Switzerland's Greenhouse Gas Inventory 1990–2004

National Inventory Report 2006

Submission of 10 November 2006
to the United Nations Framework Convention on Climate Change

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Glossary

AD	Activity data
AEF	area expansion factor
AREA1	Swiss Land Use Statistics 1979/85 (ASCH1 data re-evaluated according to the AREA set of land-use and land-cover categories)
AREA2	Swiss Land Use Statistics 1992/97 (ASCH2 data re-evaluated according to the AREA set of land-use and land-cover categories)
AREA3	Swiss Land Use Statistics, third survey 2004/09
ART	Agroscope Reckenholz-Tänikon Research Station (former: FAL)
ASCH1	Swiss Land Use Statistics, first survey 1979/85
ASCH2	Swiss Land Use Statistics, second survey 1992/97
BEF	biomass expansion factor
Carbura	Swiss Central Office for the Import of Liquid Fuels
Cemsuisse	Association of the Swiss Cement Industry
CC	Combination category
CH_4	Methane, IPCC GWP (1995): 21 (FCCC 2003, table 1)
CHP	Combined heat and power production
CO	Carbon monoxide
CO_2, CO_2 eq	Carbon dioxide (equivalent)
CRF	Common reporting format
CSS	Mix of special waste with saw dust; used as fuel in cement kilns
DBH	Diameter (of trees) at breast height
EF	Emission factor
EMIS	Swiss national air pollution database
EMPA	Swiss Federal Laboratories for Material Testing and Research
DETEC	Department of the Environment, Transport, Energy and Communication
FAL	Swiss Federal Research Station for Agroecology and Agriculture (since 2006: ART)
FCCC	Framework Convention on Climate Change
FOCA	Federal Office of Civil Aviation
FOAG	Federal Office for Agriculture
FOEN	Federal Office for the Environment (former name SAEFL until 2005)
Gg	Gigagram (10^9 g = 1’000 tons)
GHG	Greenhouse gas
GWP	Global Warming Potential
ha	hectare
HFC	Hydrofluorocarbons (e.g. HFC-32 difluoromethane)

HFO	Heavy fuel oil
IDP	Inventory Development Plan
IPCC	Intergovernmental Panel on Climate Change
kha	kilo hectare
LFO	Light fuel oil (Gas oil)
LPG	Liquefied Petroleum Gas (Propane/Butane)
LTO	Landing-Takeoff-Cycle (Aviation)
LULUCF	Land Use, Land-Use Change and Forestry
MSW	Municipal solid waste
NCV	Net calorific value
NFI I	First National Forest Inventory (1983-1985)
NFI II	Second National Forest Inventory (1993-1995)
NFI III	Third National Forest Inventory (2004-2006)
NIR	National Inventory Report
NIS	National Inventory System
NMVOC	Non-methane volatile organic compounds
N_2O	Nitrous oxide; IPCC GWP (1995): 310 (FCCC 2003, table 1)
NO_x	Nitrogen oxides
PFC	Perfluorinated carbon compounds (e.g. Tetrafluoromethane)
SAEFL	Swiss Agency for the Environment, Forests and Landscape (since 2006: Federal Office for the Environment FOEN)
SF_6	Sulphur hexafluoride
SGCI/SSCI	Schweiz. Gesellschaft für Chemische Industrie / Swiss Society of Chemical Industries
SFOE	Swiss Federal Office of Energy
SFSO	Swiss Federal Statistical Office
SO_2	Sulphur dioxide
SVGW/SSIG/SGWA	Schweizerischer Verein des Gas- und Wasserfaches / Société Suisse de l'Industrie du Gaz et des Eaux / Swiss Gas and Water Industry Association
SWISSMEM	Swiss Mechanical and Electrical Engineering Industries (Schweizer Maschinen-, Elektro- und Metallindustrie)
UNFCCC	United Nations Framework Convention on Climate Change
VOC	Volatile organic compounds
VTG	Verteidigung Luftwaffe (Swiss Air Force Administration)
VSAI/AISA	Vereinigung Schweiz. Automobil-Importeure / Association Importateurs Suisses d'Automobiles
WSL	Swiss Federal Institute for Forest, Snow and Landscape Research

Executive Summary

Inventory Preparation in Switzerland

On 10 December 1993, Switzerland ratified the United Nations Framework Convention on Climate Change (UNFCCC). Since 1996, the submission of its national greenhouse gas inventory has been based on IPCC guidelines. From 1998 on, the inventories have been submitted in the Common Reporting Format (CRF). The present report is Switzerland's third National Inventory Report (NIR 2006) prepared under the UNFCCC. It includes, as a separate document, Switzerland's 2004 Inventory in the CRF.

On 9 July 2003, Switzerland ratified the Kyoto Protocol to the UNFCCC. The Swiss National Inventory System (NIS) according to Article 5.1 of the Kyoto Protocol is presently being implemented and is fully operational.

The Federal Office for the Environment (FOEN; formerly known as the Swiss Agency for the Environment, Forests and Landscape, SAEFL) is in charge of compiling the emission data and bears overall responsibility for Switzerland's national greenhouse gas inventory. In addition to the FOEN, the Swiss Federal Office of Energy (SFOE), the Swiss Federal Agroscope Reckenholz-Tänikon Research Station (former: Research Station for Agroecology and Agriculture, FAL) and the Federal Office of Civil Aviation (FOCA) participate directly in the compilation of the inventory. Several other administrative and research institutions are involved in inventory preparation.

In preparing its third National Inventory Report, Switzerland took into account the findings of the 2004 in-country review, as well as the 2005 centralized review of its previous inventory submissions. Improvements are documented in the relevant chapters of this report. The Inventory Development Plan (see Annex A5) has been updated accordingly.

It should be noted that the current report is the **third submission in 2006** (first submission: 12 April, second submission 31 May). This third submission includes, beside a number of improvements and corrections, a complete time series of the LULUCF sector calculated by means of the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (2003), which has not been available yet for the submission in May 2006.

Chapter 1, the Introduction, provides an overview of Switzerland's institutional arrangements for producing the inventory, and the process and methodologies used for inventory preparation.

The data sources used to compile the national inventory and to estimate greenhouse gas emissions and removals are: the Swiss national air pollution database (EMIS), national energy statistics, data from industry associations, as well as further statistics and models for road transportation, agriculture, land use, land-use change and forestry (LULUCF) and waste. Emissions are calculated according to methodologies recommended by the IPCC and contained in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 1997a, 1997b, 1997c) and in the IPCC Good Practice Guidance (IPCC 2000). The data in the EMIS database are pre-processed in order to enable transfer to the CRF Reporter (CRF: Common Reporting Format) required for reporting under the UNFCCC.

All inventory data are assembled and prepared for input into the CRF Reporter by a specialized task force, the GHG Inventory Core Group, which is responsible for ensuring the conformity of the inventory with 2003 UNFCCC guidelines (FCCC 2003). In the preparation of this report, the Inventory Group was supported by consultants. Their mandate included editing of the NIR, and an analysis of the consistency between the emission modelling and the recommendations of the IPCC Good Practice Guidance. Furthermore, the consultants carried out the key category analysis and the uncertainty analysis, and were responsible for performing some tasks relating to the inventory development plan.

An inventory quality assurance and control system was established. It is designed to comply with the objectives of good practice guidance, i.e. to improve transparency, consistency, comparability, completeness and confidence in the Swiss inventory of GHG emission estimates. The QA/QC Officer is responsible for enforcement of the defined quality standards.

A National Inventory System Supervisory Board was established by decision of the FOEN Directorate in summer 2006. The Board oversees activities related to the GHG Inventory and to the National Registry. The QA/QC Officer advises the NIS Supervisory Board on matters relating to the conformity of the inventory with reporting requirements.

Moreover, Chapter 1 provides information on key categories and uncertainties: 37 key categories are identified for 2004 where 21 are in the energy sector. An uncertainty analysis (Monte Carlo) estimates the level uncertainty of 3.34% and the trend uncertainty of 2.43% of total CO_2-equivalent emissions in 2004.

Chapter 2 provides an analysis of Switzerland's trends in greenhouse gas emissions. The most important results are also reported below in this Executive Summary.

Chapters 3 to 8 provide principal source and sink category estimates. The NIR 2006 implements recommendations of the UNFCCC reviews by providing more detailed descriptions of the methodologies and results than the NIR 2005. A number of methodologies and input data on emission factors and activities have been revised and updated.

Chapter 9 explains and justifies recalculations that have been performed since the last inventory submission to the UNFCCC Secretariat in 2005. Actually, an exceptional number of recalculations were carried out. Simultaneously with a full redesign of the national air pollution and greenhouse gas emission database EMIS, all emission factors and activity data were checked and updated leading to recalculations of all the sectors. They result in an increase of the total 2003 emissions in CO_2 equivalents (without CO_2 emissions from LUCF) of 395 Gg CO_2 eq, which corresponds to an increase of 0.76% of the national total. For the base year,1990, the increase due to recalculations amounts to 0.58%.

Trend Summary: National GHG Emissions and Removals

In 2004, Switzerland emitted about 53'074 Gg (kilotonnes) CO_2 equivalent, or 7.16 tonnes CO_2 equivalent per capita (CO_2 only: 6.11 tonnes per capita), to the atmosphere, excluding net CO_2 emissions/removals from Land Use, Land-Use Change and Forestry (LULUCF).

For 2004, 37 key categories were identified for the country's level and trend analysis, covering 97% of total CO_2-equivalent greenhouse gas (GHG) emissions. Approximately 40% of total GHG emissions derived from the two most important key sources: CO_2 from gasoline combustion – Transport (source category 1A3b, road transportation) and CO_2 from liquid fuel combustion – Other Sectors (source category 1A4b, residential).

Table 1 shows Switzerland's annual GHG emissions by individual GHG from 1990 (base year) to 2004. Total annual GHG emissions do not show any significant trend. Fluctuations in total GHG emissions over the period 1990–2004 are less than 5%. In 2004, total gross GHG emissions (excl. LULUCF Removals/Emissions) showed an increase of 0.6% as compared to the level recorded for 1990 (see also Table 2).

Table 1 Summary of Switzerland's GHG emissions in CO_2 equivalent (Gg), 1990–2004 (CRF Table 10s5/10s5.2).

Greenhouse Gas Emissions	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	***2004/1990***
	CO_2 equivalent (Gg)															*%*
CO_2 emissions incl. net CO_2 from LULUCF	42'801	47'315	46'834	39'867	38'939	40'115	41'618	40'640	43'491	39'851	45'164	44'028	43'271	46'750	44'496	*4.0%*
CO_2 emissions excl. net CO_2 from LULUCF	44'512	46'155	46'189	43'590	42'804	43'327	44'049	43'401	44'619	44'833	43'910	44'692	43'796	44'893	45'326	*1.8%*
CH_4	4'372	4'347	4'236	4'094	4'002	3'984	3'935	3'852	3'794	3'745	3'692	3'707	3'648	3'602	3'550	*-18.8%*
N_2O	3'628	3'644	3'618	3'575	3'575	3'504	3'551	3'431	3'428	3'406	3'432	3'411	3'411	3'326	3'329	*-8.2%*
HFCs	0.02	0.2	6.1	13	30	152	193	258	311	360	418	492	502	538	617	---
PFCs	100	85	69	30	18	15	17	24	28	40	93	52	51	89	77	*-23.4%*
SF_6	144	146	148	126	112	81	82	122	152	138	186	234	209	194	175	*21.9%*
Total (incl. net CO_2 from LULUCF)	**51'045**	**55'538**	**54'912**	**47'705**	**46'676**	**47'851**	**49'395**	**48'326**	**51'204**	**47'540**	**52'984**	**51'925**	**51'092**	**54'500**	**52'244**	***2.3%***
Total (excl. net CO_2 from LULUCF)	**52'756**	**54'377**	**54'267**	**51'428**	**50'541**	**51'063**	**51'827**	**51'088**	**52'332**	**52'522**	**51'731**	**52'589**	**51'617**	**52'643**	**53'074**	***0.6%***
Total (excl. LULUCF Removals/Emissions)	**52'749**	**54'375**	**54'265**	**51'424**	**50'530**	**51'052**	**51'817**	**51'072**	**52'322**	**52'513**	**51'721**	**52'580**	**51'606**	**52'631**	**53'065**	***0.6%***

With regard to the distribution of emissions by individual greenhouse gas, CO_2 is the largest single contributor to emissions, accounting for 85.4% of total gross GHG emissions (excluding net CO_2 from LULUCF) in 2004 (1990: 84.4%). The share of CH_4 decreased from 8.3% (1990) to 6.7% (2004). Over the same period, the share of N_2O decreased from 6.9% to 6.3%, while the share of synthetic gases increased from 0.5% to 1.6%.

Table 2 Switzerland's total gross GHG emissions (excluding net CO_2 from LULUCF) in CO_2 equivalent (Gg), selected years.

Greenhouse Gas Emissions	**1990**		**1995**		**2000**		**2004**	
	Gg CO_2 eq	%	Gg CO_2 eq	%	Gg CO_2 eq	%	Gg CO_2 eq	%
CO2 emissions excluding net CO2 from LULUCF	44'512	84.4%	43'327	84.9%	43'910	84.9%	45'326	85.4%
CH_4	4'372	8.3%	3'984	7.8%	3'692	7.1%	3'550	6.7%
N_2O	3'628	6.9%	3'504	6.9%	3'432	6.6%	3'329	6.3%
HFCs	0	0.0%	152	0.3%	418	0.8%	617	1.2%
PFCs	100	0.2%	15	0.0%	93	0.2%	77	0.1%
SF_6	144	0.3%	81	0.2%	186	0.4%	175	0.3%
Total (excl. net CO_2 from LULUCF)	**52'756**	**100%**	**51'063**	**100%**	**51'731**	**100%**	**53'074**	**100%**

Figure 1 shows the shares of 2004 emissions contributed by individual greenhouse gases. As the shares of emissions contributed by the individual gases have remained relatively constant, the diagram is also representative of the other years in the period 1990–2004.

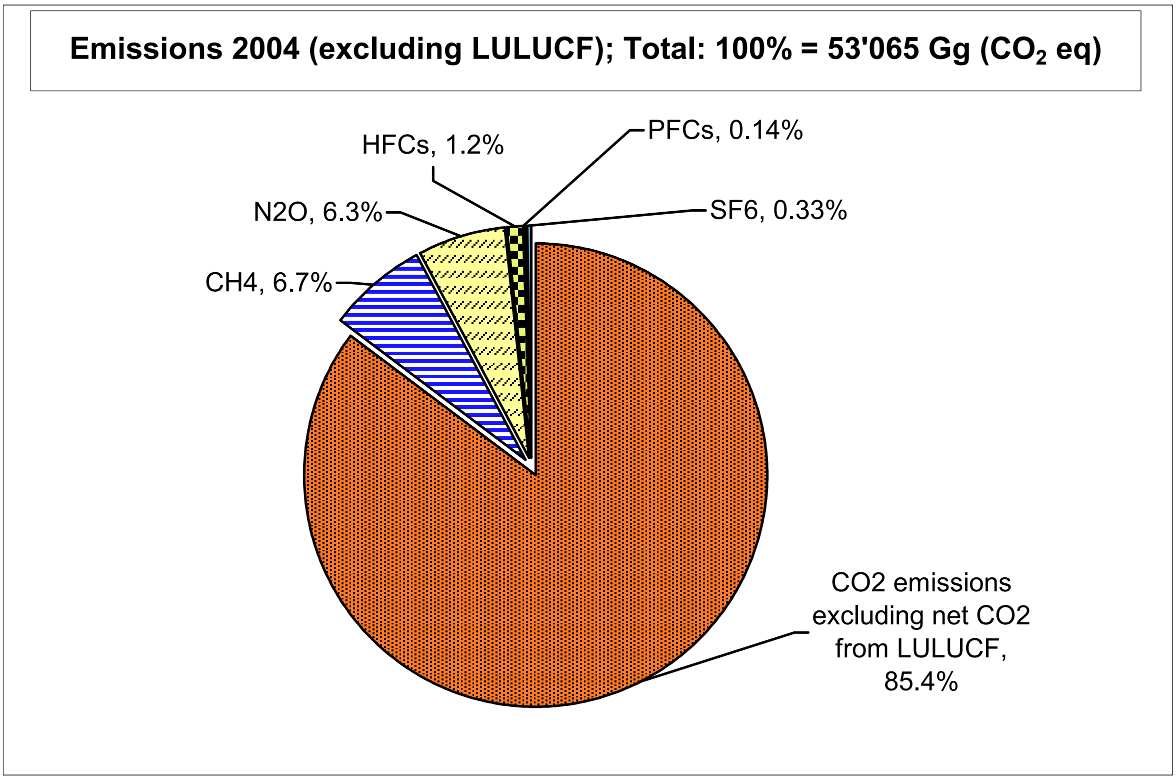

Figure 1 Contribution of individual gases to Switzerland's GHG emissions (excluding LULUCF), 2004.

Overview of Source and Sink Category Estimates and Trends

Table 3 and Figure 2 show the GHG emissions and removals by the main source and sink categories. The Energy sector (sector 1) is the largest source of national emissions. A slight upward trend is found for the Energy sector for the period 1994–2004. Year-to-year variations are mainly caused by changing winter temperatures. The emissions from all other sectors have decreased during this period.

Table 3 Switzerland's GHG emissions/removals by source and sink categories in CO_2 equivalent (Gg), 1990–2004.

Greenhouse Gas Source and Sink Categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	*2004/1990*
	CO_2 equivalent (Gg)															%
1 Energy	42'092	44'094	44'261	41'891	40'955	41'658	42'578	42'106	43'324	43'515	42'440	43'198	42'324	43'440	43'776	*4.0%*
2 Industrial Processes	3'258	2'912	2'744	2'437	2'617	2'527	2'382	2'298	2'415	2'509	2'819	2'946	2'890	2'900	3'051	*-6.3%*
3 Solvent and Other Product Use	466	444	424	400	385	367	346	324	302	292	281	270	259	250	236	*-49.3%*
4 Agriculture	5'903	5'907	5'833	5'753	5'706	5'638	5'662	5'499	5'467	5'405	5'409	5'418	5'394	5'282	5'258	*-10.9%*
5 Land-Use Change and Forestry	-1'704	1'163	647	-3'719	-3'854	-3'201	-2'421	-2'746	-1'118	-4'973	1'263	-655	-515	1'869	-821	*-51.8%*
6 Waste	1'030	1'018	1'004	943	867	861	848	845	814	791	772	747	740	760	744	*-27.7%*
Total (including LULUCF)	**51'045**	**55'538**	**54'912**	**47'705**	**46'676**	**47'851**	**49'395**	**48'326**	**51'204**	**47'540**	**52'984**	**51'925**	**51'092**	**54'500**	**52'244**	*2.3%*

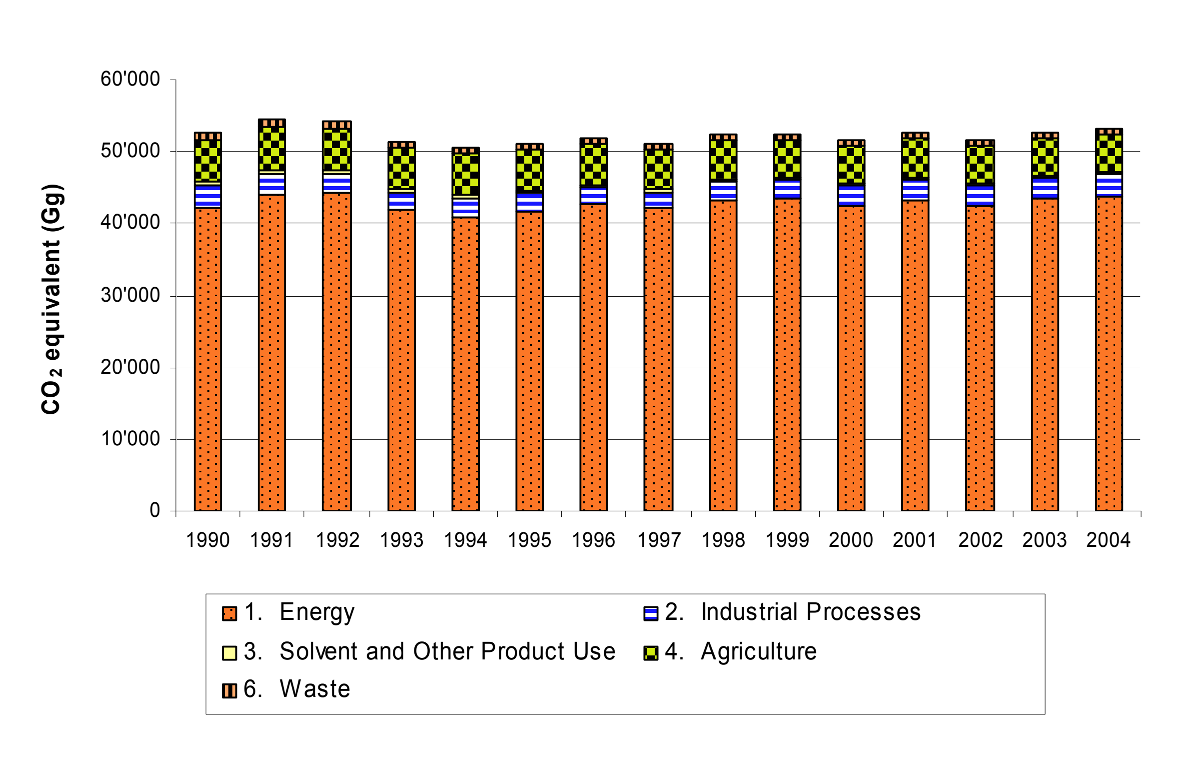

Figure 2 Switzerland's greenhouse gas emissions in CO_2 equivalent (Gg) by main source categories, 1990–2004 (Total excluding LULUCF).

Total emissions excluding LULUCF remained almost unchanged from 1990 to 2004, with an increase of 0.6% in 2004 compared to 1990. Total emissions including net CO_2 from LULUCF show an increase of 2.3% over the same period. Heavy storms in 1990 and, in particular, at the end of 1999 led to significant reductions in net removals within the LULUCF sector.

Table 4 shows the contributions of individual sectors to total gross emissions for selected years in more detail. Between 1990 and 2004, the relative contribution of source category 1 (Energy) increased from 79.8% to 82.5%, whereas decreases were seen from 6.2% to 5.7% for category 2 (Industrial Processes), from 11.2% to 9.9% for category 4 (Agriculture), and from 2% to 1.4% for category 6 (Waste).

Table 4 Switzerland's total gross GHG emissions (excluding LUCF) in CO_2 equivalent (Gg) by source category, selected years.

Greenhouse Gas Source Categories	**1990**		**1995**		**2000**		**2004**	
	Gg CO_2 eq	%	Gg CO_2 eq	%	Gg CO_2 eq	%	Gg CO_2 eq	%
1 Energy	42'092	79.8%	41'658	81.6%	42'440	82.1%	43'776	82.5%
2 Industrial Processes	3'258	6.2%	2'527	5.0%	2'819	5.5%	3'051	5.7%
3 Solvent and Other Product Use	466	0.9%	367	0.7%	281	0.5%	236	0.4%
4 Agriculture	5'903	11.2%	5'638	11.0%	5'409	10.5%	5'258	9.9%
6 Waste	1'030	2.0%	861	1.7%	772	1.5%	744	1.4%
Total (excluding LULUCF)	**52'749**	**100%**	**51'052**	**100%**	**51'721**	**100%**	**53'065**	**100%**

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We would like to thank all institutions, companies and individuals that contributed in some form to the Swiss national GHG Inventory as data suppliers, experts and national or international reviewers.

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1. Introduction

1.1. Background Information on Swiss Greenhouse Gas Inventories

On 10 December 1993, Switzerland ratified the United Nations Framework Convention on Climate Change (UNFCCC). Since 1996, the submission of its national greenhouse gas inventory has been based on IPCC guidelines. From 1998 on, the inventories have been submitted in the Common Reporting Format (CRF). In 2004 and 2005, Switzerland submitted its first and its second National Inventory Report prepared under the UNFCCC. In the present year, 2006, a first submission on 12 April and a re-submission on 31 May were made. The third, present submission includes the following improvements:

- A full time series of the LULUCF sector (according to decision 13/CP.9).
- Marginal corrections of several sources.

The submission is now considered to contain a complete inventory of all known sources. It includes, as a separate document, Switzerland's 2004 Inventory in the CRF (FOEN 2006).

On 9 July 2003, Switzerland ratified the Kyoto Protocol to the UNFCCC. The Swiss National Inventory System (NIS) according to Article 5.1 of the Kyoto Protocol has been implemented and is now operational.

1.2. Institutional Arrangements for Inventory Preparation

The Swiss National Inventory System (NIS) is developed and managed under the auspices of the Federal Department of the Environment, Transport, Energy and Communications (DETEC). It is hosted by a DETEC agency, the Federal Office for the Environment (FOEN). As stipulated in the Ordinance on the Internal Organization of DETEC of 13 December 2005, this agency has the lead within the federal administration regarding climate policy and its implementation.

As part of a comprehensive project (Swiss Climate Reporting Project), the FOEN directorate mandated its Economics, Research and Environmental Observation Division in early 2004 to design and establish the NIS in order to ensure full compliance with the reporting requirements of the UNFCCC and the Kyoto Protocol by 2006. Having regard to the provisions of Art. 5, paragraph 1 of the Kyoto Protocol, the project encompassed the following elements:

- arrangements with partner institutions, relating to
  - roles and responsibilities,
  - participation in the inventory development process,
  - data use, communication and publication
- Inventory Development Plan
- setting-up of a QA/QC system
- official consideration and approval of data
- upgrading and updating of the national air pollution database (EMIS)
- data documentation and storage

The project comes to an end with the establishment of Switzerland's Initial Report under Article 7, paragraph 4 of the Kyoto Protocol and its formal approval by the Federal Council.

Figure 3 gives a schematic overview of the institutional setting of the NIS.

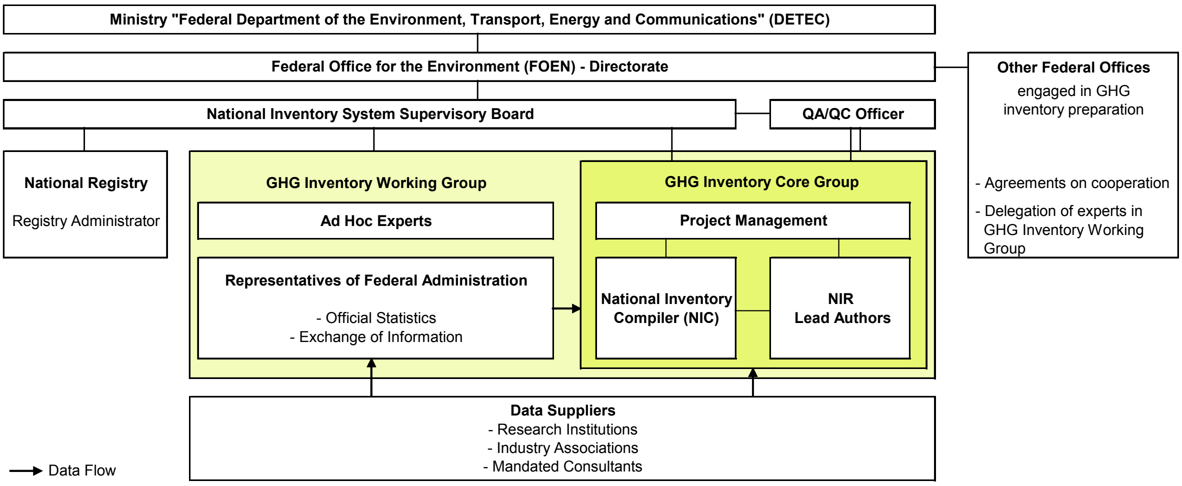

Figure 3 Institutional setting of the National Inventory System.

The **NIS Supervisory Board** was established by decision of the FOEN Directorate in summer 2006. The Board oversees activities related to the GHG Inventory and to the National Registry. It is independent of the inventory preparation process and, by its composition, combines technical expertise and political authority. According to its mandate, the main tasks of the NIS Supervisory Board are:

- official consideration of the annual inventory submission and recommendation of the inventory for official approval by the FOEN Directorate;
- assessment and approval of the recalculation of inventory data;
- handling of any issues arising from the UNFCCC review process that cannot be resolved at the level of the Inventory Project Management;
- facilitation of any non-technical negotiation, consideration or approval processes involving other institutions within the federal administration.

The **QA/QC Officer** is responsible for enforcement of the defined quality standards. He / she also advises the NIS Supervisory Board on matters relating to the conformity of the inventory with reporting requirements. His / her tasks and competencies are described in detail in the Description of the Swiss QA/QC System, annexed to this report.

The **GHG Inventory Working Group** encompasses all technical personnel involved in the inventory preparation process or representing institutions that play a significant role as suppliers of data. The group as a whole meets at least once per year to take stock of the state of the inventory, discuss priorities in the inventory development process, and to address specific issues of general interest that arise, e.g., from domestic or international reviews.

The **GHG Inventory Core Group** comprises the inventory experts employed at the FOEN or mandated on a regular basis, who are entrusted with specific, major responsibilities for inventory planning, preparation and/or management. The Core Group consists of

- the Inventory Project Management (with overall responsibility for the integrity of the inventory, communication of data, and information exchange with the UNFCCC secretariat);
- the National Inventory Compiler (responsible for the EMIS inventory data base and for the CRF tables);
- the NIR Lead Authors (responsible for the Inventory Report and carrying out centralized data assessments such as uncertainty analysis and key category analysis).

The GHG Inventory Core Group coordinates and integrates the activities of data suppliers within and outside the FOEN as well as those of mandated experts. Further data suppliers contributing to the inventory are research institutions and industry associations (Table 5). The latter are obliged by Art. 46 of the Federal Law relating to the Protection of the Environment (Swiss Confederation 1983) to provide the authorities with the information needed to enforce the law and, if necessary, to carry out inquiries or to cooperate by providing information for inquiries.

Further details of the function of the Core Group and the roles and responsibilities of its members are given in the Description of the Swiss QA/QC System, section 2.2.

Table 5 Primary and secondary data suppliers: 1–15 provide annual updates, 16–22 provide sporadic updates.

	Institution	Subject	Data supplied for inventory category...												References
			1A1	1A2	1A3	1A4	1A5	1B	R.A.	2	3	4	5	6	
	Data suppliers (annual updates)														
1	FOEN, Air Pollution Control	EMIS Database	x	x		x	x	x		x	x	x		x	FOEN 2006c
2	FOEN, Air Pollution Control	Off-road Database			x		x								SAEFL 2005a
3	FOEN, Waste and Raw Materials	Waste Statistics	x	x										x	SAEFL 2005c
4	FOEN, Forest Division	Forest Statistics											x		SAEFL 2005b
5	SFOE	Global Energy Statistics	x	x	x	x		x	x						SFOE 2005
6	FOCA	Civil Aviation			x										FOCA 2006
7	Swiss Air Force Administration	Military Aviation			x										VTG 2006
8	SFSO	Agriculture, LULUCF, Waste										x	x	x	SFSO 1997, 2000, 2000a, 2002, 2005, 2006, 2006b
9	ART	Agriculture, LULUCF										x	x		SBV 1998, 2004, 2005; SFSO 2000, 2002
10	WSL	National Forest Inventory											x		Brassel and Brändli 1999; EAFV/BFL 1988
11	Cepe/Basics	Energy Consumption		x		x									Cepe 2005; Basics 2006
12	Carbotech	Import Statistics of Synthetic Gases								x					SAEFL 2005
13	Industry Associations: SGCI, Swissmem, VSAI etc.	Synthetic Gases								x					Carbotech 2006
14	Swiss Petroleum Association	Oil Statistics							x						EV 2005
15	Cemsuisse	Cement, Clinker Production		x						x					Cemsuisse 2004
	Data suppliers (sporadic updates)														
16	SVGW	Gas Distribution Losses						x							Xinmin 2004
17	EMPA	Various Emission Factors	x	x	x	x									EMPA 1999; SFOE 2001
18	INFRAS	On-road Emission Model			x										SAEFL 2004
19	Electrowatt	Off-road Activity Data			x	x	x								Electrowatt 2005
20	TTM Mayer	Off-road Emission Factors			x	x	x								Mayer 2006
21	INFRAS	Off-road Emission Model			x	x	x								SAEFL 2005a
22	Sigmaplan, Meteotest	LULUCF											x		

The formal arrangements (agreements, contracts, and documentations of roles and responsibilities) that have been established to consolidate and formalize cooperation between the relevant partners contributing to, or involved in, the GHG inventory preparation process are described in Chapter H.1.1 of Switzerland's Initial Report under Article 7, paragraph 4 of the Kyoto Protocol.

Information relating to the Swiss GHG Inventory is made publicly accessible through the FOEN-hosted website www.climatereporting.ch, where detailed contact information is also available.

1.3. *Process for Inventory Preparation*

The data needed to prepare the UNFCCC Greenhouse Gas Inventory in the CRF is collected by the various data suppliers. Since the individual data suppliers bear the main responsibility for the quality of data provided, they are also responsible for the collection of activity data and for the selection of emission factors and methods. However, the relevant guidelines, including IPCC Good Practice Guidance, are necessarily to be taken into account. Diverse QA/QC activities (see Chapter 1.6) provide safeguards to maintain and successively improve the quality of inventory data.

The Air Pollution Control and Non-Ionizing Radiation Division at the FOEN maintains the EMIS data base, which contains all the basic data needed to prepare the GHG inventory in the CRF. At the same time, background information on data sources, activity data, emission factors and methods used for emission estimation is documented in the data base and/or the NIR.

Figure 4 illustrates in a simplified manner the data collection and processing steps leading to the CRF tables required for reporting under the UNFCCC. The FOEN internal GHG inventory files, that had been used for the generation of CRF tables (versions up to v 1.2) in previous submissions, have been replaced by a comprehensive data set produced by the redesigned national air pollution database EMIS. From EMIS, an interface transfers the data to the CRF Reporter that generates the CRF tables. Nevertheless, the internal GHG inventory files have been updated independently in order to form a rigorous controlling tool for the new EMIS database. For further details see Chapter 1.4.3.

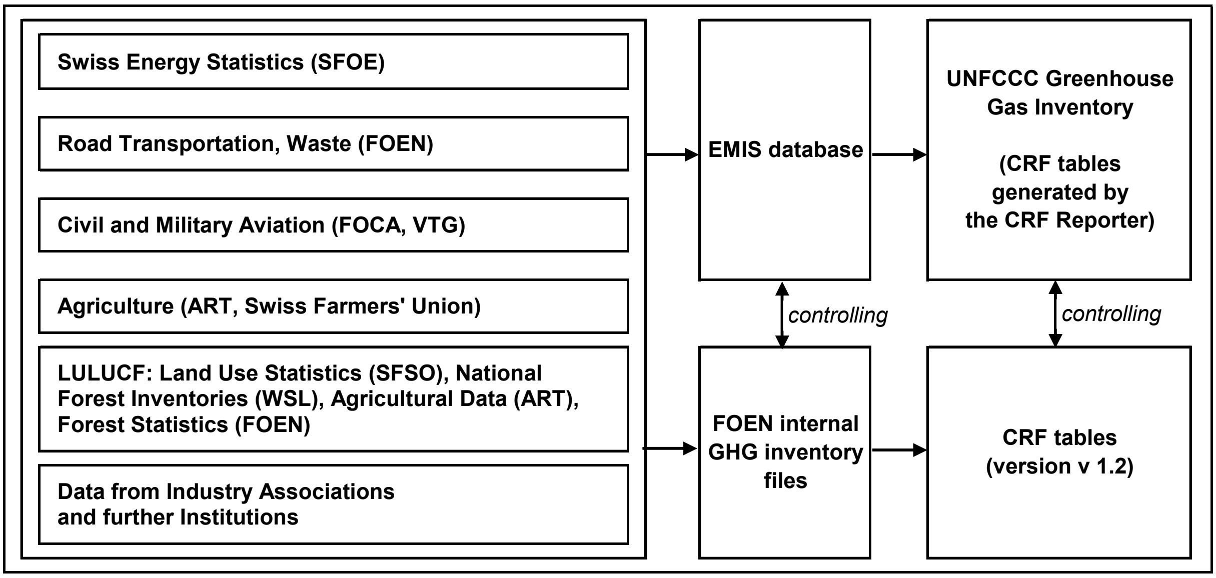

Figure 4 Data collection for EMIS database and FOEN Internal GHG inventory files, leading to the generation of two independent sets of CRF tables.

1.4. Methodologies

1.4.1. General Description

Emissions are calculated on the basis of the standard methods and procedures of the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC 1997a, 1997b, 1997c) and IPCC Good Practice Guidance (IPCC 2000, IPCC 2003), as adopted by the UNFCCC.

To date, emissions have been calculated, in part, by multiplying emission factors and activity rates in the "FOEN internal GHG inventory files" [1]. For the other part, emissions have been calculated by the data suppliers listed in Table 5 (e.g. for agriculture). In the latter cases, the resulting emission data have been directly inserted into the FOEN internal GHG inventory files. This procedure has been used for the previous submissions. For the present submission, the internal GHG inventory files have again been updated but only for controlling purposes. The GHG inventory files have now been replaced by the Swiss national air pollution database EMIS, which was redesigned and extended during 2005 to serve climate policy purposes as well. With an interface the data have been exported from EMIS into the CRF Reporter. Therefore, the data in the actual CRF tables are produced in EMIS. For further details, see Chapter 1.4.3 below.

The National Approach for source category 1 Energy is based on the statistics for fuel consumption (fuel sales in the transport sector) in Switzerland (see Chapter 1.4.2). The other sectors rely on national statistics and data surveys. For the various sectors, Tier 1, 2 and 3 methodologies according to IPCC Guidelines (IPCC 1997b) and Good Practice Guidance (IPCC 2000[2]) are used. The following list indicates the general approach adopted for each of the key categories.

1 Energy

- 1A1 Energy Industries, 1A2 Manufacturing Industries and Construction, 1A4 Other Sectors: Country-specific, Tier 2 method (1A2 also Tier 3 method).
  Emission factors: Country-specific; exception N_2O: IPCC default.
- 1A3 Transport, 1A5 Off-road: Approach is based on oil imports, refinery production numbers, fuel statistics and carbon content of the fuels.
  Other gases: country-specific bottom-up model for activities and emission factors.
  Exception: N_2O emission factors for aviation are IPCC default values.

2 Industrial Processes

- 2A1 Cement Production: IPCC Tier 2 method.
  Emission factors: Country-specific.
- 2C Metal Production: CORINAIR, Tier 2 method for CO_2, and Tier 3b method for PFCs.
  Emission factors: Country-specific.
- 2F Consumption of Halocarbons and SF_6: CORINAIR, Tier 2 method with two different approaches (statistics, surveys).
  Emission factors: Country-specific.
- Indirect CO_2 emissions from the decomposition of NMVOC in the atmosphere is accounted for.

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[1] Formerly called "SAEFL internal GHG inventory files".

[2] For the new LULUCF reporting in Annex 4, IPCC 2003 (see References LULUCF in Annex 4) is used.

3 Solvents

- Solvents: Approach is based on industry data, surveys, statistics on number of Jobs and inhabitants, etc. Indirect CO_2 emissions from the decomposition of NMVOC in the atmosphere is accounted for.

4 Agriculture

- 4A Enteric Fermentation (CH_4) and 4B Manure Management (CH_4): IPCC, Tier 2 method, Emission factors: Country-specific.
- 4B Manure Management (N_2O) and 4D Agricultural Soils (N_2O): Model and emissions factors are country-specific. The model corresponds to an extension of the IPCC Tier 2 method.

5 LULUCF

- Methods: IPCC Tier 2 due to the Good Practice Guidance 2003 (IPCC 2003). Emission factors are mainly country-specific, few are IPCC default factors.

6 Waste

- 6A Solid Waste Disposal on Land (CH_4): IPCC first order decay methane model, 6A (CO_2), 6C Waste Incineration (CO_2): country-specific Tier 2 method. Emission factors: Country-specific and IPCC default.

1.4.2. National and Reference Approach for Sector 1 Energy

The Reference Approach is used as a check for overall energy consumption as well as the resulting CO_2 emissions reported in source category 1 Energy. In Switzerland, it is applied on the basis of customs statistics for imported oil and oil products, and data published in the annual report of the Swiss Petroleum Association (Erdöl-Vereinigung/Union pétrolière, EV 2005). The results of the Reference Approach are compared with the results of the National Approach for sector 1 Energy in order to test the quality and completeness of the inventory. For the present inventory, the two approaches show very good correspondence, with CO_2 emissions differing by only 1.24% in 2004 (see Chapter 3.6).

1.4.3. National Air Pollution Database EMIS

A large body of emission data is adopted from Switzerland's national air pollution database EMIS, which is operated by FOEN (FOEN 2006c). EMIS was established at SAEFL (former name of FOEN) in the late 1980s. Its initial purpose was to record and monitor emissions of air pollutants. It has since been extended to cover greenhouse gases, too. Its structure corresponds to the EMEP/CORINAIR system for classifying emission-generating activities. EMEP/CORINAIR uses the Nomenclature for Reporting ("NFR code", UNECE 2003). The Revised 1996 IPCC Guidelines provide a correspondence key between IPCC and EMEP/CORINAIR source categories (IPCC 1997a: Annex 2). EMIS thus contains cross-references to IPCC/UNFCCC coding formats.

EMIS calculates emissions for various pollutants using emission factors and activity data according to the EMEP/CORINAIR methodology. Pollutants in EMIS include SO_2, NO_x, N_2O, NH_3, NMVOC, CO, HCl, dust, Pb, Zn, Cd, Hg, PCDD/PCDF, HF, CH_4, CO_2 (fossil origin), CO_2 (from biomass) and PM10. The input data originate from a variety of sources, such as production data and emission factors from industry, industry associations and research institutions, as well as population, employment, waste and agriculture statistics. EMIS is documented in an internal FOEN manual for the database (FOEN 2006c).

The original EMIS database underwent a full redesign in 2005. It was extended to incorporate more data sources, updated, and migrated to a new software platform. At the same time, activity data and emission factors were being checked and updated. For the present November 2006 submission, emissions from EMIS that are relevant for the GHG inventory were exported for the first time to the CRF Reporter. As a quality control measure in the implementation of the new EMIS database, all the emission estimates were generated independently by (i.) the new EMIS database and by (ii.) the existing Internal Greenhouse Gas Files, both using the same updated emission factors and activity data. The results were compared, and differences were used to identify and eliminate bugs. The output of the two approaches has proven to be fully congruent.

Input data for the EMIS database comprise the SFOE Swiss overall energy statistics, FOEN statistics and models for emissions from road transportation, statistics and models of off-road activities, import statistics for synthetic gases, waste and agricultural statistics, the National Forest Inventory and the National Forest Statistics (see Figure 4).

1.5. Key Categories

The key category analysis is performed according to the IPCC Good Practice Guidance (IPCC 2000, chapter 7). A Tier 1 level and trend assessment is applied with the proposed threshold of 95%. The same detailed disaggregation as in 2005 has been used to identify important sub-sources. A more detailed description of the key category analysis and the level of disaggregation is provided in Annex A1.1.

No Tier 2 key category analysis is carried out. This would require a Tier 2 uncertainty analysis for the whole inventory. For the present submission, such an uncertainty analysis has been performed, but only for the key categories and not for all categories of the inventory.

For the key category analysis, the category 2F Consumption of Halocarbons and SF_6 has been separated into four sub-categories:

- 2F, sum of PFC (No. 26 in Table 6)
- 2F_o (HFC), sum of HFC without HFC from 2F1 (No. 27 in Table 6)
- 2F1, HFC from 2F1 Refrigeration and Air Conditioning Equipment (No. 28 in Table 6)
- 2F_o (SF_6), sum of SF_6 without SF_6 from 2F8 (no longer a key category as in previous years, therefore not contained in Table 6)

Due to the emission dynamics within these groups, three of the four categories appear as key categories by trend (Table 6): while HFCs were not present in 1990, 617 Gg CO_2 equivalent were emitted in 2004.

For 2004, 37 key categories have been identified:

Table 6 List of Switzerland’s Key Categories 2004 sorted by category codes.

No.	IPCC Source Categories (and fuels if applicable)				Direct GHG	Level assess.	Trend assess.
1	1A1	1. Energy	A. Fuel Combustion	Gaseous Fuels	CO2	KC level	KC trend
2	1A1	1. Energy	A. Fuel Combustion	Liquid Fuels	CO2	KC level	KC trend
3	1A1	1. Energy	A. Fuel Combustion	Other Fuels	CO2	KC level	KC trend
4	1A1	1. Energy	A. Fuel Combustion	Other Fuels	N2O	-	KC trend
5	1A1	1. Energy	A. Fuel Combustion	Solid Fuels	CO2	-	KC trend
6	1A2	1. Energy	A. Fuel Combustion	Gaseous Fuels	CO2	KC level	KC trend
7	1A2	1. Energy	A. Fuel Combustion	Liquid Fuels	CO2	KC level	KC trend
8	1A2	1. Energy	A. Fuel Combustion	Other Fuels	CO2	KC level	KC trend
9	1A2	1. Energy	A. Fuel Combustion	Solid Fuels	CO2	KC level	KC trend
10	1A3a	1. Energy	A. Fuel Combustion		CO2	-	KC trend
11	1A3b	1. Energy	A. Fuel Combustion	Diesel	CO2	KC level	KC trend
12	1A3b	1. Energy	A. Fuel Combustion	Gasoline	CO2	KC level	-
13	1A3b	1. Energy	A. Fuel Combustion	Gasoline	CH4	-	KC trend
14	1A3e	1. Energy	A. Fuel Combustion		CO2	-	KC trend
15	1A4a	1. Energy	A. Fuel Combustion	Gaseous Fuels	CO2	KC level	KC trend
16	1A4a	1. Energy	A. Fuel Combustion	Liquid Fuels	CO2	KC level	KC trend
17	1A4b	1. Energy	A. Fuel Combustion	Gaseous Fuels	CO2	KC level	KC trend
18	1A4b	1. Energy	A. Fuel Combustion	Liquid Fuels	CO2	KC level	KC trend
19	1A4c	1. Energy	A. Fuel Combustion	Liquid Fuels	CO2	KC level	-
20	1A5	1. Energy	A. Fuel Combustion	Liquid Fuels	CO2	KC level	KC trend
21	1B2	1. Energy	B. Fugitive Emissions from Fuels		CH4	-	KC trend
22	2A1	2. Industrial Proc.	A. Mineral Products; Cement Production-CO2		CO2	KC level	KC trend
23	2C3	2. Industrial Proc.	C. Metal Production; Aluminium Production-PFC		PFC	-	KC trend
24	2C3	2. Industrial Proc.	C. Metal Production; Aluminium Production-CO2		CO2	-	KC trend
25	2F	2. Industrial Proc.	F. Consumption of Halocarbons and SF6		PFC	-	KC trend
26	2F_o	2. Industrial Proc.	F. Consumption of Halocarbons and SF6 without 2F1-HFC		HFC	-	KC trend
27	2F1	2. Industrial Proc.	F. Consumption of Halocarbons and SF6; Refrig. & AC Eq.		HFC	KC level	KC trend
28	3	3. Solvent and Other Product Use			CO2	KC level	KC trend
29	3	3. Solvent and Other Product Use			N2O	-	KC trend
30	4A	4. Agriculture	A. Enteric Fermentation		CH4	KC level	KC trend
31	4B	4. Agriculture	B. Manure Management		CH4	KC level	KC trend
32	4B	4. Agriculture	B. Manure Management		N2O	KC level	KC trend
33	4D1	4. Agriculture	D. Agricultural Soils; Direct Soil Emissions		N2O	KC level	KC trend
34	4D3	4. Agriculture	D. Agricultural Soils; Indirect Emissions		N2O	KC level	KC trend
35	6A	6. Waste	A. Solid Waste Disposal on Land		CH4	KC level	KC trend
36	6B	6. Waste	B. Wastewater Handling		N2O	KC level	-
37	6D	6. Waste	D. Other		CH4	-	KC trend

Of the 37 key categories, 21 are in sector 1 Energy, accounting for 81.1% of total CO_2-equivalent emissions in 2004. The other key categories are from sectors 2 Industrial Processes (4.7%), 3 Solvent and other Product Use (0.4%), 4 Agriculture (9.5%), and 6 Waste (1.2%). There are two major key sources:

- 1A3b Energy, Fuel Combustion, Road Transportation, gasoline, CO_2, level contribution 21.4%,
- 1A4b Energy, Fuel Combustion, Other Sectors, Residential, liquid fuels, CO_2, level contribution 17.8%.

The following table shows the contributions of the individual key categories. The complete results of the key category analysis are given in Annex A1.1.

Table 7 Details of Switzerland's Key Categories: contributions in level and trend analysis, and cumulative level contributions ("level cum."). The numbers (No.) correspond to those in Table 6.

No.	IPCC Source Categories (and fuels if applicable)		Direct GHG	1990 Gg CO2 eq	2004 Gg CO2 eq	Contribut. Level	Contrib. Trend	Level assess.	Trend assess.
12	1A3b	1. EnergyA. Fuel Combustion	CO2	11'332.2	11'363.4	21.4%	0.3%	KC level	-
18	1A4b	1. Energy A. Fuel Combustion	CO2	10'215.6	9'422.8	17.8%	7.6%	KC level	KC trend
16	1A4a	1. Energy A. Fuel Combustion	CO2	4'375.4	3'999.7	7.5%	3.6%	KC level	KC trend
11	1A3b	1. EnergyA. Fuel Combustion	CO2	2'412.0	3'606.7	6.8%	10.6%	KC level	KC trend
7	1A2	1. Energy A. Fuel Combustion	CO2	3'392.4	2'911.3	5.5%	4.5%	KC level	KC trend
30	4A	4. AgricultureA. Enteric Fermentation	CH4	2'474.8	2'271.0	4.3%	2.0%	KC level	KC trend
17	1A4b	1. Energy A. Fuel Combustion	CO2	1'364.9	2'249.7	4.2%	7.8%	KC level	KC trend
6	1A2	1. Energy A. Fuel Combustion	CO2	1'064.0	2'028.9	3.8%	8.6%	KC level	KC trend
3	1A1	1. Energy A. Fuel Combustion	CO2	1'519.7	1'930.6	3.6%	3.6%	KC level	KC trend
22	2A1	2. Industrial Proc.A. Mineral Products; Cement Production-CO2	CO2	2'524.8	1'714.2	3.2%	7.4%	KC level	KC trend
15	1A4a	1. Energy A. Fuel Combustion	CO2	941.0	1'415.2	2.7%	4.2%	KC level	KC trend
33	4D1	4. AgricultureD. Agricultural Soils; Direct Soil Emissions	N2O	1'389.8	1'223.3	2.3%	1.6%	KC level	KC trend
2	1A1	1. Energy A. Fuel Combustion	CO2	691.2	849.6	1.6%	1.4%	KC level	KC trend
19	1A4c	1. Energy A. Fuel Combustion	CO2	713.4	727.7	1.4%	0.1%	KC level	-
34	4D3	4. AgricultureD. Agricultural Soils; Indirect Emissions	N2O	818.9	679.3	1.3%	1.3%	KC level	KC trend
20	1A5	1. Energy A. Fuel Combustion	CO2	513.0	669.1	1.3%	1.4%	KC level	KC trend
27	2F1	2. Industrial Proc.F. Consumption of Halocarbons and SF6; Refrig. & AC Eq.	HFC	0.0	543.7	1.0%	4.9%	KC level	KC trend
9	1A2	1. Energy A. Fuel Combustion	CO2	1'391.2	541.4	1.0%	7.7%	KC level	KC trend
31	4B	4. AgricultureB. Manure Management	CH4	557.4	494.1	0.9%	0.6%	KC level	KC trend
32	4B	4. AgricultureB. Manure Management	N2O	448.2	396.8	0.7%	0.5%	KC level	KC trend
1	1A1	1. Energy A. Fuel Combustion	CO2	234.8	374.2	0.7%	1.2%	KC level	KC trend
35	6A	6. Waste A. Solid Waste Disposal on Land	CH4	693.0	348.6	0.7%	3.1%	KC level	KC trend
8	1A2	1. Energy A. Fuel Combustion	CO2	156.9	286.4	0.5%	1.2%	KC level	KC trend
36	6B	6. Waste B. Wastewater Handling	N2O	190.7	209.1	0.4%	0.2%	KC level	-
28	3	3. Solvent and Other Product Use	CO2	357.0	186.0	0.4%	1.6%	KC level	KC trend
21	1B2	1. Energy B. Fugitive Emissions from Fuels	CH4	380.5	177.9	0.3%	1.8%	-	KC trend
10	1A3a	1. EnergyA. Fuel Combustion	CO2	252.6	143.7	0.3%	1.0%	-	KC trend
4	1A1	1. Energy A. Fuel Combustion	N2O	48.4	118.9	0.2%	0.6%	-	KC trend
14	1A3e	1. EnergyA. Fuel Combustion	CO2	200.0	109.1	0.2%	0.8%	-	KC trend
5	1A1	1. Energy A. Fuel Combustion	CO2	47.0	105.4	0.2%	0.5%	-	KC trend
37	6D	6. Waste D. Other	CH4	30.3	91.4	0.2%	0.5%	-	KC trend
26	2F_o	2. Industrial Proc.F. Consumption of Halocarbons and SF6 without 2F1-HFC	HFC	0.0	73.7	0.1%	0.7%	-	KC trend
24	2C3	2. Industrial Proc.C. Metal Production; Aluminium Production-CO2	CO2	139.3	71.8	0.1%	0.6%	-	KC trend
25	2F	2. Industrial Proc.F. Consumption of Halocarbons and SF6	PFC	0.0	65.3	0.1%	0.6%	-	KC trend
29	3	3. Solvent and Other Product Use	N2O	109.4	50.4	0.1%	0.5%	-	KC trend
13	1A3b	1. EnergyA. Fuel Combustion	CH4	91.3	22.9	0.0%	0.6%	-	KC trend
23	2C3	2. Industrial Proc.C. Metal Production; Aluminium Production-PFC	PFC	100.2	11.4	0.0%	0.8%	-	KC trend

1.6. Quality Assurance and Quality Control (QA/QC)

1.6.1. The QA/QC system

In 2002, a total quality management (TQM) system was introduced within the FOEN. The GHG inventory compilation was registered as a process to be managed in line with the principles of the TQM system. In 2004, the process was subjected to an audit. Subsequently, the establishment of a QA/QC system was initiated. The QA/QC system is designed to comply with the objectives of Good Practice Guidance of IPCC (2000), i.e. to continuously improve transparency, consistency, comparability, completeness, accuracy and confidence in the Swiss inventory of GHG emission estimates. Based on these quality criteria, the objective of the Switzerland's inventory system is to annually produce a high quality inventory that ensures full compliance with the reporting requirements of the UNFCCC and the Kyoto Protocol.

The major elements of the QA/QC system are summarized below. The detailed state of its implementation is documented in the "Description of the Swiss QA/QC System", annexed to this report (FOEN 2006e).

a) Inventory agency responsible for coordinating QA/QC activities

The FOEN has the lead within the federal administration regarding climate policy and its implementation. With the establishment of Switzerland's Initial Report under Article 7, paragraph 4 of the Kyoto Protocol and its formal approval by the Federal Council the Swiss NIS became operative. By arranging the organisational structure and defining tasks and responsibilities of institutions, organisations and consultants involved, the NIS itself is a key tool in improving the quality and process management of the inventory preparation. Within the NIS, the FOEN-based QA/QC officer is responsible for enforcement of the defined quality objectives (see Figure 3).

b) QA/QC plan

The QA/QC plan contains a description of current QA/QC activities, key findings, and planned improvements. At present, specific monitoring protocols for each source and sink category are being added to ensure agreed standards and transparency. These protocols specify the methodologies to be used, institutional tasks and responsibilities, the data sources and collection processes, and relevant reference material.

The QA/QC plan will be reviewed annually and modified by the QA/QC officer if necessary (after prior consultation with the Project Management).

The annual cycle of inventory preparation including the timelines for the performance of QA/QC activities is shown in Table 8

Table 8 Annual cycle of inventory preparation.

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Meeting of NIS Supervisory Board													
Meeting of GHG Inventory Core Group													
Annual Meeting of GHG Working Group													
Consideration of UNFCCC Synthesis & Assmt. Report													
Data Collection			Energy Data				Non-Energy Data						
Quality Check of Energy Data													
Quality Check of Non-Energy Data													
Calculation of Emissions/Removals													
Compilation/Editing of NIR													
Generation of NIR Tables (EMIS)													
Generation of CRF Tables (EMIS)													
Completion of Checklists and other QC Activities													
Expert Peer Review						Not linked to specific phase							
Implementation of Individual Inventory Review													
Uncertainty Analysis													
Key Category Analysis													
Internal NIR Review													
Official Consideration and Approval													
Submission													
Publication and Archiving													

c) QC procedures

A standardized and formalized way of carrying out Tier 1 – and in part Tier 2 – QC activities was introduced in 2005 (effective for the 2006 inventory compilation process). All contributors to the inventory had to complete checklists to document their QC activities. Those checklists had been designed following the requirements of Table 8.1 of the Good Practice Guidance (IPCC 2000) and had been subsequently modified to meet the specific needs of the sectoral experts.

d) QA review procedures

QA procedures include an internal review of NIR and CRF tables by members of the GHG Inventory Core Group as well as by NIR authors prior to each submission to the UNFCCC. Every year, external experts are mandated to review selected key categories after submission. Additionally, the results of the UNFCCC inventory reviews are analysed and used to update the Inventory Development Plan.

e) Reporting, documentation, and archiving procedures

A method is currently being implemented to ensure systematic archiving of all essential documents as well as of all significant decisions reached by the experts involved in the planning, preparation and compilation of the inventory. Starting with preparations for the inventory submission in May 2006 (FOEN 2006b), the results of all QA/QC activities and procedures have been documented and archived for consultation by reviewers.

1.6.2. Treatment of Confidential Data

The FOEN collects the data needed for calculating emissions of HFCs, PFCs and SF_6 from private companies or industry associations. In the National Inventory Report, the activity data underlying emissions of HFCs, PFCs and SF_6 are only partly presented at the most disaggregated level for reasons of confidentiality. However, complete emissions are reported in aggregated tables.

Confidential data will be made available by the FOEN in line with the procedures agreed under the UNFCCC for the technical review of GHG inventories.

1.7. Uncertainty Evaluation

The IPCC Good Practice Guidance lists two methodologies (Tier 1 and Tier 2) for calculating uncertainties. For relatively small and uncorrelated uncertainties where normal distributions are appropriate, use of error propagation equations (Tier 1) is suggested. If these assumptions are not fulfilled sufficiently, a Tier 2 Monte Carlo simulation is suggested. This simulation enables the attribution of correlations and probability distributions of any physically possible shape and width.

The current NIR presents both of these quantitative uncertainty evaluations. Uncertainty of key categories is assessed in accordance with the IPCC Good Practice Guidance

- Tier 1 methodology (IPCC 2000: p. 6.13ff.)
- Tier 2 methodology, Monte Carlo simulation (IPCC 2000: p. 6.18ff.).

In Tier 1 analysis, all sources are included, partly on an aggregated level. In Tier 2 analysis, only key categories are included. In both analyses, residual non-key categories are treated as an additional single “category” with an estimated error in the virtual activity data and in the virtual emission factor. This allows the uncertainty of the whole Swiss inventory to be estimated. In this section, the aggregated results are presented. In the sectoral chapters (energy, industrial processes, etc.), specific information is provided on the uncertainty estimation for activity data, emission factors or emissions from key category sources. For other sources, a qualitative rather than quantitative estimate of uncertainties is given.

As the IPCC Guidelines suggest (IPCC 1997a), uncertainties are expressed as half of the 95% confidence interval.

The uncertainty analysis presented in the next paragraphs is not based on the data of the current GHG inventory (November 2006) but on the data submitted in April 2006 (FOEN 2006a). On the level of the emissions, the modifications carried out since the April submission (see Chapter 1.1) are modest: The national total of 2004 emissions (excluding LULUCF) changed from 53’034 Gg CO_2 eq (April 2006 submission) to 53’065 Gg CO_2 eq (present submission). For that reason, the management of the FOEN GHG Inventory Core Group decided to abandon new runs of the uncertainty analysis. Therefore, the input data and the uncertainty results shown in paragraphs 1.7.1 to 1.7.5 relate to the data submitted in April 2006 and deviate slightly from the data of the current submission. Presumably, the uncertainty results would only change marginally when applying the emission data of the current submission.

1.7.1. Data Used

For many key data sources, no explicit information on uncertainties is available – e.g., the Swiss overall energy statistics (SFOE 2005) do not provide estimates of uncertainties. For these cases, the authors of the NIR chapters, the FOEN experts involved and several data suppliers derived first estimates of uncertainties based on the IPCC Good Practice Guidance default values and on information concerning the process of data collection for activity data and emission factors (import or sales statistics, surveys or modelling). Several experts from data suppliers were contacted for further information on some of the uncertainties. Some industry associations/sources also provided published or unpublished uncertainty estimates for their data. The data sources can be found in the relevant sub-sections on “Uncertainties and Time-Series Consistency” in each of the sectoral chapters (3–8) below.

Distributions are assumed to be symmetric in the Tier 1 method. For the Monte Carlo simulation, asymmetric distributions were also adopted.

Uncertainties in the GWP values were not taken into account.

Compared to the submission April 2005 (SAEFL 2005f), significant progress has been made by running a Monte Carlo simulation. However, the uncertainty analysis still needs further improvement. An important step will be to further motivate institutions to supply not only data but also estimates of associated uncertainties. Also, it is planned to carry out the Monte Carlo simulation for all (not only key) categories, as well as for LULUCF categories.

1.7.2. Uncertainty Estimates

For non-key categories, the NIR provides qualitative estimates of uncertainties. Here, the following terms are used:

- high data quality – uncertainty in the order of ±5%,
- medium data quality – uncertainty in the order of ±20%,
- low data quality – uncertainty in the order of ±50%.

1.7.3. Results of Tier 1 Uncertainty Evaluation

a) Results for the submission April 2006

The results of the Tier 1 uncertainty analysis for GHG emissions from key categories (according to the key category analysis of the submission 12 April 2006, FOEN 2006a) in Switzerland are summarized in Table 9 and Table 10. Details of the uncertainty estimates for specific sources are provided in the sub-sections on “Uncertainties and Time-Series Consistency” in each of the chapters on source categories below.

The resulting Tier 1 uncertainty in the national total annual CO_2-equivalent emissions is estimated to be **3.34%** (level uncertainty). Trend uncertainty is **2.43%**.

It should be noted that the present results of the Tier 1 uncertainty analysis for GHG emissions from key sources in Switzerland do not (fully) take into account the following factors that may further increase uncertainties:

- correlations existing between source categories that have not been considered by the Tier 1 approach (e.g. production data used for industry emissions in both categories 1A2 Manufacturing Industries and 2 Industrial Processes, or cattle numbers used for emissions related to enteric fermentation and to animal manure production);
- errors due to the assumption of constant parameters, e.g. constant net calorific values for fuels for the entire period since 1990;
- errors due to non-normal, asymmetric distribution of the uncertainties;

- errors due to methodological shortcomings;
- errors due to sources not reported (these are estimated to be very small).

The Tier 2 uncertainty evaluation described below, on the other hand, explicitly takes account of correlations between sources and of asymmetric distributions.

Table 9 Tier 1 Uncertainty Calculation and Reporting for sources in Switzerland 2004 (IPCC 2000, Table 6.1). Note that the emissions 1990 and 2004 correspond to the values of the submission April 2006, which may slightly deviate from the data of the current submission.

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC Source category	Gas	Base year emissions 1990	Year 2004 emissions	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combinded uncertainty as % of total national emission in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data	Calc/Input						
		Gg CO2 equivalent	Gg CO2 equivalent	%	%	%	%	%	%	%	%	%
1. CO2 emissions from Fuel Combustion												
1A 1. Energy A. Fuel Combustion Gaseous fuels	CO2	3'714.50	6'186.06	5.0	4.6	6.8	0.792	0.0464	0.1172	0.21	0.83	0.86
1A 1. Energy A. Fuel Combustion Liquid fuels	CO2	34'319.03	34'143.58	1.4	0.6	1.5	0.954	-0.0067	0.6471	0.00	1.26	1.26
1A 1. Energy A. Fuel Combustion Solid fuels	CO2	1'490.48	566.35	18.4	5.0	19.1	0.203	-0.0177	0.0107	-0.09	0.28	0.29
1A 1. Energy A. Fuel Combustion Other fuels	CO2	1'676.11	2'211.82	10.0	30.0	31.6	1.319	0.0100	0.0419	0.30	0.59	0.66
Total CO2 Emissions Fuel Combustion	CO2	41'200.11	43'107.80									

A	B	C	D	E	F	G	H	I	J	K	L	M
		Gg CO2 equivalent	Gg CO2 equivalent	%	%	%	%	%	%	%	%	%
2. Non-CO2 Emissions from Fuel Combustion and Other Key Sources												
1A1 1. Energy A. Fuel Combustion 1. Energy Industries Other Fuels	N2O	48.42	112.78	10.0	80.0	80.6	0.171	0.0012	0.0021	0.10	0.03	0.10
1A3b 1. Energy A. Fuel Combustion 3. Transport; Road Tı Gasoline	CH4	91.78	23.07	10.0	*59.2*	60.0	0.026	-0.0013	0.0004	-0.08	0.01	0.08
1B2 1. Energy B. Fugitive Emissions 2. Oil and Natural Gas	CH4	385.75	182.92		*50.0*	50.0	0.172	-0.0039	0.0035	-0.19	0.00	0.19
2A1 2. Industrial Proc. A. Mineral Products; Cement Production-CO2	CO2	2'524.77	1'714.25	2.0	6.0	6.3	0.204	-0.0156	0.0325	-0.09	0.09	0.13
2B 2. Industrial Proc. B. Chemical Industry	N2O	100.75	16.12	10.0	40.0	41.2	0.013	-0.0016	0.0003	-0.06	0.00	0.06
2C3 2. Industrial Proc. C. Metal Production; Aluminium Production-PFC	PFC	100.17	11.40	5.0	48.7	49.0	0.011	-0.0017	0.0002	-0.08	0.00	0.08
2C3 2. Industrial Proc. C. Metal Production; Aluminium Production-CO2	CO2	139.26	70.24	5.0	30.0	30.4	0.040	-0.0013	0.0013	-0.04	0.01	0.04
2F 2. Industrial Proc. F. Consumption of Halocarbons and SF6	PFC	0.04	55.89		17.6	17.6	0.019	0.0011	0.0011	0.02	0.00	0.02
2F1 2. Industrial Proc. F. Consumption of Halocarbons and SF6; Refrig. & AC Eq.	HFC	0.02	544.59		13.8	13.8	0.142	0.0103	0.0103	0.14	0.00	0.14
2F_o 2. Industrial Proc. F. Consumption of Halocarbons and SF6 without 2F1-HFC	HFC	0.00	73.91		21.9	21.9	0.030	0.0014	0.0014	0.03	0.00	0.03
3 3. Solvent and Other Product Use	CO2	337.49	122.10		50.0	50.0	0.115	-0.0041	0.0023	-0.21	0.00	0.21
3 3. Solvent and Other Product Use	N2O	109.41	50.36		80.0	80.0	0.076	-0.0011	0.0010	-0.09	0.00	0.09
4A 4. Agriculture A. Enteric Fermentation	CH4	2'766.81	2'492.07	20.0	12.7	23.7	1.114	-0.0055	0.0472	-0.07	1.34	1.34
4B 4. Agriculture B. Manure Management	CH4	452.34	399.86	20.0	36.4	41.5	0.313	-0.0010	0.0076	-0.04	0.21	0.22
4B 4. Agriculture B. Manure Management	N2O	448.20	396.68	20.0	71.4	74.2	0.555	-0.0010	0.0075	-0.07	0.21	0.22
4D1 4. Agriculture D. Agricultural Soils; Direct Soil Emissions	N2O	1'389.82	1'207.74	10.0	79.8	80.4	1.832	-0.0036	0.0229	-0.29	0.32	0.43
4D3 4. Agriculture D. Agricultural Soils; Indirect Emissions	N2O	818.89	682.60	15.0	*93.9*	95.1	1.224	-0.0027	0.0129	-0.25	0.27	0.37
6A 6. Waste A. Solid Waste Disposal on Land	CH4	693.04	348.63	20.0	*56.6*	60.0	0.394	-0.0066	0.0066	-0.37	0.19	0.42
6D 6. Waste D. Other	CH4	30.34	91.38	10.0	*49.0*	50.0	0.086	0.0012	0.0017	0.06	0.02	0.06
Rest of sources	CO2	1'123.50	1'329.95	20.0	*34.6*	40.0	1.003	0.0038	0.0252	0.13	0.71	0.73
Total non-CO2 emissions from Fuel Combustion and other Key Sources		11'560.81	9'926.54									

A	B	C	D				H					M
		Gg CO2 equivalent	Gg CO2 equivalent									
3. Total (combined uncertainty of 1. and 2.)												
Total Emissions	all gases	52'760.92	53'034.33									
Total Uncertainties						Overall uncertainty in the year (%)	**3.34**				Trend uncertainty (%)	**2.43**

Table 10 Tier 1 Uncertainty Calculation and Reporting for sources in Switzerland 2004 (Continued).

A (continued)		B	N	O	P	Q
IPCC Source category		Gas	Emission factor quality indicator IPCC **D**efault, **M**easurement based, national **R**eferenced data	Activity data quality indicator IPCC **D**efault, **M**easurement based, national **R**eferenced data	Expert judgement reference numbers	Reference to section in NIR
1A	1. Energy A. Fuel Combustion Gaseous fuels	CO2	M	D		Section 3.2.3
1A	1. Energy A. Fuel Combustion Liquid fuels	CO2	M	R		Section 3.2.3
1A	1. Energy A. Fuel Combustion Solid fuels	CO2	D	D, R		Section 3.2.3
1A	1. Energy A. Fuel Combustion Other fuels	CO2	R	R		Section 3.2.3
1A1	1. Energy A. Fuel Combustion 1. Energy Ind. Other Fuels	N2O	R	R		Section 3.2.3
1A3b	1. Energy A. Fuel Combustion 3b. Road Transp. Gasoline	CH4	R	R		Section 3.2.3
1B2	1. Energy B. Fugitive Emissions 2. Oil and Natural Gas	CH4	D	D		Section 3.3.3
2A1	2. Industrial Proc. A. Mineral Products; Cement Production-CO2	CO2	D	D		Section 4.2.3
2B	2. Industrial Proc. B. Chemical Industry	N2O	R	R		Section 4.3.3
2C3	2. Industrial Proc. C. Metal Production; Aluminium Production-PFC	PFC	M	M		Section 4.4.3
2C3	2. Industrial Proc. C. Metal Production; Aluminium Production-CO2	CO2	R	R		Section 4.4.3
2F	2. Industrial Proc. F. Consumption of Halocarbons and SF6	PFC	R	R		Section 4.7.3
2F1	2. Industrial Proc. F. Consumption of Halocarbons and SF6; Refrig. & AC Eq.	HFC	R	R		Section 4.7.3
2F_o	2. Industrial Proc. F. Consumption of Halocarbons and SF6 without 2F1-HFC	HFC	R	R		Section 4.7.3
3	3. Solvent and Other Product Use	CO2	R	R		Section 5.2.3
3	3. Solvent and Other Product Use	N2O	R	R		Section 5.2.3
4A	4. Agriculture A. Enteric Fermentation	CH4	R	R		Section 6.2.3
4B	4. Agriculture B. Manure Management	CH4	R	R		Section 6.3.3
4B	4. Agriculture B. Manure Management	N2O	D	R		Section 6.3.3
4D1	4. Agriculture D. Agricultural Soils; Direct Soil Emissions	N2O	D	R		Section 6.5.3
4D3	4. Agriculture D. Agricultural Soils; Indirect Emissions	N2O	D	D		Section 6.5.3
6A	6. Waste A. Solid Waste Disposal on Land	CH4	R	R		Section 8.2.3
6D	6. Waste D. Other	CH4	R	R		Section 8.5.3
	Rest of sources	CO2	R	R		Exp. est.

Table 11 Ranked Combined Level Uncertainties for sources in Switzerland. Note that the emissions 1990 and 2004 correspond to the values of the submission April 2006, which may slightly deviate from the data of the current submission.

A	B	C	D	E	F	G	H
IPCC Source category	Gas	Base year emissions 1990	Year 2004 emissions	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t
		Input data	Input data	Input data	Input data	Calc/Input	
		Gg CO2 equivalent	Gg CO2 equivalent	%	%	%	%
4D1 4. Agriculture D. Agricultural Soils; Direct Soil Emissions	N2O	1'389.82	1'207.74	10.0	79.8	80.4	1.832
1A 1. Energy A. Fuel Combustion Other fuels	CO2	1'676.11	2'211.82	10.0	30.0	31.6	1.319
4D3 4. Agriculture D. Agricultural Soils; Indirect Emissions	N2O	818.89	682.60	15.0	93.9	95.1	1.224
4A 4. Agriculture A. Enteric Fermentation	CH4	2'766.81	2'492.07	20.0	12.7	23.7	1.114
Rest of sources	CO2	1'123.50	1'329.95	20.0	34.6	40.0	1.003
1A 1. Energy A. Fuel Combustion Liquid fuels	CO2	34'319.03	34'143.58	1.4	0.6	1.5	0.954
1A 1. Energy A. Fuel Combustion Gaseous fuels	CO2	3'714.50	6'186.06	5.0	4.6	6.8	0.792
4B 4. Agriculture B. Manure Management	N2O	448.20	396.68	20.0	71.4	74.2	0.555
6A 6. Waste A. Solid Waste Disposal on Land	CH4	693.04	348.63	20.0	56.6	60.0	0.394
4B 4. Agriculture B. Manure Management	CH4	452.34	399.86	20.0	36.4	41.5	0.313
2A1 2. Industrial Proc. A. Mineral Products; Cement Production-CO2	CO2	2'524.77	1'714.25	2.0	6.0	6.3	0.204
1A 1. Energy A. Fuel Combustion Solid fuels	CO2	1'490.48	566.35	18.4	5.0	19.1	0.203
1B2 1. Energy B. Fugitive Emissions 2. Oil and Natural Gas	CH4	385.75	182.92		50.0	50.0	0.172
1A1 1. Energy A. Fuel Combustion 1. Energy Industries Other Fuels	N2O	48.42	112.78	10.0	80.0	80.6	0.171
2F1 2. Industrial Proc. F. Consumption of Halocarbons and SF6; Refrig. & AC Eq.	HFC	0.02	544.59		13.8	13.8	0.142
3 3. Solvent and Other Product Use	CO2	337.49	122.10		50.0	50.0	0.115
6D 6. Waste D. Other	CH4	30.34	91.38	10.0	49.0	50.0	0.086
3 3. Solvent and Other Product Use	N2O	109.41	50.36		80.0	80.0	0.076
2C3 2. Industrial Proc. C. Metal Production; Aluminium Production-CO2	CO2	139.26	70.24	5.0	30.0	30.4	0.040
2F_o 2. Industrial Proc. F. Consumption of Halocarbons and SF6 without 2F1-HFC	HFC	0.00	73.91		21.9	21.9	0.030
1A3b 1. Energy A. Fuel Combustion 3. Transport; Road Tr Gasoline	CH4	91.78	23.07	10.0	59.2	60.0	0.026
2F 2. Industrial Proc. F. Consumption of Halocarbons and SF6	PFC	0.04	55.89		17.6	17.6	0.019
2B 2. Industrial Proc. B. Chemical Industry	N2O	100.75	16.12	10.0	40.0	41.2	0.013
2C3 2. Industrial Proc. C. Metal Production; Aluminium Production-PFC	PFC	100.17	11.40	5.0	48.7	49.0	0.011

Ranked by their contribution to uncertainty in the total national emissions level (cf. Column H, Table 11), direct and indirect emissions of N_2O from Agricultural Soils, CO_2 from 1A Fuel Combustion Activities (Other fuels) and CH_4 from Enteric Fermentation are the top four contributors. Their combined uncertainty amounts to 5.5% of total national emissions in 2004. The table permits the identification of future areas of improvement in the context of the Inventory Development Plan (IDP).

a) Comparison with the previous submission

For the data of the submission April 2006 (FOEN 2006a), an overall uncertainty of 3.34% has been calculated, which is greater than the value reported for the previous submission (2.97%). The difference is the result of several changes:

- In the previous submission, the term “uncertainty” was taken in many cases to be synonymous with the standard deviation. This interpretation was not in line with the recommendation of the IPCC Good Practice Guidance (IPCC 2000) and has therefore been changed.
- The uncertainties of the agricultural sector have been investigated in more detail (Leifeld and Fuhrer 2005). As a consequence of this study, several uncertainties had to be adjusted. As shown above, the uncertainties of these categories are leading contributors to the overall uncertainty of the Swiss GHG inventory.

1.7.4. Results of Tier 2 Uncertainty Evaluation (Monte Carlo)

The principle of Monte Carlo analysis is to select random values for emission factor and activity data from within their individual probability distributions, and to calculate the corresponding emission values. This procedure is repeated until an adequately stable result has been found. The results of all iterations yield the overall emission probability distribution.

In the present analysis, Monte Carlo simulations were performed to estimate uncertainties both in emissions and in emission trends, at the source category level as well as for the inventory as a whole (excluding LUCF). The simulations were run with the commercial software package Crystal Ball (® Decisioneering). This tool generates random numbers within user-defined probability ranges and probability distributions. As a result, selected statistics are produced for the forecast variables.

a) Uncertainty in emissions

As a first step, the shape and extent of the probability distributions were derived for the activity data and emission factors, based on measured data, literature or expert guess. The mean value of the probability distributions was set equal to the value of the greenhouse gas inventory. In most cases, normal distribution was assumed. However, for data with a high level of uncertainty, normal distribution would allow negative emissions. Thus, for these cases, log-normal distribution was used (cf. Annex A1.2.1). Log-normal distribution is positively skewed and produces only positive values, while the upper bound of emissions may be poorly known.

As a second step, emissions were calculated as emission factors multiplied by the relevant activity data. For those cases where the activity data or emission factor for a specific source category were not available, emissions were modelled directly, with the mean value set equal to the value of the greenhouse gas inventory and a corresponding probability distribution of the emissions.

The Monte Carlo simulation then provided information on the standard distribution, 2.5 and 97.5 percentiles of emissions at the source category level and of total emissions as reported in the inventory.

b) Dependent Uncertainties

Correlations may have a significant effect on the overall inventory uncertainty. Special care was taken when deriving the correlations of the source categories of 1A Energy – fuel combustion. Here, the uncertainty of the total source category per fuel type is well known, whereas the uncertainty of the sub-categories is derived by applying the rules of error propagation – i.e., the uncertainty of each sub-category is larger than the uncertainty of the total source category. A detailed description of this analysis and the respective correlation coefficients can be found in Annex A1.2.1. For consistency reasons, Crystal Ball software adjusted a few of the correlation coefficients by an average of 0.10.

c) Uncertainty in Emission Trends

The trend is defined as the difference between the base year and the year of interest (year t, 2004). Hence for estimation of the uncertainty in the emission trends, the Monte Carlo simulation was run for the year 2004 and for the base year 1990. The trend was then derived for the source categories as well as for the total emissions. It was assumed that the activity data of 1990 are not correlated with the activity data of 2004. On the other hand, the emission factors of the two years are assumed to be positively correlated. The probability distributions of the 1990 data are assumed to be of equal shape as the distributions derived for 2004.

d) Results

The Monte Carlo simulations reveal that the uncertainty distribution of the total emissions for 2004 (year t) is narrower than the distribution for the base year 1990. As expected, it is shifted towards higher mean emissions (cf. Figure 5).

The uncertainty estimates as derived from the Monte Carlo simulations on the key category level are shown in Table 12.

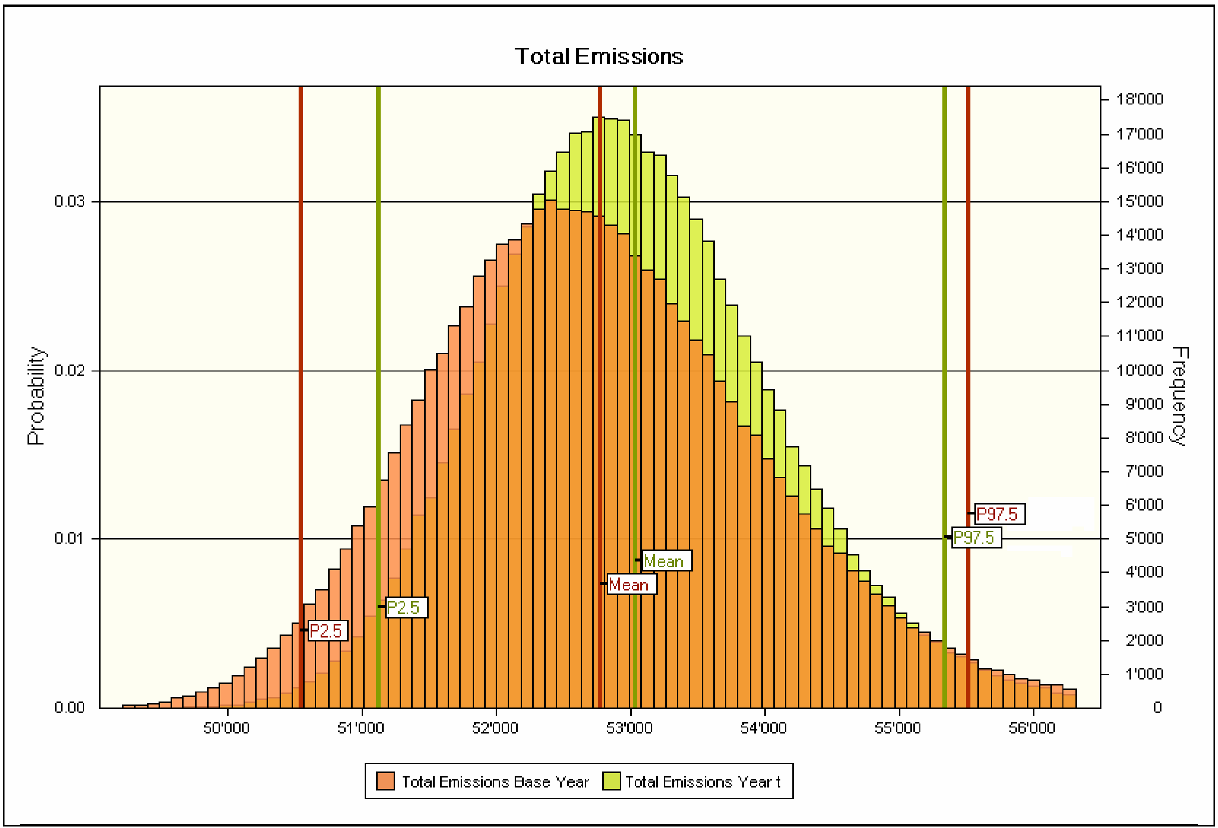

Figure 5 Probability distributions of total emissions for the base year (1990) and year t (2004). On the x-axis, the total emissions reported in the Swiss inventory (without CO_2 from LUCF) are given in Gg CO_2 equivalent. Number of Monte Carlo runs: 500'000. The vertical lines show simulated mean values (*Mean*) and the 2.5 (*P2.5*) and 97.5 (*P97.5*) percentile values.

The main results of the Monte Carlo simulation are (results hold for the data of submission April 2006, FOEN 2006a):

- The total uncertainty of the 2004 Swiss emissions is 3.98% (2'105 Gg CO_2 equivalent) of the total GHG emissions (53'034 Gg CO_2 equivalent, without CO_2 emissions from LUCF).
- The 95% confidence interval is slightly asymmetric and lies between 96.4% and 104.4% of the Swiss total GHG emissions. The end points are: 51'126 Gg (=53'034 Gg–1'908 Gg) and 55'346 Gg (=53'034 Gg+2'312 Gg).
- The change in total emissions between 1990 and 2004 is +0.52%. With a probability of 95%, the change lies within the range of -5.4% to +6.2%.

To study the influence of correlations, a sensitivity run was carried out with all correlations set equal to zero. The following results were found:

- The total uncertainty of the 2004 Swiss emissions is reduced from 3.98% (with correlations) to 3.19% (without correlations).
- The 95% confidence interval is reduced correspondingly and lies between 97.0% and 103.4% of the Swiss total GHG emissions (with correlations: 96.4% and 104.4%).
- The findings reveal that the net impact of the positive and negative correlations (see Table 170 and Table 171) is positive – i.e., the inclusion of correlations results in a 1.25-fold increase in the overall uncertainty of the GHG emissions.

Table 12 Monte Carlo (Tier 2) uncertainty reporting. Note that the emissions 1990 and 2004 correspond to the values of the submission April 2006, which may slightly deviate from the data of the current submission.

A			B	C	D	E	F	G	H	I	J
IPPC Source Category			Gas	Base year (1990) emissions	Year t (2004) emissions	Uncertainty in year t emissions as % of emissions in the category		Uncertainty introduced on national total in year t	% change in emissions between year t and base year	Range of likely % change between year t and base year	
				(Gg CO2 equivalent)	(Gg CO2 equivalent)	% below (2.5 percentile)	% above (97.5 percentile)	(%)	(%)	% below (2.5 percentile)	% above (97.5 percentile)
1A	A. Fuel Combustion										
1A1	1. Energy Industries	Gaseous Fuels	CO2	235	377	93	107	0.05	60.5	51	70
1A1	1. Energy Industries	Liquid Fuels	CO2	691	955	99	101	0.03	38.2	36	41
1A1	1. Energy Industries	Other Fuels	CO2	1519	1925	73	134	1.12	26.7	-8	47
1A1	1. Energy Industries	Other Fuels	N2O	48	113	21	180	0.17	132.9	48	226
1A2	2. Manufacturing Industries and Construction	Gaseous Fuels	CO2	1081	2051	90	110	0.38	89.8	70	109
1A2	2. Manufacturing Industries and Construction	Liquid Fuels	CO2	3411	2926	98	102	0.13	-14.2	-17	-11
1A2	2. Manufacturing Industries and Construction	Other Fuels	CO2	157	286	56	154	0.26	82.6	-18	172
1A2	2. Manufacturing Industries and Construction	Solid Fuels	CO2	1387	532	82	119	0.19	-61.7	-83	-41
1A3b	3. Transport; Road Transportation	Diesel	CO2	2424	3623	98	102	0.13	49.5	46	53
1A3b	3. Transport; Road Transportation	Gasoline	CO2	11393	11426	98	102	0.40	0.3	-2	3
1A3b	3. Transport; Road Transportation	Gasoline	CH4	92	23	36	257	0.05	-74.9	-145	-27
1A3e	3. Transport; Other Transportation (mil. aviation)	Liquid Fuels	CO2	200	109	98	102	0.00	-45.5	-47	-44
1A4a	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	CO2	950	1441	90	110	0.27	51.8	36	68
1A4a	4. Other Sectors; Commercial/Institutional	Liquid Fuels	CO2	4432	4046	98	102	0.18	-8.7	-12	-6
1A4b	4. Other Sectors; Residential	Gaseous Fuels	CO2	1409	2291	90	110	0.43	62.6	45	80
1A4b	4. Other Sectors; Residential	Liquid Fuels	CO2	10234	9438	98	102	0.42	-7.8	-11	-5
1A4c	4. Other Sectors; Agriculture/Forestry	Liquid Fuels	CO2	713	728	98	102	0.03	2.0	-1	5
1A5	5. Other	Liquid Fuels	CO2	513	671	98	102	0.02	30.7	28	34
1B	B. Fugitive Emissions from Fuels										
1B2	2. Oil and Natural Gas		CH4	386	183	51	149	0.17	-52.6	-107	2
2	Industrial Processes										
2A1	A. Mineral Products; Cement Production-CO2		CO2	2525	1714	94	106	0.20	-32.1	-40	-24
2B	B. Chemical Industry		N2O	101	16	60	141	0.01	-84.0	-119	-50
2C3	C. Metal Production; Aluminium Production-PFC		PFC	100	11	52	148	0.01	-88.6	-137	-40
2C3	C. Metal Production; Aluminium Production-CO2		CO2	139	70	70	130	0.04	-49.6	-83	-16
2F	F. Consumption of Halocarbons and SF6		PFC	0.04	56	83	117	0.02	*	*	*
2F1	F. Consumption of Halocarbons and SF6; Refrig. & AC Eq.		HFC	0.02	545	86	114	0.14	*	*	*
2F_o	F. Consumption of Halocarbons and SF6 without 2F1-HFC		HFC	0.00	74	79	121	0.03	*	*	*
3	Solvent and Other Product Use		CO2	337	122	51	149	0.11	-63.8	-116	-12
			N2O	109	50	22	178	0.07	-54.0	-140	33
4	Agriculture										
4A	A. Enteric Fermentation		CH4	2767	2492	77	123	1.09	-9.9	-41	21
4B	B. Manure Management		CH4	452	400	59	141	0.31	-11.6	-66	43
4B	B. Manure Management		N2O	448	397	33	269	0.88	-11.5	-114	85
4D1	D. Agricultural Soils; Direct Soil Emissions		N2O	1390	1208	31	273	2.75	-13.1	-125	90
4D3	D. Agricultural Soils; Indirect Emissions		N2O	819	683	29	284	1.64	-16.6	-149	102
6	Waste										
6A	A. Solid Waste Disposal on Land		CH4	693	349	41	159	0.39	-49.7	-116	16
6D	D. Other		CH4	30	91	51	149	0.08	201.2	46	357
	Other			1573	1612	61	139	1.19	2.4	-54	58
Total				52761	53034	96.4	104.4	3.98	0.52	-5.4	6.2

* Trend not calculated when base year emission ≈ 0

1.7.5. Comparison of Tier 1 and Tier 2 Results

In the GHG inventory, some of the uncertainties may become large and their statistical distribution may clearly deviate from normal distributions. Tier 1 uncertainty analysis is based on simple error propagation, which assumes only small and normally distributed uncertainties. The application of the Tier 1 method is therefore not the optimal instrument for determining the uncertainties of a GHG inventory. The more appropriate choice is the Monte Carlo simulation, which is designed for uncertainties of any shape and which is recommended by the IPCC Good Practice Guidance (IPCC 2000) as the Tier 2 method. The results of the Monte Carlo simulation are therefore considered to provide a more realistic picture of the uncertainties than the results of the Tier 1 method.

Tier 2 uncertainty analysis produces an overall uncertainty of 3.98% for 2004 emissions. This value is somewhat larger then the result of Tier 1 uncertainty analysis (3.34%). The trend uncertainty of Tier 2 (5.8%) is larger than that of Tier 1 analysis (2.4%). These differences are due to the following reasons:

- The Monte Carlo simulation produces different results as it treats large uncertainties correctly and takes log-normal distributions into account. Furthermore, the correlations existing between activity data and between emission factors are considered, which is not the case in the Tier 1 analysis. As shown above, the correlations lead to an expansion of the uncertainty. Without any correlations, the Tier 2 uncertainty would be somewhat lower than the Tier 1 uncertainty.
- For the Monte Carlo simulation, the category 1A Fuel Combustion Activities (CO_2) was split into sub-categories. This was not been done for the Tier 1 analysis. (Splitting introduces a more differentiated structure into the uncertainties of the activity data. The differentiation is derived and quantified in Annex A1.2.2.) This splitting results in a slight reduction of the overall uncertainty. A simple error propagation (in analogy to Tier 1) showed that the overall uncertainty decreases to 3.19% due to the splitting.

1.8. Completeness Assessment

For all known sources complete estimates are accomplished for all gases. From today's knowledge the Swiss inventory is complete.

2. Trends in Greenhouse Gas Emissions and Removals

This chapter gives an overview of Switzerland's GHG emissions/removals and trends for the period 1990–2004.

2.1. Aggregated Greenhouse Gas Emissions 2004

In 2004, Switzerland emitted 53'065 Gg CO_2 equivalent (excluding LULUCF) to the atmosphere. The largest contributor gas is CO_2, and the most important sources of emissions are fuel combustion activities in the Energy sector. Table 13 shows emissions by gas and sector in Switzerland for the year 2004. A breakdown of Switzerland's total emissions by gas is given in Figure 6. Figure 7 charts the relative contributions of the individual sectors (except LULUCF) to the emission of each GHG.

Table 13 Switzerland's GHG emissions in CO_2 equivalent (Gg) by gas and sector, 2004.

Emissions 2004	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Total	Share
	CO_2 equivalent (Gg)							
1 All Energy	43'121	290	364				**43'776**	**82.5%**
2 Industrial Processes	2'004	7	171	617	77	175	**3'051**	**5.7%**
3 Solvent Use	186		50				**236**	**0.4%**
4 Agriculture (1 year average)		2'775	2'483				**5'258**	**9.9%**
6 Waste	15	477	252				**744**	**1.4%**
Total (excluding LULUCF)	**45'326**	**3'550**	**3'320**	**617**	**77**	**175**	**53'065**	**100.0%**
5 LULUCF	-830	0	9				**-821**	**-1.5%**
Total (including LULUCF)	**44'496**	**3'550**	**3'329**	**617**	**77**	**175**	**52'244**	**98.5%**
International Bunkers	*3'433*	*1*	*33*				*3'468*	

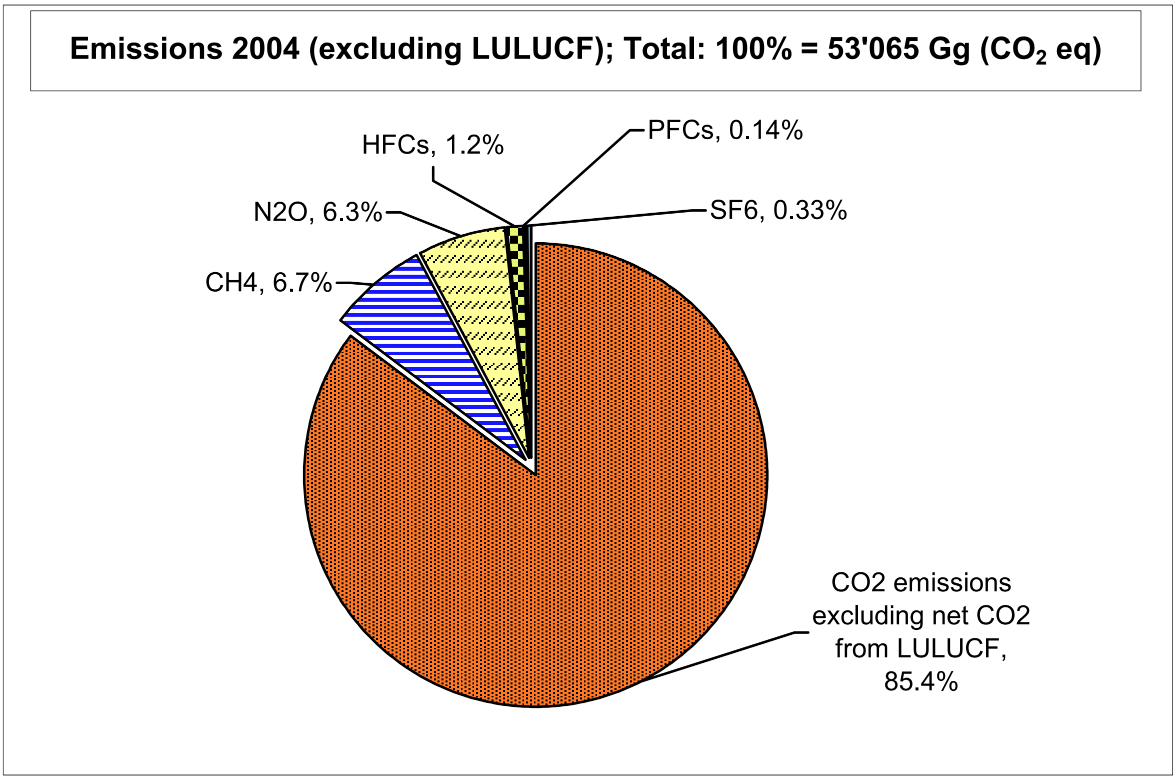

Figure 6 Switzerland's GHG emissions by gas (excluding LULUCF), 2004.

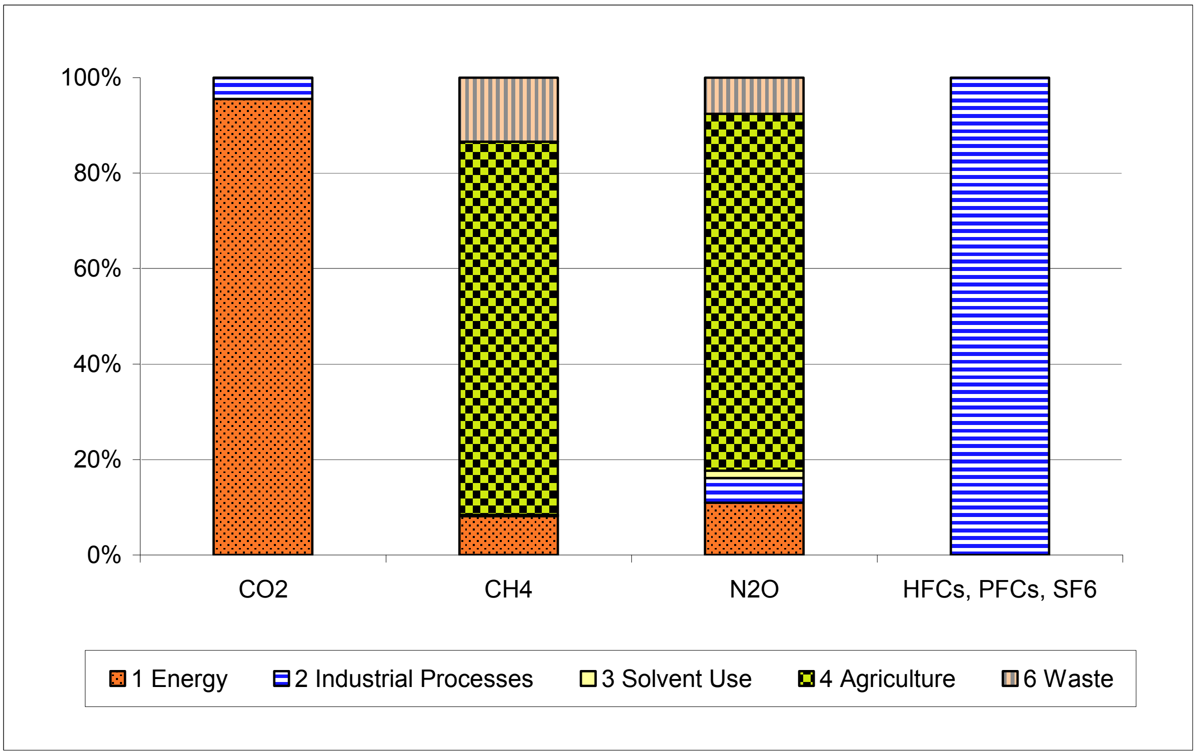

Figure 7 Relative contributions of the individual sectors (excluding LULUCF) to GHG emissions, 2004.

Fuel combustion within the Energy sector was by far the largest source of emissions of CO_2 in 2004. Emissions of CH_4 and N_2O originated mainly from agriculture, and the synthetic gas emissions stemmed by definition from industrial processes.

2.2. Emission Trends by Gas

Emission trends by gas for the period 1990–2004 are summarized in Table 14.

Table 14 Switzerland's GHG emissions in CO_2 equivalent (Gg) by gas, 1990–2004 (corresponds to CRF table 10s5/10s5.2, upper half). The column on the far right (digits in italics) indicates the percentage change in emissions in 2004 as compared to the base year 1990.

Greenhouse Gas Emissions	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	***2004/1990***
	CO_2 equivalent (Gg)															*%*
CO_2 emissions incl. net CO_2 from LULUCF	42'801	47'315	46'834	39'867	38'939	40'115	41'618	40'640	43'491	39'851	45'164	44'028	43'271	46'750	44'496	*4.0%*
CO_2 emissions excl. net CO_2 from LULUCF	44'512	46'155	46'189	43'590	42'804	43'327	44'049	43'401	44'619	44'833	43'910	44'692	43'796	44'893	45'326	*1.8%*
CH_4	4'372	4'347	4'236	4'094	4'002	3'984	3'935	3'852	3'794	3'745	3'692	3'707	3'648	3'602	3'550	*-18.8%*
N_2O	3'628	3'644	3'618	3'575	3'575	3'504	3'551	3'431	3'428	3'406	3'432	3'411	3'411	3'326	3'329	*-8.2%*
HFCs	0.02	0.2	6.1	13	30	152	193	258	311	360	418	492	502	538	617	---
PFCs	100	85	69	30	18	15	17	24	28	40	93	52	51	89	77	*-23.4%*
SF_6	144	146	148	126	112	81	82	122	152	138	186	234	209	194	175	*21.9%*
Total (incl. net CO_2 from LULUCF)	**51'045**	**55'538**	**54'912**	**47'705**	**46'676**	**47'851**	**49'395**	**48'326**	**51'204**	**47'540**	**52'984**	**51'925**	**51'092**	**54'500**	**52'244**	***2.3%***
Total (excl. net CO_2 from LULUCF)	**52'756**	**54'377**	**54'267**	**51'428**	**50'541**	**51'063**	**51'827**	**51'088**	**52'332**	**52'522**	**51'731**	**52'589**	**51'617**	**52'643**	**53'074**	***0.6%***
Total (excl. LULUCF Removals/Emissions)	**52'749**	**54'375**	**54'265**	**51'424**	**50'530**	**51'052**	**51'817**	**51'072**	**52'322**	**52'513**	**51'721**	**52'580**	**51'606**	**52'631**	**53'065**	***0.6%***

The emission trends for individual gases are as follows (see Table 14 above, Table 15 and Figure 8 below):

- Total emissions (excl. LULUCF Removals/Emissions) were almost constant, with fluctuations within a range of less than 5%. The 2004 total emissions increased by 0.6% as compared to the emissions recorded in the base year 1990. CO_2 contributed the largest share of emissions, accounting for 85.4% of the total in 2004.
- Total emissions (incl. net CO_2 from LULUCF) in 2004 show an increase of 2.3% compared to the emissions recorded in the base year 1990. Heavy storms in 1990 and, in particular, at the end of 1999 ("Lothar") led to significant reductions in net removals within the LULUCF sector (visible over several years due to 3-year averaging of the storm effects). Due to the accounting of the climatic, fluctuating parameters, the net CO_2 emissions show considerable variability from year to year.
- A comparison of CO_2 emissions with the number of heating degree days in the period 1990–2004 (see Figure 13 below) indicates a strong correlation between CO_2 emissions and winter climatic conditions.
- Between 1990 and 2004, CH_4 decreased by 18.8%, which was mainly attributable to a reduction of productive livestock, accompanied by a reduction of emissions from enteric fermentation. Moreover, from 2000, a change in waste legislation, banning the disposal of municipal solid waste in landfills, contributed to this trend. The CH_4 share of total GHG emissions decreased from 8.3% in 1990 to 6.7% in 2004.
- In parallel to the reduction of CH_4 due to decreases in livestock populations, N_2O emissions from enteric fermentation and from manure management declined by 8.2% between 1990 and 2004.
- HFC emissions increased significantly due to their application as substitutes for CFCs, while PFC emissions declined by 23.4%. SF_6 emissions have shown relatively large fluctuations between 81 and 234 Gg CO_2 eq since 1990. In 2004, SF_6 emissions increased by 21.9% compared to 1990. The share of all synthetic gases combined rose from 0.5% in 1990 to 1.6% in 2004.

Table 15 Switzerland's total GHG emissions (excl. net CO_2 from LULUCF) in CO_2 equivalent (Gg), selected years.

Greenhouse Gas Emissions	1990		1995		2000		2004	
	Gg CO_2 eq	%	Gg CO_2 eq	%	Gg CO_2 eq	%	Gg CO_2 eq	%
CO2 emissions excluding net CO2 from LULUCF	44'512	84.4%	43'327	84.9%	43'910	84.9%	45'326	85.4%
CH_4	4'372	8.3%	3'984	7.8%	3'692	7.1%	3'550	6.7%
N_2O	3'628	6.9%	3'504	6.9%	3'432	6.6%	3'329	6.3%
HFCs	0	0.0%	152	0.3%	418	0.8%	617	1.2%
PFCs	100	0.2%	15	0.0%	93	0.2%	77	0.1%
SF_6	144	0.3%	81	0.2%	186	0.4%	175	0.3%
Total (excl. net CO_2 from LULUCF)	**52'756**	**100%**	**51'063**	**100%**	**51'731**	**100%**	**53'074**	**100%**

Figure 8 below shows Switzerland's relative GHG emission trends by gas. The base year 1990 is set to 100%.

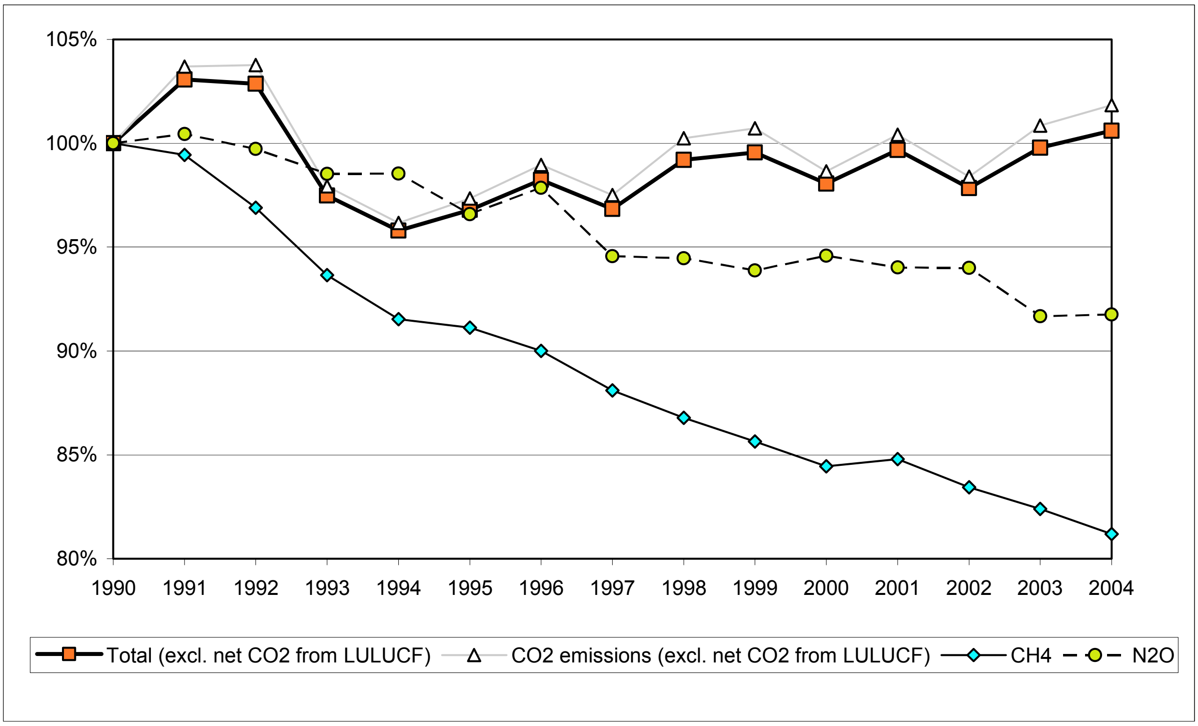

Figure 8 Relative trend of Switzerland's GHG emissions by gas, 1990–2004 (base year 1990 = 100%). The increase of the synthetic gases is not shown (356% in 2004, compared to 1990).

2.3. Emission Trends by Sources and Sinks

Table 16 shows the emission trends for all major source and sink categories. As the largest share of emissions originated from the Energy sector, the table also includes the contributions of the Energy sub-sectors.

Table 16 Switzerland's GHG emissions in CO_2 equivalent (Gg) by sources and sinks, 1990–2004.

Source and Sink Categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	CO_2 equivalent (Gg)														
1. Energy	**42'092**	**44'094**	**44'261**	**41'891**	**40'955**	**41'658**	**42'578**	**42'106**	**43'324**	**43'515**	**42'440**	**43'198**	**42'324**	**43'440**	**43'776**
1A1 Energy Industries	2'545	2'827	2'912	2'564	2'589	2'620	2'830	2'795	3'118	2'969	2'886	3'011	3'085	3'064	3'384
1A2 Manufacturing Industries and Construction	6'065	5'957	5'810	5'603	5'627	5'544	5'463	5'549	5'717	5'783	5'855	5'959	5'784	5'821	5'817
1A3 Transport	14'599	15'078	15'393	14'312	14'486	14'151	14'193	14'757	14'957	15'542	15'774	15'465	15'340	15'505	15'608
1A4 Other Sectors	17'844	19'197	19'127	18'404	17'242	18'338	19'089	18'008	18'532	18'210	16'924	17'752	17'130	18'094	18'007
1A5 Other (Offroad)	519	538	557	576	594	613	624	635	646	657	668	670	672	674	676
1B Fugitive emissions from oil and natural gas	520	497	462	432	416	392	379	361	353	355	334	342	313	282	285
2. Industrial Processes	**3'258**	**2'912**	**2'744**	**2'437**	**2'617**	**2'527**	**2'382**	**2'298**	**2'415**	**2'509**	**2'819**	**2'946**	**2'890**	**2'900**	**3'051**
3. Solvent and Other Product Use	**466**	**444**	**424**	**400**	**385**	**367**	**346**	**324**	**302**	**292**	**281**	**270**	**259**	**250**	**236**
4. Agriculture	**5'903**	**5'907**	**5'833**	**5'753**	**5'706**	**5'638**	**5'662**	**5'499**	**5'467**	**5'405**	**5'409**	**5'418**	**5'394**	**5'282**	**5'258**
6. Waste	**1'030**	**1'018**	**1'004**	**943**	**867**	**861**	**848**	**845**	**814**	**791**	**772**	**747**	**740**	**760**	**744**
Total (excl. LULUCF Removals/Emissions)	**52'749**	**54'375**	**54'265**	**51'424**	**50'530**	**51'052**	**51'817**	**51'072**	**52'322**	**52'513**	**51'721**	**52'580**	**51'606**	**52'631**	**53'065**
5. Land Use, Land-Use Change and Forestry	-1'704	1'163	647	-3'719	-3'854	-3'201	-2'421	-2'746	-1'118	-4'973	1'263	-655	-515	1'869	-821
Total (incl. net CO_2 from LULUCF)	51'045	55'538	54'912	47'705	46'676	47'851	49'395	48'326	51'204	47'540	52'984	51'925	51'092	54'500	52'244

The percentage shares of source categories are shown for selected years in Table 17. Figure 9 through Figure 12 are graphical representations of Table 16 data. For the development of the sub-sectors of source 1 Energy see Chapter 3.

Table 17 Contribution of individual source categories to total emissions (excl. LULUCF Removals/Emissions) in CO_2 equivalent (Gg), selected years.

Source and Sink Categories	**1990**		**1995**		**2000**		**2004**	
	Gg CO_2 eq	%	Gg CO_2 eq	%	Gg CO_2 eq	%	Gg CO_2 eq	%
1. Energy	42'092	79.8%	41'658	81.6%	42'440	82.1%	43'776	82.5%
1A1 Energy Industries	2'545	4.8%	2'620	5.1%	2'886	5.6%	3'384	6.4%
1A2 Manufacturing Industries and Construction	6'065	11.5%	5'544	10.9%	5'855	11.3%	5'817	11.0%
1A3 Transport	14'599	27.7%	14'151	27.7%	15'774	30.5%	15'608	29.4%
1A4 Other Sectors	17'844	33.8%	18'338	35.9%	16'924	32.7%	18'007	33.9%
1A5 Other (Offroad)	519	1.0%	613	1.2%	668	1.3%	676	1.3%
1B Fugitive emissions from oil and natural gas	520	1.0%	392	0.8%	334	0.6%	285	0.5%
2. Industrial Processes	3'258	6.2%	2'527	5.0%	2'819	5.5%	3'051	5.7%
3. Solvent and Other Product Use	466	0.9%	367	0.7%	281	0.5%	236	0.4%
4. Agriculture	5'903	11.2%	5'638	11.0%	5'409	10.5%	5'258	9.9%
6. Waste	1'030	2.0%	861	1.7%	772	1.5%	744	1.4%
Total (excl. LULUCF Removals/Emissions)	**52'749**	**100.0%**	**51'052**	**100.0%**	**51'721**	**100.0%**	**53'065**	**100.0%**

A considerable change in the share of sector 6 Waste compared to the previous submission (2005) is due to a reallocation: all emissions from waste-to-energy activities (combustion of municipal solid waste, construction and special waste) have been removed from 6C and transferred to 1A1, in line with IPCC 1997.

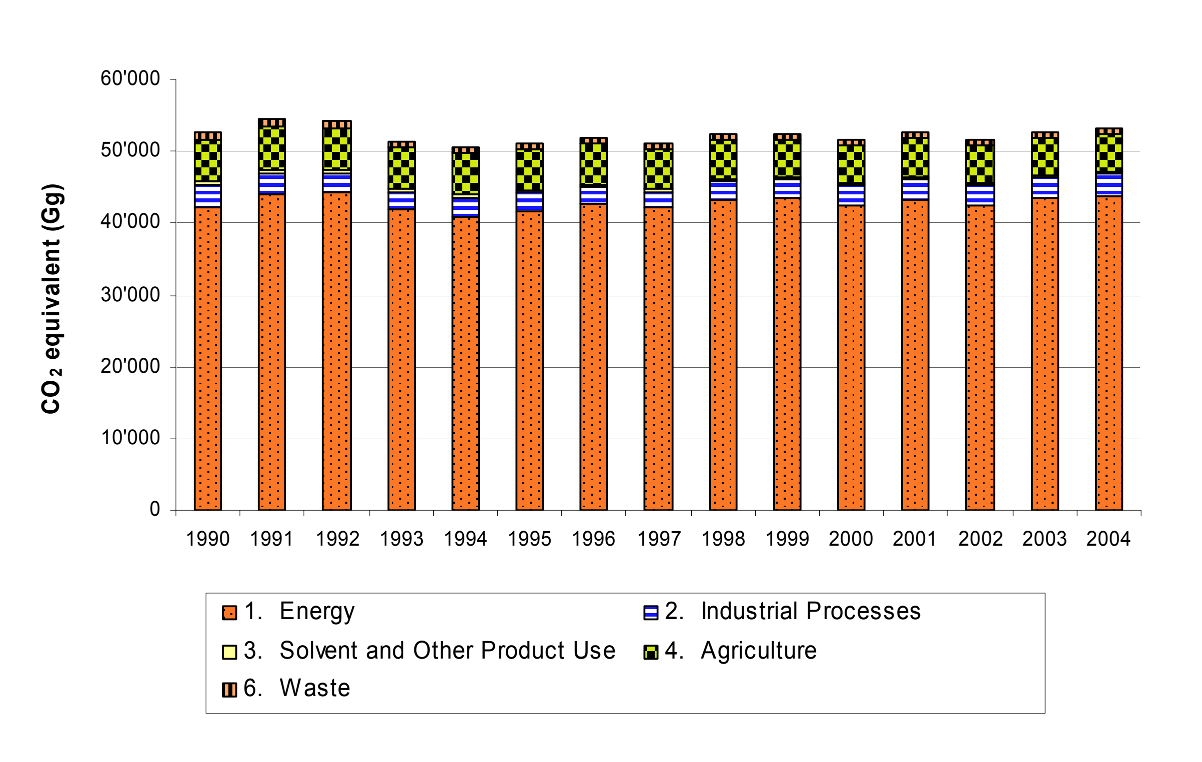

Figure 9 Switzerland's greenhouse gas emissions in CO_2 equivalent (Gg) by main source categories, 1990–2004 (Total excl. LULUCF Removals/Emissions).

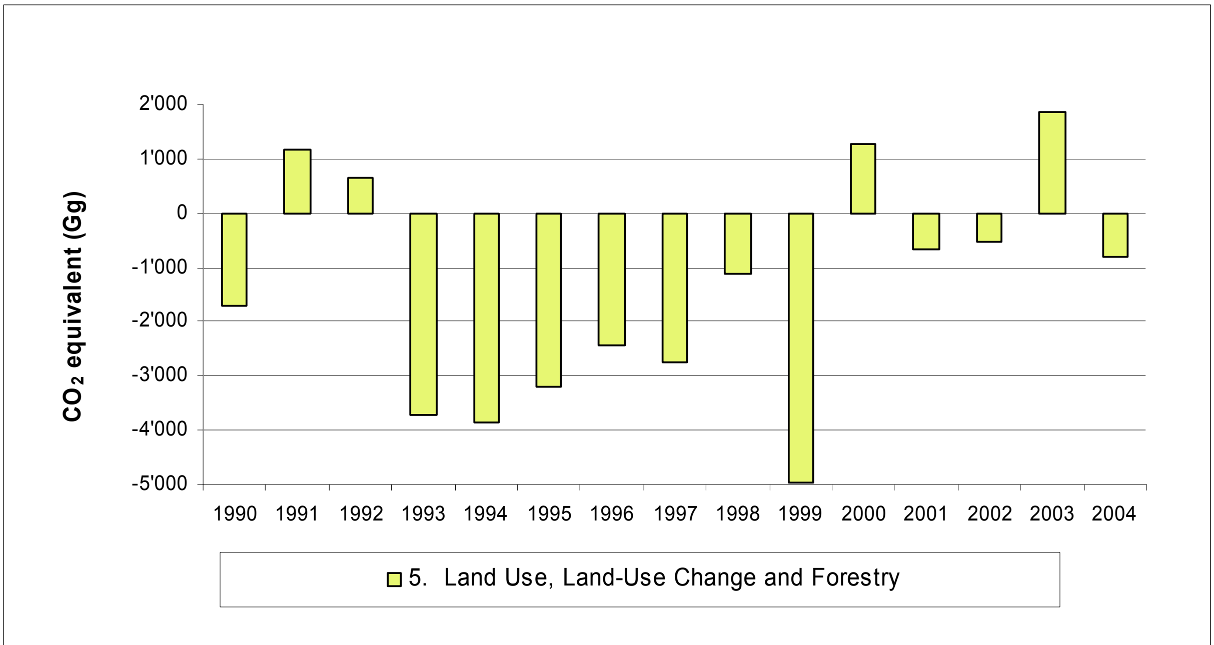

Figure 10 Switzerland's net GHG emissions and removals by sinks from LULUCF, 1990–2004.

Figure 10 shows the net emissions/removals by sources and sinks from LULUCF in Switzerland. In February 1990 and end of December 1999, two storms led to significant loss in biomass (in 1999, the amount of biomass destroyed was nearly three times higher than average annual net growth of Swiss forests). Further variation is caused by climatic fluctuations.

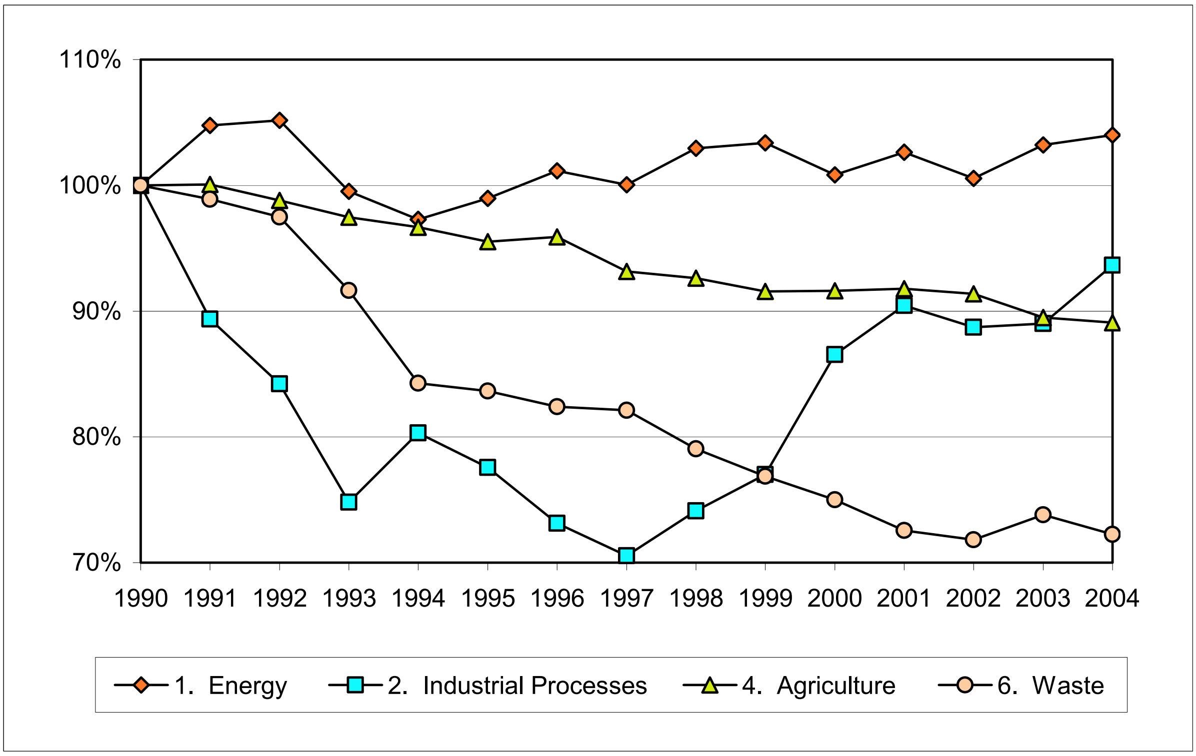

Figure 11 Relative emission trends by main source categories (base year 1990 = 100%).

Emission trends for the various sectors are as follows:

- 1 Energy: The variations can only be understood if the trends within the source sub-categories are considered separately (see Figure 12 and comments below).
- 2 Industrial Processes: In line with economic development, overall emissions in the Industry sector showed a decreasing trend at the beginning and a slight rebound towards the end of the period under review.
- 4 Agriculture: Declining populations of cattle and swine and reduced fertilizer use have led to a decrease in CO_2-equivalent emissions.
- 6 Waste: Total emissions from the source category Waste decreased steadily throughout this period. Since 2000, emissions have been further reduced by a change in legislation: disposal of municipal solid wastes on landfills has been banned, leading to an increasing amount of municipal solid waste being incinerated, with emissions reported under source 1A1 Energy Industries rather than sector 6 Waste. Altogether, "waste-related" emissions (in sources 1A, 4D and 6) have *increased* since 1990 (see Box in Chapter 8).

The main sub-categories within the Energy sector – representing the major sources of Switzerland's GHG emissions – are shown in Figure 12.

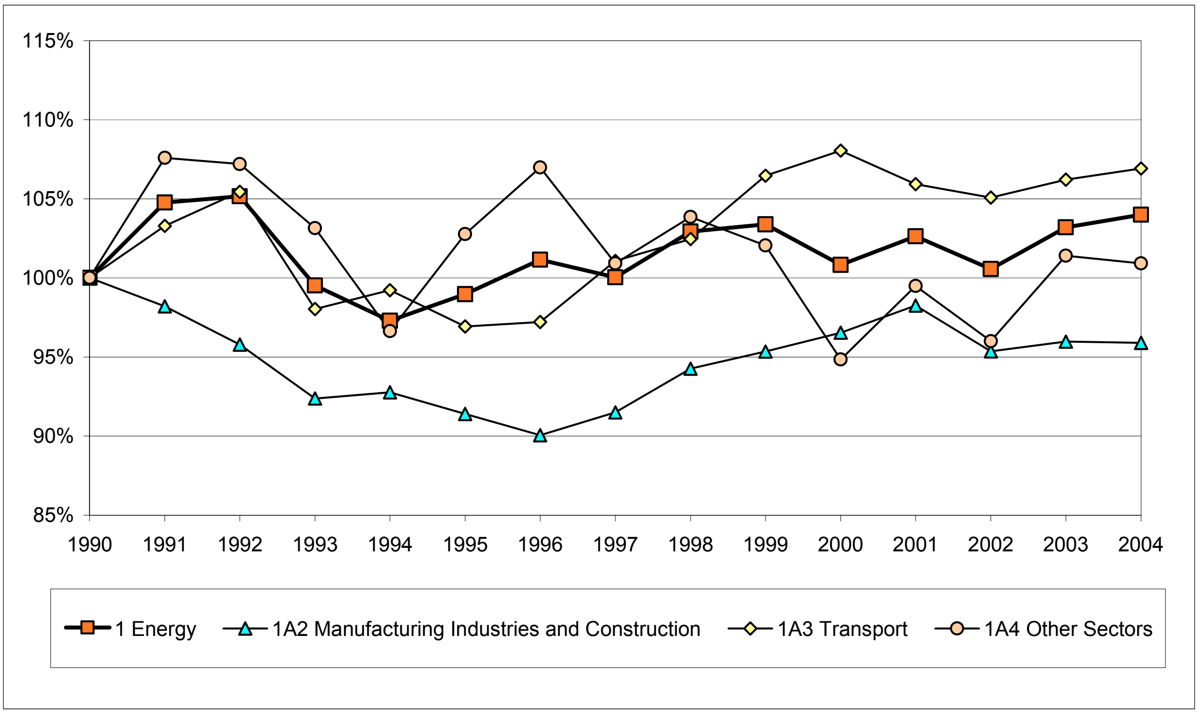

Figure 12 Emission trends for the three main sub-categories in the Energy sector, accounting for 90% of emissions in this source category (not shown are the sub-categories of minor importance: 1A1 Energy Industries, 1A5 Other/Off-road and 1B Fugitive Emissions). The trend for the sector as a whole ("1 Energy") is shown in bold.

It is noteworthy that, because of Switzerland's electricity production structure (about 95.3% generated by hydroelectric and nuclear power plants in 2004; SFOE 2005, Table 24), the sector 1A1 Energy Industries plays only a minor role – representing not classical thermal power stations but waste incineration plants in the Swiss GHG inventory. The following emission trends are observed within the Energy sector:

- The differing trends for the various sub-sectors resulted in a relatively constant overall emission level for the 1 Energy sector (bold line in Figure 12).
- The trend for the 1A3 Transport sector showed a slight increase over the period 1990–2004, but with significant fluctuations indicating a fairly strong correlation between this sector and economic development – periods of stagnation 1993–1996 and 2000–2004, and growth (gross value-added) 1996–2000.
- The trend for 1A4 Other Sectors reflects the impact of climatic variations on demand for heating. The strong correlation with the number of "heating degree days" – used as an index of cold weather conditions – is apparent from Figure 13, which shows CO_2 emissions from fuel combustion (i.e. from 1A without on-/off-road sources 1A3/1A5 or mobile sources in 1A4c).
  In the period 1990–2004, the number of buildings and apartments increased, as well as the average floor space per person and workplace. Both phenomena resulted in an increase in the total area heated. Over the same period, however, higher standards were specified for insulation and for combustion equipment efficiency for both new and renovated buildings, compensating for the emissions from the additional area heated.

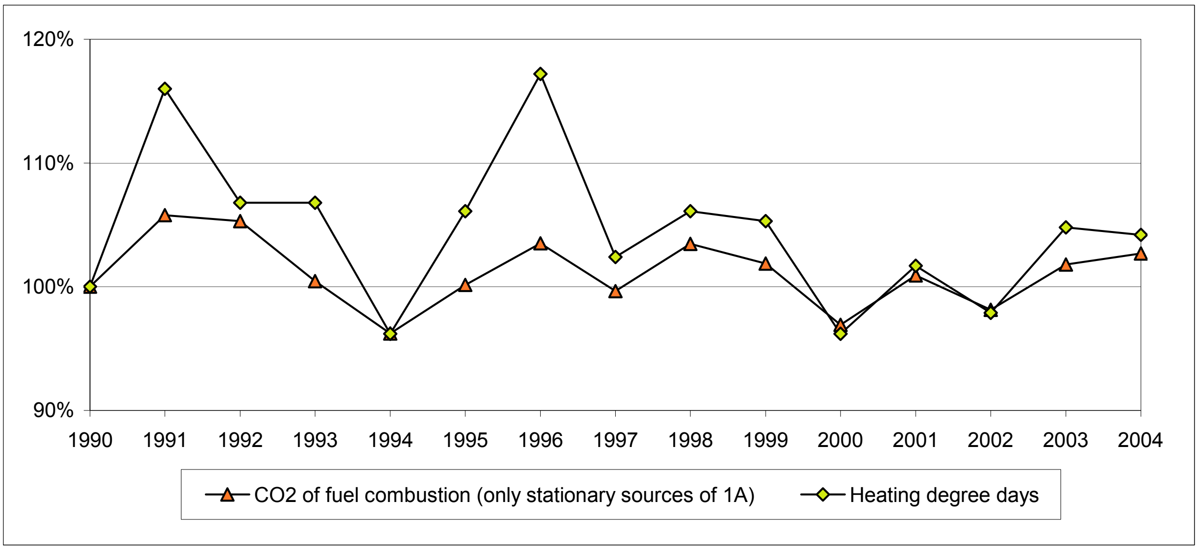

Figure 13 Relative trend for CO_2 emissions from fuel combustion (excluding transport and off-road activities) compared with the number of heating degree days (see text above).

2.4. Emission Trends for Indirect Greenhouse Gases and SO_2

Emission trends for indirect greenhouse gases show a very pronounced decline. From 1990 to 2004, a strict air pollution control policy and the implementation of a large number of emission reduction measures led to a decrease of about 50% in emissions of air pollutants. The main reduction measures were abatement of exhaust emissions from road vehicles and stationary combustion equipment, taxation of solvents and sulphured fuels, and voluntary agreements with industry sectors.

Table 18 Switzerland's indirect GHG and SO_2 emissions in Gg, 1990–2004.

Indirect Greenhouse	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Gases and SO_2	Gg														
NO_x	161	156	146	131	127	120	114	108	106	105	101	97	92	89	88
CO	719	693	653	579	541	507	496	480	467	464	448	427	402	390	372
NMVOC	291	274	255	228	207	190	178	167	153	146	140	132	122	114	106
SO_2	42	38	35	28	29	27	27	26	24	19	18	19	18	17	17

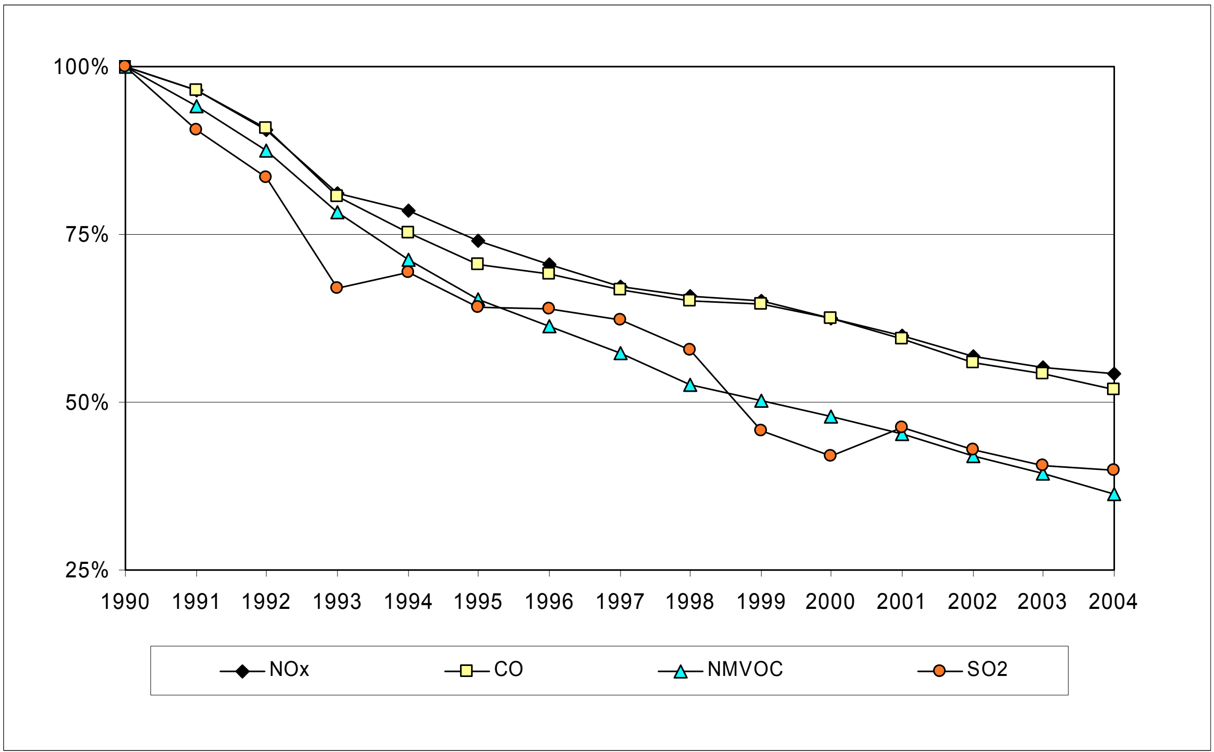

Figure 14 Relative trends for indirect GHG and SO_2 emissions, 1990–2004 (base year 1990 = 100%).

Sector 1 Energy was by far the largest source of indirect greenhouse gas emissions (see Table 19), with the only exception being NMVOCs, where category 3 Solvent and Other Product Use accounted for 48% of the total.

Table 19 Indirect GHG and SO_2 emissions in Gg by source, 2004.

Sources	**NO_x**	**CO**	**NMVOC**	**SO_2**
	Emissions 2004 (Gg)			
1 Energy	82.1	350.7	39.0	13.0
2 Industrial Processes	0.7	12.4	8.9	2.3
3 Solvent and Other Product Use	0.0	0.0	51.4	0.0
4 Agriculture	4.5	7.3	4.6	0.0
6 Waste	0.5	2.1	2.0	1.3
Total	**87.7**	**372.5**	**105.8**	**16.7**

Figure 15 shows the relative contributions of the various sectors for each individual gas (data from Table 19). Sector 1 Energy is clearly visible as the main source of NO_x, CO and SO_2.

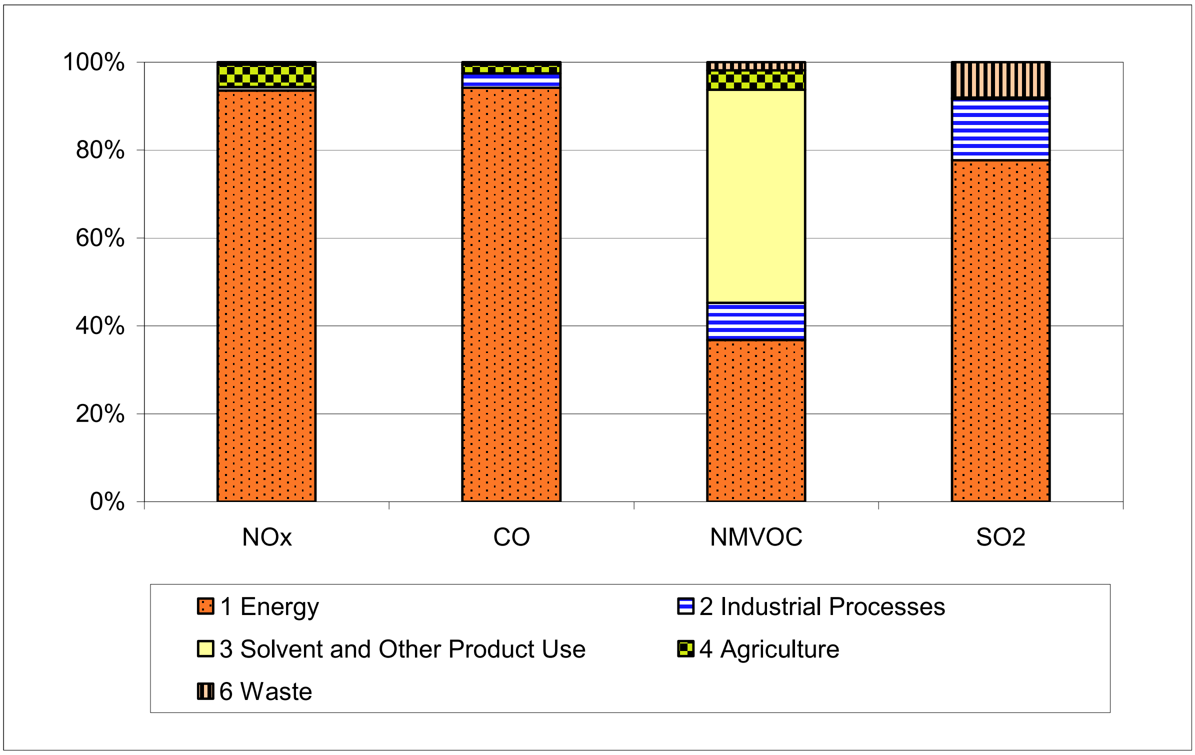

Figure 15 Relative contributions of individual sectors to indirect GHG and SO_2 emissions, 2004.

3. Energy

3.1. Overview

3.1.1. Greenhouse Gas Emissions

This chapter contains information about the greenhouse gas emissions of source category 1 “Energy”. In Switzerland, the energy sector is the most relevant greenhouse gas source. In 2004, it emitted 43’776 Gg CO_2 equivalent which correspond to 82.5% of total emissions (53’065 Gg CO_2 equivalent, Total without LULUCF). The emissions of the period 1990–2004 are depicted in Figure 16.

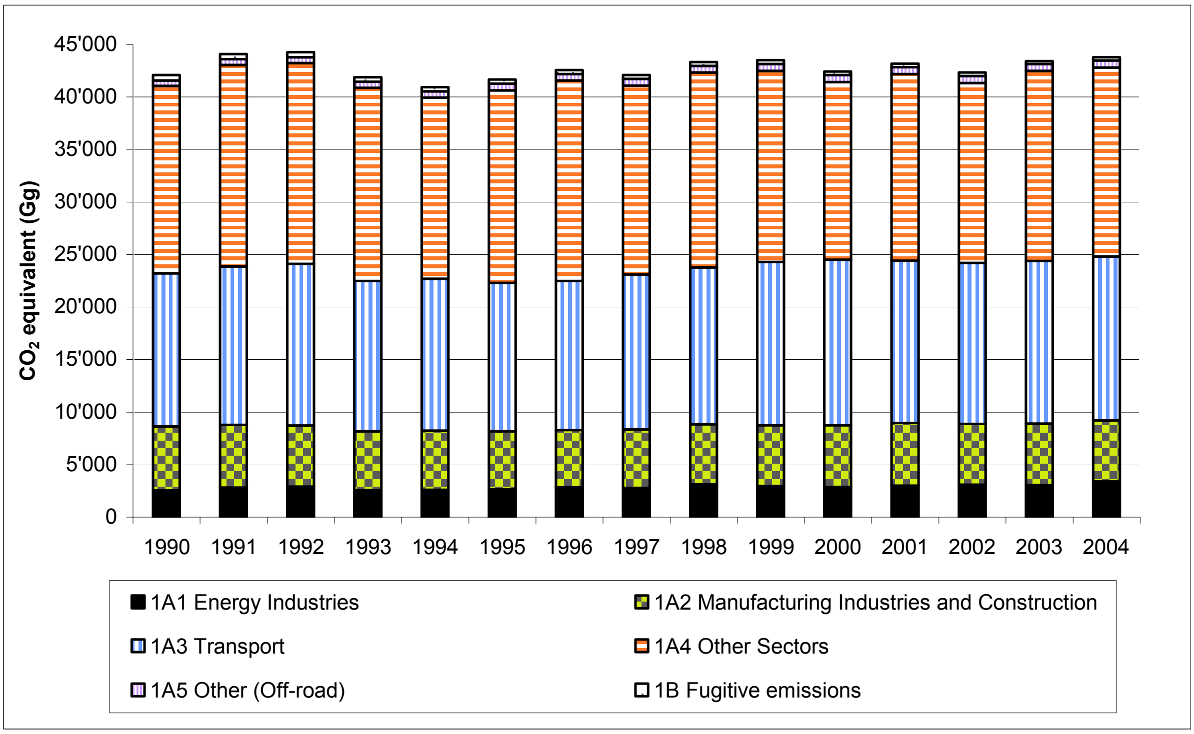

Figure 16 Switzerland’s GHG emissions of source category 1 Energy 1990–2004 in CO_2 equivalent (Gg).

For the total emissions of the energy sector, a very slight increasing but statistically not significant trend may be observed in the period 1994–2004. Three sub-categories dominate the emissions:

- 1A3 Transport and 1A4 Other Sectors are the main sources that cover 35.7% and 41.1%, respectively, of total emissions of the sector energy.
- 1A2 Manufacturing Industries and Construction are of minor importance. They contribute 13.3% to the total emissions of the sector energy.
- 1A1 Energy Industries, 1A5 Other (Off-road) and 1B Fugitive Emissions only play a minor role. In 2004, they cover 7.7%, 1.5% and 0.7%, respectively, of the total emissions of the sector energy.

The trends of the individual gases are given in the next table and figure:

- The far most important gas emitted from the sector energy is CO_2. It accounts for 98.5% of the category. Its fluctuations reflect climatic variability in Switzerland (see Figure 13 and related comments).
- In 2004, CH_4 emissions contributed 0.66% to the total emissions of the sector energy. The decreasing trend since 1990 is the result of reduced emissions from gasoline passenger cars due to catalytic converters.
- N_2O contributed 0.83% to the total emissions of the sector energy. The changes in N_2O emissions may be explained by changes in the emission of passenger cars. The first generation of catalytic converters generated N_2O as undesirable by-product in the exhaust gases, leading to an increase of N_2O emissions until 1999. With new converter materials being used, the emission factors are decreasing since 2000.

Table 20 GHG emissions of source category 1 “Energy” by gas in CO_2 equivalent (Gg), 1990–2004.

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	CO_2 equivalent (Gg)														
CO_2	41'261	43'256	43'443	41'115	40'187	40'902	41'827	41'376	42'592	42'769	41'718	42'472	41'636	42'773	43'121
CH_4	563	546	501	459	436	412	393	364	357	362	335	341	310	293	290
N_2O	268	292	317	317	332	344	359	366	375	384	387	386	379	374	364
Sum	42'092	44'094	44'261	41'891	40'955	41'658	42'578	42'106	43'324	43'515	42'440	43'198	42'324	43'440	43'776

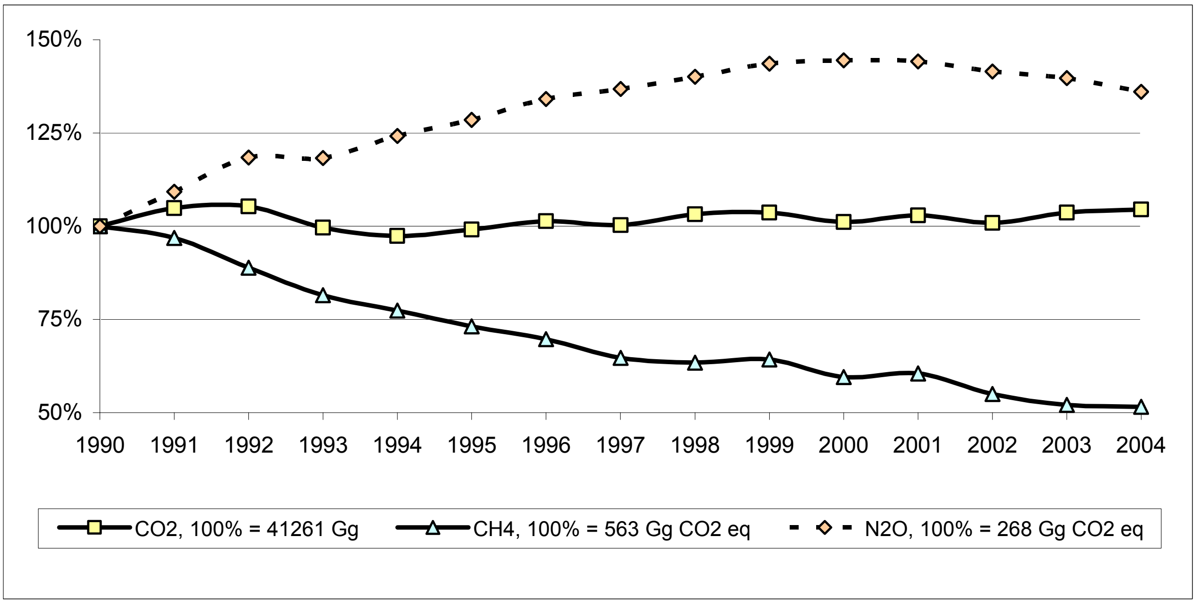

Figure 17 Relative trends of the greenhouse gases of source category 1 “Energy” in the period 1990–2004. The base year 1990 represents 100%.

The following table summarises the emissions of the sector energy in 2004. The table includes emissions from international bunkers (aviation) as well as biomass which are both not accounted for in the Kyoto Protocol but are contained in the CRF tables.

Table 21 Summary of source category 1 “Energy”, emissions[3] in 2004 in Gg CO_2 equivalent (rounded values).

Emissions 2004	CO_2	CH_4	N_2O	*Total*
	CO_2 equivalent (Gg)			
1 Energy	**43'121**	**290**	**364**	***43'776***
1A Fuel Combustion	**43'015**	**112.5**	**364.0**	***43'491***
1A1 Energy Industries	3'260	1.5	122.4	***3'384***
1A2 Manufacturing Industries and Construction	5'768	8.6	40.1	***5'817***
1A3 Transport	15'442	24.5	141.4	***15'608***
1A4 Other Sectors	17'876	76.7	54.2	***18'007***
1A5 Other	669	1.3	5.9	***676***
1B Fugitive Emissions from Fuels	**107**	**177.9**	**0.0**	***285***

International Bunkers	3'433	1.3	33.4	***3'468***
CO_2 Emissions from Biomass	2'887			***2'887***

The Swiss greenhouse gas inventory identifies 37 key sources (see Chapter 1.5), 21 of which belong to the energy sector. These are depicted in the next figure. Most dominant are the CO_2 emissions from 1A3b Transport (gasoline, CO_2) and 1A4b Other Sectors (liquid fuels, CO_2).

[3] Biomass CO_2 emissions from 1 Energy in the Table and in the CRF inventory are for technical reasons incomplete. For full biomass CO_2 emissions see Section 3.5.

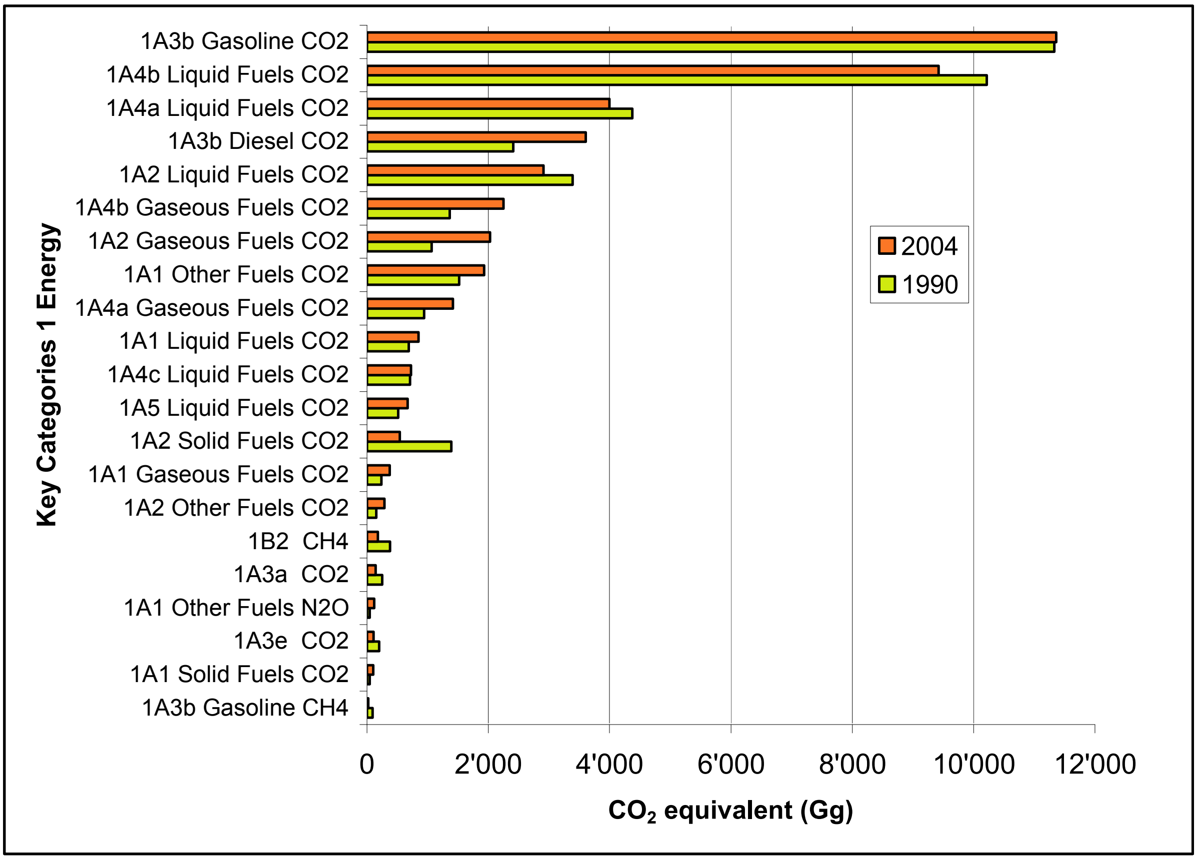

Figure 18 Key sources in the Swiss GHG inventory pertaining to the energy sector.

3.1.2. CO_2 Emission Factors

The CO_2 emission factors used for the calculation of the emissions of 1 Energy are shown in Table 22. Further details are given in Annex A2.2, Methodology for Estimating CO_2 Emissions.

Table 22 CO_2 emission factors for fuels. The values are assumed to be constant over the period 1990-2004 (SFOE 2001). The value for natural gas also holds for CNG (compressed natural gas).

CO_2 Emission Factors 1990-2004	
Fuel	t CO_2 / TJ
Hard Coal	94.0
Gas Oil	73.7
Residual Fuel Oil	77.0
Natural Gas	55.0
Gasoline	73.9
Diesel Oil	73.6
Propane/Butane (LPG)	65.5
Jet Kerosene	73.2
Lignite	104.0

3.1.3. Feedstocks

Energy data are taken from the Swiss overall energy statistics (SFOE 2005). Exceptions are coal and residual fuel oil, which are taken from Basics 2006. These statistics account for production, imports, exports, transformation and stock changes. Hence all figures for energy consumption, on which the Swiss GHG inventory is based, correspond to apparent consumption figures.

In the Reference Approach of the GHG inventory, carbon stored in feedstocks has to be subtracted from fuel import to report the effective CO_2 emissions correctly. Bitumen as refinery product is the only feedstock reported. Other feedstocks are not reported. They are assumed to be small.

3.1.4. Correction of Fuel Consumption Related to Liechtenstein

The Swiss overall energy statistics (SFOE 2005) contains the fossil fuel consumption of the Principality of Liechtenstein (about 34'600 inhabitants, 29100 employees in industrial and service sector), since the two countries form a customs and monetary union governed by a customs treaty. Until now, Switzerland therefore had included Liechtenstein's energy related emission in its GHG inventory. For the submission of 31 May 2006, Switzerland for the first time corrected the emissions by subtracting the Liechtenstein's fuel consumption from the consumption provided in the Swiss overall energy statistics. In the present submission, the same method has been applied using the same number of Liechtenstein's fuel consumption from May 2006.

Liechtenstein's activity data (energy consumption) for Gas oil, LPG and natural gas were taken from the two available CRFs for the years 1990 and 2004 of Liechtenstein and were subtracted from the corresponding figures of the Swiss overall energy statistics. The Swiss emissions were then modelled using the reduced activity data. For the other years 1991–2003, no CRF tables for Liechtenstein are available yet. FOEN interpolated (linearly) Liechtenstein's consumption data between 1990 and 2004. This procedure may seem rough but it should be noted that Liechtenstein's fuel consumption, 3700 TJ in 2004, amounts only up to 0.56% of the Swiss consumption. That means that deviations between interpolated and true consumption are not of great influence for the Swiss inventory.

3.1.5. Leakage from Natural Gas Distribution

Under Source Category 1B2 b the amount of methane leaked from the Natural Gas distribution system is reported. In order to avoid double counting, these emissions are subtracted from the consumption of natural gas in the present submission. For reasons of simplicity, the entire amount of leaking natural gas was subtracted from the category with the largest leakages i.e. 1A4b Residential.

3.2. Source Category 1A – Fuel Combustion Activities

3.2.1. Source Category Description

a) Energy Industries (1A1)

Key categories 1A1
CO_2 from the combustion of Gaseous Fuels, Liquid Fuels and Other Fuels in Energy Industries (1A1) are key categories regarding level; CO_2 from the combustion of Gaseous Fuels and Other Fuels are also key categories regarding trend; N_2O from the combustion of Other Fuels in 1A1 is a key category regarding trend.

According to IPCC guidelines, source category 1A1 “Energy Industries” comprises emissions from fuels combusted by fuel extraction and energy producing industries.

In Switzerland, fuel extraction is not occurring and 1A1 includes only emissions from the production of heat and/or electricity for sale to the public. Auto-producers in industry are included in category 1A2 “Manufacturing Industries and Construction”. An exception is auto-production in heat and power generation in waste incineration plants, which is included in 1A1.

In Switzerland, electricity production is dominated by hydroelectric power plants (55.3%) and nuclear power stations (40.0%). Other sources such as (fossil fueled) combined heat and power generation, and power generation from solar, wind and bio gas account only for about 4.7% of the electricity generated in Switzerland (SFOE 2005; table 24; data for the year 2004).

Table 23 Specification of source category 1A1 “Energy Industries”

1A1	Source	Specification	Data Source
1A1 a	Public Electricity and Heat Production	Main source are waste incineration plants with heat and power generation (Other fuels) and public district heating systems, including a small fraction of CHP. The only fossil fuelled public electricity generation unit “Vouvry” (300 MW_e; no public heat production) ceased operation in 1999.	Waste incineration: AD: SAEFL 2005c, EMIS EF: CO_2 SAEFL 2005g, EMIS Other sources: AD: SFOE 2005: EMIS EF: SAEFL 2000; SFOE 2001; EMIS
1A1 b	Petroleum Refining	Combustion activities supporting the refining of petroleum products, excluding evaporative emissions.	AD: Annual report EV 2005, SFOE 2005; EMIS EF: Industry data; EMIS
1A1 c	Manufacture of Solid Fuels and Other Energy Industries	Not occurring in Switzerland	-

b) Manufacturing Industries and Construction (1A2)

Key categories 1A2
CO_2 from the combustion of Gaseous Fuels, Liquid Fuels, Solid Fuels and Other Fuels in Manufacturing Industries and Construction (1A2) is a key category regarding both level and trend.

The source category 1A2 “Manufacturing Industries and Construction” comprises all emissions from the combustion of fuels in stationary boilers, gas turbines and engines within manufacturing industries and construction, including emissions from conventional and waste fuel use in cement production. Not included are combustion installations in the commercial/institutional and the residential sector as well as in agriculture/forestry. These are included in category 1A4 (“Other Sectors”).

In line with the IPCC guidelines, non-energy cement industry emissions of CO_2 from calcination are reported in category 2.

Table 24 Specification of source category 1A2 “Manufacturing Industries and Construction”

1A2	Source	Specification	Data Source
1A2 a	Iron and Steel	Iron and Steel industry	AD: SFOE 2005, Basics 2006 and industry data; EMIS EF: EMIS, SAEFL 2000
1A2 b	Non-ferrous Metals	Non-ferrous Metals industry	Same as in 1A2a.
1A2 c	Chemicals	Chemical industry	Same as in 1A2a.
1A2 d	Pulp, Paper and Print	Pulp, Paper and Print industry	Same as in 1A2a.
1A2 e	Food Processing, Beverages and Tobacco	Food Processing, Beverages and Tobacco industry	Same as in 1A2a.
1A2 f	Other (Combustion Installations in Industries)	Category 1A2 f contains Cement, Lime, Brick and tile, Fine ceramics, Asphalt concrete plants, Container glass, Glass, Glass wool and Mineral wool.	Same as in 1A2a and EKV 1991

c) Transport (1A3)

Key categories 1A3b
CO_2 from the combustion of diesel (level and trend)
CO_2 from the combustion of gasoline (level)
CH_4 from the combustion of gasoline (trend)

Key source 1A3e
CO_2 from military aviation (trend)

The source category includes civil and military aviation, road transportation, railways, navigation and other transportation. Further off-road transportation is included in category 1A4 Other Sectors (off-road transport in agriculture and forestry) and in 1A5 Other (off-road, e.g. construction). For information on bunker fuel emissions from international aviation, see Chapter 3.4.

Table 25 Specification of Swiss source category 1A3 “Transport”.

1A3	Transport	Specification	Data Source
1A3 a	Civil Aviation (National)	Large (jet, turboprop) and small (piston) aircrafts, helicopters	SFOE 2005, FOCA 2006
1A3 b	Road Transportation	Light and heavy motor vehicles, coaches, two-wheelers	AD: SFOE 2005, EF: SAEFL 2004-2004c, RWTÜV 2003 Hausberger et al. 2002
1A3 c	Railways	Diesel locomotives	AD: Electrowatt 2005 EF: Mayer 2006 Methods, Emissions: SAEFL 2005a
1A3 d	Navigation (National)	Passenger ships, motor and sailing boats on the Swiss lakes	AD: Electrowatt 2005 EF: Mayer 2006 Methods, Emissions: SAEFL 2005a
1A3 e	Military Aviation		VTG 2006

d) Other Sectors (1A4 – Commercial/Institutional, Residential, Agriculture/ Forestry)

Key categories 1A4a, 1A4b
CO_2 from the combustion of gaseous and liquid fuels in the Commercial/Institutional Sector (1A4a) and in the Residential Sector (1A4b) are key categories regarding both level and trend.

Key categories 1A4c
CO_2 from the combustion of Liquid Fuels in Agriculture/Forestry (1A4c) is a key category regarding level.

Source category 1A4 "Other sectors" comprises emissions from fuels combusted in commercial and institutional buildings, in households and emissions from fuel combustion for grass drying and off-road machinery in agriculture.

Table 26 Specification of source category 1A4 "Other sectors".

1A4	Source	Specification	Data Source
1A4 a	Commercial/ Institutional	Emission from fuel combustion in commercial and institutional buildings	AD: SFOE 2005, CEPE 2005 EF: EMIS, SAEFL 2000; SFOE 2001
1A4 b	Residential	Emissions from fuel combustion in households	AD: SFOE 2005 EF: EMIS, SAEFL 2000; SFOE 2001
1A4 c	Agriculture/ Forestry/ Fishing	Comprises fuel combustion for grass drying and off-road machinery in agriculture	AD: EMIS and Electrowatt 2005 EF: EMIS, SFOE 2001; Mayer 2006 Emissions, methods: SAEFL 205a

e) Other – Off-road: Construction, Hobby, Industry and Military (1A5)

Key sources 1A5
CO_2 from the combustion of liquid fuels in 1A5 Other – Off-road is a key category regarding both level and trend.

In Switzerland, the sub-sources are defined according to the next table. The IPCC category structure distinguishes mobile and stationary sources. All of the Swiss sub-categories refer to mobile sources.

Table 27 Specification of Swiss source category 1A5 "Other" (off-road).

1A5	Off-road	Specification	Data Source
	Construction	Construction vehicles and machinery	AD: Electrowatt 2005 EF: Mayer 2006 Emissions, methods: SAEFL 205a
	Hobby	Household and gardening machinery and motorised equipment	
	Industry	Industrial off-road vehicles and machinery	
	Military (without military aviation)	Tanks and similar off-road vehicles. (emissions from military road vehicles are included in 1A3b Road Transportation)	

3.2.2. Methodological Issues

General Issues

Sectoral (National) and Reference Approach

Two methods are applied for source category 1 “Energy”, the Sectoral (or National) Approach and the Reference Approach. For the Inventory of the Framework Convention and the Kyoto Protocol the Sectoral (National) Approach is used. The Reference Approach is only used for controlling purposes (quality control!).

The National Approach uses specific methods for the different source categories: Fossil fuel consumption statistics (top-down approach, tier 1) and bottom-up modelling of fuel consumption (bottom-up, tier 2 and tier 3). In the following, the National Approach is documented in detail for each source category within 1A.

For the Reference Approach, the fossil fuel supply statistics is used. All imports and exports of primary fuels (crude oil, natural gas, coal), secondary fuels (gasoline, diesel etc.) and stock changes are published in the Swiss overall energy statistics (SFOE 2005) and the yearly reports of the Swiss Petroleum Association [Erdöl-Vereinigung/Union pétrolière] (EV 2005). Exceptions are coal and residual fuel oil, which are taken from Basics 2006. These statistics account for production, imports, exports, transformation and stock changes. The Reference Approach corresponds to a top-down approach (tier 1) based on net quantities of fuel imported to Switzerland.

More detailed information on the comparison of the Sectoral with the Reference Approach can be found in Chapter 3.6.

Oxidation Factors

For the calculation of CO_2 emissions, an oxidation factor of 100% is assumed for all fossil fuel combustion processes (including coal), because technical standards for combustion installations in Switzerland are relatively high.

As the consumption of liquid fuels stagnated (1990 to 2004: -0.4% to 463'677 TJ) and gaseous fuels strongly increased (1990 to 2004: +67.2% to 111'096 TJ), overestimating of oxidation factors tends to overestimate emission increase and is therefore conservative.

For coal, IPCC 1996 provides a global average oxidation factor of 98.0%. However, most coal in Switzerland is used in cement industry. In cement production, an oxidation factor of 100% may be assumed according to EU guidelines (EC 2004)[4].

The consumption of coal plays a minor role in Switzerland. It decreased over the considered period (1990 to 2004: -54.4% to 7'247 TJ). In case of a decrease, overestimating of oxidation factors may tend to overestimate emission decrease. However, the main remaining consumer of coal in Switzerland is the cement industry that accounts for 79% of total Swiss coal consumption in 2004. With the main share of coal used in cement production, and under the assumption of high efficiency coal boilers, the overestimation of emission decrease may become minor.

Therefore, for all fuel combustion activities, an oxidation factor of 100% is assumed in Switzerland.

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[4] EC 2004, Annex VII, Section 2.1.1: "In cement kilns the incomplete combustion of fossil fuels is negligible, due to the very high combustion temperatures, long residence time in kilns and minimal residual carbon found in clinker. Carbon in all kiln fuels shall therefore be accounted for as fully oxidized (oxidation factor = 1.0)."

a) Energy Industries (1A1)

Key categories 1A1
CO_2 from the combustion of Gaseous Fuels, Liquid Fuels and Other Fuels in Energy Industries (1A1) are key categories regarding level; CO_2 from the combustion of Gaseous Fuels and Other Fuels are also key categories regarding trend; N_2O from the combustion of Other Fuels in 1A1 is a key category regarding trend.

In Switzerland, Energy Industries (source category 1A1) comprise of

- “Public Electricity and Heat Production” including heat and power production in municipal solid waste incineration plants and special waste incineration (1A1a)
- “Petroleum Refining” (1A1b).

Manufacture of Solid Fuels and Other Energy Industries (1A1c) do not occur.

Public Electricity and Heat Production (1A1a)

Methodology

For fuel combustion in Public Electricity and Heat Production (1A1a) except waste incineration, a country-specific Tier 2 method is used. A top-down method based on aggregated fuel consumption data from the Swiss overall energy statistics is used to calculate emissions. These sources are characterised by rather similar industrial combustion processes and the same emission factors are applied throughout these sources. Emissions of GHGs are calculated by multiplying fuel consumption (in TJ) by emission factors.

For heat and/or power generation in municipal solid waste and special waste incineration plants the GHG emissions are calculated by multiplying the waste quantity incinerated by emission factors.

An oxidation factor of 100% is assumed for all combustion processes and fuels (see sub-section on oxidation factors in the beginning of Section 3.2.2).

Emission Factors

(a) Waste incineration with heat and/or power generation ("Other fuels")
Emission factors for CO_2, N_2O, CO, NMVOC and SO_2 emissions per ton of waste incinerated are country specific based on measurements and expert estimates, documented in the EMIS database. Emission factors are taking into account flue gas cleaning standards in incineration plants. CH_4 is not occurring because of the high combustion temperatures in waste incineration plants. The share of organic matter in the municipal solid waste is estimated to be 60% (for all years considered), based on analysis of municipal solid waste by the SFOE's waste section. The burn-out efficiency in modern municipal solid and hazardous waste incineration plants is very high.

(b) Other Public Electricity and Heat Production
The emission factors for CO_2 and SO_2 are country specific and based on measurements and analysis of fuel samples carried out by the Swiss Federal Laboratories for Materials Testing and Research EMPA (carbon emission factor documented in SFOE 2001, Table 45: p. 51; net calorific values on p. 61. See also Annex 2.1.1).
The activity data on LFO use in the CRF includes LPG consumption. This is due to statistical reasons in the Swiss overall energy statistics (SFOE 2005). Therefore the LFO emission factor for CO_2 used for the CRF (see table below) is a mixed emission factor that results as a weighted average of the LFO emission factor and LPG emission factor.
Emission factors for CH_4, N_2O, NO_x, CO and NMVOC are country specific based on comprehensive life cycle analysis of industrial boilers, documented in SAEFL 2000 (pp. 14-

27). For NO_x emission factors, expert judgement has been used to estimate the fraction of low-NO_x burners.
All emission factors for biomass are based on SAEFL 2000 (pp. 26ff).

Since the fraction of stationary engines in total fuel consumption is rather small, emission factors for industrial combustion boilers are used for all sources and fuels. This simplification leads to a potential underestimation of CH_4 emissions from stationary sources in 1A1 of less than 2 tons of CH_4 per year (expert estimate FOEN).

The following table presents the emission factors used in 1A1a:

Table 28 Emission Factors for 1A1a Public Electricity and Heat Production in Energy Industries in 2004. Emission factors for waste incineration are provided per ton of waste incinerated for both municipal solid waste incineration and special waste incineration.

Source/fuel	CO_2 t/TJ	CO_2 bio. t/TJ	CH_4 kg/TJ	N_2O kg/TJ	NO_x kg/TJ	CO kg/TJ	NMVOC kg/TJ	SO_2 kg/TJ
1A1a Public Electricity/Heat								
Light fuel oil	73.50		1	0.6	34	11	2	33
Natural gas	55		6	0.1	15	14	2	0.5
Biomass		92	21	1.6	160	530	7	20
	CO_2 t/t	**CO_2 bio. t/t**	**CH_4 kg/t**	**N_2O g/t**	**NO_x kg/t**	**CO kg/t**	**NMVOC kg/t**	**SO_2 kg/t**
Other fuels (MSW)	0.508	0.763		113.8	0.400	0.116	0.018	0.060
Other fuels (special waste)	1.450			113.8	0.400	0.116	0.018	0.060

In the table above, the CO_2 emission factor of light fuel oil (73.50 t/TJ) is a weighted average[5] emission factor including both LFO (73.7 t/TJ) and LPG (65.5 t/TJ) emissions.

The emission factor for N_2O from municiapal solid waste incineration has almost doubled from 60 g N_2O per ton of waste in 1990 to 113.8 g/t in 2004. This is due to the increased use of DeNOx-equipment with the municipal solid waste incineration plants (EMIS). It is expected that the N_2O emission factor is back to 14g/t in 2020 (EMIS). This contributes to the fact that N_2O emissions from 1A1 are a key category regarding trend.

Activity Data

(a) Municipal solid waste incineration ("Other fuels")

Energy recovery from municipal solid waste incineration is mandatory in Switzerland and plants are equipped with energy recovery systems (Schwager 2005). The emissions from heat and/or power generation in municipal solid waste incineration plants are therefore reported under category 1A1a[6]. Included are also emissions from the incineration of special waste, because these plants are also equipped with energy recovery systems. Activity data for waste incineration is provided in the table below.

[5] Calculation: 73.50 t/TJ = (212'567 TJ * 73.7 t/TJ + 5'194 TJ * 65.5 t/TJ) / (217'206 TJ + 554 TJ) for the year 2004.

[6] In earlier submissions, some of the emissions from municipal solid waste incineration have been reported also under category 6C.

Table 29 Activity data for 1A1a "Other fuels": municipal solid waste and special waste incinerated with heat and/or power generation 1990 to 2004.

Source/fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1A1a Other fuels																
Total Other fuels in 1A1a	Gg	2'603	2'477	2'467	2'441	2'411	2'433	2'471	2'538	2'657	2'828	3'039	3'147	3'263	3'221	3'371
Municipal solid waste	Gg	2'470	2'340	2'310	2'310	2'250	2'270	2'290	2'340	2'420	2'590	2'800	2'920	3'031	2'990	3'140
Special waste	Gg	133	137	157	131	161	163	181	198	237	238	239	227	232	231	231

The table above documents the increase of municipal solid waste incinerated by 26% from 1990 to 2004. This is due to the fact that since 1^{st} of January 2000, disposal on landfill sites of waste which can be incinerated, is prohibited by law. See also Chapter 8.4 on Waste Incineration. This increase results in CO_2 emissions from "Other fuels" (i.e. MSW incineration) in category 1A1 being a key category regarding trend.

(b) Other Public Electricity and Heat Production

Activity data on fuel consumption (TJ) for Public Electricity and Heat Production (1A1a) is extracted from the Swiss overall energy statistics. The activity data for 2004 correspond to the consumption of LFO, natural gas and biomass in public district heating systems (SFOE 2005; tables 21, 26, and 28). Other fuels is calculated from the annual amount of municipal solid waste incinerated with heat and/or electricity (see Table 29).

Table 30 Activity data in 1A1a Public Electricity/Heat.

Source/fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1A1a Public Electricity/Heat Fuel Consumption																
Total	TJ	39'752	41'014	42'777	37'761	37'094	38'026	40'790	41'812	47'094	45'130	45'731	47'629	48'200	48'866	50'383
Light fuel oil	TJ	980	1'790	1'917	1'662	810	554	810	1'065	852	725	512	554	512	682	554
Heavy fuel oil	TJ	3'195	5'006	6'336	1'748	1'541	1'791	2'420	1'063	4'093	815	0	0	0	0	0
Natural gas	TJ	4'270	4'705	4'664	4'627	4'724	5'313	6'580	6'941	6'785	6'695	5'793	6'286	6'036	6'784	6'804
Coal	TJ	499	105	105	79	79	53	0	0	0	0	0	0	0	0	0
Other (waste-to-energy)	TJ	30'768	29'369	29'684	29'595	29'880	30'264	30'911	32'692	35'303	36'835	39'356	40'719	41'523	41'240	42'845
Biomass	TJ	40	40	70	50	60	50	70	50	60	60	70	70	130	160	180

The table above documents the increase of Gaseous Fuel consumption by 60% from 1990 to 2004. This increase is the first reason for category 1A1 Gaseous Fuels being a key category regarding trend.

Petroleum Refining (1A1b)

Methodology

For fuel combustion in Petroleum Refining (1A1b), a country-specific Tier 2 bottom-up method is used. The calculations are generally based on measurements and data from individual point sources from the refining industry. The unit of emission factors refers to fuel consumption (in TJ).

Emission Factors

Emission factors for CO_2, CH_4, N_2O, CO, NMVOC and SO_2 are country specific based on measurements and data from industry and expert estimates, documented in the EMIS database (see Section 1.4.3) and in SAEFL 2000.

The following table presents the emission factors used in 1A1b:

Table 31 Emission Factors for 1A1b Petroleum Refining in 2004.

Source/fuel	CO_2 t/TJ	CH_4 kg/TJ	N_2O kg/TJ	NO_x kg/TJ	CO kg/TJ	NMVOC kg/TJ	SO_2 kg/TJ
1A1 b Petroleum Refining							
Heavy fuel oil	77	4.0	0.8	110	15	2.5	490
Gas (refinery LPG)	59.3	1.0	0.6	55	15	2.3	25
P-Coke	94.1	10	1.6	200	100	10.0	500

Activity Data

Activity data on fuel combustion (TJ) for Petroleum Refining (1A1b) is extracted from the Annual Reports of the Swiss Petroleum Association (EV 2005: p. 82).

Table 32 Activity data in 1A1b Petroleum Refining (NO: not occurring).

Source/fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1A1b Petroleum Refining Fuel Consumption																
Total	TJ	5'906	8'670	8'137	9'290	10'679	10'317	11'092	10'693	11'022	11'353	10'091	10'909	11'447	10'525	14'360
Heavy fuel oil	TJ	1'296	1'216	998	1'054	1'426	1'834	1'618	1'780	1'428	1'698	1'952	1'936	1'518	1'769	1'339
Gas (refinery LPG)	TJ	4'610	7'454	7'139	8'237	9'253	8'483	9'474	8'913	9'594	9'655	8'139	8'973	9'929	8'756	11'901
Petroleum coke	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	1'120

The table above documents the increase of gas (refinery LPG) consumption for Petroleum refining by over 150% from 1990 to 2004. This is explained by the fact that in 1990 one of the two Swiss refineries operated at reduced capacity and in later years resumed full production, leading to higher fuel consumption. This increase is the second reason for CO_2 emissions from category 1A1 Gaseous Fuels being a key category regarding trend.

Since 2004, one of the Swiss refineries is using petroleum coke as a fuel.

b) Manufacturing Industries and Construction (1A2)

Key categories 1A2
CO_2 from the combustion of Gaseous Fuels, Liquid Fuels, Solid Fuels and Other Fuels in Manufacturing Industries and Construction (1A2) is a key category regarding both level and trend.

Methodology

For fuel combustion in Manufacturing Industries and Construction (1A2) a country specific Tier 2/3 method is used. The method combines both bottom-up and top-down elements (see table below). Emissions of GHGs are calculated by multiplying levels of activity by emission factors.

- A *top-down* method based on aggregated fuel consumption data from the Swiss overall energy statistics and energy-economic modelling is used to calculate CO_2 emissions of 1A2a to 1A2f (with the exception of waste derived fuels in cement industry). The top-down method is also used to estimate non-CO_2 emissions from most of the sources in 1A2 (see "methods" in Table 33 below). These sources are characterised by rather similar industrial combustion processes and assumingly homogenous emission factors, where a top-down approach is feasible. Identical emission factors for each fuel type are applied throughout these sources. The unit of emission factors refers to fuel consumption (in TJ).

- A *bottom-up* (Tier2/Tier3) method is used to calculate the non-CO_2 emissions from the remaining group of sources characterised by heterogeneous emission factors. This group comprises Iron and Steel industries (1A2a) as well as the sources in 1A2f: Cement, Lime, Brick and tile, Fine ceramics, Asphalt concrete plants, Container glass, Glass, Glass wool and Mineral wool. The calculations are based on measurements and data from individual point sources from industry. Emission factors refer both to fuel consumption (in TJ) or production data (e.g. in tons of steel or cement produced). A bottom-up approach is also used to estimate CO_2 emissions from waste derived fuels used in cement industry ("Other fuels").

Table 33 Overview on methods applied to calculate GHG emissions in 1A2.

Source/	Method applied to calculate **CO_2 emissions**	Method applied to calculate ***non*-CO_2 emissions**
1A2 a Iron and Steel	Top-down	
Iron and Steel		Bottom-up (EMIS)
Other sources in 1A2a		Top-down
1A2b Non-Ferrous Metals	Top-down	Top-down
1A2c Chemicals	Top-down	Top-down
1A2d Pulp, Paper and Print		
Biomass (waste derived fuels from paper and pulp)	Bottom-up (Industry data)	Bottom-up (Industry data)
All other fuels	Top-down	Top-down
1A2e Food Processing, Beverages, and Tobacco	Top-down	Top-down
1A2 f Other		
Cement/Lime/Glass/… industry (without "Other fuels")	Top-down	Bottom-up (Industry data and EMIS)
Cement "Other fuels"	Bottom-up	Bottom-up (Industry data and EMIS)
Other sources in 1A2f	Top-down	Top-down

An oxidation factor of 100% is assumed for all combustion processes and fuels (see sub-section on oxidation factors in the beginning of Section 3.2.2).

For the present submission, the emissions related to the use of waste derived fuel in paper and pulp industries are fully reported under 1A2 for the first time (and not under 6C anymore).

Emission factors

Top-down approach
For all sources and gases where a top-down approach is applied, emission factors are the same as for source category 1A1a.

The emission factors for CO_2 and SO_2 are country specific and based on measurements and analysis of fuel samples carried out by the Swiss Federal Laboratories for Materials Testing and Research EMPA (carbon emission factor documented in SFOE 2001, Table 45: p. 51; net calorific values on p. 61. See also Annex 2).

The activity data on LFO use from the Swiss overall energy statistics (SFOE 2005) includes also LPG consumption. Therefore the LFO emission factor for CO_2 is a mixed emission factor that results as a weighted average of the LFO emission factor and LPG emission factor as in 1A1a (See Section 3.2.2 a).

The coal emission factor for CO_2 is a mixed emission factor that results as a weighted average of the hard coal and lignite emission factors (see remark following the table below). The net calorific value of hard coal has been revised for the current submission (see Annex A2.2.1).

Emission factors for CH_4, N_2O, NO_x, CO and NMVOC are country specific based on comprehensive life cycle analysis of industrial boilers, documented in SAEFL 2000 (pp. 14-27). For NO_x emission factors, expert judgement has been used to estimate the fraction of low-NO_x burners.

All emission factors for biomass are based on SAEFL 2000 (pp. 26ff).

Since the fraction of stationary engines in total fuel consumption is rather small, emission factors for industrial combustion boilers are used for all sources and fuels. This simplification leads to a potential underestimation of CH_4 emissions from stationary sources in 1A2 of less than 4 tons of CH_4 per year (expert estimate FOEN).

The following table presents the emission factors used for the sources in categories 1A2a-f that are calculated with the top-down approach:

Table 34 Emission factors for sources in 1A2a-f for 2004. For sources that are calculated bottom-up (see Table 33 further above), the table shows implied emission factors.

Source/fuel	CO_2 t/TJ	CO_2 bio. t/TJ	CH_4 kg/TJ	N_2O kg/TJ	NO_x kg/TJ	CO kg/TJ	NMVOC kg/TJ	SO_2 kg/TJ
1A2 "top-down" sources								
1A2 a Iron and Steel (Total)								
LFO	73.50		1.0	0.6	34	11	2	33
HFO	77.00		4.0	0.8	125	15	4	369
Coal	94.11		10.0	1.6	50	1'901	9	352
Gas	55.00		6.0	0.1	38	6	2	0.5
Biomass								
Other Fuels								
1A2 b Non-Ferrous Metals								
LFO	73.50		1.0	0.6	34	366	73	33
HFO	77.00		4.0	0.8	125	15	4	369
Coal								
Gas	55.00		6.0	0.1	15	14	2	0.5
Biomass								
Other Fuels								
1A2 c Chemicals								
LFO	73.50		1.0	0.6	34	11	2	33
HFO	77.00		4.0	0.8	125	15	4	369
Coal	94.11		10.0	1.6	200	100	10	500
Gas	55.00		6.0	0.1	15	14	2	0.5
Biomass		92.0	21.0	1.6	160	530	7	20
Other Fuels								
1A2 d Pulp, Paper and Print								
LFO	73.50		1.0	0.6	34	11	2	33
HFO	77.00		4.0	0.8	125	15	4	369
Coal	94.11		10.0	1.6	200	100	10	500
Gas	55.00		6.0	0.1	15	14	2	0.5
Biomass (Black liquor)		81.34	IE	IE	52	135	IE	259
Other Fuels								
1A2 e Food Processing, Beverages and Tobacco								
LFO	73.50		1.0	0.6	34	11	2	33
HFO	77.00		4.0	0.8	125	15	4	369
Coal	94.11		10.0	1.6	200	100	10	500
Gas	55.00		6.0	0.1	15	14	2	0.5
Biomass		92.0	21.0	1.6	160	530	7	20
Other Fuels								
1A2 f Other								
LFO	73.50		1.0	0.6	34	11	2	33
HFO	77.00		4.0	0.8	125	15	4	369
Coal	94.11		10.0	1.6	200	100	10	500
Gas	55.00		6.0	0.1	15	14	2	0.5
Biomass		92.0	21.0	1.6	160	530	7	20
Other Fuels	69.97	11.08	1.2	5.8	280	381	13	44

Remark: In the table above, the CO_2 emission factor of light fuel oil of 73.50 t/TJ (2004) is a weighted average emission factor including both LFO (73.7t/TJ) and LPG (65.5t/TJ) emissions (the same as in 1A1a; see Section 3.2.2 a)). The CO_2 emission factor for coal (94.11 t/TJ in 2004) is a weighted average emission factor including hard coal (94 t/TJ), petroleum coke (94 t/TJ) and lignite (104 t/TJ) emissions[7].

Emissions of CH_4, N_2O and NMVOC from the use of biomass (black liquor) in 1A2d Pulp, Paper and Print are included in the emissions from the related heavy fuel oil use for the biomass boiler.

Emission factors from the use of light fuel oil in 1A2b Non-Ferrous Metals are the weighted average of related emission factors of aluminium second smelter and other Non-Ferrous metals.

Bottom-up approach

Following IPCC Tier 3, bottom-up non-CO_2 emission factors are based on production data (e.g. tons of cement or steel produced) or on fuel consumption in the cement, lime, glass, iron and steel industries.

The emission factors for CO_2 and SO_2 are country specific and based on measurements and analysis of fuel samples carried out by the Swiss Federal Laboratories for Materials Testing and Research EMPA (carbon emission factor documented in SFOE 2001, Table 45: p. 51; net calorific values on p. 61). The net calorific value of hard coal has been revised for the current submission (see Annex A2.2.1).

Emission factors for CH_4, N_2O, CO and NMVOC are country specific based on measurements and data from industry and expert estimates, documented in the EMIS database (see Section 1.4.3). They have been updated for the recent years by expert judgement. An overview of key processes that are documented in the old EMIS database and their relation to CRF categories is provided in Annex A3.1.2.

The following two tables present the emission factors used in the bottom-up approach for emissions of Iron and Steel (1A2a) and for the cement industry.

Table 35 Emission factors for sources in Iron and Steel 1A2a in 2004.

1A2 a Iron and Steel (Coke and gas)	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
	t/TJ	kg/TJ		g per ton of iron			
Coke cupolas	94.11	10.0	1.6	67	11	40	1.5
	t/TJ	kg/TJ		g per ton of steel			
Gas (steel plants)	55	6.0	0.1	75	0.5	2.8	0.7

7 Calculation:
94.11t/TJ = (5'623TJ * 94t/TJ + 80TJ * 104t/TJ + (423TJ + 1'120TJ) * 94t/TJ) / (5'623TJ + 80TJ + 423TJ + 1'120TJ) for 2004.

Table 36 Emission factors for cement industry in 2004 (NO: not occurring). Source: EMIS data base. Emission factors for CO_2 are fuel specific; they are the same as in the top-down approach (see Table 34).

Cement industry (part of 1A2f)	**CO_2**	**CH_4**	**N_2O**	**NO_x**	**CO**	**NMVOC**	**SO_2**
	t/TJ	kg/t cement					
Cement	fuel specific	NO	0.023	0.904	0.7	0.004	0.037

These cement fuel consumption emission factors describe emissions from average fuel mix (of liquid, solid, gaseous and waste derived fuels).

The consumption of "Other" fuels in 1A2 refers to the use of waste derived fuels in the cement industry. The following table provides an overview of the emission factors per ton of waste used. The net calorific values are taken from FOEN internal data sources and the other characteristics of waste derived fuels are from Hackl, A., Mauschitz, G. 2003[8]. These emission factors are preliminary and may be revised for future submissions.

Table 37 Emission factors and other characteristics of waste derived fuels ("Other fuels") used in the cement industry.

	NCV	**EF CO_2 Tot.**	**EF CO_2 Tot**	**Fraction biomass-C**	**EF CO_2-fossil**	**EF CO_2-biogenic**
Waste derived fuel	MJ/kg	kg CO_2 / GJ	kg CO_2/t of fuel	%	kg CO_2/t of fuel	kg CO_2/t of fuel
Waste oil	36.06	82.00	2957.31	0.00	2957.31	0.00
Sewage sludge (dried)	9.97	80.00	797.39	100.00	0.00	797.39
Wood	14.50	99.70	1445.60	100.00	0.00	1445.60
Solvents and residues from distillation	27.38	75.00	2053.85	0.00	2053.85	0.00
Waste tyres and rubber	25.57	84.00	2148.11	27.00	1568.12	579.99
Plastics	22.31	74.00	1650.85	3.00	1601.32	49.53
Animal fat	36.36	79.00	2872.07	100.00	0.00	2872.07
Animal meal	17.31	85.00	1471.37	100.00	0.00	1471.37
Mix of special waste with saw dust (CSS)	12.50	75.00	937.50	80.00	187.50	750.00
Waste coke from coke filters	23.70	97.00	2298.90	0.00	2298.90	0.00
Sawdust	13.90	104.00	1445.60	100.00	0.00	1445.60

For CSS (mix of special waste with saw dust), the share of biogenic C is estimated to be 80%.

[8] As cited in the EMIS data base.

Activity data

Top-down approach

Activity data on fuel consumption (TJ) for "top-down" sources in category 1A2 (see Table 33 above) are based on aggregated fuel consumption data from the Swiss overall energy statistics (SFOE 2005) and energy-economic modelling. A detailed description of the modelling work for the disaggregation of fuel consumption to the level of 1A2a-f is provided in Annex A2.4.1.

The resulting disaggregated fuel consumption data for 1990 to 2004 is provided in the table below.

Table 38 Activity data fuel consumption in 1A2 Manufacturing Industries and Construction 1990 to 2004; fuel consumption Other Fuels (Waste fuels in Cement) in TJ has been calculated bottom-up from the amount (in tons) of waste derived fuels used.

Source	**Unit**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
1A2 Manufacturing Industries and Constr. (Total)	*TJ*	87'972	88'026	87'412	85'767	86'726	86'354	87'058	88'464	90'641	92'427	93'536	95'640	93'801	95'086	95'670
Light fuel oil	*TJ*	26'477	29'307	29'456	28'734	27'907	28'097	29'927	31'840	34'203	34'803	33'652	34'774	34'198	34'658	33'622
Heavy fuel oil	*TJ*	18'770	17'238	16'690	14'349	14'603	11'576	11'245	10'561	10'225	9'701	7'301	7'167	6'279	5'554	5'713
Coal	*TJ*	14'774	11'486	8'980	7'638	7'956	8'210	5'533	5'014	4'386	4'392	6'388	6'502	6'002	6'074	5'753
Natural gas	*TJ*	19'346	21'386	23'545	25'804	27'141	28'634	29'465	30'561	31'371	32'834	35'021	35'438	34'537	35'477	36'889
Biomass	*TJ*	4'472	4'628	4'913	5'119	5'355	5'506	6'106	5'861	5'764	5'582	5'559	5'581	5'742	5'888	5'878
Other Fuels	*TJ*	2'047	2'082	2'118	2'598	2'324	2'974	3'509	3'439	3'586	3'420	3'922	4'732	5'301	5'549	5'786
1A2a Iron and Steel	TJ	3'036	3'158	3'381	3'355	3'393	2'895	3'003	3'142	3'355	3'379	3'750	3'850	3'830	3'830	3'755
Light fuel oil	TJ	782	806	811	803	804	652	657	701	761	785	815	811	821	806	808
Heavy fuel oil	TJ	340	339	341	338	338	96	94	99	108	109	123	123	117	119	122
Coal	TJ	469	512	544	435	429	353	290	287	314	284	279	363	385	366	234
Natural gas	TJ	1'445	1'501	1'684	1'779	1'822	1'794	1'963	2'056	2'172	2'202	2'534	2'553	2'506	2'539	2'592
Biomass	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other Fuels	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A2b Non-Ferrous Metals	TJ	517	606	460	469	458	646	687	888	974	1'112	1'100	1'014	1'097	1'181	1'206
Light fuel oil	TJ	240	241	225	201	206	215	213	251	268	270	272	259	279	283	273
Heavy fuel oil	TJ	2.0	1.7	1.5	1.2	1.3	1.9	1.1	1.4	1.3	1.3	1.1	1.0	1.0	1.0	1.1
Coal	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	TJ	275	363	233	267	250	429	472	636	705	840	827	754	817	897	931
Biomass	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other Fuels	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A2c Chemicals	TJ	15'427	14'698	14'560	13'955	14'401	15'504	15'838	15'409	15'270	14'433	14'968	15'912	15'348	14'969	15'225
Light fuel oil	TJ	3'117	3'197	2'753	2'874	2'731	3'750	3'737	3'409	2'982	2'722	3'030	3'202	3'109	3'049	3'094
Heavy fuel oil	TJ	1'741	1'172	896	1'146	893	465	486	459	360	265	261	332	180	120	147
Coal	TJ	226	214	198	184	188	179	155	136	124	118	111	95	86	79	74
Natural gas	TJ	10'343	10'116	10'712	9'751	10'590	11'109	11'460	11'405	11'804	11'329	11'566	12'282	11'972	11'721	11'909
Biomass	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other Fuels	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A2d Pulp, Paper and Print	TJ	11'659	11'278	12'698	12'475	13'302	11'787	10'792	10'939	10'610	10'875	11'120	11'189	11'706	11'591	11'429
Light fuel oil	TJ	536	777	986	926	861	954	1'051	993	1'034	1'122	1'090	1'041	1'078	1'028	996
Heavy fuel oil	TJ	5'225	4'715	4'307	3'671	3'337	3'119	2'972	3'179	3'149	2'998	2'528	2'622	2'471	2'374	2'268
Coal	TJ	1'014	619	112	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	TJ	2'798	3'269	5'582	6'354	7'662	6'357	5'495	5'579	5'321	5'061	5'809	6'080	6'415	6'305	6'135
Biomass	TJ	2'085	1'898	1'711	1'524	1'441	1'358	1'273	1'189	1'105	1'694	1'694	1'447	1'741	1'885	2'029
Other Fuels	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A2e Food Processing, Beverages and Tobacco	TJ	7'326	7'697	7'153	7'536	7'260	8'059	8'989	8'889	9'118	9'667	9'497	8'834	9'179	8'986	8'938
Light fuel oil	TJ	4'634	4'808	4'743	4'853	4'837	4'860	5'090	5'005	5'249	5'247	5'172	5'042	4'997	4'945	4'744
Heavy fuel oil	TJ	1'163	1'029	917	826	761	739	655	519	486	484	450	434	392	368	383
Coal	TJ	447	367	443	381	283	340	470	430	256	294	233	135	381	243	141
Natural gas	TJ	1'082	1'494	1'050	1'476	1'380	2'119	2'773	2'935	3'128	3'643	3'641	3'223	3'409	3'430	3'670
Biomass	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other Fuels	TJ	NO	NO	NO	NO	NO	NO	0	NO	NO	NO	NO	NO	NO	NO	NO
1A2f Other	TJ	50'007	50'589	49'161	47'977	47'911	47'463	47'749	49'197	51'314	52'960	53'100	54'841	52'642	54'528	55'118
Light fuel oil	TJ	17'168	19'478	19'937	19'077	18'466	17'665	19'179	21'481	23'910	24'657	23'274	24'419	23'914	24'547	23'707
Heavy fuel oil	TJ	10'300	9'982	10'227	8'366	9'273	7'154	7'036	6'304	6'121	5'845	3'938	3'655	3'117	2'573	2'793
Coal	TJ	12'617	9'774	7'682	6'638	7'057	7'338	4'618	4'161	3'692	3'697	5'765	5'909	5'150	5'386	5'304
Natural gas	TJ	3'402	4'643	4'285	6'178	5'437	6'826	7'301	7'951	8'240	9'759	10'643	10'545	9'417	10'585	11'650
Biomass	TJ	4'472	4'628	4'913	5'119	5'355	5'506	6'106	5'861	5'764	5'582	5'559	5'581	5'742	5'888	5'878
Other Fuels (Waste fuels in Cement)	TJ	2'047	2'082	2'118	2'598	2'324	2'974	3'509	3'439	3'586	3'420	3'922	4'732	5'301	5'549	5'786

The table above documents the increase of Natural Gas consumption for manufacturing industries by 90% from 1990 to 2004 as well as the net decrease of liquid fuel consumption by -13% and the decrease of coal consumption by -61% over the period. This shift in fuel mix is the reason for CO_2 emissions from the use of Gaseous, Liquid and Solid Fuels in category 1A2 being a key category regarding trend.

Bottom-up approach

Activity data on iron and steel production that is used to calculate bottom-up non-CO_2 emissions from cupola ovens in iron foundries and reheating furnaces in steel plants is based on data from EMIS.

Table 39 Activity data: Production in Iron and Steel that is used to calculate bottom-up non-CO_2 emissions from sources in 1A2a (EMIS database).

Source/production	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1A2a Iron and Steel																
Iron foundries: cupol ovens	Gg	90	72	68	54	55	60	51	53	57	56	55	49	37	34	40
Steel plants: reheating furnaces	Gg	1'108	1'155	1'245	1'276	1'230	716	738	789	880	918	1'022	1'048	1'125	1'110	1'094

Activity data on cement production used for the calculation of non-CO_2 emissions from fuel use in cement industry is provided by the association of Swiss cement producers (Cemsuisse 2004) (See Table 67 in Chapter 4.2.2 a). For the year 1990, activity data for fuel use in cement production from EKV 1991 has been used.

The amount of waste derived fuels used in cement industry (in tons) is provided by the following table. Data has been collected from the following sources[9]: Estimates by FOEN experts, SAEFL 2003a and Cemsuisse 2004. The activity data is used to calculate CO_2 emissions from "Other fuels" in 1A2.

[9] As cited in the EMIS data base.

Table 40 Activity data: Amount of waste derived fuels ("Other fuels") in cement industry. Sources: Estimates by SAEFL experts (in *italics*), EKV 1991, SAEFL 2003a and Cemsuisse 2004.

Year	**Waste oil**	**Sewage sludge (dried)**	**Waste wood**	**Solvents and residues from distillation**	**Waste tyres and rubber**	**Plastics**	**Animal fat and meal**	**Other waste fuels**	**Total**
	t	**t**	**t**	**t**	**t**	**t**	**t**	**t**	**t**
1990	*42’203*	5’418	3’724	*1’000*	*6’000*	0	0	*20’000*	78’344
1991	*42’936*	5’418	3’724	*1’000*	*6’000*	0	0	*20’000*	79’077
1992	*42’230*	5’418	3’724	*3’500*	*6’000*	0	0	*20’000*	80’872
1993	*42’937*	5’418	4’966	*5’500*	*15’250*	0	0	*20’000*	94’070
1994	37’205	6’897	6’534	5’354	15’245	1’089	0	18’421	90’745
1995	45’705	13’651	19’745	7’679	15’723	2’194	0	17’185	121’881
1996	46’600	18’600	24’300	11’600	15’900	7’000	9’100	14’500	147’600
1997	38’701	25’538	19’610	17’353	13’861	10’855	10’759	13’368	150’045
1998	46’474	23’046	0	15’874	13’740	20’130	10’294	15’241	144’799
1999	43’199	29’707	0	11’493	12’152	21’894	9’743	16’780	144’968
2000	46’775	35’374	0	18’063	15’929	22’680	9’113	19’619	167’553
2001	41’299	37’076	0	21’863	18’047	23’776	47’472	16’534	206’067
2002	48’735	38’296	0	30’711	17’437	20’860	54’034	15’098	225’171
2003	45’850	41’100	0	31’300	21’500	20’800	63’550	14’798	238’898
2004	47'807	42'827	0	32'618	22'409	21'662	66'232	15'687	248'994

The table above documents the increase of the use of waste derived fuels ("Other fuels") in cement industry by more than 300% from 1990 to 2004 (in tons; and by 283% in energy units). This increase is the reason for CO_2 emissions from category 1A2 Other fuels being a key category regarding trend. Please note that for some waste derived fuels no data on their use cement production is available for the years before 1994 and that estimates by SFOE experts had to be made for these years.

The following table provides an overview of fuel use in cement industry in energy units (TJ):

Table 41 Activity data: Overview on fuel use in cement industry.

Source	**Unit**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Cement industry																
Cement, total incl. waste	TJ	16'435	14'267	13'512	12'074	13'479	12'778	11'171	10'342	10'169	10'062	10'872	11'361	11'046	10'982	11'302
Cement fossil without waste	TJ	14'388	12'185	11'394	9'475	11'155	9'803	7'663	6'903	6'583	6'641	6'951	6'629	5'746	5'433	5'516
HFO	TJ	1'907	2'957	4'377	3'263	4'589	2'825	3'507	3'206	3'168	3'260	1'530	1'194	1'079	621	769
Coal	TJ	12'119	9'214	6'950	6'164	6'539	6'811	4'123	3'687	3'353	3'260	5'399	5'424	4'656	4'812	4'736
Gas	TJ	362	14	67	48	27	168	34	10	62	121	22	11	11	0	11
Cement, waste derived fuel	TJ	2'047	2'082	2'118	2'598	2'324	2'974	3'509	3'439	3'586	3'420	3'922	4'732	5'301	5'549	5'786
Cement waste biomass	TJ	122	105	88	191	429	680	973	988	693	753	850	1'698	1'835	2'098	2'190
Cement waste fossil	TJ	1'925	1'977	2'030	2'408	1'895	2'295	2'535	2'450	2'893	2'668	3'071	3'033	3'466	3'452	3'596

c) Transport (1A3)

Key categories 1A3b
CO_2 from the combustion of diesel (level and trend)
CO_2 from the combustion of gasoline (level)
CH_4 from the combustion of gasoline (trend)

Key source 1A3e
CO_2 from military aviation (trend)

In Switzerland, Transport (1A3) contains the sub-categories

- Aviation (1A3a, national civil aviation),
- Road Transportation (1A3b),
- Railways (1A3c),
- Navigation (1A3d, national),
- Military Aviation (Other Transportation 1A3e).

Aviation (1A3a)

Methodology

The methodology used so far for modelling the emissions of civil aviation has been changed, the emission calculations have been completely revised and further improved. The formerly used Tier 2 method has been replaced by a Tier 3a method (FOCA 2006). All emissions reported in this submission are modelled by using the new method. In Chapter 9.1, a comparison between the previous and the present activity data is shown.

All flights from and to Swiss airports are separated into domestic (national) and international flights. The emissions of domestic flights are reported under 1A3a Civil Aviation, the emissions of international flights are reported under international bunker emissions (memo items).

The emission factors used are country-specific or are taken from the ICAO engine emissions databank, from EMEP/CORINAIR databases (EEA 2002), Swedish Defence Research Agency (FOI) and Swiss FOCA measurements (precursors). For N_2O, the IPCC default emission factor is used. Activity data are derived from a detailed movement statistics.

A complete emission modelling (LTO and cruise emissions for domestic and international flights) has been carried out by Swiss FOCA for 1990, 1995, 2000, 2002 and 2004. The results of the emission modelling have been transmitted from FOCA to FOEN in a aggregated form. FOEN (the CRF coordinator) calculated the implied emission factors 1990, 1995, 2000, 2002, 2004 and carried out a linear interpolation for the years in-between. The interpolated implied emission factors were multiplied with the annual fuel sold from Swiss overall energy statistics (SFOE 2005), providing the missing emissions of civil aviation for the years 1991-1994, 1996-1999, 2001 and 2003.

Due to the detailed information about activity data, the resulting fuel consumption is considered complete. In spite of this, there remain small differences between the fuel consumption modelled bottom-up and the total fuel sold (SFOE 2005). In 1990, the modelled consumption adds up to 1.01 mio. tons, whereas 1.05 mio. tons were sold. The difference of 4% is considered to be acceptable, because discrepancies of 10% can easily result from fuelling strategies of airlines (FOCA investigation showed that airlines are calculating whether it is economically beneficial to refuel at a place with lower fuel prize.) In order to match the bottom up calculation with the fuel quantity sold, any occurring difference is attributed to international bunker emissions. The factor between calculated international fuel consumption and adjusted international fuel consumption is used to scale the bunker emissions linearly. For instance in 1990, the bunker fuel consumption and the emissions had to be expanded by the factor 1.045.

Details of emission factors and activity data follow below. Further tables containing more information are also given in Annex A2.5, more detailed descriptions of the emission modelling may be found in FOCA 2006.

Emission Factors

Kyoto gases:

- CO_2 :The value of 73.2 t/TJ is country specific and is based on measurements and analyses of fuel samples (see Table 22). Small yearly variations have been neglected so far.
- CH_4, NMVOC: VOC emissions (see “Precursors” below) are split into CH_4 and NMVOC by a constant share of 0.1 (CH_4) and 0.9 (NMVOC)[10]. For CH_4, the emission factor varies between 3.4 kg/TJ in 1990, minimum value 3.2 kg/TJ in 1995 and maximum value 5.3 kg/TJ in 2004.
- N_2O: The IPCC default value 2.3 kg/TJ is used for the whole period 1990-2004 (IPCC 1997b).

SO_2:

- The emission factor is taken from the IPCC Guidelines 1996, 23.3 kg/TJ, and is assumed to be constant over the period 1990–2004 (IPCC 1997c, Table 1-50)

Precursors:

- Assignment of emission factors for the 1990 and 1995: The fleet that operated in and from Switzerland during those years has been analysed. The corresponding most frequent engines within an aircraft category (ICAO Code) have been assigned to every aircraft type.
- Assignment of emission factors for the 2000, 2002 and 2004: The actual engine of every single aircraft operating in and from Switzerland has been assigned. FOCA uses the aircraft tail number as the key variable which links activity data and individual aircraft engine information (see Annex A2.5 Table “Aircraft Engine Combinations”).

FOCA uses the following emission factors of NO_x, VOC, CO and further pollutants:

LTO:
The Swiss FOCA engine emissions database consists of more than 450 individual engine data sets. Jet engine factors for engines above 26.7 kN thrust (emission certificated) are identical to the ICAO engine emissions databank. Emission factors for lower thrust engines, piston engines and helicopters were taken from manufacturers or from own measurements. Emission factors for turboprops could be obtained in collaboration with the Swedish Defence Research Agency (FOI).

Cruise:
Part of the cruise emission factors are taken from EMEP/CORINAIR 2002. Aircraft cruise emission factors are dependent on representative flight distances per aircraft type and a load factor of 65% are assumed. Part of the cruise factors are also taken from former CROSSAIR

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[10] for the previous submissions, a split of split of 0.53 : 0.47 has been used.

(FOCA 1991). The whole Airbus fleet (which produces a great portion of the Swiss inventory) has been modelled on the basis of real operational aircraft data from Swiss aircraft data acquisition system.

Some of the old or missing aircraft cruise factors had to be modelled on the basis of the ICAO engine emissions databank. For piston engine aircraft, Swiss FOCA has produced its own data, which were taken under real flight conditions (2005 data, publication envisaged in 2006).

Activity Data

Scheduled and charter aviation

The statistical basis has been extended after 1996. Therefore, the modelling details are not exactly the same for the years 1990/1995 as for the subsequent years. The source for the 1990 and 1995 modelling is the movement statistics, which records information for every movement on airline, number of seats, Swiss airport, arrival/departure, origin/destination, number of passengers, distance. From 1996 onwards, every movement in the FOCA statistics also contains the individual aircraft tail number (aircraft registration). This is the key variable to connect airport data and aircraft data. For 2004, the statistics contains up to 800'000 records with individual tailnumbers. All annual aircraft movements recorded are split into domestic and international flights (2004: 718’673 movements total).

Non-scheduled, non-charter and General Aviation (including Helicopters)

- Airports and most of the airfields report individual aircraft data (aircraft registration). FOCA may therefore compute the inventory for small aircraft with Tier 3a method, too. However, for 1990 and 1995, the emissions data for non-scheduled, non-charter and General Aviation (helicopters etc.) could not be calculated with a Tier 3 method. Its fuel consumption is estimated to 10% of the domestic fuel consumption. Data were taken from two FOCA studies (FOCA 1991, FOCA 1991a). For 2000-2004, all movements from airfields are known, which allows a more detailed modelling of the emissions.
- Helicopters: The movements were taken from "Unternehmensstatistik der Schweizer Helikopterunternehmen” (FOCA 2004). From fleet composition data, a split of 87% single engine helicopters and 13% twin engine helicopter can be derived. Note that all emissions from helicopter are considered domestic. There is a helicopter base in the Principality of Liechtenstein consuming a certain very small amount of fuel contained in the Swiss statistics. Thus, its consumption leads to domestic instead of international bunker emissions (less than 0.1 Gg CO_2). FOCA and FOEN decided to report these emissions as Swiss-domestic since it is a very small amount and the effort for a separation would be considerable.

Table 42 summarises the activity data for domestic (1A3a) and international aviation (Memo items, international bunkers/aviation). A comparison of the activity data due to the current modelling results with the former results is shown in Chapter 9.1.

Table 42 Fuel consumption of civil aviation in TJ. The "domestic" consumption and the corresponding emissions are reported under 1A3a, the "international" consumption is reported under Memo items, international bunkers/aviation.

Civil Aviation	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
	Fuel consumption in TJ														
Total domestic (1A3a)	3'450	3'194	3'217	3'165	3'077	3'075	2'972	2'850	2'742	2'684	2'539	2'296	2'028	1'951	1'963
Total international	41'891	40'879	43'506	45'349	46'847	49'925	51'982	53'990	56'606	60'813	63'694	60'105	55'475	49'771	46'900
Sum	45'341	44'074	46'724	48'515	49'924	52'999	54'954	56'840	59'348	63'497	66'233	62'401	57'503	51'722	48'863
1990 = 100%	100%	97%	103%	107%	110%	117%	121%	125%	131%	140%	146%	138%	127%	114%	108%

Road Transportation (1A3b)

Key categories 1A3b
CO_2 from the combustion of diesel (level and trend)
CO_2 from the combustion of gasoline (level)
CH_4 from the combustion of gasoline (trend)

Methodology

CO_2

The CO_2 emissions are calculated with a tier 1 method (top-down) as suggested by IPCC Good Practice Guidance using country-specific emission factors. The emission factors are derived from the carbon content of fuels (see Table 22). The activity data corresponds to the amounts of gasoline and diesel fuel sold in Switzerland (sales principle). These numbers are taken from the national fuel statistics which is part of the Swiss overall energy statistics (SFOE 2005).

Other gases

The other gases are modelled with a well-documented national method (SAEFL 1995, 2004-2004a, INFRAS 2004, RWTÜV 2003, Hausberger et al. 2002). The approach corresponds methodologically to Box 1 in the decision tree of Figure 2.5 (p. 2.45) of IPCC Good Practice Guidance.

For the determination of the other greenhouse gases and for further splitting into vehicle categories, a national road traffic model (operated by the Federal Office of Spatial Development) and a database with country-specific emission factors are used ("Handbook of Emission Factors for Road Transport", SAEFL 1995, 2004-2004a, INFRAS 2004-2004a). The traffic model is based on an origin-destination matrix that is assigned to a network of about 20'000 road segments. The model is calibrated partly bottom-up and partly top-down: Bottom-up by a number of traffic counts from the national traffic-counter network (239 stations all over Switzerland, FEDRO 2004), and top-down by the total of the mileage per vehicle category. The mileage is calculated from the specific mileage per vehicle (based on household surveys/Mikrozensus ARE/SFSO 2000) times the number of vehicles. The traffic model generates the average daily traffic (vehicles per day) per road segment and per vehicle category. Furthermore, it attributes a "traffic situation" to every road segment which characterises a specific pattern of the dynamic driving behaviour. For every traffic situation, emission factors are defined in the handbook of emission factors. The traffic situation, therefore, works as a key to select the appropriate emission factor from the handbook and assigns it to a single road segment. The daily traffic multiplied by the emission factor results in the hot exhaust emission. This procedure is carried out for all gases. Additionally, cold start excessive and evaporative emissions are modelled using data of vehicle stocks[11], number of starts, trip length distributions and parking time distributions. The fleet composition also accounts for foreign vehicles (SAEFL 2004, SAEFL/ARE 2004). Further details of emission modelling are given in Annex A2.6.

Due to fuel price differences in the vicinity of the national borders, gasoline stations sell relevant amounts of gasoline to foreign car owners. This amount of fuel is mainly consumed abroad ("tank tourism") but the whole amount must be reported as national under 1A3b Road Transportation. The non-CO_2 emissions related to the "tank tourism" are not captured by the traffic model. For the purpose of assuring completeness within the GHG inventory, these emissions are quantified on the basis of the difference between fuel consumption according to the Swiss overall energy statistics (sales principle) and fuel consumption derived from the traffic model. The resulting amount of "tank Tourism" fuel is multiplied with mean emission

[11] The vehicle registration in Switzerland delivers all inputs to build up the fleet composition 1990-2004 which is characterised e.g. by vehicle category, engine capacity, fuel type, total weight, vehicle age and exhaust technology.

factors to determine the related emissions of CH_4, N_2O, NO_x, CO, NMVOC, and SO_2. For CO_2, which dominates the emissions by a factor of ca.1000-10'000, the use of Swiss mean factors is correct, since the carbon content constitutes the emission factor. (For CH_4 and N_2O there are differences between the Swiss mean factors and the implied emission factors of the four neighbouring countries Austria (A), France (F), Germany (G), Italy (I) as a comparison with their implied emission factors for 1990 and 2004 has shown. The differences are small between Switzerland, A and G because all three countries use the same emission factors (SAEFL 2004a), whereas there are some the differences to F and I who use other emission factors (COPER[12]T) Therefore, the use of the mean Swiss emission factors seems the consistent approach).

Emission Factors

The emission factors for CO_2 are country-specific and based on measurements and analyses of fuel samples (see Table 22). Emission factors for the further gases are derived from "emission functions" which are determined from measurements of a large number of driving patterns within an international measurement program of Switzerland together with Austria, Germany and the Netherlands. The method has been developed in 1990-1995 and has been extended and updated in 2000 and 2004. The latest version is presented and documented on the website http://www.hbefa.net/. Several reports may be downloaded from there:

- Documentation of the general emission factor methodology, INFRAS 2004a (in German),
- Emission Factors for Passenger Cars and Light Duty Vehicles Switzerland, Germany, Austria, INFRAS 2004 (in English),
- Update of the Emission Factors for Heavy Duty Vehicles, Hausberger et al. 2002 (in English),
- Update of the Emission Factors for Two-wheelers, RWTÜV 2003 (in German)

The resulting emission factors are published on CD ROM ("Handbook of emission factors for Road Transport", SAEFL 2004a). The underlying database contains a dynamic fleet compositions model simulating the release of new exhaust technologies and the dying out of old technologies. Corrective factors are provided to account for future technologies. Further details are shown in Annex A2.6.

The following table gives a selection of mean emission factors. The CO_2 factors are constant over the whole period 1990–2004. Changes in the carbon content of the fuels have not been considered so far due to (approximately) constant fuel qualities. For the other gases, more or less pronounced decreases of the emission factors occur due to new emission regulations and subsequent new exhaust technologies (mandatory use of catalytic converters for gasoline cars and lower limits for sulphur content in diesel fuels). Early models of catalytic converters have been substantial sources of N_2O, leading to an emission increase until 1998. Recent converter technologies have overcome this problem resulting in a decrease of the (mean) emission factor. It should be noted that the N_2O emission factors are much smaller than the IPCC default values. The factors used in Switzerland are taken from a recent Dutch measurement programme (Gense and Vermeulen 2002, 2002a; Riemersma et al. 2003). Emission factors per emission concept are given in Annex A3.2.1. A separate table shows the details of the N_2O emission factors.

[12] see Euopean Environment Agency http://reports.eea.europa.eu/TEC05/en

Table 43 Mean emission factors for road transport for passenger cars and heavy duty vehicles. For more details see Annex A3.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Passenger Cars								**t/TJ (= kg/GJ = g/MJ)**							
CO2															
gasoline	73.9	73.9	73.9	73.9	73.9	73.9	73.9	73.9	73.9	73.9	73.9	73.9	73.9	73.9	73.9
Diesel	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6
CH4															
gasoline	0.024	0.021	0.018	0.016	0.014	0.013	0.011	0.010	0.009	0.008	0.007	0.007	0.006	0.005	0.005
Diesel	0.0012	0.0012	0.0011	0.0009	0.0009	0.0008	0.0007	0.0007	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0005
N2O															
gasoline	0.0020	0.0024	0.0028	0.0031	0.0034	0.0036	0.0038	0.0038	0.0037	0.0036	0.0034	0.0032	0.0030	0.0027	0.0025
Diesel	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.002	0.002
NOx															
gasoline	0.452	0.398	0.345	0.307	0.279	0.255	0.233	0.213	0.194	0.177	0.156	0.142	0.129	0.120	0.110
Diesel	0.227	0.230	0.221	0.216	0.219	0.214	0.213	0.213	0.215	0.218	0.221	0.221	0.215	0.211	0.204
CO															
gasoline	3.133	2.816	2.501	2.291	2.113	1.963	1.835	1.734	1.648	1.576	1.518	1.453	1.372	1.312	1.252
Diesel	0.218	0.223	0.198	0.181	0.177	0.161	0.155	0.149	0.145	0.141	0.133	0.128	0.123	0.118	0.108
NMVOC															
gasoline	0.539	0.472	0.405	0.356	0.309	0.269	0.233	0.205	0.181	0.162	0.142	0.127	0.111	0.100	0.090
Diesel	0.049	0.051	0.043	0.038	0.037	0.032	0.030	0.029	0.028	0.027	0.026	0.025	0.024	0.023	0.021
SO2															
gasoline	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.007	0.006	0.005	0.004	0.0004
Diesel	0.065	0.061	0.056	0.047	0.020	0.016	0.017	0.016	0.019	0.021	0.013	0.012	0.011	0.009	0.0005
Heavy duty vehicles								**t/TJ (= kg/GJ = g/MJ)**							
CO2	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6
CH4	0.0020	0.0020	0.0019	0.0019	0.0018	0.0018	0.0018	0.0017	0.0016	0.0016	0.0014	0.0013	0.0012	0.0011	0.0010
N2O	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0012	0.0012	0.0012	0.0012	0.0011	0.0010	0.0010	0.0009
NOx	1.027	1.028	1.028	1.022	0.994	0.961	0.938	0.924	0.926	0.928	0.911	0.893	0.859	0.827	0.786
CO	0.220	0.218	0.217	0.213	0.205	0.201	0.197	0.192	0.186	0.179	0.172	0.160	0.157	0.155	0.151
NMVOC	0.081	0.080	0.079	0.077	0.073	0.072	0.071	0.070	0.066	0.063	0.059	0.051	0.048	0.046	0.042
SO2	0.065	0.061	0.056	0.047	0.020	0.016	0.017	0.016	0.019	0.021	0.013	0.012	0.011	0.009	0.0005

Activity Data

The amount of gasoline and diesel fuel sold in Switzerland serves as the activity data for the calculation of the CO_2 emissions: The Swiss overall energy statistics gives the amount of 157’590 TJ of gasoline and 67’110 TJ of diesel oil (2004). From these numbers, the off-road consumption is subtracted. The result gives the inventory-relevant consumption for estimating the CO_2 emissions. It contains the fuel consumption due to the traffic model plus the amount of “tank tourism” (see above). The following table shows the details.

Table 44 Activity data for calculating the CO_2 emissions of Road Transportation.

Activity data 2004	**source category**	**Gasoline**	**Diesel** 1000 TJ	**Total**
on-road consumption (model)	1A3b	138.9	57.8	196.6
"tank tourism"	1A3b	15.7	-8.5	7.2
off-road consumption (models)	1A3a,c,d;e; 1A4c; 1A5	3.0	17.9	20.9
Gasoline and Diesel sold in Switzerland (CRF)	1A3; 1A4c; 1A5	157.6	67.1	224.7

Further activity data needed for modelling the non-CO_2 emissions are the mileages (vehicle kilometres) per vehicle category in Table 45.

Table 45 Mileages in millions of vehicle kilometres. PC passenger cars, LDV light duty vehicles, HDV heavy duty vehicles, UBus urban buses, 2W Two-wheelers.

Veh. cat.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	million vehicle-km														
PC	42'648	43'744	43'176	42'260	43'278	44'638	45'564	46'136	47'053	48'163	49'552	50'713	51'697	52'423	53'082
LDV	2'758	2'742	2'867	2'923	3'048	3'025	3'112	3'258	3'421	3'577	3'792	3'971	4'128	4'207	4'276
HDV	2'044	1'997	2'046	2'038	2'069	1'996	2'014	2'048	2'110	2'224	2'385	2'291	2'228	2'213	2'291
Coaches	110	110	111	111	112	112	111	110	103	100	101	97	98	96	95
UBus	175	187	188	191	190	193	189	189	190	193	197	205	208	208	209
2W	2'025	1'946	1'866	1'793	1'717	1'744	1'756	1'823	1'872	1'941	1'998	2'061	2'123	2'179	2'233
Sum	49'759	50'726	50'254	49'314	50'413	51'708	52'745	53'564	54'749	56'198	58'024	59'337	60'481	61'327	62'185
	100%	102%	101%	99%	101%	104%	106%	108%	110%	113%	117%	119%	122%	123%	125%

In 2004, 85.4% of total vehicle kilometres are driven by passenger cars, 6.9% and 3.7% by light and heavy duty vehicles, respectively. The mileages increased for all vehicle categories (except coaches), totalling 25% in the period 1990–2004 or 1.6% per year. In the same period, fuel consumption increased less strongly, by 12%, indicating improved fuel efficiency. The effect is shown in the next table indicating the specific fuel consumption per vehicle-km. For most vehicle categories, the specific consumption has decreased in the period 1990-2004 (between -7% and -20%); only two-wheelers have enhanced their consumption (4%). On an average over the whole car fleet, a decrease of 10% has been reached.

Table 46 Fuel consumption of road transport, not including “tank tourism”(abbreviations: compare with Table 44; G gasoline, D diesel fuel.

Veh. Categ.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	specific fuel consumption (MJ/veh-km)														
PC G	3.17	3.15	3.13	3.13	3.11	3.09	3.08	3.05	3.03	3.00	2.97	2.94	2.92	2.90	2.87
PC D	3.06	3.07	3.05	3.11	3.04	3.03	3.02	3.02	2.99	2.94	2.88	2.78	2.70	2.65	2.61
LDV G	4.14	4.05	3.97	3.91	3.86	3.83	3.79	3.74	3.68	3.63	3.58	3.52	3.46	3.42	3.36
LDV D	4.93	4.86	4.78	4.71	4.60	4.53	4.47	4.41	4.36	4.31	4.24	4.14	4.06	4.01	3.96
HDV D	10.85	10.85	10.85	10.74	10.75	10.61	10.47	10.34	10.20	10.10	10.00	10.19	10.17	10.15	10.13
Coach D	12.24	12.21	12.16	12.06	11.96	11.86	11.75	11.64	11.52	11.41	11.26	11.09	10.99	10.91	10.86
UBus D	16.17	16.18	16.15	16.10	16.04	15.97	15.86	15.74	15.65	15.53	15.42	15.33	15.20	15.11	15.03
2W G	1.21	1.23	1.24	1.25	1.26	1.27	1.28	1.29	1.28	1.28	1.28	1.28	1.27	1.27	1.26
Average	3.53	3.50	3.50	3.50	3.48	3.44	3.42	3.39	3.36	3.33	3.31	3.27	3.22	3.19	3.16
	100%	99%	99%	99%	99%	98%	97%	96%	95%	94%	94%	93%	91%	90%	90%

For modelling of cold start and evaporative emissions of passenger cars and light duty vehicles, also vehicle stock and start numbers are used for activity data. The corresponding numbers are summarised in the next table. Vehicle stock figures correspond to registration data. The starts per vehicle are based on specific household surveys (ARE/SFSO 2000.)

Table 47 Vehicle stock numbers and average number of starts per vehicle per day.

Veh. cat.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	stock in 1000 vehicles														
PC	2'985	3'058	3'091	3'110	3'165	3'229	3'268	3'323	3'383	3'467	3'545	3'630	3'701	3'754	3'801
LDV	221	228	229	228	232	238	241	243	247	254	260	268	274	275	277
2W	764	747	729	720	708	704	699	709	718	728	731	740	741	746	749
	starts per vehicle per day														
PC	2.91	2.90	2.88	2.86	2.84	2.83	2.82	2.80	2.78	2.76	2.75	2.74	2.72	2.71	2.69
LDV	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.96	1.96	1.96	1.96	1.96
2W	1.59	1.58	1.57	1.56	1.55	1.54	1.54	1.53	1.52	1.51	1.50	1.51	1.52	1.52	1.53

Railways (1A3c)

Methodology

The entire Swiss railway system is electrified. Electric locomotives are used in passenger as well as freight railway traffic. Diesel locomotives are used for shunting purposes in marshalling yards and for construction activities only.

The emissions of the whole off-road sector have undergone a complete revision. Railways, navigation etc. are all modelled by the same approach. The emissions are calculated with a Tier 2 method. Activity data and emission factors were updated and the emission calculation was carried out in a new database structured in analogy to the on-road database (SAEFL 2005a). More details of the emission modelling are described in Annex A2.7 Off-road Vehicles.

Emission Factors

Only diesel is being used as fuel, therefore all emission factors refer to diesel.

- The emission factor for CO_2 is assumed to be constant in the period 1990-2004 with value 73.6 t/TJ (Diesel oil, see Table 22, SFOE 2001).
- For SO_2 the emission factors are given in Table 176 in Annex A2.3, row diesel oil: Continuous decrease from 65.4 kg/TJ in 1990 to 12.7 kg/TJ in 2000 and to 0.5 kg/TJ in 2004.
- The emission factors for all other gases are shown in Table 187 in Annex A2.7.2, row diesel oil (Mayer 2006). Note that NMVOC is not modelled bottom-up. The NMVOC emissions are calculated as the difference of VOC and CH_4 emissions.
- For differences of the emission factors compared to IPCC default values, see Table 188 in the Annex A2.7.2.

Activity data

The fuel consumption is calculated by using the formula given above for the emission modelling. Instead of the emission factor, consumption factors between 283 and 300 g/kWh is used (see Table 187). The operating hours depend on the number of vehicles per age and size class. In 2000 e.g., 1255 vehicles were operating 0.773 million hours per year with an average number of 616 operating hours per year per vehicle (Electrowatt 2005.) The resulting fuel consumption is shown in Table 48.

Table 48 Activity data (diesel oil consumption) for railways.

Railways	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Diesel (TJ)	1'132	1'162	1'192	1'222	1'253	1'283	1'276	1'270	1'263	1'256	1'250	1'259	1'269	1'278	1'288
	100%	103%	105%	108%	110%	113%	112%	112%	111%	111%	110%	111%	112%	113%	114%

Navigation (1A3d)

Methodology

The emissions of the whole off-road sector including navigation have undergone a complete revision as mentioned above (railways). The emissions are calculated with a Tier 2 method. Activity data and emission factors were updated and the emission calculation was carried out in a new database that is structured in analogy to the on-road database (SAEFL 2005a). More details of the emission modelling are described in Annex A2.7 Off-road Vehicles.

There are passenger ships, dredgers, fishing boats, motor and sailing boats on the lakes of Switzerland and on the river Rhine. Every boat is registered at the cantonal authorities. The emissions are calculated with a Tier 2 approach for the years 1990, 1995, 2000, 2005 etc. up to 2020. For the other years, the emissions are interpolated linearly.

On the river Rhine, some of the boats cross the border and go abroad (Germany, France). Fuels bought in Switzerland will therefore become bunker fuel. The amount of bunker diesel has not been estimated so far. However, it is assumed to be very small compared to the domestic consumption of navigation (see Section 3.4.1). The emissions of navigation reported in the CRF under 1A3c include, therefore, the bunker emissions.

Emission Factors

- The emission factor for CO_2 is assumed to be constant in the period 1990-2004 with value 73.6 t/TJ for diesel oil, 73.9 t/TJ for gasoline and 73.7 t/TJ for gas oil (Table 22, SFOE 2001).
- For SO_2 the emission factors are given in Table 176 in Annex A2.3 (diesel oil, gasoline, gas oil).
- The emission factors for all other gases are shown in Table 187 in Annex A2.7.1. Note that NMVOC is not modelled bottom-up. The NMVOC emissions are calculated as the difference of VOC and CH_4 emissions.

Activity data

The numbers of vehicles and of operating hours are given in Annex A2.7.3 (Electrowatt 2005). Table 49 shows the fuel consumption. In 2004, the fuel-split was 51%, 35% and 14% for diesel, gasoline and gas oil.

Table 49 Fuel consumption of navigation.

Navigation	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Diesel (TJ)	928	914	900	885	871	857	858	859	860	861	863	861	860	859	858
Gasoline (TJ)	531	524	517	510	502	495	503	510	518	525	533	546	560	573	586
Gas oil (TJ)	223	227	231	235	239	243	244	244	244	244	245	245	245	245	245
Sum (TJ)	1'682	1'665	1'648	1'630	1'613	1'595	1'604	1'613	1'622	1'631	1'640	1'652	1'664	1'677	1'689
	100%	99%	98%	97%	96%	95%	95%	96%	96%	97%	97%	98%	99%	100%	100%

Military Aviation (Other Transportation 1A3e)

Key source 1A3e
CO_2 from military aviation (trend)

Methodology

To calculate the emissions from military aviation, a Tier 1 method is used.

The fuel consumption 1990–2004 is known yearly since it is being copied from the logbooks of the military aircrafts (VTG 2006). A very small fraction of fuel is consumed for training abroad and might be allocated under “International Bunkers” (less than 3% of total military aviation consumption). Since the exact number is not known, it is not subtracted from the total consumption but included under national military aviation, as recommended by the IPCC Good Practice Guidance (IPCC 2000, chapter 2.5.1.3). Emissions of NO_x, CO and VOC have been modelled in detail by the Federal Office for Military Aviation (Bundesamt für Betriebe der Luftwaffe) for 1990 and 1995. From these inputs, SAEFL determined average emission factors 1990 and 1995. For 1991-1994 the emission factors are linearly interpolated between 1990 and 1995. For 1996-2004, the factors for 1995 are used. The emissions are then calculated yearly by multiplying the average emission factors with the activity data.

The extension of the emission modelling to CO_2, CH_4, N_2O, NMVOC and SO_2 is also accomplished by FOEN.

Emission Factors

- CO_2: The emission factor of 73.2 t/TJ is country specific and is based on measurements and analyses of fuel samples (see Table 22, SFOE 2001).
- NO_x, VOC, CO: Engine producer information is used (for details see SAEFL 1996: p. 202) for calculation of the emission factors in 1990 and 1995. For 1991-1994 the values are linearly interpolated between 1990 and 1995. For 1996-2004, the values 1995 are used.
- CH_4, NMVOC: For VOC, aircraft-specific information used for calculation of the emission factors in 1990 and 1995. For 1991-1994 the values are linearly interpolated between 1990 and 1995. For 1996-2003, the values 1995 are used. The division of VOC into CH_4 and NMVOC is carried out by a constant split of 53% : 47%.
- N_2O: The IPCC default value 23 kg/TJ is used (IPCC 1997b) over the whole period 1990–2004.
- SO_2: The emission factor is taken from the IPCC Guidelines 1996, 23.3 kg/TJ, and is assumed to be constant over the period 1990–2004 (IPCC 1997c, Table 1-50)

Activity data

The fuel consumption is copied from the logbooks of the military aircrafts and summed up yearly (see Table 50).

Table 50 Activity data for military aviation (VTG 2006). The net calorific value is 34.4 MJ/ litre.

Military aviation	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
fuel cons. (TJ)	2'733	2'495	2'382	2'268	2'192	1'955	1'806	1'941	1'927	1'734	1'793	1'755	1'837	1'641	1'490
	100%	91%	87%	83%	80%	72%	66%	71%	71%	63%	66%	64%	67%	60%	55%

d) Other Sectors (Commercial, Residential, Agriculture, Forestry; 1A4)

Key categories 1A4a, 1A4b
CO_2 from the combustion of gaseous and liquid fuels in the Commercial/Institutional Sector (1A4a) and in the Residential Sector (1A4b) are key categories regarding both level and trend.

Key categories 1A4c
CO_2 from the combustion of Liquid Fuels in Agriculture/Forestry (1A4c) is a key category regarding level.

“Other Sectors” (source category 1A4) comprises

- “Commercial/ Institutional” (1A4a)
- “Residential” (1A4b)
- “Agriculture/Forestry/Fisheries” (1A4c)

Commercial/ Institutional (1A4a) and Residential (1A4b)

Methodology

For Fuel Combustion in Commercial and Institutional Buildings (1A4a) and in Households (1A4b), a country specific Tier 2 method is used. A top-down method based on aggregated fuel consumption data from the Swiss overall energy statistics is used to calculate emissions. For the emissions from the use of light fuel oil and natural gas the following sources are differentiated: (i) heat only boilers, (ii) combined heat and power production in turbines and (iii) combined heat and power production in engines. Emissions of GHGs are calculated by multiplying levels of activity by emission factors. An oxidation factor of 100% is assumed for all combustion processes and fuels (see sub-section on oxidation factors in the beginning of Section 3.2.2).

Emission Factors

The emission factors for CO_2 and SO_2 are country specific and based on measurements and analysis of fuel samples carried out by the Swiss Federal Laboratories for Materials Testing and Research EMPA (carbon emission factor documented in SFOE 2001, Table 45: p. 51; net calorific values on p. 61. See also Annex A2.2.1).

The activity data on LFO use in the CRF includes LPG consumption. This is due to statistical reasons in the Swiss overall energy statistics (SFOE 2005). Therefore the LFO emission factor for CO_2 (see table below) is a mixed emission factor that results as a weighted average of the LFO emission factor and LPG emission factor.

Emission factors for CH_4, N_2O, NO_x, CO and NMVOC for heat only boilers are country specific based on comprehensive life cycle analysis of combustion boilers, turbines and engines in the residential, commercial institutional and agricultural sectors, documented in SAEFL 2000 (pp. 42-56) and EMIS. For NO_x emission factors, expert judgement has been used to estimate the fraction of low-NO_x burners.

Emission factors for CH_4, N_2O, NO_x, CO and NMVOC for combined heat and power generation in turbines and engines are country specific based on comprehensive measurements (EMIS).

The coal emission factor for CO_2 (see table below) is a mixed emission factor that results as a weighted average of the hard coal and lignite emission factors. The net calorific value of hard coal has been revised for the current submission (see Annex A2.2.1).

All emission factors for biomass are based on SAEFL 2000 (pp. 26ff).

The following table presents the emission factors used in 1A4a and 1A4b:

Table 51 Emission Factors for 1A4a and 1A4b: Commercial/Institutional and Residential in "Other Sectors" for 2004.

Source/fuel	CO_2 t/TJ	CO_2 bio. t/TJ	CH_4 kg/TJ	N_2O kg/TJ	NO_x kg/TJ	CO kg/TJ	NMVOC kg/TJ	SO_2 kg/TJ
1A4 a Other Sectors: Commercial/Institutional								
LFO (weighted average)	73.50		1.03	0.60	35.45	12.06	6.11	32.86
LFO (heat only boilers)	73.50		1.00	0.60	33.00	11.60	6.00	32.86
LFO (turbines)	73.50		0.60	0.60	134.00	48.00	3.00	32.86
LFO (engines)	73.50		5.60	0.60	388.00	78.00	22.00	32.86
Natural gas (weighted average)	55.00		7.60	0.10	31.04	19.39	1.97	0.50
NG (heat only boilers)	55.00		6.00	0.10	15.00	16.20	2.00	0.50
NG (turbines)	55.00		3.20	0.10	120.00	22.00	0.10	0.50
NG (engines)	55.00		27.00	0.10	224.00	58.00	1.60	0.50
Coal	94.11		300	1.6	65	3'600	100	350
Biomass		92	120	1.6	150	2'100	40	20
1A4 b Other Sectors: Residential								
LFO (weighted average)	73.50		1.00	0.60	33.24	11.65	6.01	32.86
LFO (heat only boilers)	73.50		1.00	0.60	33.00	11.60	6.00	32.86
LFO (turbines)	73.50		0.60	0.60	134.00	48.00	3.00	32.86
LFO (engines)	73.50		5.60	0.60	448.00	90.00	22.40	32.86
Natural gas (weighted average)	55.00		6.19	0.10	16.13	16.63	1.99	0.50
NG (heat only boilers)	55.00		6.00	0.10	15.00	16.20	2.00	0.50
NG (turbines)	55.00		3.20	0.10	120.00	22.00	0.10	0.50
NG (engines)	55.00		21.00	0.10	106.00	51.00	1.00	0.50
Coal	94.11		300	1.6	65	3'600	100	350
Biomass		92	120	1.6	150	2'100	40	20

Remark: In the table above, the CO_2 emission factor of light fuel oil (73.50 t/TJ) is a weighted average emission factor including both LFO (73.7t/TJ) and LPG (65.5t/TJ) emissions, the same emission factor as in 1A1a and in 1A2 (see Section 3.2.2 a). The CO_2 emission factor for coal (94.11 t/TJ) is a weighted average emission factor including hard coal (94 t/TJ), petroleum coke (94 t/TJ) and lignite (104 t/TJ) emissions, the same emission factor as for 1A2 "top-down" sources (see Section 3.2.2 b).

Activity Data

Activity data on fuel consumption for Commercial/Institutional and Residential (1A4a and b) correspond to the consumption of light fuel oil (including LPG), natural gas, coal and biomass in the categories “Services” (for 1A4a) and “Households” (for 1A4b) of the Swiss overall energy statistics (SFOE 2005; Table 17).

The consumption of natural gas in 1A4b Residential has been modified to account for (the entire) leakages in the Swiss natural gas distribution system (see Section 3.1.5).

The amount of light fuel oil and natural gas that is used for co-generation in turbines and engines is taken from Kaufmann, U. (2004).

Table 52 Activity data in 1A4a Commercial/Institutional and 1A4b Residential.

Source/Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1A4a Commercial/Institutional	TJ	79'834	90'398	88'984	88'308	80'586	84'886	91'117	85'856	87'638	86'584
Light fuel oil	TJ	59'498	66'478	64'865	62'710	56'548	57'870	61'825	59'188	60'265	59'108
LFO heat only boilers	TJ	59'474	66'427	64'807	62'653	56'427	57'695	61'594	58'900	59'968	58'781
LFO turbines	TJ	0	0	0	0	0	0	0	0	0	0
LFO engines	TJ	24	51	58	56	122	175	231	288	298	327
Natural gas	TJ	17'108	19'599	19'871	21'128	19'952	21'952	23'178	21'779	22'317	22'447
NG heat only boilers	TJ	16'832	19'164	19'311	20'502	19'129	20'781	21'766	20'314	20'717	20'737
NG turbines	TJ	85	114	109	106	107	78	21	5	12	4
NG engines	TJ	192	321	451	520	716	1'093	1'390	1'460	1'588	1'707
Coal	TJ	0	0	0	0	0	0	0	0	0	0
Biomass	TJ	3'228	4'322	4'247	4'471	4'085	5'064	6'114	4'889	5'056	5'028
1A4b Residential	TJ	185'099	197'198	196'770	188'147	177'194	191'342	199'043	184'694	190'959	187'946
Light fuel oil	TJ	138'916	145'507	145'174	136'252	128'901	137'597	139'992	131'915	136'509	131'838
LFO heat only boilers	TJ	138'915	145'507	145'172	136'251	128'900	137'593	139'960	131'877	136'459	131'785
LFO turbines	TJ	0	0	0	0	0	0	0	0	0	0
LFO engines	TJ	1	1	1	1	1	5	32	38	49	53
Natural gas	TJ	24'816	28'460	29'940	30'389	28'844	33'225	37'348	33'913	35'440	37'346
NG heat only boilers	TJ	24'756	28'357	29'796	30'222	28'640	32'967	37'041	33'600	35'091	36'942
NG turbines	TJ	0	0	0	0	0	0	0	0	0	0
NG engines	TJ	60	102	144	168	204	258	308	313	349	405
Coal	TJ	607	701	486	495	449	430	243	206	131	131
Biomass	TJ	20'760	22'530	21'170	21'010	19'000	20'090	21'460	18'660	18'880	18'630

Source/Fuel	Unit	2000	2001	2002	2003	2004
1A4a Commercial/Institutional	TJ	81'052	85'086	81'603	86'899	85'648
Light fuel oil	TJ	54'173	56'194	53'520	56'224	54'415
LFO heat only boilers	TJ	53'790	55'780	53'120	55'841	54'040
LFO turbines	TJ	0	0	0	0	0
LFO engines	TJ	383	414	401	383	375
Natural gas	TJ	22'338	23'782	23'204	25'143	25'731
NG heat only boilers	TJ	20'597	21'973	21'284	23'128	23'741
NG turbines	TJ	0	3	12	28	31
NG engines	TJ	1'741	1'806	1'909	1'987	1'959
Coal	TJ	0	0	0	0	0
Biomass	TJ	4'541	5'109	4'878	5'532	5'502
1A4b Residential	TJ	173'701	183'243	177'073	187'445	187'681
Light fuel oil	TJ	120'784	127'553	122'470	129'328	128'194
LFO heat only boilers	TJ	120'730	127'497	122'413	129'268	128'119
LFO turbines	TJ	0	0	0	0	0
LFO engines	TJ	54	56	57	59	75
Natural gas	TJ	35'606	37'259	37'072	39'605	40'903
NG heat only boilers	TJ	35'166	36'799	36'606	39'087	40'394
NG turbines	TJ	0	0	5	3	2
NG engines	TJ	440	460	461	516	507
Coal	TJ	121	121	121	121	374
Biomass	TJ	17'190	18'310	17'410	18'390	18'210

The table above documents the increase of Natural Gas consumption by 52% (1A4a) and 63% (1A4b) from 1990 to 2004 as well as the net decrease of liquid fuel consumption by -8.7% (1A4a) and -7.7% (1A4b) over the period. This shift in fuel mix is the reason for CO_2 emissions from the use of these fuels in category 1A4a/b being key categories regarding trend.

Agriculture/Forestry (1A4c)

Methodology

For source category 1A4c, a country specific Tier 3 method is used. Emissions stem from two sources within the agriculture sector:

- Fuel combustion for grass drying,
- Fuel combustion in off-road machinery.

Emissions from both sources are calculated bottom up. For grass drying, emission factors refer both to fuel consumption (in TJ) and production data (i.e. in tons of dried grass).

The emissions of the whole off-road sector have undergone a complete revision. Agriculture and forestry machinery are part of the off-road sector. They were modelled with the same approach as railways, navigation etc. The emissions are calculated with a tier 2 method. An explanation of the method applied for off-road emissions is given in Annex A2.7 including emission factors and activity data.

An oxidation factor of 100% is assumed for all combustion processes and fuels (see sub-section on oxidation factors in the beginning of Section 3.2.2).

Emission Factors

Drying of grass: The emission factors for CO_2 and SO_2 are country specific and based on measurements and analysis of fuel samples carried out by the Swiss Federal Laboratories for Materials Testing and Research EMPA (carbon emission factor documented in SFOE 2001, Table 45: p. 51; net calorific values on p. 61). Emission factors for CH_4, N_2O, CO and NMVOC are country specific based on comprehensive life cycle analysis of a drying unit, documented in the EMIS database (see Section 1.4.3). Some of the emission factors have been updated based on expert judgement.

Emission Factors

- The emission factor for CO_2 is assumed to be constant in the period 1990-2004 with value 73.6 t/TJ for diesel oil and 73.9 t/TJ for gasoline (Table 22, SFOE 2001).
- For SO_2 the emission factors are given in Table 176 in Annex 2 (diesel oil, gasoline).
- The emission factors for all other gases are shown in Table 187 in Annex A2.7.2 (Mayer 2006). Note that NMVOC is not modelled bottom-up. The NMVOC emissions are calculated as the difference of VOC and CH_4 emissions.

Activity Data

Drying of grass: Activity data on grass drying (in tons of dried grass) is extracted from the EMIS database.

Off-road machinery: Activity data is shown in Annex A2.7.3 (Electrowatt 2005).

Table 53 Activity data in 1A4c Agriculture/Forestry.

Source/Fuel	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1A4c Agriculture/Forestry	TJ	10'420	10'411	10'403	10'396	10'391	10'386	10'372	10'358	10'346	10'335	10'324	10'323	10'330	10'337	10'344
Drying of Grass	TJ	1'895	1'823	1'752	1'682	1'614	1'546	1'480	1'415	1'351	1'288	1'226	1'211	1'205	1'199	1'193
of which light fuel oil	TJ	1'162	1'118	1'074	1'032	990	948	908	868	828	790	752	743	739	735	731
of which natural gas	TJ	733	705	677	650	624	598	572	547	522	498	474	468	466	463	461
Machinery	TJ	8'526	8'588	8'651	8'714	8'777	8'840	8'892	8'943	8'995	9'047	9'099	9'112	9'125	9'138	9'152

e) Other – Off-road: Construction, Hobby, Industry and Military (1A5)

Key sources 1A5
CO_2 from the combustion of liquid fuels in 1A5 Other – Off-road is a key source regarding both level and trend.

Methodology

The emissions of the whole off-road sector have undergone a complete revision. The emissions are calculated with a Tier 2 method. Activity data and emission factors were updated and the emission calculation was carried out in a new database that is structured in analogy to the on-road database (SAEFL 2005a).

The revision also affected the sections construction, hobby, industry, and military, which are summarised in 1A5 Other (Off-road).

1A5 emissions have been modelled in the same manner as those of railways and navigation (see sections above). They were all calculated in the same database and are documented in the same report (SAEFL 2005a). The emission modelling is carried out for 1990, 1995, 2000, 2005 etc. For the GHG inventory the missing years 1991, 1992 etc. are interpolated linearly by vehicle category. For more details see Annex A2.7.

Emission Factors

- The emission factor for CO_2 is assumed to be constant in the period 1990-2004 with value 73.6 t/TJ for diesel oil and 73.9 t/TJ for gasoline (Table 22, SFOE 2001).
- For SO_2 the emission factors are given in Table 176 in Annex A2.
- The emission factors for all other gases are shown in Table 187 in Annex A2.7.1 (Mayer 2006). Note that NMVOC is not modelled bottom-up. The NMVOC emissions are calculated as the difference of VOC and CH_4 emissions.
- For differences of the emission factors compared to IPCC default values, see Table 188 in the Annex A2.7.2.

Activity Data

The numbers of vehicles and operating hours are given in Annex A2.7.3 (Electrowatt 2005). Fuel consumption data is shown in Table 54.

Table 54 Activity data (fuel consumption) and CO_2 emissions for off-road activities Construction, Hobby, Industry and Military (without Military Aviation, see 1A3e).

Off-road cat.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1A5	**fuel consumption in TJ**														
Construction	5'288	5'454	5'620	5'786	5'951	6'117	6'181	6'244	6'308	6'371	6'435	6'473	6'511	6'550	6'588
Hobby	602	616	629	643	656	670	683	696	709	722	735	728	722	716	709
Industry	898	961	1'023	1'086	1'149	1'211	1'271	1'330	1'389	1'449	1'508	1'507	1'506	1'505	1'504
Military offroad	53	53	54	54	54	54	55	55	55	56	56	55	55	54	54

3.2.3. Uncertainties and Time-Series Consistency

Note that all results of this section 3.2.3 refer to the emission data according to the former submission April 2006 and not to the emission of the current submission (May 2006). The deviations are very small. For further details see 1.7.

A quantitative **Tier 1** analysis (following Good Practice Guidance; IPCC 2000: p. 6.13ff) is used to estimate uncertainties of key categories in the NIR. First, uncertainties of activity data and emission factors are estimated separately. The combined uncertainty for each source is then calculated using a Rule B approximation (IPCC 2000 p. 6.12). Further, the Rule A approximation is used to arrive at the overall uncertainty in national emissions and the trend in national emissions between the base year and the current year.

A quantitative **Tier 2** analysis (**Monte Carlo**) following Good Practice Guidance; IPCC 2000: p. 6.18ff is performed, too. It starts with the same uncertainties for activity data and emission factors as Tier 1 analysis. Other than Tier 1, the uncertainty of activity data of sector 1A Fuel Combustion are prepared on a disaggregated level. For each key category within 1A the uncertainty of the corresponding activity data and emission factor are determined (see Annex +1.2.2). In addition, correlation coefficients are implemented and adequate probability distributions are adopted: normal distributions are chosen in general except for 1A1/other fuels/CO_2 and for 1A2/other fuels/CO_2, where lognormal distributions were chosen for the uncertainty of the emission factor (large uncertainties with implied normal distributions may generate negative 2.5 percentile values for the emissions). See Table 169 and Table 170 for details.

a) Uncertainties

Uncertainties of activity data and emission factors are derived from a mixture of empirical data and expert judgment. With the submission 2006, uncertainties are consistently defined as half the 95% confidence interval divided by the mean and expressed as a percentage. (In earlier submissions, uncertainties of emissions factors and activity data that were not based on IPCC default values have been defined as *one* standard deviation divided by the mean, i.e. about halve the value of non-default-uncertainties with the present definition.)

Uncertainty in aggregated fuel consumption activity data (1A Fuel Combustion)

The level of disaggregation that has been chosen for the key category analysis provides a rather fine disaggregation of combustion related CO_2 emissions in category 1 Energy. E.g. the key category analysis distinguishes between Emissions from Commercial/Institutional (1A4a), Residential (1A4b), and Agriculture/Forestry (1A4c).

However, the data on fuel consumption originates at the aggregated level of import, export, and sales data. It is only later disaggregated using models leading to the consumption in different branches (see Annex A2.4.1). In order to avoid errors that are introduced in the process of disaggregation, but do not apply to the aggregated emissions on the national level, the analysis of uncertainties for CO_2 emissions from fuel combustion is carried out on the level of aggregated total national emissions (1A) for Gaseous, Liquid, Solid and Other fuels.

Details of uncertainty analysis of activity data (fuel consumption) in 1A are provided in the table below. For each fuel type, uncertainties of net import or net production data (column C) and uncertainties of estimates of stock changes (if applicable) have been estimated. From this, the combined uncertainty of final consumption of fuels has been calculated (column H).

Table 55 Details of uncertainty analysis of fuels in 1A (Import, production, stock changes and consumption numbers according to submission April 2006).

A	B	C	D	E	F	G	H	I
Fuel type (IPCC 2000)	Corresponding fuel type in SFOE 2005	Net import/ net production [TJ]	Import/ production data uncertainty [%]	Correction for stock changes etc. [TJ]	Correction uncertainty [%]	Consumption [TJ]	Final consumption uncertainty [%]	Comment
Liquid fuels	Erdölprodukte	511'940	1.0	26'740	20	538'680	1.4	1
Gaseous fuels	Gas	113'490	5	0	0	113'490	5.0	2
Solid fuels	Kohle	5'630	5	1'000	100	5'650	18.4	3
Other fuels	Müll- und Industrieabfälle	44'670	10	0	0	44'670	10.0	4

Comments:

1 Col. D: Expert estimate from carbura (email M. Ruffer 24.1.05; overall uncertainty has been doubled to account for 95% interval). - Col. F: Conservative interpretation of rough expert estimate from carbura ("one-digit uncertainty", i.e. 10% is one sigma, resulting in unc = 2*sigma = 20%).

2 Col. D: 5% is GPG default value for developed countries (IPCC 2000 p. 2.1).

3 Col. D: 5% is GPG default value for developed countries (IPCC 2000 p. 2.1). - Col. E and F: Data from SFOE 2005 seems to underestimate stock changes. Here a rough conservative expert estimate is given of actual stock changes.

4 Col. D: An uncertainty of amount of waste of 10% is assumed (expert judgement), because waste input is reasonably well measured since the nineties.

Data on stock changes is taken from the Swiss overall energy statistics (SFOE 2005; Table 4), except for solid fuels (coal), where the SFOE data seems to underestimate stock changes in coal considerably. New governmental policy that was introduced from 1999 reduced significantly or stopped altogether state subsidies for fuel stocks and reduced the amount of mandatory stocks that companies have to maintain ("Pflichtlager"; see FDEA 2003). Experts within the Swiss cement industry confirmed that this resulted in a significant reduction of coal and heavy fuel oil stocks (and additional consumption) during the last few years that has not yet been accounted for in current data on stock changes from SFOE. Therefore, own expert estimates on stock changes in solid fuels are used, rather than data from SFOE, based on information provided by experts from the cement industry. Uncertainties of these (coal-)stock estimates are very high (100%).

Uncertainty in CO_2 emission factors in fuel combustion (1A)

Liquid fuels: The net calorific values for liquid fuels are based on the determination of the gross calorific value and the calculation of the net calorific value by the Swiss Federal Laboratories for Materials Testing and Research EMPA. To this aim, a set of fuel samples of different sources has been selected that is representative for the fuels traded in Switzerland in the year 1998. Assuming that this data on the uncertainty of the net calorific value is representative for the uncertainty of the emission factors in fuel combustion, a combined uncertainty of 0.55% (defined as two standard deviations, STD) results for the emission factor.

Table 56 Results from the 1998 analysis of the low calorific values of liquid fuels in Switzerland (EMPA 1999).

Fuel	Net calorific value liquid fuels						
	Mean [GJ/t]	STD [GJ/t]	STD [%]	Uncertainty [%]	=(C*G)^2 [GJ^2/t^2]	No. of samples []	Share 2004 (approx.)
Heavy fuel oil	41.2	0.85	2.06	4.13	0.000132	6	1%
Light fuel oil	42.6	0.13	0.31	0.61	0.004521	10	52%
Diesel	42.8	0.10	0.23	0.47	0.000187	10	14%
Gasoline	42.5	0.29	0.68	1.36	0.009073	30	33%
Jet kerosene	43.0	0.25	0.58	1.16	0.000001	10	0.3%
Sum	42.6				0.013914	66	100%
Combined STD/Unc		0.118 =SQR(sum(E))	0.28	0.55			

Gaseous fuels: The uncertainty of the emission factor for CO_2 has been derived from data on measurements of the low calorific value of natural gas in the grid. SGWA 2005 provides a range of -2.9% and +1.7%, or an average of 2.3%. Interpreting this range as one standard deviation, a uncertainty of 4.6% results (i.e. two standard deviations).

Solid fuels: For the uncertainty of the emission factor for CO_2, the IPCC Good Practice Guidance default value of 5% for countries with well developed energy data systems is used (IPCC 2000: p. 2.15).

Other fuels (waste to energy): The dominant factor influencing the uncertainty of CO_2 emissions from municipal solid waste incineration (1A1) is the fraction of fossil carbon in the waste. For the fraction of C in incinerated waste an uncertainty of 20% has been estimated, and for the fraction of fossil C in total C an uncertainty of 10% has been estimated, resulting in a preliminary uncertainty estimate of 30% for the waste incineration CO_2 emission factor[13].

Resulting uncertainty in CO_2 emissions in fuel combustion (1A)

Table 57 below provides the results of the quantitative Tier 1 analysis (following Good Practice Guidance; IPCC 2000: p. 6.13ff) estimating uncertainties of CO_2 emissions from fuel combustion activities.

Table 57 Results from Tier 1 uncertainty calculation and reporting for CO_2 emissions in 1A Fuel Combustion (Emissions according to submission April 2006).

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC Source category	Gas	Base year emissions 1990	Year 2004 emissions	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combinded uncertainty as % of total CO2 combustion emission in year t	Type A sensitivity (CO2 from combustion)	Type B sensitivity (CO2 from combustion)	Uncertainty in trend in national emissions introduced by emission factor uncertainty (CO2 from combustion)	Uncertainty in trend in national emissions introduced by activity data uncertainty (CO2 from combustion)	Uncertainty introduced into the trend in total CO2 combustion emissions
		Gg CO2 equivalent	Gg CO2 equivalent	%	%	%	%	%	%	%	%	%
1A Gaseous fuels	CO2	3'714.50	6'186.06	5.0	4.6	6.8	0.975	0.0558	0.1501	0.26	1.06	1.09
1A Liquid fuels	CO2	34'319.03	34'143.58	1.4	0.55	1.48	1.174	-0.0425	0.8287	-0.02	1.61	1.61
1A Solid fuels	CO2	1'490.48	566.35	18.4	5.0	19.1	0.250	-0.0241	0.0137	-0.12	0.36	0.38
1A Other fuels	CO2	1'676.11	2'211.82	10.0	30.0	31.6	1.623	0.0111	0.0537	0.33	0.76	0.83
Total CO2 Emissions Fuel		41'200.11	43'107.80									
Overall uncertainty CO2 combustion emissions in the year (%):							2.24	CO2 combustion emissions trend uncertainty (%):				2.15

The analysis results in an overall uncertainty of the CO_2 emissions from 1A Fuel Combustion of 2.24% for the year 2004 and in a trend uncertainty for the period 1990 to 2004 of 2.15%.

Uncertainty in N_2O emissions from the use of (waste derived) "Other fuels" in 1A1 Energy Industries

The uncertainty for the activity data is 10%, the same as for the CO_2 emissions. Emission factor uncertainty for N_2O from municipal solid waste incineration is estimated at 80%.

Uncertainty in CH_4 emissions from Gasoline consumption in 1A3 Road Transportation

The uncertainty for the activity data is 10%. For the CH_4 emission factor, a value of 59.2% has been chosen leading to a combined uncertainty for the CH_4 emission of 60%. The values for the activity data and for CH_4 emission factor are taken from an extended uncertainty analysis (Kühlwein 2004).

[13] Personal communication by R. Quartier, SAEFL, 23 February 2005.

Qualitative estimate of uncertainties of non-key category emissions in 1A Fuel Combustion

Non-CO_2 emissions in Energy Industries (1A1), Manufacturing Industries and Construction (1A2) and Other Sectors (Commercial, Residential, Agriculture, Forestry; 1A4):
A preliminary uncertainty assessment for non-CO_2 emissions from source categories 1A1, 1A2 and 1A4 based on expert judgement results in high confidence in estimations of SO_2 emissions, because of the high quality of activity data and emission factors. Uncertainty in emissions of other non-CO_2 gases is estimated to be medium[14].

Other source categories
Uncertainty: No estimates of the uncertainties have been performed.

b) Consistency and Completeness in 1A Fuel Combustion

Consistency:

- Time series for 1A1, 1A2, 1A3, 1A4 and 1A5 are all consistent.
- CO_2 emissions from biomass in 1 Energy (memo item) are only partly included in the CRF, see Section 3.5.

Completeness:

All estimates in the sector 1A are assumed to be complete.

3.2.4. Source-Specific QA/QC and Verification

As mentioned in Sections 1.3 and 1.4.3, the former modelling of the Swiss GHG emissions by means of “internal GHG inventory files” was replaced by the (redesigned) national air pollution database EMIS. For quality control reasons, all the emissions of the energy sector were not only calculated with EMIS but with the internal GHG inventory files, too. Both tools use the same input data (energy consumption and emission factors) but calculate independently the emission numbers. Differences in the emissions were analysed, methodical and technical errors could be identified and corrected. By iteration, a perfect congruence between the two emission results was finally achieved. This process is considered to be a rather rigorous test for the correctness and completeness of the energy-related emissions of the inventory.

At the level of total energy-related CO_2 emissions, another quality control consists in the comparison of emissions modelled using the Sectoral Approach with emissions calculated from fuel consumption according to the Swiss overall energy statistics of SFOE. The differences in total CO_2 emissions for the years 1990–2004 are negligible - indicating again the completeness of the inventory.

Another quality control measure consists in the default calculation of implied emission factors in the CRF. These emission factors are compared to those in the CRF tables of previous years.

The cross-check of the Reference and Sectoral Approach is also used for an assessment of emissions related to the consumption of fuels in the energy sector. Again, a good agreement between the two approaches is found (see Chapter 3.6).

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[14] For details regarding the classification of data quality as high, medium and low, see Section 1.7

The quality control activities have been documented in checklists as described in Chapter 1.6.

Energy Industries (1A1) and Manufacturing Industries and Construction (1A2)

To date, no specific quality control measures are applied to this sector.

Transport (1A3)

Civil Aviation (1A3a)

Emissions: Total calculated emissions for domestic and international flights have been compared between different years. The development of total emissions with time is consistent with a fleet renewal of former Swissair in the early nineties, the technological improvements and changes in fleet composition.

Emission factors: From total fuel burn, total distance, number of passenger (without freight) per aircraft type, the fuel consumption per 100 passenger km has been calculated (backward calculation). The result of 2 to 10 kg fuel/100 passenger km is in line with expectations for 1990 passenger fleets.

Activity data: Comparison between total movement numbers in the calculation and in the corresponding published statistics. Example: In 1990 calculation, FOCA considered all flights for which there was a form ‘Traffic report to the airport authorities’ filled in (total heavy aircraft). The total number of movements in 1990 is 266’487 (without Basel). The published number of movements for scheduled and charter flights in 1990 is: 263’952 (without Basel). The difference is due to pure cargo, post and rerouted flights, which are not considered as scheduled or charter movements.

Fuel consumption: The bottom-up calculation of total fuel matches the total fuel sold within a few percents. The remaining difference can be attributed to fuelling.

Road Transportation (1A3b)

The international project for the update of the emission factors for road vehicles is overseen by a group of external and international experts that guarantees an independent quality control. For the update of the modelling of Switzerland’s road transport emissions, which has been carried out between 2001 and 2004, several experts from the federal administration have conducted the project. The results have undergone large plausibility checks and comparisons with earlier estimates.

Other sectors (1A4)

To date, no specific quality control measures are applied to this sector.

Other, Off–road (1A5)

The off-road emissions have been updated. For this purpose, FOEN mandated national experts. Input data, methods and results were checked by the FOEN specialists.

3.2.5. Source-Specific Recalculations

All sources 1A1-1A5 except 1A3b and 1A3e have been recalculated for 1990-2003. See Chapter 9.

The net calorific value of hard coal has been revised for the current submission (and the submission of 31 May 2006), see Annex A2.2.1.

3.2.6. Source-Specific Planned Improvements

Energy Industries (1A1), Manufacturing Industries and Construction (1A2)

CO_2 emission factors for the use of waste derived fuels in cement industry are preliminary and may be revised for future submissions.

Transport (1A3)

Civil Aviation (1A3a): FOCA has started a project to compile data on fuel consumption and emission factors for small (piston) aircraft and helicopters for which no ICAO emission certification is necessary. The results will be used for further improving the emission modelling in future years.

Other Sectors (1A4)

No source specific improvements are planned..

Other: Off-road (1A5)

After the revision of the off-road emissions, no more improvements are planned at the moment.

3.3. Source Category 1B – Fugitive Emissions from Fuels

3.3.1. Source Category Description

Key category 1B2
Fugitive Emissions of CH_4 from Oil and Natural Gas are a key category regarding trend.

Fugitive emissions arise from the production, processing, transmission, storage and use of fuels. According to IPCC guidelines, emissions from flaring at oil and gas production facilities are included while emissions from vehicles are not included in 1B.

Source Category 1B “Fugitive Emissions from Fuels” comprises the following sub-categories:

- Solid fuels (1B1)
- Oil and Natural Gas (1B2)

a) Solid fuels (1B1)

Coal mining is not occurring in Switzerland.

b) Oil and Natural Gas (1B2)

Table 58 Specification of source category 1B2 “Fugitive Emissions from Oil and Natural Gas”.

1B2	Source	Specification	Data Source
1B2 a	Oil	Emissions from refining/storage of oil and the distribution of oil products	AD: SFOE 2005 EF: EMIS
1B2 b	Natural Gas	Emissions from gas pipelines and the compressor station in Ruswil, Lucerne.	AD: SFOE 2005, SGWA 2005 EF: Battelle 1994, Xinmin 2004, SGWA 2005
1B2 c	Venting / Flaring	The release/combustion of excess gas at the oil refinery	AD: SFOE 2005 EF: EMIS

3.3.2. Methodological Issues

a) Solid fuels (1B1)

Coal mining is not occurring in Switzerland.

b) Oil and Natural Gas (1B2)

Methodology

For source 1B2a Oil, the emissions of CH_4 and NMVOC are reported.

For source 1B2b Natural Gas, the emissions of CH_4 and NMVOC leakages from gas pipelines are calculated with a new country specific Tier 3 method. The method considers the length, type and pressure of the gas pipelines as well as the annual gas consumption. The distribution network components (regulators, shut off fittings and gas meters), the losses from maintenance and extension as well as the end user losses are separately taken into account. Also, emissions of CO_2, CH_4, N_2O, NO_x, CO, NMVOC and SO2 from a compressor station located in Ruswil are considered.

For source category 1B2c Venting/Flaring (Oil), CO_2 as well as CH_4, NO_x, CO and NMVOC are considered.

The indirect CO_2 emissions from the decomposition of NMVOC in the atmosphere have been calculated (in this submission for the first time) from the average carbon contents of NMVOC emissions for the subcategory 1B2a and 1B2b.

The emissions from oil and venting/flaring (1B2a and 1B2c) are calculated based on annual production/consumption data which is consistent with the IPCC tier 1 approach. Emissions of greenhouse gases are calculated by multiplying level of activity by emission factor.

Emission factors

1B2a and 1B2c: The emission factors for direct CO_2, CH_4 and NMVOC are based on data from the refining and gas industry and expert estimates.

The emission factors for gas distribution losses (source 1B2b) depend on the type and pressure of the natural gas pipeline (see Table 59; sources: Battelle 1994, Xinmin 2004, SGWA 2005). The CH_4-emissions due to gas meters are considered with the emission factor of 5.1 m^3 CH_4 per gas meter and year. The emission factors for 1B2b are calculated for each year separately.

Table 59 CH_4-Emission Factors for 1B2 “Fugitive Emissions from Oil and Natural Gas” (Battelle 1994, Xinmin 2004, SGWA 2005)

1B2 Fugitive Emissions from Oil and Natural Gas	< 100 mbar	100-1000 mbar	1- 5 bar	> 5 bar
	Emission factors in [m^3/h/km]			
Cast iron	0.80000	1.20000	0.19200	-
Cast steel	0.08800	0.13200	0.00230	-
Steel normal	0.08800	0.01320	0.00062	-
Steel cath.	0.00800	0.01200	0.00002	0.028
HDPE (Polyethylene)	0.00800	0.01600	0.00062	-
other	0.00800	0.01600	0.00002	-

The indirect CO_2 emissions from the decomposition of NMVOC in the atmosphere have been calculated from the average carbon contents of NMVOC emissions from the EMIS database. Resulting emission factors are 3.15 Gg CO_2/Gg NMVOC for 1B2a (Oil) and 2.93 Gg CO_2/Gg NMVOC for 1B2b (Natural gas).

Activity data

The activity data for fugitive emissions such as the total annual gasoline consumption and gas imports are extracted from the Swiss overall energy statistics (SFOE 2005).

The activity data for methane of Natural Gas (source 1B2b) are provided by the Swiss gas association (SFOE 2005, SGWA 2005). Fugitive emissions from a high pressure natural gas transfer pipeline, crossing Switzerland from France to Italy, are included in the inventory. The data on fuel consumption for the operation of the compressor station in Ruswil is based on the Swiss overall energy statistics (SFOE 2005; Table 13).

3.3.3. Uncertainties and Time-Series Consistency

Uncertainty in fugitive CH_4 emissions from natural gas pipelines in 1B2
Following Good Practice Guidance (IPCC 2000: p. 2.92) overall uncertainty of bottom-up inventories of fugitive methane losses from gas activities are expected to result in errors of 25-50%. From this a conservative error of 50% is estimated for Switzerland.

Qualitative estimate of uncertainties of non-key category emissions in 1B Fugitive Emissions from Fuels
A preliminary uncertainty assessment of all other sources in source category 1B2 based on expert judgement results in medium confidence in the emissions estimate.

The time series is consistent.

3.3.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the check between EMIS and Internal GHG Files (Section 1.4.3) and the general QA/QC measures described in Section 1.6.1 have been carried out.

3.3.5. Source-Specific Recalculations

For source 1B2b Natural Gas, the emissions of CH_4 leakages from gas pipelines have been recalculated from 1990 until 2003. Also the emissions from 1B2c emissions from venting and flaring were recalculated. See Chapter 9.

3.3.6. Source-Specific Planned Improvements

Gradual improvement of the data quality in co-operation with industry is ongoing.

3.4. Source Category International Bunker Fuels

3.4.1. Source Category Description

By definition, greenhouse gas emissions from the use of International Bunker Fuels are **not a key category** (IPCC 2000).

For Switzerland, the only source of international bunker emissions is aviation. Marine bunker emissions are not estimated: The only candidate for marine bunker are the navigation activities on the river Rhine between Basel and Rotterdam (NL). Due to an economic and a technical reason, fuelling will predominantly take place abroad i.e. out of Switzerland:

- The price for Diesel oil is higher in Switzerland than in the other Rhine-abutting nations Netherlands, Germany, France.
- The main fuel consumption takes place in the upstream direction, which ends in Basel-Birsfelden, 10 km from the Swiss border (farther up the river is no more navigable).

For these reasons, the bunker fuel consumption is estimated to be very low.

Table 60 Specification of Swiss source category International Bunkers for civil aviation.

International Bunker Fuels	Specification	Data Source
Civil Aviation	Country-specific model (Tier 3a)	FOCA 2006

3.4.2. Methodological Issues

The methodologies used are described in chapter 3.2.2.c. The emissions from civil aviation (domestic and international) are calculated with a Tier 3a. The activity data of the bunker is summarised in Table 61(see also Table 42).

Table 61 International bunker fuels. Consumption of kerosene in TJ.

Civil Aviation (bunker)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	Fuel consumption in TJ														
Total international	41'891	40'879	43'506	45'349	46'847	49'925	51'982	53'990	56'606	60'813	63'694	60'105	55'475	49'771	46'900
1990 = 100%	100%	98%	104%	108%	112%	119%	124%	129%	135%	145%	152%	143%	132%	119%	112%

3.4.3. Uncertainties and Time-Series Consistency

See remarks in chapter 3.2.2.c) Aviation (1A3a).

3.4.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the check between EMIS and Internal GHG Files (Section 1.4.3) and the general QA/QC measures described in Section 1.6.1 have been carried out.

3.4.5. Source-Specific Recalculations

No source-specific recalculations have been carried out.

3.4.6. Source-Specific Planned Improvements

See remarks in Chapter 3.2.6., Aviation (1A3a).

3.5. CO_2 Emissions from Biomass

A description of the methodology for calculating CO_2 emissions from the combustion of biomass is included in the relevant Chapters 3 (Energy) and 8 (Waste).

In the present submission, energy related emissions from municipal solid waste (MSW) incineration plants have been reported under 1A1 Energy Industries (see Section 3.2.2 a). For technical reasons, it has not been possible to include the biomass CO_2 emissions from energy related MSW incineration in Table 1.A(a) of the CRF. Also CO_2 emissions related to the combustion of waste derived biomass fuels in cement production in source categories 1A2f, from 2G (Industrial Processes, Other), from 4F (Burning of Agricultural Residues), from 6A (Solid Waste Disposal on Land) and from 6B (Wastewater Handling) are not foreseen for reporting in the CRF.

Therefore, the CO_2 emissions from the combustion of biomass in the CRF are incomplete. The following table provides an overview of effective biomass combustion CO_2 emissions in Switzerland 2003 and their reporting in the CRF. Data stems from the CRF and the SAEFL internal GHG files.

Biomass combustion CO_2 emissions do not count for the national total emissions and are a memo item only.

Table 62 Effective biomass combustion CO_2 emissions in Switzerland and their representation in the CRF.

Biomass combustion CO_2 emissions	Unit	Value 2004	Note
1A1 Energy Industries (without MSW incineration)	Gg	17	Included in CRF Source 1A1
1A1 Energy generation from MSW Incineration	Gg	2'395	Not included in CRF
1A2 Manufacturing Ind. and Constr. (excluding waste fuels in cement prod.)	Gg	706	Included in CRF Source 1A2
1A2 Use of waste derived fuels in cement production	Gg	179	Not included in CRF
1A3 Transport	Gg	NO	
1A4 Other Sectors (Commercial/Institutional, Residential)	Gg	2'182	Included in CRF Source 1A4
2G Industrial Processes, Other	Gg	14	Not included in CRF
4F Agriculture, Burning of Residues	Gg	116	Not included in CRF
6A Solid Waste Disposal on Land	Gg	68	Not included in CRF
6B Wastewater Handling	Gg	295	Not included in CRF
6C Waste Incineration (without MSW incineration)	Gg	108	Included in CRF Source 6C
Total biomass combustion CO_2 emissions included in CRF	Gg	3'012	
Total energy related biomass combustion CO_2 emissions included in CRF 1A	Gg	2'904	See table "Summary 2" in CRF
Total biomass combustion CO_2 emissions in Switzerland 2004	Gg	6'078	

3.6. Comparison of Sectoral Approach with Reference Approach

The apparent consumption, the net carbon emissions, and the effective CO_2 emissions are calculated for the Reference Approach as prescribed in the CRF tables 1A(b)–1A(d). Figures are taken from the Swiss overall energy statistics (SFOE 2005) and from the yearly report of the Swiss Petroleum Association [Erdöl-Vereinigung/Union pétrolière] (EV 2005). Exceptions are coal and residual fuel oil, which are taken from Basics 2006. These statistics account for production, imports, exports, transformation and stock changes.

The Reference approach covers the CO_2 emissions of all imported fuels (import, export, stock changes), i.e. emissions from crude oil treatment (secondary fuel production) in the two Swiss refineries and emissions of imported secondary fuels. Nearly 40% of the secondary liquid fossil fuels sold in Switzerland stem from the Swiss refineries.

The following table and the figure show the differences between the Reference and the Sectoral (National) Approaches 1990–2004. The CO_2 emissions agree very well, for all years the differences are between 0.53% and 1.60%. For the energy consumption the differences are somewhat larger, between 1.11% and 2.47%, due to the CRF system for feedstocks: The carbon stored of bitumen is reported in table 1A(d) and is taken into account in the Reference Approach table 1A(b). However, the charging to account for the corresponding energy consumption of this bitumen feedstock – also reported in table 1A(d) – is not foreseen in CRF table 1A(b); this leads to a somewhat higher difference for energy consumption. The graphs in the following figure show the systematic difference between the two parameters and simultaneously the good correlation between them (correlation coeff. r = +0.86).

Table 63 Differences in energy consumption and CO_2 emissions between the Reference and the Sectoral (National) Approach. The difference is calculated according to [(RA-SA)/SA] 100% with RA = Reference Approach, SA = Sectoral (National) Approach.

Difference between Reference and Sectoral Approach															
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	%														
Energy Consumption	1.95	2.24	2.17	2.02	2.34	2.47	1.72	1.53	2.08	1.40	1.69	1.53	1.11	1.36	1.67
CO_2 Emissions	0.84	1.09	1.16	1.06	1.38	1.60	0.90	0.76	1.43	0.60	0.82	0.92	0.53	0.70	1.24

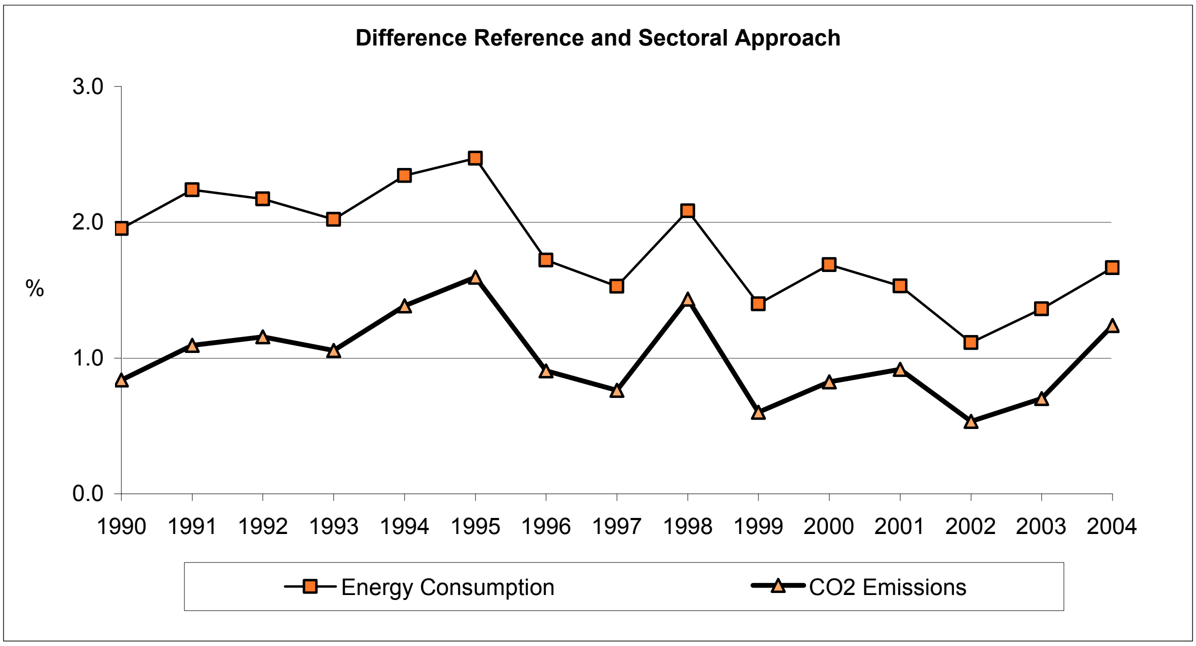


Figure 19 Time series for the differences between Reference and Sectoral Approach. Numbers are taken from the table above.

The Reference Approach is calculated and documented in the CRF under the following conditions:

- Only bitumen production from national refineries is shown in CRF Table 1.A (d). It is a refinery product and included in the crude oil amount. In the Swiss inventories, bitumen emissions (NMVOC) appear under industrial processes and not under energy use.
- Gaseous fuels: Gas distribution emissions (including emissions from compressor stations) are reported under 1B Fugitive Emissions (CRF Table 1.B.2) and do not appear in CRF Table 1.A (d).
- Liquid fuels/Solid fuels: In the Sectoral (National) Approach, petroleum coke is subsumed under solid fuels (used by cement industry where petroleum coke is treated as coal).
- The oxidations factor is consequently set to 1.0 due to the following reason: combustion installations in Switzerland have very good combustion properties; combined emissions of CO and unburnt VOC lie in the range of only 0.1 to 0.3 percent of CO_2 emissions for oil and gas combustion. Since most of the coal used in Switzerland goes to the cement industry, also for coal an oxidation factor of 1.0 was chosen (cf. Chapter 3.2.2.)
- For the Reference Approach, Liechtenstein's fuel consumption is subtracted from the input figures of fuel consumption, which originally include Liechtenstein's consumption (see also Chapter 3.1.4).

4. Industrial Processes

4.1. Overview

According to IPCC guidelines, emissions within this sector comprise greenhouse gas emissions as by-products from industrial processes and also emissions of synthetic greenhouse gases during production, use and disposal. Emissions from fuel combustion in industry are reported under category 1 Energy.

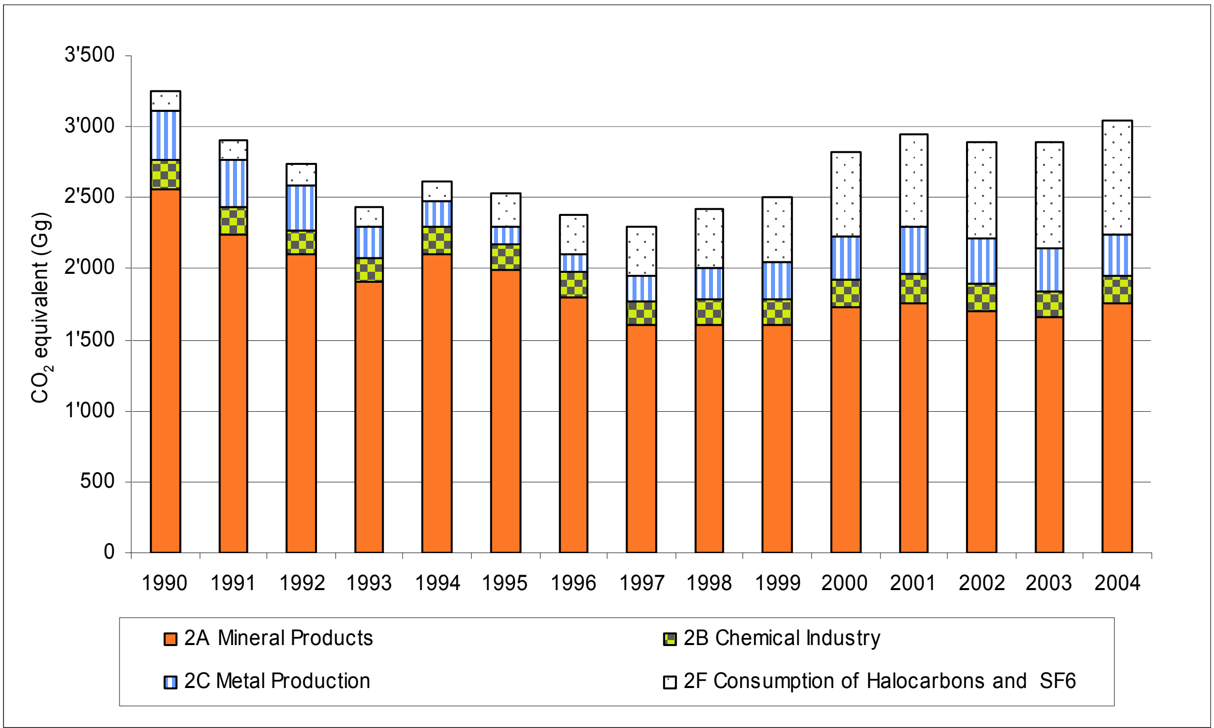


Figure 20 Switzerland's GHG emissions of source category 2 "Industrial Processes" 1990–2004. The emissions of the source category 2G "Other" are very small (about 0.3 Gg) and are not shown in the figure.

Table 64 GHG emissions of source category 2 "Industrial Processes" 1990-2004 by gases in CO_2 equivalent (Gg).

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	CO_2 equivalent (Gg)														
CO_2	2'831	2'500	2'362	2'116	2'281	2'107	1'924	1'746	1'766	1'811	1'948	1'985	1'938	1'907	2'004
CH_4	9.1	8.7	8.3	8.0	7.7	7.3	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.1	7.1
N_2O	174	172	151	144	168	165	160	141	150	153	167	176	182	163	171
Synthetic gases	244	231	224	169	160	248	292	404	492	538	697	779	762	822	869
Sum	3'258	2'912	2'744	2'437	2'617	2'527	2'382	2'298	2'415	2'509	2'819	2'946	2'890	2'900	3'051

Although its emissions have decreased by over -30% in the period 1990-2004, Mineral Products (sub-category 2A) remain the dominant source amongst the Industrial Processes. Consumption of Halocarbons and SF_6 (sub-category 2F) are of increasing importance. The emissions of synthetic gases have grown by a factor of 3.56 in the same period, primarily because of the change from CFC to HFC in a lot of technical applications.

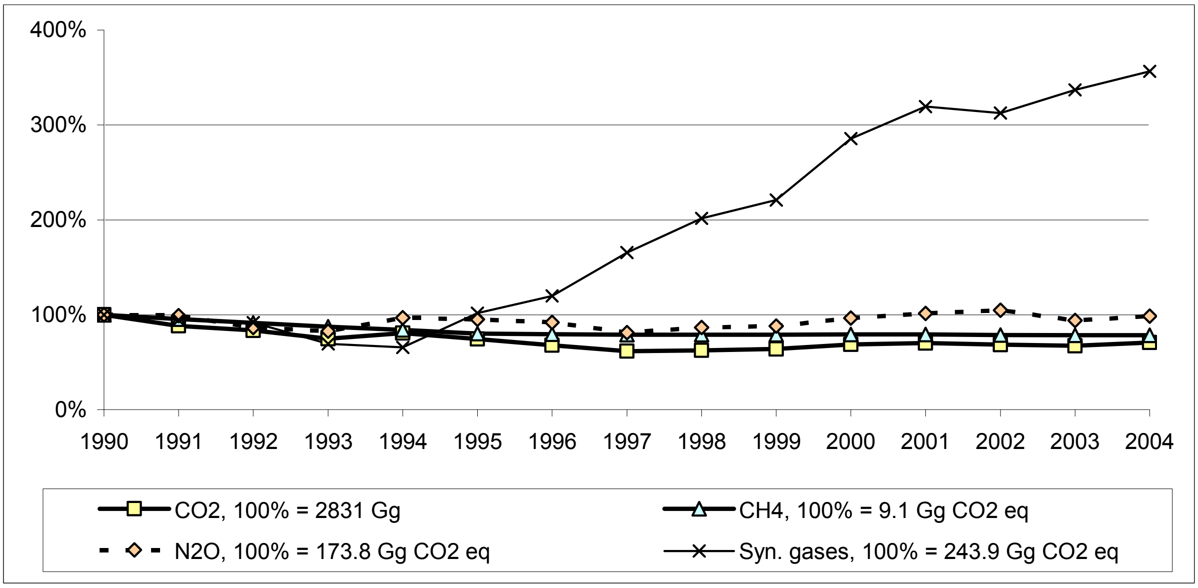


Figure 21 Relative trends of the greenhouse gases of source category 2 “Industrial Processes” in the period 1990-2004. The base year 1990 represents 100%.

The CO_2 emissions have declined to 71% whereas the synthetic gases have increased up to 356% in the period 1990-2004.

4.2. Source Category 2A – Mineral Products

4.2.1. Source Category Description

Key category 2A1
The non-energy CO_2 emissions in Cement Production (2A1) are a key category regarding level and trend.

Source category 2A1 “Mineral Products” comprises non-energy emissions from Cement Production, Lime Production and Road Paving with Asphalt. Limestone and Dolomite Use as well as Soda Ash Production and Use are not occurring in Switzerland.

Table 65 Specification of source category 2A "Mineral Products".

2A	Source	Specification	Data Source
2A1	Cement Production	Emissions from calcination process in cement production and emissions from blasting operations.	AD: Cemsuisse 2004 EMIS EF: calcination-CO_2: WBCSD 2001; EF Other gases: EMIS
2A2	Lime Production	Emissions from calcination process in lime production.	AD: EMIS EF: Industry data
2A3	Limestone and Dolomite Use	Not occurring in Switzerland	
2A4	Soda Ash Production and Use	Not occurring in Switzerland	
2A5	Asphalt Roofing	Included in 2G	
2A6	Road Paving with Asphalt	Emissions from road paving	AD: EMIS EF: EMIS
2A7	Other	Not occurring in Switzerland	

4.2.2. Methodological Issues

a) Cement Production (2A1)

Methodology

Calcination: For the CO_2 emissions in Cement Production (2A1) from calcination the Tier 2 approach of IPCC Good Practice Guidance is used. Emissions of CO_2 related to calcination are calculated bottom-up by multiplying the annual clinker output (level of activity) by emission factors. In the Swiss cement plants no cement kiln dust or bypass dust is discarded. For non-CO_2 emissions from calcination, a country specific approach based on the annual cement (not clinker) output is applied. Emissions are calculated by multiplying the annual cement (not clinker) output by emission factors.

Blasting: In addition to the IPCC approach, emissions resulting from blasting operations during the working of limestone are included, following a country specific method. Emissions of GHGs related to blasting operations are calculated by multiplying the annual cement (not clinker) output by emission factors. Please note that the CO_2 emissions from "blasting" are related to the usage of the explosive itself and are not related to fuel consumption of e.g. bulldozers etc.

Total emissions reported for Cement Production (1A2) are the sum of emissions from calcination and blasting.

Emission Factors

Calcination: The emission factor for CO_2 per ton of clinker is an improved IPCC default value and amounts to 525 kg per ton of clinker produced.

Switzerland follows the approach provided by the Working Group Cement of the World Business Council on Sustainable Development (WBCSD 2001; Appendix 4). The IPCC approach neglects CO_2 from decomposition of $MgCO_3$. In the Swiss inventory, these emissions are included based on an assumed MgO content in clinker of 2%. A CaO content of clinker of 64.2% is used following the WBCSD, broadly in line with the IPCC default weight fraction of 65%. Possible non-carbonate feeds e.g. from raw materials are not considered. Together, this results in a CO_2 emission factor of 525 kg/t clinker. This emission factor has been recommended as a default value by the Working Group Cement of the World Business Council on Sustainable Development (WBCSD 2001; Appendix 4).

Calcination emission factors for CH_4, CO, NMVOC and SO_2 per ton of cement are country specific based on measurements and data from industry and expert estimates, documented in the EMIS database (see Section 1.4.3).

Blasting: Emission factors for CO_2, NO_x, CO, NMVOC and SO_2 per ton of cement are country specific based on measurements and data from industry and expert estimates, documented in the EMIS database (see Section 1.4.3).

The following table presents the emission factors used in 2A1:

Table 66 Emission Factors for 2A1 Cement Production for 2004 (cem.: cement).

2A1 Cement Production	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
	kg/t *clinker*	kg/t cem.			kg/t cem.	kg/t cem.	kg/t cem.
Calcination	525	0.0057			0.80	0.046	0.38
	kg/t cement			g/t cem.	g/t cem.	g/t cem.	g/t cem.
Blasting Operations	0.096			3.70	22	9.6	0.16

Activity Data

Activity data on both annual clinker and cement production is provided by the Association of the Swiss Cement Industry (Cemsuisse).

Table 67 Activity data in 2A1 Cement Production.

Source/production	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
2A1 Cement Production											
Cement production	Gg	5'117	4'683	4'268	4'043	4'432	3'994	3'648	3'485	3'371	3'540
Clinker production	Gg	4'808	4'189	3'927	3'564	3'930	3'706	3'337	2'994	2'995	2'992

Source/production	Unit	2000	2001	2002	2003	2004
2A1 Cement Production						
Cement production	Gg	3'754	3'891	3'771	3'592	3'957
Clinker production	Gg	3'214	3'275	3'150	3'081	3'265

The table above documents the decrease of Swiss cement production by -22% from 1990 to 2004. This decline results in category 2A1 being a key category regarding trend.

b) Lime Production

Methodology

For CO_2 emissions in Lime Production (2A2) the approach of IPCC 1997c is used. Emissions of CO_2 are calculated by multiplying the annual lime output (level of activity) by the emission factor. Other GHGs are not considered.

Emission Factors

The emission factor for CO_2 per ton of lime produced is country specific and amounts to 560 kg/t. It has been reviewed for the present submission of the inventory. It takes into consideration measurements and data from the two existing plants, the European BREF default value and expert estimates, documented in the EMIS database (see Section 1.4.3).

Activity Data

Activity data on annual lime production is based on data from industry and expert estimates, documented in the EMIS database (see Section 1.4.3). Annual lime production is estimated at 79'800 t in 2004.

c) Road Paving with Asphalt

Methodology

For determination of NMVOC emissions from Road Paving with Asphalt a country specific method is used, based on CORINAIR. Emissions of NMVOCs are calculated by multiplying the annual amount of asphalt products used for road paving (level of activity) by the emission factor. Other GHGs are not considered.

Emission Factors

The emission factor for NMVOC emissions from Road Paving with Asphalt is country specific and amounts to 0.46 kg/t (2004). The emission factor includes emissions from both ground paint and asphalt products. It is based on measurements, industry data and expert estimates, documented in the EMIS database (see Section 1.4.3).

Activity Data

Activity data on the amount of asphalt products ("Mischgut"; containing about 5% of bitumen) used for Road Paving with Asphalt is based on data from the asphalt products industry and expert estimates, documented in the EMIS database (see Section 1.4.3).

4.2.3. Uncertainties and Time-Series Consistency

Uncertainty in non-energetic CO_2 emissions from Cement Production in 2A1

Estimate of uncertainty of CO_2 emissions from clinker calcination follows the steps in Table 3.2 in IPCC Good Practice Guidance (IPCC 2000: p. 3.15). As CO_2 emissions are calculated based on plant level clinker production data (Tier 2), activity data uncertainty of 2% is assumed. Uncertainty of the emission factor is based on the fact that an average CaO content of clinker of 64.2% is assumed. For the IPCC default value table 3.2 in the GPG estimates a default uncertainty of 4-8%; 6% is chosen for Switzerland.

Together, a combined uncertainty of 6.3% for CO_2 emissions from calcinations results.

Qualitative estimate of uncertainties of non-key category emissions in 2A

For the most important source, cement production, emissions are based on actual cement and clinker production data provided by the cement industry.

Preliminary expert judgment estimates confidence in emissions to be medium in general, whereas confidence in CO_2 emissions is high.

The time series is consistent.

4.2.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the check between EMIS and Internal GHG Files (Section 1.4.3) and the general QA/QC measures described in Section 1.6.1 have been carried out.

All emissions have been recalculated for the time series 1990–2003 due to the revision of the EMIS database. See Chapter 9.

4.2.5. Source-Specific Planned Improvements

In the calculation of the CO_2 emission factor in 2A Cement production, the WBCSD default weight fraction of 64.2% for the CaO content of clinker is used (which is close to the IPCC default value of 65%). It is planned to use country specific data on CaO content. Also, it is planned to take into account possible non-carbonate feeds (e.g. from raw materials).

4.3. Source Category 2B – Chemical Industry

4.3.1. Source Category Description

Source category 2B "Chemical Industry" is **not a key category.**

Source category 2B “Chemical Industry” comprises non-energy emissions from the Production of Nitric Acid, Carbide and Organic Chemicals. The production of Ammonia and Adipic Acid are not occurring in Switzerland.

Table 68 Specification of source category 2B “Chemical Industry”.

2B	Source	Specification	Data Source
2B1	Ammonia Production	Emissions from the production of Ammonia, including NH_3 emissions	AD, EF: EMIS
2B2	Nitric Acid Production	Emissions from the production of Nitric Acid	AD, EF: Industry data, EMIS
2B3	Adipic Acid Production	Not occurring in Switzerland	
2B4	Carbide Production	Emissions from the production of Silicon Carbide	AD, EF: EMIS
2B5	Other	Emissions from the production of Organic Chemicals (Ethylene, PVC, Formaldehyde, Acetic Acid)	AD, EF: EMIS

4.3.2. Methodological Issues

a) Ammonia Production (2B1)

Methodology

For CO_2, NO_x, CO, NMVOC and SO_2 emissions from Nitric Acid Production (2B2), a country specific approach is used. The emissions are calculated by multiplying the annual ammonia production output (levels of activity) by emission factors.

Emission Factors

Emission factors for CO_2, NO_x, CO, NMVOC and SO_2 per ton of Ammonia produced are country specific based on measurements, data from industry and expert estimates, documented in the EMIS database (see Section 1.4.3).

Activity Data

Activity data on annual production of 40'000 tons of ammonia in 1990 has been provided by industry. The level of production is assumed to remain constant since then.

b) Nitric Acid Production (2B2)

Methodology

For N_2O and NO_x emissions from Nitric Acid Production (2B2), a country specific approach is used. The emissions are calculated by multiplying the annual nitric acid production output (levels of activity) by emission factors.

Emission Factors

Emission factors for N_2O and NO_x per ton of Nitric Acid are country specific based on measurements and data from industry and expert estimates, documented in the EMIS database (see Section 1.4.3).

The following table presents the emission factors used in 2B2 for 2004:

Table 69 Emission Factors for 2B2 Nitric Acid Production in 2004.

2B2 Nitric Acid Production	N_2O	NO_x
	kg/t	kg/t
Nitric Acid Production	5.0	0.897

The emission factor for NO_x has been provided by industry. The emission factor for N_2O was not available from plant operator; therefore an older value of 5 kg of N_2O per ton of nitric acid has been assumed (EMIS). This value is in line with the value given in IPCC 1997c of 2-9 kg/t for the USA and 4-5 kg/t given for atmospheric pressure plants in Norway

Activity Data

Activity data on annual production of nitric acid from 1990 has been provided by industry.

c) Carbide Production (2B4)

Methodology

For CO_2 and SO_2 emissions from Silicon and Calcium Carbide Production (2B4), a country specific approach is used. The emissions are calculated by multiplying the annual production output (level of activity) by emission factors.

Source category 2B4 contributes less than 1% to total CO_2 emissions from 2 Industrial Processes.

Emission Factors

Emission factors for CO_2 and SO_2 are from EMIS.

Activity Data

Activity data on annual production are from industry and are confidential, but available to reviewers.

d) Other (Organic Chemicals; 2B5)

Methodology

For CH_4, CO, NMVOC and SO_2 emissions from Organic Chemicals Production (2B5), a country specific approach is used. The emissions are calculated by multiplying the annual production output (level of activity) by emission factors. The organic chemicals considered are ethylene, PVC, formaldehyde, and acetic acid.

Emission Factors

Emission factors for CH_4, CO NMVOC and SO_2 are country specific based on measurements and data from industry and expert estimates, documented in the EMIS database (see Section 1.4.3).

Activity Data

Activity data on annual production have been provided by industry as documented in the EMIS database.

4.3.3. Uncertainties and Time-Series Consistency

Time series on production data and emission factors in the EMIS database use in some cases expert judgment to estimate data for the period after 1995.

A preliminary uncertainty assessment based on expert judgment results in medium confidence in emissions estimates.

The uncertainty of the (implied) N_2O emission factor in Category 2B Chemical Industry is estimated to be 40% (expert estimate). The uncertainty of the related activity data is estimated to be 10% (expert estimate).

The time series is consistent.

4.3.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the check between EMIS and Internal GHG Files (Section 1.4.3) and the general QA/QC measures described in Section 1.6.1 have been carried out.

4.3.5. Source-Specific Recalculations

All emissions have been recalculated for the time series 1990–2003 due to the revision of the EMIS database. See Chapter 9.

4.3.6. Source-Specific Planned Improvements

In 2B1 Ammonia Production is planned to report other emissions (apart from NH_3) for future submissions.

The N_2O emission factor for 2B2 Nitric Acid Production will be reevaluated in coordination with industry.

4.4. Source Category 2C – Metal Production

4.4.1. Source Category Description

Key category 2C3
The CO_2 emissions and PFC emissions in Aluminium Production (2C3) are key categories regarding trend.

Source category 2C “Metal Production” comprises non-energy emissions from the production of iron and steel, ferroalloys, aluminium as well as from the use of SF_6 in aluminium and magnesium foundries and from other metal production.

Table 70 Specification of source category 2C “Metal Production”.

2C	Source	Specification	Data Source
2C1	Iron and Steel Production	Emissions from the production of Iron and Steel. Also included are emissions from the production of Ferroalloys including consumption of fossil fuels.	AD, EF: EMIS
2C2	Ferroalloys Production	Included in 1C1.	
2C3	Aluminium Production	Emissions from the production of Aluminium	AD: Industry Data, www.alu.ch EF for PFC: Industry Data EF other gases: EMIS
2C4	Use of SF_6 in Aluminium and Magnesium Foundries	Emissions from use of SF_6 in Aluminium and Magnesium Foundries	AD, EF: Industry Data, www.alu.ch EF: EMIS
2C5	Other	Not occurring in Switzerland	

4.4.2. Methodological Issues

Methodology

In Iron and Steel Production (2C1) a country specific approach is used to calculate CO_2, NO_x, CO, NMVOC and SO_2 emissions. The emissions are calculated by multiplying the annual production output of steel (level of activity) by emission factors.

In Aluminium Production (2C3) a country specific approach is used to calculate CO_2, NO_x, CO, NMVOC and SO_2 emissions. The emissions are calculated by multiplying the annual production output of aluminium (level of activity) by emission factors.

Emission data for PFC is based on a Tier 3b approach. Operating smelter emissions have been monitored periodically by the industry for selected years. The only Swiss factory has its own measurements for 1990, 1999 and 2000, which demonstrate smaller EFs than the European average (by factors of 3.9, 4.7 and 5.1, respectively, for those years) (Alcan 2003). Therefore a “general reduction factor” of 4.0 for both gases is adopted on the average European values as reported from the European Aluminium Association (Alcan 2002). The resulting emission factors for Switzerland are still within the uncertainty range as per IPCC GPG. To calculate the emissions factor for the year 2004 without measured emission data the European average emission factor (0.15 kg_{PFC}/t_{AL}) (IAI 2005) with a correction factor of 0.25 is being used. This results to 0.0375 kg_{PFC}/t_{AL} and the ratio of 90% CF_4 and 10% C_2F_6 is being applied. Emissions are calculated by multiplying annual production by emission factors.

SF_6 is used in aluminium foundry industry in the cleaning process. The Swiss Foundry Association (GVS) has not provided information on emission factors and hence the total imported amount of SF_6 as per the import statistic is reported as actual emission.

Emission Factors

The emission factors for CO_2, NO_x, CO, NMVOC and SO_2 emissions per ton of metal product are country specific. They are based on measurements and data from industry and expert estimates, documented in the EMIS database (see Section 1.4.3).

For CO_2 emissions from Iron and Steel Production (2C1), an emission factor of 135 kg CO_2 per ton of steel produced is used (EMIS).

For CO_2 emissions from Aluminium Production (2C3), an emission factor of 1.6 ton CO_2 per ton of aluminium is used (EMIS). This CO_2 stems from the Oxidation of the Anode in the electrolysis process ("Schmelzflusselektrolyse"). The emissions factor is based on an estimate of the amount of anode material used. In Switzerland only pre-backed processes are used. The CO_2-EF is calculated with 0.43 tons of coke (for the anode production) per ton of aluminium (value from Swiss foundries, value for 1990, assumed to be constant over the time series).

For PFC emissions the emission factors have decreased since 1990 by a factor of more than 4 due to technical efforts to reduce emissions (Alcan 2003).

The factors according to Table 71 are used.

Table 71 PFC emissions factors for aluminium production in Switzerland.

Year	Emission factor (kg/t)	
	CF_4	C_2F_6
1990	0.1530	0.0170
1991	0.1373	0.0153
1992	0.1215	0.0135
1993	0.1058	0.0118
1994	0.0900	0.0100
1995	0.0833	0.0093
1996	0.0765	0.0085
1997	0.0698	0.0078
1998	0.0630	0.0070
1999	0.0540	0.0060
2000	0.0360	0.0040
2001	0.0360	0.0040
2002	0.0360	0.0040
2003	0.0360	0.0040
2004	0.03375	0.00375

Activity Data

Activity data on metal production (without aluminium and magnesium) is based on data from industry and expert estimates, documented in the EMIS database (see Section 1.4.3).

Since 1995 data on aluminium production is based on data published regularly by the Swiss Aluminium Association (www.alu.ch). For earlier years, the data provided directly from aluminium industry is used.

SF_6 is used in Swiss magnesium foundries since 1997 and is presently used in two factories. The factories report directly the use of SF_6.

Activity data for source categories 2C1 Iron and Steel and 2C3 Aluminium are given in the following table:

Table 72 Activity data for 2C1 and 2C3 in Metal Production.

Source/production	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
2C Metal Production											
2C1 Iron and Steel	Gg	1'198	1'227	1'313	1'330	1'285	776	790	842	937	975
2C3 Aluminium	Gg	87.0	81.9	75.4	36.4	24.2	20.7	26.6	27.3	32.3	34.4

Source/production	Unit	2000	2001	2002	2003	2004
2C Metal Production						
2C1 Iron and Steel	Gg	1'078	1'097	1'162	1'143	1'134
2C3 Aluminium	Gg	35.5	36.3	40.2	43.9	44.9

The table above documents the decrease of aluminium production by almost 50% from 1990 to 2004. This decline results in CO_2 and PFC emissions from category 2C3 being a key category regarding trend (however not regarding level).

4.4.3. Uncertainties and Time-Series Consistency

Uncertainty in CO_2 and PFC emissions from Aluminium Production in 2C3

Production data of aluminium industry stems directly from the industry association with high confidence (estimated uncertainty 5%). For emission factors of CO_2 and PFC no default values are provided in IPCC 2000. The uncertainty for CO_2 emissions is roughly estimate as 30%. For PFC, an emission uncertainty of 48% (with normal distribution) is assumed, which is a result of the Monte Carlo simulation of the emissions of synthetic gases (Carbotech 2006, see also Table 9).

Qualitative estimate of uncertainties of non-key category emissions in 2C

A preliminary uncertainty assessment of non-key category emissions in 2C based on expert judgment results in medium confidence in emissions estimates.

The time series is consistent.

4.4.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the check between EMIS and Internal GHG Files (Section 1.4.3) and the general QA/QC measures described in Section 1.6.1 have been carried out.

4.4.5. Source-Specific Recalculations

In the previous years SF_6 from Aluminium Foundries in 2C4 had been reported under Solvents in category 2F5. This was due to the structure of the relevant import statistics. On the basis of different discussions this was identified as being incorrect. In 2004 the declaration is corrected and also the activity data in this category for previous years has been changed. This results in higher emissions for this category as compared to the previous reports. However the total overall emissions for the synthetic gases remain and it is only a matter of reallocation to different categories.

See also Chapter 9.

4.4.6. Source-Specific Planned Improvements

The report of the individual review of the GHG inventory submitted in 2005 (UNFCCC 2006) suggested under point 43 a more transparent reporting regarding technology changes which lead to reduction of emission factors that have reduced PFC emissions from Aluminium production. The available time was too short to obtain detailed information from the industry. It however is foreseen to include detailed information in the 2007 submission.

4.5. Source Category 2D – Other Production

Source category 2D "Other Production" is **not a key category.**

All emissions from Pulp and Paper and Food and Drink production are included under source category 2G - Other.

4.6. Source Category 2E – Production of Halocarbons and SF_6

No emissions occurring in this sector within Switzerland. There is no production of HFC, PFC or SF_6 in Switzerland.

4.7. Source Category 2F – Consumption of Halocarbons and SF_6

4.7.1. Source Category Description

Key category 2F
PFC from consumption of halocarbons and SF_6 (2F) is a key category regarding trend (no. 24 in Table 6)

Key category 2F1
HFC from consumption of halocarbons and SF_6; Refrigeration and air conditioning equipment (2F1) is a key category regarding level and trend (no. 26 in Table 6).

Key category 2F_o
Definition: 2F_o (HFC) includes all HFC sources from 2F without 2F1 (no. 25 in Table 6). 2F_o (HFC) is a key category regarding trend.

See also Chapter 1.5 and Annex A1 on key categories.

Source category 2F comprises HFC, PFC and SF_6 emissions from consumption of the applications listed below.

Table 73 Specification of source category 2F “Consumption of Halocarbons and SF_6”. Data source “import statistics”: Carbotech 2006.

2F	Source	Specification	Data Source
2F1	Refrigeration and Air Conditioning Equipment	Emissions from Refrigeration and Air Conditioning Equipment	AD: Various national statistics[15] and industry data EF: Industry data
2F2	Foam Blowing	Emissions from Foam Blowing, incl. Polyurethane Spray	AD: Industry data EF: Expert estimates
2F3	Fire Extinguishers	Not occurring in Switzerland	
2F4	Aerosol / Metered Dose Inhalers	Emissions from use as aerosols, incl. metered dose inhalers	AD: Import statistics EF: IPCC default values
2F5	Solvents	Emissions from use as solvents	AD: Import statistics EF: IPCC default values
2F6	Other applications using ODS substitutes	Not occurring in Switzerland	
2F7	Semiconductor Manufacturing	Emissions from use in semiconductor manufacturing	AD: Import statistics EF: IPCC default values
2F8	Electrical Equipment	Emissions from use in electrical equipment	AD: Industry data EF: Industry data
2F9	Other	Emissions of SF_6 which are not yet accounted under 2F8	AD: Industry data EF: Industry data

The following graph shows emissions in source category 2F by sub-sector and by different groups of gases. Refrigeration and air conditioning equipment account by far for the highest emissions in this source category with a share of 68% of the total emissions in the source category 2F.

[15] e.g. statistics on registration of cars and trucks, import statistics on synthetic gases (Carbotech 2006)

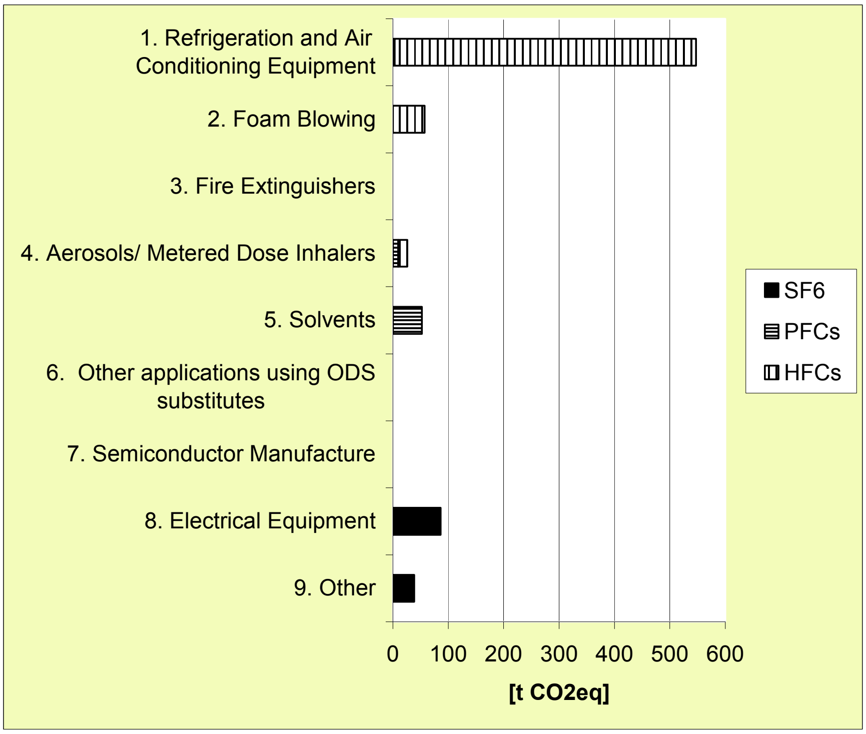


Figure 22 Distribution of emissions under source category 2F “Consumption of Halocarbons and SF_6“ (2004 data).

4.7.2. Methodological Issues

The data models used for source category 2F are complex and therefore a comprehensive documentation of all relevant model parameters is not possible in the framework of the NIR. Annex A3.3 shows an illustrative example of the model structure and parameters used for calculating emissions from mobile air-conditioning in cars. Where possible, the most important assumptions for the data model are documented (e.g. Table 74). Detailed documentation of the individual data models is available from Carbotech 2006 and related background documents. This information is SAEFL internal due to confidentiality of data, but is open for consultation by reviewers.

2F1 Refrigeration and Air Conditioning Equipment

Methodology

The inventory under this sub-source category includes the following types of equipment: domestic refrigeration, commercial and industrial refrigeration, transport refrigeration, stationary air conditioning, mobile air conditioning, and heat pumps. For each of these types of equipment individual emission models are used for calculating actual emissions as per IPCC GPG Tier 2. In order to obtain the most reliable data for the calculations, two different approaches are applied to get the stock data needed for the model calculations: ‘top down’ using available statistics or estimations on the Swiss market from experts and associations and ‘bottom up’ through questionnaires sent to companies active in importation, production and service of appliances.

Emission Factors

Emission factors for manufacturing, product life and disposal as well as average product life times are established on the basis of expert judgement. Table 74 displays the detailed model parameters used. For product life emission factors a dynamic model is applied which implies that emission losses improve linearly between 1995 and 2010 due to better production technologies. The start/end values are based on expert statements and Schwarz 2001.

Table 74 Typical values on life time, charge and emission factors used in model calculations for Refrigeration and Air Conditioning Equipment. Where values in brackets are provided, the first value shows the assumption for 1995 while the second value (in brackets) shows the assumption for 2010. Data between 1995 and 2010 is linearly interpolated.

Equipment type	Product life time [a]	Initial charge of new product [kg]	Manufacturing emission factor [% of initial charge]	Product life emission factor [% per annum]	Charge at end of life [% of initial charge of new product] *)	Disposal loss emission factor [% of remaining charge
Domestic Refrigeration	12	0.1	2	0.5	92	37
Commercial and Industrial Refrigeration	12	NR	1	10 (5)	100	10
Transport Refrigeration / Trucks	8	1.8 … 7.8	1	15	100	20
Transport Refrigeration / Railway	NA	NR	NO	10	100	20
Stationary Air Conditioning (direct / indirect cooling system)	10 / 15	1.6 … 3.1 / 18.5	1	10 (3) / 6 (4)	100	28 / 19
Heat Pumps	15	4.7 …7.5 till 1999 Going down to 2.8 …4.5 in 2010	1	0.65	100	10
Mobile Air Conditioning / Cars	12	0.78	NO	8.5 (3)	60	100 (30)
Mobile Air Conditioning / Trucks	10	1.1	NO	10 (8.5)	35	100 (30)
Mobile Air Conditioning / Railway	12	20	NO	4	100	10

*) takes into account refill of losses during product life where applicable

NA = not available
NR = not relevant as only aggregate data is used
NO = Not occurring (only import of charged units)

Activity Data

Activity data is taken from industry information and national statistics such as for admission of new cars and trucks. Stock data is modelled dynamically. Due to the large number of sub-models used for modelling the total emissions for sub-source category 2F1, no table on time series of activity data is provided here, despite 2F1 being a key category. For illustration, the detailed calculation model for car air-conditioning including the time series for the activity data for this particular sub-model can be seen from Annex A3.3. Car air-conditioning accounts for approx. 29% of the total emissions (CO_2 eq) of sub-source category 2F1 Refrigeration and Air Conditioning Equipment.

2F2 Foam Blowing

Methodology

In Switzerland no production of open cell foam based on HFCs is reported by the industry. Therefore only closed cell PU and XPS foams, PU spray applications and sandwich elements are relevant under this source category.

The emission model (Tier 2) for foam blowing has been developed 'top down' based on import statistics for products and expert assumptions for market volumes and emission factors. Emissions for sandwich elements have been calculated as residual balance between SAEFL import statistics and consumption in PU spray, PU and XPS foams.

Emission Factors

For emission factors and lifetime of XPS and PU foam, general default values according to IPCC are being used (IPCC 2000: p. 3.95). For PU spray, specific default values according to IPCC are being used (IPCC 2000: p. 3.96).

Table 75 Typical values on life time, charge and emission factors used in model calculations for foam blowing.

Application		**Product life time** years	**Charge of new product** % of product weight	**Manufacturing emission factor** % per annum	**Product life emission factor** % per annum	**Charge at end of life** % charge of new product
PU foam		50	4.5	NR	NR	NR
XPS foam	HFC 134a HFC 152a	50	6.5	10	10 / 0.7** 100 / 0**	35% 0%
PU spray		50	10.6 / 4.6 /4.6 *	0.7	95 / 2.5 **	0
Sandwich Elements		50	3	10	0.5	65

* Data for 1990 / 2000 / 2004

** Data for 1st year / following years

NR Not relevant, because no substances according to this protocol has been used, all emissions occur outside Switzerland during production

Activity Data

The export rate of PU spray from Swiss production is 96.5% of total production volume. For PU and XPS foams the export rate is around 20%. This has been taken into account. From 2000 onwards there is no production of XPS in Switzerland. The imported products have been taken into account.

Detailed activity data for this sub-source category is available at FOEN but not reported due to confidentiality.

2F3 Fire Extinguishers

No emissions occurring in this sector within Switzerland. The application of HFC, PFC and SF_6 in fire extinguishers is prohibited by law.

2F4 Aerosol / Metered Dose Inhalers

Methodology

The Tier 2 emission model for Aerosol / MDI is based on a ‘top down’ approach using import statistics for HFCs.

Emission Factors

An emission factor of 50% in the first and in the second year, respectively, is applied in line with IPCC GPG.

Activity Data

In most aerosol applications, HFC has been replaced already in the past years. According to the information of companies filling aerosol bottles for use in households, e.g. cosmetics, cloth care and paint, no HFC is being used. For special technical applications - especially metered dose inhalers (MDI) - HFC is still in use. Compared to the total amount of aerosol applied, the HFC use for MDI is considered to be irrelevant.

Activity data is based on import statistics. Detailed activity data for this sub-source category is available at FOEN but not reported due to confidentiality.

2F5 Solvents

Methodology

The use of HFC as solvent is not occurring in Switzerland. PFC emissions are calculated according to Tier 1 method according to IPCC GPG on basis of a ‘top down’ approach using import statistics.

In the previous years SF_6 from Aluminium Foundries in 2C4 had been reported under Solvents in category 2F5. This was due to the structure of the relevant import statistics. On the basis of different discussions this was identified as being incorrect. For 2004 data the declaration is corrected and also the activity data in this category for previous years has been changed. This results in higher emissions for this category as compared to the previous reports. However, the total overall emissions for the synthetic gases remain and it is only a matter of reallocation to different categories.

In the previous year all CF_4 emissions had been reported under “Other” in category 2F9. Further analysis has shown that the relevant PFC consumption can be attributed to laboratory and analytical uses. Therefore the consumption is now reported under “Solvents” in category 2F5. This has impact on the 2003 and 2004 data only and results in higher emissions for the category 2F5 “Solvents” as compared to the previous report. However, the total overall emissions for the synthetic gases remain unchanged and the modification is a matter of reallocation to different categories.

Emission Factors

An emission factor of 50% in the first and in the second year, respectively, is applied in line with IPCC GPG.

Activity Data

Activity data is based on import statistics. Detailed activity data for this sub-source category is available at SAEFL but not reported due to confidentiality.

2F6 Other applications using ODS substitutes

No emissions occurring in this sector within Switzerland.

2F7 Semiconductor Manufacturing

Methodology

No HFC, PFC and SF_6 emissions were considered for semiconductor manufacturing in 2004. The import of substances by firms delivering to semiconductor industry has mostly been declared as being used for “Syntheses / Laboratory” and “Other” and is reported under sub-source category 2F9. A small left over amount which might still be used for semiconductor manufacturing is considered not to be relevant.

2F8 Electrical Equipment

Methodology

Under an agreement with FOEN, the industry association SWISSMEM is reporting actual emissions of SF_6 on basis of a mass balance approach (Tier 3a), including data for production of electrical equipment, installation, operation and disposal.

Emission Factors

Emission factors for this sub-source category are based on industry information. The product life emission factor is varying between 0.45%/a (2001) and 0.65%/a (2004).

Activity Data

Activity data is based on industry information. The wide annual fluctuation of SF_6 emissions from electrical equipment is related to the annual fluctuation of market volumes for such equipment.

2F9 Other

Methodology

The emissions reported under 2F9 relate to windows and a small amount of unallocated SF_6 from the SWISSMEM mass balance (see above under 2F8) and since 2003 further applications such as laboratory and syntheses use. The unallocated emissions of SF_6 from the SWISSMEM mass balance have been assigned to cables and electrical control systems using a Tier 2 approach. For laboratory and syntheses uses no modelling has been possible due to lack of information. Therefore, only the activity data is reported.

Emission Factors

For windows a production emission factor of 33% and an operation emission factor of 1% per annum are applied with 100% of the remaining charge being emitted at time of disposal. Emission at time of disposal is however not yet relevant for emissions until 2008due to the long lifetime of the windows of 25 years.

For cables and electrical control systems the production emission factor is assumed at 4% and the operation emission factor at 1%. 100% of the remaining charge is emitted at time of disposal after 40 years lifetime.

Activity Data

Activity data is based on industry information. 80% of the production of cables and electrical control systems is exported.

4.7.3. Uncertainties and Time-Series Consistency

For refrigeration equipment, air-conditioning equipment as well as for the foam blowing source category, a Monte Carlo analysis according to IPCC Good Practice Guidance for the evaluation of uncertainties of model calculations according to Tier 2 has been carried out. The Monte Carlo Analysis was performed on the inventory data for 2004. It must be noted that the uncertainty analysis presented in the next paragraphs is not based on the data of the current GHG inventory (November 2006) but on the data submitted on 12 April 2006 (FOEN 2006a). For the purpose of the Monte Carlo Analysis, uncertainty of all relevant parameters (e.g. initial appliance charge, operation emission factor, import and export volumes, etc.) used in the emission models for the applications as per Table 77 below has been characterised by a statistical distribution. Frequently a triangular distribution was chosen, defined by the three parameters: minimum, maximum and most likely value. Some uniform distributions were chosen where the spectrum was assumed to have the same probability. In the other cases normal or Log normal distribution has been chosen. The analysis was carried out with 1000 cycles. Details on the distributions of parameters used (i.e. type of distribution, minimum, maximum, likeliest value) are documented in Carbotech 2006.

In this year for the first time also the uncertainty for the import statistic data has been estimated. Discussions with the persons responsible for data collection in the years 1997–2003 lead to the estimations given in Table 76.

The introduction of this uncertainty in the Monte Carlo analysis resulted in some applications in higher uncertainties compared to those reported in the previous years. This does however not mean that the uncertainty of the data has increased. It only means that the error estimation has improved.

Table 76 Estimated uncertainty for the data of the imported substances

Year	Minimal	Maximal	remarks
Up to 1999	- 10%	+30%	assumed that the data are not complete
2000 – 2003	-10%	+15%	data can be incomplete or possible double declaration
2004	-10%	+10%	

The following table summarises the results for the application-specific emission models. The "value 2004" represents the actual emissions in Gg CO_2 equivalent for the specific application as used for calculating the 2004 CRF tables. The average, median, uncertainty, minimum and maximum values are output values of the Monte Carlo Analysis.

Uncertainties with a standard deviation of more than 10% have been calculated for the following applications:

- Foam blowing
- Transport refrigeration
- Domestic refrigeration

These three applications have a contribution to the GHG potential of the synthetic gases of less than 10%. Therefore it seems not a priority issue to make major efforts for reducing these uncertainties.

Medium uncertainties of 7% to 10% have been calculated for the following applications:

- Commercial Refrigeration
- Mobile Air Condition
- Stationary Air Condition

These three applications make a contribution to the total GHG potential of the synthetic gases of about 50%. So it seems to be important to make an effort in reducing these uncertainties. More detailed information and therefore less uncertainties is to be expected for the next years regarding stationary air-conditioning and commercial and industrial refrigeration due to the new declaration of products with more than 3 kg refrigerant.

For the model calculations of stocks, uncertainties result with a maximum of 18% for R134a in Commercial/ Industrial Refrigeration and 17% for domestic refrigeration. Calculation of stocks is not reported in detail here because the uncertainties for stock and new filled refrigerant related to the split of refrigerant on different applications is of less relevance for the overall emissions. This is because different applications show similar characteristics for the building of stocks and related emissions. Detailed data is available with FOEN.

Relevant parameters for the building of stock in PU-foam are the PU-foam export rate and the PU-Spray first year emission factor. The data base for PU-Sprays has been significantly improved compared to previous years. This is attributed to improved models which are elaborated by the main producer and its blowing agent import firm. However, the high export rate of PU-Spray and the high emission factor of the first year lead to a small amount remaining in the stock with a relative high uncertainty.

Table 77 Summary of results for model parameter "emissions" from Monte Carlo Analysis for 2004 data on selected emission sources.

Application	**Model para-meter**	**value 2004** Gg CO_2 eq.	**Average** Gg CO_2 eq.	**Median** Gg CO_2 eq.	**Uncer-tainty (st. dev.)** %	**Quality Level** -	**min.** Gg CO_2 eq.	**max.** Gg CO_2 eq.
Commercial / Industrial Refrigeration	Emissions in Gg CO_2 eq.	293	257	256	8	Medium	184	320
Mobile Air-Conditioning		156	176	174	10	Medium	137	230
Stationary Air-Conditioning		82	97	96	10	Medium	67	133
Foam Blowing		59	62	62	11	Medium	44	89
Transport Refrigeration		15	13	13	15	Medium	9	17
Domestic Refrigeration		0.65	0.65	0.65	12	Medium	0.47	0.92
Others		40	52	40	-		34	196
Metal Production		62	62	62	5		53	71
Total		884	985	980	6		843	1214

As a result of the Monte Carlo simulation for the synthetic gases an overall uncertainty of 6% results.

The time series is consistent for all source categories, with exception of the sub-source category "Electrical Equipment" (2F8) where from 2000 onwards the data is based on a Tier 3a approach instead of model calculations according to Tier 2 as applied for data before 2000. Due to lack of basic information it is not possible to provide a consistent time series for category Electrical Equipment (2F8) retroactively.

4.7.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the check between EMIS and Internal GHG Files (Section 1.4.3) and the general QA/QC measures described in Section 1.6.1 have been carried out.

4.7.5. Source-Specific Recalculations

Table 78 Summary of recalculations in source category 2F.

Category	**Remarks**
Foam blowing	PU-Spray 1990 to 2004 The new distribution of the gases 134a and 152a used in PU-sprays evaluated by

	producer and importer was used also for the years 1990–2000 A new model for sandwich panels is applied, which was developed on basis of new information from the importer
Transport refrigeration	Number of vehicles corrected 2000 to 2004 Statistic of new registered vehicles till September 2004 projected to the whole year
Domestic refrigeration	The modelling of disposal has been improved. This lead to lower stocks in the following years and by consequence to lower emissions
Commercial Refrigeration	Improved modelling taking into account better data on emission factors, lifetime and disposal
Air-Conditioning	New emission factors used There was a mistake in the tier 1 calculation New modelling of the disposal Rest amount 407c applied for replacement of R22 and assuming more 407c being used in Switzerland
Heat pumps	Changes for emission factors, amount of cooling agents and disposal according to literature data
Refrigeration generally	Emission factor disposal and model calculations disposal have been improved
Mobile air condition	New modelling of the disposal, this lead to a difference in the year 2003 of less than 0.4%, but has an influence for the trend calculation up to 8% in the year 2010 There was a wrong link to the trend calculation There was a mistake in allocation of R404 refrigerant which has been corrected. This has also some impact on Commercial Refrigeration, Transport Refrigeration and Air Conditioning
Solvents	In the last years SF_6 used for the cleaning of aluminium was reported in the category solvents. This was changed now also for the past years (New assignment of imported F-gases from solvent to metal production). No change in the overall emissions A calculation mistake in the model was corrected CF_4 emission which was earlier reported under “Other” is now reported under “Solvents”. This has impact on the 2003 and 2004 data only. The total of emissions over the years remains There was a wrong link to the trend calculation.
Windows	New emission factor in production of windows, according to experts interviews found in literature, leading to changes in the period since 1990. Shorter life time leading to another disposal modelling with higher trend in the year 2010.

See also Chapter 9.

4.7.6. Source-Specific Planned Improvements

Gradual improvement of the data quality in co-operation with industry is ongoing. As in the past years, methodologies and emission models will be updated during the yearly process of F-gas inquiry. The focus will be on improvements of HFC-emission calculations from refrigeration and air-conditioning equipment.

The individual review of the GHG inventory submitted in 2005 (UNFCCC 2006) suggested under point 45 that potential emissions by sources should be filled in CRF table 2(I): Sectoral Report for Industrial Processes. Though the data is in general available it was not possible to fulfil the request of the reviewers due to the short available time between receipt of the review report and the submission deadline for the inventory. It however is foreseen to include potential emissions in future submissions.

4.8. Source Category 2G – Other

4.8.1. Source Category Description

Source category 2G “Other” is **not a key category**.

Source category 2G “Other” comprises non-energy emissions from the production in other industries, including food, drink, pulp, and paper industries.

Table 79 Specification of source category 2G “Other”.

2G	Source	Specification	Data Source
2G	Other	Emissions from the production and application of roofing fabrics, from the production of charcoal, chipboard, fibreboard, cellulose, from the production of beer, wine, alcoholics, bread, smoked meat, coffee, sugar and from the use of explosives in the production of gypsum, blasting and shooting, and from Claus-units in refineries. In the Swiss inventory, source category 2G includes the sources pertaining to source category 2D.	AD, EF: EMIS

4.8.2. Methodological Issues

Methodology

In Switzerland source category 2G “Other” represents a comprehensive set of industrial processes: production and application of roofing fabrics, the production of charcoal, chipboard, fibreboard, cellulose, the production of beer, wine, alcoholics, bread, smoked meat, coffee, sugar and the use of explosives in the production of gypsum, blasing and shooting, as well as the use of Claus-units in refineries (sulphur extraction process). Several processes reported under 2G would be part of CRF category 2D Other Production: Pulp and Paper, Food and Drink. (The present categorisation is due to a former version of EMIS.)

For the sources in 2G a country-specific approach is used to calculate CO_2, CH_4, NO_x, CO, NMVOC and SO_2 emissions. The emissions are calculated by multiplying the annual production output (level of activity) by emission factors.

Emission Factors

The emission factor for CO_2, CH_4, NO_x, CO, NMVOC and SO_2 emissions per ton of product produced are country specific. They are based on measurements and data from industry and expert estimates, documented in the EMIS database (see Section 1.4.3).

Activity Data

Activity data on production of products in category 2G is based on data from industry and expert estimates, documented in the EMIS database (see Section 1.4.3).

4.8.3. Uncertainties and Time-Series Consistency

A preliminary uncertainty assessment based on expert judgment results in medium confidence in emissions estimates.

The time series is consistent.

4.8.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the check between EMIS and Internal GHG Files (Section 1.4.3) and the general QA/QC measures described in Section 1.6.1 have been carried out.

4.8.5. Source-Specific Recalculations

All emissions have been recalculated for the time series 1990–2003 due to the revision of the EMIS database. See Chapter 9.

4.8.6. Source-Specific Planned Improvements

Transfer of processes Pulp and Paper, Food and Drink from 2G into 2D.

5. Solvent and Other Product Use

5.1. Overview

Emissions within this sector comprise NMVOC emissions from the use of solvents and other related compounds. It also includes indirect CO_2 emissions from the atmospheric decomposition of NMVOC.

Further included are evaporative emissions of N_2O, NO_x, CO and SO_2 arising form other types of product use (firework, impregnation of mineral wool) as N_2O emissions from medical use. The disposal of solvents is reported in category 6 Waste (in Chapter 8). Emissions from the use of halocarbons and sulphur hexafluoride are reported in the Industrial Processes Chapter under 2F. Other non-energy emissions not included under Industrial Processes are reported in this chapter.

Key category 3

Emissions of CO_2 and N_2O from source category 3 "Solvent and Other Product Use" are key categories regarding trend (both) and level (only CO_2).

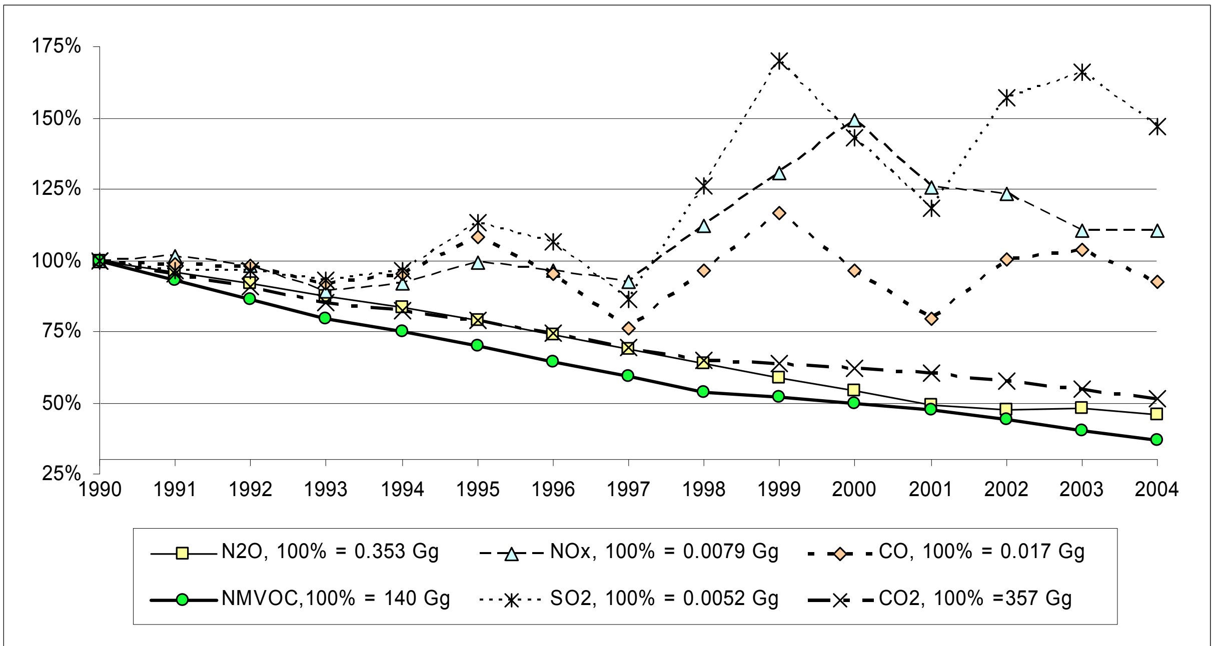


Figure 23 Overview over emissions in category 3 Solvent and Other Product Use in Switzerland. Note that CO_2 and NMVOC emissions evolve highly correlated.

Table 80 Emissions of source category 3 Solvent and Other Product Use.

Gas	unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
CO_2	Gg	357	339	323	304	294	281	265	248	232	227	222	217	206	197	186
N_2O	t	353	339	324	309	294	278	261	243	225	208	191	173	168	169	162
NO_x	t	7.9	8.0	7.8	7.0	7.3	7.8	7.6	7.3	8.8	10.3	11.8	9.9	9.7	8.7	8.7
CO	t	17	17	17	16	16	18	16	13	16	20	16	13	17	18	16
NMVOC	Gg	140	130	121	111	105	98	90	83	76	73	70	67	62	57	51
SO_2	t	5.2	5.0	5.0	4.8	5.0	5.9	5.5	4.5	6.5	8.8	7.4	6.1	8.1	8.6	7.6

NMVOC emissions have diminished since 1990 by -63% mainly due to two reduction efforts: The limitation of the application of NMVOC brought by the ordinance on Air Pollution Control

(Swiss Confederation 1985) and the introduction of the VOC-tax in 2000 (Swiss Confederation 1997). Also CO_2 and N_2O emissions decreased significantly. The other emissions have increased since 1990 or remained stable.

CO, NO_x and SO_2 emissions mainly stem from burning of fireworks. Imports of Fireworks were significantly fluctuating in the period 1993–2004 causing the variation of the emissions. The time series of NO_x emissions differ from CO and SO_2: They are not only dependent on fireworks consumption but on the impregnation of mineral wool too, which has been decreasing since 2000.

5.2. Source Category 3A – Paint Application

5.2.1. Source Category Description

Source category 3A “Paint Application” comprises NMVOC emissions from paints, lacquers, thinners and related materials used in coatings in industrial, commercial and household applications. Also, it includes indirect CO_2 emissions resulting from post-combustion of NMVOCs to reduce NMVOCs in exhaust gases.

Table 81 Specification of source category 3A “Paint Application”.

	Source	Specification	Data Source
3A	Paint Application	Paint application in households, industry and construction	AD, EF: EMIS, SAEFL 2003

5.2.2. Methodological Issues

Methodology

For paint application (3A) a bottom-up country specific method based on the consumption of paint and its solvent content is used.

The indirect CO_2 emissions from NMVOC are calculated from the average carbon contents of NMVOC emissions for the subcategory 3A based on methodology and data from the Netherlands [RIVM 2005: p. 5-2ff.], assuming that the type and characteristics of solvents used in Switzerland are roughly similar.

Emission Factors

Emission factors for NMVOC are country specific based on data from industry, documented in the EMIS database.

For paint application in households, as the most important source, the emission factor of 120 kg NMVOC/t paint for the year 2004 is based on expert estimates (EMIS).

The emission factor for the indirect CO_2-emissions from NMVOC for 3A is 2.35 Gg CO_2/Gg NMVOC [RIVM 2005: p. 5-2ff.].

Activity Data

The activity data correspond to the annual consumption of paints. They are based on data from industry, documented in the EMIS database.

For paint application in households, as the most important source, the activity data equals the consumption of 20'000 t paint in 2004 (EMIS).

5.2.3. Uncertainties and Time-Series Consistency

The uncertainty assessment (EMIS) results in medium confidence in emissions estimates.

The uncertainty of total CO_2 emissions from the entire category 3 Solvent and Other Product Use is estimated to be 50% (expert estimate). The uncertainty of N_2O emissions from the entire category 3 is estimated to be 80% (expert estimate).

Time series is consistent.

5.2.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the check between EMIS and Internal GHG Files (Section 1.4.3) and the general QA/QC measures described in Section 1.6.1 have been carried out.

5.2.5. Source-Specific Recalculations

All emissions have been recalculated for the time series 1990–2003 due to the revision of the EMIS database and the inclusion of indirect CO_2 emissions from NMVOC. See Chapter 9.

5.2.6. Source-Specific Planned Improvements

Gradual improvement of the data quality in co-operation with industry is ongoing.

5.3. Source Category 3B – Degreasing and Dry Cleaning

5.3.1. Source Category Description

Source category 3B "Degreasing and Dry Cleaning" comprises NMVOC emissions from degreasing, dry cleaning and cleaning in electronic industry. Also, it includes indirect CO_2 emissions resulting from post-combustion of NMVOCs to reduce NMVOCs in exhaust gases.

Table 82 Specification of source category 3B "Degreasing and Dry Cleaning".

	Source	**Specification**	**Data Source**
3B	Degreasing and Dry Cleaning	Degreasing, Dry Cleaning, Cleaning of electronic components, cleaning of parts in metal processing, other industrial cleaning.	AD, EF: industry data, EMIS, SAEFL 2003

5.3.2. Methodological Issues

Methodology

For degreasing and dry cleaning (3B) a country specific method based on the consumption of solvents and the resulting emissions is used.

The indirect CO_2 emissions from NMVOC are calculated from the average carbon contents of NMVOC emissions for the subcategory 3B based on methodology and data from the

Netherlands [RIVM 2005: p. 5-2ff.], assuming that the type and characteristics of solvents used in Switzerland are roughly similar.

Emission Factors

Emission factors for NMVOC are country specific based on data from industry and expert estimates, documented in the EMIS database.

Degreasing of metal is the most important source in 3B. Its emission factor of 350 kg NMVOC per ton of solvent for 2004 is based on an industry survey (EMIS).

The emission factor for the indirect CO_2-emissions from NMVOC for 3B is 2.24 Gg CO_2 per Gg NMVOC [RIVM 2005[16]: p. 5-2ff.].

Activity Data

The activity data are based on data from industry and expert estimates, documented in the EMIS database.

The activity data for degreasing of metal (5'900 t solvent in 2004), as the most important source, is based on an industry survey (EMIS).

5.3.3. Uncertainties and Time-Series Consistency

The uncertainty assessment (EMIS) results in medium confidence in emissions estimates.

The uncertainty of total CO_2 emissions from the entire category 3 Solvent and Other Product Use is estimated to be 50% (expert estimate). The uncertainty of N_2O emissions from the entire category 3 is estimated to be 80% (expert estimate).

The time series is consistent.

5.3.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the check between EMIS and Internal GHG Files (Section 1.4.3) and the general QA/QC measures described in Section 1.6.1 have been carried out.

5.3.5. Source-Specific Recalculations

All emissions have been recalculated for the time series 1990–2003 due to the revision of the EMIS database and the inclusion of indirect CO_2 emissions from NMVOC. See Chapter 9.

5.3.6. Source-Specific Planned Improvements

Gradual improvement of the data quality in co-operation with industry is ongoing.

5.4. Source Category 3C – Chemical Products, Manufacture and Processing

5.4.1. Source Category Description

Source category 3C "Chemical Products, Manufacture and Processing" comprises NMVOC emissions from manufacturing and processing chemical products. Also, it includes indirect

[16] There seems to be a typo in the relevant section of the RIVM 2005 regarding the Emission Factor for the indirect CO_2-emissions from NMVOC for 3B.

CO_2 emissions resulting from post-combustion of NMVOCs to reduce NMVOCs in exhaust gases.

Table 83 Specification of source category 3C “Chemical Products, Manufacture and Processing”.

	Source	Specification	Data Source
3C	Chemical Products, Manufacture and Processing	Handling and storage of solvents; fine chemical production; production of pharmaceuticals; manufacturing of paint, inks, glues, adhesive tape, rubber; processing of PVC, polystyrene foam, polyurethane and polyester,.	AD, EF: industry data, EMIS, SAEFL 2003

5.4.2. Methodological Issues

Methodology

For category 3C country specific methods are used. The emissions of fine chemical and pharmaceutical production are based on production and expert estimates. The emissions of handling and storage of solvents are calculated based on the imported quantities. The emissions from manufacturing paint, glues, inks, adhesive tape, rubber and polyurethane as well as the processing of PVC are calculated based on production numbers. The emissions from processing of polystyrene foam and polyester are calculated based on consumption.

The indirect CO_2 emissions from NMVOC are calculated from the average carbon contents of NMVOC emissions for the subcategory 3C based on methodology and data from the Netherlands [RIVM 2005: p. 5-2ff.], assuming that the type and characteristics of solvents used in Switzerland are roughly similar.

Emission Factors

Emission factors for NMVOC are country specific based on data from industry and expert estimates and are documented in the EMIS database. Emission factors for handling and storage of solvents are estimated according to the solvent vapor pressure.

The emission factor for the indirect CO_2 emissions from NMVOC for 3C is 2.31 Gg CO_2 per Gg NMVOC [RIVM 2005: p. 5-2ff.].

Activity Data

The activity data correspond to the annual consumption of solvents. They are based on data from industry and expert estimates, documented in the EMIS database

The activity data for fine chemical production (1'220 t NMVOC in 2004), as the most important source, is based on industry data (EMIS).

5.4.3. Uncertainties and Time-Series Consistency

The uncertainty assessment (EMIS) results in medium confidence in emissions estimates.

The uncertainty of total CO_2 emissions from the entire category 3 Solvent and Other Product Use is estimated to be 50% (expert estimate). The uncertainty of N_2O emissions from the entire category 3 is estimated to be 80% (expert estimate)

Time series is consistent.

5.4.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the check between EMIS and Internal GHG Files (Section 1.4.3) and the general QA/QC measures described in Section 1.6.1 have been carried out.

5.4.5. Source-Specific Recalculations

All emissions have been recalculated for the time series 1990–2003 due to the revision of the EMIS database and the inclusion of indirect CO_2 emissions from NMVOC. See Chapter 9.

5.4.6. Source-Specific Planned Improvements

Gradual improvement of the data quality in co-operation with industry is ongoing.

5.5. Source Category 3D – Other

5.5.1. Source Category Description

Source category 3D “Other” comprises emissions from many different solvent applications. Besides NMVOC also emissions of N_2O, NO_x, CO and SO_2 are relevant. Also, 3D includes indirect CO_2 emissions resulting from post-combustion of NMVOCs to reduce NMVOCs in exhaust gases.

The application of N_2O in households and hospitals and CO2 from the impregnation of mineral wool and the use of fireworks are the only direct greenhouse gas emission considered in this category.

Table 84 Specification of source category 3D “Other”.

	Source	**Specification**	**Data Source**
3D	Other	Use of spray cans in industry and households; domestic solvent use; print industry; application of glues and adhesives; use of concrete additives; removal of paint and lacquer; car underbody sealant; de-icing of airplanes; tanning of leather; impregnating of glass and mineral wool; use of cooling and other lubricants; extraction of oils and fats; use of pesticides; use of pharmaceutical products in households; house cleaning industry/craft/services; hairdressers; scientific laboratories; textile production; paper and paper board production; clothing production; cosmetic institutions; production and use of tobacco products; vehicles dewaxing; wood preservation; medical practitioners; other health care institutions; not attributable solvent emissions; use of N_2O in households and in hospitals; other use of gases; production of perfume /aroma and cosmetics; use of fireworks.	AD, EF: industry data, EMIS, SAEFL 2003

5.5.2. Methodological Issues

Methodology

For category 3D a country specific method based on the production/consumption of the different solvent applications is used.

The emissions from house cleaning, the most important source, is calculated proportional to the population.

The indirect CO_2 emissions from NMVOC are calculated from the average carbon contents of NMVOC emissions for the subcategory 3D based on methodology and data from the Netherlands [RIVM 2005: p. 5-2ff.], assuming that the type and characteristics of solvents used in Switzerland are roughly similar.

Emission Factors

Emission factors for NMVOC are country specific based on data from industry and expert estimates, documented in the EMIS database. The NMVOC emissions from the production of cosmetics, perfume and aroma are calculated per employee, documented in the EMIS database.

Emission factors for N_2O, NO_x, CO and SO_2 are country specific based on data from industry and expert estimates, documented in the EMIS database.

The emission factor for the indirect CO_2-emissions from NMVOC for 3D is 2.53 Gg CO_2/Gg NMVOC [RIVM 2005: p. 5-2ff.].

The emission factor for house cleaning, the most important source, is 1'200 g/inhabitant in 2004, based on Theloke et al. 2000, documented in EMIS.

Activity Data

For the calculation of NMVOC emissions, the activity data correspond to the annual production/consumption of solvents. They are based on data from industry and expert estimates, documented in the EMIS database.

For other emissions, data from EMIS is used.

The activity data for house cleaning, as the most important source, is the number of inhabitants (7'418'000 in 2004).

5.5.3. Uncertainties and Time-Series Consistency

The uncertainty assessment (EMIS) results in medium confidence in emissions estimates.

The uncertainty of total CO_2 emissions from the entire category 3 Solvent and Other Product Use is estimated to be 50% (expert estimate). The uncertainty of N_2O emissions from the entire category 3 is estimated to be 80% (expert estimate)

Time series is consistent.

5.5.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the check between EMIS and Internal GHG Files (Section 1.4.3) and the general QA/QC measures described in Section 1.6.1 have been carried out.

5.5.5. Source-Specific Recalculations

All emissions have been recalculated for the time series 1990–2003 due to the revision of the EMIS database and the inclusion of indirect CO_2 emissions from NMVOC. See Chapter 9.

5.5.6. Source-Specific Planned Improvements

Gradual improvement of the data quality in co-operation with industry is ongoing.

6. Agriculture

6.1. *Overview*

This chapter provides information on the estimation of the greenhouse gas emissions from the agriculture sector (Sectoral Report for Agriculture, Table 4 in the Common Reporting Format). The following source categories are reported:

- CH_4 emissions from enteric fermentation in domestic livestock,
- CH_4, N_2O and NO_x emissions from manure management,
- N_2O, NO_x and NMVOC emissions from agricultural soils,
- CH_4, N_2O, NO_x, CO, NMVOC and SO_2 emissions from field burning of agricultural residues.

Total greenhouse gas emissions from agriculture in 2004 were 5'258 Gg CO_2 equivalents in total which is a contribution of 9.9% to the total of Swiss greenhouse gas emissions. Main agricultural sources of greenhouse gases in 2004 were enteric fermentation emitting 2'271 Gg CO_2 equivalents, followed by agricultural soils with 2'082 Gg CO_2 equivalents.

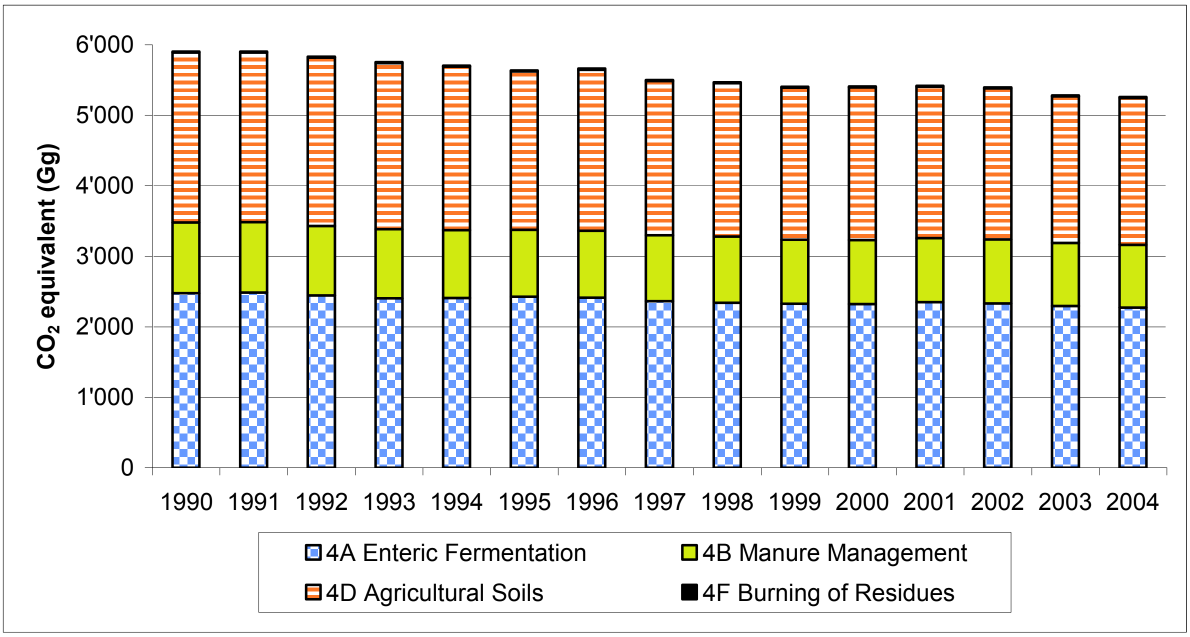


Figure 24 Greenhouse gas emissions in Gg CO_2 equivalents of agriculture1990-2004.

Main greenhouse gases are CH_4 and N_2O. No CO_2 emissions are reported in the agricultural sector. CO_2 emissions from soils are reported under Land-use Change and Forestry. CO_2 emissions from energy use in agriculture are reported under 1A4 Energy; Others Sectors.

Table 85 Greenhouse gas emissions in Gg CO_2 equivalents of agriculture1990-2004.

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	CO_2 equivalent (Gg)														
CO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH_4	3'042	3'048	2'999	2'955	2'950	2'961	2'944	2'890	2'873	2'839	2'833	2'869	2'849	2'804	2'775
N_2O	2'861	2'859	2'833	2'798	2'756	2'677	2'717	2'609	2'595	2'566	2'576	2'549	2'545	2'479	2'483
Sum	5'903	5'907	5'833	5'753	5'706	5'638	5'662	5'499	5'467	5'405	5'409	5'418	5'394	5'282	5'258

CH_4 and N_2O emissions are declining since 1990. This trend can be explained by a reduction of the number of cattle and a reduced input of mineral fertilisers. Emission factors did not change significantly.

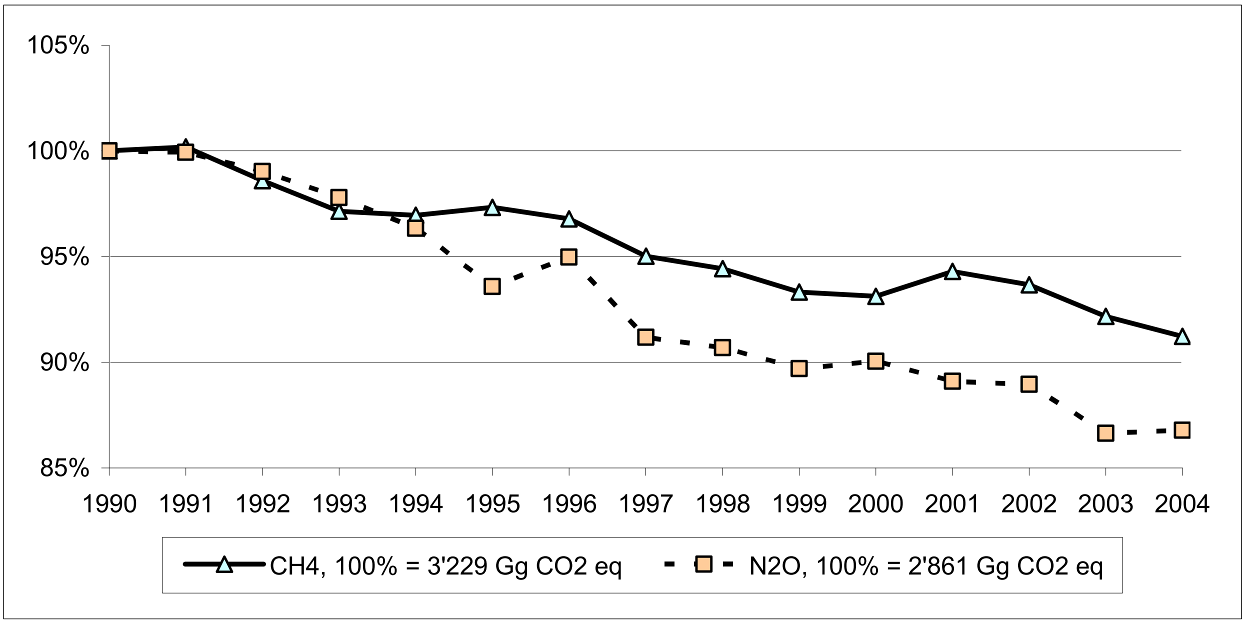


Figure 25 Trend of the greenhouse gases of the agricultural sector 1990-2004. The base year 1990 represents 100%.

Among the key sources of the Swiss inventory, five are out of the agricultural sector: CH_4 emissions from enteric fermentation, CH_4 emissions from manure management, N_2O emissions from manure management, direct N_2O emissions from agricultural soils and indirect N_2O emissions from agricultural soils.

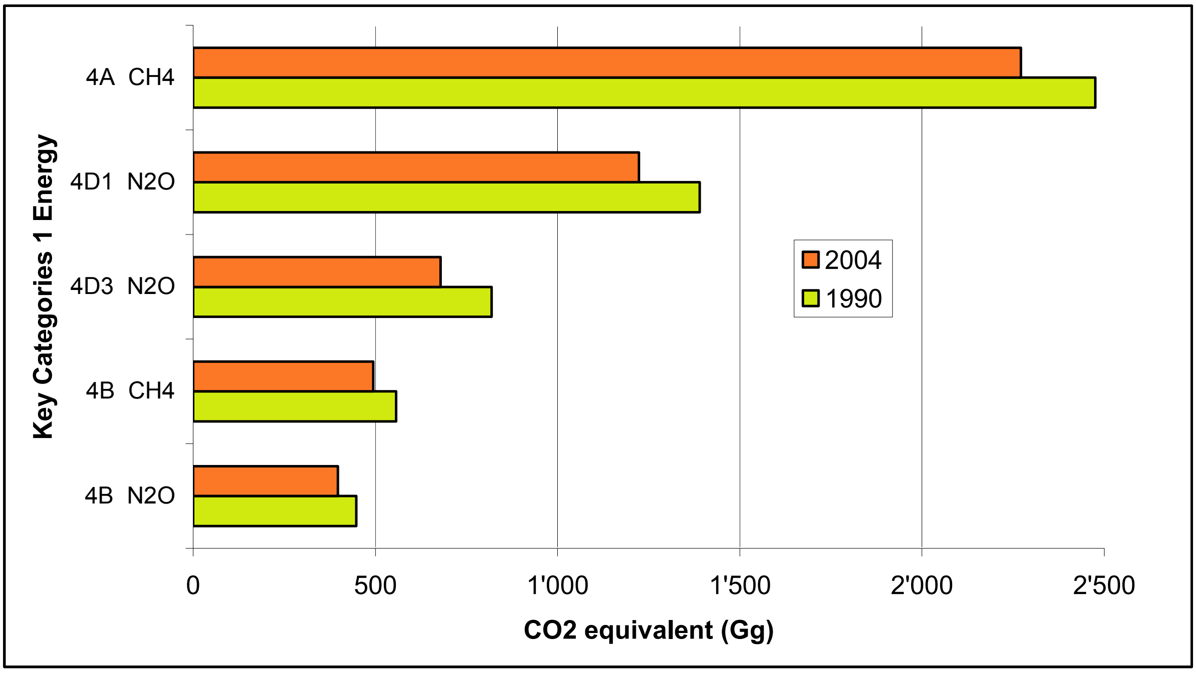


Figure 26 Key sources in Agriculture (emissions in CO_2 equivalents per source category). 4A: Enteric fermentation. 4B: Manure management. 4D: Agricultural soils.

6.2. Source Category 4A – Enteric Fermentation

6.2.1. Source Category Description

Key source 4A The CH_4 emissions from 4A Enteric Fermentation are a key source by level and trend.

The emission source is the domestic livestock population broken down into 9 cattle categories, sheep, goat, horses, mules and asses, swine and poultry. Emissions from enteric fermentations are declining since 1990, mainly due to a reduction of the number of cattle. Emissions from cattle contribute to more than 93% of the emissions from enteric fermentation.

Table 86 Specification of source category 4A “Enteric Fermentation”.

4A	Source	Specification	Data Source
4A1	Cattle	Emissions from 9 different cattle categories	AD: Livestock data, net energy, metabolizable energy (calves) and feed intake losses from SBV 2005 and RAP 1999 EF: Soliva 2006a
4A3 4A4	Sheep Goats		AD: Livestock data, net energy, and feed intake losses from SBV 2005 EF: Soliva 2006a
4A6 4A8	Horses Swine		AD: Livestock data, digestible energy, feed intake losses from SBV 2005 EF: Soliva 2006a
A47	Mules and asses		AD: Livestock data, digestible energy and feed intake losses from SBV 2005 EF: Soliva 2006a
4A9	Poultry		AD: Livestock data; metabolisable energy and feed intake losses from SBV 2005 EF: Soliva 2006a

6.2.2. Methodological Issues

Methodology

The calculation is based on methods described in the IPCC Good Practice Guidance (IPCC 2000, equation 4.14). CH_4 emissions from enteric fermentation of the livestock population have been estimated using Tier 2 methodology. This means that detailed country-specific data on nutrient requirements, feed intake and CH4 conversion rates for specific feed types are required.

For calculating the **gross energy intake** a country specific method based on available data on net energy (lactation, growth), digestible energy and metabolisable energy has been applied. Data on energy intakes are taken from SBV 2005 and from RAP 1999. The method is described in detail in Soliva 2006a.

Different energy levels (Figure 27) are used to express the energy conversion from energy intake to the energy required for maintenance and performance.

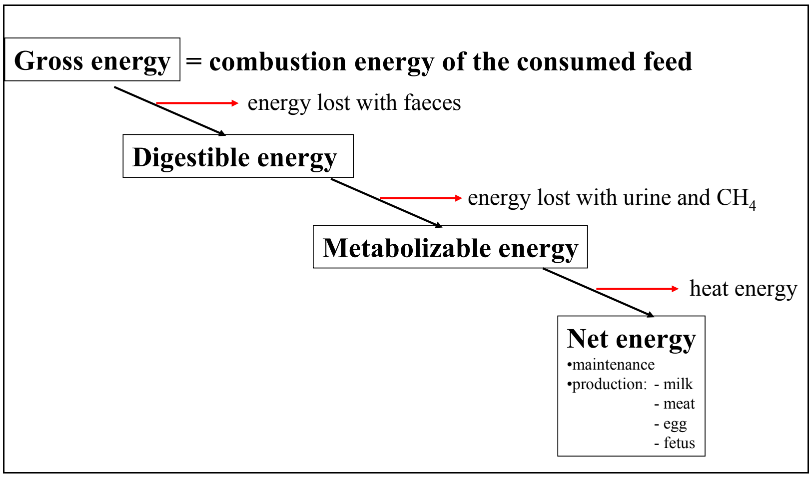


Figure 27 Levels of feed energy conversion. Reference: Soliva 2006a.

Net energy (NE) is used to express the energy required by the ruminants such as cattle, sheep and goats. NE in cattle feeding is further sub-divided into NE for lactation (NEL) and NE for growth (NEV). Exceptions in the cattle category are the calves, whose requirements for energy are expressed as metabolisable energy (ME). Horses, mules, asses and swine are fed on the basis of digestible energy (DE), whereas poultry are fed according to metabolisable energy (ME).

In the energy estimation also some feed energy losses are integrated. Feed losses are defined as the feed not eaten by the animal and therefore represent a loss of net energy. Calculation for NE, DE and ME consumption was used for the livestock categories sheep, goats, horses, mules and asses, swine and poultry, respectively.

For the livestock category cattle detailed estimations for NE are necessary. As the Swiss Farmers Union does not calculate the NE for detailed cattle sub-categories, NE data for each cattle sub-category was calculated individually according to the animal’s requirements following the feeding recommendations of RAP 1999. These RAP recommendations are also used by the Swiss farmers as basis for their cattle feeding regime and for filling in application forms for subsidies for ecological services, and are therefore highly appropriate. In the calculation of the NE data, the animal’s weight, daily growth rate, daily feed intake (DM), daily feed energy intake, and energy required for milk production for the respective sub-categories were considered.

For estimating the gross energy intake out of the available data on net energy, metabolisable energy and digestible energy, the following conversion factors were applied:

Table 87 Conversion factors used for calculation of energy requirements of individual livestock categories. Reference: Soliva 2006a: p.3. GE: Gross energy; DE: Digestible Energy; ME: Metabolisable Energy; NEL: Net energy for lactation; NEV: Net energy for growth.

Livestock Category		**Conversion Factors**	
Cattle	Milk-fed calf	ME to GE	0.930
	Suckler cow calf	NEL to GE	0.291
	Breeding calf	NEL to GE	0.341
	Breeding cattle 1 (4-12 months)	NEL to GE	0.322
	Breeding cattle 2 (more than one year)	NEL to GE	0.313
	Fattening calf	NEV to GE	0.350
	Fattening cattle	NEV to GE	0.401
	Dairy cattle	NEL to GE	0.318
	Non dairy cattle (suckler cow)	NEL to GE	0.275
Sheep	Sheep (breeding)	NEL to GE	0.287
	Sheep (fattening)	NEV to GE	0.350
Goats		NEL to GE	0.283
Horses, mules, asses		DE to GE	0.560
Swine		DE to GE	0.682
Poultry		ME to GE	0.700

For the **methane conversion rate Ym** (%) only few country-specific data exist. Therefore mainly default values recommended by the IPCC for developed countries in Western Europe were used (IPCC 1997b: Reference Manual: p. 4.32–4.35 and IPCC 2000: p. 4.27). For poultry a country specific value ($Y_{poultry} = 0.1631$) was used since no default value is given by the IPCC. This value was evaluated in an in vivo trial with broilers (Hadorn and Wenk 1996).

Emission factors

All emission factors for enteric fermentation are country specific, based on IPCC equation 4.14 IPCC 2000: p. 4.26.

$$EF = \frac{GE * Y_m * 365\,days / y}{55.65\ MJ / kg\, CH_4}$$

GE = Gross energy intake (MJ/head/day)

Y_m = Methane conversion rate, which is the fraction of gross energy in feed converted to methane

55.65 MJ/kg = energy content of methane.

The following input data are used:

Table 88 Gross energy intake of different livestock groups. Calculation is based on the above mentioned parameters net energy, digestible energy, metabolisable energy according to the method described in

Soliva 2006a. Input data on net energy, digestible energy and metabolisable energy is taken from SBV 2005 and RAP 1999.

Gross Energy Intake	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	MJ/head/day														
Cattle															
Milk-fed calf	47.6	47.6	47.6	47.6	47.6	47.6	47.6	47.6	47.6	47.6	47.6	47.6	47.6	47.6	47.6
Suckler cow calf	n.e.	n.e.	n.e.	n.e.	n.e.	n.e.	n.e.	n.e.	n.e.	55.7	55.7	55.7	55.7	55.7	55.7
Breeding calf	26.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9
Breeding cattle 1 (4-12 months)	89.2	89.2	89.2	89.2	89.2	89.2	89.2	89.2	89.2	89.2	89.2	89.2	89.2	89.2	89.2
Breeding cattle 2 (more than one year)	129.1	129.1	129.1	129.1	129.1	129.1	129.1	129.1	129.1	129.1	129.1	129.1	129.1	129.1	129.1
Fattening calf	55.6	55.6	55.6	55.6	55.6	55.6	55.6	55.6	55.6	55.6	55.6	55.6	55.6	55.6	55.6
Fattening cattle	124.6	124.6	124.6	124.6	124.6	124.6	124.6	124.6	124.6	124.6	124.6	124.6	124.6	124.6	124.6
Dairy cattle	259.1	261.2	261.8	264.2	263.7	264.7	263.9	267.7	270.2	271.2	273.4	275.3	276.1	276.6	279.1
Non-dairy cattle	n.e.	n.e.	n.e.	n.e.	n.e.	n.e.	n.e.	n.e.	n.e.	205.1	205.1	205.1	205.1	205.1	205.1
Sheep	20.8	21.4	21.7	21.1	23.2	24.3	21.4	21.8	21.6	22.8	22.1	22.8	22.6	22.5	23.0
Goats	31.7	32.0	32.3	32.3	33.2	34.8	32.4	29.3	29.2	28.9	31.9	31.9	30.9	31.4	30.9
Horses	145.3	135.1	133.4	125.2	153.3	176.8	131.9	133.9	134.1	134.1	134.1	139.4	139.2	139.6	139.7
Ponies, Mules and Asses	162.0	158.1	159.7	152.9	161.0	156.1	118.3	115.0	110.3	101.7	100.9	98.9	95.3	92.0	89.2
Swine	35.2	36.0	36.2	36.1	36.8	40.4	43.0	37.0	36.5	37.4	36.4	35.2	34.9	34.9	35.1
Poultry	1.8	1.9	1.9	1.7	1.7	1.8	1.7	1.8	1.7	1.6	1.7	1.7	1.7	1.7	1.6

The gross energy intake per head for some animal categories revealed some fluctuations during the inventory period. The energy intake for all cattle categories (except dairy cattle) is estimated to be constant. The value for dairy cows increased which is mainly a result of higher milk production (4940 kg per head and year in 1990 compared to 5680 kg per year in 2004). The gross energy intake for the horse categories showed higher values for 1994 and 1995. According to the Swiss Farmers Union data comparison of these years can be made only partially due to changes in livestock survey methods (SBV 1998). For suckler cow calves and suckler cows no activity data were collected before 1999 and therefore no energy intakes were estimated.

Activity data

The activity data input has been obtained from statistics published by the Swiss Farmers Union (SBV 2005).

The activity data are grouped into the livestock categories required for emission calculation.[17]

[17] SBV differentiates various sub-categories which are not relevant for calculation of methane emissions (e.g. 9 categories of cattle).

Table 89 Activity for calculating methane emissions from enteric fermentation (SBV 2005).

Population Size	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	1'000 head														
Cattle	1'855	1'829	1'783	1'745	1'747	1'748	1'747	1'673	1'641	1'609	1'588	1'611	1'594	1'570	1'544
Milk-fed calf	122	123	123	125	123	120	134	132	137	116	103	115	114	114	113
Suckler cow calf	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	33	36	40	47	52	57
Breeding calf	214	204	197	184	183	166	155	139	136	72	76	78	76	73	68
Breeding cattle 1 (4-12 months)	132	133	127	125	118	129	131	121	118	147	161	160	154	147	143
Breeding cattle 2 (more than one year)	404	400	397	381	379	378	383	372	350	305	352	350	345	337	326
Fattening calf	88	79	71	76	79	82	75	68	66	48	47	40	38	39	36
Fattening cattle	100	96	87	92	101	110	105	97	97	162	101	109	104	105	109
Dairy cattle	795	795	781	762	763	763	764	744	737	684	669	669	658	638	621
Non-dairy cattle (suckler cows)	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	41	45	51	58	65	70
Sheep	395	409	414	424	405	387	419	420	422	424	421	420	430	445	441
Goats	68	65	58	57	55	53	57	58	60	62	62	63	66	67	71
Horses	45	49	52	54	48	41	43	46	46	49	50	50	51	53	54
Ponies, Mules and Asses	7	7	8	8	8	8	8	9	10	11	12	12	13	14	15
Swine	1'787	1'723	1'706	1'692	1'569	1'446	1'379	1'395	1'487	1'453	1'498	1'548	1'557	1'529	1'538
Poultry	5'932	5'642	5'499	6'410	6'431	6'241	6'425	6'537	6'566	6'886	6'983	6'939	7'339	7'453	8'061

The number of cattle was slightly declining during the last 14 years, which is a result of an ongoing process to a less intensive form of animal husbandry due to ecological and economic reasons. The numbers of sheep, goats, horses and poultry were increasing. Also the number of swine is increasing again after a decrease until 1996 – a process that can be observed also in many other European countries (SBV 2004).

6.2.3. Uncertainties and Time-Series Consistency

No formal uncertainty analysis has been carried out for the actual data. A former minimum-maximum analysis based on 2001 data lead to a 95% confidence interval of 25% (FAL 2003). Correspondingly, an uncertainty of 13% is set for the emission factor. For the activity data, an uncertainty of 20% is assumed. These numbers are used as input for the Tier 1 analysis.
For Tier 2 (Monte Carlo), a combined uncertainty of 23% is used for the emissions, which is derived from the error propagation formula for the product EF*AD ($U_E^2 = U_{EF}^2 + U_{AD}^2$). A normal distribution of the uncertainties is assumed. In Table 173 in Annex A1.2.3 the Monte Carlo model uncertainty is given. It may slightly deviate from the input value (23.2% instead of 23.0%), which is the result of a consistency adjustment of the correlations coefficients carried out by Crytal Ball Software automatically.

The time series 1990–2004 is consistent.

6.2.4. Source-Specific QA/QC and Verification

The documentation about the data set and calculation method assures transparency and traceability of the calculation methods (Soliva 2006a). Additionally a document in German lists all the methodological differences between the former calculations and the current methodology (Soliva 2006b).

Quality is assured by an external peer review by Carla Soliva, which lead to a revision of the calculation methods. A countercheck was done by ART (former name FAL) who was responsible for calculation of the whole time series (refer to chapter 6.2.5). Additionally a quality control was done by INFRAS by a countercheck of the calculation sheets. This countercheck lead to minor adjustments of the calculation sheets.

6.2.5. Source-Specific Recalculations

For this submission the former calculation method was revised in detail (Soliva 2006a and Soliva 2006b). Soliva provided the methodology for the year 2003. Accordingly, time series were calculated by ART. This means that recalculations for the whole time series have been carried out for estimating methane emissions from enteric fermentation. Main differences are:

- The category cattle was divided into 9 sub-categories instead of only two sub-categories dairy and non-dairy cattle in former submissions. This lead to more accurate estimations of the emissions from cattle which is the most important contributor to methane emissions.
- Net energy estimations for all cattle categories are now based on feed requirements following feeding recommendations of RAP 1999. This is in difference to the former calculations which were based on performance.
- Conversion factors for calculation of energy requirements of individual livestock categories (conversion from net energy, metabolisable energy and digestible energy to gross energy) were recalculated.

With these adjustments the method is now closer to IPCC including Swiss specific information on feed requirements.

6.2.6. Source-Specific Planned Improvements

There are no planned improvements.

6.3. Source Category 4B – Manure Management

6.3.1. Source Category Description

Key source 4B
Source categories 4B Manure Management CH_4 and N_2O are key sources by level and trend.

CH_4, N_2O and NO_x emissions from manure management are reported. All emissions from manure management were declining since 1990, mainly due to a reduction of the cattle population.

Table 90 Specification of source category 4B “Manure Management (CH_4)”. (Activity: Activity data; EF: Emission factors).

4B	Source	Specification	Data Source
4B1 4B3 4B4 4B6 4B8	Cattle Sheep Goats Horses Swine	Emissions from 9 different cattle categories	AD: SBV 2005 EF: IPCC 2000; IPCC 1997b; FAL/RAC 2001
4B7	Mules and Asses		AD: SBV 2005 EF: IPCC 2000; IPCC 1997b; FAL/RAC 2001
4B9	Poultry		AD: SBV 2005 EF: IPCC 2000; IPCC 1997b; FAL/RAC 2001

Table 91 Specification of source category 4B “Manure Management (N_2O)”.

4B	Source	Specification	Data Source
4B11 4B12	Liquid Systems Solid storage and dry lot		AD: SBV 2005; FAL/RAC 2001; Menzi et al. 1997 EF: IPCC 2000

6.3.2. Methodological Issues

For calculation of CH_4 and N_2O emissions slightly different livestock groups are used. Nevertheless there is no inconsistency in the total number of animals as they are the same both for CH_4 and N_2O emissions.

Calculation of CH_4 emissions is based on the domestic livestock populations milk-fed calves, suckler cow calves, breeding calves, breeding cattle (4-12 months), breeding cattle (more than one year), fattening calves, fattening cattle, dairy cattle, non-dairy cattle (suckler cows), sheep, goats, horses, mules, asses, swine and poultry as reported for enteric fermentation.

Calculation of N_2O emissions are based on a slightly different livestock population break down with the sub-groups milk fed calves, suckler cow calves, breeding calves, breeding cattle (4-12 months), breeding cattle (more than one year), fattening calves, fattening cattle, dairy cattle, non-dairy cattle (suckler cows), fattening pig places, breeding pig places, sheep places, goat places, horses (foals < 1 year, foals 1-2 years, other horses), ponies, mules and asses and poultry (laying hens, young hens < 18 weeks, broilers, other poultry).

This calculation is chosen because more detailed data on N excretion for the particular animal categories are available (FAL/RAC 2001).The categories for sheep, pigs and goats as provided by FAL/RAC 2001 do not correspond to the categories of the Swiss Farmers Union (SBV 2005). The conversion from the FAL/RAC 2001 classification to the available livestock categories according to SBV is done as follows (Schmid et al. 2000):

- One fattening pig place corresponds to one fattening pig over 25 kg, 1/6 fattening pig place to one young pig below 30 kg.
- One breeding pig place corresponds to one sow, 1/2 breeding pig place to one boar.
- One sheep place corresponds to one ewe over one year. Other sheep such as lambs or rams are not included.

- One goat place corresponds to one (female) goat older 1.5 years. All goats younger than 1.5 years are not included[18].

a) CH_4 Emissions

Methodology

Calculation of CH_4 emissions from manure management is based on IPCC Tier 2 (IPCC 2000: equation 4.17).

Emission factor

Calculation of the emission factor is based on the parameters volatile substance excreted (VS), the maximum CH_4 producing capacity for manure (B_o) and the CH_4 conversion factors for each manure management system (MCF).

No country-specific values for the **daily excretion of VS** are available in Switzerland. For the livestock categories swine, sheep, goats, horses, mules and asses, and poultry default values from IPCC 1997b: Reference Manual: p. 4.41 to 4.47 were taken. The VS for cattle sub-categories were estimated according to IPCC 2000: equation 4.16: p. 4.31.

The **ash content** of cattle manure is assumed to amount to 8% on average (IPCC 1997b: Reference Manual: p. 4.47). The digestible energy of the feed for cattle is assumed to be 60% on average (IPCC 1997b: Reference Manual: p. 4.47). The calculation of gross energy intake per head is described in detail in chapter 6.2.2.

For the Methane Producing Potential (**B_o**) default values are used (IPCC 1997b: Reference Manual: p. 4.41 to 4.47).

For the Methane Conversion Factor (**MCF**) IPCC default values are used (IPCC 2000, p. 4.36 and IPCC 1997b: Reference Manual: p. 4.25). In Switzerland mainly two manure management systems exist, solid storage and liquid/slurry storage. Calves are mainly kept in deep litter systems and there are also specific MCF values for pasture and poultry systems: The following MCF's were used:

Table 92 Manure management systems and Methane conversion factors (MCFs). References: IPCC 2000, p. 4.36 and IPCC 1997b: p. 4.25 (for liquid/slurry).

Manure management system	Description	MCF
Solid manure	Dung and urine are excreted in a barn. The solids (with and without litter) are collected and stored in bulk for a long time (months) before disposal.	1%
Liquid/slurry	Combined storage of dung and urine under animal confinements for longer than 1 month.	10%
Pasture	Manure is allowed to lie as it is, and is not managed (distributed, etc.).	1%
Deep litter	Dung and urine is excreted in a barn with lots of litter and is not removed for a long time (months). This is applied for the cattle sub-categories of milk-fed calves and fattening calves, and for sheep and goats.	39%
Poultry system	Manure is excreted on the floor with or without bedding.	1.5%

[18] Since the number of (female) goats older than 1.5 years are not known, the following approximation is used: GP = DG + 0.3508*OFG. GP goat places, DG dairy goats, OFG other female goats older than 1 year.

The fraction of animal's manure handled using different manure management systems (**MS**) was separately calculated for each livestock category and the respective manure management systems. The information about the percentage of a livestock category kept in a specific housing system is based on FAL/RAC 2001. The percentages of solid manure or slurry produced by different animals within specific housing systems were obtained from Menzi et al. 1997, as were the percentages of the grazing time for each livestock category.

Activity data

Activity data on all livestock categories are taken from SBV 2005 (refer to chapter 6.2.2 for details).

b) N_2O Emissions

Methodology

For calculation of N_2O emissions the country specific method IULIA is applied. IULIA is an IPCC-derived method for the calculation of N_2O emissions from agriculture that basically uses the same emission factors, but adjusts the activity data to the particular situation of Switzerland. Further information is provided under the chapter 6.5.2. IULIA is described in detail in Schmid et al. 2000.

For calculation of emissions from manure management IULIA applies other values for the nitrogen excretion per animal category than IPCC (refer to information about activity data) and differentiates the animal waste management systems Liquid systems and Solid storage. The combined systems (liquid/slurry) are split up into Liquid systems and Solid storage. N_2O emissions from pasture range and paddock appears under the category „D Agricultural soils, subcategory 2 animal production". IPCC categories „daily spread" and „other systems" are not occurring. The basic animal waste management systems included in IULIA are defined in Menzi et al. 1997.

Emission factors

IPCC default emission factors are used for the two animal waste management systems (IPCC 2000: p.4.43).

Table 93 Emission factors for calculating N_2O emissions from manure management (IPCC 2000: p. 4.43).

Source	Emission factor per animal waste management system (kg N_2O-N / kg N)
Liquid systems	0.001
Solid storage	0.020

Activity data

Input data on all livestock categories are taken from the Swiss Farmers Union (SBV 2005).These input data are converted into the following livestock categories (Walther et al. 1994, FAL/RAC 2001).

Table 94 Activity data for calculating N_2O emissions from manure management (SBV 2005).

Population Size	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
	1'000 head														
Cattle															
Milk fed calf and suckler cow calf	122	123	123	125	123	120	134	132	137	150	139	155	161	166	170
Breeding calf and breeding cattle 1	346	337	324	308	302	295	286	260	254	219	236	238	230	220	212
Breeding cattle 2	404	400	397	381	379	378	383	372	350	305	352	350	345	337	326
Fattening calf	88	79	71	76	79	82	75	68	66	48	47	40	38	39	36
Fattening cattle	100	96	87	92	101	110	105	97	97	162	101	109	104	105	109
Dairy cattle	795	795	781	762	763	763	764	744	737	684	669	669	658	638	621
Non-Dairy cattle (only suckler cows)	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	i.e.	41	45	51	58	65	70
Sheep (Sheep places) [1]	191	201	201	211	201	191	208	208	209	222	217	217	220	229	227
Goats (Goats places) [1]	40	38	34	33	32	31	33	34	35	37	37	35	36	36	38
Horses [2]															
Foals (< 1 year)	4	4	5	5	5	5	4	4	4	4	4	4	3	3	3
Foals (1-2 years)	5	6	6	7	7	6	6	6	6	7	6	6	6	6	6
Other horses	36	39	41	43	36	30	32	36	36	38	40	40	42	43	44
Ponies, Mules and Asses	7	7	8	8	8	8	8	9	10	11	12	12	13	14	15
Swine															
Fattening pig places	1'012	977	960	931	844	757	769	769	827	830	851	868	874	857	859
Breeding pig places	184	179	178	179	168	156	142	148	156	139	145	149	148	144	146
Poultry	5'932	5'642	5'499	6'410	6'431	6'241	6'425	6'537	6'724	6'886	6'983	6'939	7'339	7'453	8'061
Laying hens	3'083	2'645	2'536	2'518	2'226	2'118	2'226	2'278	2'270	2'223	2'150	2'069	2'154	1'985	2'089
Young hens (< 18 weeks)	719	664	710	719	732	714	732	733	793	761	832	745	754	809	853
Broilers	2'020	2'199	2'096	2'990	3'293	3'231	3'293	3'342	3'502	3'747	3'808	3'993	4'298	4'518	4'971
Other poultry (turkeys)	110	134	158	183	180	177	174	184	158	155	193	132	132	140	148

Data on nitrogen excretion per animal category (kg N/head/year) is taken from FAL/RAC 2001: p. 48/49 (see Table 193 in Annex A4). These data are calculated according to the method IULIA. Unlike IPCC, IULIA distinguishes the age structure of the animals and the different use of the animals (e.g. fattening and breeding). This consideration of adopted nitrogen excretion values is one of the major advantages of the method IULIA in the Swiss context. Calculation of nitrogen excretion of dairy cattle is based on milk production reported. This more disaggregated approach leads to 30% lower calculated nitrogen excretion rates compared to IPCC, which therefore also implies to lower total N_2O emissions from manure management.

The nitrogen excretion per sheep place has been changed from 16 to 12 kg N/head/year from 1994 according to the revised standard values of N excretion (FAL/RAC 2001).

The split of nitrogen flows into the different animal waste management systems including ammonia emissions are taken from Menzi et al. 1997.

c) NO_x Emissions

Methodology

NO_x emissions from manure management are estimated by taking 0.7% of nitrogen excretion from livestock. This factor is based on the CORINAIR Emission Inventory Guidebook 2003 (EEA 2005). Data on N-excretion (kg N/head/yr) is taken from FAL/RAC 2001.

6.3.3. Uncertainties and Time-Series Consistency

a) CH_4 Emissions

No formal uncertainty analysis has been carried out for the actual data. A former minimum-maximum analysis based on 2001 data (already mentioned above in the Chapter of Enteric Fermentation) lead to a 95% confidence interval of 73% of the emission factor (FAL 2003). Correspondingly, an uncertainty of 36% (half of the confidence interval) is set for the emission factor. For the activity data, an uncertainty of 20% is assumed as in the case of enteric fermentation. These numbers are used as input for the Tier 1 analysis.
For Tier 2 (Monte Carlo), a combined uncertainty of 41% is used for the emissions, which is derived from the error propagation formula for the product EF*AD ($U_E^2 = U_{EF}^2 + U_{AD}^2$). A normal distribution of the uncertainties is assumed. In Table 173 in Annex A1.2.3 the Monte Carlo model uncertainty is given. It slightly deviates from the input value (40.7% instead of 41.0%), which is the result of a consistency adjustment of the correlations coefficients carried

out by Crystal Ball Software automatically.

Time series between 1990 and 2004 is consistent.

c) N_2O Emissions

IPCC gives the following ranges for emission factors (IPCC 1997c).

Table 95 Minimum and maximum values for the emission factor for solid storage and the emission factor for liquid systems (IPCC 1997c: p. 4.104).

	Medium	Minimum	Maximum
Emission factor Liquid systems (kg N_2O-N / kg N)	0.001	< 0.001	0.001
Emission factor Solid storage (kg N_2O-N / kg N)	0.02	0.005	0.03

For the uncertainty analysis, a mean uncertainty of 70% for the emission factors is derived from the values in Table 95. For the uncertainty of activity data, 20% as in the case of CH_4 (manure management) is taken. These numbers are used as input for the Tier 1 analysis. For Tier 2 (Monte Carlo), a combined uncertainty of 73% is used as input for the uncertainty of the emissions. The value of 73% is derived from the error propagation formula for the product EF*AD ($U_E^2 = U_{EF}^2 + U_{AD}^2$). A lognormal distribution is assumed. (With a normal distribution, the 2.5 percentile value would become negative.) In Table 173 in Annex A1.2.3 the Monte Carlo model uncertainty is given. It slightly deviates from the input value (72.7% instead of 73.0%), which is the result of a consistency adjustment of the correlations coefficients carried out by Crystal Ball Software automatically.

Time series 1990-2004 is consistent. Due to a method change in calculating the N-excretion of dairy cattle in 2001 the data between 1990 and 2000 are interpolated in order to get consistency of the time series (FAL/RAC 2001).

6.3.4. Source-Specific QA/QC and Verification

For CH_4 emissions quality is assured by an external peer review by Carla Soliva. This lead to a revision of the calculation methods, which is now compatible with IPCC 2000. A countercheck was done by ART who was responsible for calculation of the whole time series. Additionally a quality control was done by INFRAS by a countercheck of the calculation sheets. This countercheck lead to minor adjustments of the calculation sheets.

For CH_4 the documentation about the data set and calculation method assures transparency and traceability of the calculation methods (Soliva 2006a). Additionally a document in German lists all the methodological differences between the former calculations and the current methodology regarding CH_4 estimations (Soliva 2006b). For N_2O estimations an internal documentation of the Agroscope Reckenholz-Tänikon Research Station (ART, former name FAL) is available (Berthoud, 2004).

6.3.5. Source-Specific Recalculations

For this submission the former CH_4 calculation method was revised in detail (Soliva 2006a and Soliva 2006b). Soliva provided the methodology for the year 2003. Accordingly, time series were calculated by ART. This means that recalculations for the whole time series have been carried out for estimating methane emissions from manure management. In difference to former estimations the calculation is now fully compatible with IPCC 2000 (equations 4.16 and 4.17). For N2O emissions from manure management no source-specific recalculations have been carried out.

6.3.6. Source-Specific Planned Improvements

No improvements are planned in the CH_4 emission estimation. As a component of the quality control process the N_2O calculation method IULIA will however be reviewed. It is not yet assessable whether this review will lead to an adjustment of the N_2O calculations as a whole. The livestock sub-categories which now slightly differ from the ones reported for methane emissions will be revised and probably adopted.

6.4. Source Category 4C – Rice Cultivation

Rice Cultivation is of minor importance in Switzerland. There is only some insignificant upland rice cultivation which emissions are assumed to be zero. They are therefore ignored in the emission calculation.

6.5. Source Category 4D – Agricultural Soils

6.5.1. Source Category Description

Key source 4D1, 4D3
Direct (4D1) and indirect (4D3) N_2O emissions from agricultural soils are key sources by level and trend.

The source category 4D includes the following emissions: Direct N_2O emissions from soils and from animal production (emission from pasture range and paddock), indirect N_2O emissions, NO_x emissions from soils and from animal production and NMVOC emissions.

Direct and indirect N_2O emissions as well as NO_x emissions were decreasing since 1990 in almost all sub-categories.

Table 96 Specification of source category 4D "Agricultural Soils".

4D	Source	Specification	Data Source
4D1	Direct soil emissions	Includes emissions from synthetic fertilizer, animal manure, crop residue, N-fixing crops, organic soils, residues form pasture range and paddock, N-fixing pasture range and paddock	AD: SBV 2005; FAL/RAC 2001; Leifeld et al. 2003 EF: IPCC 1997b (N_2O); Schmid et al. 2000
4D2	Animal production	Only emissions from pasture range and paddock	AD: SBV 2005; FAL/RAC 2001; Menzi et al. 1997 EF: IPCC 1997b
4D3	Indirect emissions	Leaching and run-off, N deposition air to soil	AD: SBV 2005; FAL/RAC 2001; Prasuhn and Braun 1994; Braun et al. 1994 EF: IPCC 1997b
4D4	Other (sewage sludge and compost used for fertilizing)		AD: SBV 2005 EF: IPCC 1997b

6.5.2. Methodological Issues

Methodology

For calculation of N_2O emissions from agricultural soils the national method IULIA is applied. IULIA is an IPCC-derived method for the calculation of N_2O emissions from agriculture that basically uses the same emission factors, but adjusts the activity data to the particular situation of Switzerland (Schmid et al. 2000). According to expert judgement IULIA has been proven to be an adequate method for calculation of N_2O emissions under Swiss circumstances. There is no indication that the adoption of the IPCC method would lead to a better estimation of the N_2O emissions in Switzerland.

The N_2O emissions, which are considered within the calculation, are displayed in the following figure.

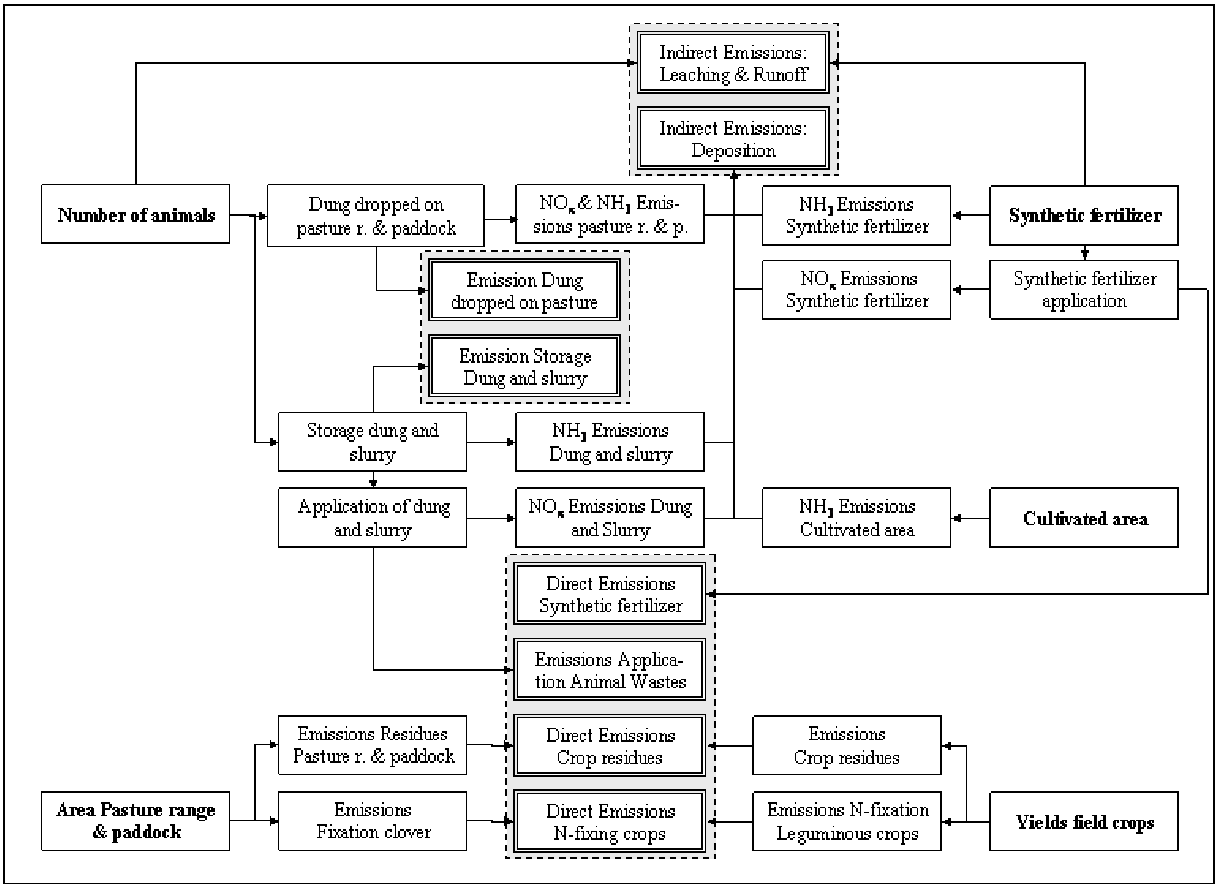


Figure 28 Diagram of the N_2O emissions in Agriculture.

Main differences between the IULIA method and IPCC are (Schmid et al. 2000: p. 74):

- IULIA estimates lower nitrogen excretion per animal category, especially due to the lower excretions of cattle (refer to chapter 6.3.2).
- The amount of losses to the atmosphere from the excreted nitrogen is more than 50% higher compared to IPCC.
- The amount of leaching (of nitrogen excreted and of synthetic fertilizers) is lower by 1/3 compared to IPCC.
- The share of solid storage out of the total manure is more than twofold; the share of excretion on pasture range and paddock is lower by 1/3.
- The nitrogen inputs from biological fixation are higher by a factor of 30 since fixation on meadows and pastures are also considered. The consideration of nitrogen fixation from grassland is one of the major advantages of the method IULIA as the grassland accounts for the majority on nitrogen fixed in Swiss agricultural soils.
- The nitrogen inputs from crop residues are only 25% higher although emissions from plant residue returned to soils on meadows and pastures are considered. This is explained by the fact that the emissions from crop residue are estimated 50% below the IPCC defaults.

Despite the different assumptions of the two methods, differences at the level of the N_2O emissions are quite moderate. In total IULIA estimations of the N_2O emissions from agriculture are 14% lower than the IPCC estimations (Schmid et al. 2000: p. 75).

Direct emissions from soil (4D1)

Calculation of direct N2O emissions from soil is based on IPCC Tier 1b.

- Emissions from **synthetic fertilizer** include mineral fertilizer. The amount of nitrogen in fertilizer is taken from SBV 2005. From the amount of nitrogen in fertilizer losses to the atmosphere in form of NH3 and NOx are subtracted and the rest is multiplied with the corresponding emission factor. According to the method IULIA losses to the atmosphere are set to 6% (NH3) and 0.7% (NOx, according to EMEP/CORINAIR, EEA 2005) instead of the IPCC value of 10% for NH3 and NOx. (Schmid et al. 2000: p. 63 and IPCC 1997c: p. 4.94).

- To model the emissions of **animal wastes applied to soils**, nitrogen input from manure applied to soils is calculated. This is calculated by the total N excretion minus N excreted on pastures minus ammonia volatilization from solid and liquid manure and excretion on pastures. The losses (to the atmosphere) as ammonia are specified for each management category instead of using a fixed ratio of 20% (Schmid et al. 2000: p. 66). The loss as NO_x is set to 0.7% of the excreted N (EMEP/CORINAIR, EEA 2005). For details regarding the volatized N refer to Table 98.

- Emissions from **crop residues** are based on the amount of nitrogen in crop residues returned to soil. In IULIA (Schmid et al. 2000: p. 68 and p. 100) this amount is based on data reported on crop yields (SBV 2005), the standard values for arable crop yields (FAL/RAC 2001) and standard amounts of nitrogen in crop residues returned to soils (FAL/RAC 2001). The calculation of the amount of nitrogen in crop residues returned to soil according to IULIA is as follows (Schmid et al. 2000: p. 101):

  $$F_{CR} = \sum_{Cr} E_{Cr} * \frac{NR_{Cr}}{Y_{Cr}}$$

  F_{CR}: Amount of nitrogen in crop residues returned to soils (t N)
  E_{Cr}: Amount of crop yields for culture Cr (t)
  Y_{Cr}: Standard values for arable crop yields for culture Cr (t/ha)
  NR_{Cr}: Standard amount of nitrogen in crop residues returned to soils (t)

  From 2001 on updated standard values and amounts of nitrogen returned to soil are used. In addition to the N transfer from crop residues, IULIA also takes into account the plant residue returned to soils on meadows and pastures (Schmid et al.: 2000). Three quarters of the agricultural land use consists of grassland which underscores the importance of the source for Switzerland. Input data on the managed area of meadows and pastures are taken from SBV 2005.

- For calculation of emissions from **N-fixing crops**, IULIA assumes that 60% of the nitrogen in crops is caused by biological nitrogen fixation (Schmid et al. 2000: p. 70). The total amount of nitrogen is calculated according to the calculation of nitrogen in crop residues. In addition, IULIA takes biological nitrogen fixation on meadows and pastures into account, assuming a nitrogen concentration of 3.5% in the dry matter from which 80% derives from biological nitrogen fixation and the rest from uptake of mineral nitrogen. For the dry matter production of clover on pastures and meadows statistical data were used (Schmid et al: 2000: p. 70). The following table gives an overview of the calculation of emissions from N-fixing crops.

Table 97 Input values for calculation of emissions from N-fixing crops according to IULIA (Schmid et al. 2000: p. 70).

Fixation	Share of N caused by fixation	Share of N in Dry matter
Leguminous (N-fixing crops)	0.6	
Clover (Fixation meadows and pastures)	0.8	0.035

- Emissions from **cultivated organic soils** are based on estimations on the area of cultivated organic soils (Leifeld et al. 2003) and the IPCC default emission factor for N_2O emissions from cultivated organic soils (IPCC 1997b).

For estimation of NO_x it is assumed that 0.7% of nitrogen in fertilizer is emitted as NO_x (EMEP/CORINAIR, EEA 2005).

Estimation of NMVOC emissions of meadows and arable land is based on Spirig and Neftel 2002. VOC flows are estimated in Warneke et al. 2002 (for meadows) and König et al. 1995 (for arable land). Emissions were measured in a field trial in Austria (Karl et al. 2001).

Emissions from animal production (4D2)

Calculation of emissions from animal production is based on IULIA. This equation is similar to equation 4.18, IPCC 2000: p. 4.42, but applies national N excretion rates. For calculation of the N excretion per animal category, please refer to chapter 6.3.2.

Only emissions of Pasture range and Paddock are to be reported under Agricultural Soils. Other emissions from animal production are reported under Manure Management. The relevant input data are taken from FAL/RAC 2001: p. 48/49 (nitrogen excretion in kg N/head/yr) and Menzi et al. 1997 (fraction of animal waste management system).

NO_x emissions from animal production are estimated by taking 0.7% of nitrogen excretion from livestock in pasture range and paddock. Data on the amount of N-excretion (kg N/head/yr) is taken from FAL/RAC 2001, the emission factor from EMEP/CORINAIR (EEA 2005).

Indirect emissions (4D3)

Calculation of the indirect emissions is based on IPCC Tier 1b.

- For calculation of N_2O emissions from **leaching and run-off**, N from fertilizers and animal wastes has to be estimated. The relevant input data (cultivated area, information on leaching and run-off) is taken from FAL/RAC 2001, Prasuhn and Braun 1994 and Braun et al. 1994. $Frac_{Leach}$ is set as 0.2 instead of the IPCC default of 0.3 (Prasuhn and Mohni 2003). This value is extrapolated from long-term monitoring and modelling studies from the canton of Berne. According to Schmid et al. 2000: p. 71, the default value of IPCC leads to an overestimation of the emissions from leaching and run-off. The default value is based on a model which assumes that 30% of nitrogen from synthetic fertilizer and deposition is reaching water bodies. According to Schmid et al. 2000 this amount cannot be applied to the N-excretion of animals for production.

- N_2O emissions from **deposition** are based on NH_3 and NO_x emissions. Losses to the atmosphere are calculated according to Menzi et al. 1997: p. 41. For NH_3 emissions losses for all livestock categories are assumed. Furthermore, it is estimated that 6% of nitrogen in mineral fertilizer is emitted as NH_3 and 1.5 kg NH_3 -N/ha agricultural soil is produced during decomposition of organic material. 0.7% of nitrogen excretion from livestock and mineral fertilizer is emitted as NO_x (Schmid et al. 2000: p. 66, EMEP/CORINAIR, EEA 2005). Details about the amount of volatized N (NH_3 and NO_x) are provided in the following table.

Table 98 Overview of the volatized N (NH_3 and NO_x) from animal wastes and fertilizer for 2004. The total amount of volatized N appears under the indirect emissions (atmospheric deposition) in the CRF, table 4D.

	N excretion (t N) / N content 2004	Losses NH3 (%)	Emissions NH3 (t N) 2004	Losses NOx (%)	Emissions NOx (t N) 2004	Volatized N total (NH3, NOx in t) 2004
Cattle						
Milk fed calf and suckler cow calf	2'183	37%	808	0.7%	15	823
Breeding calf and breeding cattle 1	5'366	22%	1'181	0.7%	38	1'218
Breeding cattle 2	14'863	22%	3'270	0.7%	104	3'374
Fattening calf	287	37%	106	0.7%	2	108
Fattening cattle	3'592	37%	1'329	0.7%	25	1'354
Dairy cattle and Non-dairy cattle (suckler cows)	73'577	32%	23'545	0.7%	515	24'060
Sheep (Sheep places) [1]	2'730	14%	382	0.7%	19	401
Goats (Goats places) [1]	606	29%	176	0.7%	4	180
Horses [2]						
Foals (< 1 year)	58	32%	19	0.7%	0	19
Foals (1-2 years)	250	32%	80	0.7%	2	82
Other horses	1'950	32%	624	0.7%	14	638
Ponies, Mules and Asses	386	32%	124	0.7%	3	126
Swine						
Fattening pig places	11'169.8	46%	5'138	0.7%	78	5'216
Breeding pig places	5'102	46%	2'347	0.7%	36	2'382
Poultry						
Laying hens	1'483	54%	801	0.7%	10	811
Young hens (< 18 weeks)	290	54%	157	0.7%	2	159
Broilers	1'988	48%	954	0.7%	14	968
Other poultry (turkeys)	207	48%	99	0.7%	1	101
Total animals			**41'139**		**883**	**42'021**
Mineral fertilizer, compost and sewage sludge (t N)	57'800	6%	3'468		405	3'873
NH3 emissions from cropland (ha)	1'064'574	1.5%	1'597			1'597
Total			**46'204**		**1'287**	**47'491**

The estimations of the ammonia emissions is based on a Swiss study, which takes into account the specific farming and manure systems (Menzi et al. 1997: p. 37). Emission factors are lower for cattle, sheep, goats and horses due to the grazing regime. Higher emission factors are estimated under stall feeding conditions.

Other (sewage sludge and compost used for fertilizing) (4D4)

This source category covers N_2O emissions from sewage sludge and from compost used for fertilizing. The calculation of the emissions corresponds to the one for synthetic fertilizer.

Emission factors

The following IPCC default emission factors for calculating N_2O emissions from agricultural soils are used.

Table 99 Emission factors for calculating N_2O emissions from agricultural soils (IPCC 1997c: tables 4.18 (direct emissions) and 4.23 (indirect emissions)).

Emission source	Emission factor
Direct emissions	
Synthetic fertilizer	0.0125 kg N_2O -N/kg N
Animal excreta nitrogen used as fertilizer	0.0125 kg N_2O -N/kg N
Crop residue	0.0125 kg N_2O -N/kg N
N-fixing crops	0.0125 kg N_2O -N/kg N
Organic soils	8 kg N_2O-N/ha/year
Residues pasture, range and paddock	0.0125 kg N_2O -N/kg N
N-fixing pasture, range and paddock	0.0125 kg N_2O -N/kg N
Indirect emissions	
Leaching and run-off	0.025 kg N_2O -N/kg N
Deposition	0.01 kg N_2O -N/kg N
Animal production	
Pasture, range and paddock	0.02 kg N_2O -N/kg N/a
Other (sewage sludge and compost used for fertilizing)	0.0125 kg N_2O –N/kg N

Activity data

Activity data for calculation of direct soil emissions has been provided by SBV 2005 (use of synthetic fertilizer, crops produced, area of pasture range and paddock), FAL/RAC 2001: p. 48/49 (nitrogen excretion), and Leifeld et al. 2003 (revised area of cultivated organic soils). The relevant activity data for calculating N_2O emissions from soils are displayed in the following table.

Table 100 Activity data for calculating N_2O emissions from agricultural soils. For the sake of completeness, values for mineral fertilizer, sewage sludge and compost are displayed where available. For calculation of the emissions only the total amount of synthetic fertilizer is used.

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	Related activity data	Value														
Direct emissions																
Fertilizer (t N/yr)		75'200	75'800	75'400	70'200	66'500	63'400	65'900	58'000	58'400	60'100	60'100	64'200	62'800	58'300	57'800
	Mineral fertilizer (t N/yr)	69'700	n.a.	n.a.	n.a.	n.a.	56'300	58'800	50'900	51'100	53'000	53'000	57'100	55'700	53'200	53'600
	Sewage sludge (t N/yr)	4'200	0	0	0	0	4'600	4'400	4'200	4'200	4'000	4'000	4'000	4'000	2'000	1'000
	Compost (t N/yr)	1'300	0	0	0	0	2'500	2'700	2'900	3'100	3'100	3'100	3'100	3'100	3'100	3'200
Animal manure	Nitrogen input from manure applied to soils (t N/yr)	81'387	81'138	79'777	78'839	77'607	76'507	76'518	74'675	74'373	73'479	72'718	71'239	71'065	70'073	69'774
N-fixing crops	Peas, dry beans, soybeans and leguminous vegetables produced (t N/yr)	29'681	29'622	30'585	33'079	34'946	32'404	32'828	33'216	32'908	33'109	32'857	31'846	32'299	32'797	32'952
Crop residue	Dry production of other crops (t N/yr)	35'605	35'490	35'474	37'387	38'443	36'780	38'610	37'999	37'722	36'270	37'869	35'217	36'458	34'581	36'902
Organic soils	Area of cultivated organic soils (ha)	17'000	17'000	17'000	17'000	17'000	17'000	17'000	17'000	17'000	17'000	17'000	17'000	17'000	17'000	17'000
Residues pasture range and paddock	Area of pasture range and paddock (ha)	784'867	788'089	792'338	791'387	785'006	798'550	802'514	803'722	798'295	805'131	806'369	809'441	809'597	812'624	812'370
N-fixing pasture range and paddock	Area of pasture range and paddock (ha)	784'867	788'089	792'338	791'387	785'006	798'550	802'514	803'722	798'295	805'131	806'369	809'441	809'597	812'624	812'370
Indirect emissions																
Leaching and run-off	N excretion of all animals (t N/yr)	149'146	148'535	146'067	144'215	141'766	139'476	139'568	136'101	135'224	132'638	132'275	128'946	128'564	126'738	126'090
	Fertilizer (t N/yr)	75'200	75'800	75'400	70'200	66'500	63'400	65'900	58'000	58'400	60'100	60'100	64'200	62'800	58'300	57'800
	N from fertilizers and animal wastes that is lost through leaching and run off (t N/yr)	44'869	44'867	44'293	42'883	41'653	40'575	41'094	38'820	38'725	38'548	38'475	38'629	38'273	37'008	36'778
Deposition	Emissions NH3 from fertilizers, animal wastes and cropland	54'358	54'054	53'217	52'418	51'220	50'117	50'277	48'850	48'885	48'510	48'132	47'316	47'183	46'308	46'204
	Emissions NOx from fertilizers and animal wastes	1'570	1'570	1'550	1'501	1'458	1'420	1'438	1'359	1'355	1'349	1'347	1'352	1'340	1'295	1'287
	Sum of volatized N (NH3 and NOx) from fertilizers, animal wastes and cropland (t N/yr)	55'928	55'624	54'767	53'919	52'678	51'538	51'715	50'208	50'240	49'859	49'478	48'668	48'522	47'604	47'491
Animal production																
Pasture, range and paddock	N excretion on pasture range and paddock (t N/yr)	20'548	20'521	20'214	19'764	19'508	19'209	19'317	18'606	17'968	16'697	17'515	16'685	16'515	16'262	15'977

The following table gives an overview on the different N amounts in 2004 that end up in N_2O emissions in the CRF tables.

Table 101 Overview on the N amounts in the subcategories of Agricultural Soils that end up in N_2O emissions. The N excretion is multiplied with the emission factors from Table 99 and the factor 44/28 for the conversion into N_2O. The data for N excretion of synthetic fertilizers already considers losses to the atmosphere in form of ammonia and is therefore not identical with the data in Table 100.

Summary of N2O emissions from agricultural soils 2004	N excretion & emission (Kg N a-1)	Emissions (t N)	Emissions (t N2O)	Emissions (Gg N2O)
Direct emissions	**190'028'842**		3'946.09	**3.95**
Synthetic fertilizers	50'384'000	630	989.69	0.99
Animal Wastes applied to Soils	69'773'597	872	1'370.55	1.37
N-fixing crops	32'951'926	412	647.27	0.65
Fixation cropland	1'328'428	17	26.09	0.03
Fixation pasture range and paddock	31'623'498	395	621.18	0.62
Crop residues	36'902'319	461	724.87	0.72
Crop residues cropland	14'567'999	182	286.16	0.29
Crop residues pasture range and paddock	22'334'320	279	438.71	0.44
Cultivation of histosols	17'000	136	213.71	0.21
Animal Production (pasture range and paddock)	**15'976'593**	320	502.12	**0.50**
Indirect emissions	**84'268'902**	0		**2.19**
Deposition	47'490'873	475	746.29	0.75
Leaching and run-off	36'778'028	919	1'444.85	1.44
Other (fertilization with compost and sewage sludge)	**3'948'000**	49	77.55	**0.08**
Total	**294'222'336**	**369**	**4'526**	**6.72**

6.5.3. Uncertainties and Time-Series Consistency

Minimum and maximum values for the related emission factors are displayed in Table 102.

Table 102 Minimum and maximum values for emission factors related to agricultural soils (IPCC 2000).

	Medium	Minimum	Maximum
	($kg N_2O$ – N/kg N)		
Emission factor Synthetic Fertilizer (4D1)	0.0125	0.0025	0.0225
Emission factor Fixation (4D1)	0.0125	0.0025	0.0225
Emission factor crop residues (4D1)	0.0125	0.0025	0.0225
Emission factor organic soils (4D1)	8	2	15
Emission factor pasture range and paddock (4D2)	0.02	0.005	0.03
Emission factor leaching and run-off (4D3)	0.025	0.002	0.12
Emission factor deposition (4D3)	0.01	0.002	0.02

From the values of Table 102, an emission factor uncertainty of 80% (4D1) and 90-95% (4D3) may be derived. An activity data uncertainty of 10% is assumed for 4D1 and 15% for 4D3. These numbers are used as input for the Tier 1 analysis.
For Tier 2 (Monte Carlo), a combined uncertainty of 80% (4D1) and 95% (4D3) is used as input for the uncertainty of the emissions. The values are derived from the error propagation formula for the product EF*AD ($U_E^2 = U_{EF}^2 + U_{AD}^2$). Lognormal distributions are assumed. (With normal distributions, the 2.5 percentile values would become negative.) In Table 173 in Annex A1.2.3 the Monte Carlo model uncertainty is given. It slightly deviates from the input value (4D1: 78.8% instead of 80.0%; 4D3: 93.2% instead of 95.0%), which is the result of a consistency adjustment of the correlations coefficients carried out by Crytal Ball Software automatically.

The time series 1990-2004 is consistent.

6.5.4. Source-Specific QA/QC and Verification

No source-specific activities have been carried out for N_2O. However, an internal quality control is done regularly. An internal documentation of the Agroscope Reckenholz-Tänikon Research Station (ART, former name FAL) about the calculation of the greenhouse gas emissions in agriculture assures transparency and traceability of the calculation methods (Berthoud, 2004).

6.5.5. Source-Specific Recalculations

No source-specific recalculations have been carried out.

6.5.6. Source-Specific Planned Improvements

As a component of the quality control process the N_2O calculation method IULIA will be reviewed. It is however not yet assessable whether this review will lead to an adjustment of the N_2O calculations as a whole.

6.6. Source Category 4E – Burning of savannas

Burning of savannas does not occur (NO) in Switzerland.

6.7. Source Category 4F – Field Burning of Agricultural Residues

6.7.1. Source Category Description

Source category 4F "Field Burning of Agricultural Residues" is **not a key source**.

Emissions from Source Category 4F "Field Burning of Agricultural Residues" occur from open burning of branches in agriculture and forestry. The source category includes CH_4, N_2O, NO_x, CO and NMVOC and SO_2 emissions. Burning of wastes in agriculture and forestry is of minor importance in Switzerland.

6.7.2. Methodological Issues

Methodology

The emissions are calculated by multiplying the annual estimate of branches burned (in Gg of wood equivalent) by emission factors.

Emissions factors

The emission factors are taken from the updated EMIS database.

Table 103 Emission factors for calculating emissions from burning of branches in agriculture and forestry (EMIS).

Emissions from burning of branches in agriculture and forestry	**Emission factor** kg/t dry matter
CH_4	6.8
N_2O	0.18
NO_x	3.6
CO	104.0
NMVOC	9.5
SO_2	0.7

Activity data

Activity data is taken from the EMIS database.

Table 104 Activity data for calculating emissions from burning of branches in agriculture and forestry (EMIS). Estimations remained unchanged since 1990.

Amount of Residues burned	**Activity data (in Gg dry matter)**
Amount of branches burned in agriculture and forestry	70

6.7.3. Uncertainties and Time-Series Consistency

No uncertainty assessment has been carried out. Uncertainty is medium or high (especially regarding activity data).

The time series is consistent.

6.7.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the check between EMIS and Internal GHG Files (Section 1.4.3) and the general QA/QC measures described in Section 1.6.1 have been carried out.

6.7.5. Source-Specific Recalculations

The emissions have been recalculated with updated emission factors (EEA 2002) and activity data from EMIS.

6.7.6. Source-Specific Planned Improvements

There are no planned improvements.

7. Land Use, Land-Use Change and Forestry

7.1. Overview

The LULUCF sector has been recalculated following the requirements of decision 13/CP.9. In 2005, Switzerland reported LUCF data that had been produced using the approach of the Revised 1996 IPCC Guidelines (SAEFL 2005f). In FOEN (2006a, b; Annex 4) a method compliant to decision 13/CP.9 was applied for the base year 1990. For details on recalculations see Chapter 9.1.

This chapter includes information about the estimation of greenhouse gas emissions and removals from land use, land-use change and forestry (LULUCF). The data acquisition and calculations are based on the Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC 2003) completed by country-specific methodologies.

The land areas from 1990 to 2004 are represented by geographically explicit land-use data with a resolution of one hectare (following approach 3 for representing land areas; IPCC 2003). Direct and repeated assessment of land use with full spatial coverage also enables to calculate spatially explicit land-use change matrices. In 2004 the new Swiss land-use statistics has been launched (referred to as AREA). AREA operates with a newly designed set of land-use and land-cover categories (SFSO 2006a). Simultaneously, aerial photos from two earlier Swiss land-use statistics (1979/85 and 1992/97) are being re-evaluated according to the new approach. At the moment the interpretation of approximately 11% of the Swiss territory is completed for all three time slices. A full coverage can be expected in 2013 To estimate the land use and land-use change for each year in the period 1990-2004, a spatial extrapolation based on the presently available AREA data in combination with earlier land-use statistics had to be performed.

Country-specific emission factors and carbon stock values for forests and partially for agricultural land and grassland are derived from surveys and measurements. For other land use categories, IPCC default values or expert estimates are used. The growth factors for forests depend on climate conditions and vary annually.

The six main land categories required by IPCC (2003) are: A. Forest Land, B. Cropland, C. Grassland, D. Wetlands, E. Settlements and F. Other Land. These categories were further divided in 18 sub-divisions of land use (see Table 106). A further spatial stratification reflects the criteria ‘altitude’ (3 zones), ‘geomorphologic and climatic conditions’ (adopting the 5 regions of the National Forest Inventory) and ‘soil type’ (mineral, organic).

Table 105 and Figure 29 summarize the CO_2 emissions and removals in consequence of carbon losses and gains for the years 1990-2004. The total net removals/emissions of CO_2 from 1990 to 2004 vary between -4’982 Gg (1999) and 1’857 Gg (2003).

In Table 105 and Figure 30, three components of the CO_2 balance are shown separately:

- Increase of living biomass on forest land: growth of biomass on forest land remaining forest land; it represents the largest sink of carbon.
- Decrease of living biomass on forest land: decrease of carbon in living biomass (by harvest and mortality) on forest land remaining forest land; it represents the largest source of carbon.
- Land-use change and soil: all the rest including carbon removals/emissions due to land-use changes and use of soils, especially of organic soils, and due to agricultural lime application.

Growth of biomass exceeds the harvesting and mortality rate, except in 2003 when growth was significantly reduced by summer heat and drought. Compared to these biomass changes in forests, the net CO_2 emissions arising from all land-use changes and from the use of soils are relatively small (see Figure 30).

Table 105 Switzerland's CO_2 emissions/removals [Gg] of the source category 5 „Land Use, Land-Use Change and Forestry" 1990-2004. Positive values refer to emissions; negative values refer to removals from the atmosphere.

LULUCF	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Mean
	Gg CO_2															
Total Sector 5: LULUCF	-1'711	1'161	645	-3'724	-3'865	-3'212	-2'431	-2'762	-1'128	-4'982	1'254	-664	-526	1'857	-830	-1'395
Increase of living biomass in forest	-13'492	-10'755	-11'296	-14'111	-14'161	-13'795	-12'507	-12'736	-11'318	-15'638	-12'157	-14'488	-14'223	-9'512	-11'865	-12'804
Decrease of living biomass in forest	9'947	10'077	10'097	8'899	8'877	9'148	8'647	8'542	8'753	9'218	11'966	12'379	12'250	9'918	9'584	9'887
Land-use change and soil	1'834	1'839	1'845	1'489	1'419	1'435	1'429	1'432	1'436	1'438	1'445	1'444	1'448	1'451	1'451	1'522

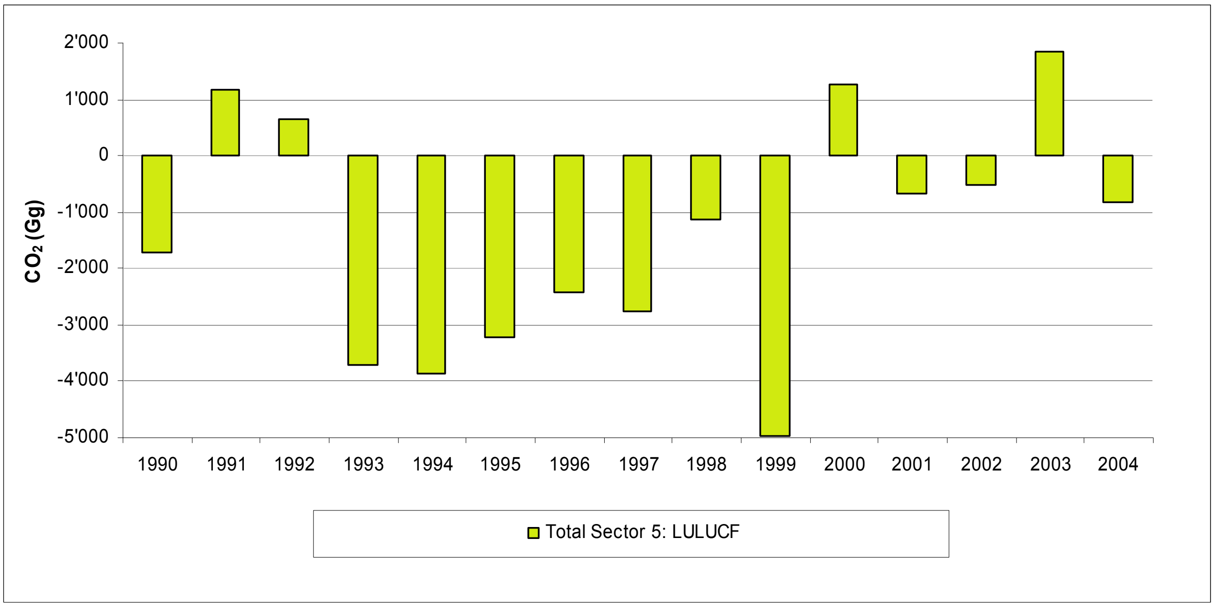


Figure 29 Switzerland's CO_2 emissions/removals of source category 5 "Land Use, Land-Use Change and Forestry" 1990–2004 in Gg CO_2. Positive values refer to emissions, negative values to removals.

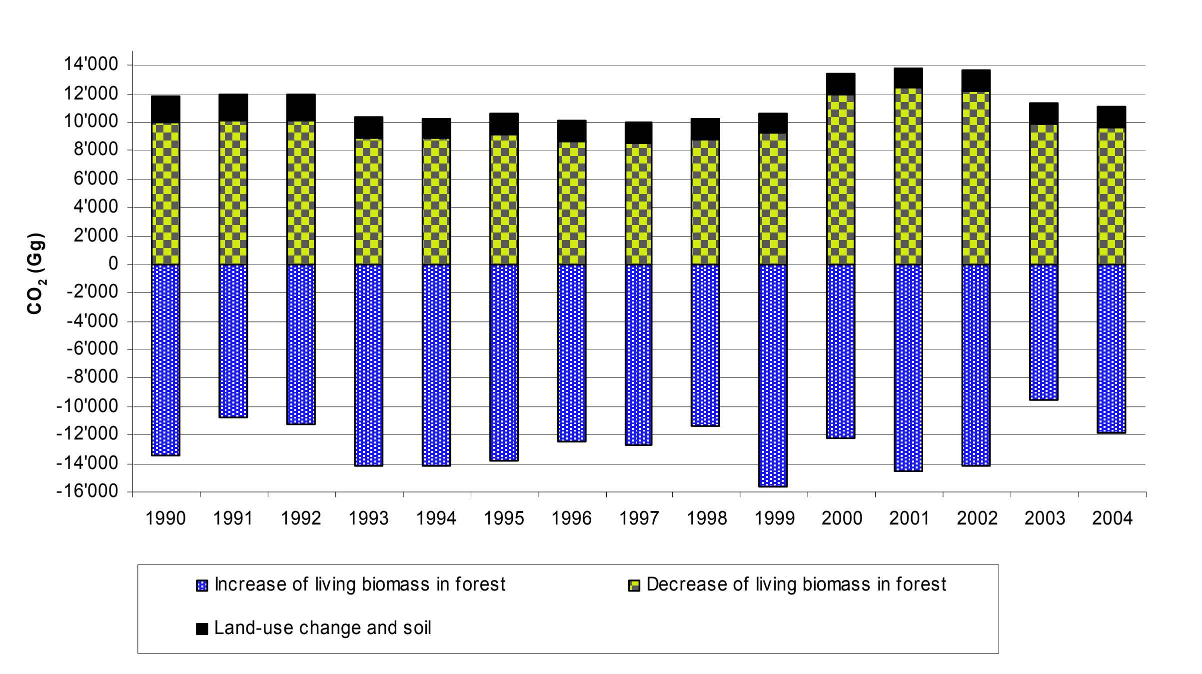


Figure 30 The CO_2 removals due to the increase (growth) of living biomass on forest land, the CO_2 emissions due to the decrease (harvest and mortality) of living biomass on forest land and the net CO_2 emissions due to land-use changes and from use of soils, 1990–2004.

The next chapter (7.2.) gives an overview of the methodical approach including the calculation of the activity data (land-use data) and carbon emissions. The following chapters (7.3-7.8) describe the details of the CO_2 equivalent removal/emission calculations for each main land-use category.

The emissions of CH_4 and N_2O are very small. They add up to less than 0.1 Gg CH_4 and less than 0.1 Gg N_2O for each year between 1990 and 2004. They arise from soil disturbance associated with land-conversion to cropland (CRF Table 5 III) and wildfires on forest land (CRF Table 5 V). The calculation methods are based on default procedures of IPCC (2003; chapter 3) and summarized in chapters 7.3 and 7.4, respectively.

7.2. Methodical Approach and Activity Data

7.2.1. General Approach for Calculating Carbon Emissions/Removals

The selected procedure for calculating carbon emissions and removals in the LULUCF sector corresponds to a Tier 2 approach as described in IPCC (2003; chapter 3). It can be summarised as follows:

- Define land use categories and sub-divisions with respect to available land-use data (see Table 106). For the present study, so-called combination categories (CC) were defined on the basis of the AREA land-use and land-cover categories (FOEN 2006d; SFSO 2006a).
- Define criteria and collect data for the spatial stratification of the land-use categories.
- Measure or estimate the carbon stocks and carbon stock changes for each spatial stratum of the land-use categories.
- Calculate the land use and the land-use change matrix in each spatial stratum.

- Calculate the carbon stock changes in living biomass (deltaC_l), in dead organic matter (deltaC_d) and in soil (deltaC_s) for all cells of the land-use change matrix.
- Finally, aggregate the results by summarising the carbon stock changes over land-use categories and strata according to the level of disaggregation displayed in the CRF tables.

For calculating carbon stock changes, the following input parameters (mean values per hectare) must be quantified for all land-use categories (CC) and spatial strata (i):

stock$C_{l,i,CC}$: carbon stock in living biomass
stock$C_{d,i,CC}$: carbon stock in dead organic matter
stock$C_{s,i,CC}$: carbon stock in soil
increase$C_{l,i,CC}$: annual increase (growth) of carbon in living biomass
decrease$C_{l,i,CC}$: annual decrease (harvesting) of carbon in living biomass
change$C_{d,i,CC}$: annual net carbon stock change in dead organic matter
change$C_{s,i,CC}$: annual net carbon stock change in soil

Table 106 Land-use categories used in this report (so-called combination categories CC): 6 main land-use categories and the 18 sub-divisions. Additionally, descriptive remarks, abbreviations used in the CRF tables, and CC codes are given. For a detailed definition of the CC categories see FOEN (2006d) and SFSO (2006a).

CC Main category	**CC Sub-division**	**Remarks**	**Terminology in CRF tables**	**CC code**
A. Forest Land	Afforestations	areas converted to forest by active measures, e.g. planting	affor	11
	Managed Forest	dense and open forest meeting the criteria of forest land	managed	12
	Unproductive Forest	brush forest and inaccessible forest meeting the criteria of forest land	unprod	13
B. Cropland		arable and tillage land (annual crops and leys in arable rotations)		21
C. Grassland	Permanent Grassland	meadows, pastures (low-land and alpine)	perm	31
	Shrub Vegetation	agricultural and unproductive areas predominantly covered by shrubs	woody, shrub	32
	Vineyards, Low-Stem Orchards, Tree Nurseries	perennial agricultural plants with woody biomass (no trees)	woody, vine	33
	Copse	agricultural and unproductive areas covered by perennial woody biomass including trees	woody, copse	34
	Orchards	permanent grassland with fruit trees	woody, orchard	35
	Stony Grassland	grass, herbs and shrubs on stony surfaces	unprod, stony	36
	Unproductive Grassland	unmanaged grass vegetation	unprod	37
D. Wetlands	Surface Waters	lakes and rivers	surface	41
	Unproductive Wetland	reed, unmanaged wetland	unprod	42
E. Settlements	Buildings and Constructions	areas without vegetation such as houses, roads, construction sites, dumps	build	51
	Herbaceous Biomass in Settlements	areas with low vegetation, e.g. lawns	herb	52
	Shrubs in Settlements	areas with perennial woody biomass (no trees)	shrub	53
	Trees in Settlements	areas with perennial woody biomass including trees	tree	54
F. Other Land		areas without soil and vegetation: rocks, sand, screes, glaciers		61

On this basis, the carbon stock changes in living biomass (deltaC_l), in dead organic matter (deltaC_d) and in soil (deltaC_s) are calculated for all cells of the land-use change matrix. Each cell is characterized by a land-use category before the conversion (b), a land-use category after the conversion (a) and the area of converted land within the spatial stratum (i). Equations 7.2.1.-7.2.3 show the general approach of calculating C-removals/emissions taking into account the net carbon stock changes in living biomass, dead organic matter and soils as well as the stock changes due to conversion of land use (difference of the stocks before and after the conversion):

$$deltaC_{l,i,ba} = [\ increaseC_{l,i,a} - decreaseC_{l,i,a} + W_l * (stockC_{l,i,a} - stockC_{l,i,b})\ ] * A_{i,ba} \qquad (7.2.1)$$

$$deltaC_{d,i,ba} = [\ changeC_{d,i,a} + W_d * (stockC_{d,i,a} - stockC_{d,i,b}\ )\ ] * A_{i,ba} \qquad (7.2.2)$$

$$deltaC_{s,i,ba} = [\ changeC_{s,i,a} + W_s * (stockC_{s,i,a} - stockC_{s,i,b}\ )\ ] * A_{i,ba} \qquad (7.2.3)$$

where:

a: land-use category after conversion (CC = a)
b: land-use category before conversion (CC = b)
ba: land use conversion from b to a
$A_{i,ba}$: area of land converted from b to a in the spatial stratum i (activity data from the land-use change matrix)
W_l, W_d, W_s: weighting factors for living biomass, dead organic matter and soil, respectively.

The following values for W were chosen:

$W_l = W_d = W_s = 0$ if land use after the conversion is 'Forest Land' (a = {11,12,13})

$W_s = 0.5$ if a or b is 'Buildings and Constructions' (a = 51 or b = 51)

$W_l = W_d = W_s = 1$ otherwise.

The difference of the stocks before and after the conversion are weighted with a factor (W_l, W_d, W_s) accounting for the effectiveness of the land-use change in some special cases. For example, the succession from grassland to forest land is quite frequent in mountainous regions in Switzerland. Immediately after the conversion young forests have lower carbon stocks than the mean carbon stock values determined for 'managed forest'. Therefore, the weighting factors for the conversion 'to forest land' was set to zero in order to avoid an overestimation of C-sinks (see also Chapter 7.3.2.I). In the case of land-use changes involving 'buildings and constructions' it is assumed that only 50% of the soil carbon is emitted as the humus layer is re-used on construction sites (see also Chapter 7.7.2).

For all land-use categories applies: If a equals b, there is no change in land use and the difference in carbon stocks becomes zero.

For calculating annual carbon stock changes in soils due to land-use conversion, IPCC (2003) suggested a default delay time (inventory period) of 20 years. In this study, the inventory period of land-use changes is predetermined by the inter-survey period of the Swiss land-use statistics and averages approximately 12 years.

In the CRF tables 5.A to 5.F, land-use categories (CC) and associated spatial strata are partially shown at an aggregated level for optimal documentation and overview. The values of deltaC are accordingly summarised. Positive values of $deltaC_{l,i,ba}$ are inserted in the column "Increase" and negative values in column "Decrease", respectively (besides $increaseC_{l,i,CC}$ and $decreaseC_{l,i,CC}$ if land-use does not change).

7.2.2. General Approach for Compiling Land-use Data

a) Swiss Land Use Statistics (AREA)

Data of the Swiss Land Use Statistics (AREA) evaluated by the Swiss Federal Statistical Office (SFSO 2006) are the basis in this report. In the course of the AREA survey, every hectare of Switzerland's territory (4'128 kha) will be assigned to one of 46 land-use categories and to one of 27 land-cover categories by means of stereographic interpretation of aerial photos (SFSO 2006a).

For the reconstruction of the land use conditions in Switzerland for the period 1990-2004 three data sets are used:

- Land Use Statistics “1979/85” (AREA1)
- Land Use Statistics “1992/97” (AREA2)
- Land Use Statistics “2004/09” (AREA3) (launched in 2004)

The aerial photos for AREA1 and AREA2 were actually taken 1977-1986 and 1990-1998 in the course of two earlier Swiss land-use statistics (ASCH1 and ASCH2), respectively. They are now simultaneously being re-evaluated according to the newly designed AREA set of land-use and land-cover categories (SFSO 2006a). Presently, coherently interpreted data of approximately 11% of the Swiss territory are available for all three time slices (AREA1-AREA2-AREA3; SFSO 2006).

aAREA3 was recently launched and it can be expected to be completed in 2013 As a direct consequence, the inter-survey period is (as it was in former surveys) not the same throughout the Swiss territory, but varies regionally. It averages approximately 12 years. This methodical characteristic needs to be considered when reconstructing the annual country-wide ‘status’ or when calculating annual rates of land-use change.

b) Combination Categories (CC) as derived from AREA Land Use Statistics

The 46 land-use categories and 27 land-cover categories of AREA were aggregated to 18 combination categories (CC, FOEN 2006d) implementing the main categories proposed by IPCC as well as country-specific sub-divisions (see Table 106). The sub-divisions were defined with respect to optimal distinction of biomass densities, carbon turnover, and soil carbon contents.

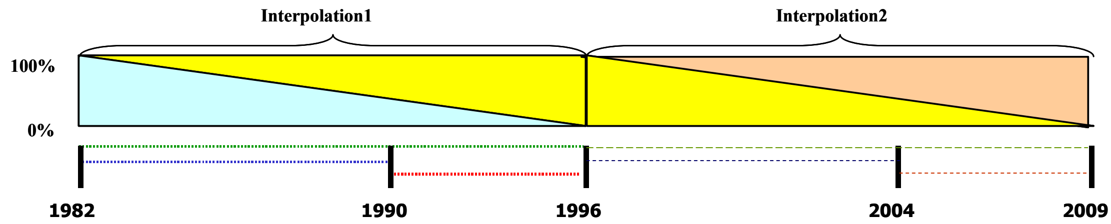
The first digit of the CC-code represents the main category, whereas the second digit stands for the respective sub-division.

c) Interpolation of the ’Status’ for each Year

The exact dates of aerial photo shootings are known for each hectare. However, the exact year of the land-use change on a specific hectare is unknown. The actual change can have taken place in any year between two AREA surveys. In this study, it is assumed that the probability of a land-use change from AREA1 to AREA2 and from AREA2 to AREA3 is uniformly distributed over the respective interim period between two surveys. Therefore, the land-use change of each hectare has to be equally distributed over its specific interim period.

Thus, the land-use ‘status’ for the years between two data collection dates can be calculated by linear interpolation. Dates of aerial photo shootings (i.e. starting and ending year of the inter-survey period) and the land-use categories of AREA1, AREA2 and AREA3 for every hectare are used for these calculations.

Example (Figure 31): A hectare has been assigned to the land-use category “cropland” (CC 21) in AREA1. A land-use change to “shrubs in settlements” (CC 53) has been discovered 14 years later in AREA2.



Definitions interpolation1:	Calculation formulas :	„State 1990" :
ydiff = 1996 - 1982	Percentage „ shrubs in settlements 1990 " = (ybefore1990 / ydiff) *100 [%]	57.14 %
ybefore1990 = 1990 - 1982	Percentage „Cropland 1990" = (yafter1990 / ydiff) *100 [%]	42.86%
yafter1990 = 1996 - 1990		

Definitions interpolation2:	Calculation formulas :	„State 2004" :
ydiff = 2009 - 1996	Percentage „shrubs in settlements 2004" = (ybefore2004 / ydiff) *100 [%]	61.53 %
ybefore2004 = 2004 - 1996	Percentage „buildings and constructions2004" = (yafter2004 / ydiff) *100 [%]	38.47%
yafter2004 = 2009 - 2004		

Figure 31 Hypothetical linear development of land-use changes between AREA1, AREA2 and AREA3 considering as example a hectare changing from "cropland" to "shrubs in settlements" and then from "shrubs in settlements" to "buildings and constructions".

The 'status 1990' is determined by calculating the fractions of the two land-use categories for the year 1990. A linear development from "cropland" to "shrubs in settlements" during the whole interim period is assumed. Thus, in 1990 the hectare is split up in two fractions: 57.14% is "shrubs in settlements" and 42.86% is "cropland". The same procedure can be applied for two survey dates between AREA2 and AREA3 (see Figure 31: example 'status 2004'). The 'status' for each individual year in the period 1990-2004 for the whole Swiss territory results from the summation of the fractions of all hectares per CC (considering the spatial strata where appropriate) (see Table 108).

7.2.3. Spatial Stratification

In order to quantify carbon stocks and increases/decreases, a further spatial stratification of the territory turned out to be useful. For forests, 3 different altitudinal belts and the 5 production regions of the National Forest Inventory (NFI; EAFV/BFL 1988; Brassel and Brändli 1999) were differentiated. The NFI regions were adopted from EAFV/BFL (1988):

1. Jura
2. Central Plateau
3. Pre-Alps
4. Alps
5. Southern Alps.

Altitude data were available on a hectare-grid from the Swiss Federal Statistical Office (SFSO 1997) and classified in belts <600 m a.s.l. (meters above sea level), 601-1200 m a.s.l., and >1200 m a.s.l. (Figure 32).

For agriculture, it was important to differentiate two soil types (organic and mineral soils) and also altitudinal zones. For mapping the occurrence of organic soils, two appropriate categories of the digital soil map "BEK" (SFSO 2000a) were selected, as shown in Figure 32. The codes F1 and Q3 represent organic soils (histosols) in the Central Plateau and in alpine valleys, respectively.

Thus, 30 different strata (i) would be theoretically possible. Not all of them, but 20 have been defined and used for the calculation of LULUCF-associated C-revomals/emissions (see below).

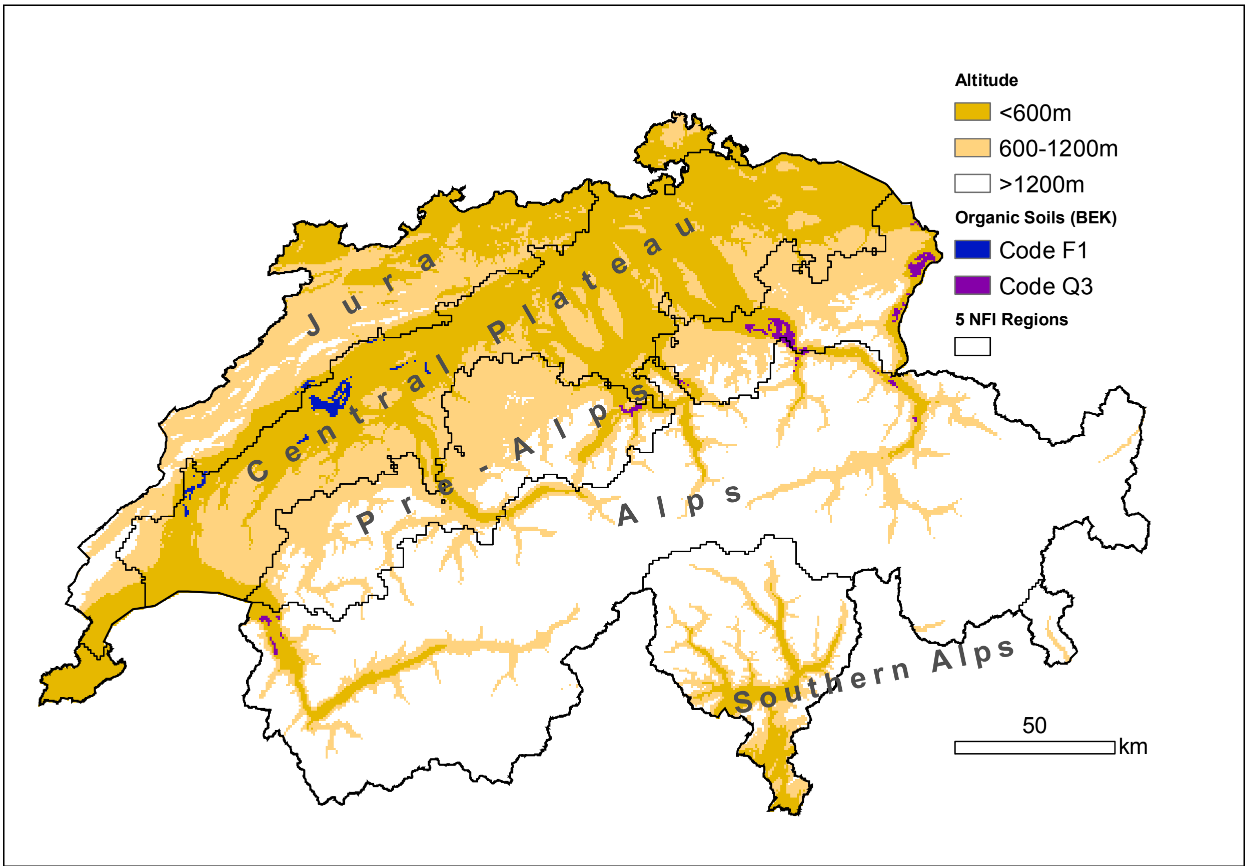


Figure 32 Map showing the spatial stratification according to altitude, soil type and NFI region.

7.2.4. Spatial Extrapolation of Land-use Statistics

The land-use survey AREA3 has been launched in 2004. Presently, a sample region covering approximately 11% of the Swiss territory has been evaluated (see Figure 33). In the same sample region, the old aerial photographs of two prior land-use statistics (ASCH1 and ASCH2) have been simultaneously re-analysed using the new interpretation categories, thus providing additional datasets for AREA1 and AREA2. For the rest of the Swiss territory data availability is currently restricted to the LUcode classification, i.e. a land-use classification that has been developed on the basis of ASCH1 and ASCH2 data (Table 107; see FOEN 2006b for details).

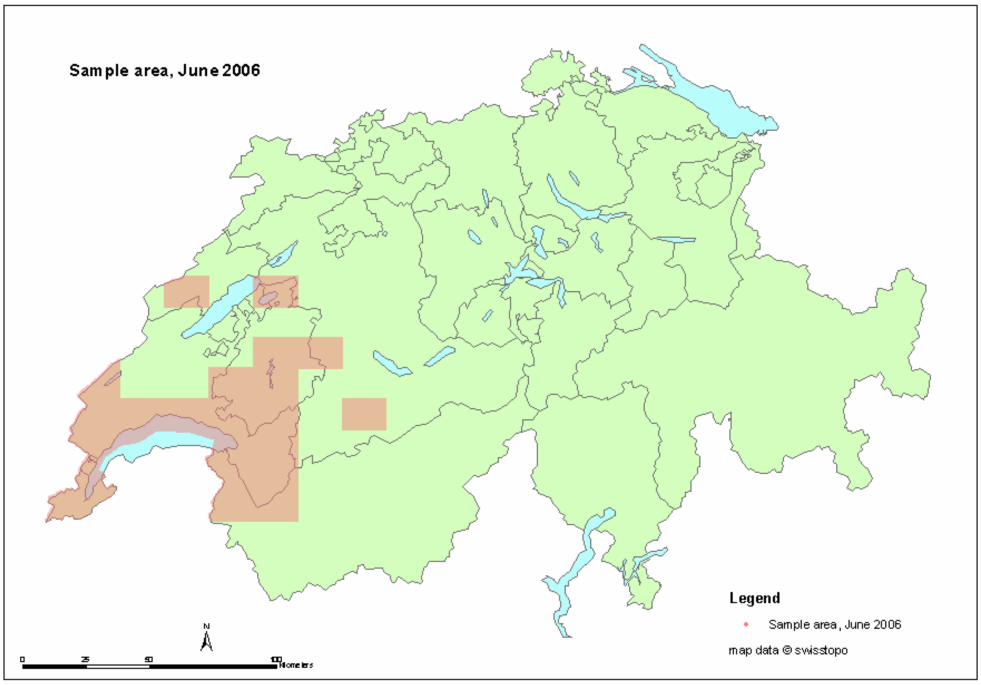


Figure 33 Map showing the regions (orange) which have already been evaluated in the land-use survey AREA3.

A spatial extrapolation of the AREA-derived CC data in the sample region (~11%) to the total Swiss territory has been carried out, using ASCH2 as a reference basis. First, the CC data in the sample region ($AREA_{samp}$) were interpolated in time for each year (see Figure 31), and then the spatial extrapolation of the respective land-use categories was calculated. In the same way the land-use *changes* detected in the sample region were extrapolated.

The LUcode classification included the 6 main categories and 13 sub-divisions (LUcode), which are an aggregation of the 74 ASCH-codes (FOEN 2006b). The CC classification is built of 6 main categories and 18 sub-divisions (Table 107). A direct correspondence of all LUcode and CC sub-divisions is not given. Therefore, an auxiliary categorisation, called 'excat' (extrapolation category) is introduced. Excat includes 11 sub-divisions. Each LUcode category and CC, respectively, can be definitely assigned to one excat code. The relation between LUcodes categories, CC and 'excat' is shown in Table 107.

Table 107 Relation between different land-use categorisations: main categories, LUcode sub-divisions, LUcode (aggregated ASCH-code; FOEN 2006b), ASCH-code, excat (extrapolation category), combination category (CC; this report) and CC code.

Main Category	LUcode Sub-division	LUcode	ASCH-code	ASCH-description	Excat code	Combination Category (CC)	CC code
Forest Land	Afforestations	11	9	Afforestations	11	Afforestations	11
	Productive Forest	12	10	Damaged forest areas	12	Managed Forest	12
			11	Normal dense forest	12		
			13	Open forest (on agricultural areas)	12		
			14	Forest stripes, edges	12		
	Unproductive Forest	13	12	Open forest (on unproductive areas)	13	Unproductive Forest	13
			15	Brush forest	13		
Cropland		20	52	Garden allotments	21		
			71	Regular vineyards	30		
			72	"Pergola" vineyards	30		
			73	Extensive vines	30		
			78	Horticulture	21		
			81	Favourable arable land and meadows	21		
					21	Cropland	21
Grassland	Permanent Grassland	31	32	Green motorway environs	31	Permanent Grassland	31
			38	Airfields, green airport environs	31		
			54	Golf courses	50		
			67	Green railway environs	31		
			68	Green road environs	31		
			82	Other arable land and meadows	31		
			83	Farm pastures	31		
			85	Mountain meadows	31		
			87	Remote and steep alpine	31		
			88	Favourable alpine pastures	31		
			89	Rocky alpine pastures	31		
	Grass with Perennial Woody Biomass	32	16	Scrub vegetation	30	Shrub Vegetation	32
			17	Groves, hedges	30		
			18	Clusters of trees (on agricultural areas)	30		
			19	Other woods	30		
			75	Intensive orchards	30		
			76	Rows of fruit trees	30		
			77	Scattered fruit trees	30		
			84	Brush meadows and farm pastures	30		
			86	Brush alpine pastures	30		
		33	97	Unproductive grass and shrubs	30		
	Unproductive Grassland				30	Vineyards, Low-Stem Orchards, Tree nurseries	33
					30	Copse	34
					30	Orchards	35
					30	Stony Grassland	36
					30	Unproductive Grassland	37
Wetlands	Surface Waters	41	91	Lakes	41	Surface Waters	41
			92	Rivers	41		
	Unproductive Wetland	42	95	Wetlands	42	Unproductive Wetland	42
			96	Water shore vegetation	42		
Settlements	Buildings/Constructions	51	20	Ruins	51	Buildings and Constructions	51
			21	Industrial buildings	51		
			23	Buildings in recreational areas	51		
			24	Buildings in special urban areas	51		
			25	One- and two-family houses	51		
			26	Terraced houses	51		
			27	Blocks of flats	51		
			28	Agricultural buildings	51		
			29	Unspecified buildings	51		
			31	Motorways	51		
			33	Roads and paths	51		
			34	Parking areas	51		
			35	Railway station grounds	51		
			36	Railway lines	51		
			37	Airports	51		
			51	Sport grounds	51		
			53	Camping, caravan sites	51		
			61	Other supply or waste treatment plants	51		
			62	Energy supply plants	51		
			63	Waste water treatment plants	51		
			64	Quarries, mines	51		
			65	Dumps	51		
			66	Construction sites	51		
	Surrounding of Buildings	52	41	Industrial grounds	50	Herbaceaus Biomass in Settlement	52
			45	Surroundings of one- and two-family	50		
			46	Surroundings of terraced houses	50		
			47	Surroundings of blocks of flats	50		
			48	Surroundings of agricultural buildings	50		
			49	Surroundings of unspecified buildings	50		
	Parks	53	56	Cemeteries	50	Shrubs in Settlements	53
			59	Public parks	50		
					50	Trees in Settlements	54
Other Land		60	69	River shores	61		
			90	Glaciers, perpetual snow	61		
			93	Flood protection structures	61		
			98	Avalanche protection structures	61		
			99	Rocks, sand, screes	61		
					61	Other Land	61

In this extrapolation approach the whole Swiss territory is divided into three main sub-regions (see Figure 34):

- Sample region (samp): CC data are available on hectare-basis for AREA1, AREA2 and AREA3. ~11% of Swiss territory.
- use can be quantified by extrapolating CC data in the sample region using excat. ~90% of Swiss territory (including the sample region).
- Substitution region (subst): This is the remaining area for which no or too little CC data in the sample region are available. Extrapolation of CC data is impossible and land-use data from the ASCH2 survey (LUcode categories) is used instead. 10% of total country area. Changes in land-use are neglected in the substitution region.

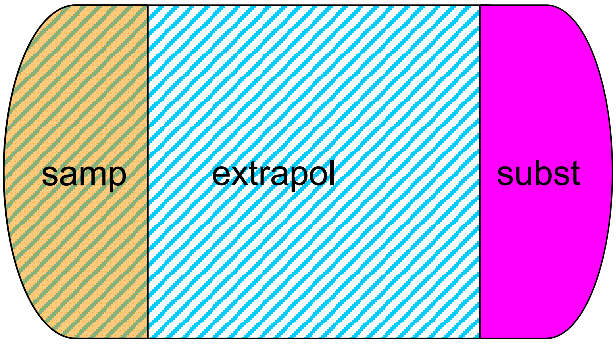


Figure 34 Scheme showing the three sub-regions of Switzerland used for the extrapolation: sampling region of AREA (samp), extrapolation region (extrapol, diagonal shading) and substitution region (subst).

As the spatial stratification is needed for the computation of CO_2 equivalent removals/ emissions the land use and land-use changes must be quantified for each stratum. The basic idea is to extrapolate the CC data of a certain stratum by applying a stratum-specific area expansion factor (AEF). As CC datasets are not available in ASCH2, excat is used instead. The AEF for a certain excat in stratum i(z,nfi,soil) can be formulated as:

$$AEF(excat,i) = ASCH2_{extrapol}(excat,i) \,/\, ASCH2_{samp}(excat,i) \qquad (7.2.4)$$

where:

$ASCH2_{extrapol}(excat,i)$: Number of hectares in the ASCH2 dataset covered by land-use type excat situated in stratum i for the whole extrapolation region

$ASCH2_{sample}(excat,i)$: Number of hectares in the ASCH2 dataset covered by land-use type excat situated in stratum i in the sample region

i: Spatial strata defined by a combination of z (altitude zone), nfi (NFI region) and soil (organic, mineral); i = i(z,nfi,soil).

To avoid arbitray results caused by very small and unrepresentative areas in the sample region, a 'decision cascade' is introduced (see Figure 35). The idea is to apply a less differentiated AEF if the size of the sub-sample does not reach a specific threshold (T). The threshold of the most differentiated case (level A in Figure 35) is calculated as follows:

$$T(excat,i) = 5.0\% * ASCH_{extrapol}(excat,i) \qquad (7.2.5)$$

The threshold was empirically tested and arbitrarily set to 5.0%. In future, the threshold will be successively set to the half of the relative size of the sample region.

description	threshold	availability	number of categories
level A: excat, i	**T (excat,i)**	**60%**	**208 (max. 330)**
level B1: excat	**T (excat)**	**91%**	**11**
level B2: i	**T (i)**	**70%**	**20 (max. 30)**
level C: main category	**T (main category)**	**50%**	**6**
level D: general	**-**	**100%**	**1**

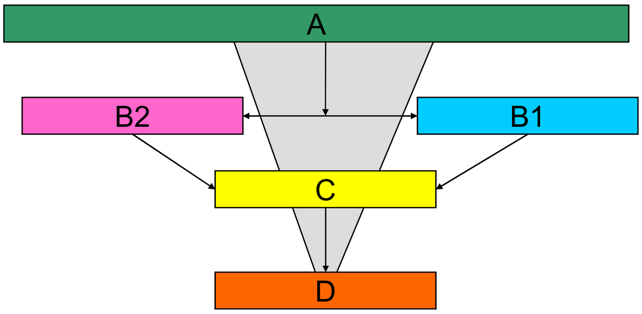


Figure 35 Extrapolation cascadea for calculating area expansion factors (AEF) at different levels of differentiation.

If the size of the sub-sample $AREA_{samp}$(excat(CC),i,yr) is greater than the threshold T(excat,i), then the extrapolated area $AREA_{extrapol}$(CC,i,yr) is calculated by the most differentiated AEF (see Equation 7.2.4). This corresponds to level A in Figure 35. With these AEF-values, the extrapolated aera of the combination category CC in the stratum i in the year yr is calculated as follows:

$$AREA_{extrapol}(CC,i,yr) = AEF(excat(CC),i) * AREA_{samp}(CC,i,yr) \quad (7.2.6)$$

where:

$AREA_{samp}$(CC,i,yr): Number of all hectares in the AREA data sample (interpolated to the year yr) covered by land-use type CC situated in stratum i.

excat(CC): Stands for the excat to which the respective CC is assigned (see Table 107).

If the threshold is not reached at level A, then the threshold values of level B1 (T(excat)) and B2 (T(i)) are calculated (with an appropriately simplified version of Equation 7.2.5) and compared. The AEF of the level with the higher value for T is calculated (only if threshold is exceeded):

$$AEF(excat) = ASCH2_{extrapol}(excat) / ASCH2_{samp}(excat) \quad (7.2.7a)$$
$$AEF(i) = ASCH2_{extrapol}(i) / ASCH2_{samp}(i) \quad (7.2.7b)$$

where:

$ASCH2_{extrapol}$(excat): Number of all hectares in the ASCH2 dataset covered by land-use type excat within the extrapolation region, regardless of the stratum i.

$ASCH2_{samp}$(excat): Number of all hectares in the ASCH2 dataset covered by land-use type excat within the sample region, regardless of the stratum i.

$ASCH2_{extrapol}$(i): Number of all hectares in the ASCH2 dataset lying in the spatial stratum i within the extrapolation region, regardless of the land-use category.

$ASCH2_{samp}$(i): Number of all hectares in the ASCH2 dataset lying in the spatial stratum i within sample region, regardless of the land-use category.

If the size of the sub-sample size does not reach the thresholds T(excat) and T(i), the threshold of the main category T(maincat) is evaluated and the AEF(maincat) is used (level C in Figure 35). 'Maincat' denotes the main land-use category according to Table 107:

$AEF(maincat) = ASCH2_{extrapol}(maincat) / ASCH2_{samp}(maincat)$ (7.2.8)

If also T(maincat) is not reached by the size of the generalised sub-sample, then the most general area expansion factor AEF(general) is used (level D in Figure 35), which is the ratio of the extrapolation region to the sample region:

$AEF(general) = ASCH2_{extrapol} / ASCH2_{samp}$ (7.2.9)

By applying area expansion factors of different accuracy levels, slight discrepancies in the total area result. Therefore, a calibration factor F is calculated *a posteriori* to adjust the sum of the calculated areas to the real total area of the extrapolation region:

$F(yr) = ASCH2_{extrapol} / [\ \Sigma\ AREA_{extrapol}(CC,i,yr)\ ]$ (7.2.10)

With the presently available sample data, an averaged value of F(yr) is used for all years: F = 1.082.

In the substitution region only ASCH data are available (i.e. $AREA_{samp}(CC,i,yr) = 0$). ASCH2 data are chosen as a surrogate for AREA. They are converted by means of the excat classification to the CC by the function 'part', which corresponds to the fraction of CC in excat:

$AREA_{subst}(CC,i,yr) = ASCH2_{subst}(excat(CC),i) * part(CC,yr)$ (7.2.11)

$part(CC,yr) = AREA_{samp}(CC,yr) / AREA_{samp}(excat(CC),yr)$ (7.2.12)

where:

$ASCH2_{subst}(excat(CC),i)$: Number of all hectares in the ASCH dataset covered by land-use excat and situated in stratum i in the substitution region.

$AREA_{samp}(CC,yr)$: Number of all hectares in the AREA dataset covered by land-use CC.

$AREA_{samp}(excat(CC),yr)$: Number of all hectares in the AREA dataset covered by land-use excat.

The total stratified area of the CC in Switzerland is the sum of the calibrated area in the extrapolation region and of the area in the substitution region:

$AREA_{Switzerland}(CC,i,yr) = F * AREA_{extrapol}(CC,i,yr) + AREA_{subst}(CC,i,yr)$ (7.2.13)

As the size of the sample region will increase continuously during the next years, the results of this extrapolation approach will successively become more precise.

7.2.5. The Land-use Tables and Change Matrices

In Table 108 the land-use statistics resulting from interpolation in time (Chapter 7.2.2.c), spatial stratification (Chapter 7.2.3) and spatial extrapolation (Chapter 7.2.4) are shown for the year 1990 as an example. This table gives also an overview of the size of the spatial strata.

Table 109 shows the overall trends of land-use changes between 1990 and 2004. For example, the area of afforestations (CC 11) decreased by 72% during this period, while the area of managed forests (CC 12) increased by 2%.

Table 108 Land use (CC) by the end of 1990, stratified separately for altitude (3 zones), soil type (mineral or organic) and NFI-region (1-5), in ha.

CC:	11	12	13	21	31	32	33	34	35	36	37	41	42	51	52	53	54	61	Sum
Altitude																			
<600	830	186520	638	353895	74724	2194	46053	18797	242	990	1816	148411	5710	129511	49415	2443	26929	2893	1052012
600-1200	1370	531203	6936	137112	428343	6385	6082	47969	195	2497	2800	9064	3844	50582	20219	1240	6654	9783	1272279
>1200	1268	386298	77800	1578	486506	97001	11817	88067	69	108788	99005	5688	20062	12543	3488	151	1325	402628	1804082
	3467	1104022	85374	492585	989574	105580	63952	154833	506	112275	103620	163164	29616	192636	73123	3833	34908	415304	4128372
Soil																			
organic	7	1125	2	16183	1745	64	144	330	1	54	206	499	336	1664	809	67	232	144	23613
mineral	3460	1102896	85373	476402	987829	105516	63808	154503	506	112220	103415	162665	29280	190971	72314	3766	34676	415161	4104759
	3467	1104022	85374	492585	989574	105580	63952	154833	506	112275	103620	163164	29616	192636	73123	3833	34908	415304	4128372
NFI-region																			
1	484	171595	49	89121	108506	847	11746	14838	56	247	380	25513	1393	31357	11962	528	5675	415	474712
2	815	244089	84	352763	150135	1413	23205	21313	225	308	829	75087	4827	93930	36320	1439	19745	2084	1028615
3	933	222882	3632	30894	287300	9775	2631	26890	15	7631	8926	33110	13829	29934	10003	830	4140	17560	710916
4	1081	342708	47025	15440	405659	83167	12280	69662	131	93755	83210	16137	9142	29209	10486	789	3347	335332	1558564
5	155	122748	34585	4367	37973	10378	14090	22131	80	10334	10275	13316	425	8206	4353	246	2001	59913	355580
	3467	1104022	85374	492585	989574	105580	63952	154833	506	112275	103620	163164	29616	192636	73123	3833	34908	415304	4128372

Table 109 Statistics of land use (CC) for the whole period 1990-2004 (in kha) and relative change (%) between 1990 and 2004.

CC:	11	12	13	21	31	32	33	34	35	36	37	41	42	51	52	53	54	61	Sum
Year:																			
1990	3.5	1104.0	85.4	492.6	989.6	105.6	63.8	155.0	0.5	112.2	103.5	163.2	29.6	192.6	73.1	3.8	34.9	415.3	4128.4
1991	3.4	1106.4	86.1	490.9	987.3	104.9	64.1	154.1	0.5	111.8	103.5	163.2	29.6	194.6	73.7	3.9	35.4	414.9	4128.4
1992	3.4	1108.7	86.8	489.3	985.1	104.2	64.3	153.2	0.4	111.4	103.5	163.2	29.6	196.6	74.4	4.0	36.0	414.4	4128.4
1993	3.3	1110.4	87.1	487.8	984.5	104.0	64.2	152.3	0.4	111.2	103.3	163.2	29.6	198.1	74.9	4.0	36.0	414.0	4128.4
1994	3.0	1111.8	87.5	485.7	985.1	103.8	64.0	151.4	0.4	111.1	103.2	163.2	29.7	199.6	75.4	4.0	36.0	413.4	4128.4
1995	2.8	1113.1	87.9	483.6	985.6	103.6	63.8	150.6	0.4	110.9	103.0	163.3	29.7	201.1	75.9	4.0	36.0	412.9	4128.4
1996	2.6	1114.5	88.3	481.5	986.1	103.5	63.7	149.7	0.4	110.8	102.8	163.3	29.7	202.6	76.4	4.0	36.0	412.3	4128.4
1997	2.4	1115.9	88.7	479.4	986.6	103.3	63.5	148.8	0.4	110.7	102.7	163.3	29.7	204.1	77.0	4.1	36.0	411.7	4128.4
1998	2.2	1117.2	89.2	477.3	987.1	103.2	63.3	148.0	0.4	110.5	102.5	163.3	29.7	205.6	77.5	4.1	36.0	411.2	4128.4
1999	2.0	1118.6	89.6	475.2	987.7	103.0	63.2	147.1	0.4	110.4	102.4	163.3	29.8	207.1	78.0	4.1	35.9	410.6	4128.4
2000	1.8	1120.0	90.0	473.2	988.2	102.8	63.0	146.2	0.4	110.2	102.2	163.3	29.8	208.6	78.5	4.1	35.9	410.1	4128.4
2001	1.6	1121.3	90.4	471.1	988.7	102.7	62.8	145.3	0.4	110.1	102.1	163.4	29.8	210.1	79.1	4.1	35.9	409.5	4128.4
2002	1.4	1122.7	90.8	469.0	989.2	102.5	62.7	144.5	0.4	109.9	101.9	163.4	29.8	211.6	79.6	4.2	35.9	409.0	4128.4
2003	1.2	1124.1	91.2	466.9	989.7	102.3	62.5	143.6	0.4	109.8	101.8	163.4	29.8	213.1	80.1	4.2	35.9	408.4	4128.4
2004	1.0	1125.4	91.6	464.8	990.3	102.2	62.3	142.7	0.3	109.7	101.6	163.4	29.9	214.6	80.6	4.2	35.9	407.9	4128.4
Change:	-72	2	7	-6	0	-3	-2	-8	-33	-2	-2	0	1	11	10	9	3	-2	

The mean annual rates of change in the whole country (change-matrix) are achieved by adding up the mean annual change rates of all hectares per combined category (CC). Table 110 shows an overview of the mean annual changes of all CC in 1990 as an example. The totals of the columns are equal to the total increase of one specific category. The totals of the rows are equal to the total decrease of one specific category. The absolute values of increases and decreases are identical.

For calculating the carbon stock changes, fully stratified land-use change matrices are used for each year (not shown here, internal document). In principle, those matrices consists of 20 matrices like the one shown in Table 110, one for each spatial stratum (see section 7.2.3.).

Table 110 Mean annual rates of land-use change in 1990 (change matrix). Units: ha/year, rounded values.

	CC	change to																		
		11	12	13	21	31	32	33	34	35	36	37	41	42	51	52	53	54	61	decrease
change from	11	0	285	0	7	125	25	0	33	0	1	4	0	7	33	4	4	3	4	534
	12	458	0	64	5	88	786	4	706	0	5	18	2	56	137	36	4	18	18	2405
	13	0	109	0	0	20	710	2	32	0	18	14	2	0	0	0	0	0	6	913
	21	7	3	0	0	128	7	333	99	16	10	0	4	0	796	611	15	46	9	2084
	31	233	104	18	155	0	708	155	42	2	194	45	3	5	901	784	31	79	40	3500
	32	56	1137	850	4	906	0	11	354	0	255	423	8	6	16	8	2	5	94	4133
	33	0	5	1	199	90	11	0	15	5	1	2	1	0	53	49	2	3	12	449
	34	60	1038	38	70	162	354	15	0	14	38	39	4	2	174	124	11	94	23	2261
	35	0	0	0	10	4	0	5	14	0	0	0	0	0	2	1	0	0	0	36
	36	3	8	22	5	257	255	1	38	0	0	274	1	1	5	1	0	0	388	1259
	37	11	25	17	1	56	423	2	39	0	274	0	2	0	8	1	0	0	114	972
	41	0	0	0	5	0	4	0	1	0	1	1	0	16	1	0	0	0	18	48
	42	11	56	0	2	5	7	0	2	0	0	0	48	0	2	4	5	2	2	145
	51	41	107	0	730	650	12	80	187	4	3	5	2	4	0	116	15	70	4	2031
	52	3	23	0	445	456	7	47	108	1	1	0	0	1	90	0	40	361	1	1584
	53	4	2	0	12	18	1	3	9	0	0	0	0	1	15	40	0	34	0	141
	54	2	11	0	32	44	2	4	81	0	0	0	1	1	52	361	34	0	1	625
	61	6	20	6	15	49	92	14	23	0	352	102	60	2	7	2	0	2	0	751
	increase	896	2932	1016	1697	3057	3403	674	1782	42	1152	928	138	102	2292	2143	165	717	735	23870

7.2.6. Carbon Emission Factors and Stocks at a Glance

Table 111 lists all values of carbon stocks, increases, decreases and net changes of carbon specified for land-use category (CC) and associated spatial strata for the year 1990. These values remain constant during the period 1990-2004 with the exception of the carbon stock, increase and decrease of living biomass of CC 12 (managed forest). The deduction of the annually changing data of CC 12 – according to specific climate conditions and harvesting statistics – is described in Chapter 7.3.2.f. The data can be found in Table 112.

Table 111 Carbon stocks and changes in biomass, dead organic matter and soils for the combination categories (CC), disaggregated for altitude, NFI-region, and soil type. These values are valid for the whole period 1990-2004 with the exception of stockCl, increaseCl and decreaseCl of CC 12; which change annually.

land-use code CC	altitude zone z	NFI region	soil type	carbon stock in living biomass (stockCl,i)	carbon stock in dead organic matter (stockCd,i)	carbon stock in soil (stockCs,i)	growth of living biomass (increaseCl,i)	harvesting of living biomass (decreaseCl,i)	net change in dead organic matter (changeCd,i)	net change in soil (changeCs,i)
	Strata			**t C ha^{-1}**			**t C ha^{-1} yr^{-1}**			
11	1	1	n.s.	12.35	0	75.00	2.56	0	0	0
	1	2	n.s.	12.35	0	62.60	2.56	0	0	0
	1	3	n.s.	12.35	0	75.30	2.56	0	0	0
	1	4	n.s.	12.35	0	72.10	2.56	0	0	0
	1	5	n.s.	12.35	0	109.00	2.56	0	0	0
	2	1	n.s.	6.70	0	75.00	1.70	0	0	0
	2	2	n.s.	6.70	0	62.60	1.70	0	0	0
	2	3	n.s.	6.70	0	75.30	1.70	0	0	0
	2	4	n.s.	6.70	0	72.10	1.70	0	0	0
	2	5	n.s.	6.70	0	109.00	1.70	0	0	0
	3	1	n.s.	2.41	0	75.00	0.85	0	0	0
	3	2	n.s.	2.41	0	62.60	0.85	0	0	0
	3	3	n.s.	2.41	0	75.30	0.85	0	0	0
	3	4	n.s.	2.41	0	72.10	0.85	0	0	0
	3	5	n.s.	2.41	0	109.00	0.85	0	0	0
12	1	1	n.s.	129.10	2.34	84.70	3.56	-2.41	0	0
	1	2	n.s.	136.68	1.72	72.10	5.57	-4.35	0	0
	1	3	n.s.	156.80	4.45	92.70	4.49	-3.05	0	0
	1	4	n.s.	95.38	7.51	105.50	3.36	-2.43	0	0
	1	5	n.s.	73.88	5.13	131.30	1.73	-1.06	0	0
	2	1	n.s.	124.71	2.19	84.70	3.44	-2.40	0	0
	2	2	n.s.	149.71	1.67	72.10	5.67	-4.07	0	0
	2	3	n.s.	152.16	4.01	92.70	4.18	-3.11	0	0
	2	4	n.s.	100.95	6.75	105.50	2.63	-1.82	0	0
	2	5	n.s.	69.74	5.06	131.30	1.86	-0.83	0	0
	3	1	n.s.	84.98	2.18	84.70	1.92	-1.50	0	0
	3	2	n.s.	93.50	1.66	72.10	1.66	-0.95	0	0
	3	3	n.s.	116.23	3.98	92.70	2.52	-2.06	0	0
	3	4	n.s.	94.53	6.22	105.50	1.90	-1.66	0	0
	3	5	n.s.	78.26	4.06	131.30	1.51	-0.48	0	0
13	1	1	n.s.	41.41	0	84.70	0	0	0	0
	1	2	n.s.	42.07	0	72.10	0	0	0	0
	1	3	n.s.	41.41	0	92.70	0	0	0	0
	1	4	n.s.	36.50	0	105.50	0	0	0	0
	1	5	n.s.	34.81	0	131.30	0	0	0	0
	2	1	n.s.	43.48	0	84.70	0	0	0	0
	2	2	n.s.	41.41	0	72.10	0	0	0	0
	2	3	n.s.	43.01	0	92.70	0	0	0	0
	2	4	n.s.	34.61	0	105.50	0	0	0	0
	2	5	n.s.	30.19	0	131.30	0	0	0	0
	3	1	n.s.	43.32	0	84.70	0	0	0	0
	3	2	n.s.	11.60	0	72.10	0	0	0	0
	3	3	n.s.	26.23	0	92.70	0	0	0	0
	3	4	n.s.	16.76	0	105.50	0	0	0	0
	3	5	n.s.	19.07	0	131.30	0	0	0	0
21	n.s.	n.s.	0	5.66	0	53.40	0	0	0	0
	n.s.	n.s.	1	5.66	0	240.00	0	0	0	-9.52
31	1	n.s.	0	7.45	0	62.02	0	0	0	0
	1	n.s.	1	7.45	0	240.00	0	0	0	-9.52
	2	n.s.	0	6.26	0	67.50	0	0	0	0
	2	n.s.	1	6.26	0	240.00	0	0	0	-9.52
	3	n.s.	0	4.45	0	75.18	0	0	0	0
	3	n.s.	1	4.45	0	240.00	0	0	0	-9.52
32	1	n.s.	n.s.	11.60	0	68.23	0	0	0	0
	2	n.s.	n.s.	11.60	0	68.23	0	0	0	0
	3	n.s.	n.s.	11.60	0	68.23	0	0	0	0
33	n.s.	n.s.	0	3.74	0	53.40	0	0	0	0
	n.s.	n.s.	1	3.74	0	240.00	0	0	0	-9.52
34	1	n.s.	n.s.	11.60	0	68.23	0	0	0	0
	2	n.s.	n.s.	11.60	0	68.23	0	0	0	0
	3	n.s.	n.s.	11.60	0	68.23	0	0	0	0
35	n.s.	n.s.	0	24.63	0	64.76	0	0	0	0
	n.s.	n.s.	1	24.63	0	240.00	0	0	0	-9.52
36	n.s.	n.s.	n.s.	*4.06*	0	26.31	0	0	0	0
37	n.s.	n.s.	n.s.	6.05	0	68.23	0	0	0	0
41	n.s.	n.s.	n.s.	0	0	0	0	0	0	0
42	n.s.	n.s.	n.s.	7.96	0	154.00	0	0	0	0
51	n.s.	n.s.	n.s.	0	0	0	0	0	0	0
52	n.s.	n.s.	n.s.	5.80	0	53.40	0	0	0	0
53	n.s.	n.s.	n.s.	4.80	0	53.40	0	0	0	0
54	n.s.	n.s.	n.s.	4.80	0	53.40	0	0	0	0
61	n.s.	n.s.	n.s.	0	0	0	0	0	0	0

(table continued)

Legend					
altitude zones:		*NFI-regions:*		*soil type:*	
1	< 600 m	1	Jura	0	mineral soil
2	601 - 1200 m	2	Central Plateau	1	organic soil
3	> 1200 m	3	Pre-Alps		
		4	Alps	n.s. = no stratification	
		5	Southern Alps	annually changing data	

On organic soils, a value of 240 t C ha^{-1} for stockC$_s$ was assumed for all land-use categories, even where this is not explicitly indicated in Table 111, i.e. where no stratification according to soil type is indicated (e.g. in CC 12). Thus, when calculating carbon changes in soils as a consequence of land-use changes, the difference of carbon stocks in organic soils is always zero.

While the carbon data for forests are derived from monitoring data of NFI I and NFI II, the data for agriculture, grassland and settlements are based on experiments, field studies, literature and expert estimates. For wetlands and other land, expert estimates or default values are available. The deduction of the individual values is explained in detail in the following chapters.

Table 112 Annually changing carbon data for managed forest (CC 12) – carbon stock, increase of living biomass and decrease of living biomass – disaggregated for altitude and NFI-region, for the whole period 1990-2004.

carbon stock in living biomass (stockCl,i) [t C ha^{-1}]

land-use code CC	altitude zone z	NFI region	soil type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
12	1	1	n.s.	129.10	129.78	130.96	132.42	133.50	134.94	135.70	136.75	137.99	139.99	140.65	141.75	144.16	144.50	145.71
	1	2	n.s.	136.68	136.25	136.13	137.71	139.11	140.02	141.00	141.60	141.53	143.54	142.14	141.06	140.40	139.17	139.17
	1	3	n.s.	156.80	157.70	158.70	161.08	163.31	165.14	166.40	168.16	169.19	171.38	170.94	171.73	172.24	172.24	173.11
	1	4	n.s.	95.38	95.36	95.29	96.37	97.70	98.77	99.39	100.52	100.67	102.05	102.29	103.81	105.22	105.57	105.87
	1	5	n.s.	73.88	74.88	76.18	77.45	78.17	79.08	79.77	80.16	80.97	81.92	82.81	83.57	84.64	84.39	84.74
	2	1	n.s.	124.71	125.04	126.16	127.56	128.82	129.83	130.84	131.90	132.56	133.72	134.36	135.40	136.69	137.31	138.56
	2	2	n.s.	149.71	149.58	149.89	151.76	153.44	154.81	156.10	157.08	157.37	159.67	158.66	157.97	157.58	156.44	156.71
	2	3	n.s.	152.16	152.72	153.40	155.52	157.51	159.22	160.46	162.21	163.33	165.54	164.81	164.90	164.52	164.10	164.50
	2	4	n.s.	100.95	101.06	100.91	102.04	103.44	129.62	105.53	106.77	107.59	109.50	110.41	112.25	113.79	114.46	115.20
	2	5	n.s.	69.74	70.98	72.38	73.67	74.70	75.79	76.81	77.74	78.65	79.63	80.71	81.82	83.06	83.54	84.31
	3	1	n.s.	84.98	85.51	86.17	87.10	87.86	88.59	89.28	90.00	90.35	91.04	91.42	92.14	92.74	93.26	94.07
	3	2	n.s.	93.50	93.79	94.19	95.00	95.76	96.42	97.06	97.61	98.01	98.91	98.91	98.97	99.07	99.02	99.34
	3	3	n.s.	116.23	116.44	116.47	117.59	118.71	119.64	120.45	121.57	122.22	123.44	122.63	122.35	121.63	120.79	120.85
	3	4	n.s.	94.53	94.23	93.73	94.08	94.94	95.78	96.41	97.22	97.83	98.88	99.62	100.79	101.71	102.02	102.61
	3	5	n.s.	78.26	79.42	80.52	81.82	82.95	83.84	84.90	85.81	86.71	88.03	89.43	90.77	92.25	92.94	93.89

growth of living biomass (increaseCl,i) [t C ha^{-1} yr^{-1}}

land-use code CC	altitude zone z	NFI region	soil type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
12	1	1	n.s.	3.56	3.02	3.46	3.71	3.44	3.89	3.22	3.49	3.69	4.51	3.32	3.56	4.71	2.36	3.28
	1	2	n.s.	5.57	3.74	4.01	5.35	5.35	4.97	4.86	4.46	3.83	6.14	4.63	5.31	5.59	3.34	4.34
	1	3	n.s.	4.49	3.92	3.98	5.09	4.90	4.63	4.00	4.55	3.88	5.20	3.47	4.97	4.64	3.38	4.13
	1	4	n.s.	3.36	2.57	2.63	3.57	3.71	3.28	2.79	3.23	2.77	4.11	2.88	3.66	3.47	2.51	2.54
	1	5	n.s.	1.73	2.06	2.44	2.56	2.12	2.39	2.24	2.05	2.58	2.72	2.58	2.36	2.61	1.31	1.90
	2	1	n.s.	3.44	2.61	3.30	3.50	3.50	3.35	3.27	3.29	2.89	3.45	3.21	3.42	3.51	2.46	3.22
	2	2	n.s.	5.67	3.79	4.17	5.35	5.35	5.15	4.85	4.51	3.84	6.08	4.71	5.42	5.65	3.21	4.41
	2	3	n.s.	4.18	3.66	3.77	4.74	4.54	4.34	3.82	4.32	3.75	5.02	3.41	4.74	4.42	3.40	3.95
	2	4	n.s.	2.63	2.19	2.00	2.92	2.98	3.48	2.26	2.54	2.27	3.43	2.34	3.09	2.74	1.96	2.04
	2	5	n.s.	1.86	2.05	2.27	2.28	2.11	2.22	2.23	2.22	2.29	2.35	2.34	2.29	2.37	1.64	1.93
	3	1	n.s.	1.92	1.92	1.96	2.14	2.08	2.11	1.98	1.99	1.59	1.99	1.93	2.16	1.93	1.56	1.98
	3	2	n.s.	1.66	1.21	1.31	1.60	1.60	1.54	1.43	1.33	1.18	1.72	1.38	1.56	1.61	1.00	1.32
	3	3	n.s.	2.52	2.28	2.10	2.80	2.73	2.58	2.42	2.69	2.27	2.95	1.98	2.94	2.68	1.84	2.48
	3	4	n.s.	1.90	1.65	1.51	1.94	2.23	2.12	1.83	1.92	1.77	2.27	1.86	2.19	1.91	1.39	1.66
	3	5	n.s.	1.51	1.57	1.52	1.80	1.69	1.47	1.68	1.61	1.61	2.02	1.96	1.81	1.90	1.16	1.44

harvesting of living biomass (decreaseCl,i) [t C ha^{-1} yr^{-1}}

land-use code CC	altitude zone z	NFI region	soil type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
12	1	1	n.s.	-2.41	-2.33	-2.28	-2.25	-2.36	-2.45	-2.45	-2.45	-2.45	-2.51	-2.65	-2.47	-2.30	-2.02	-2.06
	1	2	n.s.	-4.35	-4.18	-4.14	-3.76	-3.96	-4.06	-3.87	-3.87	-3.90	-4.13	-6.04	-6.38	-6.26	-4.56	-4.34
	1	3	n.s.	-3.05	-3.01	-2.98	-2.70	-2.68	-2.80	-2.74	-2.78	-2.85	-3.02	-3.92	-4.17	-4.13	-3.39	-3.26
	1	4	n.s.	-2.43	-2.59	-2.69	-2.50	-2.38	-2.21	-2.16	-2.10	-2.62	-2.73	-2.64	-2.13	-2.07	-2.15	-2.25
	1	5	n.s.	-1.06	-1.06	-1.14	-1.29	-1.40	-1.47	-1.56	-1.66	-1.77	-1.77	-1.69	-1.60	-1.55	-1.56	-1.56
	2	1	n.s.	-2.40	-2.28	-2.19	-2.10	-2.24	-2.34	-2.26	-2.24	-2.22	-2.29	-2.56	-2.38	-2.21	-1.84	-1.96
	2	2	n.s.	-4.07	-3.91	-3.87	-3.47	-3.67	-3.79	-3.56	-3.54	-3.55	-3.77	-5.72	-6.11	-6.04	-4.35	-4.14
	2	3	n.s.	-3.11	-3.10	-3.09	-2.62	-2.56	-2.63	-2.58	-2.57	-2.63	-2.81	-4.14	-4.65	-4.80	-3.82	-3.54
	2	4	n.s.	-1.82	-2.08	-2.15	-1.78	-1.58	-1.90	-1.39	-1.30	-1.45	-1.52	-1.43	-1.25	-1.20	-1.29	-1.30
	2	5	n.s.	-0.83	-0.81	-0.86	-0.99	-1.08	-1.13	-1.21	-1.30	-1.37	-1.37	-1.27	-1.18	-1.13	-1.16	-1.16
	3	1	n.s.	-1.50	-1.39	-1.30	-1.21	-1.32	-1.38	-1.29	-1.27	-1.25	-1.30	-1.55	-1.44	-1.33	-1.04	-1.17
	3	2	n.s.	-0.95	-0.92	-0.91	-0.79	-0.84	-0.88	-0.80	-0.78	-0.77	-0.83	-1.37	-1.50	-1.51	-1.06	-1.00
	3	3	n.s.	-2.06	-2.07	-2.07	-1.68	-1.62	-1.65	-1.61	-1.57	-1.61	-1.74	-2.78	-3.23	-3.41	-2.67	-2.42
	3	4	n.s.	-1.66	-1.95	-2.01	-1.59	-1.37	-1.28	-1.20	-1.11	-1.16	-1.22	-1.13	-1.02	-0.98	-1.08	-1.07
	3	5	n.s.	-0.48	-0.41	-0.42	-0.50	-0.56	-0.58	-0.63	-0.70	-0.71	-0.70	-0.57	-0.47	-0.42	-0.47	-0.49

7.3. *Source Category 5A – Forest Land*

7.3.1. Source Category Description

Only temperate forests are occurring in Switzerland. In the land use statistics (SFSO 2005, and 2006a) and in the National Forest Inventory (NFI; EAFV/BFL 1988; Brassel and Brändli 1999), forest land is defined by the following criteria:

- Normal dense forest: tree crown cover > 60%, width > 25m, height > 3m.
- Open forest: tree crown cover 20-60%, width > 50m, height > 3m.
- Other forest land: afforestations, brush forest, young or temporarily unstocked stands.

For reporting in the CRF tables, forest land was subdivided into afforestations (CC 11), managed forest (CC 12) and unproductive forest (CC 13) based on AREA categories (see Table 106; FOEN 2006d; SFSO 2006a).

7.3.2. Methodological Issues

a) National Forest Inventories

Data for growing stock, gross growth, cut (harvesting), and mortality were derived from the first and the second Swiss National Forest Inventory (see Table 113). The NFI I was conducted between 1983 and 1985 (EAFV/BFL 1988), the NFI II was conducted between 1993 and 1995 (Brassel and Brändli 1999). In 2007, first results from the third NFI will be available for the reporting.

Table 113 Characteristics of the National Forest Inventories I, II and III.

	NFI I	NFI II	NFI III
Inventory cycle	1983-1985	1993-1995	2004-2006
Grid size	1 x 1 km	1.4 x 1.4 km	1.4 x 1.4 km
Terrestrial sample plots	~12'000	~6'000	~6'000
Measured single trees	~130'000	~70'000	~70'000

b) Stratification, Spatial strata

Forests in Switzerland reveal a high heterogeneity in terms of elevation, growth conditions, and tree species composition. To find explanatory variables that significantly reduce the variance of gross growth and biomass expansion factors (BEFs) an analysis of variance was done (Thürig et al. 2005a). The explanatory variables considered in this study are (see also Figure 32):

- the 5 NFI production regions
  (1. Jura, 2. Central Plateau, 3. Pre-Alps, 4. Alps, 5. Southern Alps)
- altitude (<601 m, 601-1200 m, >1200 m)
- tree species (coniferous and deciduous species).

The analysis of variance indicated that production region, elevation, and tree species all significantly explain differences in gross growth and biomass expansion factors (Table 114 and Table 115). Therefore, growing stock, gross growth, harvesting, as well as BEFs were estimated and applied separately for these spatial strata.

Table 114 Analysis of variance of gross growth. Explanatory variables: Tree species, production region, and altitude.

	F value	p-value
Coniferous/Deciduous	421	<0.0001
Production region	45	<0.0001
Altitude	34	<0.0001

Table 115 Analysis of variance of BEFs. Explanatory variables: Tree species, production region, and altitude.

	F value	p-value
Coniferous/Deciduous	18'832	<0.0001
Production region	2'434	<0.0001
Altitude	103	<0.0001

In Switzerland, most forests are mixed stands. However, the forest area derived by the Swiss land use statistics does not allow separating coniferous and deciduous sites. If species specific measures for growing stock, gross growth, harvesting and BEFs are to be applied, the total forest area has to be divided according to the species mixture. It was assumed that the space asserted by a single tree is highly correlated with its basal area. The required ratio of coniferous forest area (R_c) per spatial stratum (Table 116) was calculated by dividing the sum of the basal area of the conifers (BA_c) over the sum of the basal area of all trees (BA).

$R_{ci} = BA_{ci} / BA_i$ i = spatial strata

As both species add up to 1 (or 100%) the rate of deciduous forest area (R_d) is:

$R_{di} = 1 - R_{ci}$ i = spatial strata

Table 116 Ratio of coniferous and deciduous species (source: NFI II; Brassel and Brändli 1999).

NFI region	Altitude [m]	Coniferous	Deciduous
1	<601	0.352	0.648
	601-1200	0.581	0.419
	>1200	0.751	0.249
2	<601	0.558	0.442
	601-1200	0.646	0.354
	>1200	0.902	0.098
3	<601	0.395	0.605
	601-1200	0.713	0.287
	>1200	0.925	0.075
4	<601	0.369	0.631
	601-1200	0.652	0.348
	>1200	0.962	0.038
5	<601	0.060	0.940
	601-1200	0.152	0.848
	>1200	0.810	0.190

c) Biomass Expansion Factors

In the Swiss NFI, growing stock, gross growth, cut and mortality is expressed as round wood over bark. Round wood over bark was expanded to total biomass as done in Thürig et al. (2005) by applying allometric single-tree functions to all trees measured at the NFI II. The functions were parameterized in following studies: Functions for twigs (diameter < 7 cm) and branches (diameter > 7 cm) were parameterized based on measurements from approximately 12'000 trees (Kaufmann 2001). Bark volume was estimated using the model by Altherr et al. (1978). Additional allometric functions were used to estimate the volume of coarse roots, based on data from 100 trees, as well as of foliages, based on samples from 400 trees (Perruchoud et al. 1999). BEFs were then calculated for each spatial stratum as the ratio between round wood over bark (t ha^{-1}) and the total above- and belowground biomass (t ha^{-1}). Table 117 shows the BEFs for coniferous and deciduous species stratified for production region and elevation. In some spatial strata, the number of measured trees was not sufficient to estimate robust BEFs. Therefore, coniferous trees below 1200 m in the Southern Alps and deciduous trees above 600 m on the Central Plateau, respectively, were pooled for estimating BEFs.

Table 117 Biomass expansion factors (BEFs) to convert round-wood over bark (t C ha^{-1}) to total biomass (t C ha^{-1}) for conifers and deciduous species, respectively.

NFI region	Altitude [m]	Conifers		Deciduous species	
		Number of trees	BEFs	Number of trees	BEFs
1	<601	801	1.47	1371	1.50
	601-1200	2855	1.50	2392	1.50
	>1200	549	1.60	225	1.55
2	<601	2965	1.46	2447	1.54
	601-1200	2563	1.47	1504	1.55
	>1200	106	1.65		
3	<600	129	1.48	239	1.49
	601-1200	4220	1.48	1980	1.49
	>1200	2909	1.59	241	1.56
4	<601	142	1.43	177	1.54
	601-1200	2550	1.48	1428	1.56
	>1200	8556	1.57	327	1.62
5	<601	260	1.54	547	1.64
	601-1200			1225	1.67
	>1200	1576	1.61	369	1.70

d) Wood Densities

To convert round wood over bark (m^3 ha^{-1}) into t ha^{-1} it was multiplied by a species-specific density. Table 118 shows the applied densities.

Table 118 Wood densities for coniferous and deciduous trees (Vorreiter 1949).

	Wood density [t m^{-3}]
Coniferous trees	0.4
Deciduous trees	0.55

e) Carbon Content

The IPCC default carbon content of solid wood of 50% was applied (IPCC 2003; p. 3.25).

f) Growing Stock, Gross Growth and Cut & Mortality in Managed Forests (CC 12)

Growing stock, gross growth, cut and mortality for managed forests (without afforestations) were derived from those 5'425 sample plots measured at both NFI I and NFI II (Kaufmann 2001). All values derived from the NFI I and II are related to round wood over bark (with stock, without branches) and are given in $m^3 ha^{-1}$ per spatial stratum (Table 119 and Table 120).

Table 119 Growing stock, gross growth, cut and mortality for coniferous trees (related to coniferous forest area).

NFI region	Altitude [m]	Growing stock 1985 [$m^3 ha^{-1}$]	Growing stock 1995 [$m^3 ha^{-1}$]	Gross growth [$m^3 ha^{-1}$ $10.1yr^{-1}$]	Cut and mortality [$m^3 ha^{-1}$ $10.1yr^{-1}$]
	<601	354.12	381.29	96.96	69.73
1	601-1200	372.1	393.62	97.35	75.82
	>1200	255.32	265.31	61.42	52.01
	<601	414.9	425.15	144.14	133.34
2	601-1200	458.41	477.94	146.7	127.01
	>1200	282.75	291.16	34.55	26.14
	<601	473.58	506.79	132.36	99.14
3	601-1200	482.43	515.95	132.71	98.85
	>1200	356.09	372.59	76.12	59.58
	<601	256.2	271.73	58.92	43.39
4	601-1200	322.68	338.36	78.92	63.47
	>1200	295.36	304.62	56.58	47.51
	<601	234.46	236.89	18.19	15.76
5	601-1200	245.82	263.12	46.73	29.43
	>1200	229.02	258.05	42.89	13.88

Note: 10.1 years correspond to the average inter-survey period between NFI I and NFI II; see below.

Table 120 Growing stock, gross growth, cut and mortality for deciduous trees (related to deciduous forest area).

NFI region	Altitude [m]	Growing stock 1985 [$m^3 ha^{-1}$]	Growing stock 1995 [$m^3 ha^{-1}$]	Gross growth [$m^3 ha^{-1}$ $10.1yr^{-1}$]	Cut and mortality [$m^3 ha^{-1}$ $10.1yr^{-1}$]
	<601	322.29	357.28	96.07	61.19
1	601-1200	318.04	354.25	91.93	55.75
	>1200	196.67	233.21	50.95	12.38
	<601	342.05	377.85	134.41	99.01
2	601-1200	370.66	424.4	142.1	88.57
	>1200	144.81	233.5	110.57	21.88
	<601	379.93	427.12	115.75	68.56
3	601-1200	374.75	427.88	113.4	60.82
	>1200	257.27	311.7	72.32	17.88
	<601	241.37	261.42	91.15	72.19
4	601-1200	224.59	261.49	66.1	29.38
	>1200	168.69	225.99	81.64	24.41
	<601	152.1	176.26	52.55	28.43
5	601-1200	134.02	163.17	49.93	20.96
	>1200	142.14	186.53	60.34	16.26

Note: 10.1 years correspond to the average inter-survey period between NFI I and NFI II; see below.

Conversion of NFI data to annual estimates of gross growth and cut & mortality

The average inter-survey period between NFI I and NFI II is not exactly 10 years, but 10.1 years. With regard to the individual spatial strata, the variance is even larger (Table 121).

Table 121 Average inter-survey period [in years] between NFI I and NFI II for all spatial strata.

	Altitude [m]		
NFI region	< 601	601-1200	> 1200
1. Jura	10.0	10.3	10.6
2. Central Plateau	10.3	10.4	10.7
3. Pre-Alps	10.4	10.1	10.0
4. Alps	9.9	10.0	9.9
5. Southern Alps	10.0	9.9	9.8

To convert gross growth and cut & mortality measured between NFI I and II into average annual gross growth and average annual cut & mortality, those data had to be divided by the time periods shown in Table 121.

[annual gross growth $_i$ = [gross growth between NFI I and II] $_i$ / time period $_i$

[annual cut & mortality] $_i$ = [cut & mortality between NFI I and II] $_i$ / time period $_i$

where i indicates the different spatial strata.

Influence of climate variability on annual gross growth

To estimate the influence of annual climate variability on gross growth, the process-based model Biome-BGC[19] was applied. The application of Biome-BGC in Switzerland has been evaluated by Schmid et al. (2006).

Biome-BGC was run for typical climatic conditions representing the spatial strata differentiated for the NIR. The climate data were obtained from MeteoSchweiz[20] and cover a period of at least 27 years (cf. Thürig et al. 2005a for details). First, the model was run with these annual climate data (monthly resolution) to simulate the annual net primary production (NPP). Second, the model was run with climate data averaged over all years (but still with monthly resolution) to simulate the average NPP for the same time period of at least 27 years (depending on the climate data available). The ratio between the annual growth and the average growth is called climate factor. It can be calculated for all the simulated years and represents the deviation of the growth of this specific year from the average growth in the simulated period.

In order to be able to calculate climate factors for future years without applying the complex model Biome-BGC but with simple climate data, multiple regression analyses were done. For each spatial stratum, the dependencies of the annual climate factors calculated by Biome-BGC as explained above were correlated with simple climate data of the corresponding years. The climate factors were the dependent variable and the corresponding monthly climate data were the explanatory variables. All explanatory variables had a siginificant influence on the dependent climate factor (P-Value ≤ 0.05) and the coefficient of determination R^2 of the those multiple regression analysis was between 0.43 and 0.82 (cf. Thürig et al. 2005a for details). The calibrated functions could then be applied to calculate climate factors for current and future years as a function of simple climate data. The parameters of the function for each spatial stratum can be found in Thürig et al. (2005a).

To test the quality of the parameterized functions, annual climate factors for the years 1986-1995 were calculated for all spatial strata. As the annual climate factors display the relative deviance from the average growth, the average climate factors over the same time period

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[19] See for example http://www.ntsg.umt.edu/ecosystem_modeling/BiomeBGC/

[20] http://www.meteoschweiz.ch/

should be equal to 1. Figure 36 shows the climate factors for all spatial strata averaged for the time period 1986-1995. The maximum deviance from the expected value is 7.4%, whereas the average deviance is 2.4%. Hence, these functions were assumed to be sufficiently precise to calculate annual growth values on the basis of simple annual climate data. A more detailed description of this analysis can be found in Thürig et al. (2005a).

To calculate a time series of the annual gross growth from 1990 to 2004, the average gross growth derived from the NFI I and NFI II data was multiplied with the corresponding annual climate factor as calculated by the functions mentioned above.

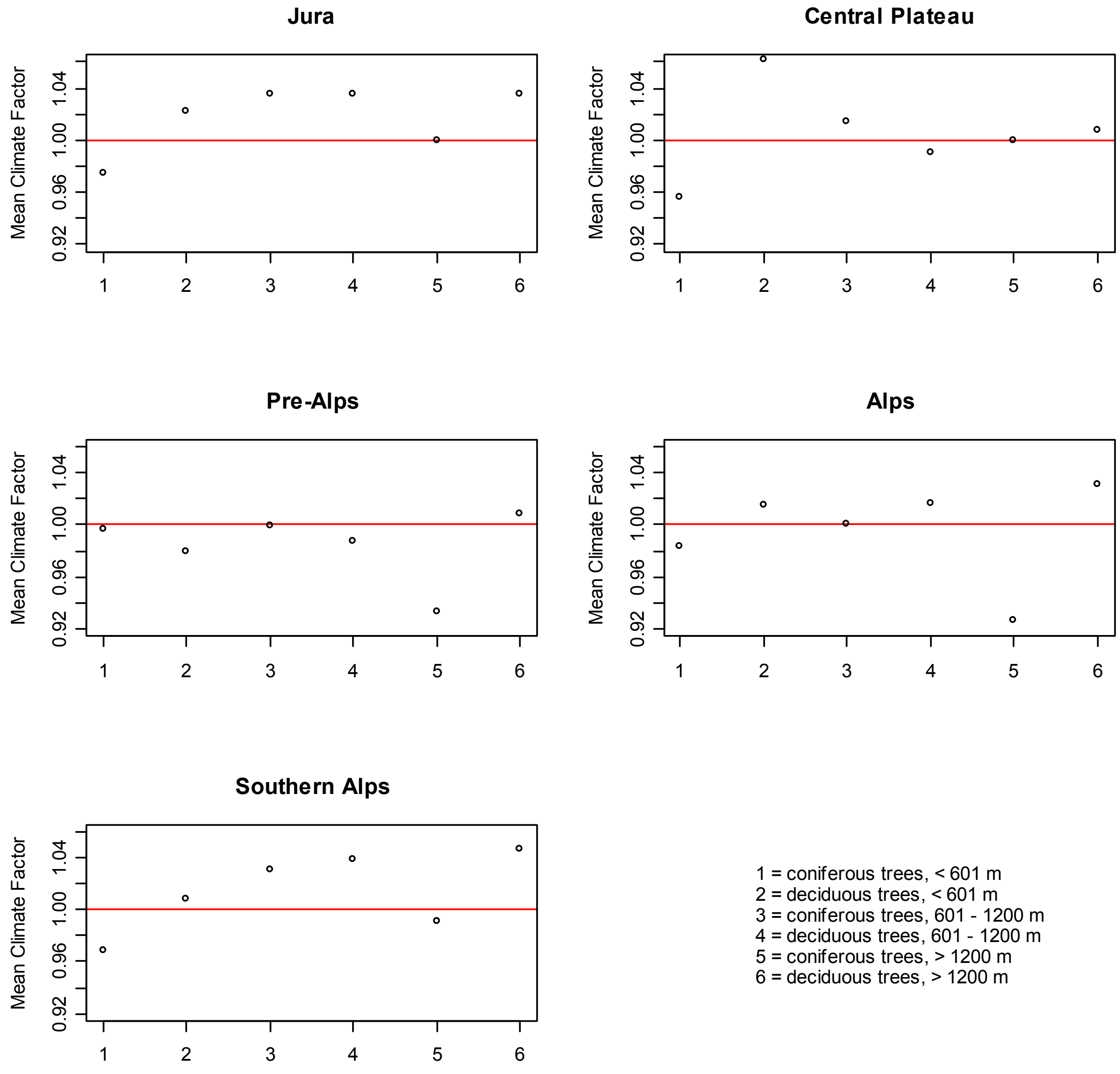

Figure 36 Climate factors calculated for the individual spatial strata, averaged for the years 1986-1995.

To avoid a systematic overestimation of the annual gross growth in the reporting, the climate factors were standardized to result in an average of 1 over the reference period (1986-1995) within all spatial strata. The same correction was then applied to climate factors going beyond the reference period. The resulting standardized climate factors for the time series 1986 to 2004 are displayed for each spatial stratum in Figure 37.

The annual climate variability has a large influence on forest growth. Studies of Jolly et al. (2005) indicate that the annual climate variability can strongly influence growth, e.g. by varying the length of the growing season. We assessed this influence by calculating climate factors with Biome-BGC. Applying Biome-BGC and parameterized functions based on simple climate data to derive climate correction factors is an interesting and innovative first step to estimate annual variability of growth caused by climate. However, further calibration and validation steps of the model are necessary to increase the plausibility of the model.

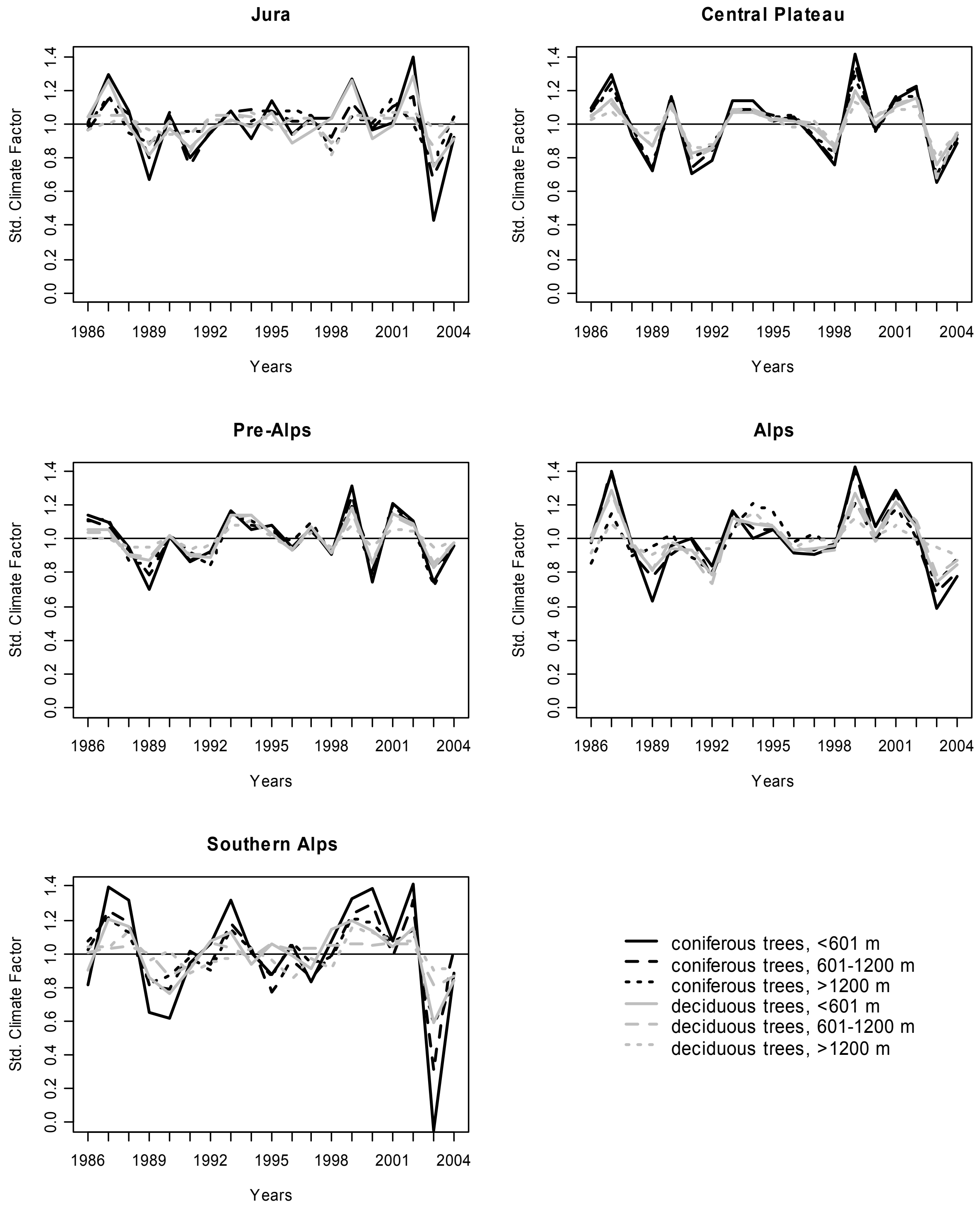

Figure 37 Standardized climate factors for the individual spatial strata from1986 to 2004.

Annual cut and mortality

Cut and mortality could only be quantified as sum of cut and mortality (CM) measured between NFI I and NFI II. To calculate the annual cut and mortality (CMy) for the years 1986 to 1995, the total amount of cut & mortality was distributed among the ten years, weighted by the percentage of the annual harvesting amounts taken from the forest statistic (Table 122, SFSO 2006b, SAEFL 2005b).

Table 122 Annual harvesting amount in m^3 merchantable timber per coniferous and deciduous tree species and production region derived from the forest statistic (SFSO 2006b, SAEFL 2005b). All values were averaged over three years to compensate for extreme events such as the storms Vivian (1990) and Lothar (1999) (e.g. value for 2004 is the average value for the years 2002-2004).

	1. Jura		2. Central plateau		3. Pre-Alps		4. Alps		5. Southern Alps	
Year	Conif.	Dec.	Conif.	Dec.	Conif.	Dec.	Conif.	Dec.	Conif.	Dec.
2004	551'910	316'752	1'617'068	509'352	1'135'069	147'134	534'976	65'377	32'781	35'617
2003	481'195	327'776	1'698'975	535'598	1'254'485	144'789	542'312	62'065	30'195	35'667
2002	626'798	351'805	2'448'000	674'298	1'603'283	168'724	491'872	60'187	24'903	35'522
2001	680'175	374'861	2'426'715	722'713	1'514'372	181'804	513'772	62'014	29'343	36'651
2000	733'872	402'682	2'196'853	733'718	1'300'811	184'017	562'665	78'246	38'806	38'572
1999	602'445	405'237	1'283'404	614'399	801'259	163'971	608'468	80'428	52'075	40'285
1998	575'006	399'476	1'191'359	590'606	744'730	156'410	579'223	77'391	53'319	40'188
1997	590'296	394'443	1'210'678	571'579	723'808	152'997	557'039	60'013	53'658	37'649
1996	597'544	393'817	1'241'999	556'409	742'348	147'125	604'935	61'095	46'972	35'501
1995	607'611	391'128	1'288'507	554'563	765'351	140'962	652'879	62'517	45'047	33'467
1994	575'928	379'505	1'225'395	554'916	752'565	132'571	701'336	67'181	43'628	31'723
1993	527'672	366'516	1'141'041	541'195	779'032	131'588	816'939	68'958	38'085	29'386
1992	573'269	361'633	1'328'880	556'023	966'390	133'405	1'034'064	71'000	31'106	25'943
1991	616'629	360'660	1'348'951	557'776	967'684	135'699	1'002'608	68'221	31'210	24'093
1990	669'756	364'296	1'400'390	582'340	963'683	138'833	851'765	65'707	38'790	24'026
1989	639'699	368'530	1'207'615	562'104	865'133	141'788	617'456	64'786	43'150	25'472
1988	630'454	368'483	1'246'394	558'806	868'603	145'121	609'846	65'259	43'327	28'118
1987	606'645	363'712	1'224'466	541'145	800'508	139'369	624'252	68'340	40'795	28'942
1986	652'936	363'906	1'287'969	523'611	697'280	130'709	643'790	65'567	40'315	29'169

For the years 1996 to 2004, no NFI data are available. Therefore, CM_y for that period were calculated on the basis of the annual harvesting amounts derived from the annual forest statistic and corrected for the amount of natural mortality. The correction factor was derived for all the production regions and tree species by building the ratio between CM and the sum of the annual harvesting amount reported in the forest statistics from 1986 to 1995:

$$\text{Correction factor}_i = [\ \Sigma_a\ (CM_a / T_a)*10\ ]_i\ /\ [\ \Sigma_y\ \text{Harvesting amount forest statistics}_y\ ]_i$$

i = 1-10 (5 production regions and 2 tree species)

a = 1-3 (3 zones of altitude: <601, 601-1200, >1200)

y = 1986-1995

where T is the exact inter-survey period between the two inventories (Table 121).

Table 123 shows the resulting correction factors for all NFI regions and tree species.

As done in all former NIRs, harvesting amounts from the forest statistics were averaged over the actual year and the previous two years in order to level out extreme events such as heavy storms.

Table 123 Correction factors to convert annual harvesting amounts from the forest statistic (SFSO 2006b) into total amount of cut & mortality for the period 1996-2004.

NFI region	Tree species	Correction factors
1	coniferous	1.177
1	deciduous	1.315
2	coniferous	1.331
2	deciduous	1.535
3	coniferous	1.543
3	deciduous	1.920
4	coniferous	1.941
4	deciduous	2.380
5	coniferous	2.262
5	deciduous	5.737

Growing stock: Calculation of time series

The time series of the growing stocks (GS) were calculated based on the growing stock measured in the NFI I for the years 1986 to 1995 and NFI II for the years 1996 to 2004 plus the annual gross growth, minus the annual amounts of cut & mortality (CM_y).

The growing stock of the years 1986-1994 was calculated by extrapolating the growing stock of 1985.

$GS_{ay} = GS1985 + \Sigma_y$ [annual gross $growth_y$] - Σ_y [CM_y]

y = 1986 to ay

ay = actual year

The growing stock of the years 1995-2004 was calculated in the same way by extrapolating the growing stock of 1995.

These values given in round wood over bark [m^3 ha^{-1}] were converted to carbon in living biomass [t C ha^{-1}] as follows:

[C in living biomass]$_s$ =

Σ_t [round wood over bark]$_{s,t}$ * $density_t$ * $BEF_{s,t}$ * C-content * [percentage of tree species]$_{t,s}$

where s indicates the 15 different spatial strata and t the two different tree species (coniferous and deciduous trees).

As an example of the calculation, the 1986-1990 development of the growing stock [t C ha^{-1}] in the Central Plateau (NFI region 2) below 601 m for coniferous and deciduous trees is shown:

$GS1986_c$ = 417.17 = 414.90 + 15.79 - 13.52 $GS1986_d$ = 346.70 = 342.05 + 14.02 - 9.37

$GS1987_c$ = 422.97 = 417.17 + 18.66 - 12.86 $GS1987_d$ = 352.42 = 346.70 + 15.40 - 9.68

$GS1988_c$ = 423.33 = 422.97 + 13.45 - 13.09 $GS1988_d$ = 355.49 = 352.42 + 13.07 - 10.0

$GS1989_c = 421.06 = 423.33 + 10.41 - 12.68$ $GS1989_d = 357.13 = 355.49 + 11.70 - 10.06$

$GS1990_c = 423.20 = 421.06 + 16.84 - 14.70$ $GS1990_d = 361.80 = 357.13 + 15.09 - 10.42$

$[\text{C in living biomass 1990}]_{\text{Central Plateau, <601, c}} = 123.57 = 423.2 * 0.4 * 1.46 * 0.5$

$[\text{C in living biomass 1990}]_{\text{Central Plateau, <601, d}} = 153.22 = 361.8 * 0.55 * 1.54 * 0.5$

$[\text{C in living biomass 1990}]_{\text{Central Plateau, <601}} = \mathbf{136.68} = 123.57 * 0.558 + 153.22 * 0.442$

Table 124 and Table 125 display the calculated growing stock values for 1990 to 2004 specified for all spatial strata. Table 126 and Table 127 display the calculated gross growth for the same time period and strata, and Table 128 and Table 129 display the calculated cut & mortality for the same time period and strata.

Table 124 Growing stock of CC12 from 1990 to 1997 in t C ha^{-1}.

		C in Biomass [t C ha^{-1}]							
Altitude [m]	**NFI region**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
<601	**1**	129.10	129.78	130.96	132.42	133.50	134.94	135.70	136.75
	2	136.68	136.25	136.13	137.71	139.11	140.02	141.00	141.60
	3	156.80	157.70	158.70	161.08	163.31	165.14	166.40	168.16
	4	95.38	95.36	95.29	96.37	97.70	98.77	99.39	100.52
	5	73.88	74.88	76.18	77.45	78.17	79.08	79.77	80.16
601-1200	**1**	124.71	125.04	126.16	127.56	128.82	129.83	130.84	131.90
	2	149.71	149.58	149.89	151.76	153.44	154.81	156.10	157.08
	3	152.16	152.72	153.40	155.52	157.51	159.22	160.46	162.21
	4	100.95	101.06	100.91	102.04	103.44	129.62	105.53	106.77
	5	69.74	70.98	72.38	73.67	74.70	75.79	76.81	77.74
>1200	**1**	84.98	85.51	86.17	87.10	87.86	88.59	89.28	90.00
	2	93.50	93.79	94.19	95.00	95.76	96.42	97.06	97.61
	3	116.23	116.44	116.47	117.59	118.71	119.64	120.45	121.57
	4	94.53	94.23	93.73	94.08	94.94	95.78	96.41	97.22
	5	78.26	79.42	80.52	81.82	82.95	83.84	84.90	85.81

Table 125 Growing stock of CC12 from 1998 to 2004 in t C ha^{-1}.

		C in Biomass [t C ha^{-1}]						
Altitude [m]	**NFI region**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
<601	**1**	137.99	139.99	140.65	141.75	144.16	144.50	145.71
	2	141.53	143.54	142.14	141.06	140.40	139.17	139.17
	3	169.19	171.38	170.94	171.73	172.24	172.24	173.11
	4	100.67	102.05	102.29	103.81	105.22	105.57	105.87
	5	80.97	81.92	82.81	83.57	84.64	84.39	84.74
601-1200	**1**	132.56	133.72	134.36	135.40	136.69	137.31	138.56
	2	157.37	159.67	158.66	157.97	157.58	156.44	156.71
	3	163.33	165.54	164.81	164.90	164.52	164.10	164.50
	4	107.59	109.50	110.41	112.25	113.79	114.46	115.20
	5	78.65	79.63	80.71	81.82	83.06	83.54	84.31
>1200	**1**	90.35	91.04	91.42	92.14	92.74	93.26	94.07
	2	98.01	98.91	98.91	98.97	99.07	99.02	99.34
	3	122.22	123.44	122.63	122.35	121.63	120.79	120.85
	4	97.83	98.88	99.62	100.79	101.71	102.02	102.61
	5	86.71	88.03	89.43	90.77	92.25	92.94	93.89

Table 126 Gross growth of living biomass of CC12 from 1990 to 1997 in t C ha^{-1}.

		C in Biomass [t C ha^{-1}]							
Altitude [m]	**NFI region**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
	1	3.56	3.02	3.46	3.71	3.44	3.89	3.22	3.49
	2	5.57	3.74	4.01	5.35	5.35	4.97	4.86	4.46
<601	**3**	4.49	3.92	3.98	5.09	4.90	4.63	4.00	4.55
	4	3.36	2.57	2.63	3.57	3.71	3.28	2.79	3.23
	5	1.73	2.06	2.44	2.56	2.12	2.39	2.24	2.05
	1	3.44	2.61	3.30	3.50	3.50	3.35	3.27	3.29
	2	5.67	3.79	4.17	5.35	5.35	5.15	4.85	4.51
601-1200	**3**	4.18	3.66	3.77	4.74	4.54	4.34	3.82	4.32
	4	2.63	2.19	2.00	2.92	2.98	3.48	2.26	2.54
	5	1.86	2.05	2.27	2.28	2.11	2.22	2.23	2.22
	1	1.92	1.92	1.96	2.14	2.08	2.11	1.98	1.99
	2	1.66	1.21	1.31	1.60	1.60	1.54	1.43	1.33
>1200	**3**	2.52	2.28	2.10	2.80	2.73	2.58	2.42	2.69
	4	1.90	1.65	1.51	1.94	2.23	2.12	1.83	1.92
	5	1.51	1.57	1.52	1.80	1.69	1.47	1.68	1.61

Table 127 Gross growth of living biomass of CC12 from 1998 to 2004 in t C ha^{-1}.

		C in Biomass [t C ha^{-1}]						
Altitude [m]	**NFI region**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
	1	3.69	4.51	3.32	3.56	4.71	2.36	3.28
	2	3.83	6.14	4.63	5.31	5.59	3.34	4.34
<601	**3**	3.88	5.20	3.47	4.97	4.64	3.38	4.13
	4	2.77	4.11	2.88	3.66	3.47	2.51	2.54
	5	2.58	2.72	2.58	2.36	2.61	1.31	1.90
	1	2.89	3.45	3.21	3.42	3.51	2.46	3.22
	2	3.84	6.08	4.71	5.42	5.65	3.21	4.41
601-1200	**3**	3.75	5.02	3.41	4.74	4.42	3.40	3.95
	4	2.27	3.43	2.34	3.09	2.74	1.96	2.04
	5	2.29	2.35	2.34	2.29	2.37	1.64	1.93
	1	1.59	1.99	1.93	2.16	1.93	1.56	1.98
	2	1.18	1.72	1.38	1.56	1.61	1.00	1.32
>1200	**3**	2.27	2.95	1.98	2.94	2.68	1.84	2.48
	4	1.77	2.27	1.86	2.19	1.91	1.39	1.66
	5	1.61	2.02	1.96	1.81	1.90	1.16	1.44

Table 128 Cut & mortality of living biomass of CC12 from 1990 to 1997 in t C ha^{-1}.

		C in Biomass [t C ha^{-1}]							
Altitude [m]	**NFI region**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
	1	-2.41	-2.33	-2.28	-2.25	-2.36	-2.45	-2.45	-2.45
	2	-4.35	-4.18	-4.14	-3.76	-3.96	-4.06	-3.87	-3.87
<601	**3**	-3.05	-3.01	-2.98	-2.70	-2.68	-2.80	-2.74	-2.78
	4	-2.43	-2.59	-2.69	-2.50	-2.38	-2.21	-2.16	-2.10
	5	-1.06	-1.06	-1.14	-1.29	-1.40	-1.47	-1.56	-1.66
	1	-2.40	-2.28	-2.19	-2.10	-2.24	-2.34	-2.26	-2.24
	2	-4.07	-3.91	-3.87	-3.47	-3.67	-3.79	-3.56	-3.54
601-1200	**3**	-3.11	-3.10	-3.09	-2.62	-2.56	-2.63	-2.58	-2.57
	4	-1.82	-2.08	-2.15	-1.78	-1.58	-1.90	-1.39	-1.30
	5	-0.83	-0.81	-0.86	-0.99	-1.08	-1.13	-1.21	-1.30
	1	-1.50	-1.39	-1.30	-1.21	-1.32	-1.38	-1.29	-1.27
	2	-0.95	-0.92	-0.91	-0.79	-0.84	-0.88	-0.80	-0.78
>1200	**3**	-2.06	-2.07	-2.07	-1.68	-1.62	-1.65	-1.61	-1.57
	4	-1.66	-1.95	-2.01	-1.59	-1.37	-1.28	-1.20	-1.11
	5	-0.48	-0.41	-0.42	-0.50	-0.56	-0.58	-0.63	-0.70

Table 129 Cut & mortality of living biomass of CC12 from 1998 to 2004 in t C ha^{-1}.

		C in Biomass [t C ha^{-1}]						
Altitude [m]	**NFI region**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
<601	**1**	-2.45	-2.51	-2.65	-2.47	-2.30	-2.02	-2.06
	2	-3.90	-4.13	-6.04	-6.38	-6.26	-4.56	-4.34
	3	-2.85	-3.02	-3.92	-4.17	-4.13	-3.39	-3.26
	4	-2.62	-2.73	-2.64	-2.13	-2.07	-2.15	-2.25
	5	-1.77	-1.77	-1.69	-1.60	-1.55	-1.56	-1.56
601-1200	**1**	-2.22	-2.29	-2.56	-2.38	-2.21	-1.84	-1.96
	2	-3.55	-3.77	-5.72	-6.11	-6.04	-4.35	-4.14
	3	-2.63	-2.81	-4.14	-4.65	-4.80	-3.82	-3.54
	4	-1.45	-1.52	-1.43	-1.25	-1.20	-1.29	-1.30
	5	-1.37	-1.37	-1.27	-1.18	-1.13	-1.16	-1.16
>1200	**1**	-1.25	-1.30	-1.55	-1.44	-1.33	-1.04	-1.17
	2	-0.77	-0.83	-1.37	-1.50	-1.51	-1.06	-1.00
	3	-1.61	-1.74	-2.78	-3.23	-3.41	-2.67	-2.42
	4	-1.16	-1.22	-1.13	-1.02	-0.98	-1.08	-1.07
	5	-0.71	-0.70	-0.57	-0.47	-0.42	-0.47	-0.49

g) Growing Stock in Unproductive Forests (CC 13)

Brush forest

Brush forests in Switzerland mainly consist of *Alnus viridis* and horizontal *Pinus mugo var. prostrata*. No NFI data are available to derive their growing stock. Therefore, following assumptions were met to describe the stocks: 4000 trees per ha, average height of 2.5 m and an average diameter at 1.3 m of 10 cm. Hence, an average growing stock (> 7 cm diameter) of 40 m^3 ha^{-1} was estimated. Multiplied by the wood density for coniferous trees (0.4 t m^{-3}; Vorreiter 1949) an average growing stock of 16 t ha^{-1} results. Applying a default BEF of 1.45 (Burschel et al. 1993), an average biomass for brush forest of 23.2 t ha^{-1} that translates to 11.6 t C ha^{-1} (using the IPCC default carbon content of 50%) was estimated.

Inaccessible forest

Inaccessible forest in Switzerland is mainly located in the Alps and the Southern Alps where the average growing stock is around 318 m^3 ha^{-1} and 219 m^3 ha^{-1}, respectively (Brassel and Brändli 1999). In the brush forest, no NFI data are available to derive growing stocks. As inaccessible forests are assumed to grow preferably on bad site conditions, an average growing stock (> 7 cm diameter) of 150 m^3 ha^{-1} was estimated. Multiplied by the wood density for coniferous trees (0.4 t m^{-3}; Vorreiter 1949) we end up with an average growing stock of 60 t ha^{-1}. Applying a default BEF of 1.45 (Burschel et al. 1993), an average biomass for inaccessible forest of 87 t ha^{-1} that translates to 43.5 t C ha^{-1} (using the IPCC default carbon content of 50%) was estimated.

Carbon content of unproductive forests (CC 13): Weighted means

The unproductive forest in Switzerland mainly consists of brush forest and inaccessible forest. The carbon content of unproductive forest was therefore calculated as a weighted average of brush forest and inaccessible forest per spatial stratum:

$[\text{weighted C content}]_i = RS_i * CS + (1- RS_i) * CI$

where RS_i is the rate of the brush forest per spatial stratum i, CS is the carbon content of brush forest (11.6 t C ha^{-1}),

CI is the carbon content of inaccessible forest (43.5 t C ha^{-1}).

Table 130 shows the carbon content per spatial stratum in t C ha^{-1}.

Table 130 Rate of brush forest and inaccessible forest and the resulting weighted carbon content in t C ha^{-1} of Swiss unproductive forests (CC 13) specified for all spatial strata.

NFI region	Altitude [m]	Brush forest(*) [ha]	Inaccessible forest (*) [ha]	Total unproductive forest [ha]	Rate of brush forest	Weighted C content [t C ha^{-1}]
1	<601	25	356	381	0.0656	41.41
	601-1200	1	1780	1781	0.000561	43.48
	>1200	1	178	179	0.00558	43.32
2	<601	25	534	559	0.0447	42.07
	601-1200	25	356	381	0.0656	41.41
	>1200	1	0	1	1	11.60
3	<601	25	356	381	0.0656	41.41
	601-1200	50	3204	3254	0.0154	43.01
	>1200	2100	1780	3880	0.541	26.23
4	<601	100	356	456	0.219	36.50
	601-1200	1925	4984	6909	0.279	34.61
	>1200	36925	7120	44045	0.838	16.76
5	<601	200	534	734	0.272	34.81
	601-1200	2550	3560	6110	0.417	30.19
	>1200	16875	5162	22037	0.766	19.07

* Derived from the NFI II (Brassel and Brändli 1999)

h) Dead Wood

In the second NFI, all dead trees (standing and lying) larger than 12 cm were measured. Thus, an estimate of the dead-wood pool in Swiss productive forests (CC 12) can be done. In Table 131, the amount of dead wood is differentiated for the production regions. So far, no data about the temporal change of the dead-wood pool are available (The dead-wood pool was not measured in the course of NFI I, and NFI III data will be available in 2007 for the first time).

Table 131 Dead wood in Swiss productive forests (CC12) specified for the NFI production regions (Brassel and Brändli 1999).

	1. Jura [m^3 ha^{-1}]	2. Central plateau [m^3 ha^{-1}]	3. Pre-Alps [m^3 ha^{-1}]	4. Alps [m^3 ha^{-1}]	5. Southern Alps [m^3 ha^{-1}]	Mean value Switzerland [m^3 ha^{-1}]
Lying trees	1.1	0.9	3.7	9.5	4.0	4.6
Standing trees	5.1	4.0	8.4	10.0	7.7	7.4
Total	6.3	4.9	12.2	19.5	11.6	11.9

Applying the same wood densities, BEFs and carbon content as for the living growing stock, dead wood per spatial stratum can be estimated (Table 132).

Table 132 Dead wood in Swiss productive forests (CC12) per spatial stratum in t C ha^{-1}.

NFI region	Altitude [m]	Carbon in dead biomass [t C ha^{-1}]
1	<601	2.34
	601-1200	2.19
	>1200	2.18
2	<601	1.72
	601-1200	1.67
	>1200	1.66
3	<601	4.45
	601-1200	4.01
	>1200	3.98
4	<601	7.51
	601-1200	6.75
	>1200	6.22
5	<601	5.13
	601-1200	5.06
	>1200	4.06

i) Soil carbon in Productive Forests (CC12), Unproductive Forests (CC13) and Afforestations (CC11)

Perruchoud et al. (2000) interpolated 136 forest soil samples from the "Waldzustandsinventar 1993 - Bodenkundliche Erhebungen" (Lüscher et al. 1994). According to this study an average carbon stock of mineral forest soils of 76 t C ha^{-1} in 0-30 cm topsoil is assumed. These soil samples were stratified for the 5 NFI production regions (Table 133).

Table 133 Soil organic carbon (SOC) of mineral forest soils (CC12, CC13) in mineral soil horizons (0-30 cm) in t C ha^{-1} in the 5 NFI production regions (N = number of samples): The average values ± standard deviation are given.

NFI egion (N)	SOC of mineral topsoil 0-30 cm
1. Jura (32)	75.0 (± 37.2)
2. Central Plateau (24)	62.6 (± 32.6)
3. Pre-Alps (25)	75.3 (± 21.4)
4. Alps (39)	72.1 (± 40.6)
5. Southern Alps (16)	109.0 (± 43.7)
Total Switzerland (136)	76.0 (± 37.6)

The soil horizons L (litter), F (fermentation) and H (humus) were not included in the soil samples analyzed by Perruchoud et al. (2000). However, especially in forests, those horizons may contain substantial amounts of carbon and should be included in the estimation of forest soil carbon. In a study done by Moeri (in prep.) soil carbon of organic soil horizons on mineral soils were estimated as follows.

Acquisition of data:
In a first phase of the study, field work was accomplished. A total of 30 additional sites were sampled from which the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) already had a complete data set of soil C concentrations and density in the mineral soils. On each of the study sites, the investigations were made within an area of 50 x 50 m. At each study site, 8 randomly distributed samples of the forest floor (20 x 20 cm) were

taken, stratified for the individual organic layers. The thickness of the organic layers (L-, F-, H- horizons was measured perpendicular to the surface. In addition, the thickness of the organic layers was recorded along 2 transects with 20 measurements.

Samples were dried at a temperature of 60°C to constant weight (at least 24 hours), weighted and the densities (g/cm^3) were calculated. The average densities (± sd) were: L = 0.09 ± 0.05, F = 0.14 ± 0.06, H = 0.22 ± 0.08. Finally, samples were milled and analysed for their C and N concentrations (NC 2500, Carlo Erba Instruments).

Database:
At WSL, approximately 1300 soil profiles had been investigated during the past 10-15 years. These existing data were arranged in a database. Approximately 870 sites with different information on the soil characteristics distributed among different forest types throughout Switzerland were chosen for the compilation presented here. This information included thickness of the organic layers and sometimes measured carbon content analysis. Some additional information had to be deduced by Moeri (in prep.) from pictures and field protocols.

The organic carbon stock at each site was calculated in two steps.

(1) The mass of the organic layers was assessed by their thickness and density (mass = density * thickness).

(2) The C concentration (%) was derived by Moeri (in prep.) from the laboratory data contained in the WSL database. Approximately 400 sites were selected and used for the present study done by Moeri (in prep.). The C concentrations from the WSL database were stratified for coniferous, mixed and for deciduous forests and average C concentrations were calculated. Those average C concentration values per strata enabled the calculation of the amount of carbon in organic soil horizons on each site. Table 134 shows the results of all sites averaged for the production regions.

Table 134 Soil organic carbon of mineral forest soils (CC12, CC13) in organic soil horizons in t C ha^{-1} in the 5 NFI production region (N = number of samples): The average values ± standard deviation are given.

NFI egion (N)	L Horizon	F Horizon	H Horizon	Total
1. Jura (72)	7.8 (± 4.6)	1.4 (± 3.3)	0.51 (± 3.1)	9.7 (± 15.1)
2. Central Plateau (281)	4.8 (± 3.5)	3.6 (± 6.9)	1.1 (± 4.5)	9.5 (± 13.3)
3. Pre-Alps (287)	4.4 (± 3.2)	6.4 (± 9.4)	6.6 (± 19.8)	17.4 (± 28.5)
4. Alps (199)	6.0 (± 5.5)	16.6 (± 26.6)	10.8 (± 24.2)	33.4 (± 43.4)
5. Southern Alps (37)	7.3 (± 4.1)	10.6 (± 14.6)	4.4 (± 14.3)	22.3 (± 29.9)
Total Switzerland (876)	5.3 (± 4.2)	7.6 (± 15.5)	5.2 (± 17.1)	18.1 (± 30.0)

Unlike stated in the GPG LULUCF (IPCC 2003), soil carbon of mineral forest soils in organic soil horizons was added to the soil carbon of the mineral layer for Swiss productive and unproductive forests (CC 12 and CC 13). According to IPCC (2003; Table 3.1.2) soil carbon of the organic soil horizons should be accounted as dead organic matter, together with dead wood.

For afforestations (CC 11), the amount of soil carbon in the soil organic horizons was assumed to be zero. Total soil carbon was defined as soil carbon contained in the 0-30 cm mineral topsoil.

Due to following reasons it is assumed that in the years 1990 to 2004 forest soils in Switzerland were no source of carbon:

- Within the last decades, no drastic changes of management practices in forests have been taken place because the Swiss forest law (Swiss Confederation 1991) is very restrictive.
- Fertilization of forests is prohibited by the Swiss forest law and adherent ordinances (Swiss Confederation 1991, 1992). Drainage of forests is not common practice in Switzerland.
- As growing stock has increased since many years, soil carbon is assumed to increase due to increasing litter production.
- As shown in the study by Thürig et al. (2005), wind-throw may have a slightly increasing effect on soil carbon. However, this study neglected the effect of soil disturbances which could equalize those effects.

k) Carbon Stock of Afforestations (CC 11)

Growing stock and growth

As the results from the NFI III were not yet available, the average growing stock and growth of afforestations were empirically assessed with NFI I and II, specifically with those stands that were approximately 10 years old in the first NFI and 20 years old in the second NFI. The average growing stock of those 20 year old stands was derived from NFI II. The NFI data were therefore stratified for site quality It was assumed that forest areas below 600 m show a good site quality, areas between 600 and 1200 m a moderate site quality, and forest areas above 1200 m show a poor site quality. The growing stock of forest stands on good sites was 90 $m^3 ha^{-1}$. The growing stock on moderate sites was assumed to be one-third smaller than on good sites (60 $m^3 ha^{-1}$), and two-third smaller on bad sites (30 $m^3 ha^{-1}$). As trees below 12 cm DBH were not measured in the NFI, the growing stock of 10 year old stands on good sites was assumed to be 2 $m^3 ha^{-1}$. Within the first few years of stand age, the growing stock was assumed to develop exponentially. The development of the growing stock on good sites between 10 and 20 years was therefore simulated by calibrating an exponential growth function. To simulate the development of growing stock on intermediate and poor sites, growing stock was assumed to develop one-third slower on intermediate, and two-third slower on poor sites. The annual growth was calculated as the difference between growing stocks of two following years. These assumptions are not valid for single stands, but can be applied as a rough simplification. Table 135 shows the simulated growing stock and growth for all three site qualities.

Table 135 Estimated average growing stock and annual growth of forest stands in stemwood (defined in Table 24) up to 20 years (CC11) specified for altitude zone.

Stand age [yr]	< 601 m altitude		601 - 1200 m altitude		> 1200 m altitude	
	Growing stock [$m^3 ha^{-1}$]	**Growth** [$m^3 ha^{-1} year^{-1}$]	**Growing stock** [$m^3 ha^{-1}$]	**Growth** [$m^3 ha^{-1} year^{-1}$]	**Growing stock** [$m^3 ha^{-1}$]	**Growth** [$m^3 ha^{-1} year^{-1}$]
0-9	0	0	0	0	0	0
10	**2**	2	0	0	0	0
11	7	5	0	0	0	0
12	13	6	1	1	0	0
13	19	6	5	4	0	0
14	27	8	10	5	0	0
15	35	8	16	6	1	1
16	44	9	23	7	5	4
17	54	10	31	8	10	5
18	66	12	40	9	16	6
19	78	12	50	10	23	7
20	**90**	12	**60**	10	**30**	7

To convert the estimated growing stock and growth into carbon, the following equations were applied:

C stock in living biomass = Average growing stock * density * BEF * C-content

Growth of living biomass = Average growth * density * BEF * C-content

In Table 136, abbreviations and units are explained. Table 137 shows the parameters and the converted values.

Table 136 Conversion of growing stock and growth to total carbon in biomass.

Name	Description	Value	Unit
Average growing stock	Average growing stock of stemwood over bark, without branches	See Table 137	$m^3 ha^{-1}$
Average growth	Average growth per ha and year	See Table 137	$m^3 ha^{-1} year^{-1}$
Density	Tree density averaged for coniferous and deciduous trees	0.47	$t m^{-3}$
BEF	Biomass expansion factor to convert stemwood over bark into total tree biomass (Burschel et al. 1993); averaged value for coniferous and deciduous trees.	1.45	-
C-content	Carbon to total biomass ratio (IPCC default)	0.5	-
C stock in living biomass	Carbon content in total above- and belowground biomass	See Table 137	$t C ha^{-1}$
Growth of living biomass	Growth of carbon in t C per ha and year	See Table 137	$t C ha^{-1} year^{-1}$

Table 137 Carbon stock in living biomass and growth of living biomass in afforestations (CC11) specified for altitude zone.

Altitude [m]	Average growing stock [$m^3 ha^{-1}$]	Average growth [$m^3 ha^{-1}year^{-1}$]	Density [$t m^{-3}$]	BEF	Carbon content	Carbon stock in living biomass [$t C ha^{-1}$]	Growth of living biomass [$t C ha^{-1} year^{-1}$]
0-600	36.25	7.5	0.47	1.45	0.5	12.35	2.56
601-1200	19.67	5	0.47	1.45	0.5	6.70	1.70
>1200	7.08	2.5	0.47	1.45	0.5	2.41	0.85

I) Specifications for Calculating Carbon Fluxes in Case of Land-use Change Comprising Forest Land

According to the land use statistic, each year certain areas switch from a non-forest land use category to forest. These are mainly areas that used to be populated with grassland or woody biomass (see Table 110) not fulfilling the definition of minimal forest density and area. According to the stock change approach, the growing stock of e.g. shrub vegetation (CC 32) (living biomass and soil carbon) should be subtracted and the average growing stock of forests should be added. However, these forests are supposed to have a growing stock smaller than the growing stock of an average forest and adding the average growing stock of forest areas would possibly overestimate the carbon increase. In terms of IPCC good practice a legitimate conservative assumption was met (see also Chapter 7.2.1): The amount of living biomass (carbon stock in living biomass) on land changing from non-forest to forest was not increased but left unchanged. The annual increase of biomass (carbon flux) on these areas was approximated by the annual gross growth rate of the respective forest type (CC 11, 12 or 13). The change of soil carbon was not considered and was set to zero.

Cut and mortality was inferred from NFI I and NFI II, applying the stock change approach on forest areas remaining forest. Thus, the total harvesting amount of Switzerland was already considered. To avoid double-counting of the harvesting amount on areas changing from non-forested to forested areas, no additional loss in terms of cut and mortality was accounted for, but the converted areas were only multiplied with the average annual gross growth of the respective spatial stratum.

The annual area of forest changing to other land use categories was also derived by land use statistics. To account for the "decrease of carbon", the current above- and belowground biomass, the amount of dead-wood and the amount of soil carbon of forest areas changing into other land use categories were subtracted. To account for the "increase of carbon", the carbon stock in biomass and soil of the new land use category was added.

m) N_2O Emissions from N Fertilization and Drainage of Soils

Fertilization of forests is prohibited by the Swiss forest law and adherent ordinances (Swiss Confederation 1991, 1992). Therefore, no emissions are reported in CRF Table 5(I).

Drainage of forests is not common practice in Switzerland. There are no survey data available, but the drained area is probably very small, if existing at all (see also Chapter 7.6.2. As a first guess drainage activity was set to zero, and no emissions are reported for forest land in CRF Table 5(II).

n) Emissions from Wildfires

Data on wildfires affecting Swiss forest land can be extracted from the EMIS database. Table 138 shows the annual number of fires and the burnt area from 1990 to 2004.

As controlled burning is not allowed in Switzerland all fires are assigned to "wildfires". It was assumed that all fires affected productive forests.

The emission factor for CH_4 is 0.065 Mg CH_4 ha^{-1} (extracted from EMIS database); country-specific value).

For N_2O, the default emission factor of 0.11 g (kg combusted biomass)$^{-1}$ is applied (IPCC 2003, Table 3A.1.16). The mass of available fuel is estimated to average 200'000 kg biomass ha^{-1} (see Table 124 and Table 125, thereby taking into consideration the respective areas). The fraction of the biomass combusted is 0.45 (IPCC 2003, Table 3A.1.12). Inserting these values in equation 3.2.20 of IPCC (2003), the emissions shown in Table 138 are calculated.

CO_2 emissions caused by wildfires are already included in CRF Table 5.A.

Table 138 Productive forest land affected by wildfires (Source: EMIS database) and resulting GHG emissions 1990-2004.

Year	Number	Area burnt [ha]	CH_4 [Mg]	N_2O [Mg]
1990	216	1102	71.63	10.91
1991	157	148	9.62	1.47
1992	111	52	3.38	0.51
1993	99	42	2.73	0.42
1994	52	293	19.05	2.90
1995	56	438	28.47	4.34
1996	61	233	15.15	2.31
1997	77	1511	98.22	14.96
1998	88	249	16.19	2.47
1999	31	9	0.59	0.09
2000	41	36	2.34	0.36
2001	39	37	2.41	0.37
2002	75	410	26.65	4.06
2003	189	564	36.66	5.58
2004	46	20	1.30	0.20

7.3.3. Uncertainties and Time-Series Consistency

In case of gross growth, cut and mortality, the uncertainty is assessed as low. In case of BEFs, the uncertainty is assessed as medium. In case of soil carbon pool, the uncertainty is assessed as medium.

7.3.4. Source-Specific QA/QC and Verification

No source-specific QA/QC activities have been carried out.

7.3.5. Source-Specific Recalculations

See Chapter 9.1.

7.3.6. Source-Specific Planned Improvements

As soon as the results from the third NFI (2004-2006) are available, gross growth rates and harvesting amounts currently extrapolated from NFI I (1983-1985) and NFI II (1993-1995) will be recalculated for the years from 1995 onwards. The publication of NFI III data is expected in 2007.

With the results of the NFI III, the growing stock and increment of afforestations will be analyzed more precisely.

In the third NFI, the total amount of dead wood will be measured by the line intersect method. Therefore, estimates about changes of the dead-wood pool will be performed in 2007.

7.4. Source Category 5B – Crop Land

7.4.1. Source Category Description

Swiss croplands belong to the cold temperate wet climatic zone. Carbon stocks in aboveground living biomass and carbon stocks in mineral and organic soils are considered. Croplands (CC 21) include annual crops and leys in arable rotations. Because arable cropping only occurs in the temperate Swiss Central Plateau and no elevation-dependent soil carbon stock could be identified for Swiss croplands (Leifeld et al. 2005), no correction for elevation was necessary.

7.4.2. Methodological Issues

a) Carbon in Living Biomass

Biomass carbon stocks are calculated as area-weighted means of standing stocks at harvest for the seven most important annual crops (wheat, barley, maize, silage maize, sugar beet, fodder beet, potatoes) and as cumulated annual harvested biomass for leys (Table 139).

Table 139 Standard values for arable crop yields (t C ha^{-1}; FAL/RAC 2001, assuming a carbon fraction of 0.5 (IPCC default).

Crop	Yield [t C ha^{-1}]
Barley	2.6
Wheat	2.6
Maize	3.4
Silage maize	21.3
Sugar beet	7.2
Fodder beet	6.8
Potatoes	4.3
Ley	5.5

The mean standing biomass carbon stock per hectare is calculated as:

$$\text{Biomass cropland} = \Sigma_f \ (A_f / A_t) * C_f$$

where A_f = Area of crop type f, A_t = total cropping area and C_f = standard yield (annual crops, leys) for the particular crop (t C ha^{-1}) according to Table 139. For A_f, means were calculated for each crop from the time series 1988 - 2003 as published by SBV (2004).

The resulting mean biomass stock for Swiss cropland is 5.66 t C ha^{-1}.

b) Carbon in Soils

Soil carbon stocks in mineral soils under cropland are calculated based on Leifeld et al. (2003, 2005). The approach correlates measured soil organic carbon stocks (t ha^{-1}) for arable land and leys with soil texture after correction for soil depth and stone content. Area upscaling uses the Swiss digital soil map (SFSO 2000a), and average stocks are calculated as weighted means using the area of arable land and leys. The mean soil organic carbon stock (0-30 cm) for cropland is 53.40 ± 5 t C ha^{-1}.

Soil carbon stocks in organic soils under cropland are calculated based on Leifeld et al. (2003), Leifeld et al. (2005). The approach uses measured carbon stocks in Swiss organic soils. The mean soil organic carbon stock (0-30 cm) for cultivated organic soils is 240 ± 48 t C ha^{-1}.

c) Changes in Carbon Stocks

Changes in carbon stocks biomass and mineral soil are assumed to be zero for cropland remaining cropland. Carbon stock changes in soil for cropland remaining cropland occur in the case of shifts from mineral to organic soils or vice versa. These soil carbon stock changes are calculated as:

delta $C_{s\ cropland}$ (t) = ($A_{s\ organic,\ t2}$ – $A_{s\ organic,\ t1}$) * ($C_{s\ organic}$ – $C_{s\ mineral}$)

where $A_{s\ organic}$ is the area of cropland on organic soils (ha), $C_{s\ organic}$ the soil carbon stock on organic soils (t ha^{-1}), $C_{s\ mineral}$ the soil carbon stock on mineral soils (t ha^{-1}), t1 and t2 beginning and end of inventory, respectively. Implicitly, this effect is included in the general equations given in section 7.2.1.

d) N_2O Emissions from Land Use Conversion to Cropland

N_2O emissions as a result of the disturbance associated with land-use conversion to cropland are reported in CRF Table 5 (III). The emissions are calculated with default values proposed by IPCC (2003, following Equations 3.3.14 and 3.3.15, and Chapter 3.3.2.3.1.2):

Emission(N_2O) = deltaC_s * 1 / (C : N) * EF1 * 44 / 28 [Gg N_2O]

where:

deltaC_s: soil carbon loss in soils induced by land-use conversion to cropland [Gg C]

C:N: IPCC default C:N ratio = 15 in forest or grassland soils

EF1: IPCC default emission factor = 0.0125 kg N_2O-N (kg $N)^{-1}$

e) Carbon Emissions from Agricultural Lime Application

In CRF Table 5 (IV) the same values are reported as in former NIRs. The total annual amount of limestone input to agricultural soils of 45’000 Mg has been stable over the period 1990-2004 and has been estimated by Würsch (2004).

The IPCC default carbon conversion factor for limestone is 0.12 Mg C per Mg Ca(CO_3). The resulting carbon emissions associated with liming are 5.4 Gg C $year^{-1}$.

7.4.3. Uncertainties and Time-Series Consistency

Uncertainties for soil carbon stocks are given together with the mean value in the text. They take into account uncertainties in measured C contents and predicted soil bulk densities, i.e., they consider only uncertainties in emission factors. The relative uncertainty in yield determination has been estimated at 13% for biomass carbon from agricultural land (Leifeld and Fuhrer 2005). Data on biomass yields for different elevations and management intensities as published by FAL/RAC (2001) are based on many agricultural field experiments and have a high reliability. Time-series are not considered yet.

7.4.4. Source-Specific QA/QC and Verification

The published data on Swiss soil carbon stocks were used to calculate C fluxes from land-use changes, and no further data for cross checking are currently available. No source-specific QA/QC has been carried out.

7.4.5. Source-Specific Recalculations

All carbon stocks were re-calculated according to the new combination categories. See Chapter 9.1.

7.4.6. Source-Specific Planned Improvements

Emissions from land-use conversion to cropland will be adopted to own C : N measurements of organic matter from a wide range of mineral soils in 2007. Ongoing efforts to combine SOC measurements on the level of soil fractions with modelled pools (Zimmermann et al. 2006) will allow for an independent check of emission rates from cropland to grassland an vice versa in the future.

7.5. Source Category 5C – Grassland

7.5.1. Source Category Description

Swiss grasslands belong to the cold temperate wet climatic zone.

Carbon stocks in living biomass and carbon stocks in soils are considered. Grasslands include permanent grassland (CC 31), shrub vegetation (CC 32), vineyards, low-stem orchards (‘Niederstammobst’) and tree nurseries (CC 33), copse (CC 34), orchards (‘Hochstammobst’; CC 35), stony grassland (CC 36), and unproductive grassland (CC 37).

In the CRF Table 5.C.2, the land-use types CC 32, 33, 34 and 35 are merged under the notation ‘woody’ as well as CC 36 and 37 are merged under ‘unproductive’ (see Table 106).

7.5.2. Methodological Issues

a) Carbon in Living Biomass

Permanent Grassland (CC 31)

Permanent grasslands range in altitude from < 300 m to 3000 m above sea level. Because both biomass productivity and soil carbon rely on the prevailing climatic and pedogenic conditions, grassland stocks were calculated separately for three altitude zones (corresponding to those used in source category 5A - Forest Land).

Standing stocks for permanent grasslands (t C ha^{-1}) are calculated as the annual cumulative yield of differentially managed grasslands (meadows, pastures, alpine meadows and pastures) based on FAL/RAC (2001;Table 140), assuming a carbon fraction of 0.5 (IPCC default). Mean standing above-ground biomass stocks were taken for each of the altitudinal zones because the spatial distribution of grassland management types is not known.

Table 140 Annual yields of differentially managed permanent grassland (CC 31). Each value represents the mean of two fertilization levels.

Management	**Altitude [m]**	**Annual yield** [t C ha^{-1}]
Meadow	<601	5.88
	601-1200	4.38
	>1200	3.25
Pasture	<601	4.63
	601-1200	3.75
	>1200	2.75
Alpine pasture and meadow	601-1200	3.75
	>1200	0.75

Root biomass-C is assumed to be 2.2 t C ha^{-1} (0-1 m; Ammann et al. in press) for all grasslands due to lack of additional data. Root biomass is added to above-ground biomass to derive the total living biomass for CC 31. Table 141 shows the living biomass of permanent grassland for the three altitudinal zones as the cumulated annual yield including roots.

Table 141 Living biomass C_l of permanent grassland (CC 31).

Altitude [m]	**C_l [t C ha^{-1}]**
<601	7.45
601-1200	6.26
>1200	4.45

Shrub Vegetation (CC 32) and Copse (CC 34)

Due to a lack of more precise data, the living biomass of shrub vegetation and copse was assumed to correspond with brush forest described in section 7.3.2. g. Brush forest is assumed to contain 11.6 t C ha^{-1}.

Vineyards, Low-stem Orchards and Tree Nurseries (CC 33)

Low-stem orchards are small fruit trees distinguished from CC 35 (‘orchards’) by a maximum stem-height of 1 m and a much higher stand density. Only low-stem orchards and vineyards are considered in the following because no stand densities for tree nurseries are available. Data from SFSO (2000) indicate a very small contribution of tree nurseries (1’378 ha) as compared to the sum of vineyards (15’436 ha, ASCH2) and low-stem orchards (240 ha, based on Widmer 2006).

The standing carbon stock of living biomass (Cl) for CC 33 is therefore calculated as:

Cl = [(Cl vineyards * area vineyards) + (Cl * area low-stem orchards)] / (area vineyards + area low-stem orchards)

Cl of vineyards is 3.61 t C ha^{-1}, calculated based on the mean stand density (5556 vines ha^{-1}) and woody biomass of a plant including roots (0.65 kg C; Ruffner 2005).

For small fruit trees on low-stem orchards, no literature value was found for biomass expansion factors. Therefore, following assumptions were met. DBH of such trees was assumed to be around 10 cm and the tree height was assumed to be around 1 m. The bole shape of low-stem apple trees can be approximated by a cylinder shape.

Stem wood volume = $r^2 * \pi *$ height = $(5\text{ cm})^2 * 3.1 * 100$ cm = 7.75 dm^3

Based on expert knowledge (Kaufmann 2005), the percentage of branches was estimated as 100%, and the percentage of roots was estimated as 30% of the stemwood volume. This results in a BEF of 2.3. A wood density of 0.55 kg dm^{-3} (Vorreiter 1949) and the default carbon content of 50% were assumed. With these assumptions the carbon content of a tree of the type low-stem ('Niederstamm') is calculated as follows:

C low-stem = stem wood volume * BEF * wood density * carbon content
= 7.75 dm^3 * 2.3 * 0.55 kg/dm^3 * 50% C-content = 4.9 kg C

The mean stand density of low-stem orchards is estimated at 2500 ha^{-1} (Widmer, 2006), resulting in a CI of 12.25 t C ha^{-1}.

The resulting CI for CC 33 is 3.74 t C ha^{-1}.

Orchards (CC 35)

Orchards are loosely planted larger fruit trees ('Hochstammobst') with grass understory. CI of orchards trees is calculated as:

CI biomass = (carbon per fruit tree [t]*number fruit trees [ha^{-1}] / area orchards [ha]) + carbon in grass [ha^{-1}]

The carbon content of a large fruit tree with a diameter at breast height (DBH) of 25 - 35 cm was calculated as follows:

C(Hochstamm) = Stem wood volume * KE-Factor = 225 kg C

where:

Stemwood volume of an apple tree with DBH between 25 and 35 cm: 0.5 m^3 (expert knowledge);

KE-Factor [tC m^{-3}]= BEF * Density * C-content = 0.45, (Wirth et al. 2004, p. 68, Table 16).

From the total fruit-growing area of 41'480 ha (ASCH2 data), the area of small fruit trees (240 ha, see CC 33) was subtracted, and the remaining area was divided by the number of large fruit trees. Large fruit trees were counted in 1991 (3'616'301) and 2001 (2'900'000; SFSO 2002), and the mean value was divided by 41'240 ha to obtain a mean stand density of 79 trees ha^{-1}. The resulting woody biomass of CC 35 is thus 17.78 t C ha^{-1}. Because orchards typically have a grass understory, the biomass of CC 31 was added to the woody biomass. ASCH2 data showed that orchards are located below 1000 m a.s.l., so the mean of grass biomass of the classes <601 and 600-1200 m a.s.l. (i.e., 6.86 t C ha^{-1};Table 141) was taken to obtain a total biomass stock of 24.63 t C ha^{-1} for CC 35.

Stony Grassland (CC 36)

Approximately 35% of the surface of category 36 (herbs and shrubs on stony surfaces) is covered by vegetation. No accurate data were available for this category. Therefore, the carbon content of brush forest (11.60 t C ha^{-1}) was multiplied by 0.35 to account for the 35% vegetation coverage. This results in a carbon content of 4.06 t C ha^{-1}.

Unproductive Grassland (CC 37)

The category CC 37 includes grass and herbaceous plants at watersides of lakes and rivers including dams and other flood protection structures, constructions to protect against avalanches and rock slides, and alpine infrastructure (e.g. for skiing). For none of these land-use types, biomass data are currently available. Therefore, the mean value of all grasslands from Table 141, 6.05 t C ha^{-1}, is arbitrarily chosen as the preliminary biomass value for CC 37.

b) Carbon in Soils

Permanent Grassland (CC 31)

Carbon stocks in grassland soil refer to a depth of 0-30 cm.

Soil carbon stocks in mineral soils under permanent grassland CC 31 are calculated based on Leifeld et al. (2003, 2005). The approach correlates measured soil organic carbon stocks (t ha^{-1}) for permanent grasslands with soil texture and elevation after correction for soil depth and stone content. Area upscaling makes use of the Swiss digital soil map (SFSO 2000a) and topography. Mean Cs values calculated for grasslands CC 31 are given in Table 142.

Table 142 Mean carbon stocks under permanent grassland on mineral soils.

Altitude [m]	C_s [t C ha^{-1}, 0-30 cm]
<601	62.02 ± 13
601-1200	67.50 ± 12
>1200	75.18 ± 9

Soil carbon stocks in organic soils under permanent grassland are calculated based on Leifeld et al. (2003, 2005). The approach uses measured carbon stocks in Swiss organic soils without differentiation among cropland and grassland. The mean soil organic carbon stock (0-30 cm) for organic soils is 240 ± 48 t C ha^{-1}.

Shrub Vegetation (CC 32)

Due to lack of data, the mean value of Table 142, 68.23 t ha^{-1} was used as the soil carbon default for this category.

Vineyards, Low-stem Orchards and Tree Nurseries (CC 33)

The category includes carbon stocks in soils of vineyards, small fruit trees and tree nurseries. In accordance to carbon stocks in biomass, only vineyards and small fruit trees are considered. Both land-use types are assumed to have no grass undercover. Therefore, the soil carbon values of cropland, i.e. 53.40 t C ha^{-1} (mineral soils) and 240 t ha^{-1} (organic soils) are taken for CC 33 (see Chapter 7.4.2.b).

Copse (CC 34)

Due to lack of data, the mean value of Table 142, 68.23 t ha^{-1} was used as the soil carbon default for this category.

Orchards (CC 35)

Cs orchards was calculated in accordance to the biomass calculation. No specific Cs orchards values are available, and so the mean value of grassland soil carbon stocks (mineral soils) from the two lower altitudinal zones (i.e., 64.76 t C ha^{-1}) was taken as Cs orchards, and the value of 240 t ha^{-1} for organic soils (see Chapter 7.4.2.b).

Stony Grassland (CC 36)

Soil organic carbon stocks under herbs and shrubs on stony surfaces were calculated according to the procedure described in Chapter 7.5.2.a. It is assumed that not more than 35% of the area of CC 36 are covered with vegetation and thus only 35% of the area bears a mineral soil while the remainder is bare rock. Land-use of this category mostly belongs to 'grassland' and 'unproductive land' and likely includes many of the former (ASCH2) alpine grasslands. These grasslands are mainly located at altitudes > 1200m a.s.l. Thus, the carbon stock Cs of CC 36 is calculated as:

Cs of CC 36 = 0.35 * Cs permanent grassland > 1200 m = 26.31 t C ha^{-1}

Unproductive Grassland (CC 37)

The category CC 37 ‚unproductive grasslands' includes grass and herbaceous plants at watersides of lakes and rivers including dams and other flood protection structures, constructions to protect against avalanches and rock slides, and alpine infrastructure (e.g. for skiing). For none of these land-use types, Cs data are currently available. Soil carbon stocks of CC 37 'unproductive grassland' were arbitrarily set as the mean value of carbon stocks under permanent grassland on mineral soils (Table 142) in accordance to the procedure followed for biomass. Cs CC 37 is thus 68.23 t C ha^{-1}.

c) Changes in carbon stocks

Changes in carbon stock biomass and mineral soil are assumed to be zero for grassland remaining grassland. Carbon stock changes in soil for grassland remaining grassland occur in the case of shifts from mineral to organic soils or vice versa. These soil carbon stock changes are calculated as:

delta $C_{s\ grassland}$ (t) = $(A_{s\ organic,\ t2} - A_{s\ organic,\ t1}) * (C_{s\ organic} - C_{s\ mineral})$

where $A_{s\ organic}$ is the area of grassland on organic soils (ha), $C_{s\ organic}$ the soil carbon stock on organic soils (t ha^{-1}), $C_{s\ mineral}$ the soil carbon stock on mineral soils (t ha^{-1}), t1 and t2 beginning and end of inventory, respectively. Implicitly, this effect is included in the general equations given in section 7.2.

d) Carbon Emissions from Agricultural Lime Application

All CO_2 emissions caused by agricultural lime application are included under 'cropland' (Chapter 7.4.2.e).

7.5.3. Uncertainties and Time-Series Consistency

Uncertainties for soil carbon stocks are given together with the mean value in the text. They take into account uncertainties in measured C contents and predicted soil bulk densities, i.e., they consider only uncertainties in emission factors. The relative uncertainty in yield determination has been estimated at 13% for biomass carbon from both, cropland and grassland (Leifeld and Fuhrer 2005). Data on biomass yields for different elevations and management intensities as published by FAL/RAC (2001) are based on many agricultural field experiments and have a high reliability. Time-series are not considered yet.

7.5.4. Source-Specific QA/QC and Verification

The published data on Swiss soil carbon stocks were used to calculate C fluxes from land-use changes, and no further data for cross checking are currently available. No source-specific QA/QC has been carried out.

7.5.5. Source-Specific Recalculations

The area of grassland covered by organic soils is somewhat higher than in former calculations due to new methods for assessing activity data.

All carbon stocks were re-calculated according to the new combination categories (CC). See Chapter 9.1.

7.5.6. Source-Specific Planned Improvements

A planned survey of existing data on root biomass in alpine grasslands will help to improve root data for CC 31.

7.6. Source Category 5D – Wetlands

7.6.1. Source Category Description

Wetlands consist of surface waters (CC 41) and unproductive wet areas such as shore vegetation and fens (CC 42) (see Table 106)

7.6.2. Methodological Issues

Surface Waters (CC 41)

Surface waters have no carbon stocks by definition.

Unproductive Wetland (CC 42)

In AREA statistics unproductive wetland may be covered by trees to a certain degree (SFSO 2006a). The tree vegetation is indicated by different tags, e.g. for tree groups or tree lines. Due to the additional woody vegetation, unproductive wetland contains more carbon than unproductive grassland. Using the information provided by the tags, the carbon stock in living biomass of unproductive wetland was estimated. CC 42 was stratified according to the different tags and each tag was assigned to a carbon content of a known combined category (CC). Table 143 shows the different tags and the assigned carbon stock in living biomass.

The CC 42 stratified for different tags were summed up for all 3 AREA inventories and the percentages within each tag category were calculated. Using the percentages and the assigned carbon stock values, a weighted average for category CC 42 was calculated (Table 144).

Table 143 Assigned carbon content of CC 42 according to different tags.

Tag	Assigned category	CC	Carbon stock in living biomass, [t C ha^{-1}]
0: No tag	Unproductive grassland	37	6.05
3: Tree group on wetland	Unproductive forest	13	33.7*
6: Biotope	Unproductive grassland	37	6.05
19: Linear tree group on wetland	Trees in settlement	54	4.80
36: Clear-cut on wetland	Unproductive grassland	37	6.05

*Arithmetical average of carbon stock in living biomass of unproductive forests over all altitudinal zones and NFI regions.

Table 144 Occurrence of tags associated with CC 42 and estimated carbon content of CC 42.

Tag	AREA surveys [ha]			Total	Percentage of total	Carbon stock in living biomass [t C ha^{-1}]
	1	2	3			
0	2610	2464	2445	7519	90%	6.05
3	165	202	206	573	7%	33.7
6	6	8	37	51	1%	6.05
19	59	75	76	210	2%	4.80
36	0	0	11	11	0%	6.05
Total	**2840**	**2749**	**2775**	**8364**	**100%**	**7.96***

*Weighted average of all categories according to occurrence.

Soil

Land cover in CC 42 explicitly includes peatlands protected by Federal Legislation (Swiss Confederation 1991a and 1994) as well as reed. For these peatlands, the same value (240 t C ha^{-1}) as for organic soils under ‘cropland’ and ‘grassland’ was taken. Currently no soil data are available for other land covers than peat in CC 42. As a first guess, it is suggested that the soil carbon stock of unproductive wetlands is the arithmetic mean of grassland on mineral soils (68.23) and organic soils (240), thus 154 t C ha^{-1}.

Changes in carbon stocks

In the case of land-use change, the net changes in biomass and soil of both CC 41 and CC 42 are calculated as described in chapter 7.2.1.

N_2O emissions from drainage of soils

Drainage of intact wetlands is very unlikely, as bogs and fens are protected to a large part by Federal Ordinances (Swiss Confederation 1991a and 1994). Therefore, no N_2O emissions are reported in CRF Table 5 (II).

7.6.3. Uncertainties and Time-Series Consistency

In case of activity data, the uncertainty is assessed as low. In case of carbon stocks, the uncertainty is assessed as high.

7.6.4. Source-Specific QA/QC and Verification

No source-specific QA/QC activities have been carried out.

7.6.5. Source-Specific Recalculations

All carbon stocks were re-calculated according to the new combination categories (CC). See Chapter 9.1.

7.6.6. Source-Specific Planned Improvements

There are no planned improvements.

7.7. Source Category 5E – Settlements

7.7.1. Source Category Description

Settlements consist of buildings/constructions (CC 51), herbaceous biomass in settlements (CC 52), shrubs in settlements (CC 53) and trees in settlements (CC 54) as shown in Table 106.

7.7.2. Methodological Issues

Buildings and Constructions (CC 51)

Buildings/constructions contain no carbon by default.

Herbaceous Biomass, Shrubs and Trees in Settlements (CC 52, 53, 54)

In a Tier 1a approach, the IPCC provides a default value for crown cover area based annual growth rate (CRW) in settlements remaining settlements (IPCC 2003; p. 3.297).This value ranges from 1.8 to 3.4 t C ha^{-1} yr^{-1}, the arithmetic mean is 2.9 t C ha^{-1} yr^{-1}. It is an estimate for the average annual growth rate per tree crown cover area in settlements remaining settlements.

Expert assessment in Switzerland estimated the average age of trees in settlements remaining settlements to be older than 20 years. In the GPG LULUCF (IPCC 2003), growth of trees in settlements is limited to the first 20 years. Therefore, the average carbon stock per tree crown cover area in settlements remaining settlements was assumed to be 20 times the crown cover area based annual growth rate (CRW, t C ha^{-1} yr^{-1}).

To estimate the tree crown cover area of the CC 52 (herbaceous biomass in settlements), CC 53 (shrubs in settlements) and CC 54 (trees in settlements) LIDAR data was used. Tree crown cover was derived by Mathys (2005) as follows. The raw LIDAR data for the entire study area was acquired from a helicopter in May 2000 using a small-footprint LIDAR system. The resulting digital terrain (DTM) and surface model (DSM) had a spatial resolution of 1 m and both were bilinearly resampled to 2.5 m. The difference between LIDAR-based digital surface model (DSM) and digital terrain model (DTM) was used to extract objects taller than 3 m to comply with the Swiss National Forest Inventory, where a tree is defined as woody vegetation greater 3 m. Objects other than tree vegetation were excluded based on the official building map and secondary mapping information on constructed objects. Tree crown cover was then derived at a hectare scale based on focal analyses within a rectangular moving window of 100 m x 100 m applied to the generated 2.5 m raster of tree vegetation. For the application in the GHG inventory report, the centre of the moving window was shifted to match the corresponding AREA CC interpretation point. The resulting tree crown cover raster covers the Canton of Geneva. This raster was then spatially overlaid with the data from the land use statistics (SFSO 2006). Figure 38 shows the distribution of the percentages of vegetation coverage of CC 52 and CC 53. For the CC 52 and CC 53, the arithmetical average of the rate of tree vegetation coverage was calculated. The following equation was applied to estimate the average carbon pool in living vegetation of the CC 52 and CC 53.

Carbon stock of CC_i [t C ha^{-1}] = $coverage_i$ /100 * CRW * 20 years

where coverage means the average (arithmetic mean) percentage of vegetation coverage for the CC 52 (10%) and CC 53 (8.3%). CRW is the average crown cover area based annual growth rate [t C ha^{-1} $year^{-1}$] from the GPG LULUCF (IPCC 2003) and i indicates CC 52 and 53, respectively.

Using the average value for the CRW (2.9 t C ha^{-1} yr^{-1}), CC 52 is estimated to contain an average C stock of 5.8 t C ha^{-1}, and CC 53 4.8 t C ha^{-1} (Figure 38). Due to a lack of data, the carbon content of CC 53 was also used for CC 54 (4.8 t C ha^{-1}).

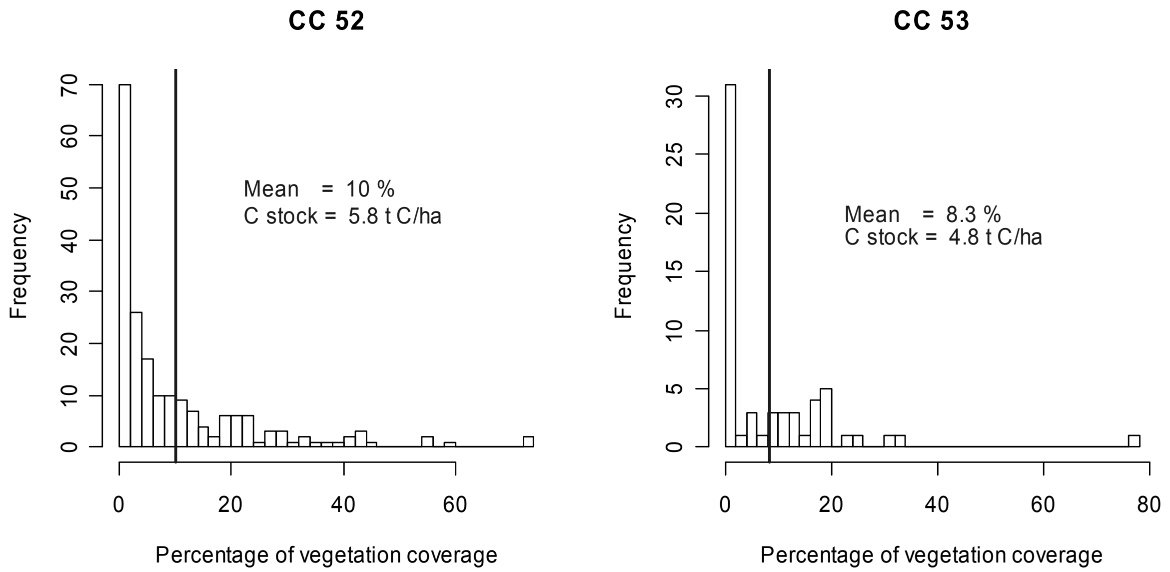

Figure 38 Vegetation cover and carbon stock of grassland vegetation with wood biomass larger than 3 m. CC 52: Herbaceous biomass in settlements, CC 53 Shrubs in settlements.

Soils

The carbon stock in soil for CC 51 (buildings and construction) was set to zero. However, a weighting factor of 0.5 was applied to soil carbon changes due to land-use changes involving CC 51 (see Chapter 7.2.1). The reason for this is that in general the soil organic matter on construction sites is stored temporarily and later used for replanting the surroundings or it is used to vegetate dumps for example. The oxidative carbon loss due to the disturbance of the soil structure may reach 50% (see discussion in Leifeld et al. 2003: 67).

The carbon stock in soil for CC 52, 53 and 54 is 53.40 t C ha^{-1} (0-30 cm, same value as for cropland).

7.7.3. Uncertainties and Time-Series Consistency

In case of activity data, the uncertainty is assessed as low. In case of carbon stocks, the uncertainty is assessed as high.

7.7.4. Source-Specific QA/QC and Verification

No source-specific QA/QC activities have been carried out.

7.7.5. Source-Specific Recalculations

All carbon stocks were re-calculated according to the new combination categories (CC). See Chapter 9.1.

7.7.6. Source-Specific Planned Improvements

Categories CC 52, 53 and 54 were estimated based on tree crown coverage situated in the Canton of Geneva, averaged over 100 m x 100 m. Following improvements will be implemented in the next submission:

(1) So far, the understory vegetation was not considered in the estimation of the C stocks for CC 52, CC 53 and CC 54. Accounting for understory vegetation will increase the estimated C stock of those categories.

(2) An error has occurred in the analysis of the spatial data. As a consequence, the estimation of the C stocks of CC 52, CC 53, and CC 54 is to low, leading to an underestimation of the C stock within those categories.

(3) The interpretation point from the AREA data was situated in the centre of the averaged window. However, this point does not necessarily represent the surrounding landscape, especially in a small-scaled landscape as it is the case in Switzerland. Therefore, planned improvements will try to analyse smaller windows or to generally improve the technique by applying appropriate process models.

(4) To convert tree crown coverage to carbon pool, the factor given by IPCC for settlements was applied. The accuracy of this factor is assumed to be low as it is only a Tier 1 standard. More reliable estimates of this factor could significantly increase the accuracy of the estimation method.

The first two points lead to an underestimation of C stocks in CC 52, CC 53, and CC 54. In case of land-use changes, this underestimation influences the general C budget. In the land-use change matrix, those categories show an increasing tendency. This indicates that the inaccuracies of the present submission lead to a slight underestimation of the general sink effect in those categories.

However, it could be shown that the applied method results in plausible estimations of the C stock and the known deficiencies will be corrected for the next submission.

Changes in the carbon stock of CC 54 will also change the carbon stock in CC 42 (see Table 143). However, as the area of CC 42 covered by linear tree groups on wetland (associated with CC 54) is only 2% of the whole category CC 42, this effect can be regarded as quantitatively insignificant.

7.8. Source Category 5F – Other Land

7.8.1. Source Category Description

As shown Table 106 other land (CC 61) covers non-vegetated areas such as glaciers, rocks and shores.

7.8.2. Methodological Issues

By definition, other land has no carbon stocks. In the case of land-use change, the net C changes in biomass and soil are calculated as described in chapter 7.2.1.

7.8.3. Uncertainties and Time-Series Consistency

In the case of other land, the uncertainty of activity data and carbon stock data is assessed as low.

7.8.4. Source-Specific QA/QC and Verification

No source-specific QA/QC activities have been carried out.

7.8.5. Source-Specific Recalculations

All carbon stocks were re-calculated according to the new combination categories (CC). See Chapter 9.1.

7.8.6. Source-Specific Planned Improvements

There are no planned improvements.

8. Waste

8.1. Overview GHG Emissions

Within the waste sector emissions from four source categories are considered:

- 6A "Solid Waste Disposal on Land",
- 6B "Wastewater Handling",
- 6C "Waste Incineration",
- 6D "Others".

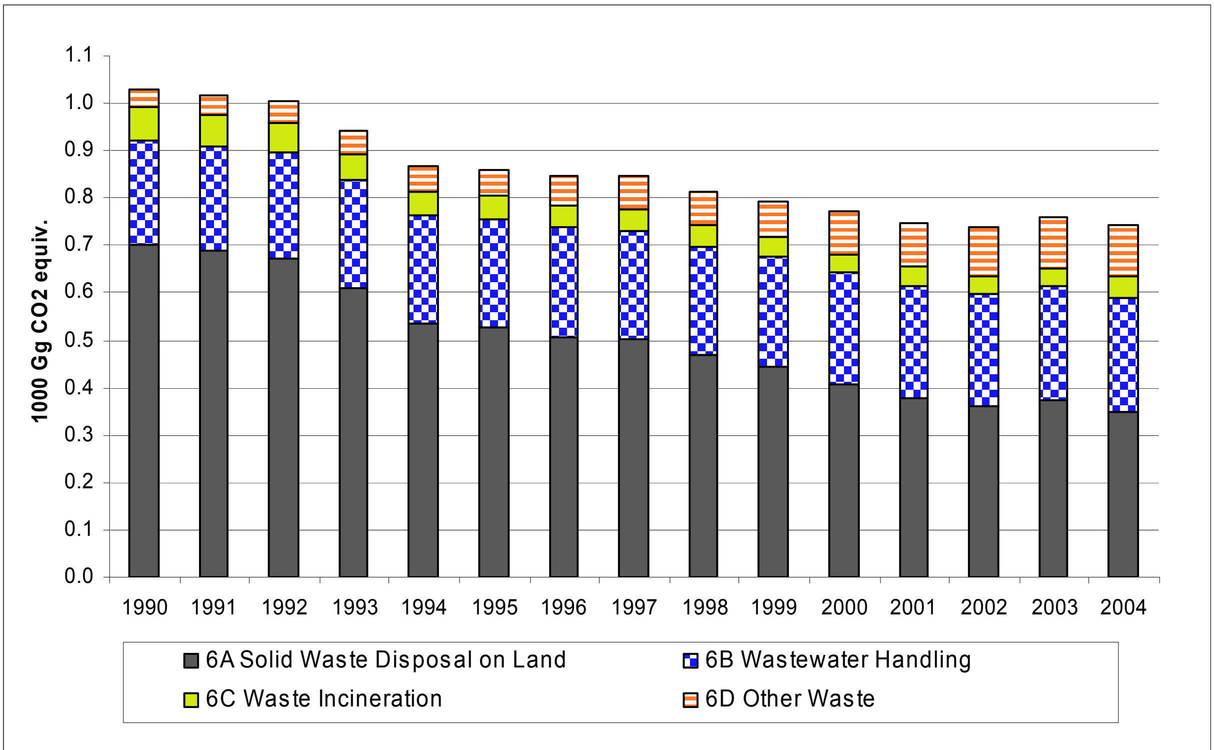

Figure 39 Switzerland's greenhouse gas emissions in the waste sector 1990–2004.

Table 145 Trend of total GHG emissions from waste management in Switzerland 1990-2004.

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	CO_2 equivalent (Gg)														
CO_2	62	59	60	54	42	37	34	31	29	25	22	19	16	16	15
CH_4	756	745	728	672	608	603	590	588	557	537	516	491	481	497	477
N_2O	212	214	216	217	218	221	224	226	228	229	234	237	242	247	252
Sum	1'030	1'018	1'004	943	867	861	848	845	814	791	772	747	740	760	744

In source category 6 "Waste" a total of 744 Gg CO_2 equivalents were emitted in the year 2004. 46.9% of the emissions stem from the sub-category 6A "Solid Waste Disposal on Land", 32.5% from 6B "Wastewater Treatment", 14.8% from 6D "Others" and 5.8% from 6C "Waste Incineration".

The total greenhouse gas emissions in source category 6 "Waste" show a decrease from 1990 until 2004. They are dominated by the greenhouse gas emissions from source category 6A "Solid Waste Disposal on Land". In this source category the CH_4 emissions decreased from 1990 until 2004. N_2O and CO_2 are of minor importance in the waste sector. The relative trends of the gases can be seen in Figure 40.

Please note that with the present submission, all emissions related to municipal solid waste incineration are reported under 1A1 Energy industries. Therefore the largest share of waste-related emissions in Switzerland is not reported under category 6 Waste, as the box below shows.

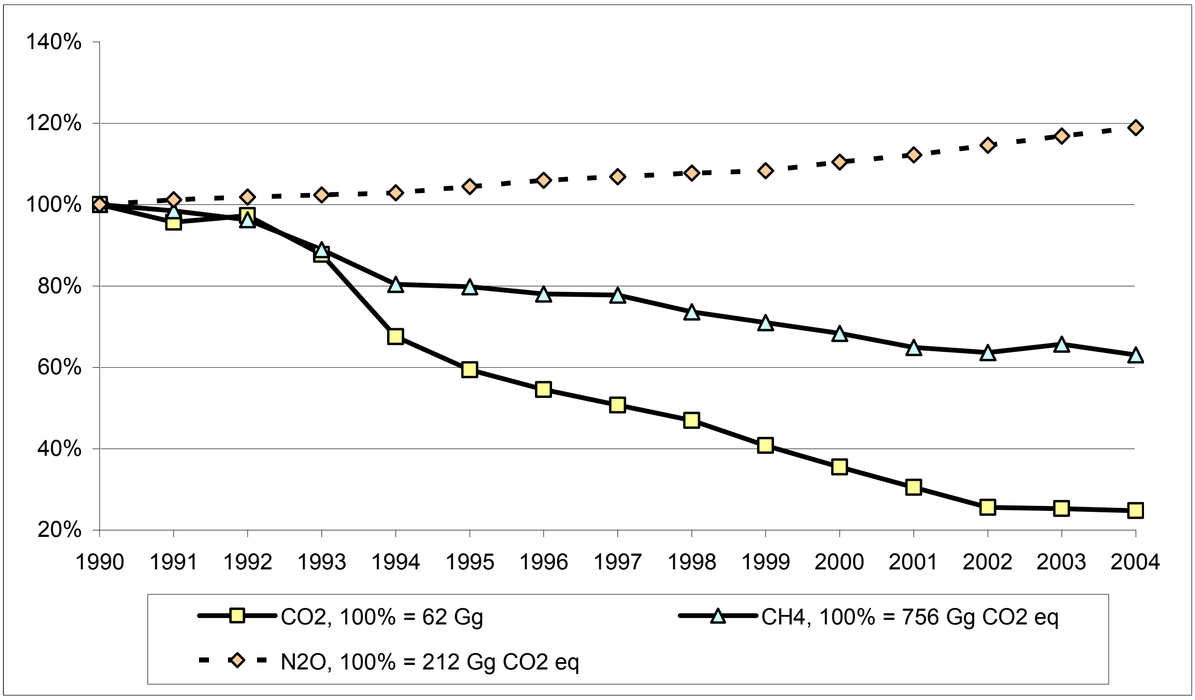

Figure 40 Trend of total GHG emissions from waste management in Switzerland 1990-2004.

Box: Waste related GHG emissions in Switzerland

There are very different activities for the proper waste disposal in Switzerland. The respective GHG emissions are reported in different chapters within the National Inventory. The following Figure provides an overview on all waste related GHG emissions in Switzerland, not only the one reported in the present Chapter 8.

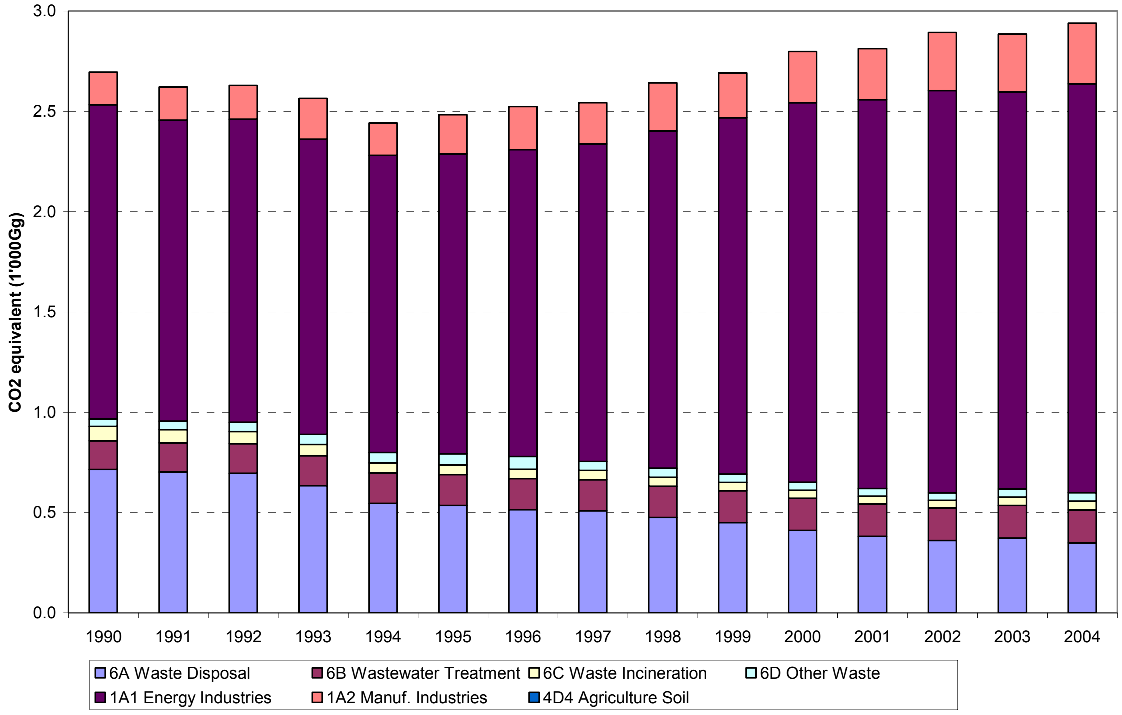

Figure 41 Waste related GHG emissions from 1990-2004.

8.2. Source Category 6A – Solid Waste Disposal on Land (Key Source)

8.2.1. Source Category Description

Key sources 6A
The CH_4 emissions from Solid Waste Disposal on Land (6A) are a key source regarding level and trend.

The source category 6A1 “Managed Waste Disposal on Land” comprises all emissions from handling of solid waste on managed landfill sites.

Emissions from the source category 6A2 “Unmanaged Waste Disposal Sites” are included in source category 6A1 “Managed Waste Disposal on Land”. This is motivated by the fact that in Switzerland officially no unmanaged waste disposal sites exist. The effective quantity of waste not properly treated in landfills is estimated to be very small. However, no reliable data is available.

As of the year 2004, 11 managed “reactive” landfills have been equipped to recover landfill gas (SFOE 2004). The landfill gas is generally used in co-generation plants in order to produce electricity and heat. Some landfill gas is used to generate heat only. A very small portion of the landfill gas is flared.

Table 146 Specification of source category 6A “Solid Waste Disposal on Land”.

6A	Source	Specification	Data Source
6A1	Managed Waste Disposal on Land	Emissions from handling of solid waste on managed landfill sites.	EMIS
6A2	Unmanaged Waste Disposal Sites	Emissions from all other waste disposal sites that don’t fall into 6A1. (included in 6A1)	EMIS
6A3	Others	Not occurring in Switzerland	

8.2.2. Methodological Issues

a) Managed Waste Disposal on Land (6A1)

Methodology

The emissions are calculated in four steps:

i) The rate of CH_4 generation over time is based on the First Order Decay model (FOD) according to IPCC (IPCC 1997a-c). The following equation is applied to calculate the CH_4 generation in the year t:

$$CH_4 \text{ generated in the year t [Gg/year]} = \sum_x [A \cdot k \cdot M(x) \cdot L_0(x) \cdot e^{-k(t-x)}] \cdot (1-OX)$$

where

t = current year
x = the year of waste input, $x \leq t$
A = (1-k)/k, norm factor (fraction)
k = methane generation rate [1/yr]
M(x) = the amount of waste disposed in year x
$L_0(x)$ = methane generation potential ($MCF(x) \cdot DOC(x) \cdot DOC_F \cdot F \cdot 16/12$) [Gg CH_4 / Gg waste]
MCF(x) = methane correction factor (fraction)
DOC(x) = degradable organic carbon [Gg C/ Gg waste]
DOC_F = portion of DOC, that is converted to landfill gas (fraction)
F = portion of CH_4 in landfill gas (fraction)
16/12 = factor to convert C to CH_4.
OX = oxidation factor (fraction)

The following general assumptions are made:

MCF(x) = constant = 1 (default value according to IPCC for managed solid waste disposal sites)

OX = 0.1 (default value according to IPCC 1997a-c)

DOC_F = 0.6 (default value according to IPCC 1997a-c)

F = 0.5 (default value according to IPCC 1997a-c)

The degradable organic carbon is also calculated based on the default values from IPCC 1997a-c.

For the calculation of CH_4 generation three different categories of waste are distinguished. The three categories are i) municipal solid waste, ii) construction waste, and iii) sewage sludge.

The following parameters are applied for the calculation of CH_4 generated.

Table 147 Parameters used for FOD model

	k [1/yr]	L_0 [Gg CH_4 / Gg waste]	DOC [-]
municipal solid waste	0.139	0.050	0.12
construction waste	0.046	0.08	0.20
sewage sludge	0.069	0.068	0.17

ii) In a second step, the amount of CH_4 that is recovered and used as fuel for co-generation units as well as for flaring is subtracted from the CH_4 generated in landfills (resulting from step1).

CH_4 emissions step ii) = CH_4 emissions step i) – (CH_4 emissions step i) * Fl(t)) – Qco-gen(t)

Fl(t) = portion of generated methane that is flared in the present year (fraction)
Qco-gen(t) = CH_4 which is recovered in co-generation units in the present (Gg)

iii) In the third step CH_4 emissions from on-site open burning are added. This results in the overall CH_4 emissions from landfill sites.

CH_4 emissions step iii) = CH_4 emissions step ii) + Qopen(t)

Qopen(t) = CH_4 which is emitted from open burning in the present year (Gg)

iv) In the fourth and last step the emissions of the other gases are calculated. The respective emissions are considered as proportional to the CH_4 burnt (co-generation and flaring), or to the waste quantity burnt (open burning), respectively.

Emission Factors

Emission factors for CO_2, CH_4, CO, NMVOC and SO_2 are country specific based on measurements and expert estimates, documented in EMIS and in the draft technical commentary[21] to the new EMIS. CO_2 emissions from non-biogenic wastes are included, while the CO_2 emissions from biogenic wastes are excluded from total emissions.

The following table presents the emission factors used in 6A1:

[21] As cited in the *Draft* Technical Commentary "09 04 00 Kehrichtdeponien" of the new EMIS data base of 21 February 2005.

Table 148 Emission Factors for 6A1 “Managed Waste Disposal Sites on Land” in 2004.

Source	CO_2 biogenic	CO_2 fossil	CH_4	NO_x	CO	NMVOC	SO_2
6A1 Managed Waste Disposal on Land	**t / t CH_4 produced**						
Direct emissions from landfill	3.00	0	1				
	kg / t CH_4 burned						
Co-generation	2’750	0		6	10		0
Flaring	2’750	0		1	17		0
	kg / t waste burned						
Open burning	510	760	6	2.5	50	16	0.8

Activity data

One set of activity data for Managed Waste Disposal on Land (6A1) are the waste quantities disposed on landfills and the municipal solid waste burned on-site.

Activity data for Managed Waste Disposal on Land (6A1) are extracted from in the draft technical commentary[22] to the new EMIS.

Table 149 Activity data in 6A1: Waste disposed of on Managed Landfill Sites from 1990 to 2004.

Source/Parameter	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
6A1 Managed Waste Disposal on Land																
Municipal solid waste (MSW)	Gg	637	637	637	637	581	532	483	473	463	465	287	184	81	54	27
Construction waste	Gg	147	171	169	122	77	59	41	47	53	53	53	29	5	5	5
Sewage sludge	Gg (dry)	59	59	58	35	41	30	19	16	13	9	4.8	4.6	4.5	3.96	4
Open burned waste	Gg	17	20	30	27	11.4	10	8.7	8.6	8.6	5.7	3.9	2.4	0.95	0.67	0.2
Total waste quantity	**Gg**	**860**	**887**	**894**	**821**	**710.4**	**631**	**551.7**	**544.6**	**537.6**	**532.7**	**348.7**	**220**	**91.45**	**63.63**	**36.2**

Table 149 documents the reduction by about 24 times of municipal solid waste, construction waste and sewage sludge disposed of over the period 1990–2004. This is due to changes in the legislative framework, making incineration the mandatory disposal option for municipal solid waste and banning its disposal on landfills from 1 January 2000.

The other set of activity data for Managed Waste Disposal on Land (6A1) are CH_4 recovered as fuel for co-generation units and the fraction of CH_4 recovered. The landfill gas recovered in co-generation units as well as the landfill gas flared is metered.

Table 150 Activity data in 6A1: Share of CH_4 used as fuel in co-generation units and flared from 1990 to 2004.

Source/Parameter	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
6A1 Managed Waste Disposal on Land																
CH4 as fuel for co-generatio units	Gg	4.9	5.7	7.6	10.4	12.6	12.1	12.1	11.5	11.3	11.4	11.3	9.9	8.1	5.7	4.1
CH4 flared	%	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

The CH_4 generated in landfills decreases since 1990, due to the fact that waste quantities disposed of in landfills are decreasing. Together with the relative increase of CH_4 recovery from 1990 until 2004 this is the reason for CH_4 emissions from the source category 6A being a key source regarding trend.

[22] As cited in the *Draft* Technical Commentary "09 04 00 Kehrichtdeponien" of the new EMIS data base of 21 February 2005.

8.2.3. Uncertainties and Time-Series Consistency

Uncertainty in CH_4 emissions from Solid Waste disposal on land in 6A

Uncertainty of direct CH_4 emissions from sanitary landfills is estimated at about 60%[23].

An uncertainty in the amount of waste disposed of on a landfill of 20% is assumed, because most of the emissions in the nineties result from waste deposed of in the eighties, when waste statistics were less elaborated. From this, an emission factor uncertainty of 56.6% is calculated (resulting in combined uncertainty of 60%).

Qualitative estimate of uncertainties of non-key source emissions in 6A

A preliminary uncertainty assessment based on expert judgment results in medium confidence in emissions estimates.

Consistency: The time series is consistent.

8.2.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the check between EMIS and Internal GHG Files (Section 1.4.3) and the general QA/QC measures described in Section 1.6.1 have been carried out.

8.2.5. Source-Specific Recalculations

A recalculation for 6A Solid Waste Disposal on Land was carried out. See Chapter 9.

8.2.6. Source-Specific Planned Improvements

It is planned to use country specific parameters for the CH_4-model.

8.3. Source Category 6B – Wastewater Handling

8.3.1. Source Category Description

Source category 6B “Wastewater Handling” is **not a key source**.

The source category 6B1 “Industrial Waste Water” comprises all emissions from the handling of liquid wastes and sludge from industrial processes such as food processing, textiles, or pulp and paper production. Emissions from this source category 6B1 are included in source category 6B2 “Domestic and Commercial Waste Water”. This is motivated by the fact that most of the industrial waste water is treated in the municipal waste water treatment plants considered under 6B2.

The source category 6B2 “Domestic and Commercial Waste Water” comprises all emissions from handling of liquid wastes and sludge from housing and commercial sources (including gray water and night soil).

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[23] Source: EMIS. The uncertainty value from EMIS has to be doubled for the NIR, because in EMIS uncertainty relates to *one* standard deviation, whereas in the NIR uncertainty relates to a 95% confidence interval (i.e. *two* standard deviations).

Table 151 Specification of source category 6B “Wastewater Handling”.

6B	Source	Specification	Data Source
6B1	Industrial Waste Water	Emissions from handling of liquid wastes and sludge from industrial processes. (included in 6B2)	
6B2	Domestic and Commercial Waste Water	Emissions from handling of liquid wastes and sludge from housing and commercial sources	AD: EMIS EF: EMIS
6B3	Others	Not occurring in Switzerland	

The emissions related to wastewater treatment fall under various categories as laid out in Figure 42 below. The system boundaries of category 6B contain all emissions from direct wastewater handling, some emissions from sewage sludge drying and no emissions from sewage sludge use or disposal.

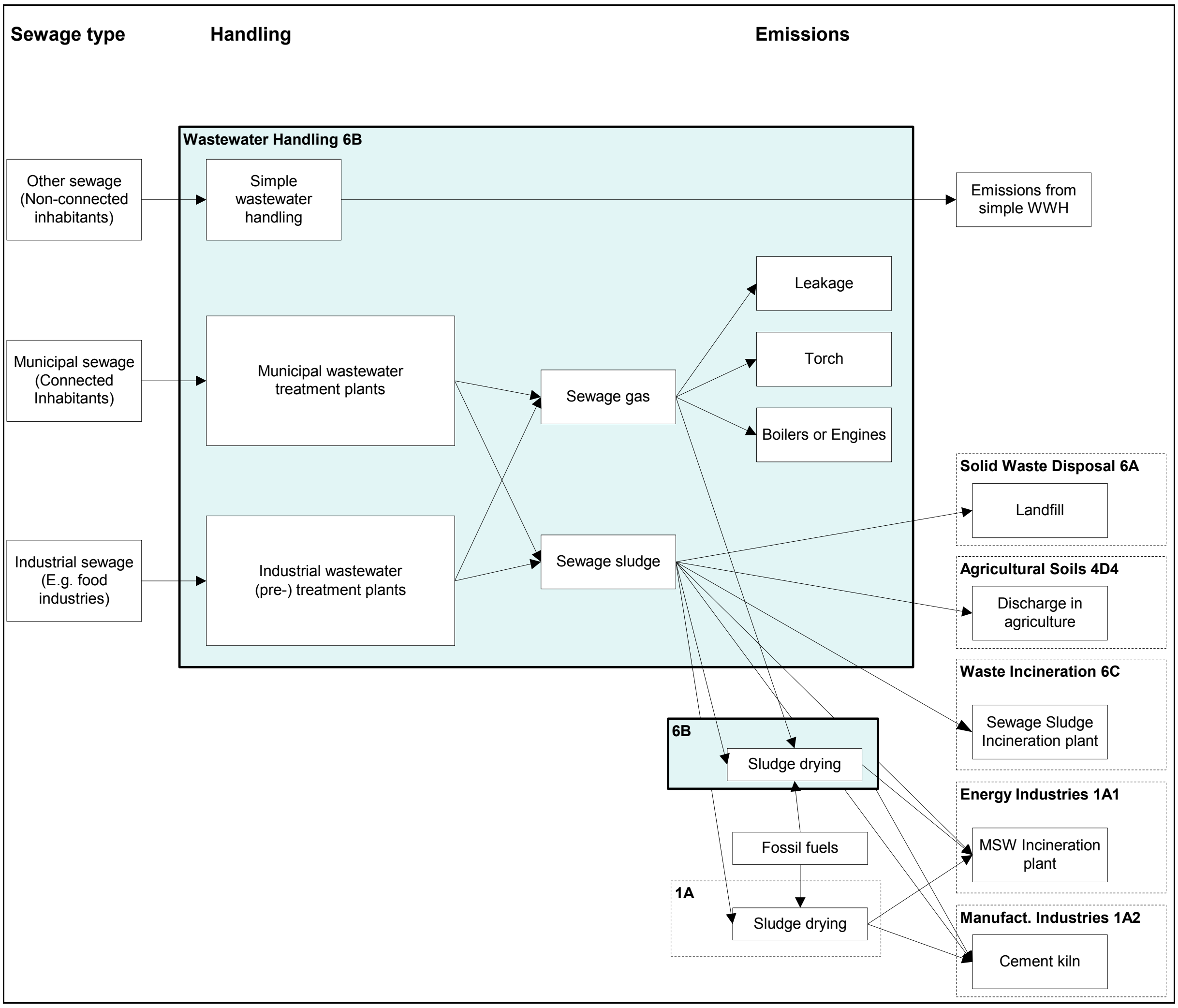

Figure 42 System boundaries of emissions related to wastewater treatment.

Methodological Issues

a) Domestic and Commercial Waste Water (6B2)

Methodology

For domestic and commercial waste water treatment (6B2), a country specific method based on CORINAIR is used. The GHG emissions are calculated by multiplying the number of inhabitants connected to waste water treatment plants by emission factors. The unit of emission factors refers to the number of inhabitants connected, and not to the population equivalent.

Emission Factors

Emission factors for CO_2, CH_4, N_2O, CO, NMVOC and SO_2 are country specific based on measurements and expert estimates, documented in the EMIS database. N_2O is derived from the IPCC-default method.

The following table presents the emission factors used in 6B2:

Table 152 Emission Factors for 6B2 Domestic and Commercial Waste Water in 2004.

Source	CO_2 biog.	N_2O	CH_4	NO_x	CO	NMVOC	SO_2
	kg/connected inhabitant	g/inhabitant	g/connected inhabitant				
6B2 Domestic and Commercial Waste Water	41.5	90.5	220	37	57	1	180

Please note that the activity data for N_2O emissions is the total number of inhabitants, in line with IPCC, whereas the emissions of other gases are calculated based on the fraction of inhabitants that are connected to wastewater treatment plants.

Activity data

Activity data for Domestic and Commercial Waste Water (6B2) are extracted from EMIS.

Table 153 Activity data in 6B2 Domestic and Commercial Waste Water: Population and fraction connected to waste water treatment plants.

Source/Parameter	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
6B2 Domestic and Commercial Waste Water																
Population	inhabitants in 1000	6'796	6'880	6'943	6'989	7'037	7'081	7'105	7'113	7'132	7'167	7'209	7'285	7'343	7'405	7'454
Fraction connected to waste water treatment plants	%	91.1%	91.5%	92.0%	92.4%	92.8%	93.2%	93.7%	94.1%	94.5%	95.0%	95.4%	95.4%	95.4%	95.4%	95.4%
Sonnectd inhabitants	inhabitants in 1000	6'191	6'295	6'388	6'458	6'530	6'599	6'658	6'694	6'740	6'809	6'877	6'950	7'005	7'064	7'111

8.3.2. Uncertainties and Time-Series Consistency

A preliminary uncertainty assessment based on expert judgment results in medium confidence in emissions estimates.

The time series is consistent.

8.3.3. Source-Specific QA/QC and Verification

No source-specific activities beyond the check between EMIS and Internal GHG Files (Section 1.4.3) and the general QA/QC measures described in Section 1.6.1 have been carried out.

8.3.4. Source-Specific Recalculations

A recalculation for 6B Waste-water Handling was carried out. See Chapter 9.

8.3.5. Source-Specific Planned Improvements

No plans for source-specific improvements have been made so far.

8.4. Source Category 6C – Waste Incineration

8.4.1. Source Category Description

Source category 6C "Waste Incineration" is **not a key source**.

There is a long tradition in Switzerland for waste to be incinerated. The waste heat generated during the incineration has to be recovered if technically and economically feasible. In accordance with the IPCC provisions (IPCC 1997c) emissions from the combustion of waste-to-energy activities are dealt with in 1A "Fuel Combustion Activities".

The following sources are included in source category 6C:

Table 154 Overview on waste incineration sources reported under 6C.

Waste incineration	Specification	Data Source
Hospital waste incineration	Emissions from incinerating hospital waste in hospital incinerators	AD, EF: EMIS
Illegal waste incineration	Emissions from illegal incineration of gardening and household wastes Emissions from waste incineration at construction sites (open burning)	AD, EF: EMIS
Insulation material from cables	Emissions from incinerating cable insulation materials	AD, EF: EMIS
Sewage sludge	Emissions from sewage sludge incineration plants	AD, EF: EMIS
Crematoria	Emissions from the burning of dead bodies	AD, EF: EMIS
Sewage sludge	Emissions from sewage sludge incineration plants	AD, EF: EMIS

The following table gives an overview on other waste incineration sources in Switzerland and the respective source category, where the GHG emissions are reported in the national inventory.

Table 155 Overview of other waste incineration activities in Switzerland, and indication of source categories where the waste incineration activity is reported in the national inventory.

Waste incineration	Specification	Source category
Paper and pulp industries	Emissions from incineration of residues and sludge from industrial waste water treatment plants as fuel for paper/pulp production	1A2 d Biomass
Municipal solid waste incineration plants	Emissions from waste incineration in municipal solid waste incineration plants	1A1 a Other
Waste in cement plants	Emissions from waste incineration as alternative fuels in cement kilns	1A2 f Other
Special waste	Emissions from incinerating industrial and hazardous wastes	1A1 a Other

8.4.2. Methodological Issues

Methodology

For the calculation of the greenhouse gas emissions a country specific Tier 2 method is used, based on CORINAIR. In general, the GHG emissions are calculated by multiplying the waste quantity incinerated by emission factors. For crematoria, the GHG emissions are calculated by multiplying the number of cremations by emission factors.

For sewage sludge incineration plants the respective waste quantities are based on reliable statistical data and the emission factors are taking into account different flue gas cleaning standards.

For hospital waste incineration, illegal waste incineration and incineration of insulation material, the waste quantities used are based on rough expert estimates.

Emission Factors

Emission factors for CO_2, CH_4, N_2O, CO, NMVOC and SO_2 are country specific based on measurements and expert estimates, documented in the EMIS database.

The following table presents the emission factors used in 6C:

Table 156 Emission Factors for 6C "Waste Incineration" in 2004.

6C Waste Incineration							
Source	CO_2 t/t	CH_4 kg/t	N_2O g/t	NO_x kg/t	CO kg/t	NMVOC kg/t	SO_2 kg/t
Hospital waste incineration	0.9	0	60	1.5	1.4	0.3	1.3
Illegal waste incineration	0.508	6	0	2.5	50	16	0.75
Insulation material cables	1.3	0	0	1.3	2.5	0.5	6
Sewage sludge plants	0	0.09	800	0.7	0.18	0.0047	0.43
	CO_2 t/crem.	CH_4 kg/crem.	N_2O g/crem.	NO_x kg/crem.	CO kg/crem.	NMVOC kg/crem.	SO_2 kg/crem.
Crematoria	0	0	0	0.270	0.310	0.024	0

Additional information on the emission factor CO_2:

For all waste incineration options the CO_2 emissions only from non-biodegradable waste is taken into account.

- Hospital waste incineration plants: Mainly waste of fossil origin. Default value for the CO_2 emission factor taken from CORINAIR (1992).
- Illegal waste incineration: The main source of non-biodegradable CO_2 emissions is plastic. The assumption was taken, that the waste mix will be the same as the one for municipal solid waste incineration, i.e. 40% of the waste mix is of fossil origin.
- Insulation materials: The CO_2 emission factor is based on measurements of the flue gas quantity and the assumption, that the ratio CO_2/O_2 is the same as in municipal solid waste incineration plants.
- Sewage sludge plants: Sewage sludge is biodegradable waste. Emission factor for CO_2 is 0. The assumption is taken, that the share of fossil fuel used during the start-ups is very small.

Activity Data

The activity data for Waste Incineration (6C) are the quantities of waste incinerated.

Table 157 Activity data for the different emission sources within source category 6C “Waste Incineration”.

Source/Parameter	**Unit**	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Hospital Waste Incineration	Gg	30	27.5	25	22.5	20	17.5	15	12.5	10	7.5	5	2.5	0	0	0
Illegal waste	Gg	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Insulation material cables	Gg	7.5	6	4.5	3	1.5	0	0	0	0	0	0	0	0	0	0
Sewage sludge	Gg dry	57	53.85	50.7	47.55	44.4	50.2	56	59.6	63.2	63.75	64.3	70.15	76	86	96
Total	**Gg**	**124.5**	**117.4**	**110.2**	**103.1**	**95.9**	**97.7**	**101**	**102.1**	**103.2**	**101.3**	**99.3**	**102.7**	**106**	**116**	**126**
Cremations	Numb.	37'513	37'407	37'939	38'884	39'620	40'986	40'998	42'460	42'536	43'480	43'604	45'681	46'419	48'080	48'100

Note: Since 2002, all special hospital waste incinerator plants have been closed and all hospital waste is incinerated in municipal solid waste incineration plants (accounted for in 1A1).

8.4.3. Uncertainties and Time-Series Consistency

Qualitative estimate of uncertainties of (non-key source) emissions in 6C

A preliminary uncertainty assessment based on expert judgment results in medium confidence in emissions estimates.

The time series is consistent.

8.4.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the check between EMIS and Internal GHG Files (Section 1.4.3) and the general QA/QC measures described in Section 1.6.1 have been carried out.

8.4.5. Source-Specific Recalculations

With the submission 2006 all emissions from the incineration of municipal solid waste and of special waste is reported under 1A1. Therefore, a recalculation of 6C Waste Incineration was carried out. See Chapter 9.

8.4.6. Source-Specific Planned Improvements

There are no planned improvements.

8.5. Source Category 6D – Other

8.5.1. Source Category Description

Key sources 6D The CH_4 emissions from Others (6D) are a key source regarding trend.

The source category 6D "Other" comprises the GHG emissions from car shredding plants, from composting and from digesting organic waste.

Within the composting activity four types of composting means are distinguished, i.e. i) hall composting, ii) field edge composting, iii) box composting and iv) windrow composting. Composting covers the GHG emissions from centralized composting plants with a capacity of more than 100 tons organic matter/year. Backyard composting is also common practice in Switzerland. However, there are only estimates concerning these respective quantities.

The digestion of organic waste takes places under anaerobic conditions. The digestate (solids left-overs after completion of a process of anaerobic microbial degradation of organic matter) is composted. The biogas generated during the fermentation is used as fuel in co-generation plants or upgraded and used as fuel for cars.

Table 158 Specification of source category 6D "Other".

6D		Specification	Data Source
	Car shredding plants	Emissions from car shredding plants	AD, EF: EMIS
	Composting and digesting	Emissions from composting and digesting organic waste	AD, EF: EMIS

8.5.2. Methodological Issues

Methodology

For the emissions from car shredding a country specific method is used, based on CORINAIR. The GHG emissions are calculated by multiplying the quantity of scrap by the emission factors. For all years the same constant emission factors have been applied.

For the emissions from composting a country specific method is used. The GHG emissions are calculated by multiplying the quantity of wastes by the emission factors. For all years the same constant emission factors have been applied.

For the emissions from digesting a country specific method is used. Digestion plants lead to GHG emissions from (i) the use of biogas in engines and (ii) the composting of the residues of the fermentation process. The GHG emissions are calculated by (i) multiplying the amount of CH_4 (biogas) times the emission factor and (ii) by multiplying the quantity of fermented wastes by the emission factors. For all years the same constant emission factors have been applied.

Because of the increase in composting and digesting organic waste the source category 6D "Others" is a key source regarding trend.

Emission Factors

Emission factors for car shredding, composting and digestion are country specific based on measurements and expert estimates, documented in the EMIS database. Data used included Edelmann and Schleiss 1999, and AQMD 2002.

The following table presents the emission factors used in 6D:

Table 159 Emission Factors for 6D Others in 2004.

Source	CH_4	N_20	NO_X	CO	NMVOC	SO_2
Shredder [g/t scrap]				5	100	
Composting [g/t composted waste]	5'000	70			1'700	
Fermentation [g/t fermented waste]	5'300	70			1'700	
Fermentation engine [g/t CH_4]			6'000	10'000		

Activity data

Activity data for Other (6D) are extracted from EMIS.

Activity data for composting and digesting are generally based on reliable statistical data. The quantities for backyard composting are estimated values, i.e. 10% of the amount of waste from composting plants.

Table 160 Activity data in 6D Other.

Source/Parameter	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Shredder	Gg	280	284	288	292	296	300	300	300	300	300	300	300	300	300	300
Compost	Gg	260	300	320	350	370	400	450	480	500	510	640	650	730	745	760
Fermentation	Gg	27.3	31.8	33.9	37.1	39.22	42.8	48.15	51.84	54	55.59	69.76	71.5	81.03	95.53	104
Fermentation (CH4 used in engine)	Gg	1.4	1.6	1.7	1.9	2	2.2	2.4	2.6	2.7	2.8	3.5	3.6	4.1	4.68	5.26

8.5.3. Uncertainties and Time-Series Consistency

A preliminary uncertainty assessment based on expert judgment results in medium confidence in emissions estimates.

The uncertainty of the CH_4 emissions in Category 6D from composting and digestion of organic waste is estimated to be 50% (expert estimate). The uncertainty of the related activity data is estimated to be 10% (expert estimate), because waste statistics are rather reliable.

The time series is consistent.

8.5.4. Source-Specific QA/QC and Verification

No source-specific activities beyond the check between EMIS and Internal GHG Files (Section 1.4.3) and the general QA/QC measures described in Section 1.6.1 have been carried out.

8.5.5. Source-Specific Recalculations

Emissions from composting and digesting of organic waste have been reported for the first time. Therefore a recalculation of 6D Other was carried out. See Chapter 9.

8.5.6. Source-Specific Planned Improvements

The activity data for backyard composting are based on rough estimates. For further submissions more reliable data will be sought.

9. Recalculations

9.1. Explanations and Justifications for Recalculation

An exceptional number of recalculations were carried out for the current submission. In the last few years, Switzerland undertook strong efforts to update and complete its GHG inventory. Not only the data but also the software tools were brought up to date. As explained in Chapter 1.4.3, the national database EMIS was fully redesigned, was extended to incorporate more data sources, updated and migrated to a new software platform. Based on new studies, all activity data and all emission factors were checked and updated at the same time.

All source categories affected – 1 Energy (without 1A3b/e), 2 Industrial Processes, 3 Solvent and other Product Use, 4 Agriculture, 5 Land Use, Land-Use Change and Forestry 6 Waste – have therefore been recalculated for the full time series 1990-2003. Note that the recalculation refers to the data of CRF re-submission on 25 May 2005 (SAEFL 2005f).

1 Energy

- General:
  - All previous submissions of Switzerland until 12 April 2006 contained the emissions "1 Energy, 1A Fuel Combustion Activities" of the Principality of Liechtenstein. For submission 31 May 2006 and for the present submission (November 2006), Liechtenstein's emissions have been subtracted. Liechtenstein's activity data (energy consumption) was used as follows: Gas oil, LPG and natural gas consumption were taken from the two available CRFs 1990/2004 and were subtracted from the corresponding figures of the Swiss overall energy statistics (which, due to the customs union, contains the sum of Swiss and Liechtenstein's consumption data). The Swiss emissions were then modelled using the reduced activity data. For the other years 1991–2003, no CRF tables for Liechtenstein are available yet. FOEN interpolated (linearly) Liechtenstein's consumption data between 1990 and 2004. (This procedure may be rough but it should be noted that Liechtenstein's consumption, 3700 TJ in 2004, is only 0.56% of the Swiss consumption. That means that deviations between interpolated and true consumption are not of great influence for the Swiss inventory.)
  - All source categories affected by the update of EMIS – 1A1 Energy Industries, 1A2 Manufacturing Ind. and Construction, 1A4 Other Sectors, 1A5 Others (off-road) – have therefore been recalculated for the full time series 1990-2003. Also, the 1A3 categories have been partly recalculated (see below).
  - In the present submission (and already for the submission 12 April 2006), the net calorific value of hard coal has been revised (for details see Annex A2.2.1). The net calorific value is used to convert the hard coal consumption data from the Swiss overall energy statistics from tons to energy units (TJ). Therefore, the time series 1990-2003 of solid fuel related emissions (in 1A2 and 1A4) have been recalculated.
- 1A1 Energy Industries:
  - All emissions from the combustion of waste-to-energy activities (municipal solid waste, construction and hazardous waste) have been removed from 6C and transferred to 1A1 in order to conform with IPCC guidelines. In the 2005 submission, this was implemented only partially. The transfer corresponds to a change in allocation of emissions but the total emissions remain unchanged. See also 6C Waste Incineration below.

- The emission factors for waste incineration ("Other fuels") have been revised. Also, other (non-CO_2) emission factors have been revised based on new studies (SAEFL 2005d).

- 1A2 Manufacturing Industries and Construction:
  - In the 2005 submission, estimated stock changes of heavy fuel oil and coal have been introduced to improve consistency of bottom-up and top-down energy consumption data. In the present 2006 submission, a different approach has been used; bottom-up modelled consumption data of heavy fuel oil and coal are used for the various processes in 1A2 (see Annex A2.4.1).
  - 1A2a-f: The disaggregation of activity data on the level of processes has been improved (Basics 2006, CEPE 2005).
  - 1A2d Pulp, Paper and Print: The energy produced by the incineration of black liquor and bark has been transferred from 6C Waste Incineration to 1A2d, in line with IPCC 1997. See also in 6C Waste Incineration below.
  - The non-CO_2 emission factors have been revised based on a new evaluation of the periodic control of stationary installations in the cantons of Berne and Zurich. The results of the evaluation led to a revision of the emission factors. They are published on the internet (SAEFL 2005e).

- 1A3 Transport and further Off-road transportation in 1A4c and 1A5:
  - 1A3a: The emissions of civil aviation have been completely revised using a detailed Tier 3a method. It replaces the former method based on Tier 2 combined with a Tier 1 top-down element for the splitting of domestic and international flights. Since this splitting is crucial (emissions from international flights are reported under memo items/international bunker emissions), the new method stands for an important improvement regarding the precision and the reliability of the Swiss GHG inventory.

Table 161 Civil aviation, comparison of activity data (fuel consumption). Due to the recalculation, the total domestic consumption is higher and the bunker consumption is correspondingly lower. The sum of domestic and bunker, which is identical to the fuel sold, remains the same.

Civil Aviation	**Submission**	**1990**	**2003**	**1990**	**2003**
		fuel consumtion (TJ)		current subm (prev.=100%)	
Total domestic	Submission Apr 2005 (previous; Tier 2)	1'270	1'366	100%	100%
1A3a	Submission Nov 06 (current; Tier 3a)	3'450	1'951	272%	143%
Total international	Submission Apr 2005 (previous; Tier 2)	44'071	50'355	100%	100%
Bunker	Submission Nov 06 (current; Tier 3a)	41'891	49'771	95%	99%
Sum of	Submission Apr 2005 (previous; Tier 2)	45'341	51'722	100%	100%
fuel sold	Submission Nov 06 (current; Tier 3a)	45'341	51'722	100%	100%

  - 1A3c-d, 1A4c, 1A5: The emissions of off-road vehicles and machinery (railways, navigation, agriculture, forestry, construction, hobby, industry vehicles, military) have been completely revised (SAEFL 2005a). In an in-depth study the activity data has been updated by surveys and in collaboration with professional associations (Electrowatt 2005). Emission factors were updated where new country-specific or published measurements were available (Mayer 2006).

- 1A4 Other Sectors
  - 1A4a and 1A4b: The non-CO_2 emission factors have been revised: For stationary sources new data is available from the compulsory periodic control of stationary installations (see 1A2 above). The results of the evaluation led to a revision of the emission factors. They are published on the internet (SAEFL 2005e). For mobile

sources, the update is based on the new off-road study (SAEFL 2005a, Electrowatt 2005, Mayer 2006).

- 1A4a: The calculated gas losses of the Swiss gas pipeline network are presently subtracted from the consumption of natural gas, which was not the case in the previous submissions. The consumption of natural gas is therefore decreased by ca. 0.3% in 2004 and 1% in 1990 respectively. For reasons of simplicity, the losses were subtracted from the category with the largest leakages (1A4b Residential). The whole time series has been recalculated.
- 1A4c grass drying: The activity data have been updated in EMIS. The update is based on new data gathered by the branch association "Verband schweizerischer Trocknungsbetriebe". The data is documented in EMIS.

- 1B Fugitive Emissions from Fuels
    - 1B2b Fugitive emissions from natural gas: In the submission 2005, the emission data have been supplied by the Swiss Gas and Water Industry Association. In the present submission, FOEN has adopted a more sophisticated model. Current activity data and emission factors were used to calculate the methane losses of the gas distribution network, and additional leakage sources are considered (e.g. gas metering equipment). The model is published in Xinmin (2004).
    - 1B2a.iv/v, 1B2b.ii: NMVOC losses of refining/storage (1B 2a.iv), distribution of oil products (1B2a.v) and of transmission(1B2b.ii) are transformed into CO2 emissions and are added. The whole time series are recalculated.
    - 1B2c Fugitive emissions from venting and flaring: The emission factors have been revised in EMIS.

2 Industrial Processes

- In the course of the implementation of the new EMIS database, numerous activity data and emission factors have been updated; more than 95% of the processes were affected. The source categories concerned were recalculated for the full time period 1990–2003.
- Synthetic gases: The organisation for the compilation of the data of the import statistics has been centralised (Carbotech 2006). This has led to improved consistency of the activity data. Together with the implementation of the 2004 data, the full time series has been recalculated.

3 Solvent and other Product Use

- In the submission 2005, no indirect CO_2 emissions from NMVOC had been calculated in the sectors 3A-3D. For the current submission this has been carried out by applying the methodology used by the Netherlands (RIVM 2005). The full time period has been recalculated correspondingly.
- IPCC categories 3A-3D include now CO_2 emissions from post combustion of NMVOC, which was not the case for the previous submissions. Therefore, a recalculation was carried out for the whole time series.

4 Agriculture

- In former submissions subcategories for dairy and non-dairy cattle were not differentiated in the calculations of CH_4 emission from enteric fermentation and manure management. According to the improvement plan it was recommended to consider further subcategories. This was done in this submission. The full time period has been recalculated correspondingly.

- Additionally the revision of the animal categories was taken as an opportunity to adjust the methodology for CH4 calculation from enteric fermentation and manure management and to bring the national approaches closer to the IPCC equations. The country specific calculation of the gross energy intake for cattle is now based on feeding recommendations, which are reliable and highly appropriate under Swiss circumstances. The calculation of emissions from manure management is now fully compatible with IPCC. Due to these changes a recalculation was carried out for the whole time series.

5 LULUCF

The LULUCF sector has been recalculated for the time series 1990-2003 following the requirements of decision 13/CP.9. In 2005, Switzerland reported LUCF data that had been produced using the approach of the Revised 1996 IPCC Guidelines (SAEFL 2005f). In FOEN (2006a, b; Annex 4) a method compliant to decision 13/CP.9 was applied only for the base year 1990. For the calculation of the LULUCF time series as presented in this submission, the latter methodological approach has been revised with respect to

- The collection of the land-use change data: The land-use change matrix is now based on the recently launched third survey of the Swiss Land Use Statistics (AREA 2004/09). Thus, a further temporal extrapolation of the former Land Use Statistics (ASCH1 1979/85 and ASCH2 1992/97) was avoided and a considerably improved correspondence between GPG LULUCF categories and the combined categories (CC) deduced from AREA could be achieved. The interpretation of the AREA (2004/2009) survey will last until 2013. Current activity data rely on the part of the Swiss territory evaluated by June 2006 (~11%).
- The consideration of climate variability on forest growth (CC12): Because of the influence of annual climate variability on growth, climate factors were introduced to account for that impact.
- The consideration of soil carbon of organic soil horizons on mineral forest soils (CC12, CC13): Newly available data were incorporated into the calculations.
- The estimation and inclusion of the average carbon stock and increment for afforestations (CC11): In previous reporting, growing stock and increment on afforested areas were assumed to be zero.

Table 162 Recalculations A) Total LUCF net CO_2 emissions for 1990-2003, old method (SAEFL 2005f), B) total LULUCF net CO_2 emissions for 1990, new method (FOEN 2006a, b; Annex 4), C) total LULUCF CO_2 net emissions for 1990-2003 new revised method (current this submission).

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
		CO_2 (Gg)													
A	5 Total Land-Use Change and Forestry	-1'273	-1'339	-1'424	-2'388	-2'392	-2'355	-2'507	-2'674	-2'602	-2'256	149	450	305	-1'766
B	5 Total Land Use, Land-Use Change and Forestry	-1'784													
C	5 Total Land Use, Land-Use Change and Forestry	-1'711	1'161	645	-3'724	-3'865	-3'212	-2'431	-2'762	-1'128	-4'982	1'254	-664	-526	1'857

6 Waste

Emissions of 6 Waste were recalculated for the full time period 1990–2003.

- 6A1 Managed Waste Disposal on Land: The activity data has been updated in line with waste statistics (SAEFL 2002). The emission factor for the transformation of methane into CO_2 has been modified slightly. The emission factors for open burning has been revised.
- 6B2 Domestic and Commercial Wastewater: Emission factors and activity data have been updated in EMIS (source data from wastewater treatment plant operators and technology providers for gas engines and flares).
- 6B Waste Water Handling: N_2O emissions from human sewage have newly been modelled according to IPCC method. The time series was recalculated.
- 6C Waste Incineration: All emissions from the combustion of waste-to-energy activities (municipal solid waste and special waste, incineration of black liquor and bark) have been removed from 6C and transferred to 1A1 Energy Industries or 1A2d Pulp, Paper and Print. See also 1A1 and 1A2d above.
- 6D Other: Emissions from composting and digestion of organic waste are reported for the first time in the present submission. Data sources used include Edelmann and Schleiss 1999, AQMD 2002.

9.2. Implications for Emission Levels 2003 and 1990

Table 163 Overview of implications of recalculations on 2003 data. Emissions are shown before the recalculation according to the previous submission in 2005 "Prev." (SAEFL 2005f) and after the recalculation according to the present submission "Latest". The differences "Differ." are defined as latest minus previous submission.

Recalculation	**CO_2**			**CH_4**			**N_2O**			**Sum (CO_2, CH_4 and N_2O)**		
Emissions for 2003	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.
Source and Sink Categories	CO_2 equivalent (Gg)									CO_2 equivalent (Gg)		
1 Energy	41'721	42'773	1'051	355	293	-56	291	374	120	42'368	43'440	1'072
2 Ind. Processes (without syn. gases)	1'815	1'907	93	9	7	-2	97	163	67	1'921	2'078	157
3 Solvent and Other Product Use	NO	197	197.1	0	0		124	52	-72	124	250	126
4 Agriculture	IE	IE		2'898	2'804	-94	2'475	2'479	4	5'372	5'282	-90
5 LULUCF	-1'766	1'857	3'624	NO	1	1	NO	11	11	-1'766	1'869	3'635
6 Waste	1'188	16	-1'172	407	497	90	92	247	155	1'686	760	-926
Sum (without synthetic gases)	42'957	46'750	3'793	3'669	3'602	-61	3'079	3'326	285	49'705	53'678	3'974

Recalculation	**HFC**			**PFC**			**SF6**			**Sum (synthetic gases)**		
Emissions for 2003	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.
Source and Sink Categories	CO_2 equivalent (Gg)									CO_2 equivalent (Gg)		
2 Ind. Processes (only syn. gases)	529	538	9	66	89	23	169	194	24	765	822	57

Recalculation		**Sum (all gases)**		
Emissions for 2003		Prev.	Latest	Differ.
Source and Sink Categories		CO_2 equivalent (Gg)		
Total CO_2 eq Em. with LULUCF		**50'469**	**54'500**	**4'031**
		100.00%	107.99%	7.99%
Total CO_2 eq Em. without LULUCF		**52'236**	**52'631**	**395**
		100.00%	100.76%	0.76%

The recalculations result in an increase of the total 2003 emissions in CO_2 equivalents (without CO_2 emissions from LUCF) of 395 Gg CO_2 eq. This corresponds to an increase of the latest submission compared to the previous submission of 0.76% of the national total. If LULUCF sector is included, the latest, recalculated emissions differ by 7.99% from the previous emissions. This large difference arises due to the new method for LULUCF modelling based on the requirements of decision 13/CP.9 on the one hand, and due to the first-time consideration of the influence of the annual climate variability on annual gross growth on the other hand. In 2003, this consideration heavily reduced the increase of living biomass, reducing the removals of the LULUCF sector from the observed range -13’000 to -15’000 Gg CO_2 eq to -9500 Gg CO_2 eq. The reason for the reduction is the exceptionally hot and dry period in summer 2003. See also Table 162.

Table 164 shows the recalculation results for the base year 1990. The recalculations result in a slight decrease of the total emissions in CO_2 equivalents (without CO_2 emissions from LULUCF) of 135 Gg CO_2 eq. This corresponds to a decrease of the latest submission compared to the previous submission of -0.26% of the national total. If the LULUCF sector is included, the recalculation leads to an increase of the total emissions of 303 Gg CO_2 eq or 0.58% of the national total.

Table 164 Overview of implications of recalculations on 1990 data. Emissions are shown before the recalculation according to the previous submission in 2005 ”Prev.” (SAEFL 2005f) and after the recalculation according to the present submission “Latest. The differences “Differ.” are defined as latest minus previous submission.

Recalculation	CO_2			CH_4			N_2O			Sum (CO_2, CH_4 and N_2O)		
Emissions for 1990	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.
Source and Sink Categories	CO_2 equivalent (Gg)									CO_2 equivalent (Gg)		
1 Energy	40'267	41'261	994	473	563	90	227	268	41	40'968	42'092	1'124
2 Ind. Processes (without syn. gases)	2'841	2'831	-10	9	9	0	99	174	75	2'949	3'014	65
3 Solvent and Other Product Use	NO	357	357	0	0	0	108	109	2	108	466	359
4 Agriculture	IE	IE	---	3'225	3'042	-183	2'857	2'861	4	6'082	5'903	-179
5 LULUCF	-1'273	-1'711	-437	NO	2	1.5	NO	5	5	-1'273	-1'704	-431
6 Waste	1'264	62	-1'202	743	756	13	54	212	157	2'061	1'030	-1'032
Sum (without synthetic gases)	43'099	42'801	-298	4'451	4'372	-80	3'344	3'628	284	50'894	50'801	-93

Recalculation	HFC			PFC			SF6			Sum (synthetic gases)		
Emissions for 1990	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.
Source and Sink Categories	CO_2 equivalent (Gg)									CO_2 equivalent (Gg)		
2 Ind. Processes (only syn. gases)	0	0	0	100	100	0	179	144	-35	279	244	-35

Recalculation	Sum (all gases)		
Emissions for 1990	Prev.	Latest	Differ.
Source and Sink Categories	CO_2 equivalent (Gg)		
Total CO_2 eq Em. with LULUCF	**51'173**	**51'045**	**-128**
	100.00%	99.75%	-0.25%
Total CO_2 eq Em. without LULUCF	**52'446**	**52'749**	**303**
	100.00%	100.58%	0.58%

9.3. Implications for Emissions Trends, including Time Series Consistency

Due to recalculations, the emission trend 1990–2003 reported in the 2005 submission is slightly changed. Compared to 1990, 2003 emissions showed a decrease of -0.40% before recalculation (previous submission). After recalculation, the decrease turns out to be smaller, -0.22% (latest submission).

All time series in the present submission are consistent.

Table 165 Change of the emission trend 1990–2003 due to recalculations

Recalculation	**1990**		**2003**		**change 1990/2003**	
submission	previous	latest	previous	latest	previous	latest
unit	CO_2 eq (Gg)				%	
Total excl. LULUCF	52'446	52'749	52'236	52'631	-0.40%	-0.22%

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Annexes

Annex 1: Key Category Analysis and Uncertainty Evaluation (Monte Carlo)

A1.1 Key Category Analysis

Methodology

The key category analysis is performed according to the IPCC Good Practice Guidance (IPCC 2000, chapter 7): A Tier 1 level and trend assessment is applied with the proposed threshold of 95%. All main source categories have been disaggregated into sources (e.g. 2A, 2B, 2C etc.) and gases (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6).

For some important sources, an even more detailed level of disaggregation has been used in order to clearly identify and isolate the most important sources.

In the important Source Category 1A Energy Fuel Combustion sources have been disaggregated further to the level of sub-categories (e.g. 1A1 Fuel Combustion – Energy Industries, 1A2 Fuel Combustion – Manufacturing Industries, etc.) as well as fuels (e.g. gaseous fuels, liquid fuels, etc.). The source Transport (1A3) has been further split into Civil Aviation (1A3a), Road Transportation (1A3b), and Other Transportation (military aviation; 1A3e) and the newly defined source "1A3_o" which is the rest (i.e. includes all sources of 1A3 without 1A3a, 1A3b and 1A3e).

A more detailed disaggregation has been carried out for Other Sectors (1A4) which has been split into Commercial/Institutional (1A4a), Residential (1A4b) and Agriculture/Forestry (1A4c). A similar partial disaggregation as with Transport has been carried out for CO_2 emissions from Cement Industry (2A1-CO2) which has been separated from the rest (2A1_o). Also CO_2 and PFC emissions from Aluminium Production (2C3-CO2, 2C3-PFC) has been separated from the rest (2C_o). In Consumption of Halocarbons and SF_6 (2F), HFC from Refrigeration and AC Equipment (2F1-HFC) and SF_6 from Electrical Equipment (2F8-SF6) is separated from the rest (2F_o). In Agricultural Soils (4D), N_2O from Direct respectively Indirect soil Emissions (4D1-N2O, 4D3-N2O) is separated from the rest (4D_o).

Results of Key Category Analysis – Level

Table 166 Key category analysis 2004 regarding level.

A				B	C	D	E-L	F-L	M
IPCC Source Categories (and fuels if applicable)				Direct GHG	Base Year 1990 Estimate	Year t Estimate	Level Assess.	Cumulative Total Col. E-L	Result level assess.
					[Gg CO2eq]	[Gg CO2eq]			
TOTAL				All	52'749.22	53'065.25	100.00%	0.00%	
1A3b	1. Energy	3. Transport; Road Transportation	Gasoline	CO2	11'332.18	11'363.39	21.41%	21.41%	KC level
1A4b	1. Energy	4. Other Sectors; Residential	Liquid Fuels	CO2	10'215.56	9'422.83	17.76%	39.17%	KC level
1A4a	1. Energy	4. Other Sectors; Commercial/Institutional	Liquid Fuels	CO2	4'375.36	3'999.73	7.54%	46.71%	KC level
1A3b	1. Energy	3. Transport; Road Transportation	Diesel	CO2	2'411.97	3'606.74	6.80%	53.51%	KC level
1A2	1. Energy	2. Manufacturing Industries and Construction	Liquid Fuels	CO2	3'392.42	2'911.27	5.49%	58.99%	KC level
4A	4. Agriculture			CH4	2'474.84	2'270.99	4.28%	63.27%	KC level
1A4b	1. Energy	4. Other Sectors; Residential	Gaseous Fuels	CO2	1'364.86	2'249.66	4.24%	67.51%	KC level
1A2	1. Energy	2. Manufacturing Industries and Construction	Gaseous Fuels	CO2	1'064.04	2'028.87	3.82%	71.33%	KC level
1A1	1. Energy	1. Energy Industries	Other Fuels	CO2	1'519.73	1'930.63	3.64%	74.97%	KC level
2A1	2. Industrial Proc.			CO2	2'524.77	1'714.25	3.23%	78.20%	KC level
1A4a	1. Energy	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	CO2	940.95	1'415.20	2.67%	80.87%	KC level
4D1	4. Agriculture			N2O	1'389.82	1'223.29	2.31%	83.17%	KC level
1A1	1. Energy	1. Energy Industries	Liquid Fuels	CO2	691.23	849.56	1.60%	84.78%	KC level
1A4c	1. Energy	4. Other Sectors; Agriculture/Forestry	Liquid Fuels	CO2	713.45	727.72	1.37%	86.15%	KC level
4D3	4. Agriculture			N2O	818.89	679.25	1.28%	87.43%	KC level
1A5	1. Energy	5. Other	Liquid Fuels	CO2	513.00	669.06	1.26%	88.69%	KC level
2F1	2. Industrial Proc.			HFC	0.02	543.72	1.02%	89.71%	KC level
1A2	1. Energy	2. Manufacturing Industries and Construction	Solid Fuels	CO2	1'391.18	541.43	1.02%	90.73%	KC level
4B	4. Agriculture			CH4	557.39	494.13	0.93%	91.66%	KC level
4B	4. Agriculture			N2O	448.20	396.83	0.75%	92.41%	KC level
1A1	1. Energy	1. Energy Industries	Gaseous Fuels	CO2	234.83	374.20	0.71%	93.12%	KC level
6A	6. Waste			CH4	693.04	348.63	0.66%	93.77%	KC level
1A2	1. Energy	2. Manufacturing Industries and Construction	Other Fuels	CO2	156.87	286.36	0.54%	94.31%	KC level
6B	6. Waste			N2O	190.67	209.12	0.39%	94.71%	KC level
3	3. Solvent and Other Product Use			CO2	357.01	185.98	0.35%	95.06%	KC level
4D_o	4. Agriculture			N2O	200.19	179.70	0.34%	95.40%	-
1B2	1. Energy	2. Oil and Natural Gas		CH4	380.47	177.93	0.34%	95.73%	-
2B	2. Industrial Proc.			N2O	173.76	171.06	0.32%	96.05%	-
2C_o	2. Industrial Proc.			CO2	112.45	155.95	0.29%	96.35%	-
1A3a	1. Energy	3. Transport; Civil Aviation		CO2	252.55	143.72	0.27%	96.62%	-
1A3d	1. Energy	3. Transport; Navigation		CO2	123.97	124.45	0.23%	96.85%	-
1A1	1. Energy	1. Energy Industries	Other Fuels	N2O	48.42	118.87	0.22%	97.08%	-
1A3b	1. Energy	3. Transport; Road Transportation	Gasoline	N2O	87.76	117.35	0.22%	97.30%	-
1A3e	1. Energy	3. Transport; Other Transportation (military aviation)		CO2	200.04	109.07	0.21%	97.50%	-
1B2	1. Energy	2. Oil and Natural Gas		CO2	139.33	106.67	0.20%	97.71%	-
1A1	1. Energy	1. Energy Industries	Solid Fuels	CO2	46.99	105.40	0.20%	97.90%	-
1A3c	1. Energy	3. Transport; Railways		CO2	83.29	94.78	0.18%	98.08%	-
6D	6. Waste			CH4	30.34	91.38	0.17%	98.25%	-
2F7	2. Industrial Proc.			SF6	64.04	86.28	0.16%	98.42%	-
2F_o	2. Industrial Proc.			HFC	0.00	73.66	0.14%	98.56%	-
2C3	2. Industrial Proc.			CO2	139.26	71.84	0.14%	98.69%	-
2F	2. Industrial Proc.			PFC	0.04	65.34	0.12%	98.81%	-
3	3. Solvent and Other Product Use			N2O	109.41	50.36	0.09%	98.91%	-
2C_o	2. Industrial Proc.			SF6	0.00	50.19	0.09%	99.00%	-
1A4b	1. Energy	4. Other Sectors; Residential	Biomass	CH4	52.32	45.89	0.09%	99.09%	-
2A_o	2. Industrial Proc.			CO2	40.16	44.70	0.08%	99.17%	-
2F_o	2. Industrial Proc.			SF6	79.58	38.60	0.07%	99.25%	-
1A4b	1. Energy	4. Other Sectors; Residential	Solid Fuels	CO2	57.20	35.18	0.07%	99.31%	-
6B	6. Waste			CH4	28.60	32.85	0.06%	99.38%	-
1A4c	1. Energy	4. Other Sectors; Agriculture/Forestry	Gaseous Fuels	CO2	40.29	25.36	0.05%	99.42%	-
1A4b	1. Energy	4. Other Sectors; Residential	Liquid Fuels	N2O	25.84	23.84	0.04%	99.47%	-
6C	6. Waste			N2O	14.69	23.81	0.04%	99.51%	-
1A3b	1. Energy	3. Transport; Road Transportation	Gasoline	CH4	91.29	22.95	0.04%	99.56%	-
1A3b	1. Energy	3. Transport; Road Transportation	Diesel	N2O	7.66	19.70	0.04%	99.59%	-
6D	6. Waste			N2O	6.23	18.75	0.04%	99.63%	-
6C	6. Waste			CO2	52.87	15.25	0.03%	99.66%	-
1A2	1. Energy	2. Manufacturing Industries and Construction	Other Fuels	N2O	5.08	14.35	0.03%	99.68%	-
1A4a	1. Energy	4. Other Sectors; Commercial/Institutional	Biomass	CH4	8.13	13.87	0.03%	99.71%	-
2B	2. Industrial Proc.			CO2	13.60	13.60	0.03%	99.74%	-
1A2	1. Energy	2. Manufacturing Industries and Construction	Solid Fuels	N2O	31.37	12.25	0.02%	99.76%	-
2C3	2. Industrial Proc.			PFC	100.17	11.40	0.02%	99.78%	-
1A4a	1. Energy	4. Other Sectors; Commercial/Institutional	Liquid Fuels	N2O	11.07	10.12	0.02%	99.80%	-
4F	4. Agriculture			CH4	10.00	10.00	0.02%	99.82%	-
1A2	1. Energy	2. Manufacturing Industries and Construction	Liquid Fuels	N2O	13.84	9.39	0.02%	99.84%	-
1A4b	1. Energy	4. Other Sectors; Residential	Biomass	N2O	10.30	9.03	0.02%	99.85%	-
2B	2. Industrial Proc.			CH4	8.16	6.51	0.01%	99.87%	-
1A4c	1. Energy	4. Other Sectors; Agriculture/Forestry	Liquid Fuels	N2O	5.90	6.24	0.01%	99.88%	-
1A5	1. Energy	5. Other	Liquid Fuels	N2O	4.53	5.90	0.01%	99.89%	-
1A4b	1. Energy	4. Other Sectors; Residential	Gaseous Fuels	CH4	3.16	5.31	0.01%	99.90%	-
1A2	1. Energy	2. Manufacturing Industries and Construction	Gaseous Fuels	CH4	2.39	4.65	0.01%	99.91%	-
1A4a	1. Energy	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	CH4	2.35	4.10	0.01%	99.92%	-
6C	6. Waste			CH4	3.96	3.96	0.01%	99.92%	-
4F	4. Agriculture			N2O	3.91	3.91	0.01%	99.93%	-
2G	2. Industrial Proc.			CO2	1.09	3.49	0.01%	99.94%	-
1A2	1. Energy	2. Manufacturing Industries and Construction	Biomass	N2O	2.22	2.92	0.01%	99.94%	-
1A4a	1. Energy	4. Other Sectors; Commercial/Institutional	Biomass	N2O	1.60	2.73	0.01%	99.95%	-

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A				B	C	D	E-L	F-L	M
IPCC Source Categories (and fuels if applicable)				Direct GHG	Base Year 1990 Estimate	Year t Estimate	Level Assess.	Cumulative Total Col. E-L	Result level assess.
					[Gg CO2eq]	[Gg CO2eq]			
TOTAL				All	45.09	27.83	0.05%	0.00%	
1A4b	1. Energy	4. Other Sectors; Residential	Liquid Fuels	CH4	5.83	2.70	0.01%	99.95%	-
1A1	1. Energy	1. Energy Industries	Liquid Fuels	N2O	2.15	2.65	0.00%	99.96%	-
1A2	1. Energy	2. Manufacturing Industries and Construction	Biomass	CH4	1.97	2.59	0.00%	99.96%	-
1A4b	1. Energy	4. Other Sectors; Residential	Solid Fuels	CH4	3.83	2.36	0.00%	99.97%	-
1A3_o	1. Energy	3. Transport without 3a, 3b & 3e		N2O	1.90	1.91	0.00%	99.97%	-
1A3a	1. Energy	3. Transport; Civil Aviation		N2O	2.46	1.40	0.00%	99.97%	-
1A4b	1. Energy	4. Other Sectors; Residential	Gaseous Fuels	N2O	0.77	1.27	0.00%	99.98%	-
1A5	1. Energy	5. Other	Liquid Fuels	CH4	1.47	1.26	0.00%	99.98%	-
1A4c	1. Energy	4. Other Sectors; Agriculture/Forestry	Liquid Fuels	CH4	1.40	1.19	0.00%	99.98%	-
1A4a	1. Energy	4. Other Sectors; Commercial/Institutional	Liquid Fuels	CH4	2.50	1.18	0.00%	99.98%	-
1A2	1. Energy	2. Manufacturing Industries and Construction	Gaseous Fuels	N2O	1.49	1.17	0.00%	99.98%	-
1A2	1. Energy	2. Manufacturing Industries and Construction	Liquid Fuels	CH4	1.97	1.12	0.00%	99.99%	-
1A3e	1. Energy	3. Transport; Other Transportation (military aviation)		N2O	1.97	1.07	0.00%	99.99%	-
1A1	1. Energy	1. Energy Industries	Gaseous Fuels	CH4	0.54	0.86	0.00%	99.99%	-
1A4a	1. Energy	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	N2O	0.53	0.80	0.00%	99.99%	-
1A3b	1. Energy	3. Transport; Road Transportation	Diesel	CH4	1.35	0.79	0.00%	99.99%	-
1A1	1. Energy	1. Energy Industries	Solid Fuels	N2O	0.25	0.56	0.00%	99.99%	-
1A3_o	1. Energy	3. Transport without 3a, 3b & 3e		CH4	0.46	0.41	0.00%	100.00%	-
2A_o	2. Industrial Proc.			CH4	0.58	0.39	0.00%	100.00%	-
1A1	1. Energy	1. Energy Industries	Liquid Fuels	CH4	0.49	0.37	0.00%	100.00%	-
2G	2. Industrial Proc.			CH4	0.37	0.24	0.00%	100.00%	-
1A1	1. Energy	1. Energy Industries	Solid Fuels	CH4	0.10	0.24	0.00%	100.00%	-
1A3a	1. Energy	3. Transport; Civil Aviation		CH4	0.24	0.22	0.00%	100.00%	-
1A2	1. Energy	2. Manufacturing Industries and Construction	Solid Fuels	CH4	0.56	0.21	0.00%	100.00%	-
1A1	1. Energy	1. Energy Industries	Gaseous Fuels	N2O	0.13	0.21	0.00%	100.00%	-
1A4b	1. Energy	4. Other Sectors; Residential	Solid Fuels	N2O	0.30	0.19	0.00%	100.00%	-
1A3e	1. Energy	3. Transport; Other Transportation (military aviation)		CH4	0.16	0.11	0.00%	100.00%	-
6A	6. Waste			CO2	9.13	0.10	0.00%	100.00%	-
1A1	1. Energy	1. Energy Industries	Biomass	N2O	0.02	0.09	0.00%	100.00%	-
1A1	1. Energy	1. Energy Industries	Biomass	CH4	0.02	0.08	0.00%	100.00%	-
1A4c	1. Energy	4. Other Sectors; Agriculture/Forestry	Gaseous Fuels	CH4	0.09	0.06	0.00%	100.00%	-
1B2	1. Energy	2. Oil and Natural Gas		N2O	0.03	0.02	0.00%	100.00%	-
1A4c	1. Energy	4. Other Sectors; Agriculture/Forestry	Gaseous Fuels	N2O	0.02	0.01	0.00%	100.00%	-
1A1	1. Energy	1. Energy Industries	Other Fuels	CH4	0.00	0.00	0.00%	100.00%	-
1A2	1. Energy	2. Manufacturing Industries and Construction	Other Fuels	CH4	0.00	0.00	0.00%	100.00%	-
1A4a	1. Energy	4. Other Sectors; Commercial/Institutional	Solid Fuels	CO2	NO	NO	0.00%	100.00%	-
1A4a	1. Energy	4. Other Sectors; Commercial/Institutional	Solid Fuels	CH4	0.00	0.00	0.00%	100.00%	-
1A4a	1. Energy	4. Other Sectors; Commercial/Institutional	Solid Fuels	N2O	0.00	0.00	0.00%	100.00%	-
2A_o	2. Industrial Proc.			N2O	NO	NO	0.00%	100.00%	-
2B	2. Industrial Proc.			HFC	NO	NO	0.00%	100.00%	-
2B	2. Industrial Proc.			PFC	NO	NO	0.00%	100.00%	-
2B	2. Industrial Proc.			SF6	0.00	0.00	0.00%	100.00%	-
2C_o	2. Industrial Proc.			PFC	0.00	0.00	0.00%	100.00%	-
2C_o	2. Industrial Proc.			CH4	NO	NO	0.00%	100.00%	-
2C_o	2. Industrial Proc.			N2O	NO	NO	0.00%	100.00%	-
2D	2. Industrial Proc.			CO2	IE	IE	0.00%	100.00%	-
2E	2. Industrial Proc.			CO2	0.00	0.00	0.00%	100.00%	-
2F_o	2. Industrial Proc.			CO2	0.00	0.00	0.00%	100.00%	-
2G	2. Industrial Proc.			N2O	NO	NO	0.00%	100.00%	-
4C	4. Agriculture			CH4	NO	NO	0.00%	100.00%	-
4D_o	4. Agriculture			CH4	NO	NO	0.00%	100.00%	-
4E	4. Agriculture			CH4	NO	NO	0.00%	100.00%	-
4E	4. Agriculture			N2O	NO	NO	0.00%	100.00%	-
4G	4. Agriculture			CH4	NO	NO	0.00%	100.00%	-
4G	4. Agriculture			N2O	NO	NO	0.00%	100.00%	-
6D	6. Waste			CO2	NO	NO	0.00%	100.00%	-

Results of Key Category Analysis – Trend

Table 167 Key category analysis 2004 regarding trend.

A				B	C	D	E-L	E-T	F-T	G-T	M	N
IPCC Source Categories (and fuels if applicable)				Direct GHG	Base Year 1990 Estimate	Year t Estimate	Level Asses.	Trend Assess.	% Contribution in Trend	Cumulative Total Col. F	Level assess.	Trend assess.
					[Gg CO2eq]	[Gg CO2eq]						
TOTAL				*All*	*52'749.22*	*53'065.25*	*100.00%*	*0.209246*	100.00%			
1A3b	1. Energy	3. Transport; Road Transportation	Diesel	CO2	2'411.97	3'606.74	6.80%	0.022110	10.6%	10.6%	KC level	KC trend
1A2	1. Energy	2. Manufacturing Industries and Construction	Gaseous Fuels	CO2	1'064.04	2'028.87	3.82%	0.017954	8.6%	19.1%	KC level	KC trend
1A4b	1. Energy	4. Other Sectors; Residential	Gaseous Fuels	CO2	1'364.86	2'249.66	4.24%	0.016421	7.8%	27.0%	KC level	KC trend
1A2	1. Energy	2. Manufacturing Industries and Construction	Solid Fuels	CO2	1'391.18	541.43	1.02%	0.016074	7.7%	34.7%	KC level	KC trend
1A4b	1. Energy	4. Other Sectors; Residential	Liquid Fuels	CO2	10'215.56	9'422.83	17.76%	0.015996	7.6%	42.3%	KC level	KC trend
2A1	2. Industrial Proc.			CO2	2'524.77	1'714.25	3.23%	0.015467	7.4%	49.7%	KC level	KC trend
2F1	2. Industrial Proc.			HFC	0.02	543.72	1.02%	0.010185	4.9%	54.6%	KC level	KC trend
1A2	1. Energy	2. Manufacturing Industries and Construction	Liquid Fuels	CO2	3'392.42	2'911.27	5.49%	0.009394	4.5%	59.1%	KC level	KC trend
1A4a	1. Energy	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	CO2	940.95	1'415.20	2.67%	0.008778	4.2%	63.3%	KC level	KC trend
1A4a	1. Energy	4. Other Sectors; Commercial/Institutional	Liquid Fuels	CO2	4'375.36	3'999.73	7.54%	0.007528	3.6%	66.9%	KC level	KC trend
1A1	1. Energy	1. Energy Industries	Other Fuels	CO2	1'519.73	1'930.63	3.64%	0.007527	3.6%	70.5%	KC level	KC trend
6A	6. Waste			CH4	693.04	348.63	0.66%	0.006530	3.1%	73.6%	KC level	KC trend
4A	4. Agriculture			CH4	2'474.84	2'270.99	4.28%	0.004096	2.0%	75.5%	KC level	KC trend
1B2	1. Energy	2. Oil and Natural Gas		CH4	380.47	177.93	0.34%	0.003837	1.8%	77.4%	-	KC trend
4D1	4. Agriculture			N2O	1'389.82	1'223.29	2.31%	0.003276	1.6%	78.9%	KC level	KC trend
3	3. Solvent and Other Product Use			CO2	357.01	185.98	0.35%	0.003244	1.6%	80.5%	KC level	KC trend
1A1	1. Energy	1. Energy Industries	Liquid Fuels	CO2	691.23	849.56	1.60%	0.002888	1.4%	81.9%	KC level	KC trend
1A5	1. Energy	5. Other	Liquid Fuels	CO2	513.00	669.06	1.26%	0.002866	1.4%	83.2%	KC level	KC trend
4D3	4. Agriculture			N2O	818.89	679.25	1.28%	0.002708	1.3%	84.5%	KC level	KC trend
1A1	1. Energy	1. Energy Industries	Gaseous Fuels	CO2	234.83	374.20	0.71%	0.002584	1.2%	85.8%	KC level	KC trend
1A2	1. Energy	2. Manufacturing Industries and Construction	Other Fuels	CO2	156.87	286.36	0.54%	0.002408	1.2%	86.9%	KC level	KC trend
1A3a	1. Energy	3. Transport; Civil Aviation		CO2	252.55	143.72	0.27%	0.002067	1.0%	87.9%	-	KC trend
1A3e	1. Energy	3. Transport; Other Transportation (military aviation)		CO2	200.04	109.07	0.21%	0.001726	0.8%	88.7%	-	KC trend
2C3	2. Industrial Proc.			PFC	100.17	11.40	0.02%	0.001674	0.8%	89.5%	-	KC trend
2F_o	2. Industrial Proc.			HFC	0.00	73.66	0.14%	0.001380	0.7%	90.2%	-	KC trend
1A1	1. Energy	1. Energy Industries	Other Fuels	N2O	48.42	118.87	0.22%	0.001314	0.6%	90.8%	-	KC trend
1A3b	1. Energy	3. Transport; Road Transportation	Gasoline	CH4	91.29	22.95	0.04%	0.001291	0.6%	91.4%	-	KC trend
2C3	2. Industrial Proc.			CO2	139.26	71.84	0.14%	0.001279	0.6%	92.0%	-	KC trend
4B	4. Agriculture			CH4	557.39	494.13	0.93%	0.001247	0.6%	92.6%	KC level	KC trend
2F	2. Industrial Proc.			PFC	0.04	65.34	0.12%	0.001223	0.6%	93.2%	-	KC trend
6D	6. Waste			CH4	30.34	91.38	0.17%	0.001140	0.5%	93.8%	-	KC trend
3	3. Solvent and Other Product Use			N2O	109.41	50.36	0.09%	0.001118	0.5%	94.3%	-	KC trend
1A1	1. Energy	1. Energy Industries	Solid Fuels	CO2	46.99	105.40	0.20%	0.001089	0.5%	94.8%	-	KC trend
4B	4. Agriculture			N2O	448.20	396.83	0.75%	0.001013	0.5%	95.3%	KC level	KC trend
2C_o	2. Industrial Proc.			SF6	0.00	50.19	0.09%	0.000940	0.4%	95.8%	-	-
2C_o	2. Industrial Proc.			CO2	112.45	155.95	0.29%	0.000802	0.4%	96.1%	-	-
2F_o	2. Industrial Proc.			SF6	79.58	38.60	0.07%	0.000777	0.4%	96.5%	-	-
6C	6. Waste			CO2	52.87	15.25	0.03%	0.000711	0.3%	96.9%	-	-
1A3b	1. Energy	3. Transport; Road Transportation	Gasoline	CO2	11'332.18	11'363.39	21.41%	0.000687	0.3%	97.2%	KC level	-
1B2	1. Energy	2. Oil and Natural Gas		CO2	139.33	106.67	0.20%	0.000628	0.3%	97.5%	-	-
1A3b	1. Energy	3. Transport; Road Transportation	Gasoline	N2O	87.76	117.35	0.22%	0.000544	0.3%	97.7%	-	-
1A4b	1. Energy	4. Other Sectors; Residential	Solid Fuels	CO2	57.20	35.18	0.07%	0.000419	0.2%	97.9%	-	-
2F7	2. Industrial Proc.			SF6	64.04	86.28	0.16%	0.000409	0.2%	98.1%	-	-
4D_o	4. Agriculture			N2O	200.19	179.70	0.34%	0.000406	0.2%	98.3%	-	-
1A2	1. Energy	2. Manufacturing Industries and Construction	Solid Fuels	N2O	31.37	12.25	0.02%	0.000362	0.2%	98.5%	-	-
6B	6. Waste			N2O	190.67	209.12	0.39%	0.000324	0.2%	98.7%	KC level	-
1A4c	1. Energy	4. Other Sectors; Agriculture/Forestry	Gaseous Fuels	CO2	40.29	25.36	0.05%	0.000284	0.1%	98.8%	-	-
6D	6. Waste			N2O	6.23	18.75	0.04%	0.000234	0.1%	98.9%	-	-
1A3b	1. Energy	3. Transport; Road Transportation	Diesel	N2O	7.66	19.70	0.04%	0.000225	0.1%	99.0%	-	-
1A3c	1. Energy	3. Transport; Railways		CO2	83.29	94.78	0.18%	0.000206	0.1%	99.1%	-	-
1A4c	1. Energy	4. Other Sectors; Agriculture/Forestry	Liquid Fuels	CO2	713.45	727.72	1.37%	0.000187	0.1%	99.2%	KC level	-
1A2	1. Energy	2. Manufacturing Industries and Construction	Other Fuels	N2O	5.08	14.35	0.03%	0.000173	0.1%	99.3%	-	-
6A	6. Waste			CO2	9.13	0.10	0.00%	0.000170	0.1%	99.4%	-	-
6C	6. Waste			N2O	14.69	23.81	0.04%	0.000169	0.1%	99.4%	-	-
1A4b	1. Energy	4. Other Sectors; Residential	Biomass	CH4	52.32	45.89	0.09%	0.000126	0.1%	99.5%	-	-
1A4a	1. Energy	4. Other Sectors; Commercial/Institutional	Biomass	CH4	8.13	13.87	0.03%	0.000106	0.1%	99.6%	-	-
1A2	1. Energy	2. Manufacturing Industries and Construction	Liquid Fuels	N2O	13.84	9.39	0.02%	0.000085	0.0%	99.6%	-	-
2A_o	2. Industrial Proc.			CO2	40.16	44.70	0.08%	0.000080	0.0%	99.6%	-	-
6B	6. Waste			CH4	28.60	32.85	0.06%	0.000076	0.0%	99.7%	-	-
2B	2. Industrial Proc.			N2O	173.76	171.06	0.32%	0.000070	0.0%	99.7%	-	-
1A4b	1. Energy	4. Other Sectors; Residential	Liquid Fuels	CH4	5.83	2.70	0.01%	0.000059	0.0%	99.7%	-	-
2G	2. Industrial Proc.			CO2	1.09	3.49	0.01%	0.000045	0.0%	99.8%	-	-
1A2	1. Energy	2. Manufacturing Industries and Construction	Gaseous Fuels	CH4	2.39	4.65	0.01%	0.000042	0.0%	99.8%	-	-
1A4b	1. Energy	4. Other Sectors; Residential	Liquid Fuels	N2O	25.84	23.84	0.04%	0.000040	0.0%	99.8%	-	-
1A4b	1. Energy	4. Other Sectors; Residential	Gaseous Fuels	CH4	3.16	5.31	0.01%	0.000040	0.0%	99.8%	-	-
1A4a	1. Energy	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	CH4	2.35	4.10	0.01%	0.000033	0.0%	99.8%	-	-
2B	2. Industrial Proc.			CH4	8.16	6.51	0.01%	0.000032	0.0%	99.8%	-	-
1A4b	1. Energy	4. Other Sectors; Residential	Solid Fuels	CH4	3.83	2.36	0.00%	0.000028	0.0%	99.9%	-	-
1A5	1. Energy	5. Other	Liquid Fuels	N2O	4.53	5.90	0.01%	0.000025	0.0%	99.9%	-	-
1A4a	1. Energy	4. Other Sectors; Commercial/Institutional	Liquid Fuels	CH4	2.50	1.18	0.00%	0.000025	0.0%	99.9%	-	-
1A4b	1. Energy	4. Other Sectors; Residential	Biomass	N2O	10.30	9.03	0.02%	0.000025	0.0%	99.9%	-	-
1A4a	1. Energy	4. Other Sectors; Commercial/Institutional	Biomass	N2O	1.60	2.73	0.01%	0.000021	0.0%	99.9%	-	-
1A3a	1. Energy	3. Transport; Civil Aviation		N2O	2.46	1.40	0.00%	0.000020	0.0%	99.9%	-	-
1A4a	1. Energy	4. Other Sectors; Commercial/Institutional	Liquid Fuels	N2O	11.07	10.12	0.02%	0.000019	0.0%	99.9%	-	-
1A3e	1. Energy	3. Transport; Other Transportation (military aviation)		N2O	1.97	1.07	0.00%	0.000017	0.0%	99.9%	-	-
1A2	1. Energy	2. Manufacturing Industries and Construction	Liquid Fuels	CH4	1.97	1.12	0.00%	0.000016	0.0%	99.9%	-	-
1A2	1. Energy	2. Manufacturing Industries and Construction	Biomass	N2O	2.22	2.92	0.01%	0.000013	0.0%	99.9%	-	-
1A2	1. Energy	2. Manufacturing Industries and Construction	Biomass	CH4	1.97	2.59	0.00%	0.000011	0.0%	100.0%	-	-
1A3b	1. Energy	3. Transport; Road Transportation	Diesel	CH4	1.35	0.79	0.00%	0.000011	0.0%	100.0%	-	-
1A4b	1. Energy	4. Other Sectors; Residential	Gaseous Fuels	N2O	0.77	1.27	0.00%	0.000009	0.0%	100.0%	-	-
1A1	1. Energy	1. Energy Industries	Liquid Fuels	N2O	2.15	2.65	0.00%	0.000009	0.0%	100.0%	-	-
1A2	1. Energy	2. Manufacturing Industries and Construction	Solid Fuels	CH4	0.56	0.21	0.00%	0.000007	0.0%	100.0%	-	-
1A2	1. Energy	2. Manufacturing Industries and Construction	Gaseous Fuels	N2O	1.49	1.17	0.00%	0.000006	0.0%	100.0%	-	-
1A1	1. Energy	1. Energy Industries	Gaseous Fuels	CH4	0.54	0.86	0.00%	0.000006	0.0%	100.0%	-	-
1A1	1. Energy	1. Energy Industries	Solid Fuels	N2O	0.25	0.56	0.00%	0.000006	0.0%	100.0%	-	-
1A4c	1. Energy	4. Other Sectors; Agriculture/Forestry	Liquid Fuels	N2O	5.90	6.24	0.01%	0.000006	0.0%	100.0%	-	-
1A4a	1. Energy	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	N2O	0.53	0.80	0.00%	0.000005	0.0%	100.0%	-	-

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A				B	C	D	E-L	E-T	F-T	G-T	M	N
IPCC Source Categories (and fuels if applicable)				Direct GHG	Base Year 1990 Estimate	Year t Estimate	Level Asses.	Trend Assess.	% Contribution in Trend	Cumulative Total Col. F	Level assess.	Trend assess.
					[Gg CO2eq]	[Gg CO2eq]						
TOTAL				*All*	*163.22*	*162.92*	*0.31%*	*0.000037*	0.02%			
1A3d	1. Energy	3. Transport; Navigation		CO2	123.97	124.45	0.23%	0.000005	0.0%	100.0%	-	-
1A5	1. Energy	5. Other	Liquid Fuels	CH4	1.47	1.26	0.00%	0.000004	0.0%	100.0%	-	-
1A4c	1. Energy	4. Other Sectors; Agriculture/Forestry	Liquid Fuels	CH4	1.40	1.19	0.00%	0.000004	0.0%	100.0%	-	-
2A_o	2. Industrial Proc.			CH4	0.58	0.39	0.00%	0.000004	0.0%	100.0%	-	-
2G	2. Industrial Proc.			CH4	0.37	0.24	0.00%	0.000003	0.0%	100.0%	-	-
1A1	1. Energy	1. Energy Industries	Solid Fuels	CH4	0.10	0.24	0.00%	0.000002	0.0%	100.0%	-	-
1A1	1. Energy	1. Energy Industries	Liquid Fuels	CH4	0.49	0.37	0.00%	0.000002	0.0%	100.0%	-	-
1A4b	1. Energy	4. Other Sectors; Residential	Solid Fuels	N2O	0.30	0.19	0.00%	0.000002	0.0%	100.0%	-	-
2B	2. Industrial Proc.			CO2	13.60	13.60	0.03%	0.000002	0.0%	100.0%	-	-
1A1	1. Energy	1. Energy Industries	Gaseous Fuels	N2O	0.13	0.21	0.00%	0.000001	0.0%	100.0%	-	-
1A1	1. Energy	1. Energy Industries	Biomass	N2O	0.02	0.09	0.00%	0.000001	0.0%	100.0%	-	-
1A1	1. Energy	1. Energy Industries	Biomass	CH4	0.02	0.08	0.00%	0.000001	0.0%	100.0%	-	-
4F	4. Agriculture			CH4	10.00	10.00	0.02%	0.000001	0.0%	100.0%	-	-
1A3_o	1. Energy	3. Transport without 3a, 3b & 3e		CH4	0.46	0.41	0.00%	0.000001	0.0%	100.0%	-	-
1A3e	1. Energy	3. Transport; Other Transportation (military aviation)		CH4	0.16	0.11	0.00%	0.000001	0.0%	100.0%	-	-
1A4c	1. Energy	4. Other Sectors; Agriculture/Forestry	Gaseous Fuels	CH4	0.09	0.06	0.00%	0.000001	0.0%	100.0%	-	-
1A3a	1. Energy	3. Transport; Civil Aviation		CH4	0.24	0.22	0.00%	0.000001	0.0%	100.0%	-	-
4F	4. Agriculture			N2O	3.91	3.91	0.01%	0.000000	0.0%	100.0%	-	-
6C	6. Waste			CH4	3.96	3.96	0.01%	0.000000	0.0%	100.0%	-	-
1A4c	1. Energy	4. Other Sectors; Agriculture/Forestry	Gaseous Fuels	N2O	0.02	0.01	0.00%	0.000000	0.0%	100.0%	-	-
1B2	1. Energy	2. Oil and Natural Gas		N2O	0.03	0.02	0.00%	0.000000	0.0%	100.0%	-	-
1A3_o	1. Energy	3. Transport without 3a, 3b & 3e		N2O	1.90	1.91	0.00%	0.000000	0.0%	100.0%	-	-
1A1	1. Energy	1. Energy Industries	Other Fuels	CH4	0.00	0.00	0.00%	0.000000	0.0%	100.0%	-	-
1A2	1. Energy	2. Manufacturing Industries and Construction	Other Fuels	CH4	0.00	0.00	0.00%	0.000000	0.0%	100.0%	-	-
1A4a	1. Energy	4. Other Sectors; Commercial/Institutional	Solid Fuels	CO2	NO	NO	0.00%	0.000000	0.0%	100.0%	-	-
1A4a	1. Energy	4. Other Sectors; Commercial/Institutional	Solid Fuels	CH4	0.00	0.00	0.00%	0.000000	0.0%	100.0%	-	-
1A4a	1. Energy	4. Other Sectors; Commercial/Institutional	Solid Fuels	N2O	0.00	0.00	0.00%	0.000000	0.0%	100.0%	-	-
2A_o	2. Industrial Proc.			N2O	NO	NO	0.00%	0.000000	0.0%	100.0%	-	-
2B	2. Industrial Proc.			HFC	NO	NO	0.00%	0.000000	0.0%	100.0%	-	-
2B	2. Industrial Proc.			PFC	NO	NO	0.00%	0.000000	0.0%	100.0%	-	-
2B	2. Industrial Proc.			SF6	0.00	0.00	0.00%	0.000000	0.0%	100.0%	-	-
2C_o	2. Industrial Proc.			PFC	0.00	0.00	0.00%	0.000000	0.0%	100.0%	-	-
2C_o	2. Industrial Proc.			CH4	NO	NO	0.00%	0.000000	0.0%	100.0%	-	-
2C_o	2. Industrial Proc.			N2O	NO	NO	0.00%	0.000000	0.0%	100.0%	-	-
2D	2. Industrial Proc.			CO2	IE	IE	0.00%	0.000000	0.0%	100.0%	-	-
2E	2. Industrial Proc.			CO2	0.00	0.00	0.00%	0.000000	0.0%	100.0%	-	-
2F_o	2. Industrial Proc.			CO2	0.00	0.00	0.00%	0.000000	0.0%	100.0%	-	-
2G	2. Industrial Proc.			N2O	NO	NO	0.00%	0.000000	0.0%	100.0%	-	-
4C	4. Agriculture			CH4	NO	NO	0.00%	0.000000	0.0%	100.0%	-	-
4D_o	4. Agriculture			CH4	NO	NO	0.00%	0.000000	0.0%	100.0%	-	-
4E	4. Agriculture			CH4	NO	NO	0.00%	0.000000	0.0%	100.0%	-	-
4E	4. Agriculture			N2O	NO	NO	0.00%	0.000000	0.0%	100.0%	-	-
4G	4. Agriculture			CH4	NO	NO	0.00%	0.000000	0.0%	100.0%	-	-
4G	4. Agriculture			N2O	NO	NO	0.00%	0.000000	0.0%	100.0%	-	-
6D	6. Waste			CO2	NO	NO	0.00%	0.000000	0.0%	100.0%	-	-

List of Key Categories

Table 168 Key categories in Switzerland 2004 (sorted according to source category).

No.	IPCC Source Categories (and fuels if applicable)			Direct GHG	1990 Gg CO2 eq	2004 Gg CO2 eq	Contribut. Level	Contrib. Trend	Level assess.	Trend assess.
1	1A1	1. Energy A. Fuel Combustion	Gaseous Fuels	CO2	234.8	374.2	0.7%	1.2%	KC level	KC trend
2	1A1	1. Energy A. Fuel Combustion	Liquid Fuels	CO2	691.2	849.6	1.6%	1.4%	KC level	KC trend
3	1A1	1. Energy A. Fuel Combustion	Other Fuels	CO2	1'519.7	1'930.6	3.6%	3.6%	KC level	KC trend
4	1A1	1. Energy A. Fuel Combustion	Other Fuels	N2O	48.4	118.9	0.2%	0.6%	-	KC trend
5	1A1	1. Energy A. Fuel Combustion	Solid Fuels	CO2	47.0	105.4	0.2%	0.5%	-	KC trend
6	1A2	1. Energy A. Fuel Combustion	Gaseous Fuels	CO2	1'064.0	2'028.9	3.8%	8.6%	KC level	KC trend
7	1A2	1. Energy A. Fuel Combustion	Liquid Fuels	CO2	3'392.4	2'911.3	5.5%	4.5%	KC level	KC trend
8	1A2	1. Energy A. Fuel Combustion	Other Fuels	CO2	156.9	286.4	0.5%	1.2%	KC level	KC trend
9	1A2	1. Energy A. Fuel Combustion	Solid Fuels	CO2	1'391.2	541.4	1.0%	7.7%	KC level	KC trend
10	1A3a	1. EnergyA. Fuel Combustion		CO2	252.6	143.7	0.3%	1.0%	-	KC trend
11	1A3b	1. EnergyA. Fuel Combustion	Diesel	CO2	2'412.0	3'606.7	6.8%	10.6%	KC level	KC trend
12	1A3b	1. EnergyA. Fuel Combustion	Gasoline	CO2	11'332.2	11'363.4	21.4%	0.3%	KC level	-
13	1A3b	1. EnergyA. Fuel Combustion	Gasoline	CH4	91.3	22.9	0.0%	0.6%	-	KC trend
14	1A3e	1. EnergyA. Fuel Combustion		CO2	200.0	109.1	0.2%	0.8%	-	KC trend
15	1A4a	1. Energy A. Fuel Combustion	Gaseous Fuels	CO2	941.0	1'415.2	2.7%	4.2%	KC level	KC trend
16	1A4a	1. Energy A. Fuel Combustion	Liquid Fuels	CO2	4'375.4	3'999.7	7.5%	3.6%	KC level	KC trend
17	1A4b	1. Energy A. Fuel Combustion	Gaseous Fuels	CO2	1'364.9	2'249.7	4.2%	7.8%	KC level	KC trend
18	1A4b	1. Energy A. Fuel Combustion	Liquid Fuels	CO2	10'215.6	9'422.8	17.8%	7.6%	KC level	KC trend
19	1A4c	1. Energy A. Fuel Combustion	Liquid Fuels	CO2	713.4	727.7	1.4%	0.1%	KC level	-
20	1A5	1. Energy A. Fuel Combustion	Liquid Fuels	CO2	513.0	669.1	1.3%	1.4%	KC level	KC trend
21	1B2	1. Energy B. Fugitive Emissions from Fuels		CH4	380.5	177.9	0.3%	1.8%	-	KC trend
22	2A1	2. Industrial Proc.A. Mineral Products; Cement Production-CO2		CO2	2'524.8	1'714.2	3.2%	7.4%	KC level	KC trend
23	2C3	2. Industrial Proc.C. Metal Production; Aluminium Production-PFC		PFC	100.2	11.4	0.0%	0.8%	-	KC trend
24	2C3	2. Industrial Proc.C. Metal Production; Aluminium Production-CO2		CO2	139.3	71.8	0.1%	0.6%	-	KC trend
25	2F	2. Industrial Proc.F. Consumption of Halocarbons and SF6		PFC	0.0	65.3	0.1%	0.6%	-	KC trend
26	2F_o	2. Industrial Proc.F. Consumption of Halocarbons and SF6 without 2F1-HFC		HFC	0.0	73.7	0.1%	0.7%	-	KC trend
27	2F1	2. Industrial Proc.F. Consumption of Halocarbons and SF6; Refrig. & AC Eq.		HFC	0.0	543.7	1.0%	4.9%	KC level	KC trend
28	3	3. Solvent and Other Product Use		CO2	357.0	186.0	0.4%	1.6%	KC level	KC trend
29	3	3. Solvent and Other Product Use		N2O	109.4	50.4	0.1%	0.5%	-	KC trend
30	4A	4. AgricultureA. Enteric Fermentation		CH4	2'474.8	2'271.0	4.3%	2.0%	KC level	KC trend
31	4B	4. AgricultureB. Manure Management		CH4	557.4	494.1	0.9%	0.6%	KC level	KC trend
32	4B	4. AgricultureB. Manure Management		N2O	448.2	396.8	0.7%	0.5%	KC level	KC trend
33	4D1	4. AgricultureD. Agricultural Soils; Direct Soil Emissions		N2O	1'389.8	1'223.3	2.3%	1.6%	KC level	KC trend
34	4D3	4. AgricultureD. Agricultural Soils; Indirect Emissions		N2O	818.9	679.3	1.3%	1.3%	KC level	KC trend
35	6A	6. Waste A. Solid Waste Disposal on Land		CH4	693.0	348.6	0.7%	3.1%	KC level	KC trend
36	6B	6. Waste B. Wastewater Handling		N2O	190.7	209.1	0.4%	0.2%	KC level	-
37	6D	6. Waste D. Other		CH4	30.3	91.4	0.2%	0.5%	-	KC trend

A1.2 Uncertainty Evaluation Tier 2 (Monte Carlo Simulation)

The uncertainty analysis presented in this paragraph is not based on the data of the current GHG inventory (November 2006) but on the data submitted in April 2006 (FOEN 2006a) as explained in Chapter 1.7 (on the level of the emissions, the modifications carried out since the April submission are modest).

A1.2.1 Assumptions for probability distribution and correlations

Table 169 Probability distribution assigned to activity data, emission factors and emissions (both years).

IPPC Source Category		Fuel	Gas	Probability Distribution		
				AD	EF	Emission
1A1	1. Energy Industries	Gaseous Fuels	CO2	normal	normal	---
1A1	1. Energy Industries	Liquid Fuels	CO2	normal	normal	---
1A1	1. Energy Industries	Other Fuels	CO2	normal	lognormal	---
1A1	1. Energy Industries	Other Fuels	N2O	normal	normal	---
1A2	2. Manufacturing Industries and Construction	Gaseous Fuels	CO2	normal	normal	---
1A2	2. Manufacturing Industries and Construction	Liquid Fuels	CO2	normal	normal	---
1A2	2. Manufacturing Industries and Construction	Other Fuels	CO2	normal	lognormal	---
1A2	2. Manufacturing Industries and Construction	Solid Fuels	CO2	normal	normal	---
1A3b	3. Transport; Road Transportation	Diesel	CO2	normal	normal	---
1A3b	3. Transport; Road Transportation	Gasoline	CO2	normal	normal	---
1A3b	3. Transport; Road Transportation	Gasoline	CH4	normal	---	lognormal
1A3e	3. Transport; Other Transportation (mil. aviation)	Liquid Fuels	CO2	normal	normal	---
1A4a	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	CO2	normal	normal	---
1A4a	4. Other Sectors; Commercial/Institutional	Liquid Fuels	CO2	normal	normal	---
1A4b	4. Other Sectors; Residential	Gaseous Fuels	CO2	normal	normal	---
1A4b	4. Other Sectors; Residential	Liquid Fuels	CO2	normal	normal	---
1A4c	4. Other Sectors; Agriculture/Forestry	Liquid Fuels	CO2	normal	normal	---
1A5	5. Other	Liquid Fuels	CO2	normal	normal	---
1B2	2. Oil and Natural Gas		CH4	---	---	normal
2A1	A. Mineral Products; Cement Production-CO2		CO2	normal	normal	---
2B	B. Chemical Industry		N2O	normal	normal	---
2C3	C. Metal Production; Aluminium Production-PFC		PFC	---	---	normal
2C3	C. Metal Production; Aluminium Production-CO2		CO2	---	---	normal
2F	F. Consumption of Halocarbons and SF6		PFC	---	---	normal
2F1	F. Consumption of Halocarbons and SF6; Refrig. & AC Eq.		HFC	---	---	normal
2F_o	F. Consumption of Halocarbons and SF6 without 2F1-HFC		HFC	---	---	normal
3	Solvent and Other Product Use		CO2	---	---	normal
			N2O	---	---	normal
4A	A. Enteric Fermentation		CH4	---	---	normal
4B	B. Manure Management		CH4	---	---	normal
4B	B. Manure Management		N2O	---	---	lognormal
4D1	D. Agricultural Soils; Direct Soil Emissions		N2O	---	---	lognormal
4D3	D. Agricultural Soils; Indirect Emissions		N2O	---	---	lognormal
6A	A. Solid Waste Disposal on Land		CH4	---	---	normal
6D	D. Other		CH4	---	---	normal

Table 170 Correlation coefficients of emission factors.

Emission Factors																										
IPPC Source Category					Gas		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1A1	Energy	A. Fuel Combustion	1. Energy Industries	Gaseous Fuels	CO2	1	1																			
1A1	Energy	A. Fuel Combustion	1. Energy Industries	Liquid Fuels	CO2	2		1																		
1A1	Energy	A. Fuel Combustion	1. Energy Industries	Other Fuels	CO2	3			1																	
1A1	Energy	A. Fuel Combustion	1. Energy Industries	Other Fuels	N2O	4			0.8	1																
1A2	Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Gaseous Fuels	CO2	5	1				1															
1A2	Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Liquid Fuels	CO2	6		0.7				1														
1A2	Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Other Fuels	CO2	7							1													
1A2	Energy	A. Fuel Combustion	2. Manufacturing Industries and Construction	Solid Fuels	CO2	8								1												
1A3b	Energy	A. Fuel Combustion	3. Transport; Road Transportation	Diesel	CO2	9									1											
1A3b	Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gasoline	CO2	10									0.7	1										
1A3b	Energy	A. Fuel Combustion	3. Transport; Road Transportation	Gasoline	CH4	11										0.8	1									
1A3e	Energy	A. Fuel Combustion	3. Transport; Other Transportation (mil. aviation)	Liquid Fuels	CO2	12												1								
1A4a	Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	CO2	13	1				1								1							
1A4a	Energy	A. Fuel Combustion	4. Other Sectors; Commercial/Institutional	Liquid Fuels	CO2	14		0.7				0.9								1						
1A4b	Energy	A. Fuel Combustion	4. Other Sectors; Residential	Gaseous Fuels	CO2	15	1				1								1		1					
1A4b	Energy	A. Fuel Combustion	4. Other Sectors; Residential	Liquid Fuels	CO2	16		0.7				0.9										1				
1A4c	Energy	A. Fuel Combustion	4. Other Sectors; Agriculture/Forestry	Liquid Fuels	CO2	17		0.7				0.9										0.9	1			
1A5	Energy	A. Fuel Combustion	5. Other	Liquid Fuels	CO2	18		0.3							0.9	0.5						0.5	0.9	1		
2A1	Ind. Proc.	A. Mineral Products; Cement Production-CO2			CO2	19																			1	
2B	Ind. Proc.	B. Chemical Industry			N2O	20																				1

Table 171 Correlation coefficients of emissions.

Emissions																			
IPPC Source Category			Gas		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1B2	Energy	B. Fugitive Emissions from Fuels 2. Oil and Natural Gas	CH4	1	1														
2C3	Ind. Proc.	C. Metal Production; Aluminium Production-PFC	PFC	2		1													
2C3	Ind. Proc.	C. Metal Production; Aluminium Production-CO2	CO2	3		1	1												
2F	Ind. Proc.	F. Consumption of Halocarbons and SF6	PFC	4		-0.5		1											
2F1	Ind. Proc.	F. Consumption of Halocarbons and SF6; Refrig. & AC Eq.	HFC	5					1										
2F_o	Ind. Proc.	F. Consumption of Halocarbons and SF6 without 2F1-HFC	HFC	6					-0.5	1									
3	Solvent and Other Product Use		CO2	7							1								
3	Solvent and Other Product Use		N2O	8								1							
4A	Agriculture	A. Enteric Fermentation	CH4	9									1						
4B	Agriculture	B. Manure Management	CH4	10									1	1					
4B	Agriculture	B. Manure Management	N2O	11									1	1	1				
4D1	Agriculture	D. Agricultural Soils; Direct Soil Emissions	N2O	12												1			
4D3	Agriculture	D. Agricultural Soils; Indirect Emissions	N2O	13												0.7	1		
6A	Waste	A. Solid Waste Disposal on Land	CH4	14														1	
6D	6. Waste	D. Other	CH4	15															1

A1.2.2 Derivation of Uncertainties for Sector 1A Energy

Notations

V denotes the Variation coefficient, *s* the standard deviation , AD the mean activity data and *U* the relative uncertainty

$$\mathrm{V} = \frac{\mathrm{s}}{\mathrm{AD}}, \tag{1}$$

[AD] = [s] = 1 TJ/a; for normal distributions,

$$U = t_{95\%}\frac{s}{AD}; \quad t_{95\%} \approx 2 \tag{1a}$$

Activity Data

The total AD of each fuel type is derived based on the following key source categories

gaseous: $AD_{1A}^{g} = AD_{1A1} + AD_{1A2} + AD_{1A4a} + AD_{1A4b}$

liquid (stationary): $\mathrm{A}D_{1A}^{ls} = AD_{1A1} + AD_{1A2} + AD_{1A4a} + AD_{1A4b} + AD_{1A4c}$ (2)

liquid (mobile): $\mathrm{A}D_{1A}^{lm} = AD_{1A3b} + AD_{1A3e} + AD_{1A5}$

other fuels: $AD_{1A}^{o} = AD_{1A1} + AD_{1A2}$

Note that only key categories are included in the Monte Carlo simulation. Therefore, non-key categories like 1Ac Railways, 1A3d Navigation are excluded from these considerations.

Uncertainties

Uncertainties are set equal to twice the standard deviation. For the total activity data AD_{1A}, the following uncertainty values were found for Switzerland (import statistics):

$$U_{1A}^{g} = 2V_{1A}^{g} = 5\%, \quad U_{1A}^{ls} = U_{1A}^{lm} = 2V_{1A}^{ls} = 2V_{1A}^{lm} = 1.4\%, \quad U_{1A}^{o} = 2V_{1A}^{o} = 10\% \tag{3}$$

For sub-sector 1A1 Energy Industries the consumption is recorded by the industries owners. The uncertainties are therefore set equal to the uncertainties of the sector 1A Energy.

$$U_{1A1}^{g} = 5\%, \quad U_{1A1}^{ls} = U_{1A1}^{lm} = 1.4\%, \quad U_{1A1}^{o} = 10\% \tag{4}$$

The activity data (energy consumption) for the other sub-sectors are not known explicitly and have to be derived from the given uncertainties of 1A plus some adequate approach. As suggested by Dr. M.P.J. Pulles (TNO, Netherlands, personal communications), the standard deviation may be set proportional to the activity data AD of the sub-sector:

$$s_i^{(f)} = \alpha^{(f)} \cdot AD_i, \tag{5}$$

f = g, ls, lm, o (fuel type). The proportionality constants $\alpha^{(f)}$ are independent of the sub-sector, assuming that the standard errors for all sub-sectors (other than 1A1) are equal. This may be considered as a first and simple approximation. The proportionality constants are by definition equal to the standard deviations of the sub-sectors and correspond to half of the uncertainties

$$\alpha^{(f)} = \frac{s_i^{(f)}}{AD_i^{(f)}} = \frac{s_{1A2}^{(f)}}{AD_{1A2}^{(f)}} = \frac{s_{1A4a}^{(f)}}{AD_{1A4a}^{(f)}} = \ldots = V_i^{(f)} = \frac{1}{2}U_i^{(f)} \tag{6}$$

The constants $\alpha^{(f)}$ can be determined using the formula for simple error propagation (Gauss)

$$s_{1A}^{(f)2} = s_{1A1}^{(f)2} + \sum_i s_i^{(f)2} = s_{1A1}^{(f)2} + \left(\alpha^{(f)}\right)^2 \cdot \sum_i AD_i^{(f)2} \quad (7)$$

With $V_{1A1}^{(f)} = V_{1A}^{(f)}$ and Eq. (6), Eq. (7) can be rewritten as

$$\left(\alpha^{(f)}\right)^2 = \left(V_{1A}^{(f)}\right)^2 \cdot \frac{AD_{1A}^{(f)2} - AD_{1A1}^{(f)2}}{\sum_i AD_i^{(f)2}} \quad (8)$$

Applied to the three fuel types

$$\begin{aligned}
\left(\alpha^{g}\right)^2 &= \left(V_{1A}^{g}\right)^2 \cdot \frac{\left(AD_{1A}^{g}\right)^2 - AD_{1A1}^2}{AD_{1A2}^2 + AD_{1A4a}^2 + AD_{1A4b}^2} \\
\left(\alpha^{ls}\right)^2 &= \left(V_{1A}^{ls}\right)^2 \cdot \frac{\left(AD_{1A}^{ls}\right)^2 - AD_{1A1}^2}{AD_{1A2}^2 + AD_{1A4a}^2 + AD_{1A4b}^2 + AD_{1A4c}^2} \\
\left(\alpha^{lm}\right)^2 &= \left(V_{1A}^{lm}\right)^2 \cdot \frac{\left(AD_{1A}^{lm}\right)^2}{AD_{1A3b}^2 + AD_{1A3e}^2 + AD_{1A5}^2} \\
\left(\alpha^{o}\right)^2 &= \left(V_{1A}^{o}\right)^2 \cdot \frac{\left(AD_{1A}^{o}\right)^2 - AD_{1A2}^2}{AD_{1A2}^2}
\end{aligned} \quad (9)$$

The uncertainties for sub-sectors other than 1A1 may then be derived from equations (6) and (9). In our case, this yields (see Table 172 for input values)

$$\begin{aligned}
U^{g} &= 2\alpha^{g} = 0.181 = 9.1\% \\
U^{ls} &= 2\alpha^{ls} = 0.024 = 2.3\% \\
U^{lm} &= 2\alpha^{lm} = 0.018 = 1.8\% \\
U^{o} &= 2\alpha^{o} = 0.397 = 39.7\%
\end{aligned} \quad (10)$$

Table 172 Activity data and uncertainties key categories in 1A Fuel Combustion due to the data of submission April 2006.

Source category		Activity data 2004 (TJ)				Uncertainty of activity data U			
		gaseous	liquid (s)	liquid (m)	other	gaseous	liquid (s)	liquid (m)	other
1A	Fuel Combustion	112'013	247'774	214'526	48'387	5.0%	1.4%	1.4%	10.0%
1A1	En. Industries	6'854	14'914	---	42'601	5.0%	1.4%	---	10.0%
				expansion factors		*1.81*	*1.70*	*1.32*	*3.97*
1A2	Manufacturing Ind. + Construc	37'290	39'540	---	5'786	9.1%	2.3%	---	39.7%
1A3b	Road Transportation, diesel	---	---	49'223	---	---	---	1.8%	---
1A3b	Road Transportation, gasoline	---	---	154'618	---	---	---	1.8%	---
1A3e	Military Aviation	---	---	1'490	---	---	---	1.8%	---
1A4a	Other sectors Comm./Institutio	26'209	55'037	---	---	9.1%	2.3%	---	---
1A4b	Other sectors Residential	41'660	128'400	---	---	9.1%	2.3%	---	---
1A4c	Other sectors Agricuture	---	9'883	---	---	---	2.3%	---	---
1A5	Others (Off-road)	---	---	9'195	---	---	---	1.8%	---

In Table 172, so called expansion factor $\varepsilon^{(f)}$ are given. These factors are used to expand the uncertainties of the aggregated activity data to the uncertainties of the disaggregated activity data and are derived as follows

$$\varepsilon^{(f)} = \frac{U_{1A2}^{(f)}}{U_{1A}^{(f)}} = \frac{U_{1A4a}^{(f)}}{U_{1A}^{(f)}} = \frac{U_{1A4b}^{(f)}}{U_{1A}^{(f)}} \quad (11)$$

A1.2.3 Further Results of the Monte Carlo Uncertainty Analysis

In addition to the results of Table 12, Table 173 shows results for the uncertainties of the key categories. The uncertainty of the emission is only a Monte Carlo result if uncertainty numbers are given in the corresponding columns “uncertainty of activity data” and “uncertainty of emission factors” (source categories 1A, 1B, 2A, 2B). In the other cases (2C, 2F etc.), the uncertainty of the emission is an input data for the Monte Carlo simulation.

Table 173 Activity data, emission factors, emissions (all data taken from the submission of April 2006) and their corresponding uncertainties of key categories in Monte Carlo simulation (to be compared with Table 9).

IPPC Source Category			Gas	Activity Data year t (2004)		Uncertainty of activity data	Emission factor year t		Uncertainty of emission factor	Emissions year t	Uncertainty of emissions
						%			%	(Gg CO2 equivalent)	%
1A	A. Fuel Combustion										
1A1	1. Energy Industries	Gaseous Fuels	CO2	6'854	TJ	4.9	55	t/TJ	4.5	377	6.7
1A1	1. Energy Industries	Liquid Fuels	CO2	14'914	TJ	1.3	64	t/TJ	0.5	955	1.5
1A1	1. Energy Industries	Other Fuels	CO2	42'601	TJ	9.8	45	t/TJ	29.4	1'925	31.0
1A1	1. Energy Industries	Other Fuels	N2O	42'601	TJ	9.8	3	t/TJ	78.4	113	79.2
1A2	2. Manufacturing Industries and Construction	Gaseous Fuels	CO2	37'290	TJ	8.9	55	t/TJ	4.5	2'051	10.0
1A2	2. Manufacturing Industries and Construction	Liquid Fuels	CO2	39'540	TJ	2.3	74	t/TJ	0.5	2'926	2.4
1A2	2. Manufacturing Industries and Construction	Other Fuels	CO2	5'786	TJ	38.9	49	t/TJ	29.4	286	49.0
1A2	2. Manufacturing Industries and Construction	Solid Fuels	CO2	5'651	TJ	18.0	94	t/TJ	4.9	532	18.7
1A3b	3. Transport; Road Transportation	Diesel	CO2	49'223	TJ	1.8	74	t/TJ	0.5	3'623	1.9
1A3b	3. Transport; Road Transportation	Gasoline	CO2	154'618	TJ	1.8	74	t/TJ	0.5	11'426	1.9
1A3b	3. Transport; Road Transportation	Gasoline	CH4	154'618	TJ	1.8	0.1	t/TJ	0.0	23	58.8
1A3e	3. Transport; Other Transportation (mil. aviation)	Liquid Fuels	CO2	1'490	TJ	1.8	73	t/TJ	0.5	109	1.9
1A4a	4. Other Sectors; Commercial/Institutional	Gaseous Fuels	CO2	26'209	TJ	8.9	55	t/TJ	4.5	1'441	10.0
1A4a	4. Other Sectors; Commercial/Institutional	Liquid Fuels	CO2	55'037	TJ	2.3	74	t/TJ	0.5	4'046	2.3
1A4b	4. Other Sectors; Residential	Gaseous Fuels	CO2	41'660	TJ	8.9	55	t/TJ	4.5	2'291	10.0
1A4b	4. Other Sectors; Residential	Liquid Fuels	CO2	128'400	TJ	2.3	74	t/TJ	0.5	9'438	2.4
1A4c	4. Other Sectors; Agriculture/Forestry	Liquid Fuels	CO2	9'883	TJ	2.3	74	t/TJ	0.5	728	2.4
1A5	5. Other	Liquid Fuels	CO2	9'195	TJ	1.8	73	t/TJ	0.5	671	1.9
1B	B. Fugitive Emissions from Fuels										
1B2	2. Oil and Natural Gas		CH4	--	--	--	--	--	--	183	49.0
2	Industrial Processes										
2A1	A. Mineral Products; Cement Production-CO2		CO2	3'265	kt	2.0	0.5	t/t	5.9	1'714	6.2
2B	B. Chemical Industry		N2O	65	kt	9.8	0.2	t/t	39.2	16	40.5
2C3	C. Metal Production; Aluminium Production-PFC		PFC	--	--	--	--	--	--	11	48.0
2C3	C. Metal Production; Aluminium Production-CO2		CO2	--	--	--	--	--	--	70	29.8
2F	F. Consumption of Halocarbons and SF6		PFC	--	--	--	--	--	--	56	17.2
2F1	F. Consumption of Halocarbons and SF6; Refrig. & AC Eq.		HFC	--	--	--	--	--	--	545	13.5
2F_o	F. Consumption of Halocarbons and SF6 without 2F1-HFC		HFC	--	--	--	--	--	--	74	21.4
3	Solvent and Other Product Use		CO2	--	--	--	--	--	--	122	49.0
			N2O	--	--	--	--	--	--	50	78.4
4	Agriculture										
4A	A. Enteric Fermentation		CH4	--	--	--	--	--	--	2'492	23.2
4B	B. Manure Management		CH4	--	--	--	--	--	--	400	40.7
4B	B. Manure Management		N2O	--	--	--	--	--	--	397	72.7
4D1	D. Agricultural Soils; Direct Soil Emissions		N2O	--	--	--	--	--	--	1'208	78.8
4D3	D. Agricultural Soils; Indirect Emissions		N2O	--	--	--	--	--	--	683	93.2
6	Waste										
6A	A. Solid Waste Disposal on Land		CH4	--	--	--	--	--	--	349	58.8
6D	D. Other		CH4	--	--	--	--	--	--	91	49.0
	Other			--	--	--	--	--	--	1'612	39.2
Total				--	--	--	--	--	--	53'034	3.97

Annex 2: Energy

A2.1 Swiss Energy Flux

The diagram shows a summary of the Swiss energy flux 2004 as published by the Swiss Federal Office of Energy (SFOE 2005). The diagram languages are German and French.

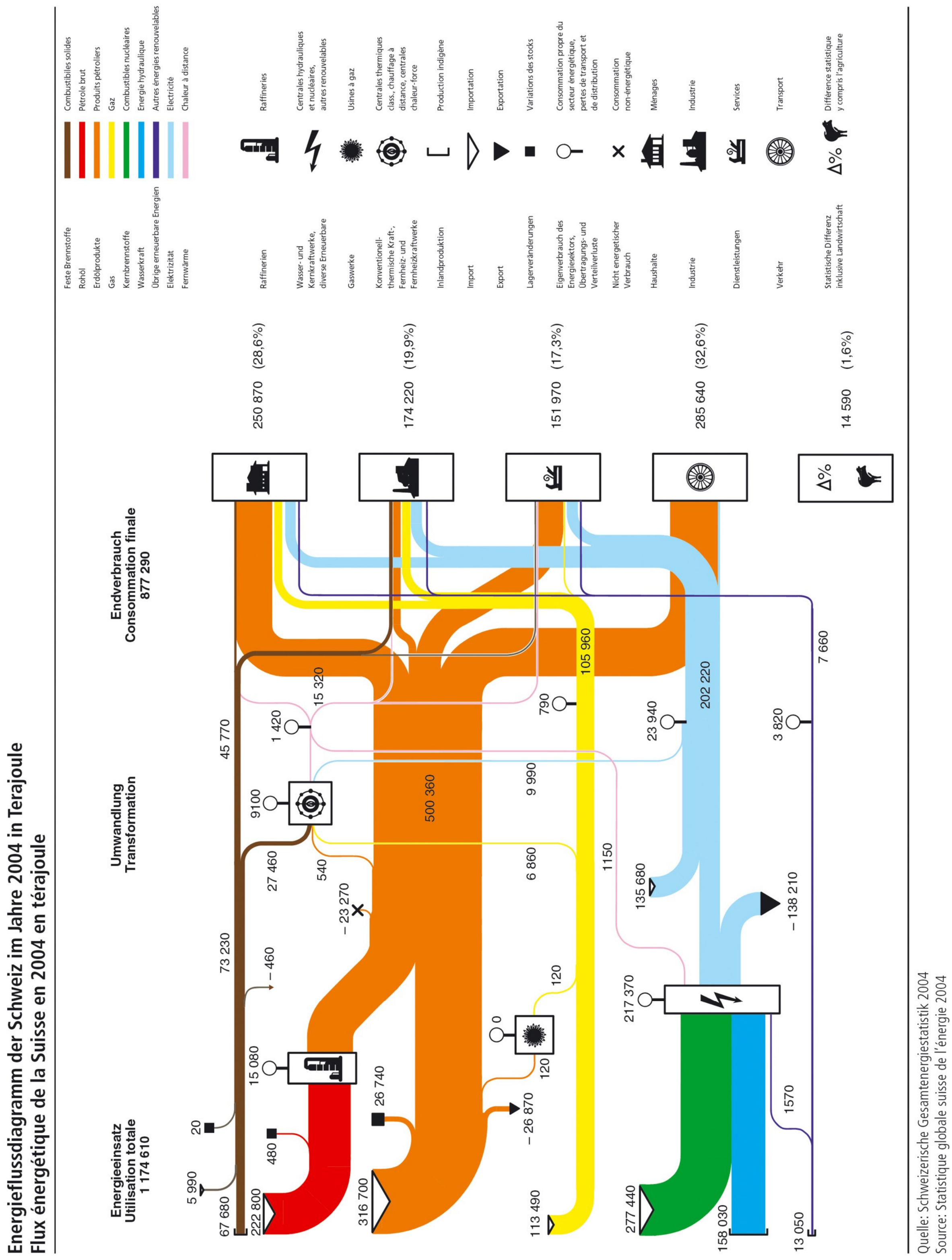

Figure 43 Energy flux in Switzerland 2004 (SFOE 2005)

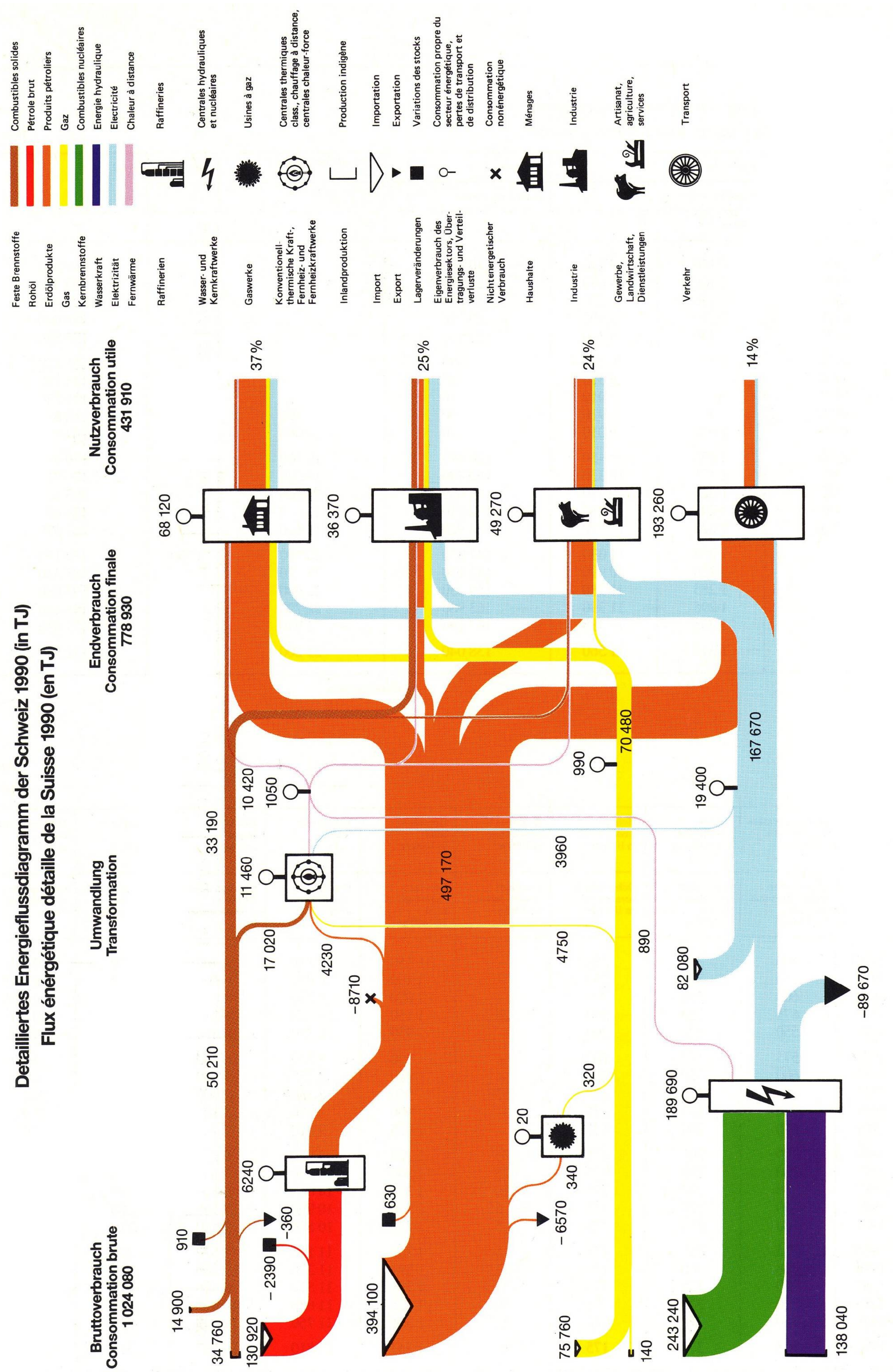

Figure 44 Energy flux in Switzerland 1990 (SFOE 1990)

A2.2 Carbon Dioxide (CO_2)

The main sources for calculating CO_2 emissions of Switzerland are the
a) net calorific values of the fuels (SFOE 2001)
b) CO_2 emission factors of the fuels (SFOE 2001)
c) Swiss overall energy statistics 2004 (SFOE 2005).

A2.2.1 Net calorific values (energy content) and density of fossil fuels

Table 174 NCV from SFOE 2001. Note that the NCV for coal has been changed from 28.1 GJ/t to 26.3 GJ/t (see below).

Fuel	Net calorific values (NCV)		Density
	GJ / t	GJ / volume	t / volume
Hard Coal	26.3	---	---
Gas Oil	42.6	36.0 / 1000 l	0.845 t / 1000 l
Residual Fuel Oil	41.2	39.1 / 1000 l	0.950 t / 1000 l
Natural Gas	46.5	36.3 / 1000 Nm^3	0.780 t / 1000 Nm^3
Gasoline	42.5	31.7 / 1000 l	0.745 t / 1000 l
Diesel Oil	42.8	35.5 / 1000 l	0.830 t / 1000 l
Propane/Butane (LPG)	46.0	---	---
Jet Kerosene	43.0	34.4 / 1000 l	0.800 t / 1000 l
Lignite	20.1	---	---

Note that the NCV for hard coal has been changed since the submission 2005 from 28.1 GJ/t to 26.3 GJ/t. Consultations with the Swiss Federal Office of Energy and with importers of coal showed that the previous NCV of 28.1 GJ/t stems from the 70ies or 80ties and is outdated. It is not representative for the coal as it has been used since 1990, which was used primarily in cement industry. Therefore from data on coal, Coke and P-coke usage from the Swiss cement industry (Cemsuisse 2004) and from the Swiss overall energy statistics (SFOE 2005) has been used to determine the corrected NCV of coal of 26.3 GJ/t.

Because the consumption of coal in Switzerland has decreased significantly in Switzerland since 1990, the reduction of the coal NCV (and therefore of the related GHG emissions) is conservative.

The NCV of fossil fuels is assumed to be constant for the period 1990 to 2004.

A2.2.2 CO_2 emission factors of fossil fuels

Table 175 CO_2 emission factors (SFOE 2001). The value for natural gas also holds for CNG (compressed natural gas). The CO_2 emission factor of fossil fuels is assumed to be constant from 1990 to 2004.

CO_2 Emission Factor			
Fuel	t CO_2 / TJ	t CO_2 / t	t CO_2 / volume
Hard Coal	94.0	2.64	---
Gas Oil	73.7	3.14	2.65t / 1000 liter
Residual Fuel Oil	77.0	3.17	3.01t / 1000 liter
Natural Gas	55.0	2.56	2.00t / 1000 Nm^3
Gasoline	73.9	3.14	2.34t / 1000 liter
Diesel Oil	73.6	3.15	2.61t / 1000 liter
Propane/Butane (LPG)	65.5	---	---
Jet Kerosene	73.2	3.15	2.52t / 1000 liter
Lignite	104.0	2.09	---

A2.3 Sulphur Dioxide (SO_2)

Table 176 Sulphur content and SO_2 emission factors. For explanations see next page.

year	maximum legal limit of sulphur content					
	Diesel oil	Gasoline	Gas oil	Natural gas	Res. fuel oil	Coal
	ppm	ppm	ppm	ppm	%	%
1990	1400	200	2000	190	1.0	1.0
1991	1300	200	2000	190	1.0	1.0
1992	1200	200	2000	190	1.0	1.0
1993	1000	200	2000	190	1.0	1.0
1994	500	200	2000	190	1.0	1.0
1995	500	200	2000	190	1.0	1.0
1996	500	200	2000	190	1.0	1.0
1997	500	200	2000	190	1.0	1.0
1998	500	200	2000	190	1.0	1.0
1999	500	200	2000	190	1.0	1.0
2000	350	150	2000	190	1.0	1.0
2001	350	150	2000	190	1.0	1.0
2002	350	150	2000	190	1.0	1.0
2003	350	150	2000	190	1.0	1.0
2004	350	150	2000	190	1.0	1.0

year	Effective sulphur content					
	Diesel oil	Gasoline	Gas oil	Natural gas	Res. fuel oil	Coal
	ppm	ppm	ppm	ppm	%	%
1990	1400	200	1600	11.6	0.97	0.9
1991	1300	200	1300	11.6	0.89	0.9
1992	1200	200	1200	11.6	0.86	0.9
1993	1000	200	1000	11.6	0.87	0.9
1994	434	200	1350	11.6	0.77	0.9
1995	341	200	1170	11.6	0.78	0.9
1996	372	200	1160	11.6	0.78	0.9
1997	353	200	1250	11.6	0.70	0.9
1998	402	200	926	11.6	0.83	0.9
1999	443	200	650	11.6	0.62	0.9
2000	272	142	680	11.6	0.66	0.9
2001	250	121	830	11.6	0.82	0.9
2002	235	101	798	11.6	0.82	0.9
2003	200	81	700	11.6	0.79	0.9
2004	10	8	700	11.6	0.76	0.9

year	Effective SO_2 emission factor					
	Diesel oil	Gasoline	Gas oil	Natural gas	Res. fuel oil	Coal
	kg/TJ					
1990	65.4	9.4	75.1	0.50	473	350
1991	60.7	9.4	61.0	0.50	432	350
1992	56.1	9.4	56.3	0.50	417	350
1993	46.7	9.4	46.9	0.50	422	350
1994	20.3	9.4	63.4	0.50	374	350
1995	15.9	9.4	54.9	0.50	377	350
1996	17.4	9.4	54.5	0.50	379	350
1997	16.5	9.4	58.7	0.50	340	350
1998	18.8	9.4	43.5	0.50	403	350
1999	20.7	9.4	30.5	0.50	301	350
2000	12.7	6.7	31.9	0.50	320	350
2001	11.7	5.7	39.0	0.50	398	350
2002	11.0	4.8	37.5	0.50	398	350
2003	9.3	3.8	32.9	0.50	383	350
2004	0.5	0.4	32.9	0.50	369	350

Explanation to Table 176

- For liquid and solid fuels the SO_2 emission factors are determined by the sulphur content. The upmost lines in Table 176 “maximum legal limit on sulphur content” show the maximum values due to the Federal Ordinance on Air Pollution Control (Swiss Confederation 1985).
- The lines in the middle part of Table 176 contain the effective sulphur contents. They are based on measurements: Summary and annual reports of the Swiss Petroleum Association (EV), reports by the Federal Administration of Customs (OZD) since 2000.
- The lines at the bottom part of Table 176 give the emission factors in kg/TJ. They are calculated from the sulphur content S, the net calorific value NCV and the quotient of the molar masses of S and SO_2

$$\frac{M_{SO_2}}{M_S}\frac{S}{NCV} = 2\frac{S}{NCV}$$

- Note on the effective sulphur content of coal: Because the net calorific value of coal had been revised in the present submission (see Section A2.2.1 above) and simultaneously, the absolute sulphur content (350 kg/TJ) is still correct, the relative sulphur content had to be corrected from 0.8% (as given in the previous submission) to the new value of 0.9% (1990-2004).

A2.4 Emissions from Fuel Consumption

A2.4.1 Disaggregation of Fuel Consumption

Swiss global energy statistics 2004

The consumption of Solid, Liquid, Gaseous and Other Fuels in the Swiss global energy statistics 2004 (SFOE 2005) are the basis for the calculations of GHG emissions in source category 1A “Energy”. The statistics provide annual aggregated consumption data for different fuels for categories of sources. The categories in the Swiss global energy statistics are more aggregated than in CRF (e.g. the energy statistics provide data for "industry" as a whole, whereas the CRF differentiate between different industrial activities in source categories 1A2a to 1A2f).

The aggregated data on fuel consumption in the Swiss global energy statistics are derived from the following sources:

- "Carbura" and Swiss Petroleum Association for data on import, export, sales, stocks of oil products and for processing of crude oil in refineries
- Annual import data for natural gas from Swiss gas industry association
- Annual customs import data for coal
- Measurements and data provided by industry associations

For a first disaggregation of fuel consumption data in the three categories (i) Energy Industries, (ii) industry, services and institutional and (iii) households, estimates based on selected surveys in industry and households, modelling, and expert judgments are used, including

- Survey on consumption of light fuel oil (“Erdöl Panel”); based on the survey, stocks are estimated; however, larger uncertainties about stock changes remain.
- Survey on consumption of natural gas to differentiate the consumption for heat, power and co-generation purposes.
- Survey with suppliers on amount and type of newly installed wood boilers and data on buildings. This data is then fed into a model that provides estimates of annual wood consumption.

Models for fuel consumption in industry and services/institutional

As the Swiss overall energy statistics provide only the sum of the combined fuel consumption in industry, services and institutional sector, SAEFL mandated the companies/institutions *Basics* and *CEPE* to model the disaggregation and to estimate consumption in source categories 1A2a-f and 1A4a.

Modelling of fuel consumption in Manufacturing Industries and Construction (Basics)

The modelling of fuel consumption in Manufacturing Industries and Construction in Switzerland from 1990 to 2004 of Basics (Basics 2006) is based on several long- and short-term bottom-up energy-economic models. Starting from individual industrial processes, the fuel consumption of 16 branches of industry is calculated as the product of activity data (e.g. tons of chocolate produced) and a specific fuel consumption factor (e.g. kWh natural gas per ton of chocolate). The model is adjusted and scaled to fit available energy data and statistics, including the Swiss overall energy statistics, the statistics of the large energy consumers (Energiekonsumenten-Verband EKV; for 1990-1998), data from soundings of Helbling Ltd. (since 1999), data from the Swiss energy agency for industry (Energieagentur der Wirtschaft ENAW, for 1990 and 2000 to 2004), industry data from annual reports, fuel supply data from CARBURA for 1985 to 2004, data on full-time-jobs and on industrial production from SFSO, as well as expert estimates.

For the context of the Swiss GHG inventory, the Basics-model output provides annual consumption (in TJ) for light fuel oil (gas oil), heavy fuel oil, coal, natural gas, and biomass in the source categories 1A2a to 1A2f:

F_{1A2a}^{Model}, F_{1A2b}^{Model}, F_{1A2c}^{Model}, F_{1A2d}^{Model}, F_{1A2e}^{Model}, F_{1A2f}^{Model}, and total consumption $F_{1A2}^{Model} = \sum_{i=a}^{f} F_{1A2i}^{Model}$.

Modelling of fuel consumption in services/institutional (CEPE)

Modelling work at the Centre for Energy Policy and Economics in Zürich (CEPE 2005) provided the basis to estimate the fuel consumption of the services and institutional sector in Switzerland from 1990 to 2004. The model calculates heat and electricity demand on the basis of heated building area. Seven fuels/heating systems are distinguished: Light fuel oil (gas oil), natural gas, electric heaters, fuel wood, district heating, electric heat pumps, and solar energy. When estimating the specific heat demand for different branches, the following factors are taken into account: changes in the cohort of buildings, changes in the efficiency of heating systems, substitution between fuels (e.g. fuel oil vs. natural gas), as well as changes in the typical behaviour of users.

For the context of the Swiss GHG inventory, the CEPE-model output provides annual consumption (in TJ) for light fuel oil, natural gas, and biomass in the source category "Services/Institutional" 1A4a:

F_{1A4a}^{Model} .

Application of model results to disaggregate fuel consumption between industry and services/institutional

With the exception of the year 2004, for which the models have been normalized, the total annual fuel consumption resulting from the two models do not exactly tally with the corresponding actual fuel consumption data in the Swiss global energy statistics. The model output is used as a proxy to distribute the total consumption from the Swiss global energy statistics between CRF source categories in the following steps:

1. The Swiss global energy statistics provide the aggregated fuel consumption in industries (1A2) and in the services/institutional sector (1A4a) in TJ, F_{1A2+4a} .

2. The aggregated fuel consumption in the statistics, F_{1A2+4a} , are distributed proportional to the model outputs between the categories Industries (1A2) and Services/Institutional (1A4a):

(1) $$F_{1A2} = F_{1A2+4a} \cdot \frac{F_{1A2}^{Model}}{F_{1A2}^{Model} + F_{1A4a}^{Model}}$$

(2) $$F_{1A4a} = F_{1A2+4a} \cdot \frac{F_{1A4a}^{Model}}{F_{1A2}^{Model} + F_{1A4a}^{Model}}$$

3. The following equations have been used to disaggregate emissions related to the combustion of light fuel oil, natural gas, and biomass from Manufacturing Industries based on the outputs of the Basics-model:

(3) $$F_{1A2a} = F_{1A2a}^{Model};\ F_{1A2b} = F_{1A2b}^{Model};\ F_{1A2c} = F_{1A2c}^{Model};\ F_{1A2d} = F_{1A2d}^{Model};$$
$$F_{1A2e} = F_{1A2e}^{Model}$$

(4) $$F_{1A2f} = F_{1A2} - \sum_{i=a}^{e} F_{1A2i}^{Model}$$

I.e. source category 1A2f “Other” serves as a buffer to offset inconsistencies between the statistical data and the model outputs. With this, the overall consumption of light fuel oil, natural gas, and biomass reported in 1A2 is consistent with the Swiss global energy statistics.

4. For heavy fuel oil and coal, the data in the Swiss overall energy statistics (SFOE 2005) underestimate stock changes considerably: New governmental policy that was introduced from 1999 reduced significantly or stopped altogether state subsidies for fuel stocks and reduced the amount of mandatory stocks that (private) companies have to maintain ("Pflichtlager"; see FDEA 2003). Experts within the Swiss cement industry confirmed that this resulted in a significant reduction of coal and heavy fuel oil stocks (and additional consumption) during the last few years that has not yet been accounted for in current data on stock changes from SFOE.

This is corroborated by the fact that summing up bottom-up data on consumption of coal and heavy fuel oil in industry results in higher total consumption than what the Swiss overall energy statistics report for these fuels.

Therefore, the results for coal and heavy fuel oil consumption from the Basics model (that are based on bottom-up data) are deemed more reliable than the consumption data from SFOE for the purpose of the Swiss inventory.

Therefore, for coal and heavy fuel oil, the consumption (in TJ) is taken directly from the model and is not "corrected" to the SFOE's overall consumption data:

(5) $$F_{1A2a} = F_{1A2a}^{Model};\ F_{1A2b} = F_{1A2b}^{Model};\ F_{1A2c} = F_{1A2c}^{Model};\ F_{1A2d} = F_{1A2d}^{Model};$$
$$F_{1A2e} = F_{1A2e}^{Model};\ F_{1A2f} = F_{1A2f}^{Model}$$

With this, the overall consumption of coal and heavy fuel oil reported in 1A2 tends to be higher than the data in the Swiss global energy statistics (SFOE 2005), because it takes into account the reduction of stocks over the last few years due to a change in governmental policy regarding stocks of coal and heavy fuel oil.

A2.5: Civil Aviation

This paragraph contains further information to the emission modelling. More complete information will be available in FOCA (2006) and on request for reviewers by FOCA.

Emission factors

Table 177 Aircraft cruise factors, used for cruise emission calculation (extract of list of 671 aircraft) GKL_ICAO = ICAO seat categories. Mass emissions are given in kilograms or grams per nautical mile (NM).

Aircraft Cruise _Factors						
Aircraft_ ICAO	GKL_ICAO	Cruise_D_Source	kg_fuel_NM	kg_NOx_NM	g_VOC_NM	g_CO_NM
AA1	0	P002FOCA	0.21	0.0098	1.79	61.7
AA5	0	P002FOCA	0.21	0.0098	1.79	61.7
AC11	0	P002FOCA	0.21	0.0098	1.79	61.7
AC14	0	P002FOCA	0.21	0.0098	1.79	61.7
AC50	0	P001FOCA	0.77	0.021	4.14	364.17
AC68	0	P001FOCA	0.77	0.0075	4.14	364.17
AC6T	1	FOCAINV95-03.2T	1.58	0.021	0.87	2.9
AC90	1	FOCAINV95-03.2T	1.58	0.021	0.87	2.9
AC95	1	FOCAINV95-03.2T	1.58	0.021	0.87	2.9
AEST	0	P001FOCA	0.77	0.021	4.14	364.17
AJET	0	FOCAEDBJ014	2.92	0.0146	8.53	63
ALO2	0	FOCAHeli	1.91	0.024	0.42	2.1
ALO3	0	FOCAHeli	1.91	0.024	0.42	2.1
AN12	0	AN26*2	5.36	0.0062	143	348
AN2	0	FOCA/91/DC3	0.82	0.0002	13.7	1000
AN22	6	FOCAINV95-03.2T*2	3.16	0.042	1.74	5.8
AN24	2	AN26	2.68	0.0031	71.7	174
AN26	1	500	2.68	0.0031	71.7	174
AN72	2	FOCAINV95-03.2J	6.4	0.1	0.83	10
AR7	0	P002FOCA	0.21	0.0098	1.79	61.7
AR7A	0	P002FOCA	0.21	0.0098	1.79	61.7
AS02	0	P002FOCA	0.21	0.0098	1.79	61.7
AS16	0	P002FOCA	0.21	0.0098	1.79	61.7
AS20	0	P002FOCA	0.21	0.0098	1.79	61.7
AS24	0	P002FOCA	0.21	0.0098	1.79	61.7
AS25	0	P002FOCA	0.21	0.0098	1.79	61.7
AS26	0	P002FOCA	0.21	0.0098	1.79	61.7
AS2T	0	FOCAEDBT758	0.95	0.005	1.8	12
AS30	0	FOCAHeli*2	3.82	0.048	0.82	4.2
AS32	1	FOCAHeli*2	3.82	0.048	0.82	4.2
AS33	0	FOCAHeli*2	3.82	0.048	0.82	4.2
AS35	0	FOCAHeli	1.91	0.024	0.42	2.1
AS50	0	FOCAHeli*2	3.82	0.048	0.82	4.2
AS55	0	FOCAHeli*2	3.82	0.048	0.82	4.2
AS65	0	FOCAHeli*2	3.82	0.048	0.82	4.2
ASK1	0	P002FOCA	0.21	0.0098	1.79	61.7
ASTA	0	FOCAINV95-03.B	3.016	0.046	0.3	2.8
ASTR	0	FOCAINV95-03.B	3.016	0.046	0.3	2.8
ASTRA	0	FOCAINV95-03.B	3.016	0.046	0.3	2.8
AT42	1	FOCAINV95-03.2T	1.58	0.021	0.87	2.9
AT43	1	500	1.6	0.013	0	15

Activity data

Table 178 LTO-cycle times (minutes). Swiss FOCA does not use all ICAO standard cycle times for all aircraft categories. For jets, the mean time for taxi-in and taxi-out at Swiss airports has been determined 20 minutes instead of the standard 26 minutes. For jets, business jets, turboprops, piston engines and helicopters, the times in mode are shown in the table and are based on ICAO, US EPA and Swiss FOCA data "Type" is a classification variable. J = Jet, T = Turboprop, P = Piston, H = Helicopter, B = Business jet, SJ = Supersonic Jet. The number in "Type" stands for the number of engines.

LTO Cycle				
Type	Time_Take_Off	Time_Climbout	Time_Approach	Zeit_Taxi
1J	0.7	2.2	4	20
1T	0.5	2.5	4.5	13
1P	0.3	2.5	3	12
1H	0	6.5	6.5	7
2B	0.4	0.5	1.6	13
3B	0.4	0.5	1.6	13
2T	0.5	2.5	4.5	13
4T	0.5	2.5	4.5	13
2J	0.7	2.2	4	20
3J	0.7	2.2	4	20
4J	0.7	2.2	4	20
2P	0.3	2.5	3	12
3P	0.3	2.5	3	12
4P	0.3	2.5	3	12
2H	0	6.5	6.5	7
4SJ	1.2	2	2.3	20
3H	0	6.5	6.5	7
4H	0	6.5	6.5	7
4B	0.4	0.5	1.6	13

Table 179 Aircraft-Engine Combinations and associated codes for SWISS FOCA emissions database. (Extract from list of 14043 individual aircraft)

Aircraft Engine Combinations							
Engine Name	Aircraft Name	Aircraft Registr.	No. Eng.	Code	Type	Aircr. ICAO	Source
V2527-A5	AIRBUS A320-232	ECHXA	2	J220	2J	A320	1IA003
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECHXM	2	J090	2J	CRJ2	1GE034
CFM56-3C1	BOEING 737-4K5	ECHXT	2	J022	2J	B734	1CM007
TPE331-11U-611G	FAIRCHILD (SWEARIN-GEN) SA227AC METR	ECHXY	2	T310	2T	SW4	FOI
CFM56-5B4/P	AIRBUS A320-214	ECHYC	2	J067	2J	A320	3CM026
CFM56-5B4/P	AIRBUS A320-214	ECHYD	2	J067	2J	A320	3CM026
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECHYG	2	J090	2J	CRJ2	1GE034
CFEC-FE738-1-1B	DASSAULT FALCON 2000	ECHYI	2	B130	2B	F2TH	FOI-Ho-neywell
GA TPE331-11U-612G		ECHZH	2	T310	2T	FA3	FOI
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECHZR	2	J090	2J	CRJ2	1GE034
CFM56-7B27B1	BOEING 737-86Q (WINGLETS)	ECHZS	2	J075	2J	B738	3CM034
CFM56-5B4/P	AIRBUS A320-214	ECHZU	2	J067	2J	A320	3CM026
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECIAA	2	J090	2J	CRJ2	1GE034
FJ44-1A	CESSNA 525 CITATIONJET	ECIAB	2	B001	2B	C525	FOCA
CFM56-5B4/P	AIRBUS A320-214	ECIAG	2	J067	2J	A320	3CM026
V2527-A5	AIRBUS A320-232	ECIAZ	2	J220	2J	A320	1IA003
BRBR700-710A2-20	BOMBARDIER BD-700-1A10 GLOBAL EX-PRE	ECIBD	2	J854	2J	GLEX	4BR009
PT6A-60A	BEECH-CRAFT KING AIR 350 (RAYTHEON B	ECIBK	2	T738	2T	B350	FOI
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECIBM	2	J090	2J	CRJ2	1GE034
CFM56-7B27B1	BOEING 737-81Q (WINGLETS)	ECICD	2	J075	2J	B738	3CM034
CFM56-5B4/P	AIRBUS A320-214	ECICK	2	J067	2J	A320	3CM026

Emissions

The output of the FOCA emission modelling consists of tables with the following structure:

Table 180 Extract of the output file of FOCA emission and fuel consumption modelling. Upper part: LTO, lower part: cruise (example for 2004). Emissions and fuel consumption in tons.

Airport	Distance	Type Traffic	Move-ments	Type	Aircraft ICAO	Engine Name	Fuel (LTO) tons	Emissions (LTO) in tons					
	Km		No.					CO_2	H_2O	SO_2	NO_x	VOC	CO
LSGG	181501.69	Taxi	165	2B	C550	JT15D-4	5673.492	17871.5	6978.395	5.673	26.04	139	359.2
LSGG	164165.197	Taxi	77	2J	B752	RB211-535E4	47470.5	149532.1	58388.72	47.47	554.91	0	361.47
LSGG	133166.837	Taxi	118	2B	F2TH	CFE738-1-1B	6164.2728	19417.46	7582.056	6.164	87.539	40.59	185.53
LSGG	117228.943	Taxi	99	3B	F900	TFE731-60-1C	5668.542	17855.91	6972.307	5.669	46.937	28.13	163.44
LSGG	114258.902	Taxi	134	2B	LJ45	TFE731-20R	4725.108	14884.09	5811.883	4.725	31.31	53.62	169.01
LSGG	112510.267	Taxi	100	2B	F2TH	CFE738-1-1B	5223.96	16455.47	6425.471	5.224	74.186	34.4	157.23
LSGG	107945.477	Taxi	96	2B	C560	JT15D-5D	3795.3216	11955.26	4668.246	3.795	16.959	271.6	287.98

Airport	Distance km	Type Traffic	Move-ments	Type	Aircraft ICAO	Engine Name	Fuel (cruise) tons	Emissions (cruise) in tons					
LSGG	181501.69	Taxi	165	2B	C550	JT15D-4	307732.68	969357.9	378511.2	307.7	4513	29.43	274.71
LSGG	164165.197	Taxi	77	2J	B752	RB211-535E4	673698.47	2122150	828649.1	673.7	7986.4	647.8	1038.2
LSGG	133166.837	Taxi	118	2B	F2TH	CFE738-1-1B	225781.85	711212.8	277711.7	225.8	3311.2	21.59	201.55
LSGG	117228.943	Taxi	99	3B	F900	TFE731-60-1C	298139.18	939138.4	366711.2	298.1	4372.3	28.52	266.14
LSGG	114258.902	Taxi	134	2B	LJ45	TFE731-20R	193723.81	610230	238280.3	193.7	2841	18.53	172.93
LSGG	106761.289	Taxi	100	2B	F2TH	CFE738-1-1B	181011.75	570187	222644.4	181	2654.6	17.31	161.58
LSGG	103217.159	Taxi	96	2B	C560	JT15D-5D	175002.74	551258.6	215253.4	175	2566.5	16.74	156.22

A2.6: Road Transportation

A2.6.1 Emission Factors

The derivation of the emission factors for road vehicles is described in detail in INFRAS 2004 (Passenger cars and light duty vehicles) and in Hausberger et al. 2002 (heavy duty vehicles). Both reports are in English. A similar report for two-wheelers exists but is available in German only (RWTÜV 2003). Some important features of the emission factor methodologies are summarised in this paragraph.

The emission factors have to differentiated according to the vehicle categories. Each category contains a number vehicle classes, which differ by emission concepts. The next table illustrates the classes of the passenger cars. Similar “segmentations” hold for the other vehicle categories too. Emission factors for vehicle classes are combined to average emission factors for vehicles categories weighted according to the fleet composition, which varies from year to year (see below).

Table 181 Vehicle segmentation of the passenger cars. Each class (segment) is subdivided into three cubic capacities: <1.4 litre, 1.4-2.0 litres, > 2.0 litres (INFRAS 2004).

Fuel	Vehicle class
Gasoline	<ECE
	ECE 15'00
	ECE 15'01-02
	ECE 15'03
	ECE 15'04
	AGV82
	Conc.div.
	unreg.Cat.
	closed L.Cat. <87
	closed L.Cat. 87-90
	closed L.Cat. 91-95(CH)
	EURO1
	EURO2
	EURO3
	EURO4
Diesel	<1986
	1986-88
	EURO1
	EURO2
	EURO3
	EURO4

The emission factors published in the handbook (CD ROM, SAEFL 2004a) are classified by “traffic situations.” A traffic situation is primarily characterised by the type of road which induces a typical driving behaviour. (Because driving behaviour is not independent of the amount of traffic on that particular road, on the same segment different driving patterns may exist.) For the handbook several typical traffic situations have been defined, based on driving behaviour studies in Germany and in Switzerland (see e.g. SAEFL 1995, chap. 4).

Table 182 Traffic situations (“TS name”) in Switzerland (SAEFL 1995, SAEFL 2004a). Every traffic situation is either equal to a driving pattern or equal to a linear combination of several driving patterns (see table below).

Traffic Situations in Switzerland							
TS Name	Description	**gradient -3% to +3%**	V (km/h)	**gradient <-3%**	V (km/h	**gradient >3%**	V (km/h
			Highway				
Highway_120	Highway, Speed limit 120, >=2 lanes/direction (avg. speed v (PC)=116 km/h, v (HDV)=86 km/h)	0.67*AE1+0.33*AE2	116	0.5*AG1+0.5*AG2	118	0.75*AS1+0.25*AS2	113
Highway_100	Highway, Speed limit 100, >=2 lanes/direction (avg. speed v (PC)=103 km/h, v (HDV)=86 km/h)	0.25*(AE1, AE2, A3, A4)	103	0.5*AG2+0.5*AGV	112	AS2	102.8

Highway_80	Highway, Speed limit 80, >=2 lanes/direction (avg. speed v (PC)=87 km/h, v (HDV)=86 km/h)	A4	87	A4	87	A4	87
Highway_100/1 lane	Highway, Speed limit 100, 1 lane/direction (avg. speed v (PC)=103 km/h, v (HDV)=86 km/h)	0.25*(AE1, AE2, A3, A4)	103				
Highway_80 /1 lane	Highway, Speed limit 80, 1 lane/direction (avg. speed v (PC)=87 km/h, v (HDV)=83 km/h)	A4	87	A4	87	A4	87
rural							
Rural_1	well developed, straight (v (PC)=77 km/h,	LE1	77	LG1	61	LS1	60
Rural_2	well developed, even bends (v (PC)=66 km/h,	LE2s	66	LG1	61	0.5*LS1+0.5*LS2	55
Rural_3	uneven bends (avg. speed v (PC)=63 km/h,	LE2u	63	LG2	51	LS2	49
Rural_4	small roads, uneven bends	LE2u	63	LG2	51	LS2	49
urban							
Urban_M1	Main road, right of way, minimal hold-ups	LE3	53	LE3	53	LE3	53
Urban_M2	Main road, right of way, medium hold-ups	0.5*LE3+0.5*LE5	42	0.5*LE3+0.5*LE5	42	0.5*LE3+0.5*LE5	42
Urban_M3	Main road, right of way, major hold-ups	LE5	31	LE5	31	LE5	31
Urban_L1	Main road, with traffic light syst, minimall hold-ups	0.25*LE3+0.5*LE5 +0.25*LE6	34	0.25*LE3+0.5*LE5 +0.25*LE6	34	0.25*LE3+0.5*LE5 +0.25*LE6	34
Urban_L2	Main road, with traffic light system, medium hold-ups	0.67*LE5+0.33*LE6	28	0.67*LE5+0.33*LE6	28	0.67*LE5+0.33*LE6	28
Urban_L3	Main road, with traffic light system, major hold-ups	0.33*LE5+0.67*LE6	24	0.33*LE5+0.67*LE6	24	0.33*LE5+0.67*LE6	24
Urban_Centre	Urban roads, in city centre	LE6	20	LE6	21	LE6	21
X:Urban_Side roads_dense	Side roads, self-contained development	LE6	21	LE6	21	LE6	21
X:Urban_Side roads_light	Side roads, light development	LE5	31	LE5	31	LE5	31
X:Urban_Stop+Go	Urban roads, Stop+Go	STGOio	5	STGOio	5	STGOio	5

Traffic situations are defined independently of vehicle categories (LDV, HDV, 2-wheelers). But behind the same traffic situation each vehicle category may know its own “driving pattern” which may be expressed as a speed curve (i.e. speed time series). Emission factors originally are derived for these underlying driving patterns based on measurements performed on laboratory test benches. Emission factors per traffic situation then are calculated by combining and weighting the emission factors of these driving patterns. In fact, the handbook provides emission factors per traffic situation which are linear combinations of emission factors per driving pattern. In the following table the driving patterns are given.

Table 183 Driving patterns in Switzerland (INFRAS 2004). “T” stands for tempo (speed) limit: T120 specifies a road with maximum velocity of 120 km/h. “v” is the average velocity driven on a road.

Driving Patterns	
A3	T 80-100, mediurm/heavy traffic; v=95.3 km/h
A4	T 80, 1-3 lanes, heavy traffic; v=86.6 km/h
A5	T 60-80, 1-3 lanes, heavy traffic; v=75.8 km/h
AB	T 80-120, 2-3 lanes, heavy traffic; v=100.2 km/h
AE1	T 120, 2-3 lanes, low traffic; v=117.8 km/h
AE2	T 100-120, 2-3 lanes; v=111.9 km/h
AG1	T 120, 2-3 lanes; v=120.1 km/h
AG2	T 100-120, 2-3 lanes; v=111.9 km/h
AGV	T 80-100; v=112 km/h
AS1	T 120
AS2	T 80-120
AV	T 80-120, 2-3 lanes, heavy traffic; v=104 km/h
K	city centre; v=19.9 km/h
LB2	continuous, acceleration phase after crossings, with priority
LB3	acceleration phase after crossings; with priority v=57 km/h
LB4	acceleration phase after settlements; v=45.4 km/h
LE1	continuous; v=77 km/h
LE2s	continuous flow; v=66 km/h
LE2u	discontinuous flow; v=62.6 km/h
LE3	with priority, undisturbed traffic flow v=53.1 km/h
LE5	traffic lights, heavily interrupted traffic flow; with priority v=31.1 km/h
LE6	traffic lights, heavily interrupted traffic flow; v=20.7 km/h
LG1	slope, continuous to narrow, v = 60.9 km/h
LG2	slope, narrow to changeable, v = 51.2 km/h
LG3	slope, changeable, v = 49.9 km/h
LS1	incline, continuous to narrow, v = 59.8 km/h
LS2	incline, narrow, changeable, v = 49.2 km/h
LS3	incline, continuous to changeable, v = 46.2 km/h
LV1	continuous,deceleration phase at settlements; v=72.9 km/h
LV2	continuous,deceleration phase at crossings; v=66.2 km/h
LV4	deceleration phase at settlements; v=43.6 km/h
STGOAB	stop and go (Highway); v=9.4 km/h
STGOio	stop and go (urban); v=5.3 km/h

Emission factors for Switzerland are shown in the next table. They represent weighted averages over all traffic situations. The year indicates the date when the corresponding vehicle class appears in the market. E.g. “Euro-3” standard came into force on Jan 1, 2001, but the first vehicles with Euro-3 standard already appeared in 1999.

Table 184 Mean emission factors of passenger cars (PW) and light duty vehicles (LI). PW/B: PC gasoline, PW/D PC diesel, LI/B LDV/gasoline, LI/D LDV diesel; G gasoline, D diesel. The values shown hold for the start year and may differ in subsequent years.

Veh categ.	Gas	Engine/Exh.Conc.	year (start)	Fuel	EF g/vec-km
PC	CO2	PW/B/Euro-1/FAV1	1987	G	224
PC	CO2	PW/B/Euro-2	1996	G	215
PC	CO2	PW/B/Euro-3	1999	G	208
PC	CO2	PW/B/Euro-4	2000	G	206
PC	CO2	PW/B/GKat<91	1986	G	225
PC	CO2	PW/B/Konv	1980	G	242
PC	CO2	PW/D/Euro-2	1995	D	219
PC	CO2	PW/D/Euro-3	1999	D	202
PC	CO2	PW/D/Euro-4	2003	D	184
PC	CO2	PW/D/konv	1980	D	227
PC	CO2	PW/D/XXIII/FAV1	1987	D	220
PC	CH4	PW/B/Euro-1/FAV1	1987	G	0.011
PC	CH4	PW/B/Euro-2	1996	G	0.015
PC	CH4	PW/B/Euro-3	1999	G	0.003
PC	CH4	PW/B/Euro-4	2000	G	0.002
PC	CH4	PW/B/GKat<91	1986	G	0.027
PC	CH4	PW/B/Konv	1980	G	0.114
PC	CH4	PW/D/Euro-2	1995	D	0.002
PC	CH4	PW/D/Euro-3	1999	D	0.001
PC	CH4	PW/D/Euro-4	2003	D	0.001
PC	CH4	PW/D/konv	1980	D	0.004
PC	CH4	PW/D/XXIII/FAV1	1987	D	0.002
PC	N2O	PW/B/Euro-1/FAV1	1987	G	0.014
PC	N2O	PW/B/Euro-2	1996	G	0.006
PC	N2O	PW/B/Euro-3	1999	G	0.003
PC	N2O	PW/B/Euro-4	2000	G	0.001
PC	N2O	PW/B/GKat<91	1986	G	0.014
PC	N2O	PW/B/Konv	1980	G	0.000
PC	N2O	PW/D/Euro-2	1995	D	0.005
PC	N2O	PW/D/Euro-3	1999	D	0.006
PC	N2O	PW/D/Euro-4	2003	D	0.006
PC	N2O	PW/D/konv	1980	D	0.000
PC	N2O	PW/D/XXIII/FAV1	1987	D	0.000
LDV	CO2	LI/B/Euro-1/FAV1	1987	G	269
LDV	CO2	LI/B/Euro-2	1996	G	238
LDV	CO2	LI/B/Euro-3	2000	G	219
LDV	CO2	LI/B/Euro-4	2002	G	217
LDV	CO2	LI/B/GKat<91	1986	G	262
LDV	CO2	LI/B/Konv	1980	G	313
LDV	CO2	LI/D/Euro-1/FAV1	1987	D	325
LDV	CO2	LI/D/Euro-2	1996	D	321
LDV	CO2	LI/D/Euro-3	2000	D	283
LDV	CO2	LI/D/konv	1980	D	362
LDV	CH4	LI/B/Euro-1/FAV1	1987	G	0.030
LDV	CH4	LI/B/Euro-2	1996	G	0.025
LDV	CH4	LI/B/Euro-3	1999	G	0.025
LDV	CH4	LI/B/Euro-4	2001	G	0.011
LDV	CH4	LI/B/GKat<91	1986	G	0.008
LDV	CH4	LI/B/Konv	1980	G	0.104
LDV	CH4	LI/D/Euro-1/FAV1	1987	D	0.002
LDV	CH4	LI/D/Euro-2	1996	D	0.002
LDV	CH4	LI/D/Euro-3	2000	D	0.001
LDV	CH4	LI/D/konv	1980	D	0.012
LDV	N2O	LI/B/Euro-1/FAV1	1987	G	0.014
LDV	N2O	LI/B/Euro-2	1996	G	0.006
LDV	N2O	LI/B/Euro-3	2000	G	0.003
LDV	N2O	LI/B/Euro-4	2002	G	0.001
LDV	N2O	LI/B/GKat<91	1986	G	0.014
LDV	N2O	LI/B/Konv	1980	G	0.000
LDV	N2O	LI/D/Euro-1/FAV1	1987	D	0.003
LDV	N2O	LI/D/Euro-2	1996	D	0.005
LDV	N2O	LI/D/Euro-3	2000	D	0.005
LDV	N2O	LI/D/konv	1980	D	0.000

Table 185 Mean emission factors of heavy duty vehicles (HDV) and urban busses (U-Bus). SMW: schwere Motorwagen = HDV, D: diesel.

Veh categ.	Gas	Engine/Exh.Conc.	year (start)	Fuel	EF g/vec-km
HDV	CO2	SMW/60er_Jahre	1960	D	870
HDV	CO2	SMW/70er_Jahre	1970	D	838
HDV	CO2	SMW/80er_Jahre	1980	D	790
HDV	CO2	SMW/Euro-1	1993	D	709
HDV	CO2	SMW/Euro-2	1996	D	682
HDV	CO2	SMW/Euro-3	1999	D	700
HDV	CH4	SMW/60er_Jahre	1960	D	0.032
HDV	CH4	SMW/70er_Jahre	1970	D	0.026
HDV	CH4	SMW/80er_Jahre	1980	D	0.021
HDV	CH4	SMW/Euro-1	1993	D	0.016
HDV	CH4	SMW/Euro-2	1996	D	0.009
HDV	CH4	SMW/Euro-3	1999	D	0.009
HDV	N2O	SMW/60er_Jahre	1960	D	0.012
HDV	N2O	SMW/70er_Jahre	1970	D	0.012
HDV	N2O	SMW/80er_Jahre	1980	D	0.012
HDV	N2O	SMW/Euro-1	1993	D	0.012
HDV	N2O	SMW/Euro-2	1996	D	0.011
HDV	N2O	SMW/Euro-3	1999	D	0.007
U-Bus	CO2	SMW/60er_Jahre	1960	D	1'273
U-Bus	CO2	SMW/70er_Jahre	1970	D	1'250
U-Bus	CO2	SMW/80er_Jahre	1980	D	1'166
U-Bus	CO2	SMW/Euro-1	1993	D	1'082
U-Bus	CO2	SMW/Euro-2	1995	D	1'055
U-Bus	CO2	SMW/Euro-3	2000	D	1'135
U-Bus	CH4	SMW/60er_Jahre	1960	D	0.085
U-Bus	CH4	SMW/70er_Jahre	1970	D	0.065
U-Bus	CH4	SMW/80er_Jahre	1980	D	0.056
U-Bus	CH4	SMW/Euro-1	1993	D	0.024
U-Bus	CH4	SMW/Euro-2	1995	D	0.014
U-Bus	CH4	SMW/Euro-3	2000	D	0.013
U-Bus	N2O	SMW/60er_Jahre	1960	D	0.015
U-Bus	N2O	SMW/70er_Jahre	1970	D	0.015
U-Bus	N2O	SMW/80er_Jahre	1980	D	0.015
U-Bus	N2O	SMW/Euro-1	1993	D	0.015
U-Bus	N2O	SMW/Euro-2	1995	D	0.015
U-Bus	N2O	SMW/Euro-3	2000	D	0.008

Details concerning the N_2O emission factors are given in the next table. The factors are taken from recent measurements by the Netherlands Organisation for Applied Scientific Research (Gense and Vermeulen 2002, 2002a; Riemersma et al. 2003). These factors are used for emission modelling in Switzerland. They are typically lower than the default values by IPCC. The vehicle fleet composition in the Netherlands is supposed to be very similar compared to Switzerland, which is one of the reasons why Switzerland uses these factors. Another reason is the year of measurement: The Dutch factors are newer than the ones by IPCC, therefore, vehicle with later emission technology may be modelled in a more representative way.

Table 186 N_2O emission factors of passenger cars (PC), light duty vehicles (LDV), heavy duty vehicles (HDV) and two-wheelers (2-W). From Gense and Vermeulen (2002, 2002a); Riemersma et al. (2003).

Veh category	Fuel	Em. concept	urban	extra-urban	motorway
			N_2O emission factor (mg/veh-km)		
PC/LDV	Gasoline	conventional	0	0	0
		Euro 0	21	13	8
		Euro 1	21	13	8
		Euro 2	13	4	2
		Euro 3	5	2	1
		Euro 4	2.5	1	0.5
	Diesel	conventional	0	0	0
		Euro 1	2	4	4
		Euro 2	4	6	6
		Euro 3	9	4	4
		Euro 4	9	4	4
HDV	Diesel	Euro 0	16.2	13.6	9.4
		Euro 1	16.2	13.6	9.4
		Euro 2	15.9	13.6	9.4
		Euro 3	8.4	7.8	5.9
		Euro 4	8.4	7.8	5.9
		Euro 5	8.4	7.8	5.9
2-W	2-stroke	conventional	1	1	1
		catalyst	1	1	1
	4-stroke	conventional	1	1	1
		catalyst	1	1	1

A2.6.2 Activity Data

Activity data for the emission model are the mileages of the vehicle categories per traffic situation. To that aim, three steps must be carried out.

1. Vehicle turnover: The vehicle fleet is built up for each year accounting for the stock changes. This vehicle turnover is modelled on the basis of new registrations and by applying survival probabilities. Trends in traffic volume per vehicle category, including structural changes (size distributions, shares of diesel vehicles) are then combined to draw the continual substitution of older technologies by new ones altering constantly the fleet composition or mileage by emission concepts in all vehicle categories (see following figure).

2. The total mileage is calculated by vehicle stock times specific mileage per vehicle and annum. The latter data are derived from household surveys and from specific odometer readings during vehicle inspections (ARE 2002).

3. Assignment of the mileage to the traffic situations for all vehicle categories. This step requires the adoption of the traffic model: Each road segment carries its mileage and its traffic, which allows the assignment sought.

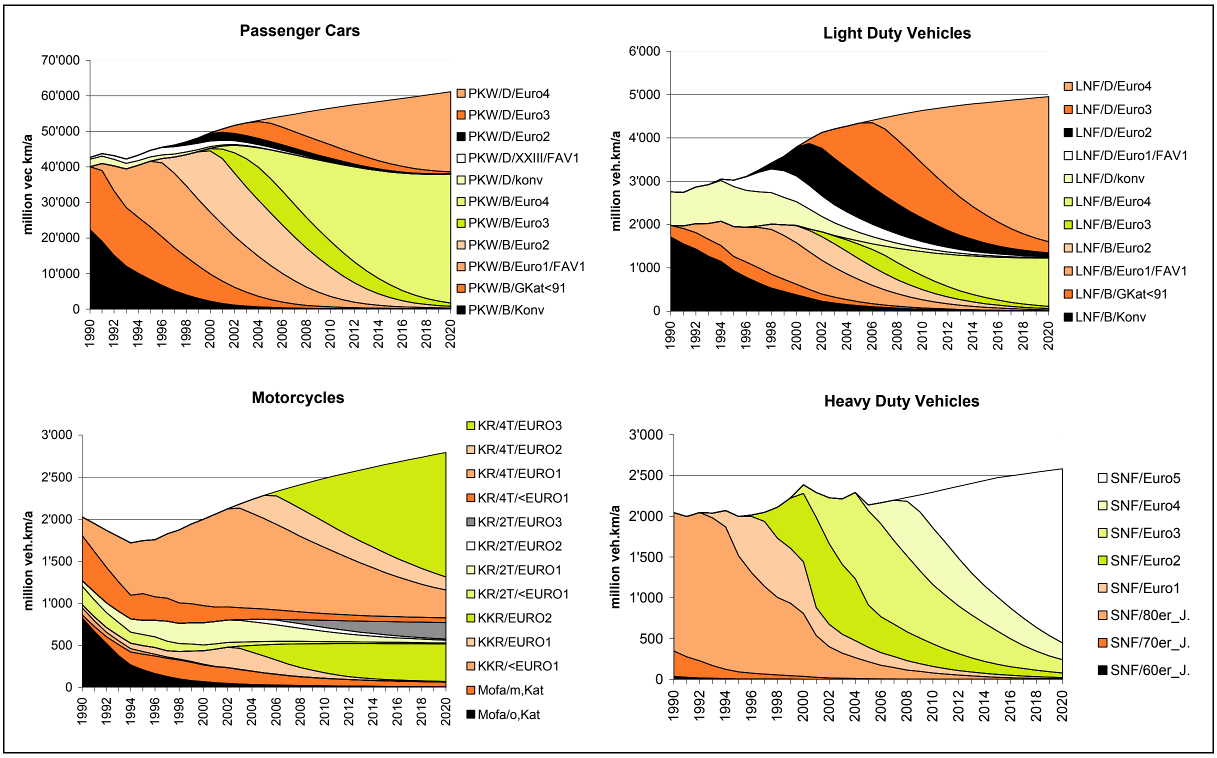

Figure 45 Mileage composition by emission concept (in million vehicle kilometres per year), SAEFL 2004.

A2.6.3 Modelling hot exhaust emissions

As a next step in the modelling process, the mileage classified by vehicle segments and traffic situations is multiplied with the emission factors resulting in hot exhaust emissions.

The results do not yet contain the emissions from tank tourism. For this purpose a special procedure is carried out (described in section 3.2.2c), providing the fuel consumption of tank tourism. From that, the emissions are calculated by multiplication with mean emission factors.

A2.6.4 Cold start and evaporative emissions

The handbook also contains emission factors for modelling cold start excess emissions and evaporative emissions (diurnal and hot/warm soak). For a technical description the reader may be referred to INFRAS (2004), SAEFL (1995, 2004).

Results show that for CO_2 the hot exhaust emissions contribute to 95% of the total. Only 5% stem from cold start excess emissions. For CH_4 however, the picture is much different. Only about a fourth of the emission total is hot exhaust. More than 50% are cold start excess emissions, the rest results evaporative emissions. For N_2O, no cold start emissions nor evaporative emissions are taken into account due to lack of data.

A2.7: Off-road Vehicles

A2.7.1 Methodology

The emissions of the whole off-road sector have undergone a complete revision. The emissions are calculated with a tier 2 method. Activity data (Electrowatt 2005) and emission factors (Mayer 2006) were updated and the emission calculation was carried out in a new database that is structured in analogy the on-road database (SAEFL 2005a).

The modelling of the emission and of the fuel consumption are carried out by using the formula

$$E^{g}_{i,j,t,\tau} = N_{i,j,t} \cdot T_{i,j,t} \cdot \omega_{t-\tau} \cdot P_{i,j} \cdot L_{i,j} \cdot \nu_{t-\tau} \cdot \varepsilon^{g}_{i,j,\tau}$$

E: Emission and fuel consumption
N: number of vehicles
T: average operating hours per year
ω: age dependency
P: motor power in kW
L: load factor
ν: degradation factor (due to aging)
ε: emission factor in g/kWh
indices: g: gas (CH_4, N_2O, CO, NO_x, SO_2) and fuel consumption,
i off-road family (railway, navigation etc.),
j size class,
t: year (1980, 1985, 1990, 1995, 2000, … , 2020)
τ: year of construction (note: t - τ = age of vehicle)

Note that the emissions are only calculated in steps of 5 years. Emissions for years in-between like 1991, 1992 etc. are interpolated linearly.

A2.7.2 Emission and fuel consumption factors for off-road vehicles

Table 187 Emission factors for off-road vehicles. The range covers the variety of engine powers (Mayer 2006).

Fuel	Fuel cons.	Emission factors in g/kWh				
		CH_4	N_2O	NO_x	VOC	CO
	g/kWh	g/kWh				
Diesel	283-310	0.0054	0.027	11.7-12.6	1.08-3.87	2.25-8.64
Gasoline, 4-Stroke	460	0.45	0.045	3.6	18	315
Gasoline, 2-Stroke	650	3.60	0.045	2.7	135	540-558
CNG	460	0.90		1.8	0.18	0.45

A comparison of the emission factors with the emission factors used in Switzerland for the CRF 2003 and the IPCC default factors (IPCC 1996) is given in the following table.

Table 188 Comparison of different emission factor sources: IPCC 1996 (vol III, tbl 1-7, 1-8, conversion factor used: 1 g/kWh = 278 kg/TJ) and Mayer 2006.

Fuel		N_2O (in g/kWh)			CH_4 (in g/kWh)		
		IPCC	CRF Switzerland		IPCC	CRF Switzerland	
		1996	2003	2004	1996	2003	2004
Diesel	Europe/USA	0.002	0.020	0.027	0.018	0.010	0.0054
Gasoline	4-stroke	0.002	0.025/0.060	0.045	0.072	0.50	0.45
	2-stroke	0.002-0.006	0.01	0.045	0.07-0.21	3.0	3.6

A2.7.3 Activity data off-road vehicles

Table 189 Number of vehicles per off-road family (Electrowatt 2005).

Off-road family	1990	1995	2000
	no. of vehicles		
Construction	56'070	52'443	47'995
Industry	12'999	17'424	21'800
Agriculture	334'375	328'987	337'933
Forestry	13'839	13'350	13'045
Garden/hobby	749'010	809'043	871'060
Navigation	93'378	89'025	82'652
Railway	1'300	1'305	1'255
Military	1'340	1'340	1'340
Sum	**1'262'311**	**1'312'917**	**1'377'080**

Table 190 Operating hours per vehicle per year and (million) operating hours per off-road family (Electrowatt 2005).

Off-road family	1990	1995	2000
	operating hours per vehicle per year		
Construction	299	353	383
Industry	623	645	658
Agriculture	160	161	155
Forestry	274	271	270
Garden/hobby	58	59	60
Navigation	40	39	40
Railway	612	627	616
Military	51	53	54
Average	**103**	**105**	**105**

Off-road family	1990	1995	2000
	mill. operating hours per year		
Construction	16.7	18.5	18.4
Industry	8.1	11.2	14.4
Agriculture	53.4	52.9	52.4
Forestry	3.8	3.6	3.5
Garden/hobby	43.4	47.9	52.5
Navigation	3.7	3.4	3.3
Railway	0.8	0.8	0.8
Military	0.1	0.1	0.1
Sum	**130.0**	**138.5**	**145.3**

Table 191 Fuel consumption of several off-road activities in 1’000 t/a (SAEFL 2005a).

Fuel	Off-road family	1990	1995	2000
		fuel consumption in 1000 t/a		
Diesel	Construction	117.5	136.7	145.0
	Industry	19.5	26.2	32.5
	Agriculture	149.3	160.2	169.3
	Forestry	9.8	10.2	11.0
	Navigation	21.7	20.0	20.2
	Railway	26.4	30.0	29.2
	Military	1.2	1.3	1.3
	Sum diesel	**345.5**	**384.5**	**408.5**
Gasoline	Construction	6.1	6.3	5.4
	Industry	1.5	2.1	2.7
	Agriculture	37.3	33.6	29.8
	Forestry	3.0	2.9	2.8
	Garden/hobby	14.2	15.8	17.3
	Navigation	12.5	11.7	12.5
	Military	0.01	0.01	0.01
	Sum gasoline	**74.6**	**72.3**	**70.4**
Gas oil	**Navigation**	**5.2**	**5.7**	**5.7**
CNG	**Industry**	**3.6**	**5.4**	**7.3**

Annex 3: Industrial Processes

A3.1 Documentation of Model for Mobile Air-Conditioning / Cars

Table 192 Model structure and assumptions for calculating emissions from mobile air conditioning in cars (2003 data. For 2004 no change in model has taken place).

Parameters for Car Air-Conditioning

Emission Factor 1995	8.5%	[% of initial charge/a]		Emissions from servicing and disposal are calculated separately
share recharged regularly	*6.0%*	Note: To correlate the data with import statistics the rehacrged amount is calculated.		
share not recharged	*2.5%*	This information is used for verification through Tier 1b.		
all units are imported with refrigerant charged				
Product life	12	[a]		
initial charge 1995 [kg]	0.81	Initial charge 2000	0.78	other years are inter-/extrapolated)
charge at end of lifetime	60%	[% of initial charge, as per literature]		
Disposal emissions	100%	up to 2004		
	30%	from 2005		
export of 2nd hand cars	50%			
Servicing emission factor	2 times	10%	of initial charge per lifetime	
Market growth rate	1%			

Model for Car A/C emissions

Year	new registered cars (VSAI, EFKO)	Stock (B. f. Statistik)	Disposed cars	A/C units new cars Car-Input [%]	R134a [%]	Units R134	Stock of A/C units Stock [%]	units R134	Disposed units R134	initial charge kg / car
1989	335'094	2'895'842		5	0	0	0	0	0	0.85
1990	327'456	2'985'399	237'899	**6**	0	0	0	0	0	0.84
1991	314'824	3'057'800	242'423	7	10	2'204	0	2'204	0	0.83
1992	296'009	3'091'230	262'579	9	30	7'992	0	10'196	0	0.83
1993	262'814	3'109'524	244'520	**14**	66	24'284	1	34'480	0	0.82
1994	270'009	3'165'043	214'490	19	90	46'172	3	80'652	0	0.82
1995	272'897	3'229'169	208'771	**24**	100	65'495	5	146'147	0	0.81
1996	269'529	3'268'073	230'625	38	100	102'421	8	248'568	0	0.80
1997	272'441	3'323'421	217'093	**52**	100	141'669	12	390'237	0	0.80
1998	297'336	3'383'275	237'482	**68**	100	202'188	18	592'426	0	0.79
1999	317'985	3'467'275	233'985	**75**	100	238'489	24	830'914	0	0.79
2000	315'398	3'545'247	237'426	77	100	242'856	30	1'073'771	0	0.78
2001	317'126	3'629'713	232'660	85	100	269'557	37	1'343'328	0	0.78
2002	295'109	3'704'822	220'000	87	100	256'745	43	1'600'073	0	0.78
2003	271'541	3'754'000	222'363	89	100	241'671	49	1'840'188	1'557	0.78
2004	*274'256*	*3'791'540*	236'716	*91*	*100*	*249'573*	*55*	*2'083'370*	6'391	0.78
2005	*276'999*	*3'829'455*	239'084	*92*	*100*	*254'839*	*60*	*2'316'117*	22'091	0.78
2006	*279'769*	*3'867'750*	241'474	*92*	*100*	*257'387*	*65*	*2'532'213*	41'292	0.78
2007	*282'567*	*3'906'427*	243'889	*93*	*100*	*262'787*	*70*	*2'736'466*	58'533	0.78
2008	*285'392*	*3'945'492*	246'328	*93*	*100*	*265'415*	*74*	*2'908'277*	93'605	0.78
2009	*288'246*	*3'984'947*	248'791	*94*	*100*	*270'951*	*77*	*3'049'857*	129'371	0.78
2010	*291'129*	*4'024'796*	251'279	*94*	*100*	*273'661*	*78*	*3'152'648*	170'870	0.78

Modelling of car A/C refrigerants

R 134a	Input [t]	Stock [t]	Emissions Stock + Servicing [t]	Disposal [t]	Servicing [t]	Import for Servicing [t]
1990	0	0	0	0.0	0	0
1991	2	2	0	0.0	0	0.1
1992	7	8	0	0.0	0	0.3
1993	20	28	2	0.0	0	1.1
1994	38	64	4	0.0	0	2.8
1995	53	113	8	0.0	0	5.3
1996	82	188	13	0.0	1	9.0
1997	113	287	22	0.0	2	14.3
1998	160	425	34	0.0	4	21.4
1999	187	579	48	0.0	5	30.1
2000	189	720	63	0.0	8	39.0
2001	210	867	79	0.0	11	47.6
2002	200	989	95	0.0	16	55.7
2003	**189**	**1'082**	**107**	0.8	**19**	**62.1**
2004	*195*	*1'169*	*115*	*3.2*	*19*	67.5
2005	*199*	*1'250*	*124*	*3.3*	*21*	72.6
2006	*201*	*1'324*	*129*	*6.1*	*20*	77.2
2007	*205*	*1'393*	*134*	*8.5*	*19*	81.5
2008	*207*	*1'458*	*141*	*13.5*	*19*	85.5
2009	*211*	*1'515*	*146*	*18.6*	*20*	89.2
2010	*213*	*1'563*	*151*	*24*	*20*	92.3

Annex 4: Agriculture

Livestock Population Data for N_2O Emission Calculation

Table 193 Livestock population data 2004 for N_2O calculation.

Animals 2004		Number of animals	kg N per head/year	FracGASM (6)	N volatilized (kg N)
Cattle		**854'241**			
	Milk fed calf and suckler cow calf	167'950	13	0.01	13'988
	Breeding calf and breeding cattle 1	214'653	25	0.01	50'245
	Breeding cattle 2	326'262	40-55	0.01	194'877
	Fattening calf	35'823	8	0.00	241
	Fattening cattle	108'862	33	0.01	37'871
	Dairy cattle (1)	621	106.5	0.19	12'347
	Non-Dairy cattle (only suckler cows) (1)	70	106.5	0.19	1'392
Swine		**1'537'505**			
	Fattening pig places (2)	859'216	13	0.04	455'164
	Breeding pig places (3)	145'760	35	0.02	94'949
Sheep		**440'522**			
	Sheep places (4)	227'499	12	0.00	8'275
Goats		**70'627**			
	Goat places (5)	37'864	16	0.00	844
Horses		**53'701**			
	Foals < 1 year	3'414	17	0.00	9
	Foals 1 - 2 years	5'964	42	0.00	159
	Other horses	44'323	44	0.00	9'652
Ponies, Mules and Asses		**14'846**	26	0.00	378
Poultry		**8'060'688**			
	laying hens	2'088'751	0.7	0.01	9'419
	young hens < 18 weeks	853'080	0.3	0.00	360
	broilers	4'970'793	0.4	0.01	15'050
	turkeys	148'064	1.4	0.00	164
Total		**11'032'130**		**0.33**	**905'384**

(1) N excretion calculated based on milk production: 105 kg N/head/year at a milk production of 5000 kg/head/year, increased by 10% for every 500 kg additional milk production. Milk production 2004: 5680 kg/head/year.
(2) One fattening pig place corresponds to one fattening pig over 25 kg, 1/6 fattening pig place to one young pig below 30 kg.
(3) One breeding pig place corresponds to one sow, 1/2 breeding pig place to one boar.
(4) One sheep place corresponds to one ewe over one year. Other sheep are not included.
(5) One goat place corresponds to one goat over 1.5 years. Goats younger than 1.5 years are not included.
(6) includes ammonia volatilization calculated for each species based on management practice and NO emissions of 1.5% of the excreted N.

Additional Data for N_2O Emission Calculation of Agricultural Soils

Table 194 Additional data for N_2O emission calculation of agricultural soils.

2004	Nitrogen incorporated with crop residues (t N)	Dry matter production (kg DM)	N2O emissions from crop residues (t N2O)	N fixed per kg crop (kg N/kg crop)	N fixed (kg N)	N2O emissions from N fixation (t N2O)
1. Cereals						
Wheat	3'413	458'065'000	67			
Barley	1'245	218'875'000	24			
Maize	1'287	153'510'000	25			
Oats	99	13'175'000	2			
Rye	76	9'350'000	1			
Other (please specify)						
Spelt	77	8'585'000	2			
Triticale	832	70'720'000	16			
Mix of fodder cereals	7	1'190'000	0			
Mix of bread cereals	1	85'000	0			
2. Pulse						
Dry bean	31	787'950	1	0.0443	41'020	0.8
Eiweisserbsen/peas	335	14'224'750	7	0.0330	552'255	10.8
Soybeans	254	6'137'000	5	0.0571	412'406	8.1
Other (please specify)						
Leguminous vegetables	336	3'277'895	7	0.0177	322'747	6.3
3. Tuber and Root						
Potatoes	503	115'676'000	10			
Other (please specify)						
Fodder beet	185	19'800'000	4			
Sugar beet	3'009	318'780'000	59			
5. Other (please specify)						
Grass	22'334	6'255'233'127	439	0.0051	31'623'498	621.2
Silage corn	247	1'094'280'000	5			
Green corn	27	186'027'600	1			
Fruit	267	66'786'030	5			
Vine	182	30'380'600	4			
Renewable energy crops	49	3'150'000	1			
Non-leguminous vegetables	1'081	69'200'000	21			
Sunflowers	243	11'475'000	5			
Tobacco	36	1'400'000	1			
Rape	746	47'988'000	15			
Total Non-leguminous	13'612	2'898'498'230	267	0.0051	31'623'498	621.2
Total Leguminous	956	24'427'595	19	0.1521	1'328'428	26.1
Total	14'568	2'922'925'825	286	0.1571	32'951'926	647.3

Annex 5: Inventory Development Plan

Updated Version 26 October 2006

This updated version of the Inventory Development Plan covers the inventory status of the 10 November 2006 submission (together with the Initial Report). New improvement items are listed in chapter 10.

Explanation of column "Responsibility":

If more than one institution is mentioned, the first one has the lead.

Explanation of column "Status":

P: Work in progress

F: Work finished

pR: Work partially realized

Abbreviations

AD	Activity data	LUCF	Land Use Change and Forestry
CS	Country-specific	LULUCF	Land Use, Land Use Change and Forestry
CRF	Common Reporting Format	NIR	National Inventory Report
EF	Emission factor	NFI	National Forest Inventory
ERT	Expert review team	Para.	Paragraph
ICR	In-country review	QA/QC	Quality assurance/Quality control
IEF	Implied emission factor	Ref.	Reference
GPG	Good Practice Guidance	Sub.	Submission

Agencies / Consultants

ART	Agroscope Reckenholz-Tänikon Research Station (former: FAL)
Carbotech	Private Consultants (Experts synthetic gases)
EBP	Ernst Basler + Partner AG, private consultants (NIR co-authors)
ETHZ	Swiss Federal Institute of Technology, Zürich, Institute of Animal Sciences / Animal Nutrition
FOCA	Federal Office of Civil Aviation
FOEN	Federal Office for the Environment FOEN
INFRAS	INFRAS Forschung und Beratung, private consultants (NIR co-authors)
SFOE	Swiss Federal Office of Energy

Persons (from FOEN)

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NM	Nauser Markus
SA	Schellenberger Andreas
THE	Thürig Esther

1. General Aspects

	Improvement	Ref. to paragraph of review report[1]	Priority	Time-schedule Implementation	Responsibility	Workload	Status
1	Implementation of National Inventory System within Climate Reporting Project	8, 34					F
2	Redesign of EMIS database including a checking and updating of activity data and emission factors	33, 106					F
3	Exclusion of the fossil fuel emissions of Liechtenstein from Swiss GHG inventory for all inventory years	5, 35g					F
4	Consistent use of notation keys and extended use of documentation boxes	19, 35c					F
5	Background documentation in English	107					pR (see item 111)

2. Transparency and Completeness

	Improvement	Ref. to paragraph of review report[1]	Priority	Time-schedule Implementation	Responsibility	Workload	Status
6	Increase of transparency: - in particular for country-specific approaches, - for Agriculture - and LUCF sector; - Better explanation of external sources for estimating country-specific emission factors	7, 9a, 32, 35c, 40 20, 111,112 20, 139 21					F
7	Data in CRF and NIR not identical, to be corrected in NIR	22					F
8	Documentation and verification of the decisions to use country-specific approaches	7					F

3. Recalculations, Time Series Consistency, Key Source Analysis

	Improvement	Ref. to paragraph of review report[1]	Priority	Time-schedule Implementation	Responsibility	Workload	Status
9	Refinement of key source analysis, more detailed disaggregation to identify important sub-sources	77, 110 +Verbal Proposition of experts during ICR					F
10	Explanation of the reasons and expanded discussion of recalculations, QA/QC procedures before starting recalculations	9c, 24, 35c, 44					F

4. Uncertainties and Quality Assurance / Quality Control

	Improvement	Ref. to paragraph of review report[1]	Priority	Time-schedule Implementation	Responsibility	Workload	Status
11	Quantitative uncertainty analyses	9b, 11, 25, 26, 32, 35d, 47, 105, 115, 141, 155, 166					F
12	Development of a formal Quality assurance/quality control plan	9c, 9d, 22, 27, 28, 35f, 48, 116, 142, 156, 167					F
13	Plan for the verification of AD provided by outside agencies	48					F

5. Institutional Arrangements and Record Keeping / Archiving

	Improvement	Ref. to paragraph of review report[1]	Priority	Time-schedule Implementation	Responsibility	Workload	Status
14	Establishment of institutional and procedural arrangements for collaboration between the SAEFL and other contributors	30, 113, 71, 162					F
15	Institutional arrangements and responsibility in LULUCF sector to be defined	137, 158					F
16	Improving flow of information for CRF and NIR in LUCF sector						F
17	Improving archiving system for documentation	9d, 31, 35b					pR (see item 111)
18	Improving archiving system for data sets	9d, 31					F

6. Energy

	Improvement	Ref. to paragraph of review report[1]	Priority	Time-schedule Implementation	Responsibility	Workload	Status
19	Time series inconsistency of manufacturing Industries and Other Sectors (new division of data into industry and commercial sector)	46, 71					F
20	Industry-data of 1.A.2f Other to be disaggregated into the IPCC categories	60, 71					F
21	More details for emissions from waste fuels in cement industry (AD and EF)	63					F
22	More details on use of EF’s across the time series and carbon content / heating value of fuels in NIR (year-to-year variations of carbon content)	42, 47, 75					F
23	Revision of oxidation factor (in particular coal), inclusion in uncertainty estimate	73					F
24	Emissions arising from electricity generation by waste combustion to be moved from Waste to Energy sector	74, 160					F
25	Clear distinction between annually collected and interpolated data	41					F

	Improvement	Ref. to paragraph of review report[1]	Priority	Time-schedule Implementation	Responsibility	Workload	Status
26	Description of interpolation/extrapolation methods	41					F
27	Inclusion of new Off-Road data, better description of off-road data	44, 55, 59, 66, 71					F
28	More precise description of methodologies that differ from IPCC	35e					F
29	Better Documentation of weighted fuel averages in sector 1.A.1 as well as in general	42, 65					F
30	Further details on military and civil aviation (separate reporting)	58					F
31	New modeling of aviation emis-sions (division domestic vs. international)	71					F
32	Better documentation for civil aviation	44, 51, 52					F
33	Further details on estimation of 1990, 91 emissions of cement industry	63					F
34	Table of EFs used in the calculations for cement industry	63					F

	Improvement	Ref. to paragraph of review report[1]	Priority	Time-schedule Implementation	Responsibility	Workload	Status
35	Inconsistent IEF (1994 CRF) for biomass from commercial/institutional	45					F
36	CO2 emissions from oil refinery fugitives to be included	39					F
37	International marine bunker to be included	39, 50					F
38	Inconsistencies of trend shown for iron and steel combustion and process emission	48, 61					F
39	Improved AD for grass drying (held constant since 1990)	55					F
40	Discrepancy with IEA aviation data	58					F
41	Different EF for industrial boilers and engines (precursors only)	62, 71					F
42	CH4 and N2O emissions from fuel consumption of cement industry to be included	63, 71					F
43	Details on AD of lime and glass production in NIR	64					F
44	Estimation of CO2 emissions from distribution of oil products missing	67					F
45	New estimation of emissions from CH4 leaks in gas	68					F

	Improvement	Ref. to paragraph of review report[1]	Priority	Time-schedule Implementation	Responsibility	Workload	Status
	pipelines (incl. transfer pipeline crossing Switzerland)						
46	EF for flaring of oil is outlier and should be checked	69					F

7. Industrial Processes and Solvent Use

	Improvement	Ref. to paragraph of review report[1]	Priority	Time-schedule Implementation	Responsibility	Workload	Status
47	Inconsistencies in CRF and NIR data (synthetic gases, errors in CRF, wrong units in NIR)	84, 85, 92					F
48	Review of emission factor for CO2 from clinker. Measurements of CaO content of clinker and possible non-carbonate feeds to kiln	88					P (see item 114)
49	PFC EF not consistent between CRF and NIR, better description in NIR	98					F
50	SF6 from magnesium foundries: NIR incorrect for start time (1997), use of notation key “C” in CRF	102					F
51	CO2 from solvent emission missing (oxidation in atmosphere), to be checked	Not covered in ICR report					F
52	Consistency of time series of SF6 for 1990-94 to be checked, better documentation of recalculation of 1990 SF6 data	82					F
53	Difference between CRF and UN statistics for cement	90					F

	Improvement	Ref. to paragraph of review report[1]	Priority	Time-schedule Implementation	Responsibility	Workload	Status
	production to be explained						
54	Move emissions from ferroalloys production to non-ferrous metals	101					F
55	C3F8 ratio of potential to actual emissions should be checked	104					F
56	SF6 in sub-source 2.F.5. Solvents not covered by IPCC GPG	94					F
57	CO2 EF for Iron and Steel and Aluminium Production to be documented	95					F
58	Revision of country-specific PFC emission factor	98					F
59	Review of EF and AD of lime production	99, 100					F

8. Agriculture

	Improvement	Ref. to paragraph of review report[1]	Priority	Time-schedule Implementation	Responsibility	Workload	Status
60	Improve documentation in the NIR	133					F
61	Consideration of subcategories of dairy and non-dairy cattle	117					F
62	Units of EFs of crop residues and N-fixing crops to be checked	120					F
63	Information currently given in Table 4.F to be included in a table in NIR	126					F
64	Explanation of „animal places“, discussion of use in tables 4.A and 4.B	129					F
65	Not enough information in NIR about country-specific methods and EFs	111, 112					F
66	Time series inconsistency in N2O from cattle	Not covered in ICR report					F
67	ERT questions low uncertainty for enteric fermentation	115, 25					F
68	More detailed description of country-specific method for calculating gross energy intake	118					F

	Improvement	Ref. to paragraph of review report[1]	Priority	Time-schedule Implementation	Responsibility	Workload	Status
69	Emissions from sewage sludge and compost used for fertilizing to be reported in table 4.D. Other (AD in NIR)	119					F
70	Explanation of choice of $Frac_{Leach}$ of 0.2 instead of 0.3 (IPCC)	122					F
71	Documentation of N-input values as AD for indirect emissions of N2O from leaching and run-off	123					F
72	Documentation of NH3 input values for calculation of indirect N2O emissions from deposition, more details on losses of NH3 from pasture	124					F
73	Create table for N amount that ends up in N2O in NIR	125					F
74	Check table of fractions used for N2O from soils (not filled in properly)	126					F
75	More information about CS values for volatile solids in manure (CH4)	127					F
76	Are all manure management systems covered? NIR should mention on what basis the distribution between the	128					F

	Improvement	Ref. to paragraph of review report[1]	Priority	Time-schedule Implementation	Responsibility	Workload	Status
	management systems has been made						
77	Description of the method used for CH4 conversion rate of poultry missing	118					F
78	N2O from burning of agricultural residues missing	111					F
79	Notation key NO in 4.C and 4.E	131					F
80	Tables 4.C, 4.E to be completed	19					F

9. Land Use, Land-Use Change and Forestry

	Improvement	Ref. to paragraph of review report[1]	Priority	Time-schedule Implementation	Responsibility	Workload	Status
81	Gross annual growth of timber still among the highest values reported by Annex 1 countries; to be checked	147					F
82	Conversion from cropland or grassland to forest (as well as other Land use changes) to be reported separately; Accounting for land use changes in general	138, 157					F
83	CO2 emissions from liming to be estimated	138, 149					F
84	More detailed information in NIR on how annual changes in forest area from annual forest statistics are combined with NFI data	138					F
85	NIR not transparent enough: - Sources of AD for forest area - methodological approach of NFI - method to estimating area covered by cultivated organic soils	139, 158					F

	Improvement	Ref. to paragraph of review report[1]	Priority	Time-schedule Implementation	Responsibility	Workload	Status
86	Better fit with IPCC categories; disaggregation 5.A., 5.B., 5.C.; fill in data in 5.B (Forest and Grassland Conversion) and 5.C (Abandonment of Managed Land)	144, 146, 19					F
87	Problems of different forest definitions by AD (from NFI, Area statistics, digital maps)	145					F
88	Information in table 5.D missing	151					F
89	Estimation of above-ground and below-ground carbon budgets	152					pR (see item 112)
90	Notation keys and AD for cultivated organic soils to be checked	143					F
91	Incorporate non-forest trees	148					pR (see item 112)

10. Waste

	Improvement	Ref. to paragraph of review report[1]	Priority	Time-schedule Implementation	Responsibility	Workload	Status
92	Completeness of Waste sector to be checked: - CH4 from composting - N2O and CH4 from on-site waste water treatment for commercial sources and industrial waste water	162, 170					F
93	Check use of notation keys and give values of methane correction factor and degradable organic carbon in 6.A and 6.C	163					F
94	Check fractions of waste in additional info to table 6.A	163					F
95	Inconsistency CRF – NIR (IEF in CRF not given, but EF given in NIR, e.g. 6.A)	163					F
96	Not enough information about existing model on CH4 from solid waste disposal. Country specific model not in line with IPCC (redesign of model)	164, 168					F
97	More information on activity data in NIR	164					F
98	Documentation of recalculations	165					F

	Improvement	Ref. to paragraph of review report[1]	Priority	Time-schedule Implementation	Responsibility	Workload	Status
99	Improvement of waste database	162					F
100	N2O from human sewage missing, more information on human sewage in general	163, 175					F
101	Better documentation in NIR on CH4 recovered for energy generation	169					F
102	More information on recycling activities to be provided in the NIR and reflected in CRF table 6.A (other waste)	170					F
103	Information on specific EFs on each type of waste incinerated and explanation of selection of 60 % for organic fraction	172					F
104	Improve transparency for each type of incinerated waste	172					F
105	Emissions from industrial waste-water treatment plants and industrial disposal facilities not covered, to be included	173					F
106	Improve method for estimating municipal waste water treatment	174					F
107	Various burn-out efficiencies for different kinds of waste not taken into account, to be	172					F

	Improvement	Ref. to paragraph of review report[1]	Priority	Time-schedule Implementation	Responsibility	Workload	Status
	checked						
108	Better data on clinical and special waste	171					F

11. New Items (2005/2006)

	Improvement	Ref. to paragraph of review report[1]	Priority	Time-schedule Implementation	Responsibility	Workload	Status
109	CO_2 Emissions from thermal post-combustion of VOC's						F
110	Synthetic gases: Fill in of potential emissions by sources in Table 2(I); Documentation of PFC emissions in aluminium industry		Medium	Submission April 07	Carbotech	Low	P
111	QA/QC: Further development and implementation of the quality management system		High	End 07	FOEN (SA)	High	P
112	LULUCF: Enlargement of sampling size; Small methodological adjustments; Implementation of results of National Forest Inventory III		High	Depending on data availability	LULUCF working group (SA, THE)	High	P
113	Uncertainty analysis: Improvement of uncertainty estimations; Inclusion of LULUCF categories		Medium	End 07	EBP	Medium	P
114	Cement Industry: Internal Review of CaO content in clinker and of EF of waste-derived fuels		High	Depending on data availability	FOEN (FP) / EBP	Medium	P
115	Key Category Analysis: Use of Tier 2 method; Inclusion of LULUCF categories		Medium	End 07	EBP / INFRAS	Medium	P