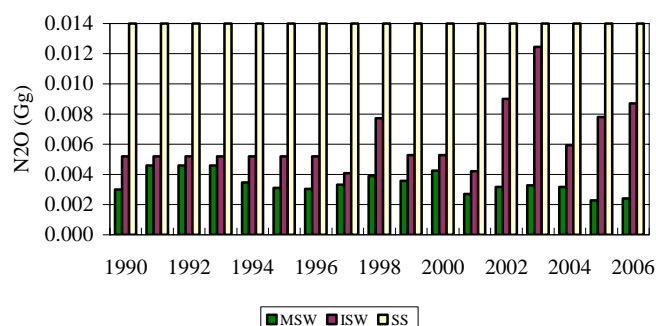
Summary on N₂O emissions

The estimation of N₂O emissions from waste incineration is summarised here:

- Emissions from MSW should not be included in Waste Sector balances, due to energy recovery,
- 20 % of all ISW is incinerated without energy recovery, these data should be included in waste sector balance
- Sewage sludge incineration should be fully included in Waste Sector balance, as majority of sludge is incinerated without energy recovery.

Emissions from clinical waste incineration were not estimated, as it is not expected, that this leads to emissions influencing the N₂O balance of the waste sector (Figure 8. 9).

Figure 8. 9: The N₂O emissions from waste incineration in the SR during 1990–2006



Biological Treatment of Solid Waste - Methodology and Activity Data

This chapter is aimed on review of preparedness of the Slovak Republic to provide estimates of GHG emissions from following processes:

- Composting
- Anaerobic digestion of organic waste

The EU requirement to reduce the amount of landfilled biodegradable waste supports installation of mechanical–biological treatment facilities, which may include also composting or anaerobic treatment. It is expected that the share of waste treated in MF facilities will grow, resulting in higher GHG emissions, which should be included in national balances.

Biological treatment of solid waste is a new chapter in GL2006. The IPCC methodology, presented in IPCC Guidelines 2006, expects estimation of CH₄ and N₂O, using following equations:

$$E_{CH_4} = \sum (M_i * EF_i) * 10^{-3} - R$$

where:

- E_{CH_4} total CH₄ emissions in inventory year, Gg CH₄
- M_i mass of organic waste treated by biological treatment type i, Gg
- EF_i emission factor for treatment i, g CH₄/kg waste treated
- i composting or anaerobic digestion
- R total amount of CH₄ recovered in inventory year, Gg CH₄

$$E_{N_2O} = \sum (M_i * EF_i) * 10^{-3}$$

where:

E_{N_2O} total N_2O emissions in inventory year, Gg N_2O
 M_i mass of organic waste treated by biological treatment type i , Gg
 EF_i emission factor for treatment i , g N_2O /kg waste treated
 i composting or anaerobic digestion

Three tiers for this category are summarised below.

- Tier 1: Tier 1 uses the IPCC default emission factors.
- Tier 2: Country-specific emission factors based on representative measurements are used for Tier 2.
- Tier 3: Tier 3 methods would be based on facility or site-specific measurements (on-line or periodic).

Tier 1 is used for emission estimation (Table 8. 42).

The Slovak Statistical Office publishes data on composted MSW since 1993. The reported amount of composted MSW remain stable, about 35–40 Gg/y. The data on composted ISW are from the same source and are published since 2002. The reported data are too few and in too big variation to identify a trend in emission. There are no centrally collected data on anaerobic treatment or on recovery of methane emissions from composting.

Biological Treatment of Solid Waste - Emission Factors and Emissions

Because there were no data on anaerobic treatment available, only emissions from composting were estimated, separately for MSW and ISW. Default IPCC emission factors for wet weight were used. In case of MSW, emission data were extrapolated back to 1990. using 1993 and 1994 data as a base (Table 8. 42, Table 8. 43 and Table 8. 44).

Table 8. 42: Parameters IPCC default EFs

IPPC Default Emission factors				
Treatment	CH ₄ Emission Factor		N ₂ O Emission Factor	
	Dry weight	Wet weight	Dry weight	Wet weight
Composting	10 (0.08 – 20)	4 (0.03 – 8)	0.6 (0.2 – 1.6)	0.3 (0.06 – 6)
Anaerobic digestion	2 (0 – 20)	1 (0 – 8)	0 (Negligible)	0 (Negligible)

Table 8. 43: Methane and N₂O emissions from MSW composting during 1990–2006

Emissions from MSW Composting				
Year	Composted waste (Gg/y)	CH ₄	N ₂ O	Number of municipalities composting MSW
		(Gg/y)	(Gg/y)	
1990	20	0.08	0.006	
1991	20	0.08	0.006	
1992	20	0.08	0.006	
1993	21.4	0.086	0.0064	472
1994	19.1	0.076	0.0057	479
1995	35.4	0.142	0.0106	577
1996	31.5	0.126	0.0095	676
1997	38.8	0.155	0.0116	659
1998	38	0.152	0.0114	748
1999	39.3	0.157	0.0118	807
2000	36.3	0.145	0.0109	819
2001	43.5	0.174	0.0131	780
2002	39.3	0.157	0.0118	691
2003	40.7	0.163	0.0122	659
2004	40.9	0.164	0.0123	635
2005	20.8	0.083	0.0062	501
2006	51.6	0.206	0.0155	

Table 8. 44: Methane and N₂O emissions from ISW composting during 2002–2006

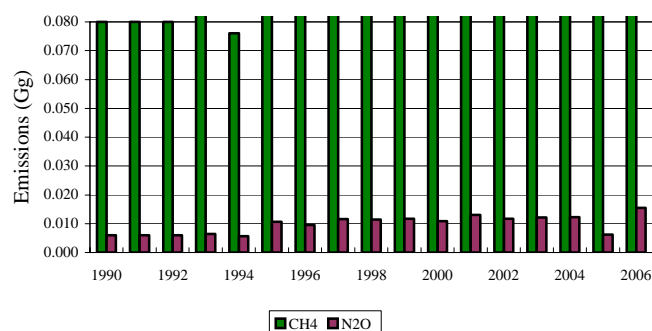
Emissions from ISW Composting				
Year	Composted waste (Gg/y)	CH ₄	N ₂ O	
		(Gg/y)	(Gg/y)	
2002	1133.5	4.534	0.3401	
2003	1156.6	4.626	0.347	
2004	411.5	1.646	0.1235	
2005	579.1	2.316	0.1737	
2006				

Note: No data for 2006 available.

Biological Treatment of Solid Waste - Summary on Emissions

The attempt to estimate emissions from biological treatment in the Slovak Republic identified following issues (Figure 8. 10):

- There are sufficient activity data on MSW composting, the resulting emissions can be included in Waste Sector balance (there is no explanation for the drop in 2005, probably reporting error)
- The data on ISW are available only for the period 2002–2005. The 2006 data are not published yet.
- There are no data on anaerobic treatment of solid waste available.

Figure 8. 10: The CH₄ and N₂O emissions from waste composting in the SR during 1990–2006

Biological Treatment of Solid Waste - Recalculation

Comparing to previously reported emissions from these categories, all activity data were critically reviewed and complete recalculation were done. The following major improvements were applied to emission estimations:

- The IPCC Guidelines 2006 were used as the basis for emission estimation for the first time,
- For disposal and incineration of ISW the emission assessment is based on individual waste streams, not on the total amount of ISW,
- Emissions from composting were estimated,
- Recovery of methane from MSW disposal was included into the balance.

Sewage sludge and clinical waste emissions from incineration were assessed separately

The key category of the waste sector categories is disposal of solid waste to the SWDS, emitting in total 83.85 Gg CH₄/y (or 1 762 Gg CO₂ eq/year). The total emissions from the waste sector activities are estimated to 2 528 Gg CO₂ eq.

Table 8. 45: Comparison of GHG emissions estimated from waste treated or disposed

Comparison of Emissions from Waste Sector (Gg/y)					
		CH ₄	N ₂ O	CO ₂	eq CO ₂
SWDS (4A)	MSW	47.25			992.3
	ISW	36.64			769.4
	MSW – total		0.0024	49.1	44.1
	MSW – no energy recovery		0	0	0
	ISW – total		0.0437	64.3	47.9
	ISW – no energy recovery		0.0087	22.51	14.9
	Incineration (4C) SS		0.0135		4.2
	Biological treatment (4B)	0.21	0.0155		9.1
TOTALS (for no energy recovery)		84.1	0.0401	22.51	1800.9

9 RECALCULATION

The several recalculations in CRF 2006 submission 2008 are mentioned against the previous CRF 2004 submissions 2006. The most important are following highlighted by ERT on the in-depth review in March 2007.

9.1 Energy Sector

For the submission in 2007, the Slovak Republic has made extensive methodology changes and recalculations. The previous submissions to the UNFCCC were based on the reference approach in calculation of the national GHGs emission total. In the latest submission 2007, the Slovak Republic is using sectoral approach as a reference value of the Energy sector for the all years 1990-2006.

The following issues were included into the final document of ERT in the energy sector:

CO₂ emissions from combustion of natural gas in the energy sector, categories 1A1, 1A2, 1A4, 1A5

The problem identified by ERT was inconsistency between EF for natural gas before and after year 2000. Before 1 of January 2000 SR hasn't enough information and detailed analyses about the NG composition and therefore energy sectoral expert used default EF from IPCC guidelines (56.10 t/TJ) for the time series 1990-1999. The ERT considered this approach not consistent with IPCC GPG 2000 and invited to revise EF using extrapolation method based on national data after 2000.

CO₂ emissions from international aviation in the energy sector

The GHG emissions estimation was performed according the totals of sale fuels on the important Slovak airports in the period 1990-2005 and the expert estimated consumption of the fuels to the national and international fuel consumption.

For the emissions estimation and balance of GHGs in the period 1990-2005 the mixed emission factors were used for jet kerosene and aviation gasoline. The mixed emission factors determine average production of GHG emissions during all flight phases (LTO and flight).

CO₂ Emissions from international navigation in the energy sector

Slovakia was used Tier 1 methodology based on transportation model (fuel consumption by transit transport) for emission estimation of marine transport on Danube River, not occurring national ship-ping activity. According recommendations of ERT final findings and IPCC GPG 2000, the recalculation in category 1.A.3d – Navigation was provided.

Fugitive CO₂ emissions from 1.B.2 category – natural gas

Slovakia made decision to re-evaluated CO₂ emissions from natural gas categories 1.B.2.B-d (production, processing, transmission, distribution, other leakage, venting and flaring and storage) according to the recommendations of ERT during in-country review. The emission factor for CO₂ fugitive emissions was estimated from the specific analytical measurements of natural gas composition shown in the following table. The measurements are provided by accredited laboratories of Slovak Gas Industry company Ltd

9.2 Industrial Processes Sector

The following issues were included into the final document of ERT in the industrial processes sector:

CO₂ emissions from cement production in the industrial processes sector, category 2A1

According to the IPCC Guidelines it is a good practice that the amount of CO₂ emission is calculated from the mass of produced cement clink. However, in the Slovak Statistical Annual Report only mass of produced cement is published. Therefore, the emission factor of CO₂ has to be recalculated to the

mass of produced cement. For this reason two values of emission factor of CO₂ are presented. One of them is related to the cement clink production, the other to the cement production. The content of CaO in the cement clink varies from 65 % to 69 %. The value of the weighted average is calculated annually. It follows with the estimation of the emission factor of CO₂ related to the cement clink.

N₂O emissions from nitric acid production in the industrial processes sector, category 2B2

The emission factors of N₂O was presented as 5.43 kg N₂O / 1 t HNO₃ and 5.58 kg N₂O / 1 t HNO₃ until now. Direct measurements of N₂O emissions were realized in Duslo Sala in the period 2005-2006, the following EFs on the basis of Norsk Hydro since 1990 are correct 13 kg N₂O/1 t HNO₃ for atmospheric plant, 7 kg N₂O / 1 t HNO₃ for medium pressure and 9 kg N₂O /1 t HNO₃ for high pressure plant. It is in agreement with the data presented by Norsk Hydro according to the IPCC Good Practice Guidance. It seems that discrepancy between previously and recently used EFs is based on the non-correct information about holding time of gasses at catalyst and temperature in reactor. KD1 in Duslo was last time improved in 70-ties, EF for "out-dated plants" according GPG 2000 10-19, in the lowest part (13 kg N₂O/1 t HNO₃). KD2 in Duslo was improved in 80-ties. It is very realistic, that now is EF higher than 7 kg N₂O/1 t HNO₃, but not enough evidences are available. According the measurements from 2005, real EF should be about 7.3 kg N₂O/1 t HNO₃.

CO₂ emissions from ammonia production in the industrial processes sector, category 2B2

The CO₂ emissions were re-allocated from the energy sector, technological emissions from ammonia production were separated from combustion emission from the category 1A2c to the 2B2 category.

9.3 Agricultural Sector

Recalculation in the category of methane emissions from enteric fermentation, according the Tier 2 methodology and country specific input data was made. Detail analysis of animal housing and digestion are known. Direct soil emissions for crop incorporated and N-fixing crop was recalculated according the ERT recommendations.

The following issues were included into the final document of ERT in the agricultural sector:

N₂O Emissions from agricultural soils (incorporation of crop residues into the soil) in the agriculture sector, category 4D.

Coefficients for the nutrient estimations and the model for the nutrient input into the soils from crop residuals have a high importance in nutrient balance and agricultural practice by sowing, cultivation and harvesting of effective plant production in agriculture. The nitrogen input into the soils from plants were recalculated

N₂O Emissions from manure management in the Agriculture sector, category 4B

Total N₂O emission estimation from Manure management was revised and no changes of methodology were necessary. Input data about nitrogen from pasture range and paddocks and inconsistencies were revaluated and the correct information about Frac_{GRAZ} were provided.

9.4 Solvent and Other Products Use Sector

The sector were completely estimated according the new information from 1998–2005.

9.5 LULUCF

The following issues were included into the final document of ERT in the LULUCF sector:

CO₂ Emissions from 5.C Grassland remaining grassland

The negligible difference (0.002 % decrease) in the reported emissions from grassland in base year 1990 (2007) was caused by the precision characteristic function in the CRFReporter program after

upgrading. The following figure for the net carbon stock in soil is correct and more precision: 146.1535 Gg of carbon. The total difference between new submitted value is 0.0035 Gg, the third and fourth decimal places were deleted in the new submitted inventory. No further recalculations were provided in the LULUCF sector.

9.6 Waste

The following issues were included into the final document of ERT in the LULUCF sector:

CH₄ Emissions from 6.A Solid waste disposal on land

Slovakia is provided and reviewed during in-country review before the ERT new recalculated inventory of methane emissions from solid waste disposal sites 6.A category. It is important to say, that data needed for methane emission estimation from waste disposed to SWDS, especially those needed for defining national-based parameters, are not collected directly and IPPC default values or expert estimates must be used. This situation has impact on the level of uncertainty of total methane emission estimation from the waste management. The methane emissions from MSW disposed to SWDS are estimated using the Tier 2 method, as the data on disposed MSW are available for the current and previous years.

9.7 Improvements

The Slovak Inventory Agency (SHMI) is evolving the permanent activity to improve annually GHG emission inventory for the UN FCCC secretariat in Common Reporting Format following the IPCC methodology (IPCC, 1996 and 2000). The major accent is put on consistency of time series data and transparency of choosing methodology and activity data. The most important improving in the 2007 submission was the change CRF tables for reporting to the CRFReporter program and reporting the base year emissions (1990) and the years 2000–2003, certainly the actual emission from 2004. The improvements of sectoral approach in Energy sector were made. The categorization of fuels and improving some fuel's characteristics were made. The Slovak Republic is improving annually the database of sources of pollution (NEIS) in Energy sector and fuel combustion. There were made some consistency improvements in transport and activity data for the emissions in road transportation. The most touched sector with the methodological changes is LULUCF. The complete methodology was changed and the new time series of emissions from 1990 were provided. Many steps were made in the harmonization the national methodology for the emission estimation and in the National Inventory System.

9.8 Additional information to the FCCC/IRR/2007/SVK/E/118 according to 15/CMP.1 - 32/E National registries

The national registry data exchange between national registries the CDM and the ITL is in line with the Data Exchange Standards (DES) that was certified by the administrator of the ITL. The Slovak national registry received on 13/09/2007 an Independent assessment report (IAR) available at <<http://unfccc.int/resource/docs/2007/iar/svk01.pdf>>. This report is a guarantee of conformity with the DES.

Slovak national registry also has done the connectivity tests composed of establishing the VPN connectivity on 11/06/2007 between registry and ITL, SSL connection and WEB service communication - all with the status PASS. Also there were done on 08-09/08/2007 other tests carried out by the ITL Operator called "Interoperability tests" with positive Recommendation by ITL Operator and authorisation by ITL Administrator with reference to the IAR.

10 CONCLUSION

The National Inventory Report 2008 of the Slovak Republic is inseparable part of reviewed CRF 2006 submission 2008 (from 15. April 2008) of national inventory of GHGs. This report is trying to explain and compare the informational about emissions inventory in all six sectors of IPCC categories in the Slovak Republic for all GHG basic pollutants for the whole time series. The 2006 emission inventory is based on IPCC Methodology and is related to the previous inventory period 1990–2006. The methodological progress for calculation of national total emissions is consistent from base year (1990). The IPCC default and national determined emission factors were used. The following Table 10. 1 gives the summary about total emission of GHGs in the Slovak Republic in the period 1990–2006.

Table 10. 1: An overview of GHG emissions (in Gg of CO₂ equivalents) in 1990–2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Net CO ₂	59.43	52.02	47.78	43.41	42.12	41.22	39.95	39.92	39.98	39.59	37.79	36.42	34.73	36.53	36.81	39.83	36.93
CO ₂ *	61.84	55.53	51.93	47.69	45.44	43.92	42.37	41.33	41.92	41.23	40.20	41.64	39.97	41.36	41.07	40.70	39.98
CH ₄	5.40	5.15	4.85	4.47	4.45	4.64	4.58	4.63	4.86	5.07	4.68	4.73	5.33	4.96	4.93	4.63	4.63
N ₂ O	6.17	4.97	4.15	3.51	3.85	4.08	4.21	4.10	3.70	3.25	3.52	3.72	3.68	3.72	3.82	3.79	4.04
HFCs	NA,NO	NA,NO	NA,NO	NA,NO	0.00	0.02	0.04	0.06	0.04	0.07	0.08	0.08	0.10	0.13	0.15	0.17	0.20
PFCs	0.27	0.27	0.25	0.16	0.13	0.11	0.03	0.03	0.03	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.04
SF ₆	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
GHG	71.29	62.41	57.05	51.55	50.58	50.11	48.83	48.78	48.64	48.03	46.11	44.99	43.89	45.39	45.77	48.48	45.87
GHG*	73.68	65.91	61.19	55.83	53.88	52.79	51.24	50.16	50.57	49.65	48.50	50.20	49.11	50.21	50.00	49.33	48.90

*CO₂ emissions with LULUCF, **CO₂ emissions without LULUCF

Note: emissions are determined as of 15.04.2008

The over view Table 10. 1 shows trend in reduction of GHG emissions compare to the base year 1990. The total decrease in anthropogenic GHG emissions represents 33.6 % reduction of total anthropogenic emissions from the base year including LULUCF and the Kyoto conditions for the Slovak Republic are already realised at the present.

In accordance with the actually emission inventory, the total emissions decreasing of GHGs in CO₂ equivalent is about 30 % against the base year 1990. The adopted reduction commitment of SR for the first period 2008–2012 of the KP is real to reach. The indicated reduction of emission evaluation is the result of the number of impacts and processes linked with the transformation of economy. As the most decisive reasons in relation with the followed subject we can consider: gradual decrease in energy intensity since 1993; higher share of services in the GDP generation; higher share of gas fuels in the economy; structural changes in industry and the decrease of energy consumption in energy intensive sectors (without metallurgy), as well as in less energy intensive industries; and the impact of legislative measures influencing directly or indirectly the generation of greenhouse gas emissions.

Concerning the actual and proposed dynamics of GDP growth in the Slovak Republic there exist legitimate assumption that GHG emissions will increase in line with it. Due to this scenario there is necessary to prepare investment strategies and programs that allow us to achieve permanent distribution of GDP growth and emissions growth with the regards to the further the post-Kyoto reduction goals.

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