

NATIONAL INVENTORY REPORT

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**GREENHOUSE GAS EMISSION  
INVENTORY IN THE SR  
1990-2005**

BRATISLAVA 2007

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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## CONTENTS

<b>EXECUTIVE SUMMARY .....</b>	<b>5</b>
<b>1 INTRODUCTION.....</b>	<b>12</b>
1.1 Background Information on GHG Inventories and Climate Change.....	12
1.2 Institutional Arrangement .....	15
1.3 Process of Inventory Preparation .....	16
1.4 General Description of Methodologies and Data Sources.....	18
1.5 Description of Key Sources.....	20
1.6 QA/QC Procedure .....	21
1.7 General Uncertainty Evaluation .....	26
1.8 General Assessment of the Completeness .....	27
<b>2 TRENDS IN GREENHOUSE GAS EMISSIONS .....</b>	<b>29</b>
2.1 Emission Trends for Aggregated GHG Emissions.....	29
2.2 Emission Trend by Gas.....	30
2.3 Emission Trend by Source.....	31
2.4 Emission Trends for Indirect GHGs and SO <sub>2</sub> .....	31
<b>3 ENERGY SECTOR .....</b>	<b>33</b>
3.1 Fuel Combustion Activities.....	33
3.1.1 Energy Industry.....	33
3.1.2 Road Transport.....	40
3.1.3 Non-Road Transport.....	42
3.2 Fugitive Emissions from Fuels.....	48
3.2.1 Coal Mining.....	48
3.2.2 Oil and Natural Gas Production.....	51
<b>4 INDUSTRIAL PROCESSES .....</b>	<b>56</b>
4.2 Cement Production .....	56
4.3 Lime Production .....	58
4.4 Limestone and Dolomite Use.....	58
4.5 Magnesite Use .....	59
4.6 Ammonia Production.....	59
4.7 Nitric Acid Production.....	60
4.8 Production of Calcium Carbide .....	61
4.9 Production of Metals .....	61
4.10 Consumption of HFCs, PFCs and SF <sub>6</sub> .....	63
<b>5 SOLVENT AND OTHER PRODUCT USE .....</b>	<b>69</b>
<b>6 AGRICULTURE .....</b>	<b>70</b>
6.2 Cross-cutting.....	70
6.3 Methane Emissions.....	70
6.4 Nitrous Oxide Emissions.....	75
<b>7 LAND USE, LAND USE CHANGE AND FORESTRY .....</b>	<b>89</b>
7.2 Input Data.....	89
7.3 Forest Land.....	89
7.4 Cropland.....	90
7.5 Grassland.....	91

7.6 Other Land .....	92
7.7 Controlled Burning and Forest Fires .....	93
7.8 Total LULUCF .....	93
<b>8 WASTE .....</b>	<b>94</b>
8.2 Input Data.....	94
8.3 Emissions of CH <sub>4</sub> from SWDS .....	94
8.4 Emissions of CH <sub>4</sub> from Wastewater.....	105
8.5 Emissions of N <sub>2</sub> O from Wastewater.....	109
8.6 Emissions from Waste Incineration.....	111
<b>9 RECALCULATION AND IMPROVEMENTS .....</b>	<b>112</b>
9.1 Energy Sector .....	112
9.2 Industrial Processes Sector .....	112
9.3 Agricultural Sector.....	112
9.4 Solvent and Other Products Use Sector.....	112
9.5 Waste .....	112
9.6 Improvements .....	113
<b>10 CONCLUSION .....</b>	<b>114</b>
<b>11 REFERENCES.....</b>	<b>115</b>

Annex 1: The list of sectoral cooperation in the frame of National inventory system in 2005

Annex 2: The Key Source Analysis and Uncertainty Management in the SR in 2005

## 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

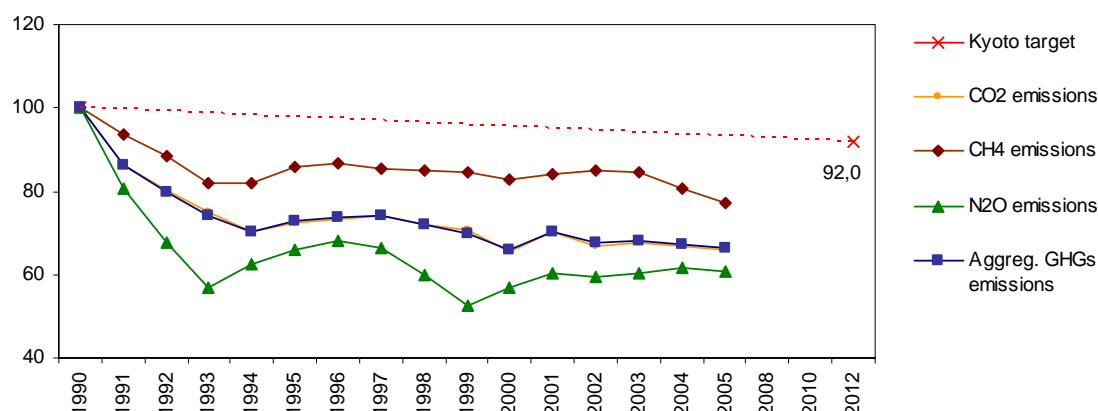
Climate change, caused by increasing anthropogenic emission of greenhouse gases, represents the most serious environmental issue in the history of humankind. The most important anthropogenic greenhouse gases are carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), and nitrous oxide (N<sub>2</sub>O). Other greenhouse gases included in GHGs inventory are halogenated hydrocarbons (PFCs, HFCs) and SF<sub>6</sub>, which are not controlled by the Montreal Protocol. Photochemical active gases such as carbon monoxide (CO), nitrogen oxides (NO<sub>x</sub>) 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 (SO<sub>2</sub>) 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 (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFCs, PFCs and SF<sub>6</sub>) on average by 5.2 % from the level of the year 1990 during the first commitment period 2008 – 2012. 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.<sup>1</sup>

Total GHG emissions without LULUCF in the EU-15 were 0.7 % below the base year in 2004. In the EU-25 total emissions decreased by 4.9 % between 1990 and 2004. The new member states (EU-10) reduced together the GHG emissions in average about 32 % in the 1990-2004 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)

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<sup>1</sup> Kyoto Protocol came into force on February 14., 2005

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

CO<sub>2</sub> Emissions without LULUCF; emissions are determined as of 02.07.2007

## ES.2 National Circumstances

The Slovak Ministry of the Environment ([www.enviro.gov.sk](http://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](http://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 - 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.

Slovak Republic has 5.38 mills. inhabitants (as of 31.12.2006). The average population density is 110 inhabitants/km<sup>2</sup>. The population is concentrated in the cities in the lowlands and the main basins. Mountains areas are randomly populated. In 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 EU25 countries.

### ES.3 Overview of Source and Sink

The GHG emissions presented in the National Inventory Report 2007 were updated and converted using the newest available methods, national conditions and data published by the Slovak Statistical Office. Total GHG emissions represented 47 866.31 Gg in 2005 (without LULUCF). This represents a reduction by 33.6 % in comparison with the reference year 1990. In comparison with 2004, 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 SF<sub>6</sub>). 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 1991-2005, 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 July 02, 2007 are shown below.

**Table ES. 1: The total anthropogenic greenhouse gas emissions (Tg of CO<sub>2</sub> eq.)**

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Net CO <sub>2</sub>	57.82	48.44	44.09	41.02	39.01	41.02	41.83	43.13	41.52	40.83	36.98	37.07	35.10	35.81	35.99	38.88
CO <sub>2</sub> *	60.22	51.95	48.24	45.30	42.33	43.72	44.25	44.53	43.46	42.47	39.38	42.29	40.35	40.65	40.24	39.76
CH <sub>4</sub>	5.39	5.06	4.76	4.41	4.43	4.62	4.68	4.61	4.59	4.56	4.46	4.53	4.59	4.56	4.35	4.15
N <sub>2</sub> O	6.16	4.97	4.16	3.52	3.86	4.07	4.20	4.10	3.70	3.25	3.50	3.71	3.67	3.71	3.81	3.74
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
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
SF <sub>6</sub>	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
GHG	69.66	58.75	53.27	49.11	47.45	49.86	50.80	51.96	49.90	48.75	45.06	45.44	43.51	44.27	44.36	47.02
GHG*	72.05	62.24	57.41	53.38	50.76	52.55	53.21	53.35	51.82	50.37	47.45	50.65	48.74	49.08	48.59	47.87

\* Total aggregated GHGs emission without LULUCF, emissions are determined as of 02.07.2007

### ES.4 CO<sub>2</sub> Emissions

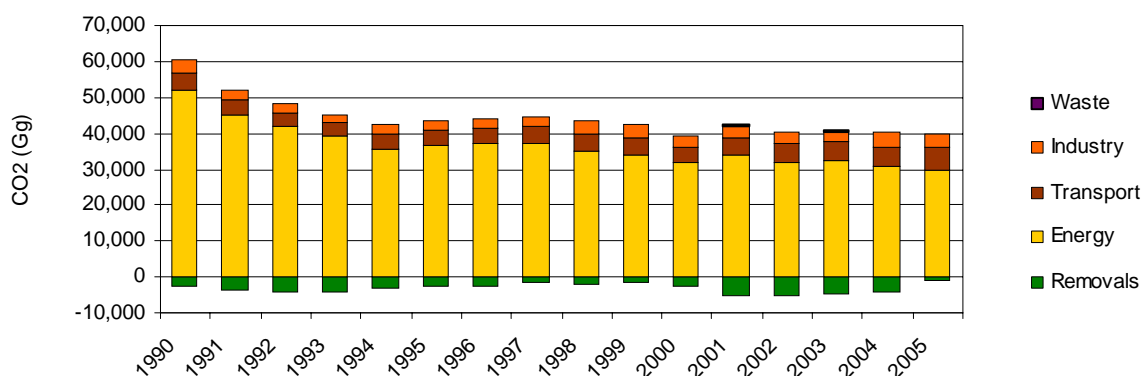
A most important anthropogenic source of CO<sub>2</sub> emissions in the atmosphere is combustion and transformation of fossil fuels, which account for about 95 % of the total CO<sub>2</sub> emissions in the SR (Table ES. 2). A calculation of CO<sub>2</sub> emissions is based on energy statistical data 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 CO<sub>2</sub> 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 CO<sub>2</sub> emissions by sectors (Tg)**

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Energy	51.85	45.21	41.79	39.02	35.68	36.69	37.19	37.20	35.14	34.19	31.94	34.21	32.06	32.47	31.05	29.80
Transport	4.89	4.11	3.79	3.77	4.01	4.25	4.31	4.48	4.76	4.65	4.18	4.75	4.89	4.99	5.27	6.21
Industry	3.48	2.63	2.67	2.52	2.64	2.78	2.76	2.86	3.56	3.62	3.10	3.20	3.25	3.04	3.77	3.59
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
Waste	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	0.16	0.14	0.14	0.14	0.15	0.15
Total CO <sub>2</sub> *	57.82	48.44	44.09	41.02	39.01	41.02	41.83	43.13	41.52	40.83	36.98	37.07	35.10	35.81	35.99	38.88

\*Total CO<sub>2</sub> with LULUCF, emissions are determined as of 02.07.2007, emissions in Tg.

**Figure ES. 2: Share of individual sector on CO<sub>2</sub> emissions (Gg) in 1990-2005**



## ES.5 CH<sub>4</sub> Emissions

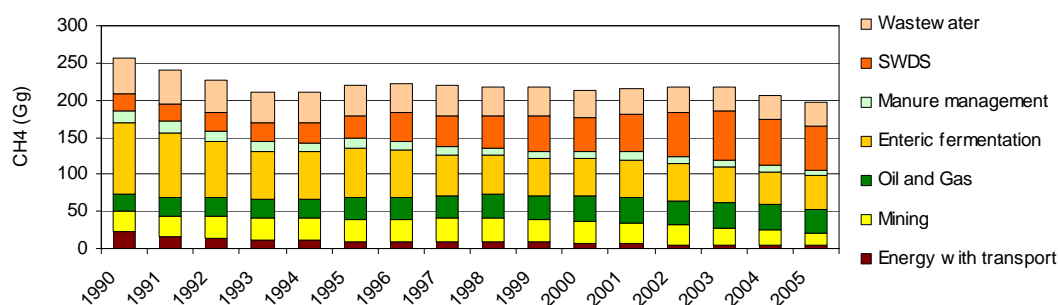
Agriculture, large-scale beef cattle and pig breeding, are major sources of methane on the Slovak territory (Table ES. 3). The CH<sub>4</sub> does arise as the direct product of the metabolism in herbivores and as the product of organic degradation in animal excrement. Calculations of emissions for the Slovak Republic are based on the data listed in the Statistical yearbook of the Slovak Republic (Statistical yearbook, 2005) and the Green Report of the Slovak Ministry of Agriculture (Green Report, 2005). 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 CH<sub>4</sub> emissions by sectors (Tg)**

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Energy with transport	22.26	14.93	13.45	11.68	10.90	9.80	9.78	9.63	9.04	8.74	7.57	7.42	5.51	5.46	5.03	4.95
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
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
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
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
SWDS	22.37	23.45	24.16	24.89	27.75	30.85	37.86	41.19	43.93	46.80	47.57	50.74	58.65	65.61	63.99	59.52
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
<b>Total CH<sub>4</sub></b>	<b>256.8</b>	<b>240.9</b>	<b>226.7</b>	<b>210.0</b>	<b>210.8</b>	<b>220.0</b>	<b>222.8</b>	<b>219.4</b>	<b>218.4</b>	<b>217.3</b>	<b>212.6</b>	<b>215.9</b>	<b>218.6</b>	<b>217.1</b>	<b>207.2</b>	<b>197.9</b>

\*Total CH<sub>4</sub> emissions without LULUCF are determined as of 02.07.2007, emissions in Tg.

**Figure ES. 3: Share of individual sector on CH<sub>4</sub> emissions (Gg) in 1990-2005**





## ES.6 N<sub>2</sub>O Emissions

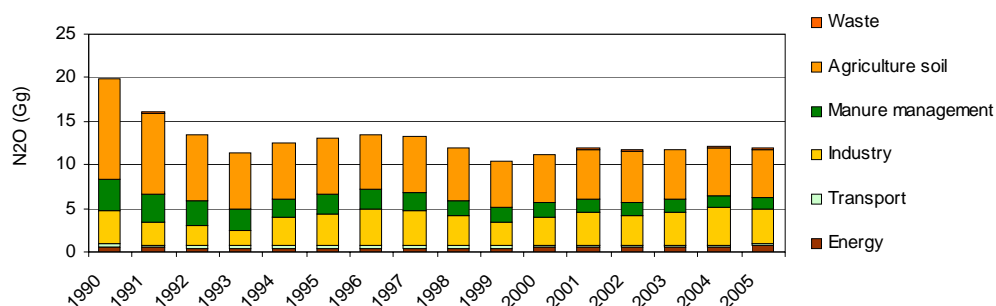
In comparison with other greenhouse gases, the mechanism of N<sub>2</sub>O emissions and sinks develops from the nitrogen cycle in the atmosphere and their quantification is rather difficult (Table ES. 4). Global anthropogenic emission is estimated to be 3-7 billion tons of nitrogen per year. Natural sources are approximately twice as large as anthropogenic ones. The primary sources of N<sub>2</sub>O in the Slovak Republic are agriculture, waste treatment and N<sub>2</sub>O from combustion of fuels (energy and transport) (Figure ES. 4).

**Table ES. 4 The total N<sub>2</sub>O emissions by sectors (Tg)**

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Energy	0.577	0.523	0.463	0.433	0.396	0.394	0.391	0.380	0.350	0.335	0.541	0.627	0.612	0.643	0.639	0.728
Transport	0.394	0.320	0.282	0.266	0.286	0.325	0.354	0.390	0.432	0.444	0.143	0.145	0.143	0.156	0.151	0.146
Industry	3.766	2.635	2.379	1.844	3.226	3.631	4.241	4.013	3.412	2.563	3.330	3.767	3.369	3.730	4.263	4.046
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
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
Waste	0.065	0.065	0.050	0.040	0.041	0.039	0.043	0.040	0.041	0.036	0.039	0.072	0.122	0.090	0.095	0.095
<b>Total N<sub>2</sub>O</b>	<b>19.89</b>	<b>16.03</b>	<b>13.42</b>	<b>11.35</b>	<b>12.45</b>	<b>13.12</b>	<b>13.53</b>	<b>13.22</b>	<b>11.94</b>	<b>10.48</b>	<b>11.29</b>	<b>11.96</b>	<b>11.84</b>	<b>11.96</b>	<b>12.29</b>	<b>12.07</b>

\*Total N<sub>2</sub>O emissions without LULUCF are determined as of 02.07.2007, emissions in Tg.

**Figure ES. 4: Share of individual sectors in N<sub>2</sub>O emissions (Gg) in 1990-2005**



## ES.7 HFCs, PFCs and SF<sub>6</sub> Emissions

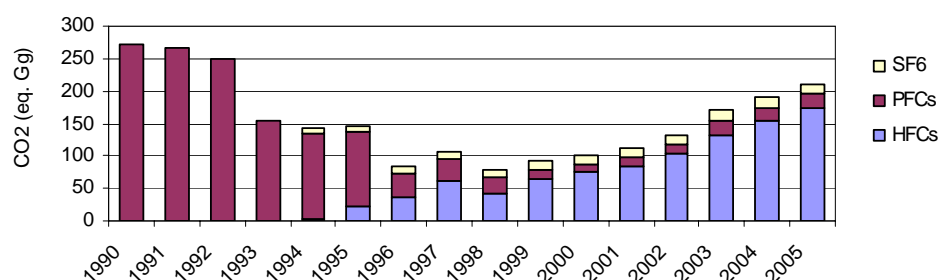
The first inventory of these substances<sup>2</sup> was executed in 1995. HFCs, PFCs and SF<sub>6</sub> are not produced in the SR, only data on consumption of these substances are available (Table ES. 5). They are used as coolants, extinguishing agents, blowing agents for PUR, in aerosol products and as insulating gases (SF<sub>6</sub>). (Figure ES. 5)

**Table ES. 5 The total HFCs, PFCs and SF<sub>6</sub> emissions by sectors (Gg)**

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
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
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
SF <sub>6</sub>	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
<b>Total F-gases</b>	<b>271.4</b>	<b>267.0</b>	<b>248.5</b>	<b>155.5</b>	<b>144.2</b>	<b>146.4</b>	<b>82.9</b>	<b>107.2</b>	<b>78.6</b>	<b>91.5</b>	<b>100.7</b>	<b>112.2</b>	<b>131.6</b>	<b>170.2</b>	<b>190.2</b>	<b>211.5</b>

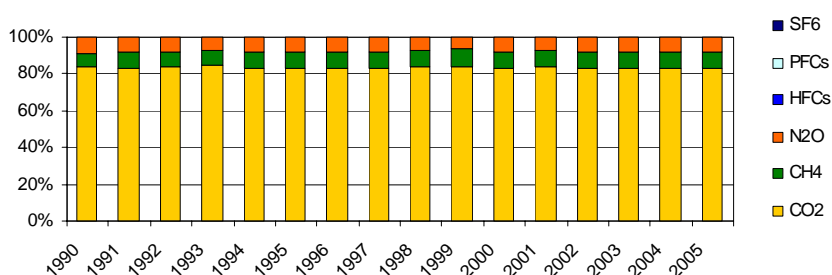
\*Total HFCs, PFCs and SF<sub>6</sub> emissions are determined as of 02.07.2007, emissions in Gg.

<sup>2</sup> 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.

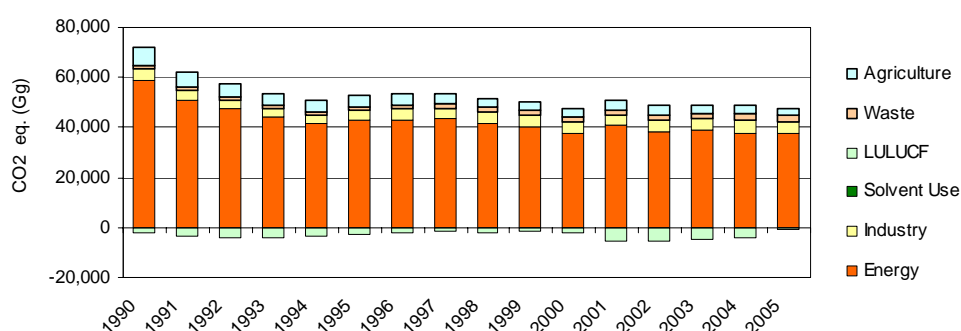
**Figure ES. 5: Share of individual F-gases emissions (Gg of CO<sub>2</sub> eq.) in 1990-2005**

## ES.8 Aggregated Emissions

These are the emissions of greenhouse gases recalculated via GWP100 (Global Warming Potential)<sup>3</sup> on the CO<sub>2</sub> equivalent (Figure ES. 6). Expressed as the CO<sub>2</sub> equivalent, carbon dioxide emissions contributed by more than 83 % to the total emissions, CH<sub>4</sub> (GWP = 21) emissions by about 9 %, N<sub>2</sub>O (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 1990-2005 in percent**

Emissions without LULUCF in CO<sub>2</sub> equivalents; emissions are determined as of 02.07.2007

**Figure ES. 7: The aggregated emissions of greenhouse gases by sectors in 1990-2005**

Emissions without LULUCF in CO<sub>2</sub> equivalents; emissions are determined as of 02.07.2007

<sup>3</sup> According to the currently valid Convention, the emission reduction expressed in CO<sub>2</sub> equivalent should be reported

## ES.9 Indirect Greenhouse Gases

A major source of SO<sub>2</sub>, NO<sub>x</sub> and CO emissions is power and heat generation. A contribution of transport to NO<sub>x</sub> 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<sub>x</sub>, CO, NM VOC and SO<sub>2</sub> (Gg) in 1990-2005**

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
<b>CO</b>	<b>505,0</b>	<b>482,0</b>	<b>441,0</b>	<b>452,0</b>	<b>427,0</b>	<b>416,0</b>	<b>359,0</b>	<b>359,0</b>	<b>342,0</b>	<b>330,0</b>	<b>312,9</b>	<b>315,1</b>	<b>292,3</b>	<b>308,2</b>	<b>309,8</b>	<b>299,4</b>
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
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
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
<b>NO<sub>x</sub></b>	<b>222,0</b>	<b>201,0</b>	<b>188,0</b>	<b>180,0</b>	<b>170,0</b>	<b>178,0</b>	<b>135,0</b>	<b>127,0</b>	<b>133,0</b>	<b>121,0</b>	<b>109,2</b>	<b>108,7</b>	<b>101,1</b>	<b>98,1</b>	<b>98,1</b>	<b>98,0</b>
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
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
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
<b>NM VOC</b>	<b>136,6</b>	<b>136,6</b>	<b>136,6</b>	<b>111,2</b>	<b>111,2</b>	<b>105,2</b>	<b>103,2</b>	<b>93,4</b>	<b>90,5</b>	<b>83,6</b>	<b>78,8</b>	<b>81,6</b>	<b>77,1</b>	<b>81,2</b>	<b>82,8</b>	<b>78,9</b>
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
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
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
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
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
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
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
<b>SO<sub>2</sub></b>	<b>526,0</b>	<b>445,0</b>	<b>390,0</b>	<b>328,0</b>	<b>245,0</b>	<b>246,0</b>	<b>231,0</b>	<b>205,0</b>	<b>184,0</b>	<b>173,0</b>	<b>127,0</b>	<b>131,2</b>	<b>103,3</b>	<b>106,1</b>	<b>96,9</b>	<b>89,0</b>
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
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
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

\*Biomass burning and forest fires, emissions are determined as of 15.01.2007

# 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 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 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 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.<sup>4</sup>

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 (H<sub>2</sub>O), 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 (CO<sub>2</sub>) contributes to the greenhouse effect 30 %, methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O) and ozone (O<sub>3</sub>), all three together 3 %. The group of synthetic (artificial) substances - chlorofluorocarbons (CFCs), their substitutes,

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<sup>4</sup> Kyoto Protocol came into force on February 14., 2005

hydrofluorocarbons (HCFCs, HFCs) and others such as fluorocarbons (PFCs) and SF<sub>6</sub>, also belong to the greenhouse gases. There are other photochemical active gases as well, such as carbon monoxide (CO), oxides of nitrogen (NO<sub>x</sub>) 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 CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O 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 CO<sub>2</sub> per capita in the globe). The most important source of "new" carbon dioxide is presented by the fossil fuel combustion and cement production. The CO<sub>2</sub> 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 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 CO<sub>2</sub>, 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 (IPCC<sup>5</sup> 1995). PFCs, HCFCs, HFCs (perfluorocarbons, hydrochlorofluorocarbons, hydrofluorocarbons, etc.) and SF<sub>6</sub> 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 semiconductors 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 (CF<sub>4</sub>) 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<sub>x</sub> 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. N<sub>2</sub>O 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

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<sup>5</sup> 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.

inconvenient agriculture-technical procedures). Fuel combustion, some industrial technologies, large-scale livestock breeding and sewage are the sources of N<sub>2</sub>O 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 N<sub>2</sub>O is disintegrated mainly photo chemically in the stratosphere.

According to the emission inventory of July, 2007, Slovak Republic has achieved a reduction of total anthropogenic emissions of greenhouse gasses expressed as CO<sub>2</sub> 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 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 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.

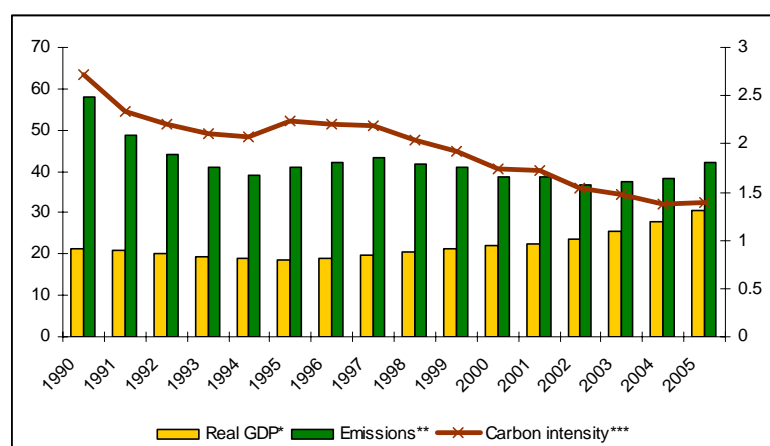
In May 2004, Slovak Republic joined the European Union. Relevant European legislation is expected to have additional positive direct and indirect effects to reduction of GHG emissions, mainly in the energy sector. The introduction of emission trading scheme will allow for the implementation of further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

**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
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
Emissions**	58.131	48.606	44.246	41.140	39.122	41.145	41.967	43.260	41.709	40.994	38.521	38.671	36.702	37.529	38.247	42.250
Carbon intensity***	2.718	2.343	2.198	2.107	2.065	2.239	2.201	2.187	2.032	1.925	1.743	1.726	1.549	1.478	1.381	1.385

The values are absolute, \*in billion Euro in year 2000, \*\*Tg of CO<sub>2</sub> emissions, \*\*\*Tg of CO<sub>2</sub>/billions Euro 2000

**Figure 1. 1: Comparison of CO<sub>2</sub> emissions per GDP (carbon intensity)**



## 1.2 Institutional Arrangement

The Slovak Ministry of the Environment (MoE) ([www.enviro.gov.sk](http://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. 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>.<sup>6</sup>

Supporting institutions founded by the Ministry of Environment play an important role. These include the Slovak Hydrometeorological Institute (SHMI) ([www.shmu.sk](http://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) 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 SO<sub>2</sub>, NO<sub>x</sub>, CO at regional level and to fulfil reporting commitments of national and EU Directives ([http://www.spirit.sk/ie\\_home.html](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.

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<sup>6</sup> 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

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;
- 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-inventory.gov.sk](http://www.ghg-inventory.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 fulfilled.

### 1.3 Process of Inventory Preparation

The process of greenhouse gases inventory according the UNFCCC requirements is realized in 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.



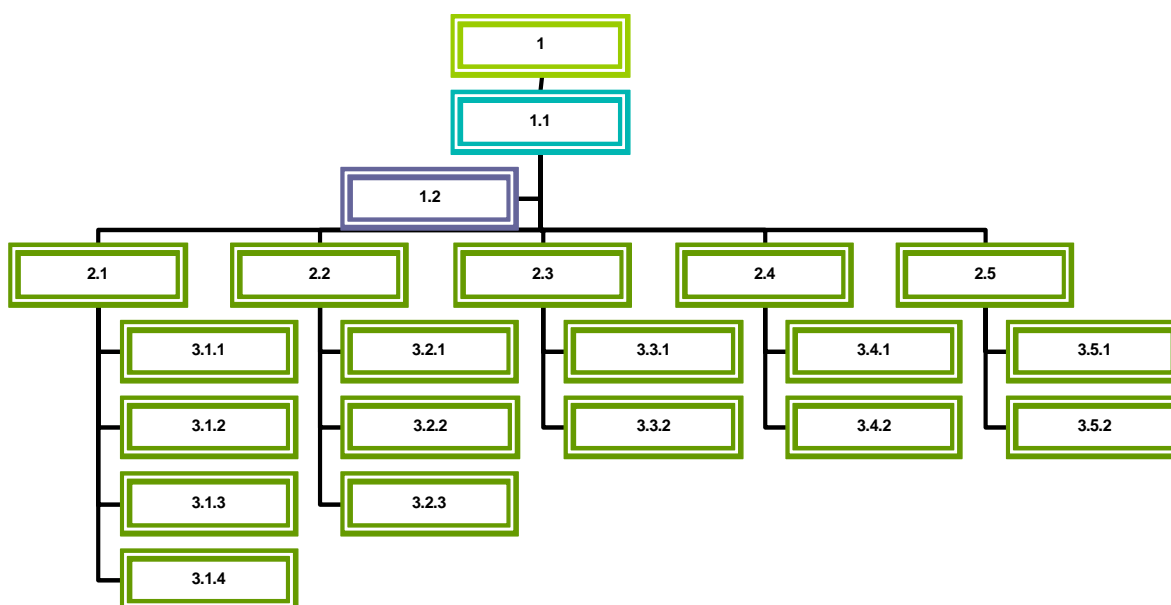
The emissions of GHGs in the Slovak Republic were estimated in compliance with the methods provided in IPCC 1996 Revised Guidelines, IPCC Good Practice Guidelines for LULUCF (2003) and IPCC Good Practice Guidance and Uncertainty Management in National GHG Inventories (GPG 2000); CORINAIR (2003), COPERT 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 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, NEC, IPPC and EPER). 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- NFP – the controlling unit of MŽP

Single National Entity = 1.1 – The chief coordinator of GHG inventories  
 1.2 – The coordinator of quality, uncertainties and projections

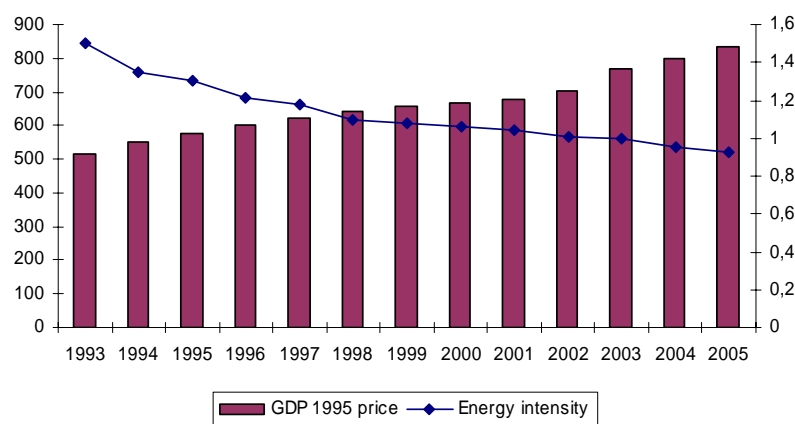
- 2.1 - Coordinator of the energy sector
  - 3.1.1 - NEIS bottom-up methodology expert
  - 3.1.4 - Top-down methodology expert
  - 3.1.2 - Transport expert
  - 3.1.3 - Fugitive emissions expert
- 2.2 - Coordinator of the industrial sector
  - 3.2.1 - Industry expert
  - 3.2.2 - Expert F-gases
  - 3.2.3 - Solvents expert
- 2.3 - Coordinator of the agricultural sector
  - 3.3.1 - Animal production expert
  - 3.3.2 - Plant production expert
- 2.4 - Coordinator of the LUCF sector
  - 3.4.1 - Landscape use expert
  - 3.4.2 - Forestry expert
- 2.5 - Coordinator of the waste sector
  - 3.5.1 - Expert on waste landfills
  - 3.5.2 - Expert on waste water

## 1.4 General Description of Methodologies and Data Sources

### Energy sector – category energy industry

In 2005, 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 GDP 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. Slovak Republic is using reference approach as a national total emission estimate of CO<sub>2</sub>, 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 (CH<sub>4</sub>) 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 CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, NO<sub>x</sub>, CO, NM VOC, SO<sub>2</sub>, CF<sub>4</sub>, C<sub>2</sub>F<sub>6</sub>, and SF<sub>6</sub> pollution. Even though the emissions of CO<sub>2</sub> and N<sub>2</sub>O 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 CO<sub>2</sub> 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 N<sub>2</sub>O emissions were estimated from 2001, according the internal statistics of distributors for medicinal and food purposes.

### **Agriculture sector**

The sources of N<sub>2</sub>O and CH<sub>4</sub> 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 CH<sub>4</sub> and N<sub>2</sub>O 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 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 2005 followed the Good Practice Guidance (IPCC, 2000 and 2003). The Slovak Republic determined in year 2005 14 key source categories by level assessment with LULUCF and 16 key source categories without LULUCF (Table 1. 3). The SR determined in year 2005 19 key source categories by trend assessment with LULUCF) and 16 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 N<sub>2</sub>O from agricultural soil and methane emissions from SWDS etc. The identification includes all reported greenhouse gases CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFCs, PFCs and SF<sub>6</sub> 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 2007 to the EC (280/2004/EC) and comprises a level assessment for years 1990 and 2000-2005 and a trend assessment for the trend of the years 1990 (1995) to 2005.

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 CO<sub>2</sub> equivalent emissions for the years 1990 (1995) to 2005.

#### **Level Assessment**

For the level assessment the contribution of GHG emissions (expressed in CO<sub>2</sub> 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 2005 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 2005 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**

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 2005

Source Category Analysis Summary (2005 GHGs Inventory)			
Quantitative Method Used: TIER 1 with LULUCF			
ENERGY SECTOR	GHG	Key Source	Criteria
1.A.1 Energy Industries	CO <sub>2</sub>	yes	Level, Trend
1.A.1 Energy Industries	CH <sub>4</sub>	no	
1.A.1 Energy Industries	N <sub>2</sub> O	no	
1.A.2 Manufacturing Industries and Construction	CO <sub>2</sub>	yes	Level, Trend
1.A.2 Manufacturing Industries and Construction	CH <sub>4</sub>	no	
1.A.2 Manufacturing Industries and Construction	N <sub>2</sub> O	no	
1.A.4 Other sector	CO <sub>2</sub>	yes	Level, Trend
1.A.4 Other sector	CH <sub>4</sub>	no	
1.A.4 Other sector	N <sub>2</sub> O	no	
1.A.3.a Transport - Civil Aviation	CO <sub>2</sub>	no	
1.A.3.a Transport - Civil Aviation	N <sub>2</sub> O	no	
1.A.3.b Transport - Road Transportation	CO <sub>2</sub>	yes	Level, Trend
1.A.3.b Transport - Road Transportation	CH <sub>4</sub>	no	
1.A.3.b Transport - Road Transportation	N <sub>2</sub> O	no	
1.A.3.c Transport - Railways	CO <sub>2</sub>	no	
1.A.3.c Transport - Railways	CH <sub>4</sub>	no	
1.A.3.c Transport - Railways	N <sub>2</sub> O	no	
1.A.3.d Transport - Navigation	CO <sub>2</sub>	no	
1.A.3.d Transport - Navigation	CH <sub>4</sub>	no	
1.A.3.d Transport - Navigation	N <sub>2</sub> O	no	
1.A.5.a Other non-specified	CO <sub>2</sub>	yes	Level, Trend
1.A.5.a Other non-specified	CH <sub>4</sub>	no	
1.A.5.a Other non-specified	N <sub>2</sub> O	no	
1.B.1.a Coal Mining and Handling	CH <sub>4</sub>	yes	Trend
1.B.1.b Fugitive Emission from Oil, Natural Gas and Other	CH <sub>4</sub>	yes	Level, Trend
INDUSTRIAL SECTOR	GHG	Key Source	Criteria
2(I).A.1 Cement Production	CO <sub>2</sub>	yes	Level, Trend
2(I).A.2 Lime Production	CO <sub>2</sub>	yes	Level, Trend
2(I).A.3 Limestone and Dolomite Use	CO <sub>2</sub>	yes	Trend
2(I).A.7 Magnesite Use	CO <sub>2</sub>	yes	Trend
2(I).B.2 Nitric Acid Production	N <sub>2</sub> O	yes	Level, Trend
2(I).C.1 Iron and Steel Production	CO <sub>2</sub>	yes	Level, Trend
2(I).C.3 Aluminium Production	CO <sub>2</sub>	no	
2(I).C.3 Aluminium Production	PFCs	no	
2(I).F HFCs emissions	HFCs	no	
2(I).F SF <sub>6</sub> emissions	SF <sub>6</sub>	no	
SOLVENT SECTOR	GHG	Key Source	Criteria
3.D Other Solvent Use	N <sub>2</sub> O	no	
AGRICULTURE SECTOR	GHG	Key Source	Criteria
4.A Enteric Fermentation	CH <sub>4</sub>	yes	Level, Trend
4.B Manure Management	CH <sub>4</sub>	no	
4.B Manure Management	N <sub>2</sub> O	yes	Trend
4.D Agricultural Soils	N <sub>2</sub> O	yes	Level, Trend
LULUCF SECTOR	GHG	Key Source	Criteria
5.A Forest Land	CO <sub>2</sub>	no	
5.A Forest Land	CH <sub>4</sub>	no	
5.A Forest Land	N <sub>2</sub> O	no	
5.B Cropland	CO <sub>2</sub>	no	
5.C Grassland	CO <sub>2</sub>	no	
5.F Other Land	CO <sub>2</sub>	yes	Trend
WASTE SECTOR	GHG	Key Source	Criteria
6.A Solid Waste Disposal on Land	CH <sub>4</sub>	yes	Level, Trend
6.B Wastewater Handling	CH <sub>4</sub>	yes	Level, Trend
6.B Wastewater Handling	N <sub>2</sub> O	no	



Table 1. 3: Results of key source analysis in trend and level assessment without LULUCF, year 2005

Source Category Analysis Summary (2005 GHGs Inventory)			
Quantitative Method Used: TIER 1 without LULUCF			
ENERGY SECTOR	GHG	Key Source	Criteria
1.A.1 Energy Industries	CO <sub>2</sub>	yes	Level, Trend
1.A.1 Energy Industries	CH <sub>4</sub>	no	
1.A.1 Energy Industries	N <sub>2</sub> O	no	
1.A.2 Manufacturing Industries and Construction	CO <sub>2</sub>	yes	Level, Trend
1.A.2 Manufacturing Industries and Construction	CH <sub>4</sub>	no	
1.A.2 Manufacturing Industries and Construction	N <sub>2</sub> O	no	
1.A.4 Other sector	CO <sub>2</sub>	yes	Level, Trend
1.A.4 Other sector	CH <sub>4</sub>	no	
1.A.4 Other sector	N <sub>2</sub> O	no	
1.A.3.a Transport - Civil Aviation	CO <sub>2</sub>	no	
1.A.3.a Transport - Civil Aviation	N <sub>2</sub> O	no	
1.A.3.b Transport - Road Transportation	CO <sub>2</sub>	yes	Level, Trend
1.A.3.b Transport - Road Transportation	CH <sub>4</sub>	no	
1.A.3.b Transport - Road Transportation	N <sub>2</sub> O	yes	Trend
1.A.3.c Transport - Railways	CO <sub>2</sub>	no	
1.A.3.c Transport - Railways	CH <sub>4</sub>	no	
1.A.3.c Transport - Railways	N <sub>2</sub> O	no	
1.A.3.d Transport - Navigation	CO <sub>2</sub>	no	
1.A.3.d Transport - Navigation	CH <sub>4</sub>	no	
1.A.3.d Transport - Navigation	N <sub>2</sub> O	no	
1.A.5.a Other non-specified	CO <sub>2</sub>	yes	Level, Trend
1.A.5.a Other non-specified	CH <sub>4</sub>	no	
1.A.5.a Other non-specified	N <sub>2</sub> O	no	
1.B.1.a Coal Mining and Handling	CH <sub>4</sub>	yes	Trend
1.B.1.b Fugitive Emission from Oil, Natural Gas and Other	CH <sub>4</sub>	yes	Level, Trend
INDUSTRIAL SECTOR	GHG	Key Source	Criteria
2(I).A.1 Cement Production	CO <sub>2</sub>	yes	Level, Trend
2(I).A.2 Lime Production	CO <sub>2</sub>	yes	Level, Trend
2(I).A.3 Limestone and Dolomite Use	CO <sub>2</sub>	yes	Level, Trend
2(I).A.7 Magnesite Use	CO <sub>2</sub>	yes	Level, Trend
2(I).B.2 Nitric Acid Production	N <sub>2</sub> O	yes	Level, Trend
2(I).C.1 Iron and Steel Production	CO <sub>2</sub>	yes	Level, Trend
2(I).C.3 Aluminium Production	CO <sub>2</sub>	yes	Trend
2(I).C.3 Aluminium Production	PFCs	no	
2(I).F HFCs emissions	HFCs	yes	Trend
2(I).F SF <sub>6</sub> emissions	SF <sub>6</sub>	no	
SOLVENT SECTOR	GHG	Key Source	Criteria
3.D Other Solvent Use	N <sub>2</sub> O	no	
AGRICULTURE SECTOR	GHG	Key Source	Criteria
4.A Enteric Fermentation	CH <sub>4</sub>	yes	Level, Trend
4.B Manure Management	CH <sub>4</sub>	yes	Trend
4.B Manure Management	N <sub>2</sub> O	yes	Trend
4.D Agricultural Soils	N <sub>2</sub> O	yes	Level, Trend
WASTE SECTOR	GHG	Key Source	Criteria
6.A Solid Waste Disposal on Land	CH <sub>4</sub>	yes	Level, Trend
6.B Wastewater Handling	CH <sub>4</sub>	yes	Level, Trend
6.B Wastewater Handling	N <sub>2</sub> O	yes	Trend

## 1.7 General Uncertainty Evaluation

The uncertainty of estimation of CO<sub>2</sub> 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 8.41 % by level assessment and 6.25 % 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 published<sup>7</sup> 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 CH<sub>4</sub> 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

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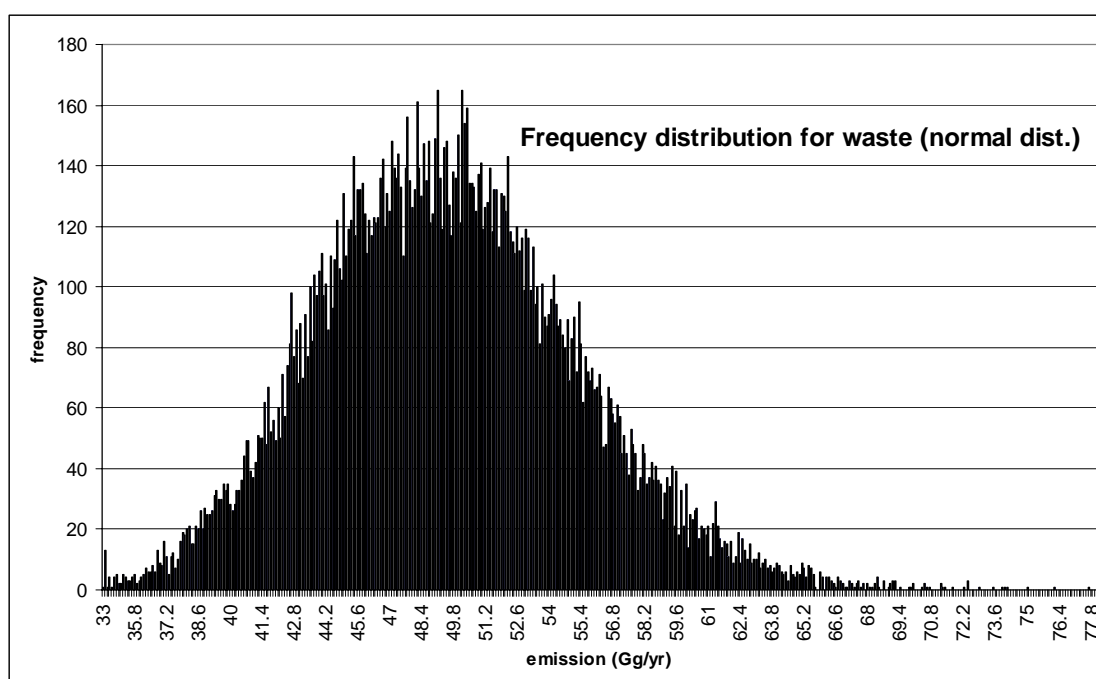
<sup>7</sup> J. Szemesova, M. Gera: *Contributions to Geophysics & Geodesy*, accepted 2007

developed. With help of AuvTool software, they create useful tools for uncertainties estimation. In developed packages the next statistical distributions are supported.<sup>8</sup>

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 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 CH<sub>4</sub> 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 2005 submission 2007 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

<sup>8</sup> Gumbel, Exponential, Weibull, Lognormal, Uniform, Triangular, Beta, Binomial, Neg\_binomial, Chisq, Nc\_chisq, F, Nc\_F, Gamma, T, Nc\_T, Normal and Poisson.

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) indicate that the emissions are included in the main categories.

**Solvent use** – emissions and sources were not estimated (NE) before 2001, lack of input data. The expert estimation will be performed for the next submission.

**Waste incineration** – emissions of CO<sub>2</sub> and N<sub>2</sub>O for the waste incineration before year 2000 were included (IE) in the energy sector – other fuels, because different allocation and different methodological approach of the national database of stationary sources (NEIS) before year 2000. Total sum of emissions from waste incineration is consistent and avoiding double counting.

## 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 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 1990-2005 is given in Table 2. 1.

**Table 2. 1: The Indicators of per capita trend 1990-2005**

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
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
Total GHGs	69,662	58,746	53,270	49,110	47,452	49,864	50,802	51,957	49,895	48,748	45,062	45,438	43,515	44,267	44,365	47,017
Per capita	13.15	11.12	10.04	9.22	8.87	9.30	9.45	9.65	9.26	9.04	8.34	8.45	8.09	8.23	8.24	8.73

In accordance with the generally expected results, the aggregated emission of GHGs in year 2005 moderate decreased comparable to the previous inventory year 2004 about more than 720 Gg excluding LULUCF, it means approximately 1.5 %. With the including the sector LULUCF the net aggregated emissions in 2005 inventory year increased comparable to previous year 2004 about 2 600 Gg it means more than 5 %. The reason is in decreasing the sinks in LULUCF sector, as has been expected in the projections last year. According the natural catastrophe in the large part of forest in the end of 2004 in High Tatra Mountains, the forest was destroyed.

There is the significant decreasing of aggregated emission against the base year (1990) about approximately 24 000 Gg it means the decreasing about more then 33 % without LULUCF and more than 32 % with LULUCF sector.

The total national emission in the current inventory year 2005 was estimated to be 47 866.31 Gg of CO<sub>2</sub> eq. without LULUCF sector and the net GHG emission was 47 016.74 Gg including the sinks from LULUCF. The Slovak Republic reported the national emission from energy sector based on sectoral approach data in 2005 to be 37 402.51 Gg CO<sub>2</sub> equivalent including the transport emissions (6 429.48 Gg of CO<sub>2</sub> eq.), which represent decrease compare the base year by about 36 %, but increase in the transport sub-sector against previous year 2004 about 22 %.

The total emissions from industrial processes sector in 2005 were estimated to be 5 060.33 Gg of CO<sub>2</sub> eq. This is increase compare the base year by about 2.8 %, but decrease compare to previous year about more than 4 %. The numbers were changed because the recalculation of all time series in the nitric acid production.

The total emissions from sector of solvent use were estimated to be 72.76 Gg of CO<sub>2</sub> eq. this is decreasing comparable to previous year about 10 %, the time series is not complete and the comparison with the base year is not provided.

The emissions from agriculture sector were estimated to be 3 219.46 Gg of CO<sub>2</sub> eq. It is decrease compare the base year by about 54 % and minor decrease comparable to the previous year. The agriculture sector was the most decreasing sector comparable to the base year 1990.

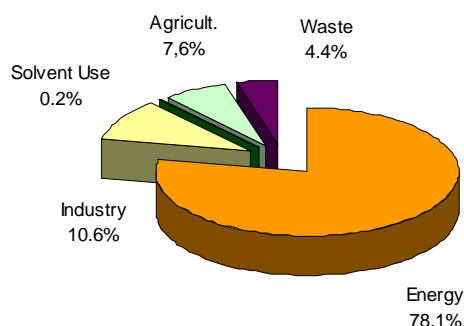
The total emissions and sinks from LULUCF sector were estimated to be -849.56 Gg of CO<sub>2</sub> eq., the whole time series 1990-2005 were recalculated according the new methodology and those emissions and sinks were included into the submission. The estimation of emissions and sinks in the LULUCF sector are complicated to explain with the consistent time series.

The emissions from waste sector were estimated to be 2 111.24 Gg of CO<sub>2</sub> eq. The decrease comparable to the previous inventory year is about 4 %, but comparable to the base year no decrease was registered, because of including the waste incineration from year 2000 and incompleteness of time series.

A major share of aggregated emission covers the energy sector by about 78.1 %, the industrial processes sector covers about 10.6 %, the solvent use sector about 0.2 %, the agriculture sector about 7.6 % and the waste sector about 4.4 % (Figure 2. 1). The major share of aggregated emission covers CO<sub>2</sub> emissions by about 83.1 %, CH<sub>4</sub> emissions by about 8.7 %, N<sub>2</sub>O emissions by about 7.8 % and F-gases emissions by about 0.4 % (Figure 2. 2).

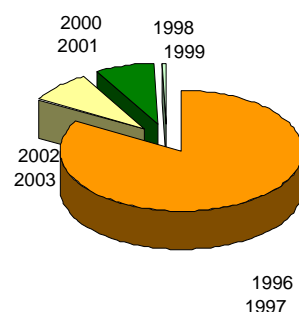
**Figure 2. 1:**

**The aggregated GHG emissions by sectors in 2005**



**Figure 2. 2:**

**The aggregated GHG emissions by gases in 2005**



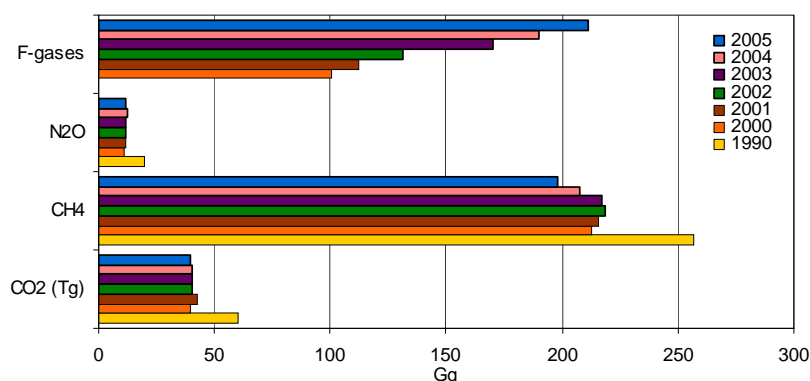
## 2.2 Emission Trend by Gas

The total anthropogenic emissions of carbon dioxide decreased relating to the base year (1990) by about 34 % without LULUCF and represented in current year 39 757.23 Gg of CO<sub>2</sub> without LULUCF sector. Comparable to the previous inventory year, the decreasing is about 500 Gg of CO<sub>2</sub>.

The total anthropogenic emissions of methane reached in the 2005 almost 4 154.88 Gg of CO<sub>2</sub> equivalent without LULUCF and decreased relating the base year about 23 %. The significant decreasing of CH<sub>4</sub> emissions from energy and agriculture sector caused this effect. Comparable to the previous inventory year, the increasing is about 150 Gg of CO<sub>2</sub> equivalents.

The total emissions of N<sub>2</sub>O increased relating the previous year to 3 742.69 Gg of CO<sub>2</sub> equivalent without LULUCF and decreased relating the previous year about 60 Gg. The total decreasing comparable with the base year presents 39 %.

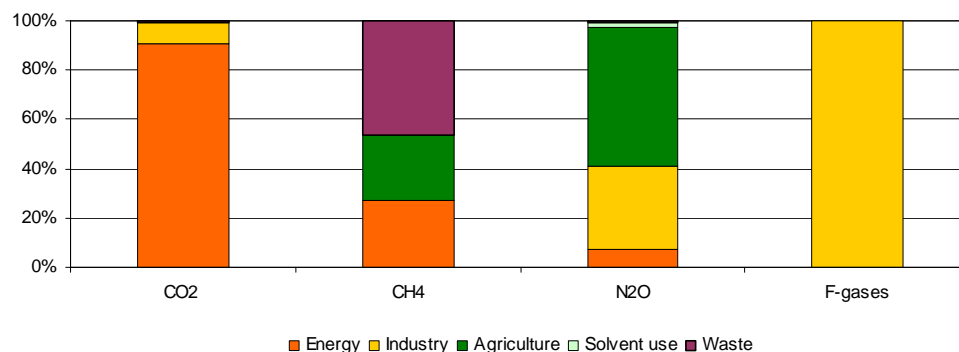
The total emissions of F-gases represented 211.51 Gg and are increased comparable with the previous year's inventory by about 20 Gg, but beside the base year (1995) shows a more than 30 % decreasing, caused by decreasing a consumption of perfluorocarbons (Figure 2. 3).

**Figure 2. 3: The emission trends by gas for the recalculated years 1990, 2000-2005**

The total anthropogenic emissions of CO<sub>2</sub> are depicted in Tg (not in scale).

### 2.3 Emission Trend by Source

The major share of CO<sub>2</sub> emissions is from energy sector (fuel combustion, transport) with more than 90 % from the total carbon dioxide emissions in last 2005 inventory. More than 42 % of CH<sub>4</sub> emissions produces waste sector (SWDS), more than 21 % of N<sub>2</sub>O 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 2005**

### 2.4 Emission Trends for Indirect GHGs and SO<sub>2</sub>

The total anthropogenic emission of NO<sub>x</sub> was estimated to 98.03 Gg and the major share was produced by energy sector. The total emission of CO was estimated to 299.44 Gg and the major share of emissions was produced by energy sector. The emission of NM VOC was estimated to 78.94 Gg per year 2005 and the major share was produced by energy sector, industrial processes sector and solvent-use sector. The emissions of SO<sub>2</sub> were estimated to 89.01 Gg per year 2005 and the major share of emissions was produced by energy sector. Emissions of all indirect GHG and SO<sub>2</sub> 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](http://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:

<b>1.A.1</b>	<b>Energy industry</b>
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
<b>1.A.2</b>	<b>Manufacturing Industries and Construction</b>
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
<b>1.A.4</b>	<b>Other Sectors</b>
1.A.4.a	Commercial/Institutional
1.A.4.b	Residential
1.A.4.c	Agriculture/Forestry/Fisheries
<b>1.A.5</b>	<b>Other</b>
1.A.5.a	Stationary

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. 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](http://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 form 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](http://www.spirit.sk), [www.air.sk](http://www.air.sk))

The following revision and recalculation of sectoral approach between 2000 and 2004 was necessary. The changes are based on the different distribution of fuels inside of IPCC categories and excluding or excluding the fuels consider as waste into the category 6.c – waste incineration.

**Figure 3. 1: A distribution of emissions CO<sub>2</sub> eq. in type of fuels in SA in 2005 IPCC 1.A sub-sector and according the fuel types**



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 m<sup>3</sup> or tones) with the corresponding calorific values (GJ/thous.m<sup>3</sup> 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 CO<sub>2</sub> emission balance, but is provided.

According to the quantity and calorific values the sectoral expert completes the calculation of the quantity of 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 CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O are calculated. The emission factors for the non-CO<sub>2</sub> are default (IPCC), most of the CO<sub>2</sub> 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.

A consumption of biomass is not included in the total CO<sub>2</sub> emission balance.

### Reference approach

Upper level of emissions and sinks of CO<sub>2</sub> 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 CO<sub>2</sub> 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;

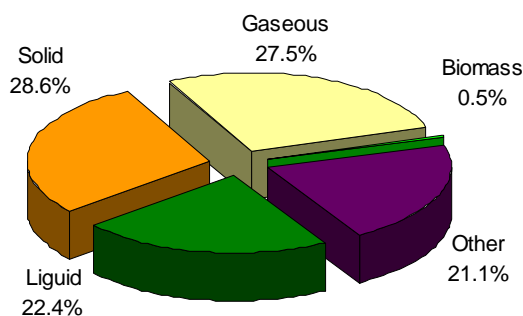
- Information Entries - Solid Biomass, Liquid Biomass, Gas Biomass.

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 2005 was determined to 1 003 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 CO<sub>2</sub> emissions in type of fuels in RA in 2005**



### Emission Factors

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 CO<sub>2</sub> are in use for this time, for natural gas from year 2000. The emission factors for natural gas are based on previously measurements and calculation published every month by Slovak Gas Industry Ltd. These EFs are in use for installations joined in the Emission Trading Scheme and for the requirements of the Ministry of Environment of SR.

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.

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 Slovak Republic are based on previously 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%20plynu2005SK.pdf>. These EFs are in use for installations joined in the ETS and for the requirements of the Ministry of Environment of SR (Table 3. 1).

Table 3. 1: EF CO<sub>2</sub> and NCV for NG [15°C; 101,325 kPa]

Year 2005	Natural gas [mol %]	NCV	EF [CO <sub>2</sub> ]									
Month	CH <sub>4</sub>	C <sub>2</sub> H <sub>6</sub>	C <sub>3</sub> H <sub>8</sub>	i-C <sub>4</sub> H <sub>10</sub>	n-C <sub>4</sub> H <sub>10</sub>	i-C <sub>5</sub> H <sub>12</sub>	n-C <sub>5</sub> H <sub>12</sub>	C <sub>6</sub> H <sub>14</sub>	CO <sub>2</sub>	N <sub>2</sub>	MJ/m <sup>3</sup>	tCO <sub>2</sub> /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. 2).

Table 3. 2 The parameters of the natural gas published by Slovak Gas Industry on-line ([www.spp.sk](http://www.spp.sk))

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

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. 3).

Table 3. 3: Table of the revised CO<sub>2</sub> 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
EF t/TJ	55,47	55,45	55,42	55,40	55,38	55,36	55,34	55,31	55,29	55,27	55,28	55,22	55,19	55,16	55,13	55,18
	extrapolated values										real national data					

Calculated extrapolated values were used for calculation of carbon emission factors for natural gas, used in reference approach, too (Table 3. 4).

**Table 3. 4: 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
EF t/TJ	15,54	15,47	15,40	15,35	15,29	15,25	15,20	15,17	15,13	15,11	15,09	15,07	15,06	15,06	15,05	15,06
	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 1990-2005. 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

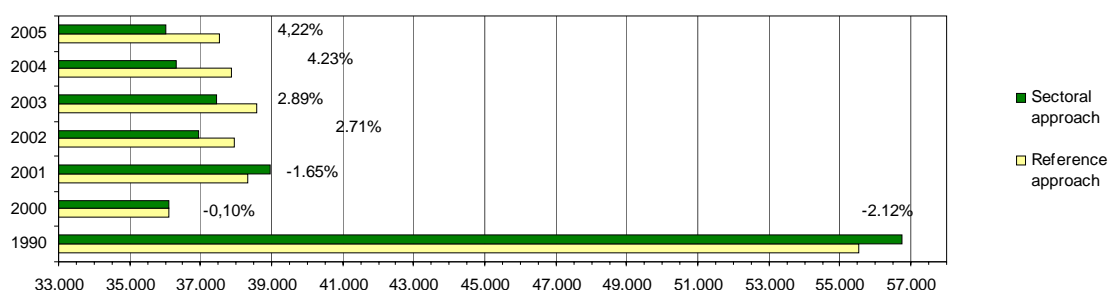
The complete time series of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions for reference and sectoral approach from base year were estimated and the differences are summarized in the Table 3. 5. The higher difference between sectoral and reference approach in the older submissions is caused 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.

**Table 3. 5 The sectoral and reference approaches for the recalculated years 1990, 2000-2005**

Year	1990	2000	2001	2002	2003	2004	2005
Sectoral approach (CO <sub>2</sub> Gg)	56 737.64	36 124.07	38 960.71	36 953.23	37 466.36	36 321.75	36 017.09
Reference approach (CO <sub>2</sub> Gg)	55 534.49	36 089.01	38 318.93	37 953.43	38 582.91	37 859.21	37 538.01
Difference in %	-2.12	-0.10	-1.65	2.71	2.98	4.23	4.22

The total anthropogenic emission of carbon dioxide from energy sector, fuel combustion was estimated in the inventory year 2005 to be 36 017 Gg as a national total CO<sub>2</sub> emissions (Figure 3. 3).

**Figure 3. 3: A comparisons of SA and RA in 1990, 2000-2005**



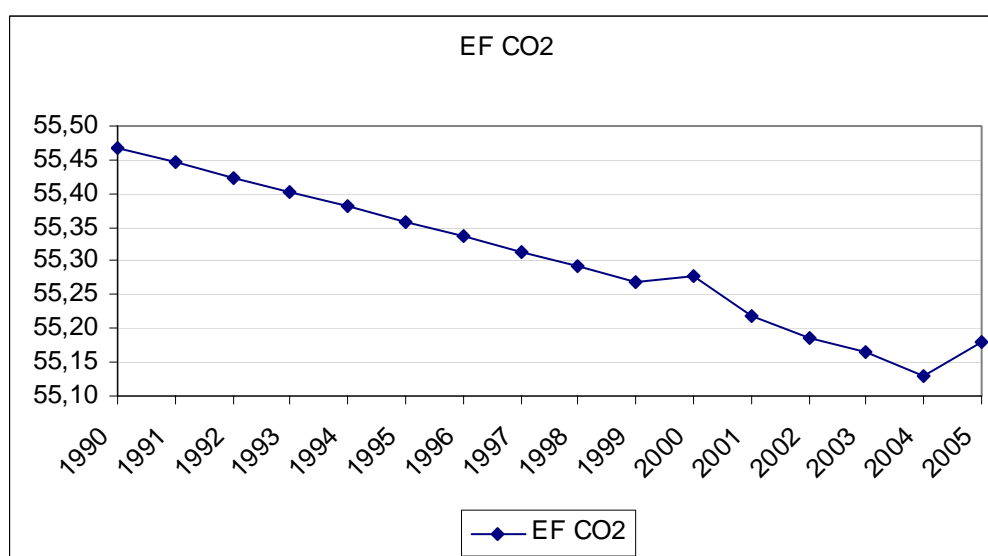
Reference and sectoral approach are estimated on fully independent data sets, whereby obtained differences are negligible. The difference between the top down and the bottom up energy balance was calculated to be 21 %. The differences in fuel consumption between these two approaches can be caused by 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 alternative 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 Statistical 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

Total reduction of CO<sub>2</sub> emissions from gaseous fuel (natural gas) in 1990 was 1.14 % in comparison to the previous submission (2006). The results according energy categories are summarized in the table below (Figure 3. 4).

**Figure 3. 4: Graph of the development of EFs for natural gas according linear function calculation before 2000**



**Table 3. 6: Table of recalculation changes in the main energy categories in CO<sub>2</sub> (Gg) emissions from natural gas**

Year of sub.	Category	1A1	1A2	1A4	1A5
1990 (2006)		2 213,55	4 816,61	2 874,17	1 657,36
1990 (2007)		2 188,64	4 762,40	2 841,82	1 638,71
Differences in %		1,13	1,13	1,13	1,13
Differences in Gg of CO <sub>2</sub>		24,91	54,21	32,35	18,65

For the submission in 2007, the Slovak Republic has made small changes and recalculations in the sectoral approach for the years 1990, 2000-2004. Several changes in the other fuel category were included into waste and biomass according the implementation of new legal documents: Regulation of MZP SR No. 706/2002, Regulation of MZP SR No. 129/2004, amended Regulation MZP SR 284/2001

to established catalogue of the waste and Directive No. 200/76/EC about waste incineration. The difference of year 2004 in the view of last submission is decrease of 5.5 % in energy sector.

### Key Source and Uncertainties

The emissions of CO<sub>2</sub> 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 (CH<sub>4</sub>, N<sub>2</sub>O) 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<sub>x</sub>, SO<sub>2</sub>) and solid particles - TSP, PM<sub>10</sub>, PM<sub>2.5</sub>, 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 2005. 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 2005 included also the emissions from light and heavy-duty vehicles, buses operated by CNG (Compressed Natural Gas) for 2000-2005. 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

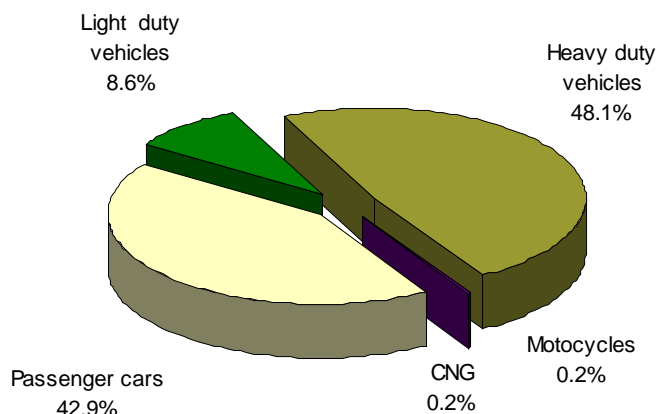
The emission factors for the group of pollutants such as CO<sub>2</sub>, SO<sub>2</sub>, N<sub>2</sub>O, NH<sub>3</sub>, PM and partially also CH<sub>4</sub> is possible to obtain with the simply formula between driving mode and consumed fuel. This value is constant for the different vehicles categories. 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 2005 is presented on the Figure 3. 5 and in the Table 3. 7 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 2005 – 6 297.59 Gg of CO<sub>2</sub> eq. The major share belongs to the duty vehicles and passenger cars. Table 3. 7: is completed with the information about share of emissions to the operations: city, road and highway traffic.

**Figure 3. 5: A share of individual vehicles in road transport in 2005 according the emissions in CO<sub>2</sub> eq.**



**Table 3. 7: The results in GHGs emission balance in 2005 in the road transport**

Category of road vehicles	Emissions GHG in 2005 [t]			Category of road vehicles	Emissions GHG in 2005 [t]		
	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
<b>Passenger cars</b>	<b>2 567 183</b>	<b>902</b>	<b>374</b>	<b>Heavy duty vehicles</b>	<b>2 975 111</b>	<b>264</b>	<b>149</b>
gasoline < 1,4 l	1 191 492	544	181	gasoline > 3,5 t	0	0	0
gasoline 1,4 l - 2,0 l	724 596	271	107	diesel 3,5 - 7,5 t	629 698	71	54
gasoline > 2,0 l	131 127	43	12	diesel 7,5 - 16 t	540 363	35	28
diesel < 2,0 l	328 633	12	52	diesel 16 - 32 t	1 252 811	103	48
diesel > 2,0 l	81 095	3	14	diesel > 32 t	119 974	4	3
LPG	109 798	29	8	City buses	226 006	29	8
Two stroke engine	442	0	0	Long-line buses	206 259	22	8
<b>Light duty vehicles</b>	<b>529 512</b>	<b>41</b>	<b>40</b>	Vehicles on CNG	<b>10 602</b>	<b>106</b>	<b>0,4</b>
gasoline < 3,5 t	168 076	32	16	<b>Motorcycles</b>	<b>12 587</b>	<b>18</b>	<b>0</b>
diesel < 3,5 t	361 436	9	24	< 50 cm <sup>3</sup>	4 581	4	
				Two stroke engine > 50 cm <sup>3</sup>	6 136	9	
				Four stroke engine < 250 cm <sup>3</sup>	257	1	
				Four stroke engine 250 - 750 cm <sup>3</sup>	613	1	
				Four stroke engine > 750 cm <sup>3</sup>	985	2	
				<b>Sum in the SR</b>	<b>6 094 995</b>	<b>1 331</b>	<b>563</b>
<b>Traffic</b>				<b>Emissions GHG [t]</b>			
				<b>CO<sub>2</sub></b>	<b>CH<sub>4</sub></b>	<b>N<sub>2</sub>O</b>	
City	2 678 068			1 031			278
Road	2 416 696			237			189
Highway	1 000 231			63			96
<b>Sum in the SR</b>	<b>6 094 995</b>			<b>1 331</b>			<b>563</b>

### Recalculation and Time Series

No recalculations were provided.

### Trends in Emissions and Fuels

The trend in the production of the CO<sub>2</sub> and N<sub>2</sub>O 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 CH<sub>4</sub> emissions are primary important the vehicles alteration for the vehicles with better environmental and energetic parameters (mostly personal cars with catalyzes).

#### 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 2005. 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 cooperation 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 represented a total anthropogenic pollution of airport environment.

#### 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. 8). 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. 9).

**Table 3. 8 The statistic information about the railways organisation structure in 2005 (Traction 70+80)**

	Number Year run Consumption Consumption	Košice	Žilina	Zvolen	Bratislava	Sum
Statistic Data Traction 70+80	[number]	242	125	181	193	741
	[km]	5 619 872	3 020 607	8 511 427	4 863 990	22 015 896
	[hrtkm]	551 645 800	253 882 400	1 844 876 700	722 972 070	3 373 376 970
	[l]	10 329 847	3 931 832	15 965 601	9 576 100	39 803 380
	[t]	8 677	3 303	13 411	8 044	33 435

**Table 3. 9 The diesel oil consumption in the railways motor traction section according the RC SR**

Year	1990	1991	1992	1993	1994	1995	1996	1997
Diesel oil (kt)	118.18	88.90	73.35	62.97	59.44	64.01	62.82	59.03
Year	1998	1999	2000	2001	2002	2003	2004	2005
Diesel oil (kt)	54.15	49.57	48.86	48.18	44.76	35.80	34.33	33.44

**Navigation** - 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.

Two relevant ports on Danube River take into consideration for the emission estimation in the Slovak marine international transport – Bratislava and Komarno. The activity data for the period 1994-2005 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 Slovak Republic and decreasing prices of fuels in the neighbours' counties (market discrepancies).

**Civil Aviation** – 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.

The overall view of the sale the aviation fuels according type (aviation gasoline and jet kerosene) during 1990-2005 is shown in the tables 4A and 4B. For the period 1994-2005 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 1990-2005. The average consumption of the 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. 10. The emissions are divided according the type of the railways operation (passenger, freight and service transport) from 1995.

**Table 3. 10 The fuel consumption and the emissions in the 2005 in the railways**

Traction 70+80	Diesel oil consumption		Emissions [ t ]		
	[l]	[t]	CO <sub>2</sub>	N <sub>2</sub> O	CH <sub>4</sub>
<b>Emission factors for the motor locomotives and wagons kg / t diesel oil</b>			<b>3 188</b>	<b>1,37</b>	<b>0,19</b>
Košice	10 329 847	8 677	27 662,5	11,89	1,65
Žilina	3 931 832	3 303	10 529,1	4,52	0,63
Zvolen	15 965 601	13 411	42 754,6	18,37	2,55
Bratislava	9 576 100	8 044	25 644,0	11,02	1,53
<b>RC SR Sum</b>	<b>39 803 380</b>	<b>33 435</b>	<b>106 590,3</b>	<b>45,81</b>	<b>6,35</b>

**Navigation** – The GHG emissions from the diesel oil consumption sold in the Slovak Republicn important ports Bratislava and Komarno was balanced in the period 1990-2005. Two variant were take into consideration:

Variant 1 on Table 3. 11 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).

**Table 3. 11: Emission balance of GHGs from diesel oil sold for shipping companies in the SR between 1990-2005 based on historical EFs in that time**

Year	Sold	Sold	Emissions [ t ]		
	Diesel oil [t]	Diesel oil [TJ]	CO <sub>2</sub>	N <sub>2</sub> O	CH <sub>4</sub>
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

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

Varian B on Table 3. 12 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 1990-2005 (not applied).

**Table 3. 12: Emission balance of GHGs from diesel oil sold for shipping companies in the SR between 1990-2005 based on recent EFs**

Year	Sold Diesel oil [t]	Sold Diesel oil [TJ]	Emissions [ t ]		
			CO <sub>2</sub>	N <sub>2</sub> O	CH <sub>4</sub>
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

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

**Civil Aviation** – 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 (Table 3. 13) 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).

**Table 3. 13: 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

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. 14).

**Table 3. 14: 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 <sub>2</sub>	3150	3150
N <sub>2</sub> O	0.104	0.35
CH <sub>4</sub>	0.05	0.25
GHGs	Aviation Gasoline	
CO <sub>2</sub>	3150	
N <sub>2</sub> O	0.1	
CH <sub>4</sub>	1.9	

It is generally know, that in the period 1990-2005 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 2005 was 34 529 cycles. The total consumption of jet kerosene was 31 775.33 t (40 737 597 l) and the consumption of aviation gasoline was 185.42 t (250 562 l).

#### Recalculation and Time Series

**Railways** - the inter-annual decreasing of the diesel oil consumption in motor traction of railways in 2004/2005 is 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 (2006). The results are summarized in Table 3. 15 and Table 3. 16. All emissions were considered to be international bunkers according to the character of shipping activity on Danube River in the SR.

**Table 3. 15: The recalculation changes in the navigation transport in Gg**

Year of sub.	Category	1A3d			Year of sub.	Category	1C		
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O			CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> 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. 16: New estimated emissions in the 1990-2005 from international navigation transport in Gg**

Emissions 1A3d			
Year	International bunkers		
	CO <sub>2</sub>	N <sub>2</sub> O	CH <sub>4</sub>
1990	65 354.00	2.05	5.13
1991	57 384.00	1.80	4.50
1992	54 196.00	1.70	4.25
1993	44 632.00	1.40	3.50
1994	42 677.76	18.34	2.68
1995	57 594.41	24.75	3.61
1996	49 063.32	21.08	3.08
1997	29 224.40	12.56	1.83
1998	40 847.84	17.55	2.56
1999	8 610.79	3.70	0.54
2000	0.00	0.00	0.00
2001	26 670.81	11.46	1.67
2002	28 778.71	12.37	1.72
2003	21 793.17	9.37	1.30
2004	8 483.17	3.65	0.51
2005	682.23	0.29	0.04

**Civil Aviation** - Total reduction of CO<sub>2</sub> emissions from aviation transport in 1990 was 84.76 % in comparison to the previous submission (2006). Total reduction of N<sub>2</sub>O emissions from aviation transport in 1990 was 98.83 % in comparison to the previous submission (2006). Total increasing in methane emissions (100 %) was caused by estimation CH<sub>4</sub> 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. 18 below.

Table 3. 17: Table of recalculation changes in the domestic and international aviation transport in Gg

Year of sub.	Category	1A3a			Year of sub.	Category	1C		
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O			CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> 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. 18: Table of new estimated emissions in the 1990-2005 from domestic and international transport

Year	Emissions of GHG in 1.A.3a in tons					
	National airlines			International airlines		
	CO <sub>2</sub>	N <sub>2</sub> O	CH <sub>4</sub>	CO <sub>2</sub>	N <sub>2</sub> O	CH <sub>4</sub>
1990	7 736.72	0.80	1.00	63 103,64	2,08	1,05
1991	7 192.87	0.75	0.93	58 675,21	1,94	0,98
1992	6 649.02	0,69	0,86	54 246,78	1,79	0,90
1993	6 649.02	0,69	0,86	54 246,78	1,79	0,90
1994	5 495.56	0,57	0,71	44 775,50	1,48	0,75
1995	5 484.66	0,57	0,69	45 043,00	1,49	0,75
1996	6 427.86	0,67	0,79	53 157,46	1,75	0,88
1997	5 694.56	0,60	0,70	47 080,99	1,55	0,78
1998	5 233.49	0,55	0,63	43 410,98	1,43	0,72
1999	5 305.71	0,55	0,65	43 804,71	1,45	0,72
2000	5 498.52	0,57	0,73	44 510,88	1,47	0,74
2001	5 228.76	0,53	0,72	41 864,09	1,38	0,70
2002	5 453.22	0,56	0,76	43 463,91	1,43	0,73
2003	6 987.57	0,73	0,87	57 455,90	1,90	0,95
2004	9 069.50	0,97	0,95	77 681,35	2,56	1,26
2005	10 534.88	1,13	1,11	90 141,45	2,98	1,47

Against the previous year 2004 was in the emissions from civil aviation strong increasing development observed - about 14 % in the actual year 2005. 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.

### 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 2005 are mined 2 511.2 kt of coal from domestic production, of it 357 kt of assorted coal for the habitants. The coal market is fully liberalized, the domestic production not covers all demand, because of 663 kt of brown coal were imported (mostly from Czech Republic). A total methane emission from underground coal mining in 2005 was estimated to be 16.17 Gg (14.66 Gg of CH<sub>4</sub> from underground coal mining and 1.51 Gg of CH<sub>4</sub> from post-mining activity) (Figure 3. 6). 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 2005 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. 19 provides the values of coal production from 1993.

**Table 3. 19: The total brown coal production in the SR during 1993-2005**

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
	Brown coal (kt)												
<b>Mining</b>	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

**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;<sup>5</sup>
- 3. EF(CH<sub>4</sub>) specified of mines operator - HBP, a.s.

<sup>5</sup> <http://spider.iea.org/ciab/>



Table 3. 20: The  $EF_{CH_4}$  for coal mining a handling assigned to single mines in SR

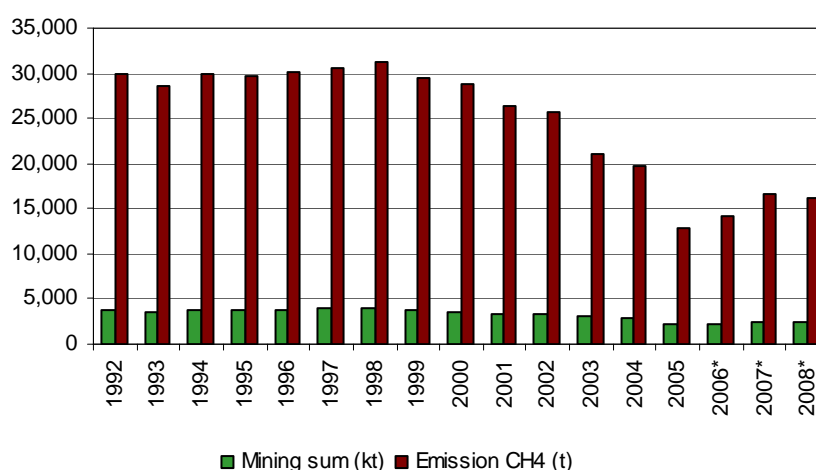
Mine	Mine Nováky	Mine Nováky 6.ŤÚ	Mine Cígeľ	Mine Cígeľ 7.ŤÚ	Mine Handlová	Mine Handlová vŠ	Mine Dolina	Mine Záhorie
Depth of mine [m]	200	200	500	500	500-1500	500-1500	600	400
	EF <sub>CH4</sub> [m³/t]							
1. IPCC Guidance for National Greenhouse Gas Inventories								
IPCC mining tier1	10	10	10	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 <sub>CH4</sub> 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

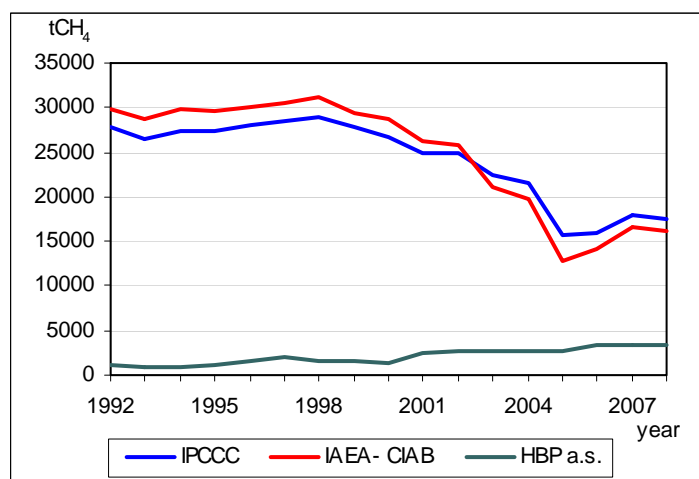
Emission factors according to IPCC Guidance - for all mines have been used the identical values 10 m<sup>3</sup> CH<sub>4</sub>/t for coal mining and 0.9 m<sup>3</sup> CH<sub>4</sub>/t for post-mining. Both values are on the lower level of the suggested scale. Emission factors according to IEA – CIAB – the published values for mining were assigned according to the depth of the mines within 6 a 13 m<sup>3</sup> CH<sub>4</sub>/t and 0.9 m<sup>3</sup> CH<sub>4</sub>/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.  $EF(CH_4)$  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.  $EF(CH_4)$  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. 6).

Figure 3. 6: Trends in coal mining productivity and methane emissions from mining and post-mining activity in 1990-2008\* (\*with predictions)



The Figure 3. 7 below shows comparison of trends emissions CH<sub>4</sub> in SR in years 1992 - 2008, calculated according to emission factors of IPCC, IEA-CIAB methodology and EF (CH<sub>4</sub>) HBP a.s. In the case of emissions calculation with using of IPCC emission factors, the trend of fugitive emissions CH<sub>4</sub> is declining in accordance to reduction of coal mining in SR. Application EF (CH<sub>4</sub>) specified of mines operator (HBP, a.s.) - trend of fugitive emissions CH<sub>4</sub> 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. 20 point 2) as a best appropriated. Table 3. 21 presents recalculated fugitive emissions from coal mining and handling and the post-mining activities during 1990-2005.

**Figure 3. 7: Comparison of trends emissions CH<sub>4</sub> in SR in years 1992 – 2008\* (\*with predictions)**



**Table 3. 21: The total CH<sub>4</sub> fugitive emissions from mining and post-mining activities in the SR in 1990-2005**

Year	1990	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
<b>Fugitive emissions of CH<sub>4</sub> (Gg)</b>															
<b>Mining</b>	25.11	27.64	26.43	27.65	27.44	27.76	28.25	28.79	27.20	26.62	24.27	23.64	19.26	17.99	14.66
<b>Post-mining</b>	2.084	2.294	2.179	2.258	2.267	2.316	2.360	2.382	2.295	2.201	2.065	2.051	1.854	1.780	1.514
<b>Total</b>	27.20	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

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 CH<sub>4</sub> 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. 22 presents the emission factors for the Slovak mines.

Table 3. 22: The post-mining EFs in the mines in the SR

Mines	Post-mining EF CH <sub>4</sub>	
	m <sup>3</sup> CH <sub>4</sub> /t brown coal	kgCH <sub>4</sub> /t brown coal
Mine Nováky	0.39	0.261
Mine Cígel'	0.00	Non-gaseous
Mine Cígel' 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 last submission 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 CH<sub>4</sub> emissions from the ventilated air are made with the  $\pm 20$  % accuracy with the dependence of the measurement's installation. The repeatability of the measurements increases accuracy up to  $\pm 5$  %. For the continual measurement is the uncertainty in the range of  $\pm 10$ -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 CO<sub>2</sub> emissions in 2005 were 0.17 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 CH<sub>4</sub> 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 – Slovak Gas Industry, Ltd., Ministry of Economy of SR and Statistic Office of the SR (Table 3. 23).

**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 2 105 501 m<sup>3</sup> (15°C; 101.325 kPa) (1 396 t of CH<sub>4</sub>) according to preliminary balances of gas fuels in year 2005 (Statistical office of SR). This value represented approximately 0.03 % of total NG consumption in SR.

**Table 3. 23: The data in year 2005 - production, export and import NG in SR**

SR	Natural gas [m <sup>3</sup> ]	Natural gas [PJ]
Indigenous production	147 000 000	5.289
Associated gas	14 000 000	0.504
Nonassociated gas	133 000 000	4.785
Stock changes	50 000 000	-1.799
Gas vented	0	0
Gas flared	1 000 000	0.360
Export	369 000 000	13.276
Import	7 399 000 000	266.204
Inland consumption	7 227 000 000	260.016

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 Rožnava, HPS Velky Krtis, ZLC Nitra) in the Slovak Republic. The estimation of the leakages from these facilities is 7 678 t of CH<sub>4</sub> (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 CH<sub>4</sub>] = 257 000 [m<sup>3</sup> ZP] \* 0.975 \* (273.15/(273.15+15)) \* 0.7176 = 171 t of CH<sub>4</sub>.

Fugitive emission CH<sub>4</sub> from transit and distribution of NG = 7 678 + 171 = 7 849 t of CH<sub>4</sub>.

An additional emissions are fugitive emissions from NG and oil production in SR = 1 153 – 3 008 t of CH<sub>4</sub> (calculated according to IPCC methodology – table 6). That is mean, that the total fugitive emissions of CH<sub>4</sub> from transit and distribution of NG + from NG and oil production in SR 9 002 - 10 857 of CH<sub>4</sub> according to the national methodology. This approach seems to be less quality, that the estimation with the applications new refined EF (CH<sub>4</sub>) (high) for tier 1, based on North America data (IPCC). The national data from 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 (CH<sub>4</sub>) for tier 1, based on North America data - IPCC Good Practice Guidelines, table 2-16 (max. level of emissions – 31 957 t CH<sub>4</sub>). In the Table 3. 24 are presented of fugitive methane emissions for activities related to NG and Oil operations, calculated with applications new refined EF (CH<sub>4</sub>) (high) for tier 1, based on North America data.

Table 3. 24: New refined EF (CH<sub>4</sub>) for tier 1, based on the balance in North America

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

The results of the calculated fugitive methane emissions (Table 3. 25) 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 (CH<sub>4</sub>) (high) for tier 1, based on North America data are the most real values. The trend of fugitive emissions CH<sub>4</sub> 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. 25: Fugitive methane emissions calculated with applications new refined EF (CH<sub>4</sub>)

Category	Quantity	Unit	EF(low)	EF(high)	CH <sub>4</sub> (low)	CH <sub>4</sub> (high)
			GgCH <sub>4</sub> /mil.m <sup>3</sup> NG GgCH <sub>4</sub> /km	GgCH <sub>4</sub> /mil.m <sup>3</sup> NG GgCH <sub>4</sub> /km	t CH <sub>4</sub>	t CH <sub>4</sub>
NG* production fugitive	147 000 000	m <sup>3</sup> ZP	2.60E-03	2.90E-03	426.30	<b>426.30</b>
NG* production flaring	147 000 000	m <sup>3</sup> ZP	1.10E-05	1.10E-05	1.62	<b>1.62</b>
NG processing fugitive	147 000 000	m <sup>3</sup> ZP	6.90E-04	1.07E-03	101.43	<b>157.29</b>
NG processing flaring	147 000 000	m <sup>3</sup> ZP	1.30E-05	1.30E-05	1.91	<b>1.91</b>
NG storage fugitive	32 542 000	m <sup>3</sup> ZP	4.30E-04	4.20E-03	21.50	<b>210.00</b>
NG transport fugitive	2 270	km	2.10E-03	2.90E-03	4 767.00	<b>6 583.00</b>
NG transport venting	2 270	km	8.00E-04	1.20E-03	1 816.00	<b>2 724.00</b>
NG distribution fugitive	30 566	km	5.20E-04	7.10E-04	15 894.32	<b>21 701.86</b>
Oil production fugitive	31 000	t	1.40E-03	1.50E-03	43.40	<b>46.50</b>
Oil production venting	31 000	t	6.20E-05	2.70E-04	1.92	<b>8.37</b>
Oil production flaring	31 000	t	5.00E-06	2.70E-04	0.16	<b>8.37</b>
Oil transport fugitive	10 662 338	t	5.40E-06	5.40E-06	57.58	<b>57.58</b>
<b>Total</b>					<b>24 200.13</b>	<b>31 956.72</b>

Note: NG\* production – the values of fugitive and flaring methane emissions were calculated on base reported data of vented NG – 2.2 mil.m<sup>3</sup> and flared NG - 1 mil.m<sup>3</sup> (Statistic Office of the SR - 2005).

Table 3. 26 presents recalculated fugitive emissions of methane from transport and distribution of natural gas activities during 1990-2005 according the IPCC Good Practice Guidelines, Table 2-16 methodology using the EF (high) (IPCC, 1996).

**Table 3. 26: The total CH<sub>4</sub> fugitive emissions from transport and distribution of NG in the SR in 1990-2005**

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
	Fugitive emissions of CH <sub>4</sub> (Gg)															
NG	24.46	24.31	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

### Trends

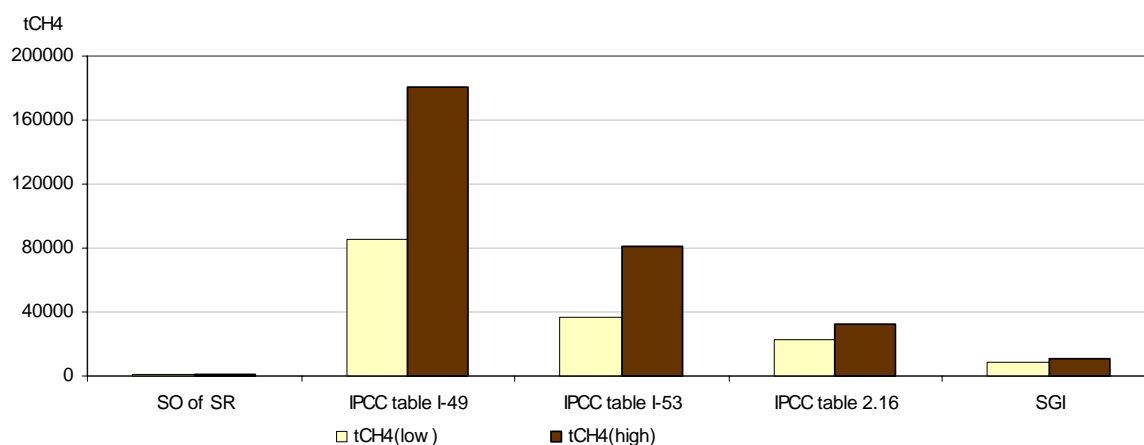
The trend of fugitive emissions of CH<sub>4</sub> from transport and distribution of natural gas in SR is increasing. It is due to the expansion of the distributed system and growth of NG consumption in SR.

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. 8.

The application EFCH<sub>4</sub> - IPCC default EF CH<sub>4</sub> from oil and NG for regions of former USSR and Eastern Europe (IPCC Guidelines, Reference Manual Table I-49) gives too high results (85 376-180 463 t CH<sub>4</sub>) and are approximately 3.7 - 5.7 times higher as the above-mentioned values. The estimate of Statistical office for distributed losses (1 396 t CH<sub>4</sub>) 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 CH<sub>4</sub> for tier 1, based on North America data - IPCC Good Practice Guidelines, Table 2-16 (max. level - 31 957 tCH<sub>4</sub>)

**Figure 3. 8: Comparison of the fugitive methane emissions calculated from IPCC factors and Slovak Gas Industry, Ltd. methodology**



### Recalculation and Time Series

#### Fugitive CO<sub>2</sub> emissions from 1.B.2 category – natural gas

Slovak Republic made decision to re-evaluated CO<sub>2</sub> 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 CO<sub>2</sub> fugitive emissions was estimated from the specific analytical measurements of natural gas composition shown in the following Table 3. 27. The measurements are provided by accredited laboratories of Slovak Gas Industry Company, Ltd.

**Table 3. 27: The results from the analytical measurements due in accredited laboratories of Slovak Gas Industry company in the period 2000-2005**

Year	Composition of Natural Gas [%]									
	CH <sub>4</sub>	C <sub>2</sub> H <sub>6</sub>	C <sub>3</sub> H <sub>8</sub>	i-C <sub>4</sub> H <sub>10</sub>	n-C <sub>4</sub> H <sub>10</sub>	i-C <sub>5</sub> H <sub>12</sub>	n-C <sub>5</sub> H <sub>12</sub>	C <sub>6</sub> H <sub>14</sub>	CO <sub>2</sub>	N <sub>2</sub>
2000	97,14	1,13	0,37	0,05	0,07	0,01	0,01	0,02	<b>0,27</b>	0,93
2001	97,37	1,03	0,32	0,04	0,06	0,01	0,01	0,01	<b>0,23</b>	0,92
2002	97,42	1,03	0,32	0,04	0,06	0,01	0,01	0,01	<b>0,21</b>	0,89
2003	97,57	0,96	0,31	0,05	0,06	0,01	0,01	0,01	<b>0,15</b>	0,87
2004	97,69	0,95	0,29	0,05	0,05	0,01	0,01	0,01	<b>0,12</b>	0,82
2005	97,50	1,04	0,34	0,05	0,06	0,01	0,01	0,01	<b>0,14</b>	0,84

According the activity and input data provided in the Table 3. 27, the calculation of so-called recalculation factor for estimation CO<sub>2</sub> emissions from natural gas treatment was evaluated to be 5,31116367 CO<sub>2</sub> in g per Gg of CH<sub>4</sub> .

The N<sub>2</sub>O emissions are not estimated (negligible) in the total content of natural gas and oil composition by flaring (measurements in the accredited laboratories).

Total increasing of CO<sub>2</sub> emissions from category 1.B.2.b-d fugitive emissions from natural gas treatment in 1990 was 100 % in comparison to the previous submission (2006). The results are summarized in Table 3. 28 and Table 3. 29.

**Table 3. 28: The recalculation changes in the fugitive emissions of natural gas in category 1B2 in Gg of CO<sub>2</sub>**

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

**Table 3. 29: The new estimated CO<sub>2</sub> emissions in the 1990-2005 from fugitive emissions**

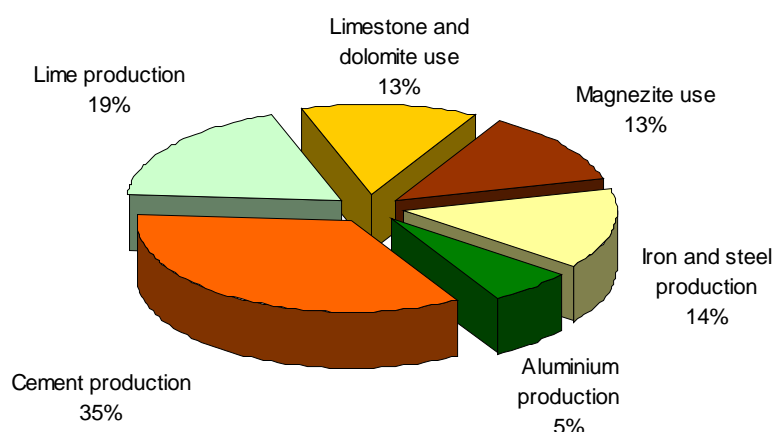
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO <sub>2</sub> (t)	145,68	132,60	128,76	133,24	141,19	154,70	157,88	159,22	170,03	169,90	180,91
Year	2001	2002	2003	2004	2005						
CO <sub>2</sub> (t)	185,24	179,32	190,92	182,38	169,70						

## 4 INDUSTRIAL PROCESSES

The Industrial Processes sector in the Slovak Republic is a source of CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, NO<sub>x</sub>, CO, NM VOC, SO<sub>2</sub>, CF<sub>4</sub>, C<sub>2</sub>F<sub>6</sub>, and SF<sub>6</sub> pollution. Even though the emissions of CO<sub>2</sub> and N<sub>2</sub>O 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 CO<sub>2</sub> 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 N<sub>2</sub>O emissions comes from the nitric acid production only (4.05 Gg of N<sub>2</sub>O) (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 CO<sub>2</sub> emissions. Total anthropogenic emissions of CO<sub>2</sub> from this sector are 3 594.50 Gg and the major share comes from mineral production (2 857.81 Gg) (Figure 4. 1).

**Figure 4. 1: The share of individual technologies in the industrial processes sector in 2005**



### 4.2 Cement Production

#### Methodology and Activity Data

According to the IPCC Guidelines, it is a good practice that the amount of CO<sub>2</sub> 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 CO<sub>2</sub> has to be recalculated to the mass of produced cement. For this reason two values of emission factor of CO<sub>2</sub> 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 CO<sub>2</sub> 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 CO<sub>2</sub> at the cement production because the chemical reactions are rather simple. Content of cement clink in cement varies in the range 68.8 % - 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 % to 69 %. The value of the weighted average is calculated annually. It follows with the estimation of the emission factor of CO<sub>2</sub> related to the cement clink.

Cement is produced by a high temperature reaction of calcium oxide (CaO) with silica (SiO<sub>2</sub>) and with alumina (Al<sub>2</sub>O<sub>3</sub>). A source of calcium oxide is limestone (CaCO<sub>3</sub>). 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 (SO<sub>2</sub>).

The weighted average value of the clink content in the cement is 75.2 % in 2005. This value is known for every cement plant. According to the IPCC Methodology (IPCC, 1996) it is good practice, that amount of CO<sub>2</sub> emission is calculated from the mass of produced cement clink. However, in the Statistical yearbook (SY, 2004) there is only mass of produced cement available. Therefore, emission of CO<sub>2</sub> is calculated from the mass of produced cement. The content of CaO in the cement clink varies from 65 % to 69 %. The value of the weighted average is 66.8 % in 2005.

Slovak Republic is using Tier 1 methodology for CO<sub>2</sub> 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 CO<sub>2</sub> related to the cement clink is 524.30 kg CO<sub>2</sub> / 1 t of cement clink in 2005. The emission factor of CO<sub>2</sub> recalculated to the production of cement is 375.02 kg CO<sub>2</sub> / 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 3 289 203 t and total sum of cement clink production was 2 352 678 tons. The emission factor of CO<sub>2</sub> was 524.3 kg CO<sub>2</sub>/1 t of cement clink based on the total cement clink production (Table 4. 1).

**Table 4. 1: The comparison of EFs and emissions of CO<sub>2</sub> in 2001-2005**

	2001	2002	2003	2004	2005
<b>Emission Factor of CO<sub>2</sub> [t/t of cement clink]</b>	0.5016	0.5063	0.5157	0.5261	0.5243
<b>Emission Factor of CO<sub>2</sub> [t/t of cement]</b>	0.3800	0.3643	0.3862	0.3862	0.3750
<b>Emission of CO<sub>2</sub> [Gg]</b>	1 187.430	1 144.187	904.995	1 194.840	1 233.509

#### 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 2.1 % and uncertainty of CO<sub>2</sub> emissions is 3.5 %.

### 4.3 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 96.6 % with uncertainty 3.0 %.

#### Emission Factors and Emissions

The emission factor of CO<sub>2</sub> using the new data on purity of lime is 758.02 kg CO<sub>2</sub> 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 CO<sub>2</sub> emissions from lime production in the SR in 2000-2005**

Year	2000	2001	2002	2003	2004	2005
	(Gg)					
<b>Lime Production</b>	754	816	919	847	961	946
<b>Emissions CO<sub>2</sub></b>	540	584	658	606	688	677

#### 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 CO<sub>2</sub> emissions from lime production is 1.4 %.

### 4.4 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 CO<sub>2</sub> is 440 kg CO<sub>2</sub>/1 t of consumed limestone, which is the recommended value according to the IPCC. However, the average content of CaCO<sub>3</sub> in raw material in the Slovak Republic is 97 %, therefore the emission factor CO<sub>2</sub> 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 CO<sub>2</sub> are summarized in Table 4. 3. 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 CO<sub>2</sub> 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 CO<sub>2</sub> 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 CO<sub>2</sub> at limestone utilization in the period 2000 – 2005**

Year	2000	2001	2002	2003	2004	2005
	(Gg)					
<b>Limestone Use</b>	404	387	362	375	616	471

It should be mentioned that consumption of iron ore decreased in the comparison with 2004. It follows that consumption of limestone decreased from this source as well (Table 4. 4).

**Table 4. 4: Total emission of CO<sub>2</sub> and the emission factors of CO<sub>2</sub> at limestone utilization in 2005**

Year	Consumption of limestone at				CO <sub>2</sub> Emission [t]	EF (CO <sub>2</sub> ) [kg / t of limestone]
	Iron and Steel Production [t]	Calcium Carbide Production [t]	Glass Production [t]	Total [t]		
2005	876 851	151 501	75 129	1 103 481	471 187	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 CO<sub>2</sub> emission is 4.1 %.

**4.5 Magnesite Use****Methodology and Activity Data, Emission Factors and Emissions**

At thermal decomposition of magnesite carbon dioxide is produced. Maximum emission factor of CO<sub>2</sub> is 522 kg CO<sub>2</sub>/1 t of magnesite or after recalculating 1 092 kg CO<sub>2</sub>/1 t of magnesite clink. Purity of magnesite in the SR varies mainly from 84 % to 94 %. The weighted average is 90.46 % and the emission factor of CO<sub>2</sub> is 978.8 kg CO<sub>2</sub> / 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 CO<sub>2</sub> are summarized.

**Table 4. 5: Total emission of CO<sub>2</sub> at magnesite clink production in the period 2000 – 2005**

Year	2000	2001	2002	2003	2004	2005
	(Gg)					
Magnesite Clink	436	460	467	479	514	482
Emissions CO <sub>2</sub>	410	432	439	450	483	476

**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 2.1 % and uncertainty of CO<sub>2</sub> emissions from production of magnesite clinker is 2.5 %.

**4.6 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 CO<sub>2</sub> and CH<sub>4</sub> 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 2000-2005 and the theoretical emissions, which are included in the energy sector.

Table 4. 6: Total production of ammonia in the SR in 2000-2005

Year	2000	2001	2002	2003	2004	2005
	(Gg)					
NG Consumption	284	290	282	249	287	300
Ammonia Produced	403	412	400	354	408	426
Emissions CO <sub>2</sub>	605	618	600	531	612	640

## 4.7 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 N<sub>2</sub>O emissions from industrial processes and key source category in level and trend assessment.

### Emission Factors and Emissions

The emission factors of N<sub>2</sub>O was presented as 5.43 kg N<sub>2</sub>O / 1 t HNO<sub>3</sub> and 5.58 kg N<sub>2</sub>O / 1 t HNO<sub>3</sub> until now. Direct measurements of N<sub>2</sub>O 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 N<sub>2</sub>O/1 t HNO<sub>3</sub> for atmospheric plant, 7 kg N<sub>2</sub>O / 1 t HNO<sub>3</sub> for medium pressure and 9 kg N<sub>2</sub>O / 1 t HNO<sub>3</sub> 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 N<sub>2</sub>O/1 t HNO<sub>3</sub>). KD2 in Duslo was improved in 80-ties. It is very realistic, that now is EF higher than 7 kg N<sub>2</sub>O/1 t HNO<sub>3</sub>, but not enough evidences are available. According the measurements from 2005, real EF should be about 7.3 kg N<sub>2</sub>O/1 t HNO<sub>3</sub>.

The technology used in Chemko, a.s. is the same as in Duslo, a.s. (medium pressure plant). The production technology 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 N<sub>2</sub>O was necessary on the basis of Norsk Hydro data since 1990. The following emission factor was used in 1990 based on weighted average: 9.4 kg N<sub>2</sub>O/1 t HNO<sub>3</sub> for total amount of produced nitric acid. New, corrected data are presented in Table 4. 7. Emission of N<sub>2</sub>O at nitric acid production in 2005 was 4.0462 tons.

Table 4. 7: Table of new estimated N<sub>2</sub>O emissions and weighted EFs in the 1990-2005 from nitric acid production

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
N <sub>2</sub> O (Gg)	3.77	2.63	2.38	1.84	3.23	3.63	4.24	4.01	3.41	2.56	3.33	3.77	3.37	3.73	4.26	4.05
EF kg/t	9.40	8.73	8.54	7.89	8.94	9.10	9.49	9.52	9.04	8.36	8.18	8.11	8.34	8.20	8.12	8.13

### 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 N<sub>2</sub>O emissions is 6.7 %.

### Recalculation and Time Series

Total increasing of N<sub>2</sub>O 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 N<sub>2</sub>O**

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

## 4.8 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 CO<sub>2</sub>. Emission factors for CO<sub>2</sub> (0.76 t CO<sub>2</sub>/t of CaC<sub>2</sub> at decomposition of limestone; 1.09 t CO<sub>2</sub>/t of carbide at the reduction and 1.1 t CO<sub>2</sub>/t of carbide at using of the product) were taken from the IPCC recommendation. Emissions of CO<sub>2</sub> emitted at decomposition of limestone are included in limestone and dolomite use in this inventory and emissions of CO<sub>2</sub> at the reduction are included in energy sector - consumption of coke (1.A.2b) and category limestone and dolomite use (2(l)A.3).

97 029 tons of CaC<sub>2</sub> (calcium carbide) was produced in the Slovak Republic in 2005. According to data supplied by NCHZ, a.s. Nováky, 65 710 tons of produced calcium carbide was exported from the SR. The rest was used for acetylene production. At this production no emission of CO<sub>2</sub> is released. The emissions of CO<sub>2</sub> at the reduction step are 105 762 tons.

## 4.9 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 CO<sub>2</sub>. 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 CO<sub>2</sub>. Iron ore was processed to pig iron. The emissions of CO<sub>2</sub> 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 4 238 124 tons of steel was produced, the emission factor for CO<sub>2</sub> being 119.4 kg CO<sub>2</sub>/t of steel. This emission factor results from decreasing of carbon from pig iron (40 kg/t) to steel (2.5 kg/t). 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 CO<sub>2</sub> from coke production were included in iron and steel production as well. In 2001, the method used for calculation of emission was changed. It was based on the mass of the used coke and the amount of used iron ore (Tier 2 in IPCC Guidelines – recommended method).

In order to summarize the data based on this new approach the emissions of CO<sub>2</sub> from steel production, which are not included in energy sector are presented in Table 4. 9 for the period 2000 – 2005.

**Table 4. 9: Emissions of CO<sub>2</sub> from steel production for the period 2000 – 2005**

Year	2000	2001	2002	2003	2004	2005
	Emissions of CO <sub>2</sub> (Gg)					
<b>Steel production</b>	415	443	484	535	540	506

#### **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 CO<sub>2</sub> 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 2005, the production of ferroalloys in the Slovak Republic was as follows: 89,467 tons of ferroalloys based on Mn, 826 tons based on Cr and 14,409 tons based on Si.

#### **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 ( $\text{Na}_3\text{AlF}_6$ ) are aluminium fluoride ( $\text{AlF}_3$ ) and  $\text{CaF}_2$ . From the point of emissions view, the content of  $\text{AlF}_3$  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  $\text{CF}_4$  and  $\text{C}_2\text{F}_6$  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<sub>2</sub> was taken from the IPCC recommendation (1.5 t CO<sub>2</sub>/t of aluminium). The emission factors of PFC ( $\text{CF}_4$ ,  $\text{C}_2\text{F}_6$ ) were calculated according to the Tabereaux's equation. According to the data from plants average current efficiency was 93.12 % in 2005, the number of the anode effects per pot day equals to 0.047 and their average duration was 2.47 min. It follows that the

emission factors were 0.0169 kg CF<sub>4</sub>/1 t of aluminium and 0.00169 kg C<sub>2</sub>F<sub>6</sub>/1 t of aluminium, respectively. In 2005, minor change in composition of the electrolyte was made. The solubility of alumina decreased and the number of anode effects increased. In 2005, the Slovak aluminium company produced 159 203 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 2005**

	CO <sub>2</sub>	CF <sub>4</sub>	C <sub>2</sub> F <sub>6</sub>
<b>Emission [t]</b>	230 646	2.696	0.2696
<b>Emission factor [kg/t]</b>	1 448.754	0.016935	0.0016935

### 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<sub>6</sub> at the casting house

In 2005, SF<sub>6</sub> was not used in the Slovak Republic at casting. Thus, the consumption of SF<sub>6</sub> in 2005 was 0 kg.

## 4.10 Consumption of HFCs, PFCs and SF<sub>6</sub>

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);
- SF<sub>6</sub> – sulphur hexafluoride;
- PFCs – perfluorocarbons (CF<sub>4</sub>, C<sub>2</sub>F<sub>6</sub>, C<sub>3</sub>F<sub>8</sub>, C<sub>4</sub>F<sub>10</sub>, C<sub>4</sub>F<sub>8</sub>, C<sub>5</sub>F<sub>12</sub>, C<sub>6</sub>F<sub>14</sub>, CF<sub>3</sub>Br).

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 1990-2004 based on acquired data from importers and users in 2005;
- 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:

- SF<sub>6</sub> emissions from electrical equipment and other sources;<sup>6</sup>
- Fluorinated carbon emissions<sup>7</sup> from semiconductor manufacturing;

<sup>6</sup> SF<sub>6</sub> 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.

<sup>7</sup> Including CF<sub>4</sub>, C<sub>2</sub>F<sub>6</sub>, C<sub>3</sub>F<sub>8</sub>, C<sub>4</sub>F<sub>8</sub>, CHF<sub>3</sub>, NF<sub>3</sub>, SF<sub>6</sub>.

- 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).<sup>8</sup>

### **Actual emission**

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

### **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 1990-2004 are used also in 2005 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.

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<sup>8</sup> 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.



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 SF<sub>6</sub> is up to 3 200 years, GWP is up to 23 900 kg CO<sub>2</sub>/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 SF<sub>6</sub> 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 SF<sub>6</sub> is used for anti noise and thermal isolation into windows. It is filled in close cycles practically without releases.

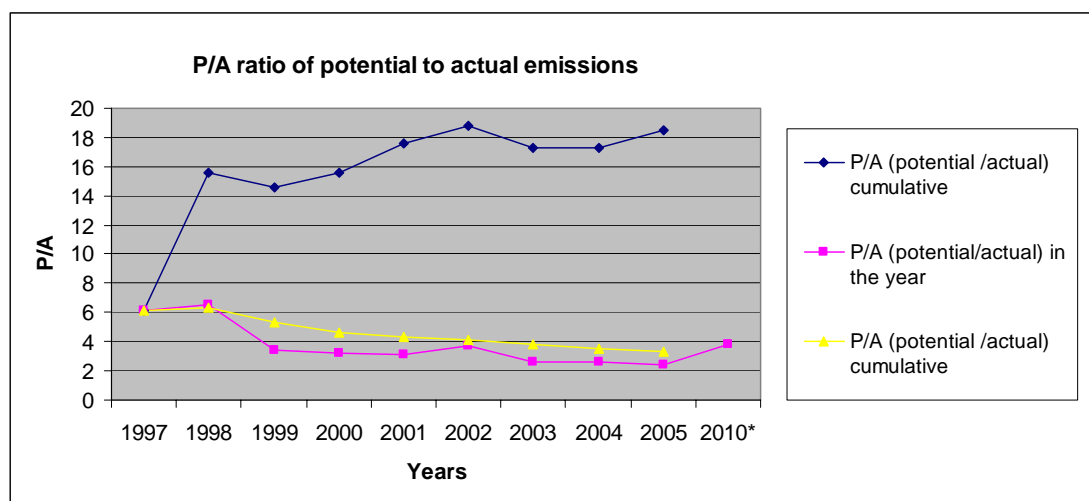
The perfluorocarbons are produced already 30 years. They are used in special heating and cooling. In electronics, they are used in gaseous state as a protection against explosion, isolation and detection gases. Further, they are used for cleansing, dissolving, fluorine etching of glass and as extinguishing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

Because of expected prohibition of coolant R12 import, 700 tones of it were 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 70 % Up to 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 R410 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. Coolants R407C and R410A shows the growth tendency since 1999. Coolant R134a showed continuing growth tendency until the year 2001. In the near future, we can 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 (Figure 4. 2).

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



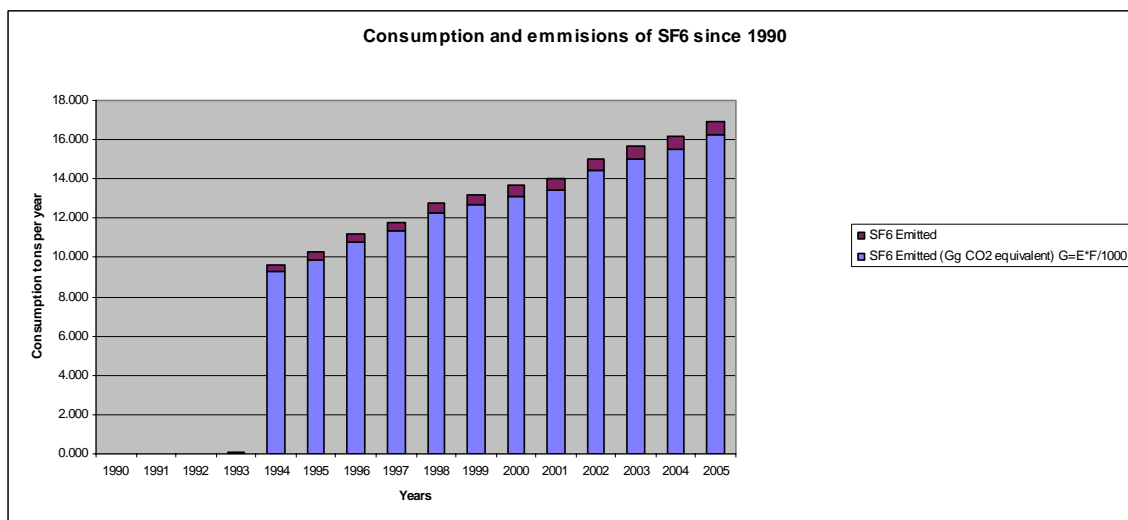
Notices: Potential and actual emissions of PFC 14 and PFC116 - C<sub>2</sub>F<sub>6</sub> Perfluorethane originates as a by-product during the aluminium production in Žiar nad Hronom. Since 2000 PFC 14 and PFC116 originated as a by-product during the aluminium production hasn't been included to the emissions 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).

In relation with the high reliability of the new cooling equipments with the content of HFCs, PFCs and SF<sub>6</sub> and progressive implementation of preventive service, the ratio of cumulative potential and actual emissions was rising and in the years 2003 and 2004 is 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 2005 was reached faster application of HFCs because the HCFCs applications have been completely forbidden in new installations by the Act n. 76/1998 Z.z. in version n. 408/2000 Z.z. in the year 2004.

Decline of extinguishing media consumption is because they are very expensive and the investment to them is planned for a longer time.

Consumption of SF<sub>6</sub> 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<sub>6</sub> 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<sub>6</sub> since 1990**

### Key Source and Uncertainties

Inventory of F-gases is complicated due to high number of substances HFCs, PFCs a SF<sub>6</sub>, 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 than 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, uncertainty comes out from the assessing of emission factor, which is gradually decreasing during the years 1994 - 2005 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 CO<sub>2</sub>, N<sub>2</sub>O and NM VOC (photochemical smog) from solvent and other product use according to the IPCC Guidelines. The emissions of CO<sub>2</sub> from these sources are not included in the Slovak emission inventory until now. The lack of relevant input sources and emission factors for CO<sub>2</sub> has the significant reason for the omission this source from the inventory. In other way, the CO<sub>2</sub> emissions might be ballast with the high uncertainty.

The primary attention in the 2007 submission in the solvent use sector inventory was put in to the N<sub>2</sub>O 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 N<sub>2</sub>O 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 N<sub>2</sub>O 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 N<sub>2</sub>O 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 total numbers of used N<sub>2</sub>O in the sector are showed in the Table 5. 1

**Table 5. 1: The consumption of N<sub>2</sub>O for the period 1998 – 2005**

Year	1998	1999	2000	2001	2002	2003	2004	2005
	tons							
<b>Medicine</b>	17.4600	18.7350	34.1850	80.9880	76.2200	73.3555	65.1325	21.8100
<b>Food</b>	0.0000	0.0000	0.0000	14.2800	107.2900	116.4800	192.6700	212.9000

The input data before year 1998 are not available; there is a big data gap.

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 N<sub>2</sub>O 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 N<sub>2</sub>O in the solvent and other product use sector are 234.71 tons in 2005.

The total emissions of NM VOC from this category were 33.153 Gg per year 2005.

## 6 AGRICULTURE

### 6.2 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 CO<sub>2</sub> are gases of the highest importance sharing greenhouse effect of the atmosphere, N<sub>2</sub>O and CH<sub>4</sub> 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 N<sub>2</sub>O and CH<sub>4</sub> 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 N<sub>2</sub>O, CH<sub>4</sub> and NH<sub>3</sub> 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 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. Šiška 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 1998-2006, Ministry of Agriculture of the SR;
- Statistical Yearbook 1990-2006, Statistic Office of the SR.

### 6.3 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 CH<sub>4</sub> 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

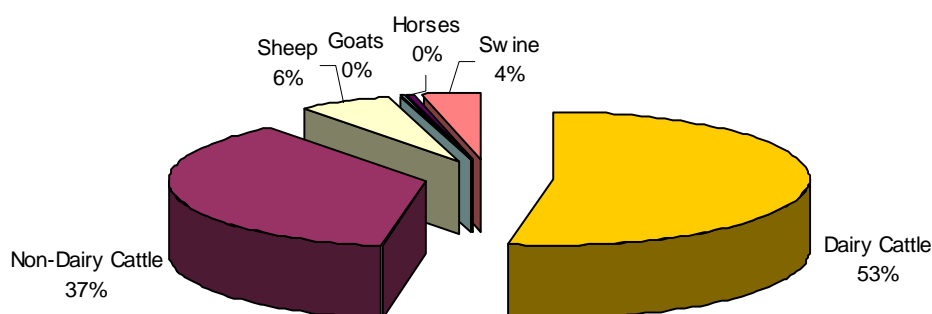
nearly half of emissions in the category. Less than 10 % of emissions produce other categories of domestic livestock. An intensification of animal husbandry increased also methane emissions on level 100 kg CH<sub>4</sub> per head per year. On the other hand, higher efficiency leads to decrease of numbers 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. 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](http://www.land.gov.sk)) and verified by district offices statistical farm information (bottom-up approach).

### Emission Factors and Emissions

Total emissions of methane from enteric fermentation decreased from 94.77 Gg in year 1990 to 44.91 Gg in year 2005, what is decrease by about 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 than one third of emissions of 1990 (Figure 6. 1).

**Figure 6. 1: Methane emissions from enteric fermentation according to livestock categories in 2005**



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 CH<sub>4</sub> per head per year was used and for productivity 4 200 l was used the EF 100 kg CH<sub>4</sub> per head per year (Table 6. 2).

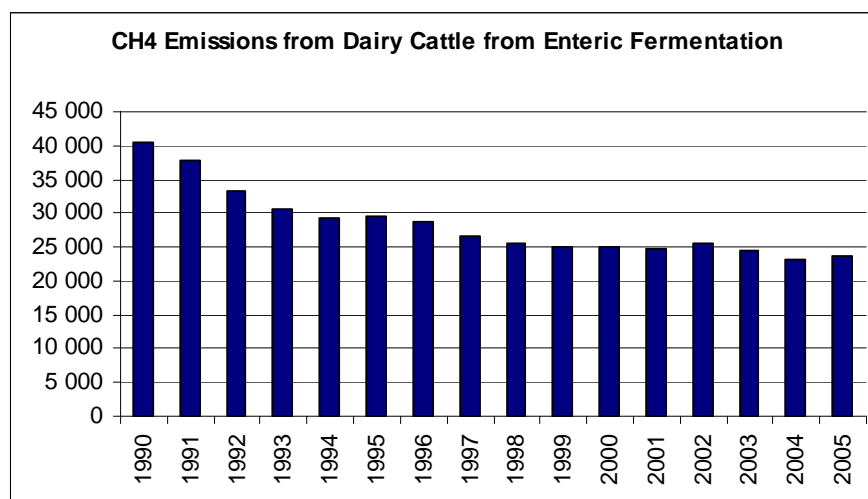
Table 6. 1: The milk production in kg per dairy cow in the SR for the period 1997 – 2005

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005
Milk production in l per cow per year	3592	3 967	4 074	4 278	4 626	4 866	4 959	5 006	5 302

Table 6. 2: The new estimated CH<sub>4</sub> emissions and EFs in the 1990-2005 from enteric fermentation of dairy cattle based on milk production

	Calculated linear regression								
Year	1990	1991	1992	1993	1994	1995	1996		
Milk (kg)	6.34	6.86	7.38	7.91	8.43	8.95	9.48		
EF (kg/head)	73.53	75.51	77.49	79.48	81.46	83.44	85.42		
CH <sub>4</sub> (Gg)	40.37	37.83	33.24	30.68	29.24	29.64	28.65		
	Statistical data Tier 2								
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005
Milk (kg)	9.65	10.65	10.94	11.99	12.43	13.07	13.32	13.45	14.24
EF (kg/head)	86.35	90.26	91.37	92.58	95.98	98.56	99.79	100.12	102.97
CH <sub>4</sub> (Gg)	26.75	25.65	25.04	25.10	24.88	25.61	24.53	23.22	23.64

Total emissions of methane from enteric fermentation for dairy cattle decreased from 40.37 Gg in year 1990 to 23.64 Gg in year 2005, what is decrease by about 41 % (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).

Figure 6. 2: The development of CH<sub>4</sub> emissions in tons according linear function calculation before 1997

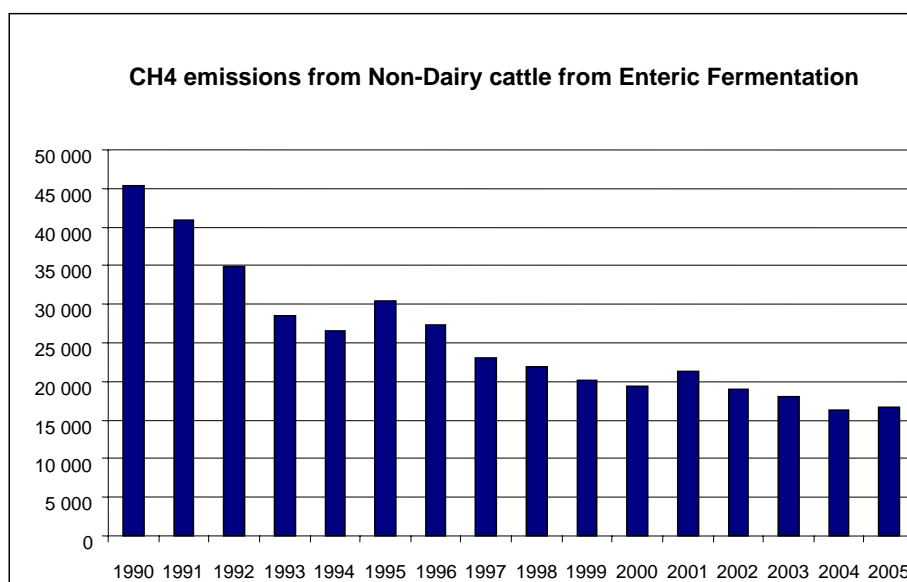
Total emissions of methane from enteric fermentation for non-dairy cattle decreased from 45.44 Gg in year 1990 to 16.69 Gg in year 2005, what is decrease by about 63 % (Table 6.3) (Figure 6. 3).



**Table 6. 3: The new estimated CH<sub>4</sub> emissions and EFs in the 1990-2005 from enteric fermentation of non-dairy cattle based on average gross energy intake in MJ**

	Calculated linear regression								
Year	1990	1991	1992	1993	1994	1995	1996		
AGEI (MJ)	122.0	123.0	124.1	125.1	126.1	127.1	128.1		
EF (kg/head)	44.82	45.55	46.28	47.01	47.75	48.48	49.21		
CH <sub>4</sub> (Gg)	45.44	40.81	34.85	28.54	26.54	30.42	27.39		
	Statistical data Tier 2								
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005
AGEI (MJ)	131.4	130.2	130.2	131.4	133.6	130.9	135.9	134.3	140.8
EF (kg/head)	46.57	51.93	51.79	51.67	58.51	54.50	51.83	53.10	55.95
CH <sub>4</sub> (Gg)	22.99	21.84	20.25	19.38	21.41	18.96	18.01	16.37	16.69

**Figure 6. 3: The development of CH<sub>4</sub> emissions in tons according linear function calculation before 1997**



### Recalculation and time series

Total decreasing of CH<sub>4</sub> 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 CH<sub>4</sub> emissions from enteric fermentation of Cattle in category 1A1**

		4A1 Dairy Cattle	4A1 Non-Dairy Cattle
Year of sub.	Category	CH <sub>4</sub>	
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 7.66 Gg in 2005. Total methane emissions in 2005 from agricultural sector (animal husbandry) were 52.57 Gg. A trend of emissions during evaluated period is depicted on Figure 6.5. Total CH<sub>4</sub> 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 2006 and during period of years 2006 – 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 2005

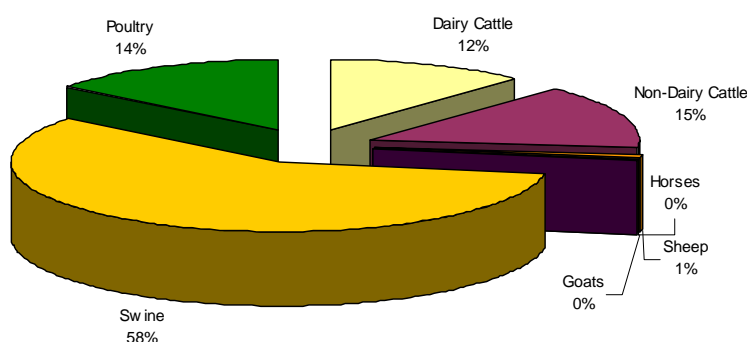
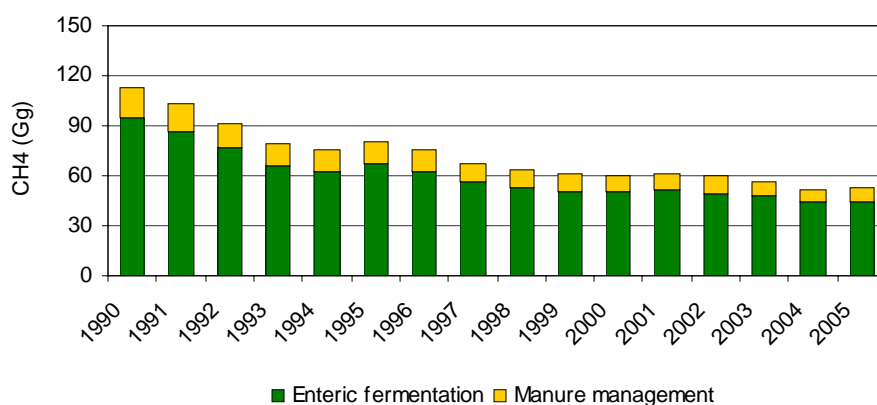


Table 6. 5: The total methane emissions in the SR for the period 1990 – 2005

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
	Emissions of CH <sub>4</sub> (Gg)															
Enteric Fermentation	94.8	86.9	76.4	66.1	62.4	66.9	62.7	56.1	52.9	50.8	49.9	51.4	49.8	47.7	44.2	44.9
Manure Management	17.6	16.3	14.8	13.6	12.9	13.3	12.6	11.6	10.2	9.9	9.5	9.6	9.7	9.3	7.8	7.7
Total	112.3	103.2	91.2	79.7	75.3	80.2	75.3	67.7	63.1	60.6	59.4	61.1	59.5	56.9	52.1	52.6

**Figure 6. 5: The trend of CH<sub>4</sub> emissions in agriculture in 1990-2005**

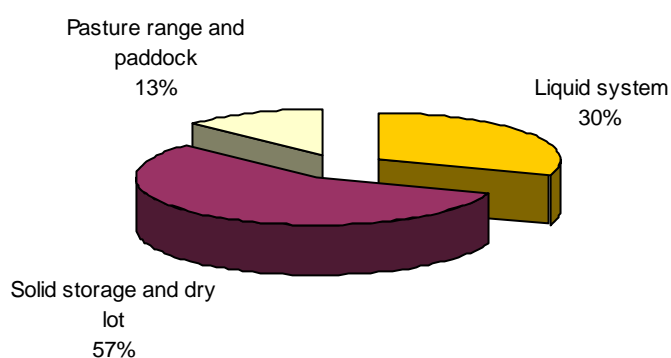
In future higher part of total methane emission will create emissions from animal excreta that are much more easy to manage, e.g. by proper storage, than emission from enteric fermentation.

## 6.4 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 2005 from this source was on level 1.377 Gg (Figure 6. 6).

**Figure 6. 6: The N<sub>2</sub>O emissions from manure management according to AWMS in 2005**

#### 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 per 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 N<sub>2</sub>O emissions. The applied animal fertilizers lost the definite amount of nitrogen by volatilization and N-NO<sub>x</sub> conversion, this amount for animal fertilizers is 20 %, it means that for the conversion of N to N<sub>2</sub>O 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 2005 from this source was on level 1.377 Gg and the total decreasing according to the base year is about 61 %.

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

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

N<sub>2</sub>O emissions from AWMS were based on analyses of housing systems on the territory of 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).

Ministry of Agriculture of Slovak republic is the second source of data on animal housing, pasture and production of manures and slurries. Therefore calculations were done in two variants (Figure 8. 1: ).

**Table 6. 7: The perceptual share of Animal Waste Management Systems (AWMS) in 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 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 N<sub>2</sub>O 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<sub>GRAZ</sub> were provided. No recalculation, no changes were made (Table 6. 8.).

**Table 6. 8: The new estimated Frac<sub>GRAZ</sub> in the 1990-2005 in %**

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Frac <sub>GRAZ</sub>	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

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

[illegible]

### 6.3.2 Direct N<sub>2</sub>O Emissions from Cultivated Soils

The N<sub>2</sub>O emissions from cultivated soils are of natural origin from microbial processes – nitrification and denitrification. The direct N<sub>2</sub>O 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 20<sup>th</sup> century, from 200.0 Gg in 1990 to 76.2 Gg in 2005 (with the prognosis of 84 Gg in 2006 of N-input). The synthetic fertilizers in year 2005 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	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
	N-input (Gg)												
<b>N</b>	222	70	73	81	85	81	76	80	88	81	80	81	84

#### Emission Factors and Emissions

The applied synthetic fertilizers lost the definite amount of nitrogen by volatilization and N-NO<sub>x</sub> conversion, this amount for synthetic fertilizers is 10 %, its means that for the conversion of N to N<sub>2</sub>O rest only 90 % of total amount applied synthetic fertilizers (73.19 kt / year 2005). After using the IPCC default emission factor 0.0125 kg N<sub>2</sub>O-N / kg N the total emissions of N<sub>2</sub>O from using the synthetic fertilizers in 2005 were 1.438 Gg (0.898 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)<sup>9</sup> higher inputs of nitrogen from animal excreta are calculated – in average higher by about 5 % as compared with detailed method (Method B).<sup>10</sup> Since 1990 there was recorded decrease of nitrogen inputs from 171.4 Gg to 74.9 Gg in year 2005 – 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 per 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

<sup>9</sup> Method A: nitrogen input was calculated for animal categories of domestic livestock according to IPCC Methodology<sup>12</sup> cattle (dairy and others), pigs, sheep, goats, horses, and poultry, 1996

<sup>10</sup> Method B: the more detailed values for calculation of N<sub>2</sub>O emissions were used, when categories of domestic livestock per year for other cattle were supposed.

recommended values of produced nitrogen in methodologies what directly influence also N<sub>2</sub>O 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 [%]
<b>Cattle</b>	Dairy cows	5	75	20
	Non dairy cows	5	85	10
<b>Pigs</b>	Mean	76	24	0
	Fattening pigs	91	9	0
	Sows	41.6	58.4	0
<b>Sheep and goats</b>		4	41	55
<b>Poultry</b>	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
<b>Horses</b>		0	45	55

#### 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<sub>2</sub>O emissions from animal excreta in 2005 were 0.897 Gg (0.561 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 2004 were 1 149 857 ha and the direct inputs of nitrogen from crop residuals were 66 600 t per year 2005. The crops residuals from previous year were base for calculation of N<sub>2</sub>O emissions (according the used methodology). The used emission



factor 0.0125 kg N<sub>2</sub>O-N / kg N is according the IPCC methodology (IPCC, 1996) and gives the total N<sub>2</sub>O emissions from crops residuals in 2005 – 1.3082 Gg (0.082 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]	Average nutrient potential [N kg/ha]	2005 N [t]
Cereals	Wheat	418 158	405 800	306 900	367 800	53.0	19.493
	Ray	46 335	38 000	25 200	32 500	45.0	1.463
	Barley	190 634	194 700	269 300	222 000	45.0	9.990
	Oat	13 015	20 500	30 400	24 500	55.0	1.348
	Maize	150 731	140 400	146 000	147 800	39.0	5.764
potato		55 245	26 100	25 700	24 200	59.0	1.428
sugar beet		51 288	30 900	32 000	35 500	20.0	710
oil plants		70 906	201 600	208 900	196 700	107.0	21.047
tobacco		3 019	1 234	1 234	957	45.0	43
fodder crops		9 718	0	0	2 000	20.0	40
maize for silage		179 888	96 787	98 973	95 900	55.0	5.275

## Results and Discussion

According 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 been, 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 Slovak Republic it is not possible to split fodder crops and grasslands into year subcategories (Table 6. 13).

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	

## 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 N<sub>2</sub>O 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.

## Calculation Procedure

Nitrogen input from symbiotic fixation of leguminous plants was calculated according to their growing areas, when value 26 kg.ha<sup>-1</sup> (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 [kgN.ha<sup>-1</sup>]

$SA_T$  = acreage of crop in category T [ha]

## Recalculation and Time Series

Total reduction of N<sub>2</sub>O 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<sub>2</sub>O 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 <sub>2</sub> O	Year of sub.	4D1.4	N <sub>2</sub> O
1990 (2006)		0.90375	1990 (2006)		2.76802
1990 (2007 – June)		0.61977	1990 (2007 - June)		1.19488
<b>Differences in %</b>		<b>31.1</b>	<b>Differences in %</b>		<b>57.0</b>
Differences in Gg		0.28	Differences in Gg		1.58

**Table 6. 15: New estimated emissions in the 1990-2004 from direct soil emissions from crop and N-fixing crops residuals in Gg of N<sub>2</sub>O, comparison of old and new estimated dataset**

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
<b>4D1.3 -old</b>	0.90	0.89	0.88	0.91	0.82	0.75	0.71	0.70	0.62	0.61	0.56	0.58	0.46	0.51	0.53
<b>4D1.3 -new</b>	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
<b>Difference %</b>	<b>-31.1</b>	<b>-31.9</b>	<b>-30.5</b>	<b>-30.3</b>	<b>-30.0</b>	<b>-32.4</b>	<b>-34.6</b>	<b>-40.4</b>	<b>-40.3</b>	<b>-42.2</b>	<b>-38.5</b>	<b>-46.7</b>	<b>-37.6</b>	<b>-45.4</b>	<b>-47.1</b>
<b>4D1.4 -old</b>	2.77	2.78	2.80	2.77	2.81	2.83	2.88	2.92	2.92	2.94	3.12	3.11	3.11	3.11	3.14
<b>4D1.4 -new</b>	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
<b>Difference %</b>	<b>-57.0</b>	<b>-56.5</b>	<b>-56.1</b>	<b>-57.9</b>	<b>-57.8</b>	<b>-56.5</b>	<b>-55.3</b>	<b>-56.1</b>	<b>-55.7</b>	<b>-56.4</b>	<b>-57.4</b>	<b>-58.4</b>	<b>-57.9</b>	<b>-57.2</b>	<b>-58.2</b>

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<sub>2</sub>O 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:

1. Missing statistics on yield of some fodder crops at the beginning of evaluated period,
2. 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<sub>2</sub>O emissions. Therefore the acreage of field crops and national data about nitrogen content in crop residuals looks as more representative data for calculation procedure,
3. 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.

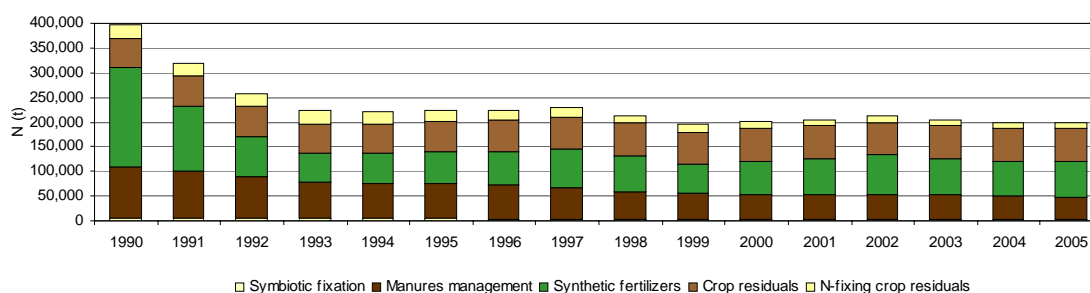
The total growing areas of N-fixing crops (peas, lens, beans, mix of fodder beans and cereals, soybeans, alfalfa, clover) in 2004 were 93 273 ha and the direct inputs of nitrogen from N-fixing crops were 11 738 t of N per year 2005. The crops residuals from previous year were base for calculation of N<sub>2</sub>O emissions from N-fixing crops (according the used methodology). The used emission factor 0.0125 kg N<sub>2</sub>O-N / kg N is according the IPCC methodology and gives the total N<sub>2</sub>O emissions from N-fixing crops in 2005 - 0.2306 Gg (0.017 Gg of N).

**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]	Average nutrient potential [N kg/ha]	2005 N [t]
N-fixing crops	peas	28 446	8 776	9 000	11 710	112.0	1 311 498
	lens	2 579	546	1 000	1 003	163.0	163 518
	beans	2 272	781	1 000	696	192.0	133 693
	mix of fodder beans and cereals	11 707	2 527	3 000	2 200	134.0	294 800
	soybeans	5 474	9 326	11 600	10 663	132.0	1 407 544
	alfalfa	118 125	62 481	61 532	61 000	126.0	7 686 000
	clover	35 068	8 761	6 494	6 000	123.5	741 000

Biologic fixation from 93 273 ha of N-fixing crops were 2 425 t N per year 2005. The used emission factor 0.0125 kg N<sub>2</sub>O-N / kg N is according the IPCC methodology and gives the total N<sub>2</sub>O emissions from biologic fixation in 2005 – 0.0476 Gg (0.003 Gg of N). The total N<sub>2</sub>O emissions from N-fixing crops (residuals + biologic fixation) in 2005 were 0.2782 Gg. A trend of direct N input in agricultural soils according to the sources during 1990-2005 is depicted on the Figure 6. 7.

**Figure 6. 7: The trend of direct N inputs in soils according to sources (SR 1990-2005)**



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 N<sub>2</sub>O emissions and so trends reflect their sources.

### 6.3.3 Indirect N<sub>2</sub>O Emissions

This part of N<sub>2</sub>O emissions resulted from processes of atmospheric deposition of ammonia and NO<sub>x</sub>, 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.

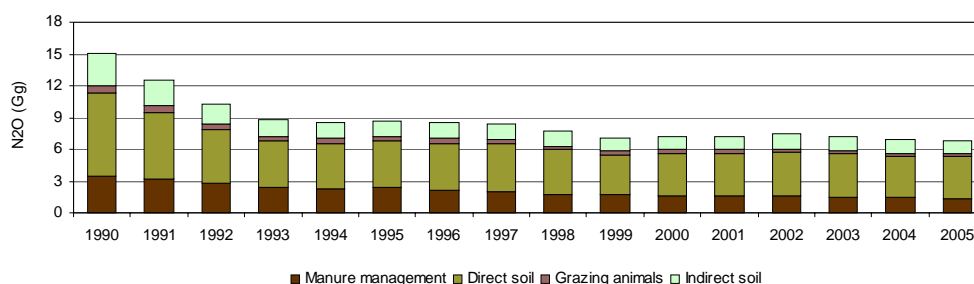
### Emission Factors and Emissions

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 N<sub>2</sub>O from atmospheric deposition create 363.29 tons per year 2005; the emissions of N<sub>2</sub>O from nitrogen leaching and run-off are 859.39 tons per year 2005. The total indirect emissions in 2005 are 1.223 Gg with the reduction of 60 % compared to the 1990 year.

### Trends and Recalculations of N<sub>2</sub>O Emissions

Trends of the total N<sub>2</sub>O 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<sub>x</sub>. After big decrease of N<sub>2</sub>O emissions in the 1<sup>st</sup> half of 90's (from 15.1 Gg in 1990 to 6.4 Gg in 1995) the emissions stabilized on level 6.8 Gg per year (Figure 6. 8).

Figure 6. 8: The trend of N<sub>2</sub>O emissions in agriculture in 1990-2005



The N<sub>2</sub>O emissions from agriculture sector create about 67 % of total N<sub>2</sub>O emissions in the SR. The total N<sub>2</sub>O 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 N<sub>2</sub>O 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 N<sub>2</sub>O emissions from agriculture (IPCC, 1996)

EF <sub>1</sub>	Direct emissions - cultivated soils	0.0125 (0.0025-0.0225) kg N <sub>2</sub> O - N/kg
EF <sub>3</sub>	AWMS - liquid storage	0.001 (0.001) kg N <sub>2</sub> O - N/kg
	AWMS - dry storage	0.02 (0.005-0.03) kg N <sub>2</sub> O - N/kg
	AWMS - pasture	0.02 (0.005-0.03) kg N <sub>2</sub> O - N/kg
EF <sub>4</sub>	Indirect emissions – atmospheric deposition	0.01(0.002-0.02) kg N <sub>2</sub> O-per kg emitted NH <sub>3</sub> and NO <sub>x</sub>
EF <sub>5</sub>	Indirect emissions - leaching	0.025 (0.002-0.12) kg N <sub>2</sub> 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, 2004), as well as Statistical yearbook (Statistical yearbook, 2004) 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 NH<sub>3</sub> 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  $\pm 10$  %. 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<sub>2</sub>O 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 data 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 than 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  $kg \cdot ha^{-1}$  (Bielek, 1998). As an average value can be accepted 26  $kg \cdot N \cdot ha^{-1}$  (Vostál at all., cit. in Bielek, 1998). This value varies in range  $\pm 20$  % 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  $\pm 20$  % year to year.

#### **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  $kg \cdot ha^{-1}$  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

### 7.2 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/m<sup>3</sup>. 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: An overview of land use input data according the new methodology

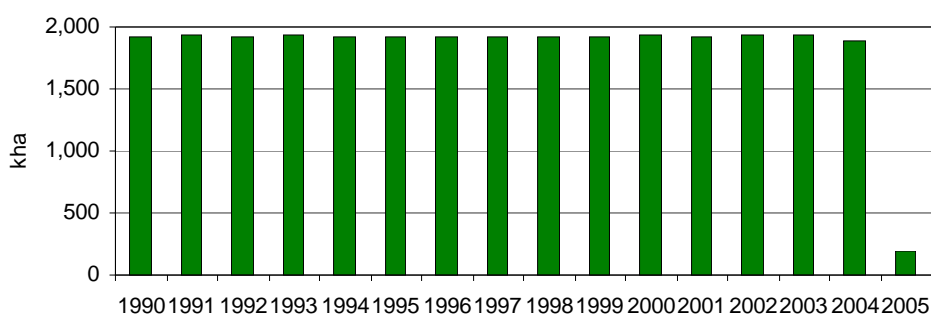
	Forest land	Grassland	Cropland	Wetland	Settlements	Other
Area - 1990, ha	1 921 705	813 000	1509 000	38 053	0	621 846
Area - 2005, ha	1 931 640	893 600	1423 118	38 053	0	697 160

### 7.3 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 2005. The Figure 7. 1 shows the activity data in ha per estimated time series 1990-2005.

Figure 7. 1: The development of total forest area in the SR – Forest land remaining Forest land



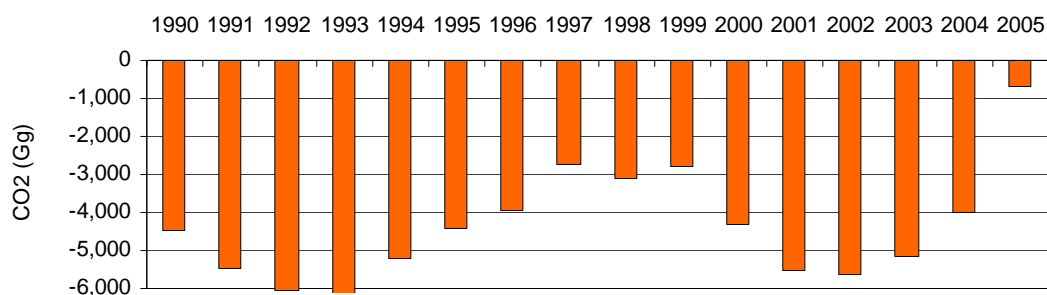
The total area of Forest land remaining the Forest land in 2005 was 1 880 kha, the changes in the forest land were following Grassland converted to Forest land 23.04 kha and Other land converted to the Forest land 28.6 kha per 2005. Total forest area in 2005 was 1 931.6 kha, with the net carbon stock change into the soil per area 72.60 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 4 159 kt C. The total annual carbon consumption from forest harvest in the Slovak forests is 2 938 kt C.

#### Emission Factors and Emissions

The carbon stock change in soil from the forest land per 2005 is 140.28 Gg of C or -701.25 Gg of CO<sub>2</sub>. 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<sub>2</sub> balance from managed forests – Forest land in 1990-2005**

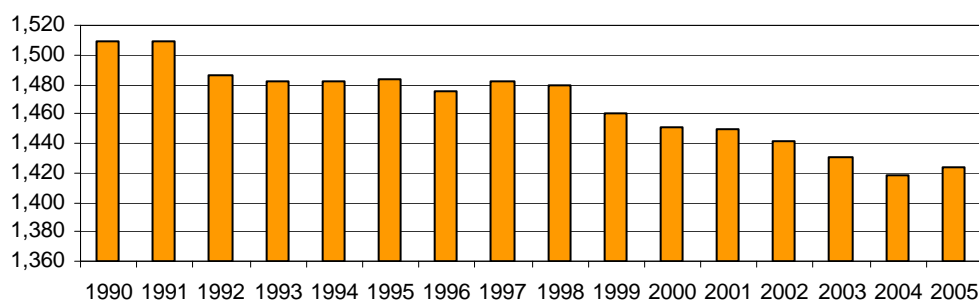


## 7.4 Cropland

### 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 2005. The Figure 7. 3 shows the activity data in ha per recalculated time series 1990-2005.

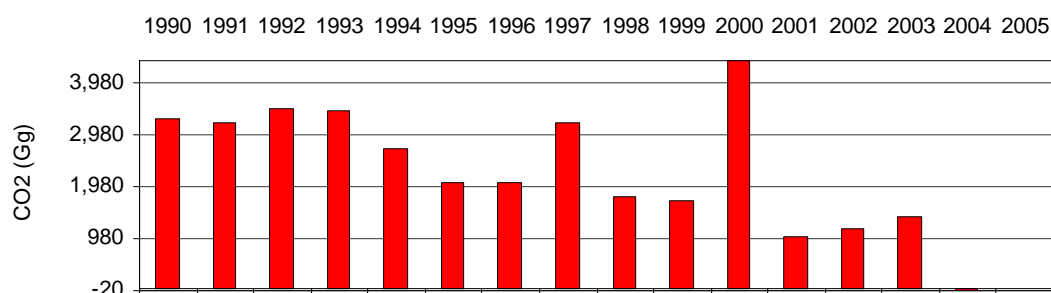
**Figure 7. 3: A development of total Cropland area in the SR – Cropland remaining Cropland in 1990-2005**



The total area of cropland remaining cropland in 2005 was 1 423.1 kha per 2005. Total cropland area in 2005 was 1 423 kha.

### Emission Factors and Emissions

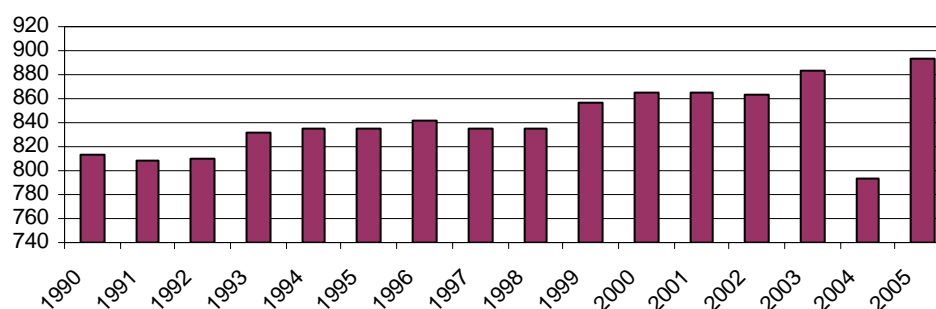
The carbon stock change in soil from the cropland per 2005 is 4.89 Gg of C. The total quantity of removed CO<sub>2</sub> in this subcategory is 1.08 Gg CO<sub>2</sub>. The summary results from this category are depicted on Figure 7.4. Total decreasing of the removals from the cropland in the SR comparable to the 1990 is more than 100 % caused by shifted from the positive emissions to the removals in 2005.

**Figure 7. 4: The CO<sub>2</sub> balance from Cropland in 1990-2005**

## 7.5 Grassland

### Methodology and Activity Data

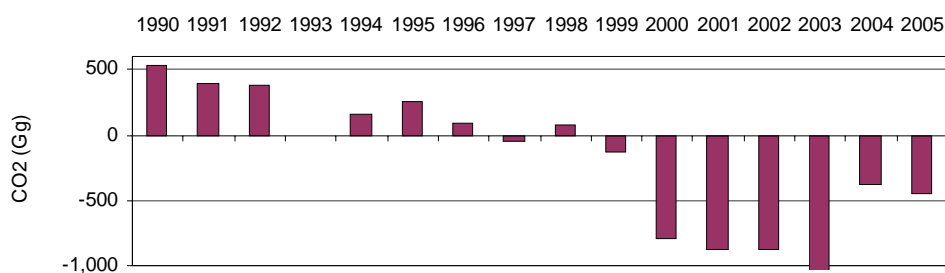
Results of recalculations were obtained by using the new LULUCF Methodology (IPCC, 2003) and national data on area of grassland and land converted to the grassland during the inventory year 2005. The Figure 7. 5 shows the activity data in ha per recalculated time series 1990-2005.

**Figure 7. 5: The development of total grassland area in the SR – Grassland remaining Grassland in 1990-2005**

The total area of grassland remaining grassland in 2005 was 792.8 kha, the changes in the grassland were following cropland converted to the grassland 73.5 kha per 2005 and other land converted to the grassland 27.1 kha per 2005. Total grassland in 2005 was 893.6 kha, with the net carbon stock change into the soil per area 134.8 kg C/ha.

### Emission Factors and Emissions

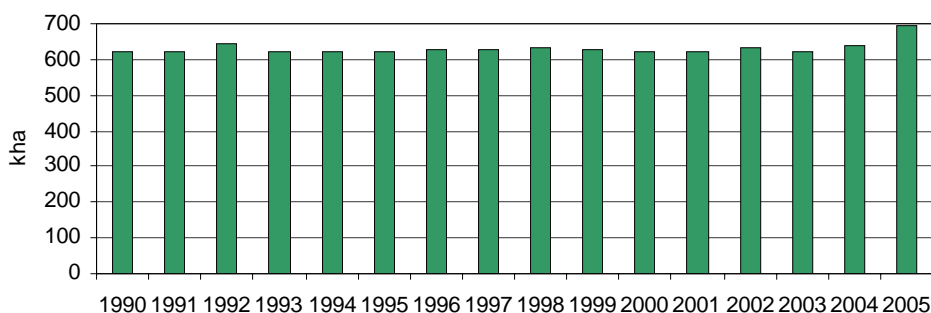
The carbon stock change in soil from the Grassland per 2005 is 120.45 Gg of C. The total quantity of removed CO<sub>2</sub> in this subcategory is -441.65 Gg CO<sub>2</sub>. The summary results from this category are depicted on Figure 7.6. Total decreasing of the removals from the cropland in the SR comparable to the 1990 is more than 100 % caused by shifted from the positive emissions to the removals in 2005.

**Figure 7. 6: The CO<sub>2</sub> balance from Grassland in 1990-2005**

## 7.6 Other Land

### Methodology and Activity Data

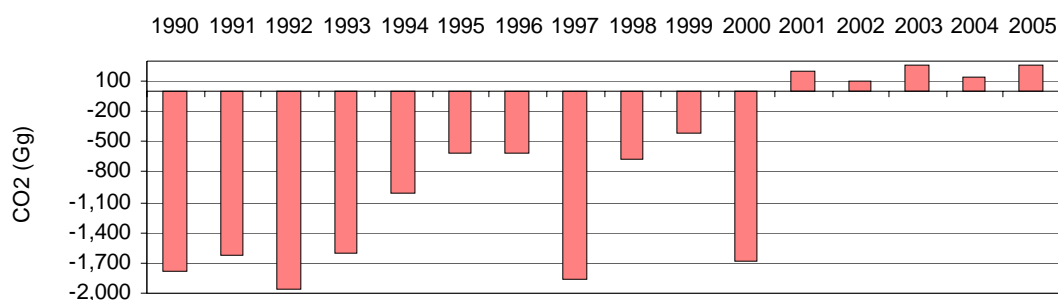
Results of recalculations were obtained by using the new LULUCF Methodology (IPCC, 2003) and national data on area of other land and land converted to the other land during the inventory year 2005. The Figure 7. 7 shows the activity data in ha per recalculated time series 1990-2005.

**Figure 7. 7: A development of total other land area in the SR – Other land remaining Other land in 1990-2005**

The total area of other land remaining other land in 2005 was 637.0 kha, the changes in the other land were following forest land converted to the other land 20 kha per 2005, Cropland converted to Other land 33 kha per 2005 and Grassland converted to Other land 7 kha per 2005. Total Other land in 2005 was 697.2 kha, with the net carbon stock change into the soil per area -14.16 kg C/ha.

### Emission Factors and Emissions

The carbon stock change in soil from the other land per 2005 is -98.73 Gg of C. The total quantity of removed CO<sub>2</sub> in this subcategory is 267.48 Gg CO<sub>2</sub>. 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 2005.

**Figure 7. 8: The CO<sub>2</sub> balance from Other land in 1990-2005**

## 7.7 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.

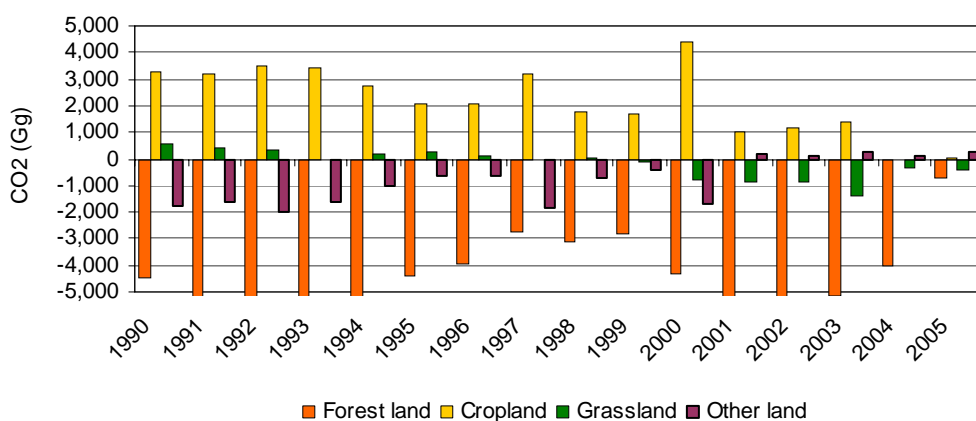
**Table 7. 2: Forest fires and controlled burning of the forest in 1990 and 2000-2005**

Year	1990	2000	2001	2002	2003	2004	2005
<b>Biomass burned</b>	t dm						
Controlled Burning	82.6	69.3	83.6	82.4	89.2	110.2	131.5
Forest Fires	4.8	14.1	0.5	0.5	2.5	2.1	2.1

## 7.8 Total LULUCF

The total carbon dioxide emissions represent -877.342 Gg due to Forest land (-701.25 Gg), Cropland (1.08 Gg), Grassland (-441.65 Gg) and Other land (264.48 Gg). Total amount of methane emission from LULUCF sector represents 1.069 Gg of CH<sub>4</sub> and total amount of N<sub>2</sub>O is 0.017 Gg. The emissions of other pollutant come from forest fire and controlled burning of Forest land. The NO<sub>x</sub> emissions are 0.531 Gg and emissions of CO are 9.35 Gg in 2005. Summary results are presented on Figure 7. 9. The total removals from the LULUCF sector increase between 1990 and 2005 by more than 64 %.

**Figure 7. 9: The total CO<sub>2</sub> balance in LULUCF sector**



## 8 WASTE

### 8.2 Input Data

The production of emission of CH<sub>4</sub> and N<sub>2</sub>O 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 2004 is presented:

- CH<sub>4</sub> from solid waste;
- CH<sub>4</sub> from domestic and industrial wastewater (including sludge);
- N<sub>2</sub>O from wastewater.

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, 2004, Green Report, 2004).

### 8.3 Emissions of CH<sub>4</sub> from SWDS

#### 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 CH<sub>4</sub>, 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 CH<sub>4</sub> emissions from SWDSs. One of these methods is a default base method, which all countries can use to estimate CH<sub>4</sub> 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 CH<sub>4</sub> 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 CH<sub>4</sub> 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 three versions of FOD method described in the IPCC GPG 2000 were considered for the use as Tier 2 method for estimation of methane emissions from SWDS in the Slovak Republic. 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 that 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 changes 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 practise 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:

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

Where:

- $G_t$  = landfill gas generation per year ( $m^3/t$ )
- $C_O$  = organic carbon in waste (recommended 150 – 200 kg/t)
- $\delta$  = temperature (recommended 20 – 40°C)
- $k$  = decay parameter (recommended 0.03 – 0.06)
- $t$  = time (years).

### Activity Data and Other Parameters

The IPCC 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. **1Chyba! Nenašiel sa žiaden zdroj odkazov.**) 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 2005)
1995	Marius Pedersen started operation in Slovak Republic (serving about 20% of population in 2005)
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

#### 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.

#### 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 1997-2005) 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 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. 2 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. 2: The DOC based on individual MSW analyses**

Location	Paper, textile	Bio waste	Wood	DOC
D. Streda	18.5 %	28.2 %	1.3 %	0.12
Prešov	15.0 %	44.5 %	2.1 %	0.14
Poprad	20.9 %	45.4 %	1.8 %	0.16
Humenné	17.7 %	25.2 %	2.2 %	0.12
Košice	24.0 %	45.0 %		0.17
Prievidza	10.5 %	36.0 %		0.10
Brezno	14.0 %	31.0 %		0.11
Čifáre	11.6 %	28.3 %		0.09
Kálna n/H	17.8 %	31.3 %		0.12
Levice	23.0 %	24.9 %		0.13
Nitra	11.1 %	31.5 %	18.6 %	0.15
Trebišov	8.0 %	51.0 %		0.11

The average DOC value from the Table 8. 2 is 0.13. 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. 3: The DOC based on type of dwelling**

MSW fraction	C1	C2	S	V
Paper and textile	28.3 %	28.8 %	30.7 %	9.8 %
Biowaste	18.2 %	19.6 %	17.3 %	6.3 %
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. 4: 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. 2 and Table 8. 3 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. 4.

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

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.

**Table 8. 5: The Estimation of historical DOC data**

Year	Households with central heating	DOC by Table 8. 3	DOC by Table 8. 4
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

The remaining DOC data were interpolated using linear regression.

#### 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 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.

#### Methane generation potential

The methane generation potential is calculated using values proposed in Table 8. 4 and Table 8. 5. 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.

#### Estimating methane emissions from SWDS in Slovak Republic

When using the FOD method for estimating methane emissions from SWDS, variability of parameters in time must be taken into account, which should correspond with development of waste management and life standard in the Slovak Republic. In addition, the activity data must be critically reviewed, because there is little information on the history of waste management.

#### Overview of Constant Parameters

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

**Table 8. 6: 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 Slovak Republic
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. 7: 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 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 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 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. 8: :

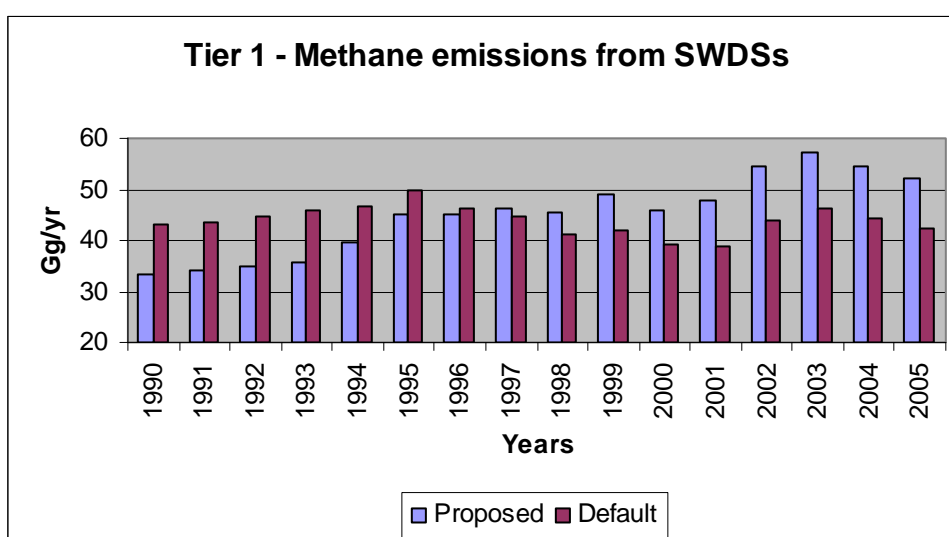
**Table 8. 8: The MSW typical values for the Slovak Republic 1995 – 2005**

MSW generation:	268	kg MSW/cap/yr
	0.73	kg MSW/cap/day
Fraction of MSW disposed to SWDS:	0.82	
MSW disposal rate:	0.60	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 – 2005 for both Tier 1 and Tier 2 methodologies.

The Figure 8. 1: shows methane emissions from SWDSs according to Tier 1 methodology using default and new proposed parameters. Modified activity data were used. The following parameters were considered constant for estimation using proposed parameters:  $DOC$  (0.12),  $DOC_F$  (0.6),  $F$  (0.5) and  $R$  (0). For estimation using default parameters additionally following parameters were used:  $DOC_F$  (0.77),  $MCF$  (0.6) and  $OX$  (0).

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

The resulting estimation of methane emissions for the year 2005 according to the Tier 1 methodology is shown in the table below:

**Table 8. 9: Methane emissions in 2005 (MSW, Tier 1)**

Parameters	Emissions (Gg CH <sub>4</sub> /yr)
Proposed	52.08
Default	42.21

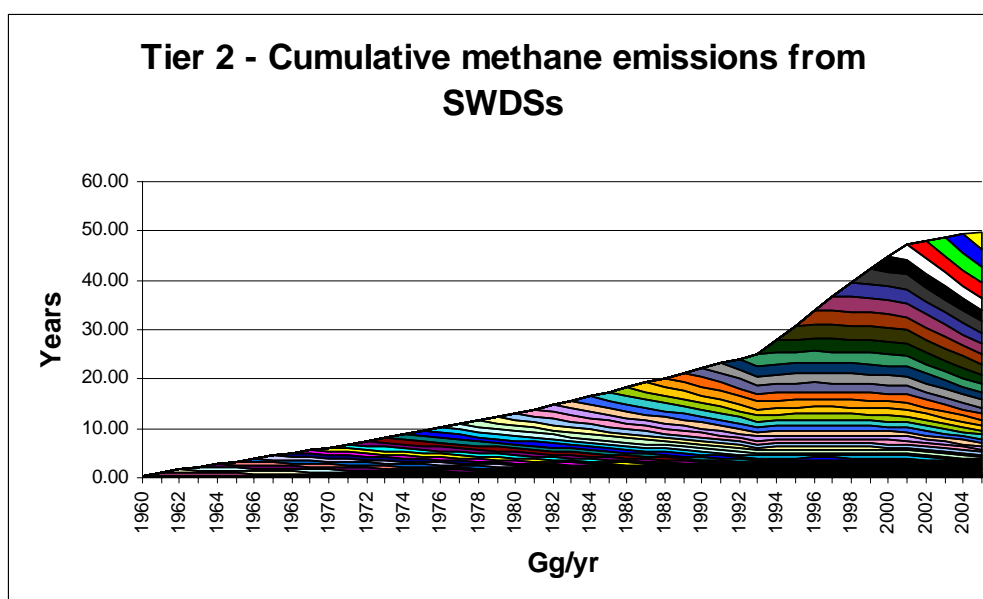
Table 8. 10: MSW disposed to SWDS – Activity data

Year	Population	MSW T(X) (Gg/yr)		MSWF	MSW L(X) (Gg/yr)		NOTE
		Original	Modified		Original	Modified	
1960	3,994,270	<b>565</b>	565	1.00	565	565	Tölgyessy&Piatrik
1961	4,191,977	595	595	1.00	595	595	Interpolated
1962	4,238,056	604	604	1.00	604	604	
1963	4,282,865	613	613	1.00	613	613	
1964	4,327,949	622	622	1.00	622	622	
1965	4,373,595	630	630	1.00	630	630	
1966	4,413,853	639	639	1.00	639	639	
1967	4,450,880	646	646	1.00	646	646	
1968	4,483,656	654	654	1.00	654	654	
1969	4,518,773	661	661	1.00	661	661	
1970	4,528,459	<b>665</b>	665	1.00	665	665	Tölgyessy&Piatrik
1971	4,559,341	692	692	1.00	692	692	Interpolated
1972	4,596,330	719	719	1.00	719	719	
1973	4,640,673	749	749	1.00	749	749	
1974	4,691,014	780	780	1.00	780	780	
1975	4,739,301	811	811	1.00	811	811	
1976	4,789,452	843	843	1.00	843	843	
1977	4,840,819	875	875	0.90	788	788	
1978	4,891,673	908	908	0.90	817	817	
1979	4,940,223	941	941	0.90	847	847	
1980	4,984,331	973	973	0.90	876	876	
1981	5,017,032	1,004	1,004	0.90	904	904	
1982	5,054,770	1,036	1,036	0.90	933	933	
1983	5,091,537	1,068	1,068	0.90	962	962	
1984	5,127,719	1,101	1,101	0.90	991	991	
1985	5,161,789	1,133	1,133	0.90	1,020	1,020	
1986	5,192,789	1,165	1,165	0.90	1,049	1,049	
1987	5,223,609	1,197	1,197	0.90	1,078	1,078	
1988	5,251,120	1,229	1,229	0.90	1,106	1,106	
1989	5,276,186	1,260	1,260	0.90	1,134	1,134	
1990	5,297,774	1,291	1,291	0.90	1,162	1,162	
1991	5,283,404	1,313	1,313	0.90	1,182	1,182	
1992	5,306,539	<b>2,461</b>	1,345	0.90	<b>2,247</b>	1,210	Modified
1993	5,324,632	<b>2,331</b>	1,375	0.90	<b>2,025</b>	1,238	data
1994	5,347,307	<b>1,909</b>	1,407	0.90	<b>1,709</b>	1,266	zone
1995	5,363,676	<b>1,570</b>	<b>1,570</b>	0.86	<b>1,347</b>	<b>1,347</b>	Statistical office data bold
1996	5,373,793	<b>1,458</b>	<b>1,458</b>	0.86	<b>1,249</b>	<b>1,249</b>	
1997	5,383,233	<b>1,451</b>	<b>1,451</b>	0.83	<b>1,206</b>	<b>1,206</b>	
1998	5,390,866	<b>1,366</b>	<b>1,366</b>	0.81	<b>1,113</b>	<b>1,113</b>	
1999	5,395,324	<b>1,380</b>	<b>1,380</b>	0.82	<b>1,134</b>	<b>1,134</b>	
2000	5,400,679	<b>1,339</b>	<b>1,339</b>	0.79	<b>1,056</b>	<b>1,056</b>	
2001	5,379,780	<b>1,258</b>	<b>1,258</b>	0.83	<b>1,049</b>	<b>1,049</b>	
2002	5,378,809	<b>1,524</b>	<b>1,524</b>	0.78	<b>1,192</b>	<b>1,192</b>	
2003	5,378,950	<b>1,599</b>	<b>1,599</b>	0.79	<b>1,256</b>	<b>1,256</b>	
2004	5,382,574	<b>1,475</b>	<b>1,475</b>	0.81	<b>1,195</b>	<b>1,195</b>	
2005	5,387,285	1,468	1,468	0.78	1,145	1,145	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).

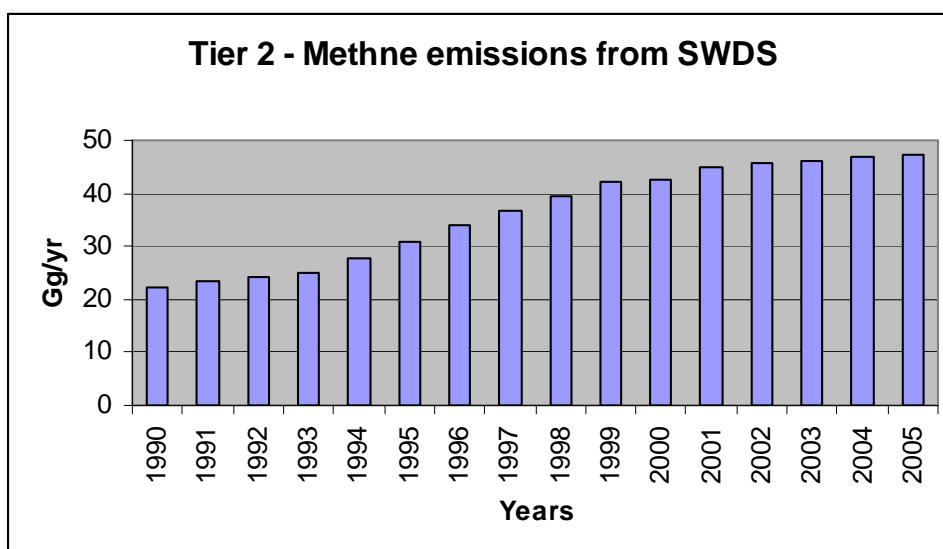
The estimation of methane emissions from SWDSs using FOD method were calculated using a spreadsheet model. Results are presented as cumulative diagram (Figure 8. 2: ), which shows contribution of emissions from MSW disposed each year and covers the entire period 1960 – 2005 and as a bar chart showing total emissions for the period 1990 – 2005.

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



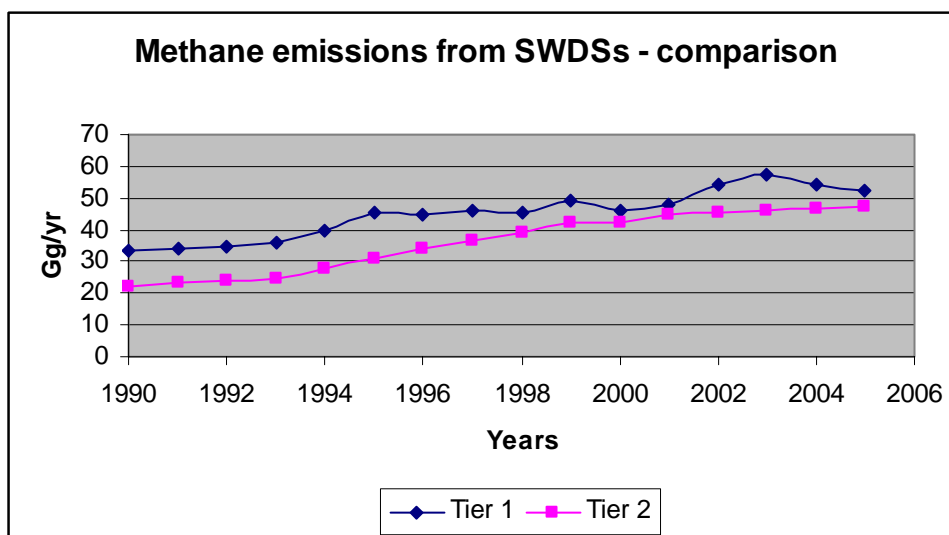
According to the used model for estimation of methane emissions from MSW disposed to SWDSs the total emissions reached 47.12 Gg/yr in 2005. Values and parameters used for emission estimations according to Tier 2 are in the **Chyba! Nenašiel sa žiaden zdroj odkazov..** The cumulative diagram shows fast 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.

Figure 8. 3: Methane emissions from SWDS in the period 1990-2005



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 – 2005. In both cases modified activity data and proposed parameters were used (Figure 8. 4: ).

**Figure 8. 4: The comparison of Tier 1 and Tier 2 methodology**



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.

#### Industrial Waste and Other Waste Streams

The review of available waste data has shown, that industrial waste and other waste streams include significant amount of biodegradable waste, which should be included into the national methane emissions from SWDSs balance. For description of these two waste groups the following approach based on European Waste Catalogue (EWC) is proposed:

- Industrial waste – all waste types which (may) contain biodegradable waste and are destined to disposal on SWDSs, listed in ECW in groups 01 – 19;
- Other waste streams – all waste types which (may) contain biodegradable waste and are destined to disposal on SWDSs, listed in ECW in the group 20 (except mixed MSW and waste water treatment sludges).

The selection of individual waste types for estimation of methane emissions is based on the Waste Management Programme of Slovak Republic (2006), which defines as biodegradable wastes. The estimated emissions are shown in the Table 8. 11: below.



The same parameters as for mixed MSW emissions were used for methane emission estimation for this group of wastes.

**Table 8. 11: Methane emissions from industrial waste and other waste streams**

Waste group (EWC)	Amount disposed (Gg/yr)	CH <sub>4</sub> Emissions (Gg/yr)
Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing (02)	5.341	0.313
Wastes from wood processing and the production of panels and furniture, pulp, paper and cardboard (03)	22.301	3.390
Municipal wastes (household waste and similar commercial, industrial and institutional wastes) including separately collected fractions (20)	50.882	2.945
<b>TOTAL</b>	<b>78.525</b>	<b>6.648</b>

## 8.4 Emissions of CH<sub>4</sub> 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 CH<sub>4</sub> 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 CH<sub>4</sub> 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 m<sup>3</sup> 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 CH<sub>4</sub> per kg DC. The emissions factors depend on the fraction of wastewater managed by each wastewater handling method, maximum CH<sub>4</sub> 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 CH<sub>4</sub> 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 m<sup>3</sup> 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 m<sup>3</sup>/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 as Statistical yearbook, Green Report of Ministry of Soil Management and from the database of waste waters, which is administrated by 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. 12: and Table 8. 13: are data used for calculation of methane emissions from domestic organic wastewater and industrial wastewater and sludge.

**Table 8. 12: Data used for calculation of methane emissions from domestic wastewater and sludge**

Parameter	Amount	Unit	Data Source
P	5 384 783	persons	Statistical authority SR, year 2005
D <sub>dom</sub>	18 250	Kg BOD/1000 persons/yr	IPCC, one person produces 50 g BOD for day
DS <sub>dom</sub>	0.5	kg CH <sub>4</sub> /kg BOD	Appraisal value
B <sub>oi</sub>	0.6	kg CH <sub>4</sub> /kg BOD	IPCC default 0.6
B <sub>oj</sub>	0.6	kg CH <sub>4</sub> /kg BOD	IPCC default 0.6
WS <sub>ix</sub>	<sup>1)</sup>		Appraisal value - according to percentage of population connected to the sewerage system - Green report
SS <sub>iy</sub>	<sup>1)</sup>		Appraisal value - according to percentage of population connected to the sewerage system - Green report
MCF <sub>x</sub>	<sup>1)</sup>		Appraisal value - according information about type of wastewater treating
MCF <sub>y</sub>	<sup>1)</sup>		Appraisal value - according information about type sludge handling system
MR	<sup>1)</sup>	kg CH <sub>4</sub>	Appraisal value - (20 % of methane emissions are recovered or flared)

<sup>1)</sup> values are the tables in IPCC format were are in annex (worksheet 6.2 - sheet 2, 3)

Table 8. 13: Data used for calculation of methane emissions from industrial wastewater and sludge

Parameter	Amount	Unit	Data Source
TOW <sub>ind</sub>	1)	kg COD/yr	Database of Hydrometeorological institute ( 50 % of COD was removed as a sludge)
TOS <sub>ind</sub>	1)	kg COD/yr	Database of Hydrometeorological institute ( 50 % of COD was removed as a sludge)
DS <sub>ind</sub>	0.5		Appraisal value
B <sub>oi</sub>	0.25	kg CH <sub>4</sub> /kg COD	IPCC default 0.25
B <sub>oij</sub>	0.25	kg CH <sub>4</sub> /kg COD	IPCC default 0.25
WS <sub>ix</sub>	2)		Appraisal value - according information about type of wastewater treating
SS <sub>iy</sub>	2)		Appraisal value - according information about type sludge handling system
MCF <sub>x</sub>	2)		Appraisal value - according information about type of wastewater treating
MCF <sub>y</sub>	2)		Appraisal value - according information about type sludge handling system
MR	0	kg CH <sub>4</sub>	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)

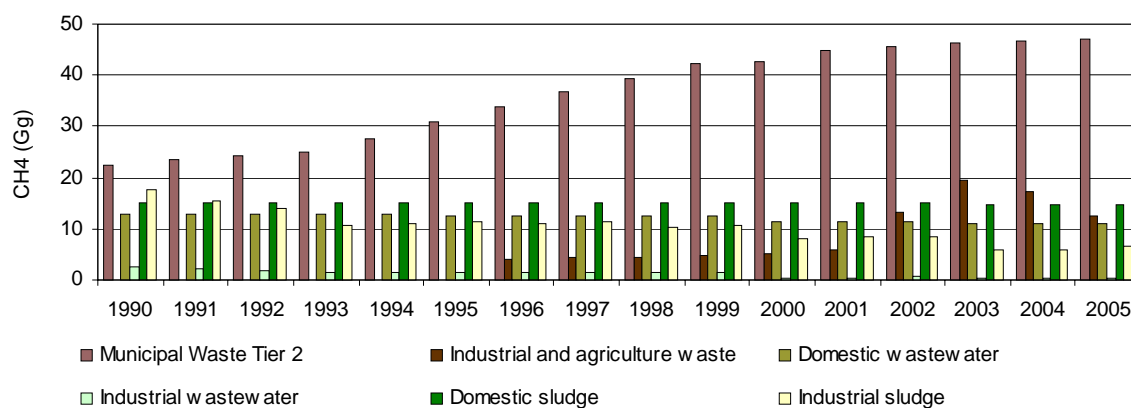
2) values are the tables in IPPC format were are in annex (worksheet 6.3 - sheet 2,3,4)

Parameters WS<sub>ix</sub> a SS<sub>iy</sub> for domestic wastewater are appraised from information about percentage of population connected in sewage system. In the year 2005 is 57 % of population connected in sewerage system and domestic wastewater is handled in aerobic treatment facilities and lagoons. The 43 % of population collect domestic wastewater in sewer systems as septic tanks or latrines. The situation is similar like in the year 2004. 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 2004 COD produced in all industry is little increased about 16 %.

#### Emission Factors and Emissions

The total emissions of methane in 2005 from wastewater are 32.68 Gg. The industrial wastewater represents 0.43 Gg of CH<sub>4</sub>, the domestic and commercial 10.99 Gg of CH<sub>4</sub>. The industrial sludge produces 6.70 Gg of CH<sub>4</sub> emissions and 14.56 Gg of CH<sub>4</sub> are from domestic and commercial sludge (Figure 8.5). It's difficult to say reason of this increasing, because disposal of data, in comparison of year 2004 some data are missing, some was added. Maybe some industry produced more of COD.

**Figure 8. 5: The total methane emissions from waste sector in 1990-2005**

### Recalculations and Time Series

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 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.

The estimation of methane emissions from industrial waste is based on Tier 1 method, because biodegradable waste was not defined until recently and currently available historical data (due to changes in waste classification) do not allow development of realistic data time-line for industrial waste.

Methane emissions from MSW disposal to SWDSs have been re-calculated due to change of methodology and critical review of parameters and activity data. The Tier 2 methodology required development of new activity data, now the MSW generation and disposal data are available from 1960 – 2005.

Total decreasing of CH<sub>4</sub> emissions from category 6.A solid waste disposal on sites in 1990 was 55.5 % in comparison to the previous submission (2006). The results are summarized in Table 8. 14: and Table 8. 15: .

Table 8. 14: New estimated CH<sub>4</sub> emissions and EFs in the 1990-2005 from SWDS by Tier 2 methodology

Year	MSWL	MCF	DOC	L0	OX	Rec	CH <sub>4</sub> (Gg)
1990	1 162	0.6	0.12	0.028	0.00	0.00	22.37
1991	1 182	0.6	0.12	0.029	0.00	0.00	23.45
1992	1 210	0.6	0.12	0.029	0.00	0.00	24.16
1993	1 238	0.6	0.12	0.029	0.00	0.00	24.89
1994	1 266	0.65	0.12	0.031	0.00	0.00	27.75
1995	1 347	0.7	0.12	0.034	0.00	0.00	30.85
1996	1 249	0.75	0.12	0.036	0.00	0.00	33.81
1997	1 206	0.8	0.12	0.038	0.00	0.00	36.70
1998	1 113	0.85	0.12	0.041	0.00	0.00	39.40
1999	1 134	0.9	0.12	0.043	0.00	0.00	42.18
2000	1 056	0.95	0.12	0.046	0.05	0.00	42.51
2001	1 049	1	0.12	0.048	0.05	0.00	44.94
2002	1 192	1	0.12	0.048	0.05	0.00	45.54
2003	1 256	1	0.12	0.048	0.05	0.00	46.27
2004	1 195	1	0.12	0.048	0.05	0.00	46.79
2005	1 142	1	0.12	0.048	0.05	0.00	47.12

Table 8. 15: The recalculation changes in the SWDS in category 6A in Gg of CH<sub>4</sub>

		6A
Year of sub.	Category	CH <sub>4</sub> (Gg)
1990 (2006)		50.27
1990 (2007)		22.37
Differences in %		55.50
Differences in Gg		27.90

## 8.5 Emissions of N<sub>2</sub>O 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. 16: .

Table 8. 16: Parameters for calculation of emissions nitrous oxide for domestic wastewater – IPCC

Parameter	Amount	Unit	Data Source
Proteins	33.0	kg /person/yr	Statistical authority SR, year 2004, Is known only one amount from year 1999, but this information isn't changed
PO	5 384 783	persons	Statistical authority SR, year 2004
EF <sub>6</sub>	0.01	kg N <sub>2</sub> O-N/kg N in domestic wastewater	IPCC default 0.01
Frac <sub>NPR</sub>	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 N<sub>2</sub>O. For calculation N<sub>2</sub>O, 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  $N_2O$  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. 17: , Table 8. 18: ).

**Table 8. 17: 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
$k_{N_2O}$	0.0165	kg $N_2O$ -N/kg N in domestic wastewater	ISI default 0.009-0.024 kg $N_2O$ -N/kg N, medial value are used 0.0165 kg $N_2O$ -N/kg N
$K_{diss}$	0.65		IPCC default 0.5-0.8, medial value are used 0.65

**Table 8. 18: The parameters for calculation of emissions nitrous oxide for industrial wastewater – ISI**

Parameter	Amount	Unit	Data Source
$mn_i$		[m <sup>3</sup> /day]	Data for individual wastewater plant – database SHMU
(N)i		[mg/l]	Data for individual wastewater plant – database SHMU
$k_{N_2O}$	0.0165	kg $N_2O$ -N/kg N in domestic wastewater	ISI default 0.009-0.024 kg $N_2O$ -N/kg N, medial value are used 0.0165 kg $N_2O$ -N/kg N
$K_{diss}$	0.65		IPCC default 0.5-0.8, medial value are used 0.65

### Emission Factors and Emissions

Since  $N_2O$  emissions from human sewage are closely linked to the agricultural N cycle, the method is further discussed in the Agricultural Chapter (on indirect  $N_2O$  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. 19: .

**Table 8. 19: The total  $N_2O$  emissions from wastewaters handling in 2005 – IPCC, ISI**

Method	$N_2O$ emit from domestic wastewater [t/yr]	$N_2O$ emit from domestic wastewater [t/yr]	Emissions of $N_2O$ [t/yr]
IPCC 1996	-	-	450.39
ISI	45.676	43.104	88.784

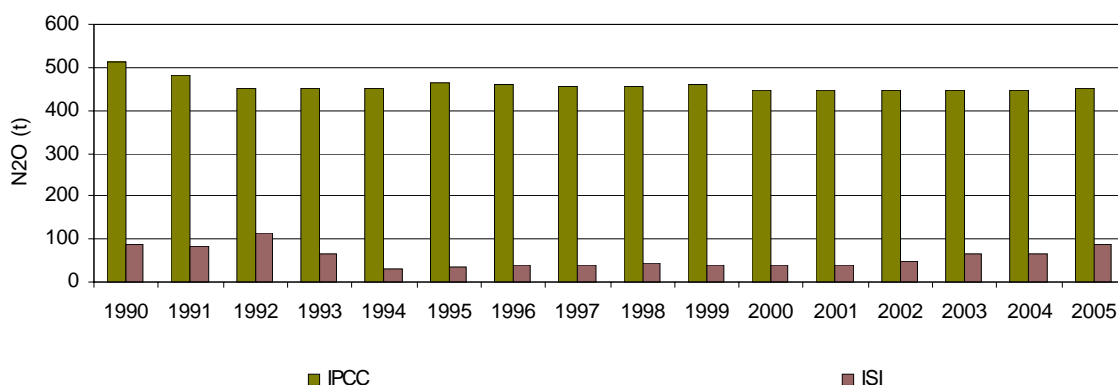
For estimation of methane emissions the default method given by the Revised 1996 IPCC Guidance for National Greenhouse Gas Inventories has been used, also respect to IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories was taken. For estimation of  $N_2O$  emissions two different methodologies – IPCC (1996), ISI have been used. ICCP tables are in annex. From results the order of emissions in 2005 are following:

- $CH_4$  from domestic wastewater (including sludge) 25.55Gg
- $CH_4$  from industrial wastewater (including sludge) 7.13 Gg

In comparison between year 2005 and 2004 emission from domestic is decreased and from industrial waste is increased. Emission from domestic wastewater is about in the same level as in the year 2004, emissions from industrial wastewater and from industrial waste is little increased from 6.1 Gg to 7.13 Gg. 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: .

**Figure 8. 6: The comparison of N<sub>2</sub>O emissions from wastewater treatment in 1990-2005**



## 8.6 Emissions from Waste Incineration

### Methodology and Activity Data

The emissions from the waste incineration are estimated for the CO<sub>2</sub> and N<sub>2</sub>O GHGs. The category waste incineration is included into the emission inventory – Waste sector only from 2000. The reason for this is in the methodology of estimation the quantity of waste incinerated. The quantity is estimated from National Emission Inventory System (NEIS) – database of stationary sources of pollution and consummated fuels. As we assumed in the Energy chapter, in 2000 extensive change of national database of sources was performed. The inconsistencies in the fuel's categories of and data providing by sources caused this problem. The consistency data series exists only from 2000 and are summarized in the Table 8. 20: .

### Emission Factors and Emissions

The emission factors for the CO<sub>2</sub> emission is depending on the type of waste, municipal waste EF 557.33 kg per tons of waste and for the other non-specified waste (the waste from hospitals, dangerous waste and industrial waste) EF 836 kg per tons of waste. The emission factors for the N<sub>2</sub>O are default from the IPCC Guidelines municipal waste EF 0.03 kg per tons of waste and for the other non-specified waste EF 0.042 kg per tons of waste. The total CO<sub>2</sub> emissions of waste incinerated in 2005 is 145.65 Gg and total N<sub>2</sub>O emissions is 0.0060 Gg.

**Table 8. 20: The total CO<sub>2</sub> and N<sub>2</sub>O emissions from waste incineration in 2000-2005**

Year	2001	2002	2003	2004	2005	2001	2002	2003	2004	2005
Waste incinerate	CO <sub>2</sub> (Gg)					N <sub>2</sub> O (Gg)				
Municipal waste	81.68	89.49	97.22	91.29	107.79	0.0039	0.0050	0.0052	0.0049	0.0036
Other waste	53.40	53.57	43.01	56.68	37.85	0.0050	0.0051	0.0034	0.0028	0.0024
<b>Total Emissions</b>	<b>135.07</b>	<b>143.06</b>	<b>140.22</b>	<b>147.97</b>	<b>145.65</b>	<b>0.0089</b>	<b>0.0100</b>	<b>0.0086</b>	<b>0.0078</b>	<b>0.0059</b>

## 9 RECALCULATION AND IMPROVEMENTS

The several recalculations in CRF 2005 submission 2007 are mentioned against the previous CRF 2004 submissions 2006. The most important are following.

### 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 year 1990 and 2000-2005.

The national emission factors for CO<sub>2</sub> are in use for this time, for natural gas from year 2000. The emission factors for natural gas are based on precious measurements and calculation published every month by Slovak Gas Industry Ltd. These EFs are in use for installations joined in the Emission Trading Scheme and for the requirements of the Ministry of Environment of the SR.

The emissions of GHGs from road transport in 2002 were recalculated. In the time series 2000-2005 was the consumption of the fuels in 2002 for *road transport* outside the consistency check. The inconsistency was caused by double counting of the fuels sale by Slovnaft Ltd. company into the distribution net (from import) and the same inclusion of fuels from the Customs Directory of the SR. This information were not available in the 2003, submission 2005.

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 last submission 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.

### 9.2 Industrial Processes Sector

Recalculation in the category of nitric acid production was made, according the new plant specific data for emission factors. The harmonisation with ETS data was evaluated.

### 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.

### 9.4 Solvent and Other Products Use Sector

The sector were completely estimated according the new information from 1998-2005.

### 9.5 Waste

The recalculation of methane emission estimation from solid waste disposal sites according more sophisticated Tier 2 FOD methodology was made. Country specific activity data from 1960 were collected and evaluated. The uncertainty analysis by Tier 2 – Monte Carlo method was provided.



## 9.6 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.

## 10 CONCLUSION

The National Inventory Report 2007 of the Slovak Republic is inseparable part of reviewed CRF 2005 submission 2007 (from July 2007) 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 2005 emission inventory is based on IPCC Methodology and is related to the previous inventory period 1990-2004. 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 1990-2005.

**Table 10. 1: An overview of GHG emissions (in Gg of CO<sub>2</sub> equivalents) in 1990-2005**

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
GHG	Gg of CO <sub>2</sub> equivalents															
CO <sub>2</sub> *	57 815	48 440	44 089	41 015	39 010	41 020	41 833	43 131	41 517	40 830	36 979	37 069	35 105	35 812	35 993	38 880
CO <sub>2</sub> **	60 222	51 948	48 240	45 299	42 327	43 716	44 254	44 532	43 457	42 466	39 382	42 294	40 348	40 645	40 244	39 757
CH <sub>4</sub>	5 407	5 068	4 771	4 421	4 435	4 630	4 689	4 618	4 597	4 576	4 478	4 547	4 605	4 575	4 369	4 177
N <sub>2</sub> O	6 168	4 970	4 162	3 519	3 862	4 068	4 197	4 101	3 702	3 251	3 504	3 710	3 674	3 710	3 813	3 748
HFCs	NA,NO	NA,NO	NA,NO	NA,NO	2.91	22.15	37.58	61.13	41.00	65.19	75.79	82.81	103.10	133.16	154.43	174.65
PFCs	271.37	266.94	248.42	155.42	132.06	114.32	34.51	34.62	25.40	13.60	11.65	11.43	11.41	20.87	19.32	20.25
SF <sub>6</sub>	0.03	0.03	0.04	0.06	9.27	9.91	10.76	11.34	12.24	12.69	13.25	13.84	14.78	15.39	15.89	16.61
<b>Total<sup>†</sup></b>	<b>69 662</b>	<b>58 746</b>	<b>53 270</b>	<b>49 110</b>	<b>47 452</b>	<b>49 864</b>	<b>50 802</b>	<b>51 957</b>	<b>49 895</b>	<b>48 748</b>	<b>45 062</b>	<b>45 438</b>	<b>43 515</b>	<b>44 267</b>	<b>44 365</b>	<b>47 017</b>
<b>Total<sup>**</sup></b>	<b>72 051</b>	<b>62 242</b>	<b>57 409</b>	<b>53 382</b>	<b>50 758</b>	<b>52 548</b>	<b>53 210</b>	<b>53 345</b>	<b>51 821</b>	<b>50 368</b>	<b>47 448</b>	<b>50 645</b>	<b>48 741</b>	<b>49 082</b>	<b>48 595</b>	<b>47 866</b>

\*CO<sub>2</sub> emissions with LULUCF, \*\*CO<sub>2</sub> emissions without LULUCF

Note: emissions are determined as of 15.04.2006

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 32.5 % 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 CO<sub>2</sub> 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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