

NATIONAL INVENTORY REPORT

GREENHOUSE GAS EMISSION INVENTORY IN THE SR 1990-2004

BRATISLAVA 2006

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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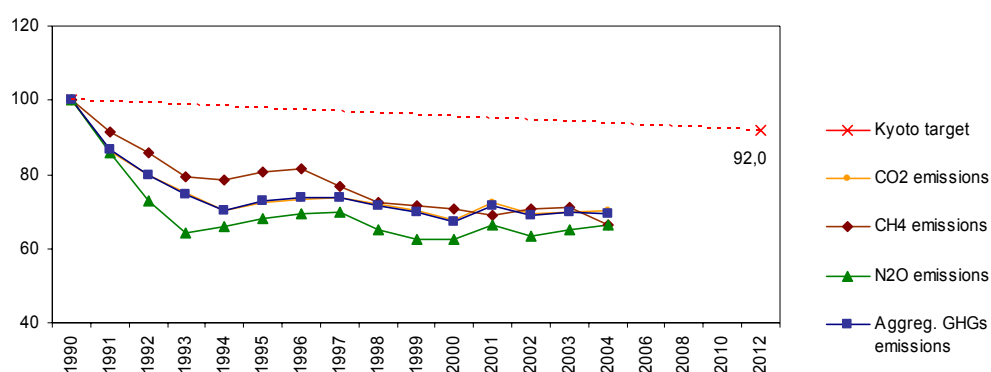
Annex 1: The Key Source Analysis and Uncertainty Management in the SR in 2004

EXECUTIVE SUMMARY

ES.1 Introduction

Climate change, caused by increasing anthropogenic emission of greenhouse gases, represents the most serious environmental issue in the history of humankind. The most important anthropogenic greenhouse gases are carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O). Other greenhouse gases included in GHGs inventory are halogenated hydrocarbons (PFCs, HFCs) and SF₆, which are not controlled by the Montreal Protocol. Photochemical active gases such as carbon monoxide (CO), nitrogen oxides (NO_x) and non-methane volatile organic hydrocarbons (NM VOCs) are not greenhouse gases, but they contribute indirectly to the greenhouse effect in the atmosphere. These have generally referred to as ozone precursors because they affect the creation and destruction of ozone in the troposphere. Precursors of sulphates - sulphur dioxide (SO₂) and aerosol - reduce the greenhouse effect. According to the text of the Final Protocol from Kyoto, the countries of Annex I have agreed to reduce aggregated emissions of all greenhouse gases (CO₂, CH₄, N₂O, HFCs, PFCs and SF₆) on average by 5.2% from the level of the year 1990 during the first commitment period of the years 2008-2012. The Slovak republic (SR), as well as EU, has accepted a target to reduce emissions by 8% in comparison with their level in the base year 1990. The Slovak republic and the EU countries ratified the Kyoto Protocol on May 31, 2002.¹ Total GHG emissions without LULUCF in the EU-15 were 1.7% below the base year in 2003. New Member States decreased GHG emissions by 32% between 1990 and 2003. Main factors for decreasing emissions for other new Member States - was the decline of energy inefficient heavy industry and the overall restructuring of the economy. The notable exception was transport (especially road transport) where emissions increased (IR EC, 2006). In the SR, by adoption of the reduction commitment of the Kyoto Protocol, pressure is put on a formulation of an efficient strategy to mitigate greenhouse gas emissions.

Figure ES.1 GHG emission trends compared with the Kyoto target in percent



Note: CO₂ Emissions without sinks in LULUCF; emissions are determined as of 15.04.2006

ES.2 National Circumstances

This National inventory report (NIR) presents the results of a greenhouse gas emissions inventory in the Slovak republic within the period 1990-2004 as well as summary results of NO_x, CO, NM VOC and SO₂ emissions. The base year in view of the UN Framework Convention and the Kyoto Protocol for the Slovak republic is the year 1990 for all GHGs except halogenated hydrocarbons (PFCs, HFCs) and

¹ Kyoto Protocol came into force on February 14, 2005

SF₆, where reference year is the year 1995. The inventory was developed in compliance with the methodology indicated in the IPCC 1996 Revised Guidelines. Detailed inventory results have submitted in CRF format to the DG ENV by January 15, 2006 (2004 CRF, 2006).

ES.3 Overview of Source and Sink

In the period 1991-2004, the total greenhouse gas emissions in the Slovak republic did not exceed the level of the year 1990 (**Figure ES.1**). The national total emissions determined as of April 15, 2006 are shown in **Table ES.1**.

Table ES.1 The total anthropogenic greenhouse gas emissions

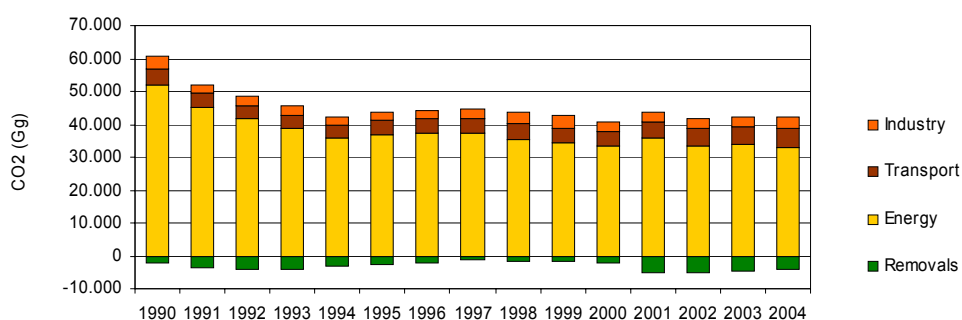
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Gas	CO ₂ equivalent (Tg)														
CO ₂	60.5	52.1	48.4	45.4	42.4	43.8	44.4	44.7	43.6	42.6	40.9	43.9	41.9	42.4	42.5
CH ₄	6.4	5.9	5.5	5.1	5.0	5.2	5.2	5.0	4.7	4.6	4.5	4.5	4.6	4.6	4.3
N ₂ O	6.1	5.2	4.5	3.9	4.1	4.2	4.2	4.3	3.9	3.8	3.8	4.1	3.9	4.0	4.1
F-Gases	0.27	0.27	0.25	0.16	0.14	0.15	0.08	0.11	0.08	0.09	0.10	0.11	0.13	0.17	0.19
GHGs	73.4	63.5	58.6	54.6	51.7	53.4	54.0	54.0	52.4	51.2	49.4	52.5	50.5	51.1	51.0

Total aggregated GHGs emission without LULUCF

ES.4 CO₂ Emissions

A most important anthropogenic source of CO₂ emissions in the atmosphere is combustion and transformation of fossil fuels, which account for about 95% of the total CO₂ emissions in the SR. A calculation of CO₂ emissions is based on energy statistical data when the IPCC sectoral method (sectoral approach) was applied. In addition, carbon dioxide arises during technological process of cement, lime, magnesite production and using of limestone. The balance includes also the production of coke, iron and steel, as well as CO₂ emissions arising during aluminium and ammonia production (**Figure ES.2**). 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 A share of individual sector on CO₂ emissions (Gg) in 1990-2004



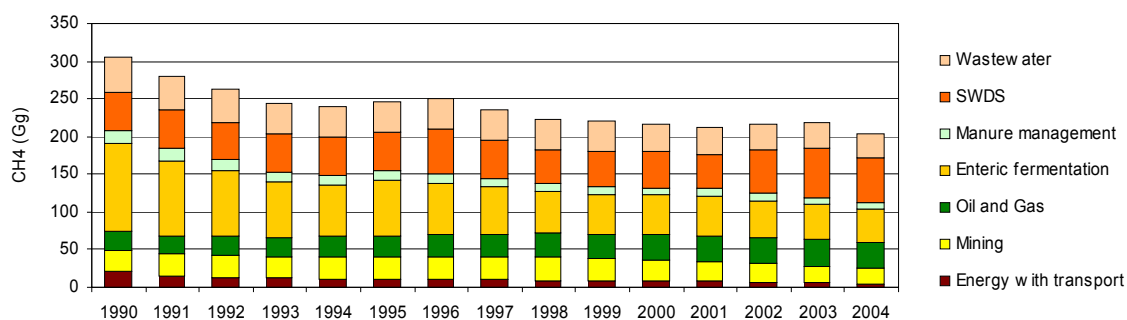
Note: CO₂ Emissions without LULUCF; emissions are determined as of 15.04.2006

ES.5 CH₄ Emissions

Agriculture, large-scale beef cattle and pig breeding, are major sources of methane on the Slovak territory. The CH₄ does arise as the direct product of the metabolism in herbivores and as the product of organic degradation in animal excrement. Calculations of emissions for the Slovak republic are based on the data listed in the Statistical yearbook of the Slovak republic (Statistical yearbook, 2004) and the Green Report of the Slovak Ministry of Agriculture (Green Report, 2004). 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**).

Figure ES.3 A share of individual sector on CH₄ emissions (Gg) in 1990-2004

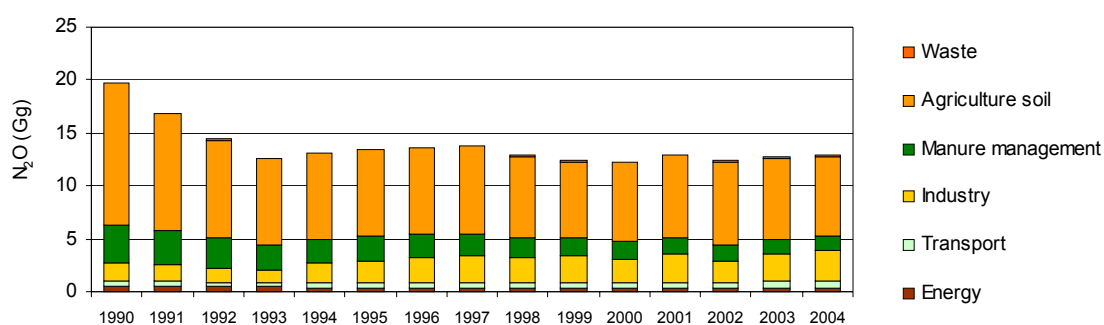


Note: CH₄ Emissions; emissions are determined as of 15.04.2006

ES.6 N₂O Emissions

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

Figure ES.4 A share of individual sectors in N₂O emissions (Gg) in 1990-2004



Note: N₂O Emissions; emissions are determined as of 15.04.2006

ES.7 HFCs, PFCs and SF₆ Emissions

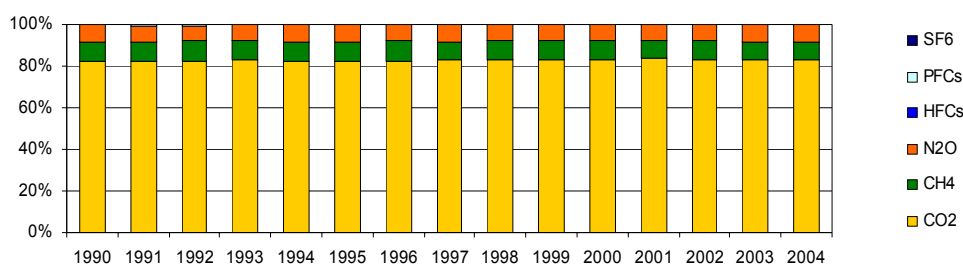
The first inventory of these substances² was executed in 1995. HFCs, PFCs and SF₆ are not produced in the SR, only data on consumption of these substances are available. They are used as coolants, extinguishing agents, blowing agents for PUR, in aerosol products and as insulating gases (SF₆).

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

ES.8 Aggregated Emissions

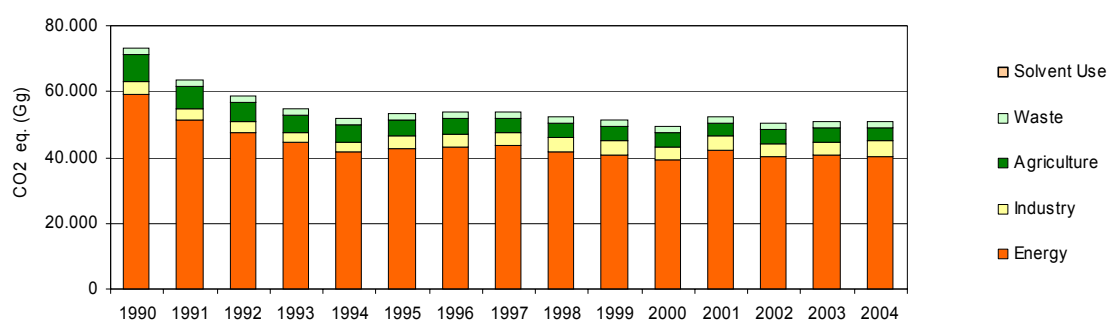
These are the emissions of greenhouse gases recalculated via GWP100 (Global Warming Potential)³ on the CO₂ equivalent. Expressed as the CO₂ equivalent, carbon dioxide emissions contributed by more than 80% to the total emissions, CH₄ (GWP = 21) emissions by about 10%, N₂O (GWP = 310) emissions by about 7% and the contribution of F-gases is below 1% (**Figure ES.5, ES.6**).

Figure ES.5 The aggregated emissions of greenhouse gases in 1990-2004 in percent



Note: CO₂ Emissions without LULUCF; emissions are determined as of 15.04.2006

Figure ES.6 The aggregated emissions of greenhouse gases by sectors in 1990-2004



Note: Aggregated emissions are determined as of 15.04.2006

ES.9 Indirect Greenhouse Gases

A major source of SO₂, NO_x and CO emissions is power and heat generation. A contribution of transport to NO_x and CO emissions is still growing. Metallurgy is an important source of CO emissions. Emissions of NM VOC are regularly estimated in the framework of the National Program of NM VOC Emissions Reduction in the SR. In the frame of this Program were revised emission factors for asphalt paving and residential plants combustion (total emission's decrease in 1990 about 45%). The year 1990 was used as a starting point and updating was carried out for the years 1990, 1993, 1996-1999, 2005. A major source of NM VOC emissions come from the use of solvents, transport, refinery/storage and transport of crude oil and petrol. The categories of emission sources in National Emission Inventory System (NEIS) are based on Air Pollution Act (478/2002) and they do not correspond exactly to the structure of sources to CRF requirements. Therefore, it is impossible to provide information on emissions and emission factors according to the classification requested in standard tables (**Table ES.2**).

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

Table ES.2 The anthropogenic emissions of NO_x, CO, NM VOC and SO₂ (Gg) in 1990-2004

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
CO	505	482	441	452	427	416	359	359	342	330	307	309	306	302	310
Stationary	345	335	296	297	268	255	204	201	183	180	179	169	159	178	190
Transport	154	142	141	151	155	157	151	153	154	145	122	134	141	118	113
Other*	6	5	4	4	4	4	4	5	5	5	6	6	6	6	7
NO_x	222	201	188	180	170	178	135	127	133	121	109	108	105	98	98
Stationary	165	154	144	138	126	133	90	82	87	78	71	67	60	59	55
Transport	57	47	44	42	44	45	45	45	46	43	38	41	45	39	37
Other*	0.35	0.28	0.23	0.24	0.2	0.23	0.25	0.27	0.26	0.3	0.33	0.33	0.33	0.36	0.40
NM VOC	138	NE	NE	113	NE	107	105	95	92	85	80	83	82	82	85
Energy	13	NE	NE	12	NE	10	10	8	9	8	8	9	8	8	9
Industry	11	NE	NE	8	NE	5	5	5	3	3	3	3	3	3	3
Crude oil	26	NE	NE	20	NE	17	17	17	15	13	13	12	12	12	13
Sol. Use	48	NE	NE	38	NE	41	40	32	32	29	30	31	31	32	34
Transport	35	NE	NE	31	NE	33	32	32	32	29	25	27	27	26	25
Other**	5	NE	NE	2	NE	1	1	1	1	1	1	1	1	1	1
SO₂	526	445	390	328	245	246	231	205	184	173	127	131	103	106	97
Stationary	523	442	388	326	243	244	228	202	181	172	126	130	102	105	96
Transport	3	3	2	2	2	2	3	3	3	1	1	1	1	1	1

* Biomass burning and forest fires ** waste, agriculture Note: emissions are determined as of 15.04.2006

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

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

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

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

Globally (Climate Change, 1995) the annual anthropogenic emission of carbon dioxide ranges between 4-8 billion tons of carbon (about 4t of CO₂ per capita in the globe). The most important source of "new" carbon dioxide is presented by the fossil fuel combustion and cement production. The CO₂ is also released from the soil (deforestation, forest fires and conversion of grasslands into agricultural soil), but this contribution is more difficult to quantify. Carbon dioxide is very stable in the atmosphere;

its residence time is tens of years (60-200 yrs.) and is removed from the atmosphere by a complex of natural sink mechanisms. It is expected that 40% of carbon dioxide presently emitted be absorbed by the oceans. Photosynthesis by vegetation and sea plankton is a further important sink mechanism, though only a transitional one, because after the death (eating) of a plant, carbon dioxide is released again. The level of methane in the ambient air is affected by human activity in more ways. Land transformation into an agricultural one (mainly rice fields), animal husbandry, coal mining, natural gas mining, its transport and use as well as the biomass burning are all anthropogenic activities. The natural methane sources are not yet fully investigated and thus the role of methane in the climate change mechanism is not quite clear. As distinct from CO₂, the disintegration of methane in the atmosphere is via chemical reactions (by OH radical). Residence time of methane in the atmosphere is 10-12 years. At present, the annual total anthropogenic methane emission is said to be approximately 0.4 billion tons, emission from natural sources is about 0.16 billion tons (IPCC⁴ 1995). PFCs, HCFCs, HFCs (perfluorocarbons, hydrochloroflourocarbons, hydrofluorocarbons, etc.) and SF₆ are entering the atmosphere only because of human activity. They are used as carrier gases for sprays, fillings in cooling and extinguishing systems, as insulating substances, as solvents at the production of 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 (CF₄) of 50 000 years. It means that even minor emissions have a great negative effect. The ground level ozone concentrations are growing as a consequence of CO, NO_x and NM VOC emissions. They have very important source in exhaust gases, fossil fuel combustion and as far as NM VOCs are considered, the use of solvents, as well. N₂O enters the atmosphere from several small sources. The most important source does seem to be the emission from soil (nitrogen surpluses because of intensive fertilising and inconvenient agriculture-technical procedures). Fuel combustion, some industrial technologies, large-scale livestock breeding and sewage are the sources of N₂O emissions. Global anthropogenic emission is estimated to be 3-7 million tons of nitrogen per year. Natural sources are approximately twice as large as anthropogenic ones. The N₂O is disintegrated mainly photo chemically in the stratosphere.

1.2 Institutional Arrangement

Ministry of Environment (MoE) of the Slovak republic, Department of Air Protection is the national focal point to the UN FCCC. MoE is granting and supervising development and maintenance of national emission inventories on annual bases. Slovak Hydrometeorological Institute (SHMI), Department of Air Quality (DoAQ) is responsible for coordination and compilation of national emission inventories for all pollutants. SHMI also prepares inventories for international reporting to the UN FCCC and UNECE. SHMI is responsible also for filling the new obligations regarding the EU legislation in air protection and climate change. Slovak Environmental Agency has responsibility for official correspondence between EU and the Slovak republic and SEA is a partner organization to the EEA.

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.).

The SHMI is up to that developing and maintaining a National Emission Inventory System (NEIS) - database of stationary sources to follow development of emissions of SO₂, NO_x, CO at regional level

⁴ *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.*

and to fulfil reporting commitments of national and EU Directives. The NEIS software product is constructed as a multi-module system, corresponding fully to the requirements of current legislation. The NEIS database contains also some technical information about sources like fuel consumption and use for estimation of sectoral approach.

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

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

- to define a National Inventory System (institutions, competences), which will group the experts from all sectors according to IPCC (NFP, SNE, scientific institutions, universities, research institutes, private sector, non-governmental organisations, Statistic Office...);
- to establish an independent working unit entitled the Single National Entity (SNE – according to a COP recommendation), which will coordinate the NIS and have competencies and responsibilities stipulated by law. The SNE will be controlled directly by NFP (MŽP SR), including financial resources;
- the SNE should interlink all stakeholders at the horizontal level with regard to expert, financial, legal and information issues. The SNE should also be responsible for achieving the commitments under the UNFCCC and KP in the field of reporting, assessment and providing information to all stakeholders, administration of national databases (NEIS, IPCC – 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.

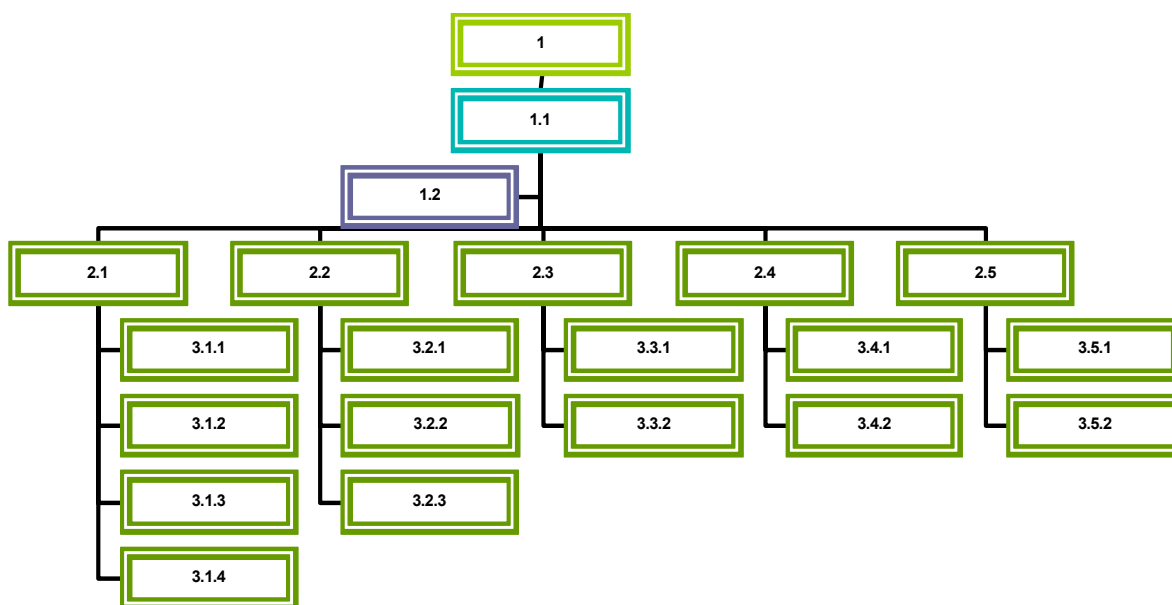
Actually is in place (already prepared Terms of Reference and allocated financial resources) project of the Slovak Ministry of the Environment aimed at proposal of national integrated system of inventory and projections of GHG emissions. The project will be carried out in two phases – after the first phase focused on methodological and organisational aspects 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).

1.3 Process of Inventory Preparation

The emissions of GHGs in the Slovak republic were estimated in compliance with the methods provided in IPCC 1996 Revised Guidelines (IPCC, 1996), Good Practice Guidance (IPCC, 2000), Good Practice Guidelines in LULUCF (IPCC, 2003) and the national methodology in important categories. The values listed in Tables are updated annually if information provided in the Statistical yearbook of the SR is revised and/or if methodology is changed.

The proposed organisational structure (**Figure 1.1**) 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 1.1 The proposal of the organisational structure of the National Inventory System in the SR



1- NFP – the controlling unit of MŽP

Single National Entity 4.1 – 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

Slovak Inventory Agency (SHMI) is using only official IPCC methodology (IPCC, 1996, 2000 and 2003). The data sources are based on official statistical information.

Energy sector - national energy balance – reference approach of CO₂ emissions are based on the Statistic Office of the SR data source for fuels consumption in all relevant categories. The SR was using reference approach as a national total emission's estimate of CO₂ until 2003, but recalculation was providing in the last submission 2006. The national energy balance is based on the sectoral approach from 2000-2004 and the base year 1990 was recalculated, too. The data of fuels

consumption in sectoral approach are based on database NEIS. For preparation of emission inventory in Energy sector was used the IPCC Tier 1 and 2 methodologies.

Transport - The emission balance from road transport was established by using the COPERT III method (EEA, ETC/ACC 2001) and the consistent dataset was recalculated from the base year (1990). The emissions of GHGs from off-road transport were calculated by using CORINAIR (CORINAIR, 2003).

Fugitive emissions - The fugitive emissions from mining and gas distribution were calculated based on the IPCC Methodology (IPCC, 1996) and Good Practice Guidance (IPCC, 2000) by using Tier 1 and Tier 2, IEA CIAB and national data. The sources of data were the Statistic Office of the SR (SO), Ministry of Economy (MoE) and Slovak Gas Industry (SGI).

Industrial Processes sector - This sectoral emission inventory summarizes the emissions of greenhouse gases and precursors CO₂, CH₄, N₂O, NO_x, CO, NM VOC, SO₂, CF₄, C₂F₆, and SF₆ produced by industry in the Slovak republic in each inventory year, followed the instructions of the IPCC Methodology (IPCC, 1996) and IPCC Good Practice Guidance (IPCC, 2000). The information used in the sector was obtained from different sources, the Statistic Office of the SR and major sources of industrial production information.

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).

Agriculture sector - The sources of N₂O and CH₄ emissions from agriculture are analyzed according to IPCC Methodology (IPCC, 1996), when principles of Good Practice (IPCC, 2000) in GHGs inventory in agriculture (1999) were taking account. The basic sources of data used for evaluations of emissions in this study were published in (Statistical yearbook, 1990-2004, Green Report, 1998-2004).

Land Use, Land Use Change and Forestry sector - 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 - Emissions of methane from SWDS and wastewater management were estimated by using the IPCC Methodology (IPCC, 1996) Tier 1 method and Good Practice Guidance (IPCC, 2000). The emissions of N₂O from wastewater management were estimated by using both IPCC and ISI methodology (ISI, 1993). For the national emission inventory was used ISI methodology, which brings the more comparable and consistence dataset in time.

Other sectors - Other sectors are not relevant in national emission inventory balance.

1.5 Description of Key Sources

To reduce uncertainty in emission inventory is important to recognise the key source categories. 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 2004 sixteen key source categories by level assessment and twenty-four key source categories by trend assessment (Annex 1). The most important key source categories in the SR are fuel combustion, road transport and the emissions of CO₂ from agricultural soil etc.

1.6 QA/QC Procedure

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.). 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 Emission System. Structural changes of the current national inventory system, 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.

1.7 General Uncertainty Evaluation

The uncertainty of estimation of CO₂ emissions is mainly caused by uncertainty of statistical data on consumption. Another source of uncertainty is the applied default emission factors. An additional error in calculation of the other greenhouse gas emissions may occur as a result 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). The calculation uncertainty by using the more sophisticated Tier 2 - Monte Carlo method was at this time impossible due to the lack of input data and resources. Even though the Tier 1 uncertainty analysis were estimated the uncertainties to be 9.70% by level assessment and 3.58% by trend assessment (Annex 1).

1.8 General Assessment of the Completeness

The Slovak republic is reported in its CRF 2004 submission 2006 gases or source/sink categories as not estimated (NE) and categories, whose are reported as included elsewhere (IE) are explained in Tables 9 CRF. The additional GHG emissions are not reported. In some categories (waste incineration, off-road transport etc.) 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.

2 TRENDS IN GREENHOUSE GAS EMISSIONS

2.1 Emission Trends for Aggregated GHG Emissions

In accordance with the generally expected results, the aggregated emission of GHGs in year 2004 moderate decreased comparable to the year 2003 about more than 50 Gg without sinks from LULUCF (app. 1%). There is the significant decreasing of aggregated emission against the base year (1990) about approximately 22 000 Gg it means the decreasing about more than 30% without sinks. The total national emission in the current year 2004 was estimated to be 51 046.16 Gg without sinks from LULUCF sector and the net GHG emission was 46 795.27 Gg including the sinks from LULUCF. The Slovak republic reported the national emission from Energy sector based on sectoral approach data in 2004 to be 40 150.30 Gg CO₂ equivalent including the transport emissions (5 682.46 Gg of CO₂ eq.), which represent decrease compare the base year by about 32%. The total emissions from Industrial Processes sector in 2004 were estimated to be 4 852.27 Gg of CO₂ eq. (decrease compare the base year by about 14%). The emissions from Agriculture sector were estimated to be 3 859.54 Gg (decrease compare the base year by about 52%), the emissions from Waste sector were estimated to be 2 083.40 Gg of CO₂ eq. (no decrease was registered, because of including the waste incineration from year 2000). The emissions from solvent use were estimated to be 79.92 Gg of CO₂ equivalents and were included the first time into the submission. The whole time series from 1998 were recalculated according the activity data, which were available. The total sinks from LULUCF sector were estimated to be -4 230.16 Gg of CO₂, the whole time series 1990-2004 were recalculated according the new methodology and those emissions and sinks were included into the submission. A major share of aggregated emission covers the Energy sector by about 79%, the Industrial Processes sector covers about 10%, the Agriculture sector about 8% and the Waste sector about 4% (**Figure 2.1**). The major share of aggregated emission covers CO₂ emissions by about 83%, CH₄ emissions by about 8%, N₂O emissions by about 8% and F-gases emissions by about 0.4% (**Figure 2.2**).

Figure 2.1 The aggregated GHG emissions by sectors in 2004

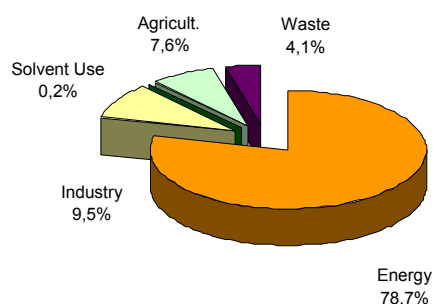
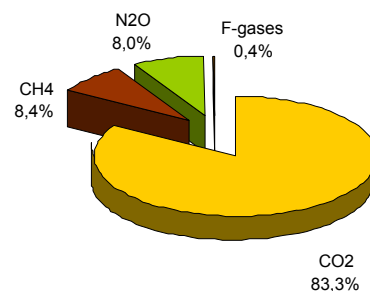


Figure 2.2 The aggregated GHG emissions by gases in 2004

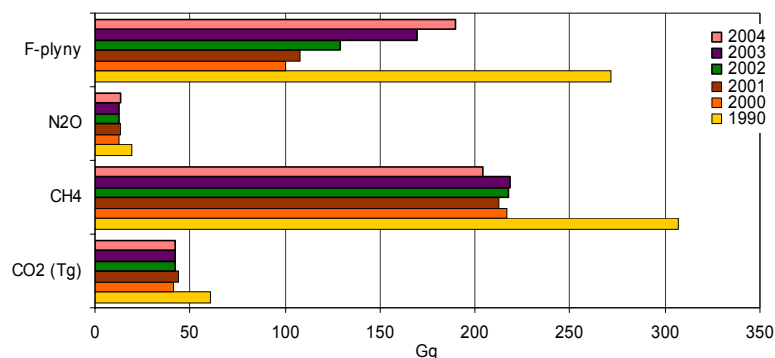


2.2 Emission Trend by Gas

The total anthropogenic emissions of carbon dioxide decreased relating to the base year (1990) by about 30% without LULUCF and represented in current year 42 498.11 Gg without LULUCF. The total anthropogenic emissions of methane reached in the 2004 almost 204 Gg and decreased relating the previous year about 15 Gg. The significant decreasing of CH₄ emissions from energy and Agriculture sector caused this effect. On the other hand, the total anthropogenic emissions remarked the 33% decreasing comparable with the base year (1990). The total emissions of N₂O increased relating the previous year to 13.15 Gg and increased relating the previous year about 0.5 Gg. The total decreasing comparable with the base year presents 33%. The total emissions of F-gases represented 189.64 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 22% decreasing, caused by decreasing a consumption of perfluorocarbons (**Figure 2.3**).

Figure 2.3 The emission trends by gas in 2004 submission for the recalculated years 1990, 2000-2004

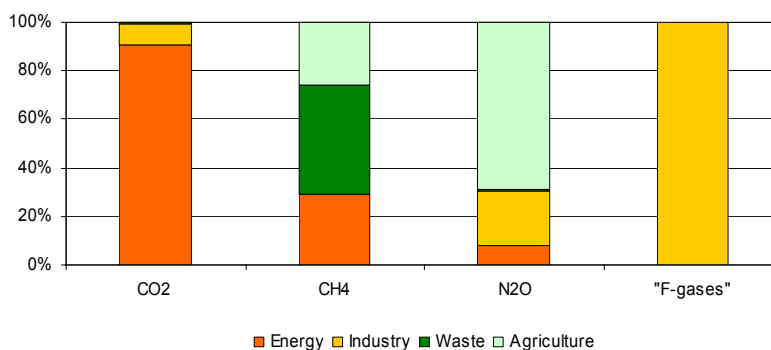


*The total anthropogenic emissions of CO₂ are depicted in Tg (not in scale)

2.3 Emission Trend by Source

The major share of CO₂ emissions is from Energy sector (fuel combustion, transport) with more than 90% from the total carbon dioxide emissions in last 2004 inventory. More than 44% of CH₄ emissions produces Waste sector (SWDS), more than 68% of N₂O emissions produces Agriculture sector (fermentation) and 100% F-gases emissions come from Industrial Processes sector as depicted on **Figure 2.4**.

Figure 2.4 The emission trends by source in 2004



2.4 Emission Trends for Indirect GHGs and SO₂

The total anthropogenic emission of NO_x was estimated to 98.19 Gg and the major share was produced by Energy sector. The total emission of CO was estimated to 309.78 Gg and the major share of emissions was produced by Energy sector. The emission of NM VOC was estimated to 85.03 Gg per year 2004 and the major share was produced by Energy, Industrial Processes and Solvent-Use sectors. The emissions of SO₂ were estimated to 96.86 Gg per year 2004 and the major share of emissions was produced by Energy sector.

3 ENERGY SECTOR

3.1 Fuel Combustion Activities

3.1.1 Energy Industry

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 (**Figure 3.1**).

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 accredit 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. New system contained 925 large point sources from 79 the NEIS BU district databases in 2004. 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 2004 system NEIS registered 12 697 medium sources of the heating output of 0.2-5 MW. The emission balance in 2000-2004 was 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 3.2**).

The energy balance "bottom up" using the IPCC (IPCC, 1996) detail method Tier 2 and IPCC default emission factors for each fuel category and each IPCC category (Annex 3). The CRF sectoral background tables 1.A(a)s1-4 are estimated and filled in according the parameters published in NEIS system by operators of large, medium and small sources. Each operator is obligate to publish type of production, amount of consumed fuel's types in kt, separation of fuel use for combustion and technology, fuel's type of specific NCVs and other relevant parameters. The default and national emission factors for each IPCC subcategory 1.A.1-5 and each fuel type (coking coal, lignite, natural gas etc.) are used based on recommendation IPCC Guidelines and experts from Profing Ltd. Bratislava (Profing, 2003).

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

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 2004 was determined to 707.92 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 balance.

Figure 3.1 A distribution of CO₂ emissions in type of fuels in RA in 2004

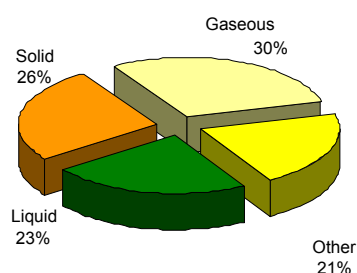
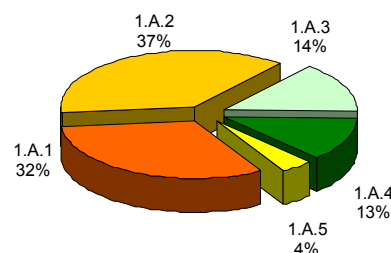


Figure 3.2 A distribution of CO₂ emissions in the IPCC categories in SA in 2004



Emission Factors

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). The national emission factors for CO₂ are in use for this time, for natural gas from year 2000. The emission factors for natural gas are based on preciously 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 (**Table 3.1**).

Table 3.1 The parameters of the natural gas published by Slovak Gas Industry on-line (www.spp.sk)

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

For the time series 1990-1999 the IPCC default emission factor for natural gas was used (56.1 t CO₂/TJ) and the emissions from combustion of NG were recalculated. The values of fraction of carbon oxidized were changed followed the recommendation of IPCC representative back to the IPCC default values (0.99 for liquid and gaseous fuels, 0.98 for solid fuels) for whole time series.

Recalculation and Time Series

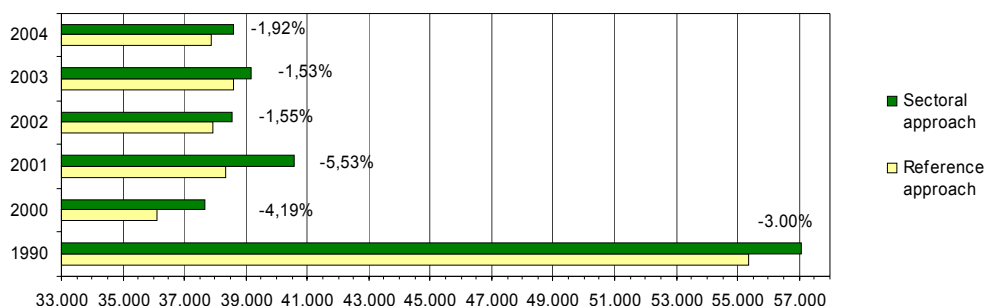
For the submission in 2006, the Slovak republic has made extensive methodology changes and recalculations. The previous submissions to the UNFCCC were based on the reference approach in calculation of the national GHGs emission total. In the latest submission 2006, the Slovak republic is using sectoral approach as a reference value of the Energy sector for the year 1990 and 2000-2004. The recalculation and difference between two approaches are showed in **Table 3.2**. The other years (1991-1999), which were not recalculated until now, use the reference approach for estimation a national total.

Table 3.2 The sectoral and reference approaches for the recalculated years 1990, 2000-2004

Year	1990	2000	2001	2002	2003	2004
Sectoral approach (CO ₂ Gg)	57 053.26	37 665.82	40 562.61	38 550.83	39 183.33	38 592.94
Reference approach (CO ₂ Gg)	55 342.48	36 088.63	38 318.52	37 953.07	38 582.53	37 850.05
Difference in %	-3.00	-4.19	-5.53	-1.55	-1.53	-1.92

The total anthropogenic emission of carbon dioxide from Energy sector – fuel combustion was estimated in the inventory 2004 to be 38 592.94 Gg as a national total CO₂ emissions (**Figure 3.3**). The higher difference between sectoral and reference approach in the older submissions is caused by the complicated situation in the national database NEIS in 2000 and 2001, changes in the legislation in air protection.

Figure 3.3 A comparisons of SA and RA in 1990, 2000-2004



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 -1.92% (**Figure 3.3**). The differences in fuel consumption between these two approaches can be caused by using average NCVs (net calorific values) in reference approach and fuel specific NCVs in sectoral approach. In the sectoral approach, the quantities of fuels used in blast furnace (IPCC category 1.A.2a – solid fuels and gaseous fuels) were excluded from energy balance and the quantities of residual carbon from combustion which stayed in products were excluded from energy balance (IPCC categories 1.A.1c – other fuels and 1.A.2c – liquid and gaseous fuels). Since 1990, the total fuel combustion decreased significantly and the share of natural gas as an alternatively fuel type increased. After the medium increase of solid fuels in 2001, the slightly decreasing in 2002-2004 was appeared in energy balance. The balance of solid fuels consumption is complicated with the calculation of the stock change. The Statistic Office of the SR updates the fuel's categories and methodology for stock fuel annually. Therefore, it is a problematic situation with providing the consistent data series in last year's inventories in reference approach. The quality of data used for bottom-up approach is higher, because this data are checked more time (by the operators, by providers of NEIS database, by sectoral expert and by inventory unit).

The Slovak republic is preparing the deep revision of national energetic balance from 1991-1999. The base problem is to change inventory methodology from reference approach (the national energetic total from 1990) to the sectoral approach (now only informative character). The revision will be touching the fuels base, NCV and emission factors at all in the comparison of data from EC Emission Trading Scheme. The revision was started this year and will be develop with the Profing Ltd.

Key Source and Uncertainties

The emissions of CO₂ from these categories (liquid, solid and gaseous fuel's combustion) are the most important key sources and they have a decisive effect on the level and trend uncertainty management (Annex 1). The emission balance of other GHGs (CH₄, N₂O) from 1.A.1-5 IPCC categories was estimated by using IPCC methodology (IPCC, 1996) and default emission factors in like manner as previous year. These categories are not key source.

3.1.2 Road Transport

Aim of the transport category is the emission check of basic pollutants (CO, NO_x, SO₂) and solid particles - TSP, PM₁₀, PM_{2.5}, NM VOC emissions and heavy metals, emissions of persistent organic substances (POPs) and greenhouse gases (GHG) produced by road transport in the Slovak Republic in year 2004. 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 2004 included also the emissions from light and heavy-duty vehicles, buses operated by CNG (Compressed Natural Gas) for 2000-2004. 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 1).

Methodology and Activity Data

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

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

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

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

Emission Factors

The emission factors for the group of pollutants such as CO₂, SO₂, N₂O, NH₃, PM and partially also CH₄ is possible to obtain with the simply formula between driving mode and consumed fuel. This value is constant for the different vehicles categories. Emission factors are automatically calculated by

COPERT III based on input parameters – average speed, quality of fuel, age of vehicles, weight of vehicles, and volume of cylinders...

Emissions

The share of emission estimation of GHGs from road transport in 2004 is presented on the **Figure 3.4** and in the **Table 3.3** in the classification of the based group of vehicles fleet, according the structure of COPERT III. The total emissions of CO₂ from road transport reached in 2004 - 5 154.79 Gg. The major share belongs to the duty vehicles and passenger cars.

Figure 3.4 A share of individual vehicles in road transport in 2004

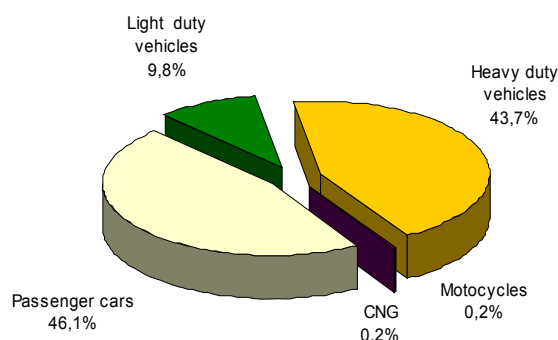


Table 3.3 is completed with the information about share of emissions to the operations: city, road and highway traffic.

Table 3.3 The results in GHGs emission balance in 2004 in the road transport

Category of road vehicles	Emissions GHG in 2004 [t]			Category of road vehicles	Emissions GHG in 2004 [t]		
	CO ₂	CH ₄	N ₂ O		CO ₂	CH ₄	N ₂ O
Passenger cars	2 377 520	878	322	Heavy duty vehicles	2 253 115	232	114
gasoline < 1,4 l	1 117 520	547	154	gasoline > 3,5 t	292	0	0
gasoline 1,4 l - 2,0 l	599 272	239	83	diesel 3,5 - 7,5 t	484 940	60	42
gasoline > 2,0 l	138 363	48	12	diesel 7,5 - 16 t	494 783	35	25
diesel < 2,0 l	325 878	12	52	diesel 16 - 32 t	775 357	75	29
diesel > 2,0 l	82 998	3	13	diesel > 32 t	44 263	2	1
LPG	112 627	29	8	City buses	235 633	34	8
Two stroke engine	862	0	0	Long-line buses	217 847	26	9
Light duty vehicles	503 594	42	34	Vehicles on CNG	8 768	88	0,3
gasoline < 3,5 t	132 577	33	10	Motorcycles	11 792	16	0
diesel < 3,5 t	371 017	9	24	< 50 cm ³	3 801	3	
				Two stroke engine > 50 cm ³	6 136	9	
				Four stroke engine < 250 cm ³	257	1	
				Four stroke engine 250 - 750 cm ³	613	1	
				Four stroke engine > 750 cm ³	985	2	
				Sum in the SR	5 154 789	1 256	471
Traffic				Emissions GHG [t]			
				CO₂	CH₄	N₂O	
City				2 345 741	971	231	
Road				1 992 481	224	160	
Highway				816 567	61	80	
Sum in the SR				5 154 789	1 256	471	

Recalculation and Time Series

The emissions of GHGs from road transport in 2002 were recalculated. In the time series 2000-2004 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 2004. The year 2002 was recalculated and the actual emissions are included into the CRF 2004.

Avoiding this double counting in the future is to higher the objectivity and verification of the data from the companies and organisations. The data are required in the more aggregated format.

Trends in Emissions and Fuels

The trend in the production of the CO₂ and N₂O emissions from road transport correspond with the consumption of the fuels. The emission factors are constant during the time series. The development of the Slovak economy is accompanied with the increasing of the road transport and the fuel consumption (mostly diesel). For the CH₄ emissions are primary important the vehicles alteration for the vehicles with better environmental and energetic parameters (mostly personal cars with catalyzes).

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 2004. 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 3.4**). The consumption of the fuels (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 3.5**).

Table 3.4 The statistic information about the railways organisation structure in 2004 (Traction 70+80)

Statistic Data Traction 70+80	Number Year run Consumption Consumption	Košice	Žilina	Zvolen	Bratislava	Sum
	[number]	218	111	233	183	745
	[km]	8 196 553	2 995 849	10 470 431	6 518 785	28 181 618
	[hrtkm]	577 907 411	242 573 449	2 056 800 304	567 896 544	3 445 177 708
	[l]	10 410 919	3 364 179	18 377 820	8 719 223	40 872 141
	[t]	8 745	2 826	15 437	7 324	34 333

Table 3.5 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	
Diesel oil (kt)	54.15	49.57	48.86	48.18	44.76	35.80	34.33	

Navigation - the most important source of pollution from navigation transport in the SR is the shipping activity on the Danube River. Other shipping activities are negligible. The shipping on Danube is realized from 1 708-river km (Szob) to the 1 880-river km (Devin) in the three basic shipping modes: transit, Bratislava port and Komarno port. The most of the navigation transport in the SR is international. The statistical information about fuel consumption are not available from the objectives reasons, the national method was developed. The method is based on the indirect determination of the fuel consumption from the statistical information about shipping activity and technical parameters of the ships.

Civil Aviation – the emission balance was performance from the most important civil airports in the SR whit the international operation: Bratislava, Piestany, Sliac, Poprad – Tatry, Kosice and Zilina. Avian motors produce the local emissions pollution of the airports during the operation on the airport – it is called LTO cycle. This LTO cycle involves engine idle and rolling, take-off, elevation into the 900 m, landing and set-down. The pollution from the airport's service mechanisms is counted into the emissions from aviation transport, too.

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 3.6**. The emissions are divided according the type of the railways operation (passenger, freight and service transport) from 1995.

Table 3.6 The fuel consumption and the emissions in the 2004 in the railways

Traction 70+80	Diesel oil consumption		Emissions [t]		
	[l]	[t]	CO ₂	N ₂ O	CH ₄
Emission factors for the motor locomotives and wagons	kg / t diesel oil		3 188	1,37	0,19
Košice	10 410 919	8 745	27 879.6	11.98	1.66
Žilina	3 364 179	2 826	9 009.0	3.87	0.54
Zvolen	18 377 820	15 437	49 214.3	21.15	2.93
Bratislava	8 719 223	7 324	23 349.4	10.03	1.39
RC SR Sum	40 872 141	34 333	109 452.3	47.04	6.52

Navigation – the same EFs for the diesel oil consumption in the navigation transport were used like in the railways transport. The following **Table 3.7** shows the balance of the fuel (diesel oil) consumption in the navigation transport with the used EFs and the estimated emissions of GHG.

Civil Aviation – 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 2004 was 32 072 cycles. The total consumption of jet kerosene was 27 383.44 t (35 106 972 l) and the consumption of aviation gasoline was 156.51 t (211 505 l). The CO₂ emission factors (EFs) from consumption of aviation gasoline and jet kerosene are irrelevant (Table 1.A.3a), the estimation of emissions from aviation was based on Tier 2 method (LTO cycles) using the corresponding default EFs from this methodology and not from consumption of fuels.

Table 3.7 The fuel consumption and the emissions in the 2004 in the navigation transport

Year	Diesel oil consumption [t]	Emissions [t]		
		CO ₂	N ₂ O	CH ₄
EFs kg/t diesel oil		3 188	0.10	0.25
1990	44 732.7	142 608	4.47	11.18
EFs kg/t diesel oil		3 188	1.37	0.20
1995	32 540.7	103 740	44.58	6.51
2000	35 729.0	113 904	48.95	7.15
2001	37 460.2	119 423	51.32	7.49
EFs kg/t diesel oil		3 188	1.37	0.19
2002	38 539.6	122 864	52.80	7.32
2003	38 481.9	122 680	52.72	7.31
2004	43 092.5	137 379	59.04	8.19

The statistic information about national and international consumption of aviation fuels are missing. That the reason for the expert estimation in the international bunkers from civil aviation. The emissions from international bunkers from civil aviation were improved in the last year and the expert's judgment was used in this estimation. A total consumption of gasoline was divided in domestic consumption (80%) and international consumption (20%). The total consumption of jet kerosene was estimated in opposite ratio (25% of domestic and 75% of international consumption). There is no relationship between international bunkers from civil aviation and the total emissions of CO₂ from aviation, which are based on LTO cycles.

For the purpose of the international bunkers is necessary to estimate the so-called mixed EFs for aviation gasoline, and jet kerosene. The information are shown in the following **Table 3.8**. The mixed emission factors estimated according the input data and the CORINAIR (CORINAIR, 2003) methodology are shown in the next **Table 3.9**. With the mixed EFs were performed the estimation of GHGs emissions based on the fuel consumption for the national and the international civil aviation transport. This estimation is with no relationship with estimation of GHGs emissions based on LTO cycles, which is determining in the SR.

Table 3.8 The data of national and international flights in 2004

Input data for the estimation of mixed EFs		
Parameter	International flights	National flights
Fuel	Jet kerosene	
Aircraft	B 737-500, (400,100)	EMB-120, Saab 340B
Average distance of the flight	1365 km	375 km
Average duration of the flight	1.75 hrs	0.75 hrs
Average speed	780 km/hrs	500 km/hrs

Table 3.9 The mixed EFs in the estimation of international bunkers

Mixed EFs		
Parameter	EFs [g/kg fuel]	
	International flights	National flights
Emissions	Jet kerosene	
CO ₂	3 150	3 150
N ₂ O	0.104	0.35
CH ₄	0.05	0.25
Emissions	Aviation gasoline	
CO ₂	3 150	
N ₂ O	0.1	
CH ₄	1.9	

Recalculation and Time Series

The inter-annual decreasing of the diesel oil consumption in motor traction of railways in 2003/2004 is 4.1% (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.

The navigation transport shows an increasing in the diesel oil consumption and the higher shipping activity in 2004 comparable with the year 2003 by 12%. This is the reason of the higher emission of GHGs. According to the environmental and energetic most beneficial transport is this fact evaluated positive despite of increasing the emissions. We are expected this trend also in the future.

Against the previous year 2003 was in the emissions from civil aviation strong increasing development observed - about 16% in the actual year 2004. 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 1). In the 2004 are mined 2 951 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 2004 was estimated to be 19.77 Gg (17.99 Gg of CH₄ from underground coal mining and 1.78 Gg of CH₄ from post-mining activity) (**Figure 3.5**). The Slovak inventory team with cooperation of Profing Ltd. was provided the revision of emissions and emission factors for underground coal mining and handling during the year 2004 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 post-mining 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 3.10** provides the values of coal production from 1992.

Table 3.10 The total brown coal production in the SR during 1992-2004

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	Brown coal (kt)												
Mining	3 803.5	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

Step B – Emission factors. For the calculation of fugitive methane emissions there were used the emission factors from following sources (**Table 3.11**):

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

Table 3.11 EF_{CH₄} 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 _{CH4} [m ³ /t]							
1. IPCC Guidance for National Greenhouse Gas Inventories								
IPCC mining tier1	10	10	10	10	10	10	10	10
IPCC post mining	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
2. IEA - CIAB Global Methane and the Coal Industry								
EF(CIAB) mining	6	6	13	13	13	13	13	13
IPCC post mining	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
3. EF _{CH4} specified of the mines operator - HBP, a.s.								
Mining-measure	0.92	4.17	0.00	4.17	0.00	4.17	0.02	0.02
Post mining	0.39	0.46	0.00	0.46	0.00	0.46	0.01	0.01

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

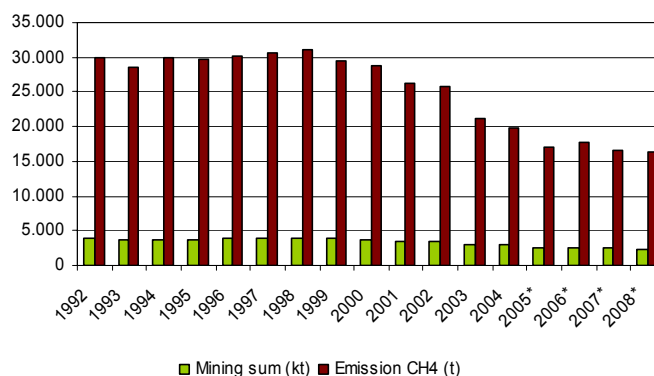
Emission Factors and Emissions

Emission factors according to IPCC Guidance - for all mines have been used the identical values 10 m³ CH₄/t for coal mining and 0.9 m³ CH₄/t for post-mining. Both values are on the lower level of the suggested scale. Emission factors according to IEA – CIAB – the published values for mining were assigned according to the depth of the mines within 6 a 13 m³ CH₄/t and 0.9 m³ CH₄/t for post-mining activity. There were used the values on the lower level of the suggested scale as well as in the previous case. EF (CH₄) specified of the mines operator - HBP, a.s. on the base of measurement concentration values of the methane and amount of ventilation air data, were assigned to single mines according to suggestion of the operators. EF (CH₄) for post-mining have been used from IPCC Good

⁵ <http://spider.iea.org/ciab/>

Practice Guidance (IPCC, 2000), for mining without drainage, with known of gas amount - in the coal after mining is present 30% of gas and for mines with pre-drainage, 10% of gas (**Figure 3.5**).

Figure 3.5 Trends in coal mining productivity and methane emissions from mining and post-mining activity in 1990-2008* (*with predictions)



The **Figure 3.6** below shows comparison of trends emissions CH₄ in SR in years 1992 - 2008, calculated according to emission factors of IPCC, IEA-CIAB methodology and EF (CH₄) HBP a.s. In the case of emissions calculation with using of IPCC emission factors, the trend of fugitive emissions CH₄ is declining in accordance to reduction of coal mining in SR. Application EF (CH₄) specified of mines operator (HBP, a.s.) - trend of fugitive emissions CH₄ 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 3.11** point 2) as a best appropriated. **Table 3.12** presents recalculated fugitive emissions from coal mining and handling and the post-mining activities during 1990-2004.

Figure 3.6 Comparison of trends emissions CH₄ in SR in years 1992 – 2008* (*with predictions)

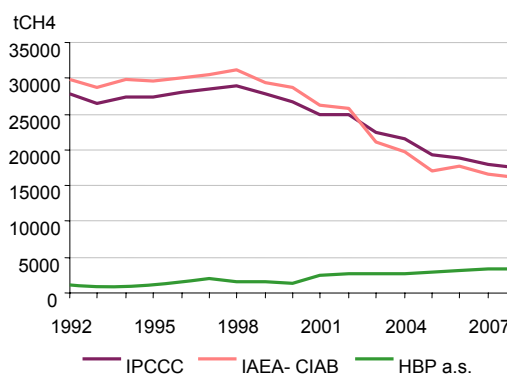


Table 3.12 The total CH₄ fugitive emissions from mining and post-mining activities in the SR in 1990-2004

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	Fugitive emissions of CH ₄ (Gg)														
Mining	25.11	26.62	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
Post-mining	2.084	2.209	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
Total	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

Post-mining activity emissions represents the rest of gaseous methane present in the mined coal. This source of emission releases the methane into the atmosphere during the manipulation and storage of coal. The measurement of these emissions are not realised and the emission estimation must be done with the default emission factors. It is assumed, that 25-40% of CH₄ is present into the coal. For the without drainage mines is recommended to use 30% and for the pre-drainage mines the emission factor 10%. The following **Table 3.13** presents the emission factors for the Slovak mines.

Table 3.13 The post-mining EFs in the mines in the SR

Mines	Post-mining EF CH ₄	
	m ³ CH ₄ /t brown coal	kgCH ₄ /t brown coal
Mine Nováky	0.39	0.261
Mine 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 CH₄ 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 $\pm 10\text{-}15\%$ 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 1). The total methane emissions represent 34.32 Gg in 2004 and were recalculated in the previous submission back to the base year because of estimation of emissions from venting and flaring. The fugitive emissions CH₄ from transport and distribution of natural gas in SR have been calculated with IPCC default methodology from following activity data into the three steps:

Step A - Data of natural gas have been obtained from official sources – Slovak Gas Industry, Ltd., Ministry of Economy of SR and Statistic Office of the SR (**Table 3.14**).

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 the SR are 152 mil.m³ (106 937 t CH₄) according to preliminary balances of gas fuels in year 2004 (Statistic Office of the SR). This value represented approximately 2% of total NG consumption in SR.

Table 3.14 The data in year 2004 - production, export and import NG in SR

SR	Natural gas [m ³]	Natural gas [PJ]
Indigenous production	165 000 000	5.943
Associated gas	16 000 000	0.576
Nonassociated gas	149 000 000	5.367
Stock changes	-393 000 000	-13.449
Gas vented	2 000 000	0.071
Gas flared	4 000 000	0.141
Export	1 000 000	0.035
Import	6 949 000 000	237.750
Inland consumption	6 720 000 000	230.205

The calculation of fugitive methane emissions from transport and distribution of NG in SR according to Slovak Gas Industry, Ltd. methodology (national approach) is based on the calculation of leakages of NG from the compression stations and from transport pipelines. There are four big compression stations (KS1 – Velke Kapusany, KS2 – Jablonov nad Tunov, KS3 – Velke Zlievce and KS4 – Ivanka pri Nitre) and three transport pipelines (ZLC Roznava, HPS Velky Krtis, ZLC Nitra) in the Slovak republic. The estimation of the leakages from these facilities is **7 448 t of CH₄** (according the continual measurements). The distribution losses in the distribution pipelines were estimated according to the expert's judgment of the Slovak Gas Industry, Ltd. with the following methodology:

Distribution losses [kg CH₄] = 1 000 000 [m³ NG] * (273.15/(273.15+15))*0.7176 = **703 t of CH₄**.

Fugitive emission CH₄ from transit and distribution of NG = 7 448 + 703 = **8 151 t of CH₄**.

An additional emissions are fugitive emissions from NG and oil production in SR = **1 434 – 3 755 t of CH₄** (calculated according to IPCC methodology – table 6). That is mean, that the total fugitive emissions of CH₄ from transit and distribution of NG + from NG and oil production in SR are **9 5853 – 11 904 t of CH₄** according to the national methodology. This approach seems to be less quality, that the estimation with the applications new refined EF (CH₄) (high) for tier 1, based on North America data (IPCC). The national data from Slovak Gas Industry, Ltd. are not available for the whole time series from 1990.

Emission Factors and Emissions

The fugitive emissions from transport and distribution of NG were calculated according using the new emissions factor refined EF (CH₄) for tier 1, based on North America data - IPCC Good Practice

Guidelines, table 2-16 (max. level of emissions – 34 318 t CH₄). In the **Table 3.15** are presented of fugitive methane emissions for activities related to NG and Oil operations, calculated with applications new refined EF (CH₄) (high) for tier 1, based on North America data.

Table 3.15 New refined EF (CH₄) for tier 1, based on the balance in North America

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

The results of the calculated fugitive methane emissions (**Table 3.16**) show, that disaggregating of gas and oil industry to main- and sub-categories according to principles „good practice“ improved quality of balances. The results received from the calculation of methane emissions with applications new refined EF (CH₄) (high) for tier 1, based on North America data are the most real values. The trend of fugitive emissions CH₄ from transport and distribution of natural gas in SR is increasing. It is due to the expansion of the distributed system and growth of NG consumption in SR.

Table 3.16 Fugitive methane emissions calculated with applications new refined EF (CH₄)

Category	Quantity	Unit	EF(low)	EF(high)	CH ₄ (low)	CH ₄ (high)
			GgCH ₄ /mil.m ³ NG GgCH ₄ /km	GgCH ₄ /mil.m ³ NG GgCH ₄ /km	t CH ₄	t CH ₄
NG* production fugitive	165 000 000	m ³ ZP	2.60E-03	2.90E-03	1 323.76	1 323.76
NG* production flaring	165 000 000	m ³ ZP	1.10E-05	1.10E-05	25.01	25.01
NG processing fugitive	165 000 000	m ³ ZP	6.90E-04	1.07E-03	113.85	176.55
NG processing flaring	165 000 000	m ³ ZP	1.30E-05	1.30E-05	2.15	2.15
NG storage fugitive	32 542 000	m ³ ZP	4.30E-04	4.20E-03	168.99	1 650.60
NG transport fugitive	2 268	km	2.10E-03	2.90E-03	4 762.80	6 577.20
NG transport venting	2 268	km	8.00E-04	1.20E-03	1 814.40	2 721.60
NG distribution fugitive	29 000	km	5.20E-04	7.10E-04	15 877.68	21 679.14
Oil production fugitive	42 000	t	1.40E-03	1.50E-03	53.20	57.00
Oil production venting	42 000	t	6.20E-05	2.70E-04	2.36	10.26
Oil production flaring	42 000	t	5.00E-06	2.70E-04	0.19	10.26
Oil transport fugitive	9 929 496	t	5.40E-06	5.40E-06	55.75	55.75
Total					24 200.13	34 289.27

Note: NG* production – the values of fugitive and flaring methane emissions were calculated on base reported data of vented NG - 2 mil.m³ and flared NG - 2 mil.m³ (Statistic Office of the SR - 2005).

Table 3.17 presents recalculated fugitive emissions of methane from transport and distribution of natural gas activities during 1990-2004 according the IPCC Good Practice Guidelines, Table 2-16 methodology using the EF (high) (IPCC, 1996).

Table 3.17 The total CH₄ fugitive emissions from transport and distribution of NG in the SR in 1990-2004

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	Fugitive emissions of CH ₄ (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

Trends and Time Series

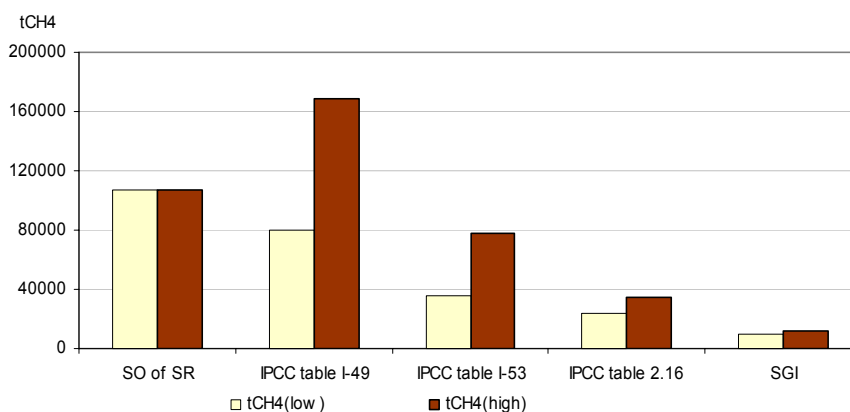
The trend of fugitive emissions of CH₄ from transport and distribution of natural gas in SR is increasing. It is due to the expansion of the distributed system and growth of NG consumption in SR.

The comparison between the methodologies used for calculation (national approach according the Slovak Gas Industry, Ltd. and IPCC) of the fugitive methane emissions from transport and distribution of natural gas in SR is shown on **Figure 3.7**.

The application EF(CH₄) - IPCC default from oil and NG for regions of former USSR and Eastern Europe (IPCC Guidelines, Reference Manual Table I-49) gives too high results (79 769 – 168 730 t of CH₄). As the estimate of Statistic Office for distributed losses (106 937 t of CH₄), are approximately 3.3 - 4.9 times higher as the recommended values (34.32 kt of CH₄).

For the balance of the fugitive methane emissions from transport and distribution of natural gas in SR is by expert's judgment recommended to use value, calculated using applications new refined EF CH₄ for tier 1, based on North America data - IPCC Good Practice Guidelines, Table 2-16 (max. level – 34.32 t of CH₄).

Figure 3.7 Comparison of the fugitive methane emissions calculated from IPCC factors and Slovak Gas Industry, Ltd. methodology

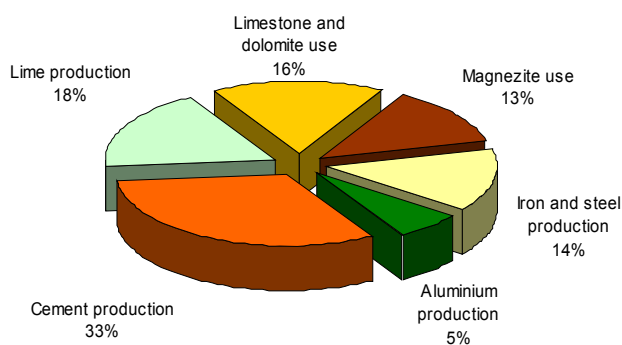


4 INDUSTRIAL PROCESSES

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

Whereas the N₂O emissions comes from the nitric acid *production* only (2.92 Gg) (this category is key source by level and trend assessment), the cement, lime, limestone and dolomite use and iron & steel production are very important key sources of CO₂ emissions. Total anthropogenic emissions of CO₂ from this sector are 3 757.20 Gg and the major share comes from mineral production (2 982.04 Gg) (**Figure 4.1**).

Figure 4.1 A share of individual technologies in Industrial Processes sector in 2004



4.1 Cement Production

Methodology and Activity Data

Cement is produced by a high temperature reaction of calcium oxide (CaO) with silica (SiO₂) and with alumina (Al₂O₃). A source of calcium oxide is limestone (CaCO₃). As the cement clink is produced at the temperature of 1 450°C the reaction produces carbon dioxide. The other emissions originate from impurities in the raw material (SO₂). Content of cement clink in cement varies in the range 63.6%-94%. The weighted average value of the clink content in the cement is 75.1% in 2004. This value is known for every cement plant. According to the IPCC Methodology (IPCC, 1996) it is good practice, that amount of CO₂ emission is calculated from the mass of produced cement clink. However, in the Statistical yearbook (SY, 2004) there is only mass of produced cement available. Therefore, emission of CO₂ is calculated from the mass of produced cement. The weighted average value of the clink

content in the cement is 74.9% with uncertainty 5.7%. The content of CaO in the cement clink varies from 65% to 70%. The value of the weighted average is 67.0% with uncertainty 1.2%.

Emission Factors and Emissions

In 2004 it follows that the emission factor of CO₂ related to the cement clink is 526.1 kg CO₂/t of cement clink with uncertainty 1.2% in 2004 (0.785×0.526). The emission factor of CO₂ recalculated to the production of cement is 400.6 kg CO₂/t of cement with uncertainty 9.4% (only the plants, where the clink is produced, are included). The total sum of cement production in the Slovak republic was 2 982 510 t. The emission factor of CO₂ is 386.2 kg CO₂/t of cement based on the total cement production. However, this emission factor has no theoretical background (**Table 4.1**).

Table 4.1 A comparison of EFs and emissions of CO₂ in 2000-2004

	2000	2001	2002	2003	2004
Emission Factor of CO ₂ [t/t of cement clink]	0.5052	0.5016	0.5063	0.5157	0.5261
Emission Factor of CO ₂ [t/t of cement]	0.3800	0.3800	0.3643	0.3862	0.3862
Emission of CO ₂ [Gg]	1 168.884	1 187.430	1 144.187	904.995	1 194.840

Key Source and Uncertainties

The cement clink category is a key source in level and trend assessment. 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 clink (2%), composition of limestone (3%), composition of clink (2%, except of Povazska cementaren, Ladce – 7%) and mass of non-reacted limestone (5%) were estimated according to IPCC Good Practice Guidelines for each plant. It follows that uncertainty of EF (per clink) is 2.1% and uncertainty of CO₂ emissions from cement clink production is 3.5%.

4.2 Lime Production

Methodology and Activity Data

From a chemical point of view, lime is calcium oxide (CaO). It is produced by the thermal decomposition of limestone at the temperatures of 1 040°C-1 300°C. Carbon dioxide is produced according to the same reaction scheme as shown above in the case of cement production. According to the new data on average purity of lime, the purity of lime varies in the range 84 – 97%. The weighted average value is 92.5% with uncertainty 3.0%.

Emission Factors and Emissions

The emission factor of CO₂ using the new data on purity of lime is 725.9 kg CO₂ per 1 ton of lime (0.785×0.925). In older inventories, the value 97% was used. Therefore, the recalculation of the CO₂ emissions since 1990 has been necessary (**Table 4.2**).

Table 4.2 The recalculated CO₂ emissions from lime production in the SR in 1990-2004

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	(Gg)														
Lime Production	1.076	819	616	727	765	803	764	685	744	759	754	816	919	847	961
Emissions CO ₂	770	586	441	521	548	575	547	490	533	544	540	584	658	606	688

Key Source and Uncertainties

It should be mentioned that calculation of uncertainties according to Monte-Carlo method could not be done because of lack of necessary data. Thus, the uncertainties in mass of lime (2%) and content of CaO in lime (2%) were estimated according to the IPCC Good Practice Guidelines for each plant. It

follows that uncertainty of EF (per clink) is 0.9% and uncertainty of CO₂ emissions from lime production is 1.5%.

4.3 Limestone and Dolomite Use

Methodology and Activity Data, Emission Factors and Emissions

At thermal decomposition or chemical reactions of limestone to clink carbon dioxide is produced. The maximum value of emission factor of CO₂ is 440 kg CO₂/1 t of consumed limestone, which is the recommended value according to the IPCC. However, the average content of CaCO₃ in raw material in the Slovak republic is 97%, therefore the emission factor CO₂ has to be lowered to 427 kg/1 t of consumed limestone (440 × 0.97). In this category the mass of consumed limestone in industrial processes except of cement and lime production is presented. The recalculated amounts from the previous submission of consumed limestone according to the sources and emissions of CO₂ are summarized in **Table 4.3**. The new data are correct while the previous ones were influenced by wrong methodology that yielded to high consumption of limestone at iron and steel production. (According to the information from the plant, instead of limestone consumption per iron ore the CO₂ emission per tone of pig iron was used in the older inventories. Therefore, the mass of the consumed limestone after our recalculation was more than two times higher.) The amount of CO₂ emissions is based on the consumption of limestone and dolomite at production of calcium carbide, glass and iron & steel.

Table 4.3 Total emission of CO₂ at limestone utilization in the period 1990 – 2004

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	Emissions of CO ₂ (Gg)														
Limestone Use	302	271	262	313	340	339	321	338	334	319	404	387	362	375	616

The total amount of the limestone utilised is depicted on the following **Table 4.4** and as is visible, the amount of total consumption in the industry is twice higher, then last year 2003. That is the reason for the higher emissions from this source (see **Table 4.3**).

Table 4.4 Total emission of CO₂ and the emission factors of CO₂ at limestone utilization in 2004

Year	Consumption of limestone at				CO ₂ Emission [t]	EF (CO ₂) [kg / t of limestone]
	Iron and Steel Production [t]	Calcium Carbide Production [t]	Glass Production [t]	Total [t]		
2004	1 228 711	156 140	55 422	1 442 516	615 954	427

Key Source and Uncertainties

It should be mentioned that calculation of uncertainties according to Monte-Carlo method couldn't be done because of lack of necessary data. Thus, the uncertainties in mass of used limestone and dolomite (2%) and their composition (3%) were estimated according to IPCC Good Practice Guidelines for each plant. It follows that uncertainty of EF (per clink) is 0.9% and uncertainty of CO₂ emission is 4.4%.

4.4 Magnesite Use

Methodology and Activity Data, Emission Factors and Emissions

At thermal decomposition of magnesite carbon dioxide is produced. Maximum emission factor of CO₂ is 522 kg CO₂/1 t of magnesite or after recalculating 1 092 kg CO₂/1 t of magnesite clink. Purity of magnesite in the SR varies mainly from 84% to 94%. The weighted average is 87.3% and the emission factor of CO₂ is 953.0 kg CO₂ / 1 t of magnesite clink. Finally, all the necessary data on *magnesite* clink production are available. In **Table 4.5**, the data on produced magnesite clink together with emission data of CO₂ are summarized.

Table 4.5 Total emission of CO₂ at magnesite clink production in the period 1990 – 2004

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	(Gg)														
Magnesite Clink	460	274	234	240	218	313	321	330	401	421	436	460	467	479	514
Emissions CO₂	432	257	220	226	204	294	301	310	377	395	410	432	439	450	483

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 Good Practice Guidelines for each plant. It follows that uncertainty of EF (per clink) is 3.1% and uncertainty of CO₂ emissions from production of magnesite clinker is 4.0%.

4.5 Ammonia Production**Methodology and Activity Data, Emission Factors and Emissions**

Ammonia is made from nitrogen and hydrogen by fine-tuned versions of the process developed by Haber, Nernst and Bosch. In principle, the reaction between hydrogen and nitrogen is easy. However, to get a respectable yield of ammonia in a chemical plant is necessary to use a catalyst and extreme pressure. For estimation of the greenhouse emissions from the production of ammonia was used the emission factors recommended by IPCC (1.5 t/t of ammonia). However, the emissions of CO₂ and CH₄ are included in Energy sector in natural gas consumption (1.A.2c). The **Table 4.6** shows the total consumption of natural gas by production of ammonia, total ammonia production in the SR in 1990-2004 and the theoretical emissions, which are included in the Energy sector.

Table 4.5 Total production of ammonia in the SR in 1990-2004

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	(Gg)														
NG Consumption	254	248	242	146	249	270	290	289	257	256	284	290	282	249	287
Ammonia Produced	360	352	344	207	354	384	412	410	364	364	403	412	400	354	408
Emissions CO₂	540	527	516	310	531	576	618	615	547	546	605	618	600	531	612

4.6 Nitric Acid Production**Methodology and Activity Data**

In a world measure, the nitric acid production consumes about 20% of all ammonia produced. Thorough analysis of technology in Slovak plants was made. The result in the plant with measurement of emissions of N₂O and NO_x was that there was an error in calculating of emissions of N₂O and NO_x. It was necessary to correct emission factors of NO_x and N₂O. The average emission factor of N₂O until 1996 was 5.43 kg/t of produced HNO₃ and emission factor of NO_x was 11 kg/t of produced HNO₃, which were the values recommended by IPCC Methodology (IPCC, 1993). In 1996, a selective catalytic reduction of NO_x based on ammonia became operational.

Emission Factors and Emissions

Since 1996, emission factor of N₂O was 5.58 kg/t of produced HNO₃ and emission factor of NO_x was 0.5 kg/t produced HNO₃. In other plant, concentrate nitric acid is also produced without measurement of emissions of N₂O and NO_x. According to the IPCC recommendation, the emission factor is 5.43 kg N₂O/1 t HNO₃. Combined emission factor of N₂O according to these data is 5.56 kg N₂O/1 t of nitric acid. Emission of N₂O at *nitric acid production* in 2004 was 2 921 tons (**Table 4.6**).

Table 4.6 Total emissions of N₂O and NO_x from nitric acid production in the SR in 1990-2004

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	(Gg)														
HNO₃ Production	302	283	257	216	341	374	433	449	420	441	407	464	359	455	525
N₂O Emissions	1.640	1.539	1.398	1.174	1.853	2.033	2.416	2.503	2.342	2.456	2.272	2.584	1.996	2.530	2.921
NO_x Emissions	3.226	3.014	2.697	2.266	3.655	3.982	0.230	0.244	0.230	0.253	0.212	0.270	0.218	0.278	0.315

Key Source and Uncertainties

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

4.7 Production of Calcium Carbide**Methodology and Activity Data**

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

100 000 tons of CaC₂ (calcium carbide) was produced in the Slovak republic in 2004, 56% of produced calcium carbide is exported from the Slovak republic. The rest is used for acetylene production. At this production, no emission of CO₂ is released. The emissions of CO₂ at the reduction step are 109 000 tons.

4.8 Production of Metals**4.8.1 Iron and Steel Production****Methodology and Activity Data**

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

Emission Factors and Emissions

In an open-hearth process the steel was produced, the emission factor for CO₂ being 122.8 kg CO₂/t of steel. This emission factor results from decreasing of carbon from pig iron (40 kg/t) to steel (2.5 kg/t). Differences between the emission factors are caused by different amounts of iron scrap added to charge at steel making process. For estimation of emission, recommended emission factors at steel processing were used. In older inventories, the emissions of CO₂ from coke production were included in iron and steel production as well. In 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 CO₂ from steel production, which are not included in Energy sector are presented in **Table 4.7** for the period 1990 – 2004.

Table 4.7 Emissions of CO₂ from steel production for the period 1990 – 2004

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	Emissions of CO ₂ (Gg)														
Steel production	420	373	348	378	393	379	345	363	366	404	415	443	484	535	540

Key Source and Uncertainties

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

4.8.2 Ferroalloys Production

Methodology and Activity Data

Ferroalloys are produced in arc furnaces and submerged arc furnaces by the reduction of the mixture of iron ore and added metal and/or metalloid (Si) oxides. In 2004, the production of ferroalloys in the Slovak republic was as follows: 127 648 tons of ferroalloys based on Mn, 1 634 tons based on Cr and 31 966 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 (Na_3AlF_6) are aluminium fluoride (AlF_3) and CaF_2 . From the point of emissions view, the content of AlF_3 is of great interest. However, it should be also mentioned that the Slovak plant uses a modern technology in which most of the HF and other fluorides escaping from the electrolytic cells are absorbed and adsorbed on alumina, which is used subsequently in the electrolytic process. The anodes are made from graphite. Production of the so-called pre-baked anodes is made in a separate plant. As a result of that the emissions are much lower than in the so call Soederberg process. It may happen that at a special technological disturbance (the anode effect) the production of CF_4 and C_2F_6 can occur. Because of progress in process control this irregularity occur only 1-2 times in a month.

Emission Factors and Emissions

The emission factor for CO₂ was taken from the IPCC recommendation (1.5 t CO₂/t of aluminium). The emission factors of PFC (CF_4 , C_2F_6) were calculated according to the Tabereaux's equation.

According to the data from plants average current efficiency was 3.12% in 2004, the number of the anode effects per pot day equals to 0.44 and their average duration was 2.61 min. It follows that the emission factors were 0.0166 kg CF₄/1 t of aluminium and 0.00166 kg C₂F₆/1 t of aluminium, respectively. In 2004, minor change in composition of the electrolyte was made. The solubility of alumina decreased and the number of anode effects increased. In 2004, the Slovak aluminium company produced 156 894 t of aluminium. The EFs correspond to the most modern technology and they are summarized together with the total amounts of emissions in **Table 4.8**.

Table 4.8 An overview of emissions and EFs in aluminium production in 2004

	CO ₂	CF ₄	C ₂ F ₆
Emission [t]	235 340	2.604	0.260
Emission factor [kg/t]	1 500	0.0166	0.00166

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 SF₆ at the casting house

In 2004, SF₆ was not used in the Slovak republic at casting. Thus, the consumption of SF₆ in 2004 was 0 kg.

4.9 Consumption of HFCs, PFCs and SF₆

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

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

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

- An evaluation of the sources and emissions of selected substances in 1990-2003 based on acquired data from importers and users in 2004;
- An evaluation of the data storage in own tables and CRF tables according to IPCC methodology.

Methodology and Activity Data

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

- SF₆ emissions from electrical equipment and other sources;⁶

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

- Fluorinated carbon from semiconductor manufacturing;
- HFCs emissions from refrigeration and air conditioning.

Good practice recommendations on seven sources of emissions of:

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

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

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

Actual emission

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

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 1990-2003 are used also in 2004 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;

⁷ Including CF_4 , C_2F_6 , C_3F_8 , C_4F_8 , CHF_3 , NF_3 , SF_6 .

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

- An approximation of the trend of total consumption and emissions of particular halogenated coolants.

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

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

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

Emission Factors and Emissions

The lifetime of SF₆ is up to 3 200 years, GWP is up to 23 900 kg CO₂/kg, and it is used as an extinguishing medium in electronics, protection against explosion, isolation, sterilization, detection gas, alloying of Al and Mg, tobacco production. Beside that it is substitute for halons, 90% of its use is devoted to the isolation in high and low voltage electric equipment because of higher safety level and dimension reducing, 10% of its use is devoted to the surface treatment of metals and so on in the world. Up to thousands kg of SF₆ can be in one interrupter of high voltage. Highly toxic products originate at temperatures over 400°C. Alternatives at low voltage are vacuum and air. In last times, it was used in the older types of extinguishers and at aluminium production in the Slovak republic. Today it is used especially as an isolating gas in high voltage switchgears, in high voltage switchers at electricity distribution plant with supposed release 1% of filling per year. A filling is dimension for 30 years without refilling. Since 1993, the SF₆ is used for anti noise and thermal isolation into windows. It is filled in close cycles practically without releases.

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

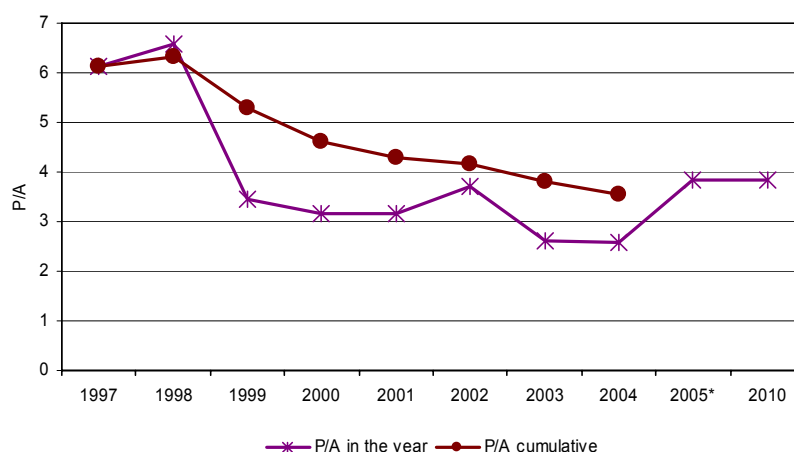
Because of expected prohibition of coolant R12 import, 700 tones of it were purchased in years 1993 and 1995. This amount is gradually consumed and coolant R12 was still available in 2001. Coolants consumption has decreased in the Slovak republic comparing to 1990 by 70%. Up to 1998 the products designed 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: The potential and actual emissions of PFC 14 and PFC 116 originated as a by-product during the aluminium production. Since 2000 PFC 14 and PFC 116 originated as a by-product during the aluminium production has not been included to the emissions of this part of inventory. There are calculated only 1% emissions from new extinguishing media (without consumption for extinguishing).

The above analysis shows that in the year 2004 in spite of the forbidden HCFCs applications by the Act n. 76/1998 Z. z. in version n. 408/2000 Z. z. wasn't reached significant faster application of HFCs. A decline of extinguishing media consumption is because they are very expensive and the investment to them is planned for a longer time. Consumption of SF₆ is not rising. 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 SF₆ 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.

Key Source and Uncertainties

Inventory of F-gases is complicated due to high number of substances HFCs, PFCs a SF₆, totally 12 HFCs substances. They are components of different mixtures used in different more than 15 applications. Each application has its own development of consumption and trend of emission development. According to the IPCC GPG it is no sense to deal with uncertainties, which do not have fundamental influence to the total emissions. This should be taken into account in all numerous applications of different F-gases. That why in the coincidence with IPCC GPG the first step is the quantifying of uncertainties and it is done by expert judgment due to this large extent of different applications and gases for potential and actual emissions.

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

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

Similarly, uncertainty come out from the assessing of emission factor, which is gradually decreasing during the years 1994 - 2004 in the range from 17 to 8% according to the application. The lowest emission factors are on the products completed in the factories mainly in domestic refrigerators, chillers and so on. Higher emission factors are in cooling circuits assembled on the place of application for example commercial, agricultural, industrial, transport refrigeration and so on. Given range of emission factors is overcome only in car air conditioning, where emission factor is expected over 20%. From this assessment comes out that emission factor in all applications is in the range from 8 to 25%.

Assessment of uncertainties by expert judgment is considered for the development of potential and actual emissions. Potential emissions depended on preciseness and completeness of reported data is evaluated in the range from - 5 to 15% and actual emissions in the range from 8 to 17%. Both distributions are nonsymmetrical. In the case of potential emissions, we suppose that reported data are sooner underestimated and in the case of emission factor, we suppose in more applications trend to the lower emission factor.

Potential emissions have correlation to economical development in the SR. Uncertainties in to the relation of potential emissions are dependent on time (years). Trend of development of potential emissions can have fluctuating mainly increasing tendency, which in the future will be decreasing due to implementation of alternative natural refrigerants. Nowadays the development is given mainly by the fact that HFCs substances are substituting CFCs and HCFCs substances excluded from usage by Montreal Protocol.

Emission factors depend on time (years) and correlate with the technical and technological development and to the implementation of legal acts, technical standards and so on. Trend of the development of emission factor should have decreasing tendency.

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

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

5 SOLVENT AND OTHER PRODUCT USE

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

The primary attention in the 2006 submission in the Solvent Use sector inventory was put in to the N₂O emissions. The most important problem was to collect all available input data in a consistency manner. The statistical information are poor, so it was decided to request directly the producers, importers, distributors and users.

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

Methodology and Activity Data

The aim of N₂O emission inventory from Solvent and Other Product Use sector is in the medicine (anesthesia) and food use (aerosol cans). There is also the consumption of N₂O for the analytical purposes, but the gas is burned after the use, so this source is not included into the total inventory. The amounts are negligible. The activity data come from the three major distributors of N₂O liquid gas – Messer-Tatragas, Linde and SIAD companies. The methodology is very simple, because the source is not key one. We can suppose that the final emissions from these sources are equal to the consumed gas. The total numbers of used N₂O in the sector are showed in the **Table 5.1**.

Table 5.1 The consumption of N₂O for the period 1998 – 2004

Year	1998	1999	2000	2001	2002	2003	2004
	tons						
Medicine	17.4600	18.7350	34.1850	80.9880	76.2200	73.3555	65.1325
Food	0.0000	0.0000	0.0000	14.2800	107.2900	116.4800	192.6700

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 N₂O for the medicine and food purposes are equal to the activity data, with the supposing, that all gas is evaporated into the atmosphere. The total emissions of N₂O in the Solvent and Other Product Use sector are 257.8 tons in 2004.

The total emissions of NM VOC from this category were 33.634 Gg per year 2004.

6 AGRICULTURE

6.1 Cross-cutting

The humankind activities in Agriculture sector significantly contribute to changes of concentration of some gases in atmosphere what consequently increase its greenhouse effect as well as acidity of environment. Despite of fact that water vapour and CO₂ are gases of the highest importance sharing greenhouse effect of the atmosphere, N₂O and CH₄ emitted in Agriculture sector are considered as the most important gases from the point of view of planning adaptive measures to reduce their influence on environment. Sources of N₂O and CH₄ emissions are analyzed according to revised IPCC Methodology (IPCC, 1996), when principles of Good Practice in GHGs inventory (IPCC, 2000) in agriculture were taking account. Some national data from research projects were utilized too. Some of N₂O, CH₄ and NH₃ emissions can be reduced if effective adaptation measures are accepted in agricultural practice. Effective measures were proposed for condition of the Slovak republic in other studies (NC SR, 2005), shortage of data, especially on storage and application of manures, resulted in fact that emissions are evaluated on the level business as usual in this study. Methodology used in this study utilized also results of research institutions sharing nitrogen fluxes in condition of 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 1998-2005, Ministry of Agriculture of the SR;
- Statistical Yearbook 1990-2005, Statistic Office of the SR.

6.2 Methane Emissions

6.2.1 Enteric Fermentation

Methodology and Activity Data

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

Methane emissions from enteric fermentation are dominant emissions from animal husbandry and from agriculture at all. The cattle produce more than 90% of these emissions and dairy cattle give

nearly half of emissions in the category. Less than 10% of emissions produce other categories of domestic livestock. An intensification of animal husbandry increased also methane emissions on level 100 kg CH₄ per head per year. On the other hand, higher efficiency leads to decrease of numbers of dairy cattle and consequently decrease of total methane emissions from this category.

Emission Factors and Emissions

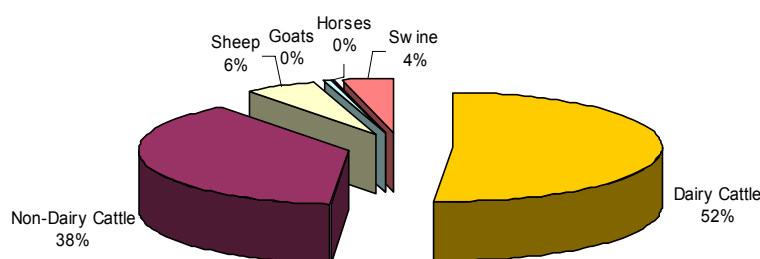
Methane emissions from enteric fermentation for dairy cattle reflect milk production during evaluated period of year given in **Table 6.1**. The emission factor for enteric fermentation was recalculated according to milk productivity for each year by interpolation when for milk productivity 2 550 l the EF 81 kg CH₄ per head per year was used and for productivity 4 200 l was used the EF 100 kg CH₄ per head per year.

Table 6.1 Milk production in kg per dairy cow in the SR for the period 1990 – 2004

Year	1990	1995	2000	2001	2002	2003	2004
Milk production in l per cow per year	3 557	3 292	4 337	4 654	4 900	4 990	5 560

Total emissions of methane from enteric fermentation decreased from 116.3 Gg in year 1990 to 45.1 Gg in year 2004, what is decrease by about 61%. 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 2004



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 6.2**).

Emission Factors and Emissions

Methane emissions from this source decreased from 17.6 Gg in year 1990 to 7.8 Gg in 2004. Total methane emissions in 2004 from Agricultural sector (animal husbandry) were 52.93 Gg. A trend of emissions during evaluated period is depicted on **Figure 6.3**. Total CH₄ emissions (**Table 6.2**) from 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 55% in category manure management and total methane emissions from agriculture decreased by about 60%. Next decrease is supposed also in year 2005 and during period of years 2005 – 2012 the total emissions will reach level 45.0 Gg per year. Methane emissions can drop by about 10% up to year 2012 because of next decrease of populations of cattle.

Figure 6.2 Methane emissions from manure management according to livestock categories in 2004

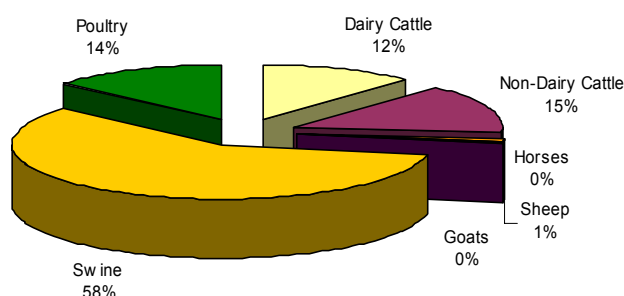
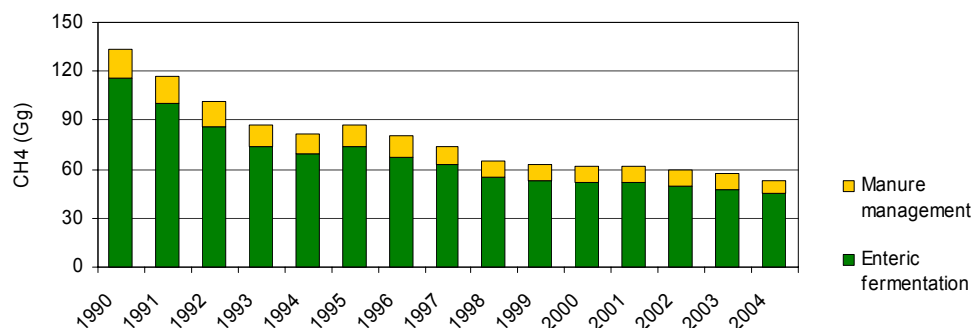


Table 6.2 The total methane emissions in the SR for the period 1990 – 2004

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Emissions of CH ₄ (Gg)															
Enteric Fermentation	116.3	100.3	86.3	73.7	69.0	73.6	67.7	62.5	55.0	53.3	52.3	52.4	49.4	47.8	45.1
Manure Management	17.6	16.3	14.8	13.6	12.9	13.3	12.6	11.6	10.2	9.9	9.5	9.5	9.7	9.3	7.8
Total	133.8	116.6	101.1	87.3	81.9	86.9	80.3	74.1	65.2	63.2	61.8	61.9	59.1	57.0	52.9

Figure 6.3 A trend of CH₄ emissions in agriculture in 1990-2004



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.

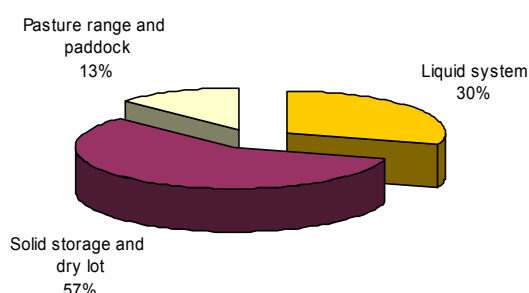
6.3 Nitrous Oxide Emissions

6.3.1 Manure Management

Methodology and Activity Data

Decreasing numbers of domestic livestock especially in categories pigs (as was mentioned above) and dairy cows also produced lower amount of nitrogen. Numbers of animals in category dairy cows start to be limited by milk quotation. Input of nitrogen from manure management in 2004 from this source was on level 1.426 Gg (**Figure 6.4**).

Figure 6.4 N₂O emissions from manure management according to AWMS in 2004



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 6.3**). Direct measurements of nitrogen produced by domestic livestock in the Czech Republic showed that real amounts could be much more higher than recommended values of produced nitrogen in methodologies what directly influence also N₂O emissions. The applied animal fertilizers lost the definite amount of nitrogen by volatilization and N-NO_x conversion, this amount for animal fertilizers is 20%, its means that for the conversion of N to N₂O rest only 80% of total amount applied synthetic fertilizers. For category manure management (especially sows and pigs) is the most often form of management solid and liquid system for storage of excreta in the Slovak republic. For the sheep, horses and goats is characteristic management system - the pasture range in some period of year (mean is 200 days per year). Input of nitrogen from manure management in 2004 from this source was on level 1.426 Gg and the total decreasing according to the base year is about 60%.

Table 6.3 N production (kg/head/year) for different categories of domestic livestock (IPCC, 1996)

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

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

6.3.2 Direct N₂O Emissions from Cultivated Soils

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

Methodology and Activity Data

A consumption of synthetic fertilizers decreased during last decade of 20th century, from 222.3 Gg in 1990 to 76.4 Gg in 2004 (with the prognosis of 80 Gg in 2005). The synthetic fertilizers in year 2004 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 2003 and 2004 by about 10-12% during last year as compare with year 2000 (**Table 6.4**). 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, 2004).

Table 6.4 Total inputs of N (thousands of t) from mineral fertilizers applied in agriculture during years 1990-2004 with estimations up year 2012

Year	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2010	2012
	N-input (Gg)														
N	222	70	73	81	85	81	76	80	88	222	70	73	81	107	111

Emission Factors and Emissions

The applied synthetic fertilizers lost the definite amount of nitrogen by volatilization and N-NO_x conversion, this amount for synthetic fertilizers is 10%, its means that for the conversion of N to N₂O rest only 90% of total amount applied synthetic fertilizers (68.78 kt / year 2004). After using the IPCC default emission factor 0.0125 kg N₂O-N / kg N the total emissions of N₂O from using the synthetic fertilizers in 2004 were 1.351 Gg (0.860 Gg of N).

Methodology and Activity Data

The direct inputs of nitrogen slightly vary according to applied methodology. According to IPCC Methodology (IPCC, 1996) (Method A)⁹ higher inputs of nitrogen from animal excreta are calculated – in average higher by about 5% as compared with detailed method (Method B).¹⁰ Since 1990 there was recorded decrease of nitrogen inputs from 171.4 Gg to 76.4 Gg in year 2004 – what represent more than half of original emissions. Because domestic livestock produce different kind of nitrogen inputs (liquid or dry) into the ecosystem there is important also structure of domestic livestock (ratio of different categories of domestic livestock) from the point of view of direct emissions as well as emissions from AWMS. Except for it production of nitrogen per head per year also plays some role. There is used production of nitrogen in category cattle 90 kg per head per year in this study (according to IPCC, 1996). For dairy cows of productivity higher than 4 500 l there is also published amount 100 kg N per head per year (CORINAIR, 2003). There are also some differences in category other cattle, where for intensive animal husbandry are presented higher production of nitrogen (instead of 56 kg amount of 60 kg of N pre head per year is recommended). Direct measurements of nitrogen produced by domestic livestock in Czech republic showed that real amounts could be much more higher than recommended values of produced nitrogen in methodologies what directly influence also N₂O emissions.

Based on data about management in 222 agriculture farms were performing the total analysis of manure production in the SR (**Table 6.5**).

Emission Factors and Emissions

The calculated amount of nitrogen from animal waste applied on fields were 46.65 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 N₂O emissions from animal excreta in 2004 were 0.916 Gg (0.583 Gg of N).

Table 6.5 Housing of animals and production of liquid and solid manures in percent (Brestensky, 1998)

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

Methodology and Activity Data

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, 1998). The details for

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

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

estimation total input of nitrogen from residual crops are depicted in **Table 6.6** and were calculated according the growing areas of crops and vegetable.

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 2003 were 2 255 445 ha and the direct inputs of nitrogen from crop residuals were 159 607.14 t per year 2003. The crops residuals from previous year were base for calculation of N₂O emissions (according the used methodology). The used emission factor 0.0125 kg N₂O-N / kg N is according the IPCC methodology (IPCC, 1996) and gives the total N₂O emissions from crops residuals in 2004 – 3.135 Gg (1.995 Gg of N).

Table 6.6 Growing areas and total nitrogen amount of crops and leguminous in the SR

Crop		1990 [ha]	2001 [ha]	2002 [ha]	2003 [ha]	crop residuals [t/ha]	% N in kg of biomass	N [t/ha]	2003 N [t]
Cereals	Wheat	418 158	448 900	405 800	306 900	5.60	0.81	0.0454	13 920.98
	Ray	46 335	38 200	38 000	25 200	4.06	0.68	0.0276	695.72
	Barley	190 634	186 400	194 700	269 300	3.97	0.91	0.0361	9 729.00
	Oat	13 015	17 000	20 500	30 400	3.90	1.00	0.0390	1 185.60
	Maize	150 731	122 600	140 400	146 000	3.38	1.40	0.0473	6 908.72
	Other	6 323	12 000	15 000	15 000	3.90	1.00	0.0390	585.00
Potato		55 245	26 200	26 100	25 700	2.44	2.79	0.0681	1 749.55
Sugar beet		51 288	31 500	30 900	32 000	1.11	1.52	0.0169	539.90
Oil plants		70 906	180 700	201 600	208 900	10.00	1.10	0.1100	22 979.00
Tobacco		3 019	1 234	1 234	1 234	3.16	2.10	0.0664	81.89
Vegetable		30 075	40 000	33 600	34 500	1.11	0.96	0.0107	367.63
Fodder crops on arable land		48 611	21 960	24 072	24 487	5.49	1.62	0.0169	2 177.82
Maize for silage		179 888	100 030	96 787	98 973	4.67	1.40	0.0889	6 470.85
Grassland and other crops		870 778	1 037 428	1 016 027	1 036 851	5.49	1.62	0.0654	92 215.45

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

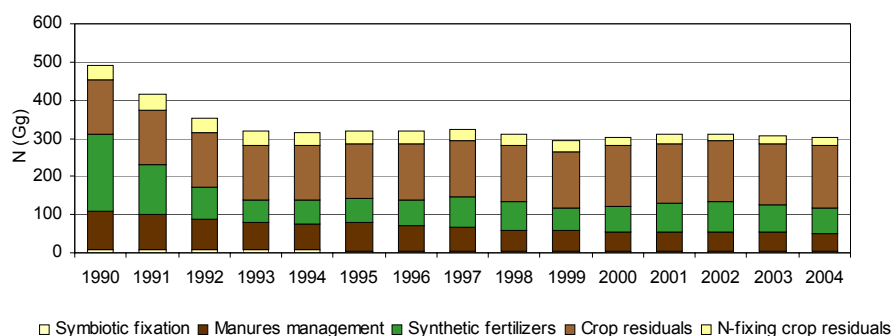
For the conditions of the SR are the nitrogen inputs from symbiotic fixation in the range 20-30 kg/ha (Bielek 1998), but is enough reasons to accept an experimental value 26 kg N/ha. The details for estimation total input of nitrogen from N-fixing residual are in **Table 6.7** and were calculated according the data obtained from direct measurement (Jurcova, 1998) 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 (pea, lens, bean, other leguminous plants, soybean, alfalfa, clover and other fodder crops) in 2003 were 157 919 ha and the direct inputs of nitrogen from N-fixing crops were 22 783 t of N per year 2003. The crops residuals from previous year were base for calculation of N₂O emissions from N-fixing crops (according the used methodology). The used emission factor 0.0125 kg N₂O-N / kg N is according the IPCC methodology and gives the total N₂O emissions from N-fixing crops in 2004 - 0.448 Gg (0.285 Gg of N).

Table 6.7 Growing areas and total nitrogen amount of N-fixing crops in the SR

Crop		1990 [ha]	2001 [ha]	2002 [ha]	2003 [ha]	crop residuals [t/ha]	% N in kg of biomass	N [t/ha]	2003 N [t]
N-fixing crops	Pea	28 446	11 629	8 776	9 000	6.51	1.66	0.1081	972,59
	Lens	2 579	500	546	1 000	7.00	2.42	0.1694	169,40
	Bean	2 272	1 745	781	1 000	7.00	2.96	0.2072	207,20
	Other leguminous plants	11 707	2 400	2 527	3 000	10.94	2.96	0.3238	971,47
	Soybean	5 474	6 430	9 326	11 600	3.44	4.19	0.1441	1 671,98
	Alfalfa	118 125	61 435	62 481	61 532	7.00	2.42	0.1694	10 423,52
	Clover	35 068	12 000	8 761	6 494	6.00	1.97	0.1182	767,59
	Other fodder crops	51 605	40 478	57 643	64 293	6.00	1.97	0.1182	7 599,43

Biologic fixation from 157 919 ha of N-fixing crops were 4 105.89 t N per year 2003. The used emission factor 0.0125 kg N₂O-N / kg N is according the IPCC methodology and gives the total N₂O emissions from biologic fixation in 2004 – 0.081 Gg (0.05 Gg of N). The total N₂O emissions from N-fixing crops (residuals + biologic fixation) in 2004 were 0.528 Gg. A trend of direct N input in agricultural soils according to the sources during 1990-2004 is depicted on the **Figure 6.5**.

Figure 6.5 A trend of direct N inputs in soils according to sources (SR 1990-2004)

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

6.3.3 Indirect N₂O Emissions

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

Methodology and Activity Data

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

Emission Factors and Emissions

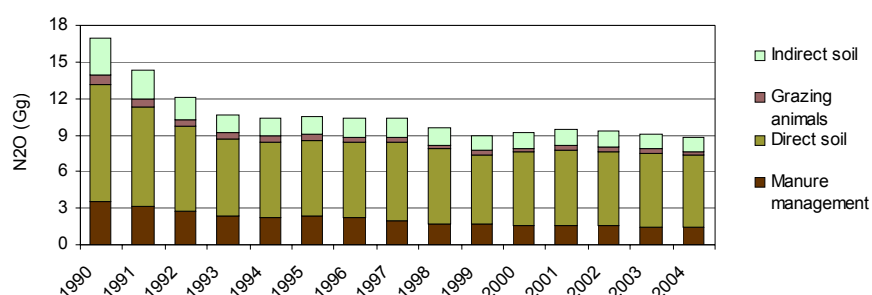
Mean value for leaching of nitrogen vary in range 7-10 kg per 1 ha per year (7% of N-inputs) in condition of SR. Next nitrogen losses 5 – 10 (7% of N-inputs) kg per ha per year are caused by soil erosion and runoff (Bielek 1998). Totally soils loss about 14% of nitrogen input due to leaching, runoff and erosion in climatic condition of the Slovak republic. Total indirect emissions of N₂O from

atmospheric deposition create 360.23 tons per year 2004; the emissions of N₂O from nitrogen leaching and run-off are 840.56 tons per year 2004. The total indirect emissions in 2004 are 1.201 Gg with the reduction of 60% compared to the 1990 year.

Trends and Recalculations of N₂O Emissions

Trends of the total N₂O emissions from Agriculture sector reflect trends of direct emissions from cultivated soils, emissions from AWMS and indirect emission from leaching and deposition of ammonia and NO_x. After big decrease of N₂O emissions in the 1st half of 90's (from 17.0 Gg in 1990 to 10.0 Gg in 1995) the emissions stabilized on level 9.0 Gg per year (**Figure 6.6**).

Figure 6.6 A trend of N₂O emissions in agriculture in 1990-2004



The N₂O emissions from Agriculture sector create about 67% of total N₂O emissions in the SR. The total N₂O emissions in Agriculture sector are given by direct emissions from cultivated soils and animal husbandry and indirect emissions from leaching and nitrate depositions. The emission factors for calculation of direct N₂O emissions from Agriculture sector, emissions from AWMS and indirect emissions from leaching were used according to **Table 6.8**.

Table 6.8 The EFs for the calculation of N₂O emissions from agriculture (IPCC, 1996)

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

Key Source and Uncertainties

Activity data

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

- Green Report of SR;
- Statistical yearbook.

Data published in Green Report of the SR (Green Report, 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_3 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_2O emissions from AWMS were based on analyses of housing systems on the territory of the Slovak Republic that was made by Research Institute of Animal Production in Nitra (Brestenský, 1998). There was supposed that sheep, goats and horses can stay on pasture 200 days a year, 40% of dairy cattle 150 days during day only. Results of analyses on animal waste management system were used for calculation of nitrogen input from animal husbandry into N-cycle. This analysis was based on questionnaire. 222 agricultural subjects were included (21.3% of total amount of subjects in the SR) in this research. Those subjects cultivated 14.7% of total agricultural land and 15.2% of arable land. It is very probable that answers were received first of all from farmers were elements of good practice in agriculture started to apply. Storage of dry manures is probably more frequent then questionnaire showed and emissions from AWMS will be higher. For sheep, goats and horses is frequent housing on grasslands since April to October. Duration of grazing period can vary significantly in dependence on weather conditions in different part of the SR. There is not enough date for statistical evaluation but in this point can be found significant differences.

Nitrogen enters into cultivated soils due to mankind activities mainly through use of synthetic fertilizers, manures, crop residuals, increased biological fixation of leguminous crops and cultivating of histosols.

- Synthetic fertilizes;
- Organic manures from animal husbandry;
- Biological fixation of nitrogen;
- Crop residuals.

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.ha⁻¹ (Bielek, 1998). As an average value can be accepted 26 kg N.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 N₂O emissions calculated values from reality can differ in range 20- 200%, for N₂O from animal waste management system in range 25 – 150%, for indirect N₂O emissions from NH₃ volatilization in range 20- 200 % and for indirect N₂O emissions from leaching I range 10- 500%.

Great uncertainties are defined for N₂O and NH₃ 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.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 (Bielek, 1998).

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 NH₃ and N₂O emissions from cultivated soils is possible to reach by modelling e.g. by DNDC model. Today this kind of model is tested at the Department of Biometeorology and Hydrology at the Slovak Agricultural University in Nitra.

7 LAND USE, LAND USE CHANGE AND FORESTRY

7.1 Input Data

Forest and research institute in Zvolen namely Dr. J. Mindáš (external expert for SHMI) took responsibility for the inventory emission balance from LULUCF. Basic input data used for calculations of GHG emissions from forestry and land use change are showed in **Table 7.1**. According to present knowledge, about 55-90% (depending on tree species) of the total tree's biomass can be assumed stored in the stems. The density of wood (at dry weight) varies from 350 to 800 kg/m³. Using these data and a carbon content of 49.7% for wood (other parts of trees 46.7-52.8%, mean value 50% was used). The total carbon stored in biomass of forest trees of 157.4 Tg C (1990) was estimated based on stemwood biomass data; conversion/expansion factors were estimated according to the experimental data for main forest tree species (Sebik, 1989). The average stock of carbon varies from 47.9 (Poplars) to 108.8 (Beech) tons of carbon per hectare.

Table 7.1 An overview of land use input data according the new methodology

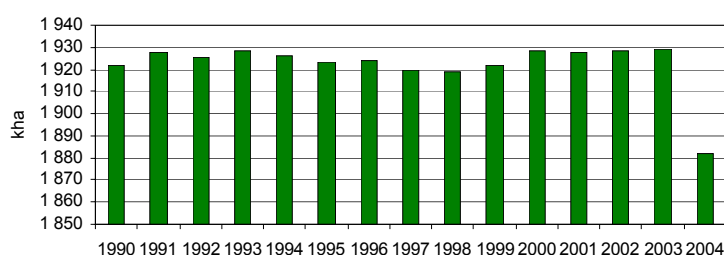
	Forest land	Grassland	Cropland	Wetland	Settlements	Other
Area - 1990, ha	1 921 705	813 000	1 509 000	38 053	0	621 846
Area - 2004, ha	1 930 700	885 000	1 425 000	38 053	0	662 900

7.2 Forest Land

Methodology and Activity Data

Results of calculations were obtained by using the new LULUCF Methodology (IPCC, 2003) and national data on area of *Forested land* and land converted to the forest during the inventory year 2004. The **Figure 7.1** shows the activity data in ha per recalculated time series 1990-2004.

Figure 7.1 A development of total forest area in the SR – Forest land remaining Forest land



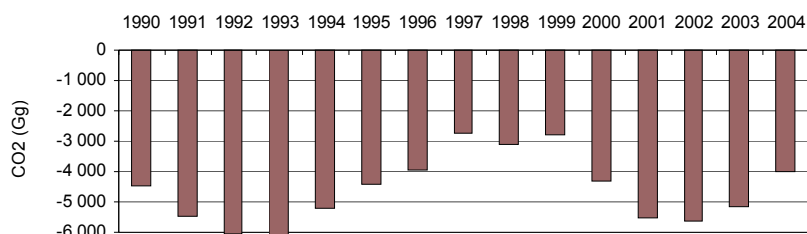
The total area of Forest land remaining the Forest land in 2004 was 1 882 kha, the changes in the forest land were following Grassland converted to Forest land 25.2 kha and Other land converted to the Forest land 23.5 kha per 2004. Total forest area in 2004 was 1 930.7 kha, with the net carbon stock change into the soil per area 65.60 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 4 101 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 2004 is 126.65 Gg of C or -3 995.38 Gg of CO₂. 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 CO₂ balance from managed forests – Forest land in 1990-2004

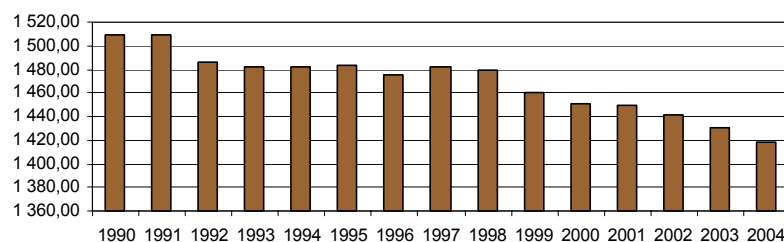


7.3 Cropland

Methodology and Activity Data

Results of recalculations were obtained by using the new LULUCF Methodology (IPCC, 2003) and national data on area of Cropland and land converted to the Cropland during the inventory year 2004. The **Figure 7.3** shows the activity data in ha per recalculated time series 1990-2004.

Figure 7.3 A development of total Cropland area in the SR – Cropland remaining Cropland

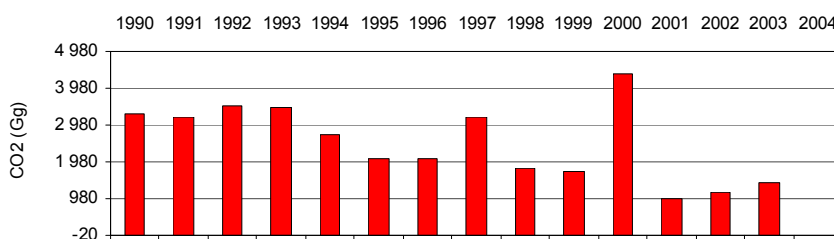


The total area of Cropland remaining Cropland in 2004 was 1 417.8 kha, the changes in the Cropland were following Other land converted to the Cropland 7.2 kha per 2004. Total Cropland area in 2004 was 1 425 kha, with the net carbon stock change into the soil per area 2.92 kg C/ha.

Emission Factors and Emissions

The carbon stock change in soil from the Cropland per 2004 is 4.16 Gg of C. The total quantity of removed CO₂ in this subcategory is -14.17 Gg CO₂. 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 2004.

Figure 7.4 CO₂ balance from Cropland in 1990-2004

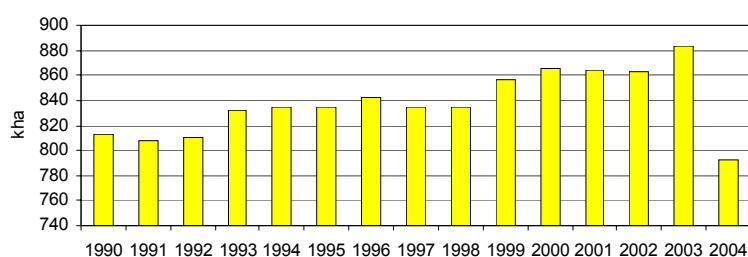


7.4 Grassland

Methodology and Activity Data

Results of recalculations were obtained by using the new LULUCF Methodology (IPCC, 2003) and national data on area of Grassland and land converted to the Grassland during the inventory year 2004. The **Figure 7.5** shows the activity data in ha per recalculated time series 1990-2004.

Figure 7.5 A development of total Grassland area in the SR – Grassland remaining Grassland

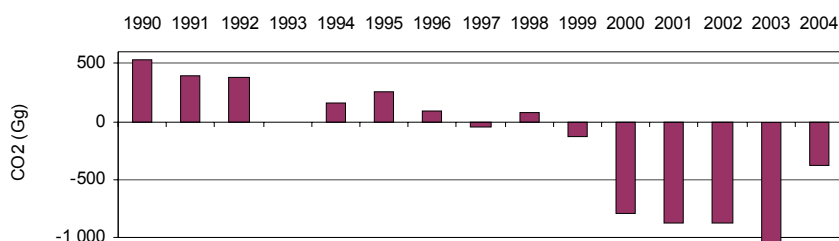


The total area of Grassland remaining Grassland in 2004 was 792.8 kha, the changes in the Grassland were following Cropland converted to the Grassland 82.2 kha per 2004 and Other land converted to the Grassland 10 kha per 2004. Total Grassland in 2004 was 885 kha, with the net carbon stock change into the soil per area 115 kg C/ha.

Emission Factors and Emissions

The carbon stock change in soil from the *Grassland* per 2004 is 101.8 Gg of C. The total quantity of removed CO₂ in this subcategory is -373.27 Gg CO₂. The summary results from this category are depicted on **Figure 7.6**. Total decreasing of the removals from the Cropland in the SR comparable to the 1990 is more than 100% caused by shifted from the positive emissions to the removals in 2004.

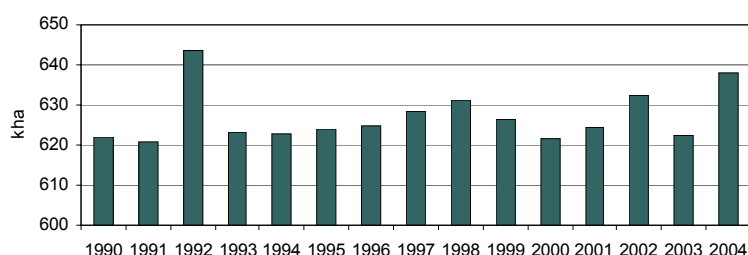
Figure 7.6 CO₂ balance from Grassland in 1990-2004



7.5 Other Land

Methodology and Activity Data

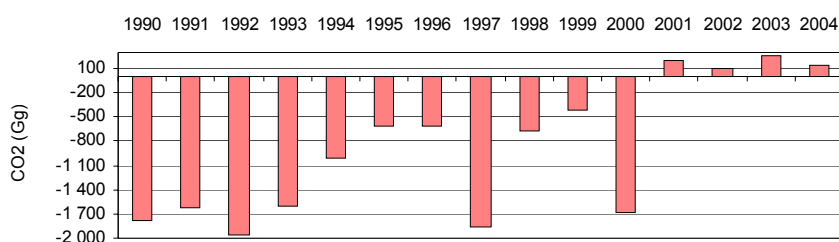
Results of recalculations were obtained by using the new LULUCF Methodology (IPCC, 2003) and national data on area of Other land and land converted to the Other land during the inventory year 2004. The **Figure 7.7** shows the activity data in ha per recalculated time series 1990-2004.

Figure 7.7 A development of total Other land area in the SR – Other land remaining Other land

The total area of Other land remaining Other land in 2004 was 637.9 kha, the changes in the Other land were following Forest land converted to the Other land 15 kha per 2004, Cropland converted to Other land 5 kha per 2004 and Grassland converted to Other land 5 kha per 2004. Total Other land in 2004 was 662.9 kha, with the net carbon stock change into the soil per area -94.4 kg C/ha.

Emission Factors and Emissions

The carbon stock change in soil from the Other land per 2004 is -62.58 Gg of C. The total quantity of removed CO₂ in this subcategory is 131.93 Gg CO₂. The summary results from this category are depicted on **Figure 7.8**. Total decreasing of the removals from the Other land in the SR comparable to the 1990 is more than 100% caused by shifted from the removals to the emissions in 2004.

Figure 7.8 CO₂ balance from Other land in 1990-2004

7.6 Controlled Burning and Forest Fires

Activity data and emissions from controlled burning and forest fires are summarized in the following **Table 7.2**. The input data come from the Statistic Office of the SR.

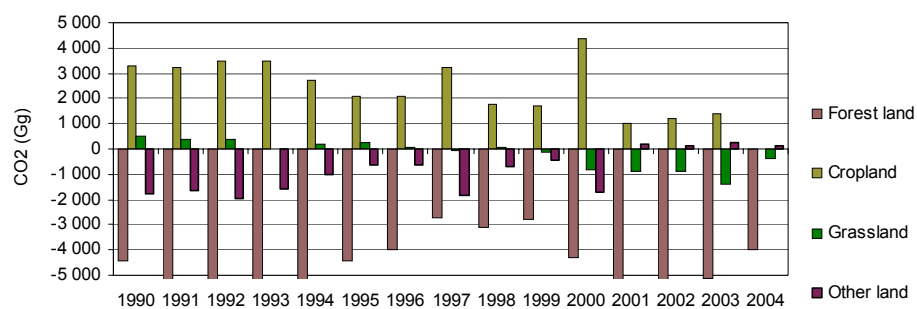
Table 7.2 Forest fires and controlled burning of the forest in 1990-2004

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Biomass burned	t dm														
Controlled Burning	82.6	52.5	47.0	47.8	50.0	56.0	60.2	65.8	65.8	76.1	69.3	83.6	82.4	89.2	110
Forest Fires	4.8	1.9	10.6	11.6	1.4	1.4	3.5	1.9	0.5	0.4	14.1	0.5	0.5	2.5	2.1

7.7 Total LULUCF

The total carbon dioxide emissions represent -4 590.895 Gg due to Forest land (-3 995.38 Gg), Cropland (-14.17 Gg), Grassland (-373.27 Gg) and Other land (131.93 Gg). Total amount of methane emission from LULUCF sector represents 0.822 Gg of CH₄ and total amount of N₂O is 0.0112 Gg. The emissions of other pollutant come from forest fire and controlled burning of Forest land. The NO_x emissions are 0.4016 Gg and emissions of CO are 7.07 Gg in 2004. Summary results are presented on **Figure 7.9**. The total removals from the LULUCF sector increase between 1990 and 2004 by more than 76%.

Figure 7.9

The total CO₂ balance in LULUCF sector

8 WASTE

8.1 Input data

The production of emission of CH₄ and N₂O are important by disposal waste and wastewater treatment. Disposal of wastes and handling of wastewater results in production of greenhouse gases emissions. An estimation of the following emissions in 2004 is presented:

- CH₄ from solid waste;
- CH₄ from domestic and industrial wastewater (including sludge);
- N₂O 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).

8.2 Emissions of CH₄ 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 CH₄, can be a local environmental hazard if precautions are not taken to prevent uncontrolled emissions or migration into surrounding land. Landfill gas is known to be produced both in managed "landfill" and "open dump" sites. Both are considered here as solid waste disposal sites (SWDSs). Either gas can migrate from SWDSs laterally or by venting to atmosphere, causing vegetation damage and unpleasant odours at low concentrations, while at concentrations of 5-15% in air, the gas may form explosive mixtures. It will then describe two methodologies for estimating CH₄ emissions from SWDSs. One of these methods is a default base method, which all countries can use to estimate CH₄ emissions from different types of SWDSs. It is recommended that countries, which have adequate data, also estimate their emissions using the second method presented.

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

The methods described below include the theoretical gas yield methodology, of which the default methodology is one variation, and a first order kinetics methodology.

Theoretical gas yield methodology – this is the simplest method for calculating CH₄ emissions from SWDSs. It is based on a mass balance approach, and does not incorporate any time factors into the methodology. Rather, this methodology assumes that all potential CH₄ is released from waste in the year that the waste is disposed of. Although this is not what actually occurs, it gives a reasonable estimate of the current year's emissions if the amount and composition of the waste disposed of has been relatively constant over the previous several years.

If, however, there have been significant changes in the rate of waste disposal, this simple method will likely not provide a good estimate of current emissions.

Default methodology - the default methodology is a mass balance approach that involves estimating the degradable organic carbon (DOC) content of the solid waste, i.e., the organic carbon that is accessible to biochemical decomposition, and using this estimate to calculate the amount of CH₄ that can be generated by the waste. It is the most widely accessible, easy to-apply methodology for calculating country-specific emissions of CH₄ from SWDSs. It requires the least amount of data to perform the calculations, and it can be modified and refined as the amount of data available for each country increases. This approach was provided as the default methodology in the (IPCC, 1996):

- Rather than distinguishing between “landfills” and “open dumps,” the methodology uses a continuum of solid waste disposal sites, characterised by the degree of waste management and depth;
- Default DOC values are provided for different waste streams so that countries can calculate the DOC content of their waste rather than relying on single default values;
- Emphasising the fact that this methodology estimates CH₄ generation rather than emission, and that oxidation often occurs in the upper layers of the waste mass and in site cover material, a CH₄ oxidation factor (OX) is included in the equation (currently equal to 0, pending the availability of further data).

Data on total disposed municipal and selected industrial wastes have been obtained from Slovak Environmental Agency, from the database of Waste Management Centre.

Total amount of municipal waste in year 2004 was 1 400 031 t, amount of waste disposed to solid waste disposal sites was 1 123 397 t with the biological degradable share of 12% (expert judgment of SEA based on national data). In the **Table 8.1** are data used for calculation of methane emissions from solid waste.

Table 8.1 Data used for calculation of methane emissions from solid waste

Parameter	Amount	Data Source
MSW _T x MSW _F Municipal waste		Slovak Environmental Agency, database of Waste Management Centre
MSW _T x MSW _F Industrial waste		Slovak Environmental Agency, database of Waste Management Centre
MCF	0.6	IPCC, table 6.2 uncategorised SWDSs
DOC Municipal waste	0.12	Slovak Environmental Agency – appraisal value
DOC Industrial waste		Calculated from equation 2
DOC _F	0.77	IPCC default 0.77
F	0.5	IPCC default 0.5
R	0	IPCC default 0
OX	0	IPCC default 0

Data for industrial and yard/garden waste are in **Table 8.2**.

Table 8.2 Data used for calculation percent DOC in agriculture and industrial waste in 2004

Waste Steam	Amount of waste [t]	Percent DOC by weight
Agricultural waste	46 197	17
Paper and pulp	105 102	40
Textiles	3 631	40
Food waste	35 523	15
Wood and straw waste	2 070	30

Emission Factors and Emissions

The emissions of CH₄ from municipal waste were estimated to be 41.52 Gg. The total quantity of industrial waste and the biological degradable share were estimated according the categories of industry production (SEA, 2004). The emissions of CH₄ from industrial and agricultural waste were 17.20 Gg of CH₄. Using the values in the **Table 8.2**, the DOC content of a waste from agriculture and industry is 30%.

In comparison between year 2004 and 2003 emission from domestic and industrial waste is decreased. The amount of domestic waste is decreased about 4% and amount of industrial waste is increased about 22%. In comparison with base year emission level, there is a increase in SWDS emissions of more than 16%. The share of industrial waste increased annually from 1996 and it could be supposed to continue with this trend in the SR (**Figure 8.1**).

8.3 Emissions of CH₄ from Wastewater

Methodology and Activity Data

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

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

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

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

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

Domestic wastewater - data needed are:

- Degradable organic component (DC) indicator in kg DC per 1 000 persons per year. For domestic wastewater and sludge, BOD is the recommended DC indicator. Although COD is considered a more appropriate indicator for the organic component of the waste, BOD is the

more frequently reported indicator for domestic wastewater. Consequently, the use of BOD estimates will result in more precise calculations than when COD is used;

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

Industrial wastewater - data needed are:

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

For estimation of methane emissions from wastewater handling input data has been achieved from official documents such 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 8.3** and **8.4** are data used for calculation of methane emissions from domestic organic wastewater and industrial wastewater and sludge.

Table 8.3 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 _{dom}	18 250	Kg BOD/1000 persons/yr	IPCC, one person produces 50 g BOD for day
DS _{dom}	0.5	kg CH ₄ /kg BOD	Appraisal value
B _{oi}	0.6	kg CH ₄ /kg BOD	IPCC default 0.6
B _{oj}	0.6	kg CH ₄ /kg BOD	IPCC default 0.6
WS _x	1)		Appraisal value - according to percentage of population connected to the sewerage system - Green report
SS _{iy}	1)		Appraisal value - according to percentage of population connected to the sewerage system - Green report
MCF _x	1)		Appraisal value - according information about type of wastewater treating
MCF _y	1)		Appraisal value - according information about type sludge handling system
MR	1)	kg CH ₄	Appraisal value - (20% of methane emissions are recovered or flared)

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

Table 8.4 Data used for calculation of methane emissions from industrial wastewater and sludge

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

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

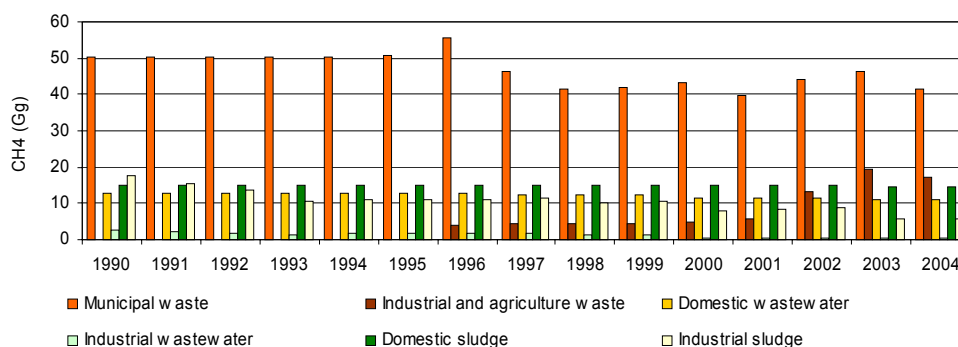
²⁾ values are the tables in IPPC format were are in annex (worksheet 6.3 - sheet 2,3,4)

Parameters WS_{ix} a SS_{iy} for domestic wastewater are appraised from information about percentage of population connected in sewage system. In the year 2004 is 56% of population connected in sewerage system and domestic wastewater is handled in aerobic treatment facilities and lagoons. The 44.2% of population collect domestic wastewater in sewer systems as septic tanks or latrines. The situation is similar like in the year 2003. 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 2003, COD produced in all industry is little decreased about 1.4%.

Emission Factors and Emissions

The total emissions of methane in 2004 from wastewater are 32.05 Gg. The industrial wastewater represents 0.37 Gg of CH₄, the domestic and commercial 11.20 Gg of CH₄. The industrial sludge produces 5.73 Gg of CH₄ emissions and 14.74 Gg of CH₄ are from domestic and commercial sludge (**Figure 8.1**). In comparison between year 2004 and 2003 emission from domestic and industrial wastewater is at the same level. In comparison with base year emission level, there is an important decreasing in wastewater of more than 33%.

Figure 8.1 The total methane emissions from Waste sector in 1990-2004

8.4 Emissions of N₂O from Wastewater

Methodology and Activity Data

For calculation, emissions of nitrous oxide are used two methods: IPCC and ISI. IPCC method use consumption of proteins for one person. Used parameters are in the **Table 8.5**.

Table 8.5 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 ₆	0.01	kg N ₂ O-N/kg N in domestic wastewater	IPCC default 0.01
Frac _{NPR}	0.16	0,16 kg N/kg proteins	IPCC default 0.16

ISI method expects that wastewater treatment plant where aren't biological nitrification haven't emission of N₂O. For calculation N₂O, we used only data for treatment plant where biological nitrification is and denitrification. Number of this type of treatment for domestic and industrial wastewater are increased, therefore this emission of N₂O in the future will increase also. In the calculation are used only data for treatment plant where is c in this case k_{denit} we can eliminate. Population we can exchange with population of equivalents, calculated from COD in the inlet in wastewater treatment and production of BOD for one person (0.05 kg/person/day) (**Table 8.6, 8.7**).

Table 8.6 Parameters for calculation of emissions nitrous oxide for domestic wastewater – ISI

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

Table 8.7 Parameters for calculation of emissions nitrous oxide for industrial wastewater – ISI

Parameter	Amount	Unit	Data Source
mn_i		[m ³ /day]	Data for individual wastewater plant – database SHMU
(N) _i		[mg/l]	Data for individual wastewater plant – database SHMU
k_{N_2O}	0.0165	kg N ₂ O-N/kg N in domestic wastewater	ISI default 0.009-0.024 kg N ₂ O-N/kg N, medial value are used 0.0165 kg N ₂ O-N/kg N
K_{diss}	0.65		IPCC default 0.5-0.8, medial value are used 0.65

Emission Factors and Emissions

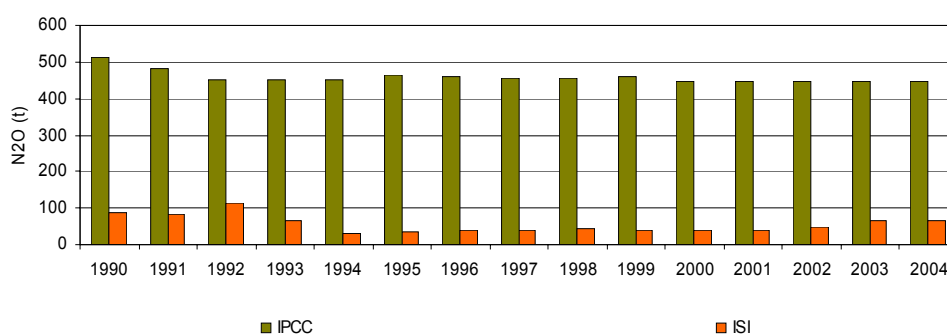
Since N₂O emissions from human sewage are closely linked to the agricultural N cycle, the method is further discussed in the Agricultural Chapter (on indirect N₂O emissions from nitrogen used in agriculture).

The emissions of nitrous oxide from wastewater management were estimated by two methods: IPCC (IPCC, 1996) and ISI (ISI, 1993) and the results are showed in **Table 8.8**.

Table 8.8 Total N₂O emissions from wastewaters handling in 2004 – IPCC, ISI

Method	N ₂ O emit from domestic wastewater [t/yr]	N ₂ O emit from domestic wastewater [t/yr]	Emissions of N ₂ O [t/yr]
IPCC 1996	-	-	446.39
ISI	48.465	38.648	87.113

In comparison between year 2004 and 2003 emission from domestic and industrial waste is decreased. The amount of domestic waste is decreased about 4% and amount of industrial waste is increased about 22%. Emission from domestic wastewater is about in the same value as in the year 2003, emissions from industrial wastewater and from industrial waste is little decreased. For calculation of nitrous oxide emissions IPCC and ISI method was used. On the basis of 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 taken in account wastewater handling. Results are assumed in the **Figure 8.2**.

Figure 8.2 The comparison of N₂O emissions from wastewater treatment in 1990-2004

8.5 Emissions from Waste Incineration

Methodology and Activity Data

The emissions from the waste incineration are estimated for the CO₂ and N₂O 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 8.9**.

Emission Factors and Emissions

The emission factors for the CO₂ 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 N₂O 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 CO₂ emissions of waste incinerated in 2004 is 147.97 Gg and total N₂O emissions is 0.0078 Gg.

Table 8.9 Total CO₂ and N₂O emissions from waste incineration in 2000-2004

Year	2000	2001	2002	2003	2004	2000	2001	2002	2003	2004
Waste incinerate	CO ₂ (Gg)					N ₂ O (Gg)				
Municipal waste	97.68	81.68	89.49	97.22	91.29	0.0044	0.0039	0.0050	0.0052	0.0049
Other waste	58.39	53.40	53.57	43.01	56.68	0.0043	0.0050	0.0051	0.0034	0.0028
Total Emissions	156.08	135.07	143.06	140.22	147.97	0.0087	0.0089	0.0100	0.0086	0.0078

9 RECALCULATION AND IMPROVEMENTS

The several recalculations in CRF 2004 submission 2006 are mentioned against the previous CRF 2003 submissions 2005. The most important are following.

9.1 Energy Sector

For the submission in 2006, 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 2006, the Slovak republic is using sectoral approach as a reference value of the Energy sector for the year 1990 and 2000-2004.

The national emission factors for CO₂ are in use for this time, for natural gas from year 2000. The emission factors for natural gas are based on preciously 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 2000-2004 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 2004. The year 2002 was recalculated and the actual emissions are included into the CRF 2004.

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

No further recalculations were made in 2006 submission. The consistent data series from 1990 are available.

9.3 Agricultural Sector

No further recalculations were made in 2006 submission. The consistent data series from 1990 are available.

9.4 Solvent and Other Products Use Sector

The sector were completely estimated according the new information from 1998-2004.

9.5 Waste

No further recalculations were made in 2006 submission. The consistent data series from 1990 are available.

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 2006 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 2006 of the Slovak republic is inseparable part of CRF 2004 submission 2006 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 2004 emission inventory is based on IPCC Methodology and is related to the previous inventory for 2003. 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 1990-2004.

Table 10.1 An overview of GHG emissions (in Gg of CO₂ equivalents) in 1990-2004

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
GHG	Gg of CO ₂ equivalents														
CO ₂ *	58 131	48 606	44 246	41 140	39 122	41 145	41 967	43 260	41 710	40 994	38 521	38 671	36 702	37 529	38 247
CO ₂ **	60 537	52 113	48 397	45 424	42 439	43 841	44 389	44 662	43 649	42 630	40 924	43 896	41 945	42 362	42 498
CH ₄	6 444	5 899	5 527	5 113	5 047	5 192	5 250	4 959	4 681	4 623	4 546	4 457	4 570	4 586	4 282
N ₂ O	6 125	5 245	4 464	3 928	4 051	4 181	4 244	4 268	3 992	3 838	3 824	4 056	3 888	3 992	4 077
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
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
SF ₆	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
Total*	70 972	60 016	54 485	50 336	48 365	50 663	51 544	52 595	50 461	49 547	46 992	47 291	45 290	46 276	46 795
Total**	73 378	63 524	58 636	54 620	51 681	53 359	53 965	53 997	52 400	51 183	49 395	52 517	50 533	51 109	51 046

*CO₂ emissions with LULUCF, **CO₂ 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 30.4% reduction of total anthropogenic emissions from the base year and the Kyoto conditions for the Slovak republic are already realised at the present.

In accordance with the actually emission inventory, the total emissions decreasing of GHGs in CO₂ equivalent is about 30% against the base year 1990. The adopted reduction commitment of SR for the first period 2008-2012 of the KP is real to reach. The indicated reduction of emission evaluation is the result of the number of impacts and processes linked with the transformation of economy. As the most decisive reasons in relation with the followed subject we can consider: gradual decrease in energy intensity since 1993; higher share of services in the GDP generation; higher share of gas fuels in the economy; structural changes in industry and the decrease of energy consumption in energy intensive sectors (without metallurgy), as well as in less energy intensive industries; and the impact of legislative measures influencing directly or indirectly the generation of greenhouse gas emissions.

Concerning the actual and proposed dynamics of GDP growth in the Slovak republic there exist legitimate assumption that GHG emissions will increase in line with it. Due to this scenario there is necessary to prepare investment strategies and programs that allow us to achieve permanent distribution of GDP growth and emissions growth with the regards to the further the post-Kyoto reduction goals.

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