National Inventory Report 2009
Sweden

Submitted under the United Nations Framework
Convention on Climate Change and the Kyoto Protocol

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Preface

According to Articles 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC), parties are required to, on an annual basis, submit national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol. This report is also a submission under the Kyoto Protocol.

This is Sweden's National Inventory Report (NIR) for the year 2009. It contains national greenhouse gas emission inventories for the period 1990 to 2007, and descriptions of methods used to produce the estimates. The methods used to calculate the emissions and removals are in accordance with the Revised IPCC 1996 Guidelines for National Greenhouse Gas Inventories and the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. The report is prepared in accordance with the Reporting Guidelines, agreed by the UNFCCC at the eighth session of the Conference of the Parties (COP) in New Delhi 2002 and subsequent decisions.

Sweden will in the beginning of 2009 submit a revised NIR and the CRF-tables for submission 2008. The reason for the resubmission is identification of an error which to a large extent affected the calculations made for the LULUCF-sector.

This inventory is coordinated, on behalf of the Swedish Ministry of Environment, by the Swedish Environmental Protection Agency.

January 2009

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Director-General in charge at the Swedish Environmental Protection Agency

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Sammanfattning

(Swedish Summary)

S 1. Bakgrund

Växthusgaser har alltid funnits i atmosfären, men på grund av mänsklig aktivitet har koncentrationen av många av dem ökat, vilket intensifierar växthuseffekten. 1988 bildades Intergovernmental Panel on Climate Change (IPCC) och två år senare konstaterade de att antropogen klimatpåverkan utgjorde ett globalt hot och efterfrågade en internationell överenskommelse för att hantera problemet. FN:s generalförsamling inledde förhandlingar om en ramkonvention kring klimatförändringar (UNFCCC), vilken trädde i kraft 1994. Dess långsiktiga mål är att stabilisera halterna av växthusgaser i atmosfären på en nivå som förhindrar skadliga antropogena klimatförändringar från att äga rum. Det viktigaste tillägget till konventionen förhandlades fram i Kyoto, Japan, 1997. Kyotoprotokollet innebär bindande åtaganden gällande utsläppsmängder för Annex I-länderna, vilket innebär att dessa länders utsläpp av växthusgaser under åren 2008-2012 i medeltal ska vara minst 5 % lägre än under basåret 1990.

Enligt Artikel 4 och 12 i UNFCCC måste medlemsstaterna årligen rapportera sina utsläpp från källor och upptag i sänkor för alla växthusgaser som inte omfattas/kontrolleras av Montrealprotokollet. Rapporteringen ska innefatta utsläppssiffror i ett speciellt format (CRF) och en nationell inventeringsrapport (NIR).

Denna rapport utgör Sveriges NIR 2009. Rapporten omfattar utsläpp till luft av de direkta växthusgaserna CO_2, CH_4, N_2O, HFC, PFC, SF_6 och de indirekta växthusgaserna NO_X, CO, NMVOC och SO_2. Rapporten innehåller information om Sveriges inventering av växthusgaser för alla år från 1990 till 2007, inklusive beskrivningar av metoder, datakällor, osäkerheter, den kvalitetssäkring och kvalitetsstyrning (QA/QC) som görs och en trendanalys.

De elektroniska data, såsom emissioner, aktivitetsdata, värmevärden och emissionsfaktorer som UNFCCC efterfrågar i CRF-tabeller, finns i en separat bilaga till denna rapport.

S 2. Sammanfattning av nationella utsläpp och upptag samt trender

Totala utsläppet av växthusgaser i Sverige, uttryckt i koldioxidekvivalenter, var 65,41 miljoner ton år 2007 (Tabell S 1), vilket är en minskning med 1,46 miljoner ton jämfört med 2006. Utsläppen har minskat med ca 9,1 %, eller ca 6,5 miljoner ton, mellan 1990 och 2007. Sedan 1999 har de totala utsläppen av växthusgaser legat på lägre nivå än 1990. Nettoupptaget för sektorn Markanvändning, Förändrad markanvändning och Skogsbruk (LULUCF) uppgick till ca 20,5 miljoner ton koldioxidekvivalenter 2007. Sänkans storlek har

varierat under perioden 1990-2007, men trenden pekar mot en något minskande sänka. (Tabell S 1).

Utsläppen av koldioxid var 51,6 miljoner ton år 2007 vilket är 8,2 % lägre jämfört med 1990 (Tabell S 1). Energisektorn, inklusive transporter, står för ca 90 % av de totala koldioxidutsläppen och är därmed den största källan till koldioxidutsläpp i Sverige. Koldioxid står för ca 79 % av de totala utsläppen av växthusgaser.

Metanutsläpp kommer framför allt från jordbruk och avfallsdeponier och var ca 5,35 miljoner ton 2007 räknat som koldioxidekvivalenter (Tabell S 1). Sedan 1990 har utsläppen av metan minskat med ca 20 %, vilket främst beror på åtgärder inom avfallssektorn.

2007 var totala utsläppen av lustgas nästan 7,2 miljoner ton räknat som koldioxidekvivalenter (Tabell S 1), vilket är en minskning med ca 15 % jämfört med 1990. Utsläpp av lustgas kommer huvudsakligen från jordbruk, men också från energiproduktion, hantering av avloppsvatten och industriprocesser. Jordbrukssektorn står för den största delen av minskningen.

Totala utsläppen av fluorerade gaser (PFCs, HFCs och SF_6) 2007 var ca 1,25 miljoner ton uttryckt i koldioxidekvivalenter (Tabell S 1). Detta innebär en ökning av utsläppen med 157 % jämfört med 1990. Ökningen beror främst på att ozonförstörande ämnen ersatts av HFC.

Tabell S 1 Utsläpp av växthusgaser ämnesvis (Gg CO_2 ekvivalenter)

UTSLÄPP AV VÄXTHUSGASER	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
	CO_2 equivalent (Gg)																	
CO_2 incl. netto CO_2 från LULUCF	24 123	23 523	26 014	27 749	33 590	32 470	31 592	22 533	21 168	20 184	17 690	21 866	20 547	22 252	23 187	23 703	27 013	31 043
CO_2 excl. netto CO_2 från LULUCF	56 257	56 930	56 722	56 203	58 865	57 993	61 504	56 925	57 441	54 610	53 370	54 110	55 064	55 888	55 317	52 950	52 727	51 621
CH_4 incl. CH_4 från LULUCF	6 711	6 697	6 784	6 831	6 754	6 667	6 632	6 579	6 405	6 258	6 075	6 045	5 871	5 733	5 754	5 629	5 543	5 360
CH_4 excl. CH_4 från LULUCF	6 709	6 696	6 782	6 830	6 752	6 666	6 630	6 570	6 404	6 255	6 072	6 042	5 866	5 727	5 749	5 624	5 530	5 357
N_2O incl. N_2O från LULUCF	8 559	8 446	8 340	8 467	8 527	8 398	8 524	8 431	8 420	7 985	7 892	7 751	7 679	7 648	7 639	7 533	7 545	7 296
N_2O excl. N_2O från LULUCF	8 480	8 385	8 288	8 411	8 471	8 334	8 460	8 366	8 354	7 914	7 818	7 676	7 606	7 567	7 548	7 430	7 431	7 181
HFCs	4	8	10	30	73	127	205	313	386	489	565	612	664	709	770	797	826	855
PFCs	377	380	252	291	312	343	303	280	272	291	241	236	261	258	254	257	245	248
SF6	107	109	108	97	100	127	108	153	99	102	94	111	104	69	81	142	111	150
Totalt (incl. LULUCF)	39 881	39 163	41 508	43 465	49 356	48 132	47 365	38 289	36 749	35 310	32 556	36 621	35 126	36 670	37 685	38 061	41 283	44 952
Totalt (excl. LULUCF)	71 934	72 508	72 163	71 861	74 573	73 590	77 210	72 607	72 957	69 662	68 159	68 788	69 565	70 220	69 718	67 200	66 870	65 412

Tabell S 2 Utsläpp av växthusgaser sektorsvis (Gg CO_2 ekvivalenter)

KÄLLOR TILL OCH SÄNKOR AV VÄXTHUSGASER	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
	CO_2 equivalent (Gg)																	
Energi	53 313	54 195	54 145	53 643	56 091	55 149	58 925	54 372	54 807	52 150	50 682	51 197	52 267	53 003	52 379	49 578	49 346	48 237
Industriprocesser	5 792	5 687	5 383	5 455	5 752	5 907	5 816	5 719	5 858	5 663	5 846	6 009	5 920	6 031	6 095	6 614	6 672	6 533
Användning av lösningsmedel och andra produkter	332	320	326	315	293	309	312	321	318	299	278	269	276	292	311	301	294	294
Jordbruk	9 383	9 146	9 150	9 398	9 503	9 300	9 257	9 328	9 160	8 858	8 747	8 753	8 689	8 590	8 641	8 553	8 502	8 431
Markanvändning, förändrad markanvändning och skogsbruk	-32 053	-33 344	-30 655	-28 397	-25 217	-25 458	-29 846	-34 319	-36 208	-34 352	-35 603	-32 167	-34 439	-33 550	-32 033	-29 139	-25 587	-20 460
Avfall	3 113	3 159	3 159	3 050	2 935	2 926	2 900	2 866	2 813	2 693	2 605	2 560	2 414	2 303	2 293	2 153	2 056	1 917

S 3. Översikt över utsläppsberäkningar och trender sektorsvis

De metoder som använts för att beräkna utsläpp och upptag överensstämmer med 'Revised IPCC 1996 Guidelines for National Greenhouse Gas Inventories' och 'IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories'. Inventeringen och rapporten är framtagen i enlighet med 'Reporting Guidelines', som beslutades av UNFCCC under den åttonde sammankomsten av Conference of the Parties (COP) i New Delhi 2002 och efterföljande beslut.

De sektorer som innefattas av inventeringen och de källor som används för aktivitetsdata och/eller utsläppsdata presenteras i Tabell S 3. Utsläppen är hämtade direkt från dessa datakällor eller beräknade baserat på aktivitetsdata.

Tabell S 3 CRF sektorer och datakällor som används i inventeringen.

CRF	Sektor	Primär källa till aktivitetdata/utsläppsdata
1	Energi	Statistiska undersökningar av energiförbrukning
	-Stationär förbränning	Statistiska undersökningar av energiförbrukning
	-Transport	Transportmyndigheter
2	Industriprocesser	Miljörapporter
		Statistiska undersökningar av energiförbrukning
		Direktkontakt med företag
		EU:s utsläppshandelssystem
3	Lösningsmedel och annan Produktanvändning	Nationella data från Produktregistret på Kemikalieinspektionen
		Nationella experter
		Miljörapporter
4	Jordbruk	Officiella statistiska rapporter
		Organisationer och Forskare
5	Förändrad Markanvändning och Skogsbruk	Sveriges lantbruksuniversitet
		Skogsstyrelsen
6	Avfall	Avfall Sverige (fd RVF)
		Skogsindustrierna
		SCB
		Naturvårdsverket
		Miljörapporter

Utsläppen av växthusgaser från energisektorn inklusive transporter var ca 48,2 miljoner ton i koldioxidekvivalenter 2007 (Tabell S 2), vilket är ca 74 % av de totala utsläppen. Utsläppen av växthusgaser från transporter visar en stigande trend, medan utsläpp från individuell uppvärmning av byggnader minskar. Detta innebär att energisektorn inklusive transporter har minskat sina utsläpp med ca 9,5 % år 2007 jämfört med 1990.

Utsläpp från industriprocesser kommer framför allt från produktionen av järn och stål samt mineralindustrin. Koldioxidutsläppen dominerar med ca 76 %, följt av fluorerade gaser

med ca 19 % och lustgas med ca 5 %. De totala utsläppen från industriprocesser var omkring 6,5 miljoner ton koldioxidekvivalenter år 2007 (Tabell S 2), vilket motsvarar omkring 10 % av totala utsläppen. Sedan 1990 har de totala utsläppen i denna sektor varierat, vilket framför allt beror på att produktionsvolymerna varierar med ekonomiska cykeln. 2007 var utsläppen 12,8 % högre än 1990.

Användningen av Lösningsmedel och andra produkter ger huvudsakligen upphov till utsläpp av flyktiga organiska ämnen, lustgas och en del koldioxid. 2007 var utsläppen av koldioxid och lustgas 0,3 miljoner ton uttryckt i koldioxidekvivalenter (Tabell S 2), vilket utgör 0,45 % av de totala växthusgasutsläppen. Jämfört med 1990 har utsläppen i denna sektor minskat med 11,5 %. Omkring 26 % av koldioxidutsläppen kommer från användningen av färg, även om dessa utsläpp har minskat p.g.a. en övergång till vattenbaserade färger.

Jordbruk är den största källan till utsläpp av metan och lustgas. 2007 var de totala utsläppen från jordbrukssektorn 8,43 miljoner ton uttryckt i koldioxidekvivalenter (Tabell S 2), vilket är en minskning med ca 10 % jämfört med 1990. Utsläpp av metan kommer framför allt från boskapens matsmältningsprocesser och avföring. Den viktigaste anledningen till de minskade utsläppen är en minskad boskapshållning. Lustgas kommer framför allt från omvandling av kväve i jorden, vilken påverkas av användningen av gödsel och handelsgödsel och odlingen av kvävefixerande växter.

Nettoupptaget för sektorn markanvändning, förändrad markanvändning och skogsbruk uppgick till 20,5 miljoner ton koldioxidekvivalenter år 2007 (Tabell S 2). Sänkans storlek har varierat under perioden 1990-2007, men trenden pekar mot en något minskande sänka.

Deponier av fast avfall är den näst största källan till utsläpp av metan. 2007 var de totala utsläppen från avfallssektorn knappt 1,92 miljoner ton (Tabell S 2) uttryckt i koldioxidekvivalenter, vilket motsvarar ca 3 % av de totala utsläppen. Detta är en minskning på 38, % jämfört med 1990. Utvinning av deponigas, deponiförbud och deponiskatter är huvudorsakerna till utsläppsminskningen.

S 4. Översikt av utsläppsberäkningar och trender för indirekta växthusgaser och SO_2

Utsläpp av flyktiga organiska ämnen (NMVOC) var ca 0,178 miljoner ton 2007 (Tabell S 4), vilket är en minskning med ca 49 % jämfört med 1990. De huvudsakliga källorna till NMVOC är produkter innehållande lösningsmedel, vägtrafik och vedeldning inom bostadssektorn. Icke-obligatoriska miljöstandarder för nya installationer av vedeldningspannor och minskade utsläpp från produkter innehållande lösningsmedel har bidragit till minskningen av utsläpp.

Tabell S 4 Utsläpp av indirekta växthusgaser och SO_2 (Gg)

GAS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
NO_X	303	308	293	272	279	266	258	245	234	224	214	204	199	193	183	177	172	167
CO	938	957	928	885	888	866	839	788	722	697	664	626	610	613	583	581	549	566
NMVOC	352	307	291	266	259	247	240	229	216	208	199	187	185	187	185	182	177	178
SO_2	105	101	94	83	80	68	67	60	57	47	44	42	42	43	39	37	37	34

Utsläppen av kväveoxider (NO_x) var 0,167 miljoner ton 2007 (Tabell S 4), vilket är en minskning med ca 45 % jämfört med 1990. De största källorna till utsläpp av kväveoxider är vägtrafik, arbetsmaskiner, sjöfart och el- och värmeproduktion. I tätorter är vägtrafiken den största källan till kväveoxidutsläpp, men införandet av katalysatorer i bilar och den påföljande successivt mer skärpta avgasstandarden har bidragit till en generell minskning av kväveoxidnivåer i tätbebyggda områden. Den ökande användningen av fjärrvärme och NO_X-avgiften i början på 1990-talet har också resulterat i stora minskningar av kväveoxid-utsläpp från energisektorn.

Utsläppen av kolmonoxid (CO) har minskat från knappt 1 miljon ton 1990 till knappt 0,6 miljoner ton 2007 (Tabell S 4), en reducering på knappt 40 %. Utsläppen härrör till ca 95 % från Energisektorn.

Utsläppen av svaveldioxid (SO_2) har minskat från ca 0,1 miljoner ton 1990 till ca 0,034 miljoner ton 2007 (Tabell S 4), en reducering på ca 67 %. Minskningen beror framför allt på en övergång till lågsvavelhaltiga bränslen, både för vägtrafik och uppvärmning. Svavel-skatt, som infördes 1991, spelar en stor roll för utvecklingen. Svaveldioxidutsläpp härrör främst från energiproduktion, transporter och industriprocesser.

Executive Summary

ES 1. Background Information

Greenhouse gases have always been present in the atmosphere, but now concentrations of several of them are rising as a result of human activity, which intensifies the greenhouse effect. An Intergovernmental Panel on Climate Change (IPCC) was established in 1988 and two years later they came up with the conclusion that anthropogenic climate change is a global threat and asked for an international agreement to deal with the problem. The United Nations started negotiations to create a framework convention on climate change (UNFCCC), which came into force in 1994. The long-term goal is to stabilize the amount of greenhouse gases in the atmosphere at a level where harmful anthropogenic climate changes is prevented. The most important addition to the convention was negotiated in 1997 in Kyoto, Japan. The Kyoto protocol involves binding obligations for the Annex I countries to decrease their emissions of greenhouse gases with at least 5% during 2008-2012 compared to the base year 1990. According to Articles 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC), parties are required to annually submit national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol. The submission of inventories should including emissions in the Common Reporting Format (CRF) and a National Inventory Report (NIR).

This report constitutes Sweden's NIR 2009 for anthropogenic emissions of direct greenhouse gases CO_2, CH_4, N_2O, HFC, PFC, SF_6 and indirect greenhouse gases NO_X, CO, NMVOC and SO_2. The report contains information on Sweden's inventories of greenhouse gases for all years from 1990 to 2007, including descriptions of methods, data sources, uncertainties, the quality assurance and quality control (QA/QC) activities carried out and a trend analysis.

Electronic data on emissions, activity data, thermal values and emission factors in the Common Reporting Format (CRF) spreadsheet files requested by the UNFCCC are provided in a separate annex to this report.

ES 2. Summary of National Emissions and Removal Related Trends

Total greenhouse gas emissions in Sweden, expressed in carbon dioxide equivalents, were 65,41 million tonnes for 2007 (Table ES 1), which is a decrease of 1,46 million tonnes compared to 2006. Emissions have fallen by about 9,1 % or approximately 6,5 million tonnes between 1990 and 2007. Aggregated emissions varied over the period but were in all cases below the 1990 level during the period 1999-2007.

The net removals by sinks for the land use, land use change and forestry (LULUCF) sector amounted to approximately 20,5 million tonnes carbon dioxide equivalents in 2007. (Table ES 1). The size of the sink varied over the period 1990-2007, but the trend points towards a somewhat decreasing sink. In 2005 a net emission was reported, due to a severe storm that devastated a large area of forest in Sweden.

Emissions of CO_2 were around 51.6 million tonnes in 2007, 8,2 % lower than in 1990 (Table ES 1). With about 90 % of total carbon dioxide emissions, the energy sector, including transport, is the largest source of carbon dioxide in Sweden. Carbon dioxide's share of the total GHG emissions is approximately 79 %.

Emissions of methane mainly arise from agriculture and landfill sites, and were approximately 5.35 million tonnes, expressed in CO_2-equivalents, in 2007 (Table ES 1). Since 1990, emissions have decreased about 20 %, primarily due to measures implemented in the waste sector.

In 2007, total emissions of nitrous oxide were around 7.2 million tonnes, as expressed in CO_2-equivalent (Table ES 1), a reduction of 15 % compared to 1990. Emissions mainly arise from agriculture, but also from energy production, wastewater handling and industrial processes. The main reduction took place in the agricultural sector.

Total emissions of fluorinated gases (PFCs, HFCs and SF_6) in 2007 were approximately 1.25 million tonnes expressed in carbon dioxide equivalents (Table ES 1). This corresponds to an increase of about 157 % compared to 1990. The increase is due to the replacement of the ozone-depleting substances by HFC.

Table ES 1 Greenhouse gas emissions by gas (Gg CO_2 equivalents)

GREENHOUSE GAS EMISSIONS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
	CO_2 equivalent (Gg)																	
CO2 incl. net CO2 from LULUCF	24 123	23 523	26 014	27 749	33 590	32 470	31 592	22 533	21 168	20 184	17 690	21 866	20 547	22 252	23 187	23 703	27 013	31 043
CO2 excl. net CO2 from LULUCF	56 257	56 930	56 722	56 203	58 865	57 993	61 504	56 925	57 441	54 610	53 370	54 110	55 064	55 888	55 317	52 950	52 727	51 621
CH4 incl. CH4 from LULUCF	6 711	6 697	6 784	6 831	6 754	6 667	6 632	6 579	6 405	6 258	6 075	6 045	5 871	5 733	5 754	5 629	5 543	5 360
CH4 excl. CH4 from LULUCF	6 709	6 696	6 782	6 830	6 752	6 666	6 630	6 570	6 404	6 255	6 072	6 042	5 866	5 727	5 749	5 624	5 530	5 357
N2O incl. N2O from LULUCF	8 559	8 446	8 340	8 467	8 527	8 398	8 524	8 431	8 420	7 985	7 892	7 751	7 679	7 648	7 639	7 533	7 545	7 296
N2O excl. N2O from LULUCF	8 480	8 385	8 288	8 411	8 471	8 334	8 460	8 366	8 354	7 914	7 818	7 676	7 606	7 567	7 548	7 430	7 431	7 181
HFCs	4	8	10	30	73	127	205	313	386	489	565	612	664	709	770	797	826	855
PFCs	377	380	252	291	312	343	303	280	272	291	241	236	261	258	254	257	245	248
SF6	107	109	108	97	100	127	108	153	99	102	94	111	104	69	81	142	111	150
Total (incl. LULUCF)	39 881	39 163	41 508	43 465	49 356	48 132	47 365	38 289	36 749	35 310	32 556	36 621	35 126	36 670	37 685	38 061	41 283	44 952
Total (excl. LULUCF)	71 934	72 508	72 163	71 861	74 573	73 590	77 210	72 607	72 957	69 662	68 159	68 788	69 565	70 220	69 718	67 200	66 870	65 412

Table ES 2 Greenhouse gas emissions by sector (Gg CO_2 equivalents)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
	CO_2 equivalent (Gg)																	
Energy	53 313	54 195	54 145	53 643	56 091	55 149	58 925	54 372	54 807	52 150	50 682	51 197	52 267	53 003	52 379	49 578	49 346	48 237
Industrial Processes	5 792	5 687	5 383	5 455	5 752	5 907	5 816	5 719	5 858	5 663	5 846	6 009	5 920	6 031	6 095	6 614	6 672	6 533
Solvent and Other Product Use	332	320	326	315	293	309	312	321	318	299	278	269	276	292	311	301	294	294
Agriculture	9 383	9 146	9 150	9 398	9 503	9 300	9 257	9 328	9 160	8 858	8 747	8 753	8 689	8 590	8 641	8 553	8 502	8 431
Land Use, Land-Use Change and Forestry	-32 053	-33 344	-30 655	-28 397	-25 217	-25 458	-29 846	-34 319	-36 208	-34 352	-35 603	-32 167	-34 439	-33 550	-32 033	-29 139	-25 587	-20 460
Waste	3 113	3 159	3 159	3 050	2 935	2 926	2 900	2 866	2 813	2 693	2 605	2 560	2 414	2 303	2 293	2 153	2 056	1 917

ES 3. Overview of Source and Sink Category Emission Estimates and Trends

The methods used to calculate the emissions and removals are in accordance with the Revised IPCC 1996 Guidelines for National Greenhouse Gas Inventories and the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. The report is prepared in accordance with the Reporting Guidelines, agreed by the UNFCCC at the eighth session of the Conference of the Parties (COP) in New Delhi 2002 and subsequent decisions.

The sectors included in the inventory and the main sources used for activity data and/or emission data are presented in Table ES 3. The emissions are collected directly from these data sources, or calculated based on activity data.

Table ES 3 CRF sectors and data sources used in the inventory.

CRF	Sector	Main source for activity/emission data
1	Energy	Statistical surveys on energy consumption
	-Stationary combustion	Statistical survey on energy consumption
	-Transport	Transport authorities
2	Industrial processes	Environmental reports
		Statistical survey on energy consumption
		Direct contact with companies
		CO_2 Data from the European trading scheme (ETS)
3	Solvent and Other Product Use	National data from the Products register at the Swedish Chemicals Agency
		National experts
		Environmental reports
4	Agriculture	Official statistical reports
		Organisations and researchers
5	Land Use Change and Forestry	Swedish University of Agricultural Sciences
		Swedish Forest Agency
6	Waste	Swedish Association of Waste Management
		The Swedish Forest Industries Federation
		Statistics Sweden
		Swedish Environmental Protection Agency
		Environmental reports

Greenhouse gas emissions from the energy sector including transport, were approximately 48,2 million tonnes of expressed as carbon dioxide equivalents in 2007 (Table ES 2), which is equivalent to 74 % of the total emissions. Total greenhouse gas emissions from transport shows a rise, while emissions from individual combustion in buildings are decreasing. This means that the energy sector, including transport, has decreased its GHG emissions with 9,5 % in 2007 compared to 1990.

Emissions from industrial processes primarily derive from production of iron and steel and the mineral industry. Carbon dioxide emissions dominate at approximately 76 %, followed by fluorinated gases with 19 % and nitrous oxide with 5 %.

Total emissions from industrial processes in 2007 were approximately 6,5 million tonnes expressed as carbon dioxide equivalents (Table ES 2), which is approximately 10 % of the total emissions. Since 1990, total emissions in this sector have varied, primarily because production volumes vary with economic cycles. In 2007 emissions were 12,8 % higher than in 1990.

The use of Solvents and Other products mainly gives rise to emissions of volatile organic substances, nitrous oxides and some carbon dioxide. In 2007, emissions of carbon dioxide and nitrous oxide expressed in carbon dioxide equivalents were 0.3 million tonnes (Table ES 2), which corresponds to 0.45 % of the total greenhouse gas emissions. Compared to 1990, emissions have decreased with about 11.5 %. About 26 % of carbon dioxide emissions arise from paint application, even though these emissions have decreased because of a transition to water-based paints.

Agriculture is the largest source of emissions of methane and nitrous oxide. In 2007, total greenhouse gas emissions expressed in carbon dioxide equivalents were 8.4 million tonnes (Table ES 2), a decrease with about 10 % compared to 1990. Methane emissions arise primarily from the digestive processes of cattle and from their manure. The most important reason for the reduced emissions is reduced livestock keeping. Nitrous oxide emissions originate mainly from transformation of nitrogen that takes place in the ground, which is influenced by the use of manure and commercial fertiliser and the cultivation of nitrogen-fixing crops.

Net removals by sinks amounted to around 20,5 million tonnes in 2007 (Table ES 2). The size of the sink varied over the period 1990-2007, but the trend points towards a somewhat decreasing sink.

Solid waste landfills are the second largest source of emissions of methane. In 2007, total emissions from the waste sector were 1,92 million tonnes (Table ES 2) expressed as carbon dioxide equivalents or about 3 % of the total GHG emissions. This is a reduction of 38 % compared to 1990. The collection of landfill gas, a ban on landfill deposit and the introduction of a landfill tax have played a key role for the decrease in emissions.

ES 4. Overview of Emission Estimates and Trends of Indirect GHGs and SO_2

Emissions of volatile organic compounds (NMVOC) were 0.178 million tonnes in 2007 (Table ES 4), a decrease of 49 % compared to 1990. The main contributors to NMVOC emissions are solvents-contiang products, road traffic and wood combustion in the residential sector. Non-compulsory environmental standards for new installations of wood-burning boilers and reduced emissions from solvent-containing products have contributed to the decrease in emissions.

Table ES 4 Emissions of indirect greenhouse gases and SO_2 (Gg)

GAS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
NO_X	303	308	293	272	279	266	258	245	234	224	214	204	199	193	183	177	172	167
CO	938	957	928	885	888	866	839	788	722	697	664	626	610	613	583	581	549	566
NMVOC	352	307	291	266	259	247	240	229	216	208	199	187	185	187	185	182	177	178
SO_2	105	101	94	83	80	68	67	60	57	47	44	42	42	43	39	37	37	34

Emissions of nitrogen oxides (NO_x) were 0.167 million tonnes in 2007 (Table ES 4), a reduction of 45 % compared to 1990. The largest sources of emissions of nitrogen oxides are road traffic, mobile machinery, maritime transport and electricity and heating production. In areas were people congregate road traffic is the most significant contributor to emissions of nitrogen oxides, but the introduction of catalytic converters in the late 1980's and the subsequent successively more stringent emission standards have contributed to a general reduction of nitrogen oxide levels in built-up areas. The increased use of district heating and the "NO_X charge" of the early 1990s have also resulted in a great reduction of emissions of nitrogen oxides from the energy sector.

Emissions of carbon monoxide (CO) have decreased from around 1 million tonnes in 1990 to 0.6 million tonnes in 2007 (Table ES 4), a reduction of about 40 %. Emissions derive mainly (about 95 %) from the Energy sector.

Emissions of sulphur dioxide (SO_2) have decreased from 0.1 million tonnes in 1990 to 0.034 million tonnes in 2007 (Table ES 4), a reduction of about 67 %. Sulphur dioxide emissions derive from the energy, transport and industrial sectors. The reduction is mainly due to a transfer from fuels with high sulphur levels to low-sulphur fuels, both for road traffic and heating. A tax on sulphur, introduced in 1991, has been important in this transition.

1 Introduction

According to Articles 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC), Annex I Parties are required to annually submit national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol. The inventory submitted to the UNFCCC Parties, through the secretariat, should include emissions in the Common Reporting Format (CRF) and a National Inventory Report (NIR).

This report constitutes Sweden's NIR 2009. The report contains information on Sweden's inventories for all years from 1990 to 2007 including descriptions of methods, data sources, uncertainties, quality assurance and quality control (QA/QC) activities carried out, and a trend analysis. In order to ensure the transparency, consistency, comparability, completeness and accuracy of the inventory, the report contains information on inventories for all years from the base year to the year of the current annual inventory submission.

This section presents background information on climate change and greenhouse gas (GHG) inventories. It also contains a description of institutional arrangements for the inventory preparation, brief descriptions of the process of inventory preparation, methodologies and data sources used and the key sources in the Swedish inventory. Finally there is information about the progress of quality assurance/quality control (OA/QC) work, the general uncertainties in the inventory and on the completeness of inventoried emissions.

1.1 Background Information

1.1.1 Historical background

In consequence of scientific indications that human activities influence the climate and an increasing public awareness about local and global environmental issues during the middle of the 1980s, climate change was brought up on the political agenda. The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 and two years later they concluded that anthropogenic climate change was a global threat and asked for an international agreement to deal with the problem. The United Nations started negotiations to create a framework convention on climate change (UNFCCC), which came into force in 1994. A decade later UNFCCC had 188 member states (including EU as a part). The long-term goal is to stabilize the amount of greenhouse gases in the atmosphere at a level where harmful anthropogenic climate changes are prevented. After the UNFCCC came into force, the framework convention has developed and every year a Conference of the Parties (COP) is held. The most important addition to the convention was negotiated in 1997 in Kyoto, Japan. The Kyoto protocol involves binding obligations for the Annex I countries (including all EU member states and other industrialized countries). Together the emissions of greenhouse gases in these countries should be at least 5 % lower during 2008-2012 compared to the base year 1990 (for fluorinated

greenhouse gases it is allowed to use 1995 as a base year). In the spring 2002 Sweden, together with the other EU member states, ratified the Kyoto protocol and the 16th of February 2005 it came into force. EU and its member states uses a paragraph in the Kyoto protocol which gives them the right to, instead of national emission objective, have a joint EU objectives of a decrease in emissions with 8 %. Within EU the 8 is shared among the member states in accordance with the burden sharing agreement[1]. For Sweden the agreement involves an allowed increase in emissions of 4 %. Above this Sweden has chosen to go beyond the EU target and have a national target to decrease the emissions with 4 %. Reduced Climate Impact is one of the 15 Swedish Environmental Quality Objectives and, except for the national target of a decrease of 4 %, the objective involves a long term aim that emissions of greenhouse gases should be lower than 4.5 tonnes per year and inhabitant in 2050, and decrease further after that. The objective also involve that Sweden should encourage the global work to aim at the objective to stabilize the concentration of greenhouse gases in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

1.1.2 Climate change

Some of the gases in the earth's atmosphere have an ability to absorb infrared radiation (heat). They do not prevent sunlight reaching the earth's surface and warming it, but they do trap some of the infrared outgoing radiation. Without the natural greenhouse effect of the atmosphere, the surface of our planet would be almost 35°C colder than it is now.

Greenhouse gases (i.e. gases which contribute to the greenhouse effect) have always been present in the atmosphere, but now concentrations of several of them are rising as a result of human activity. This is intensifying the greenhouse effect. The IPCC sums up the cause of the climate change we have witnessed over the last 50 years by stating that it is impossible to explain other than as the result of anthropogenic emissions of greenhouse gases.

Apart from carbon dioxide, other greenhouse gases are being emitted in larger quantities now than in pre-industrial times. These gases include nitrous oxide and methane. Ground-level ozone also contributes to the greenhouse effect. The amount of ozone forming in the lower atmosphere has increased as a result of emissions of nitrogen oxides, hydrocarbons and carbon monoxide.

Entirely new, man-made greenhouse gases that are entering the atmosphere cause further intensification of the greenhouse effect. These include, in particular, a number of substances containing fluorine, among them HFCs (compounds of hydrogen, fluorine and car-bon). HFCs are used instead of the ozone layer depleting CFCs (freons) in refrigerators and other applications, and their use is on the increase.

Compared with carbon dioxide, all other greenhouse gases occur at very low concentrations. Per molecule, however, these substances are much more effective as greenhouse gases than carbon dioxide, which means that they still make a con-

[1] 2002/358/EG

siderable contribution to the greenhouse effect. Furthermore, some of the fluorine compounds have such a long atmospheric lifetime that they will contribute to the greenhouse effect for ten thousands of years to come.

The threat of climate change is considered to be one of the most serious environmental problems faced by humankind.

1.1.3 Greenhouse gas inventories

The inventory covers anthropogenic emissions of direct greenhouse gases CO_2, CH_4, N_2O, HFC, PFC, SF_6 and indirect greenhouse gases NO_X, CO, NMVOC and SO_2. Indirect means that they do not contribute directly to the greenhouse effect, but that their presence in the atmosphere may influence climate in different ways. As mentioned in section 1.1.2, ozone (O_3) is also a greenhouse gas but, since it is formed by the chemical reactions of nitrogen oxides, hydrocarbons and/or carbon monoxide, a separate report is not necessary.

The obligations of the Kyoto protocol have led to an increased need for international supervision of the emissions reported by the parties. The Kyoto protocol therefore contains rules for how emissions should be estimated, reported and reviewed. Emissions of the direct greenhouse gases CO_2, N_2O, CH_4, HFCs, PFCs and SF_6 are calculated as CO_2 equivalents and added to produce a total. Together with the direct greenhouse gases, also the emissions of NO_x, CO, NMVOC and SO_2 are reported to UNFCCC. These gases are not included in the obligations of the Kyoto protocol. When a method used to estimate emissions is improved, a need to recalculate the whole time series may arise in order to maintain consistency. This means that data presented can be changed in the next submission.

1.2 Institutional arrangements

The inventory system currently used in Sweden is presented in Figure 1.1. The Swedish Ministry of Environment has overall responsibility and submits the inventory report to the European Commission and to the UNFCCC secretariat. The Swedish Environmental Protection Agency (Swedish EPA) co-ordinates the activities for developing the inventory report and is also responsible for the final quality control and quality assurance of the data before it is submitted.

A consortium called Swedish Environmental Emissions Data (SMED), composed of Statistics Sweden, the Swedish Meteorological and Hydrological Institute (SMHI), the Swedish Environmental Research Institute AB (IVL) and the Swedish University of Agricultural Sciences (SLU). These organizations collect data and calculate emissions for all sectors.

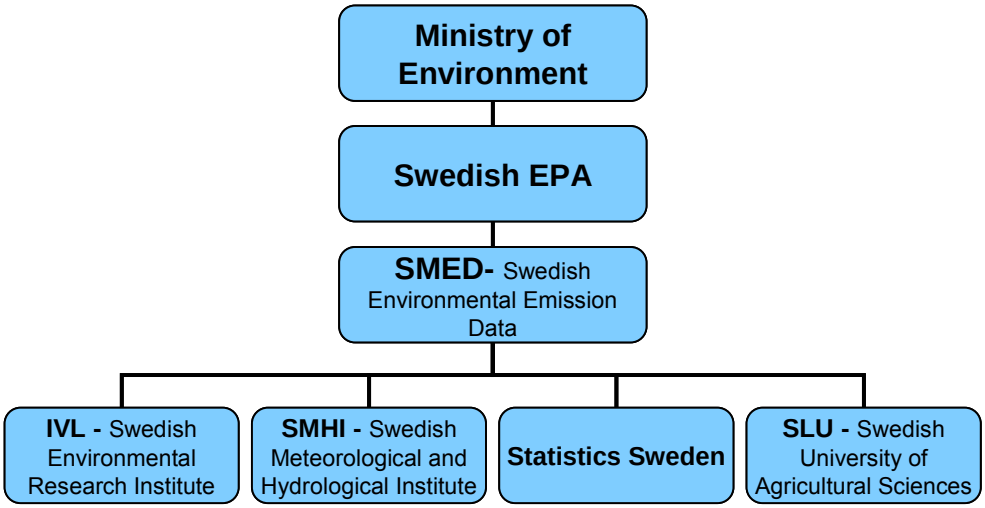

Figure 1.1 The Swedish inventory system.

A national system meeting the requirements laid down in article 5.1 of the Kyoto Protocol is developed and was fully in operation in 2006. The Swedish National System is described in Annex 6:1.

1.3 The process of inventory preparation

1.3.1 Data collection and processing

The process of inventory preparation is carried out differently for the different sectors. A brief summary is found below. Further descriptions of data collection are made for each sector in sections 3-8.

1.3.1.1 ENERGY- STATIONARY COMBUSTION

Activity data for following subgroups is used:

Energy industries: Data from quarterly fuel statistics, a total survey conducted by Statistics Sweden at plant level and by fuel type. For some petroleum refining plants, data from the European Union Emission Trading Scheme (ETS) is used.
Manufacturing industries: Data mainly from the quarterly fuel statistics, a sample survey conducted by Statistics Sweden. In some cases data from the industrial energy statistics or ETS is used as a complement. All data is at plant level and by fuel type.
Other sectors: Data from official statistical reports prepared by Statistics Sweden at national level and by fuel type.

Activity data is multiplied by thermal values, mainly from Statistics Sweden, and emission factors provided by the Swedish Energy Agency and the Swedish EPA.

1.3.1.2 ENERGY- MOBILE COMBUSTION

Data on fuel consumption at national level and by fuel type is collected from Statistics Sweden and used in combination with emissions data and fuel data from the National Road Administration, the National Rail Administration, the Civil Aviation Administration and the Swedish Military. Activity data is multiplied by thermal values, mainly provided by Statistics Sweden, and emission factors provided by the the responsible authorities.

1.3.1.3 INDUSTRIAL PROCESSES

The reported data for industrial processes is mainly based on information from environmental reports. According to Swedish environmental legislation, operators performing environmentally hazardous activities that require a permit by law are required to compile and send an annual environmental report to their supervisory authority. The County Administrative Boards audit the data from the operators' environmental reports.

The data in the environmental reports refer to emissions derived from plant specific measurements or estimates such as mass balances. The use of default emission factors is limited.

In some cases, when there are a large number of smaller companies within a specific sector, and all the environmental reports are not available, a combination of information available from environmental reports and production statistics at national level is used to estimate national emissions. Emission factors used are usually derived nationally based on available information from some facilities in a specific sector, and applied to the national level. The use of default emission factors is limited.

For most CO_2 emissions from industrial processes, activity data on e.g. the produced amount of clinker, limestone, etc. is collected directly from the operators. In some cases data on CO_2 emissions from the European trading scheme is used for 2005 and later years. Activity data on fuels used in CO_2 emitting processes are collected from the same surveys as those used for energy emissions for manufacturing industries, as described above.

1.3.1.4 SOLVENT AND OTHER PRODUCT USE

Data used for estimating emissions from solvent and other product use are based on emission factors and national activity data obtained from the Products register kept by the Swedish Chemicals Agency.

1.3.1.5 AGRICULTURE

Data on animal numbers, crop areas, yields, sales of manure, manure management and stable periods are taken from official statistical reports published by the Swedish Board of Agriculture and Statistics Sweden. Some complementary information is collected from organisations and researchers, such as the Swedish Dairy Association, Swedish Poultry Meat Association, SLU and the Swedish Institute of Agricultural and Environmental Engineering.

1.3.1.6 LAND USE, LAND USE CHANGE AND FORESTRY

Estimates presented in the LULUCF sector are mainly based on data from the SLU. The SLU is responsible for the National Forest Inventory, which focuses on living biomass, and for the Swedish Forest Soil Inventory, that focuses on dry organic matter and on soil organic carbon. The two inventories are integrated and uses the same infra structure for the field sample.

1.3.1.7 WASTE

Statistics on deposited waste quantities, methane recovery and nitrogen emissions from wastewater handling, are provided by the Swedish Association of Waste Management (Avfall Sverige, former RVF), Statistics Sweden, the Swedish Forest Industries Federation and the Swedish EPA. If new data on organic content in household waste or other relevant research is published, such reports are also considered. Profu provides estimates of deposited organic fractions of industrial waste.

Emissions reported for waste incineration are compiled from the facilities' annual environmental reports.

1.3.2 Data storage

A system for handling emission data, entitled TPS, has been developed and was implemented for the first time in submission 2007. It supports data input from Microsoft Excel sheets, and provides different types of quality gateways. For instance the system makes it possible for multiple users such as the SMED consortium and the national independent reviewers to plot time series and make comparisons between different years and submissions. For all CRF codes and sub-codes, time series from 1990-2007 of emission data, activity data, and implied emission factors where relevant can be presented. The system also allows for different types of data output, e.g. to the CRF Reporter.

The CRF-tables were generated using the export function in CRF Reporter.

1.4 Data sources and methodologies

Emission estimates are mainly based on activity data from national or official Swedish statistics, e.g. energy statistics, agricultural and forestry statistics, as well as data on production (e.g. cement) and consumption (e.g. fluorinated gases: F-gases) obtained directly from the major producers and consumers, respectively.

Emission factors and thermal values used are either developed nationally or are internationally recommended default factors.

The methodologies used for Sweden's greenhouse gas emissions inventory are in accordance with the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines)[2] and, in general, in line with IPCC´s Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (Good Practice Guidance).[3] Some parts of the methodologies are taken

[2] The IPCC Guidelines can be found at: http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm
[3] The Good Practice Guidance can be found at: http://www.ipcc-nggip.iges.or.jp/public/gp/english/

directly from the IPCC Guidelines, the Good Practice Guidance and the EMEP/CORINAIR Emission Inventory Guidebook (CORINAIR).[4]

In Table 1.1, all Tier methods used, which differ from Tier methods recommended in IPCC Guidelines or Good Practice Guidance, are presented. There is also a brief explanation of why the recommended methods have not been used. Note that for sectors where no specific recommendations are made in the IPCC Guidelines or Good Practice Guidance, these sectors are not included in Table 1.1. For an overview of the methods used in all sectors, see Summary 3 in the CRF tables and in each sector section, where a more detailed explanation on data sources and methodologies is given.

Table 1.1. Methods used that differ from recommended methods in the IPCC Guidelines or Good Practice Guidance for all sectors.

Sector	Used method Tier	IPCC Guidelines method Tier	Explanation
Energy: Emissions of CH_4 and N_2O from navigation	1	2	Reliable data required for Tier 2 is currently not available (various engine types etc).
Industrial processes: Emissions of PFC from aluminium production	2	3	No measurements are performed, so Tier 3 cannot be applied. The method used is Tier 2.
Industrial processes: Emissions of SF_6 from electrical insulation	2a	3	There is not enough information available to perform Tier 3.
Industrial processes: Semiconductor manufacture	1	2	There is not enough information available to perform Tier 2.
Industrial processes: Primary steel, pig iron production	National	2	Use of blast furnace gas is used as activity data instead of reducing agents for iron ore pellet based plants, but iron production is reported as activity data in the CRF reporter.
Waste: N_2O from waste water	National	1	Sweden uses national statistics on nitrogen emissions. Nitrogen emissions are only model calculated for the rural population.

SMED has carried out the calculations. In a few cases, estimates are based on expert judgements.

The combined effect of various greenhouse gases has been calculated using global warming potential factors (GWP). These are developed by the IPCC and are used as a means of comparing the relative significance of various gases in terms of their greenhouse effect, expressed as carbon dioxide equivalents.
Emission factors and thermal values for the energy sector are provided in19.

[4] The EMEP/Corinair Guidebook can be found at: http://tfeip-secretariat.org/unece.htm

1.5 Key categories

According to IPCC Good Practice Guidance, key categories in a national inventory including LULUCF should be identified in order to prioritize the efforts in improving the quality of the inventory estimates. Key categories are defined as sources and/or sinks that have "a significant influence on a country's total inventory of direct greenhouse gases in terms of the absolute level of emissions, the trend in emissions, or both". The identification is done in two steps, where key source categories are first identified excluding LULUCF. Key source categories are aggregated sources that together contribute with either 95 % of the level or 95 % of the overall trend of all greenhouse gas emissions in Sweden. Thereafter, still with the 95 % thresholds, the same procedures are performed but including the LULUCF sector. Any new key category identified from the LULUCF sector will be added as key category to the original key source categories.

Key categories in this inventory have been analyzed according to IPCC Good Practice Guidance for the LULUCF sector section 5.4 and IPCC Good Practice Guidance section 7.2. The resulting key categories including LULUCF are presented in Appendix 20A according to the format of CRF table 7. Corresponding background tables, according to tables 7.A1 - 7.A2 of the IPCC Good Practice Guidance are presented in Appendix 20B. The methodology is discussed in detail in Annex 1.

The level and trend assessment, excluding and including LULUCF, respectively, are presented below (Tables 1.2-1.4)

1.5.1 Level assessment excluding LULUCF

The level assessment excluding LULUCF for 2007 is presented in Table 1.2. It shows that emissions of CO_2 from Road transportation (CRF 1A3b) followed by emissions of CO_2 from Public electricity and heat production (CRF 1A1a) are in top in 2007. They contribute with 29.61% and 12.28 %, respectively, of the national total and are the top two on the level assessment list for all years.

Table 1.2. Key categories 2007 in terms of level assessment, excluding LULUCF

IPCC category	GHG	Emissions 2007	Contribution to the national total emissions 2007
		Gg CO_2 eq	
1A3b. Road Transportation	CO2	19 369,18	29,61%
1A1a. Public electricity and Heat production	CO2	8 033,92	12,28%
1A2f. Other Manufacturing Industries and Construction	CO2	4 886,20	7,47%
4D. Agricultural Soils	N2O	4 743,84	7,25%
4A. Enteric Fermentation	CH4	2 736,05	4,18%
2C. Metal Production	CO2	2 706,31	4,14%
2A. Mineral Products	CO2	2 179,72	3,33%
1A1b. Petroleum Refining	CO2	1 920,84	2,94%
6A. Solid Waste Disposal on Land	CH4	1 675,12	2,56%
1A2d. Pulp, Paper and Print	CO2	1 649,99	2,52%
1A4c. Agriculture/Forestry/Fisheries	CO2	1 639,54	2,51%
1A2c. Chemicals	CO2	1 590,29	2,43%
1A4b. Residential	CO2	1 420,25	2,17%
1A2a. Iron and Steel	CO2	1 215,13	1,86%
2F. Consumption of Halocarbons and SF6	HFCs	855,34	1,31%
1A4a. Commercial/Institutional	CO2	838,56	1,28%
1A2e. Food Processing, Beverages and Tobacco	CO2	662,28	1,01%
1B2. Oil and Natural Gas	CO2	626,92	0,96%
1B1. Solid fuels	CO2	614,93	0,94%
1A3a. Civil Aviation	CO2	605,05	0,92%
4B. Manure Management	N2O	478,40	0,73%
4B. Manure Management	CH4	472,41	0,72%
1A3d. Navigation	CO2	444,99	0,68%
1A1a. Public electricity and Heat production	N2O	382,04	0,58%
1A2f. Other Manufacturing Industries and Construction	N2O	357,74	0,55%
1A1c. Manufacture of Solid Fuels and Other Energy Industries	CO2	328,40	0,50%

1.5.2 Trend assessment excluding LULUCF

The trend assessment excluding LULUCF identifies a category as key if its trend diverges significantly from the total trend, in combination with its emission level significance. The category with increasing emission levels since 1990 are the prioritized categories regarding improvements in methodology etc., as were described in the beginning of this chapter.

In 2007, 24 key categories in terms of trend have been identified , excluding LULUCF (Table 1.3). The Energy Sector (CRF 1) contributes with the majority (15 categories) of categories, while Industrial Processes (CRF 2), Agriculture (CRF 4) and Waste (CRF 6) account for 6, 2 and 1 categories, respectively.

In 2007, the sources with the most significant increase in trend since 1990 are CO_2 from Road transport (1A3b), followed by emissions of CO_2 from Public electricity and heat production (1A1a), contributing with 21.59 % and 5.57 % to the

overall trend, respectively. Public electricity and heat production have been on the top-ten list every year since 1990 and Road transport since 1995.

Other interesting categories with regard to the trend are those with decreasing emissions. Among them, CO_2 emissions from the Residential sector (1A4b) and the Commercial/Institutional sector (1A4a) are in top in 2007 contributing 22.78 % and 7.89 % respectively to the overall trend. Emissions of CH_4 from Solid Waste Disposal on Land (6A) account for the third most significant decrease in the overall emission trend with a 5.03 % contribution.

Table 1.3. Key categories 2007 in terms of trend assessment, excluding LULUCF

IPCC category	GHG	Emissions 1990	Emissions 2007	Contribution to the emission trend 1990-2007
		Gg CO_2 eq	Gg CO_2 eq	
1A4b. Residential	CO2	6 235,91	1 420,25	22,78%
1A3b. Road Transportation	CO2	16 869,20	19 369,18	21,59%
1A4a. Commercial/Institutional	CO2	2 541,14	838,56	7,89%
1A1a. Public electricity and Heat production	CO2	7 691,36	8 033,92	5,57%
6A. Solid Waste Disposal on Land	CH4	2 874,22	1 675,12	5,03%
2F. Consumption of Halocarbons and SF6	HFCs	3,85	855,34	4,56%
1A2c. Chemicals	CO2	1 145,97	1 590,29	2,94%
2C. Metal Production	CO2	2 412,64	2 706,31	2,75%
1A5 Other	CO2	845,11	256,35	2,74%
2B. Chemical Industry	N2O	831,61	252,23	2,70%
2A. Mineral Products	CO2	1 919,29	2 179,72	2,33%
1B2. Oil and Natural Gas	CO2	311,26	626,92	1,84%
1A2d. Pulp, Paper and Print	CO2	2 186,46	1 649,99	1,81%
1A1b. Petroleum Refining	CO2	1 777,89	1 920,84	1,63%
1A2f. Other Manufacturing Industries and Construction	CO2	5 670,23	4 886,20	1,45%
1A2a. Iron and Steel	CO2	1 056,74	1 215,13	1,36%
1A4c. Agriculture/Forestry/Fisheries	CO2	1 534,25	1 639,54	1,31%
1A2e. Food Processing, Beverages and Tobacco	CO2	948,52	662,28	1,07%
4B. Manure Management	N2O	728,02	478,40	0,98%
4B. Manure Management	CH4	349,16	472,41	0,83%
1A1a. Public electricity and Heat production	N2O	304,96	382,04	0,56%
1B1. Solid fuels	CO2	789,03	614,93	0,55%
2C. Metal Production	PFCs	376,82	245,80	0,52%
2C. Metal Production	SF6	23,90	113,17	0,49%

A detailed description of the methodology used in the analysis is provided in Annex 1 and the complete analysis of Sweden's key source categories is presented in Appendix 20A and 20B.

1.5.3 Level and trend assessment including LULUCF

Table 1.4 shows the additional key categories 2007 for level and trend when including the LULUCF sector in the national inventory. Emissions/removals of CO_2 was found to be key for one or more years for Forest land (5A), Cropland (5B), Grassland (5C) and Settlements (5E). One reason for this is that these pools are important (level). Another reason is changes in harvest intensity and this may lead to high fluctuations in stocks between years (trend). Emissions of CH_4 and/or N_2O were never found to be key.

Table 1.4. Additional key categories when including the LULUCF sector 2007 for both level and trend. A negative value indicates a net removal.

IPCC category	GHG	Emissions/ Removals 1990	Emissions/ Removals 2007	Contribution to the level of national total emissions/-removals, including LULUCF 2007	Contribution to the trend of emissions/removals, including LULUCF 1990-2007
		Gg CO_2 eq	Gg CO_2 eq		
5A Forest land	CO_2	-35 471	-22 839	50,90%	43,46%
5B Cropland	CO_2	3 924	2 637	5,88%	4,53%
5C Grassland	CO_2	-646	-429	0,96%	0,76%

1.6 Information on QA/QC

1.6.1 Background

This section presents the general QA/QC plan for the Swedish GHG inventory[5]. The current system complies with the Tier 1 procedures outlined in the Good Practice Guidance (IPCC, 2000). A quality system as part of the National System has been developed and is fully in operation since January 2006 Annex 6:2.

1.6.2 Description of the QA/QC system

The Swedish EPA is responsible for the QA/QC plan for the inventory. The national GHG emissions are compiled by the Swedish Environmental Emission Data (SMED). Other contractors are also involved in the inventory preparations process.

The QA/QC plan consists of quality procedures and checklists specified for each reporting CRF-code (or group of codes). The plan is updated annually and lists all quality control steps that must be undertaken during inventory work (Tier 1 and where appropriate Tier 2). The QA/QC plan also includes descriptions of roles and responsibilities, of databases and models and documented procedures for uncertainty and key source analysis, as well as procedures for handling and responding to UNFCCC´s review of the Swedish inventory. The QA/QC plan handles follow-up and improvement by procedures of non-conformity reporting and collection of improvement needs from all stages of the annual inventory cycle. This re-

[5] Manual for SMED:s Quality System in the Swedish Air Emission Inventories

sults in a planning document, which is used as a basis for planning and selecting further actions to improve the inventory.

1.6.3 Quality assurance

Key sources should be subject to external peer review according to the Tier 2 of the Good Practice Guidance. The new QA/QC system includes national peer reviews by sectoral authorities. The procedures are described in Annex 6:2. The peer reviews include methodology and emissions factors used, as well as comparisons of activity and emission data with other national statistics. The reviewers also identify areas of improvement, which consolidates the basis for improvements in coming submissions.

1.6.4 Quality control

In this inventory, general Tier 1 QC measures, according to Table 8.1 in IPCC Guidelines, have been carried out, as have the source specific Tier 2 QC measures in Table 1.5.

Table 1.5. Source specific Tier 2 QC measures carried out in the inventory.

CRF		Action
1A, 1B and parts of 2	Energy amounts and emissions of CO_2	Analysis of differences between the sectoral and reference approach.
1B	Fugitive emissions and flaring of CO_2 CH_4 and N_2O	Measured emissions from flaring are checked to assure that the quality is sufficiently high. Trends for activity data and emissions are compared and analysed.
2A1	Cement production, process emissions of CO_2	Emissions are calculated both using the bottom-up and the top-down method, the results have been compared and differences explained. It is also stated that emission factors and activity data used are in accordance with internationally accepted methods.
2A2	Lime production, process emissions of CO_2	Emissions are calculated using both the bottom-up and the top-down method, the results have been compared and differences explained.
2B2	N_2O-emissions from Nitric Acid production	Bottom-up production data could not be compared to official data since official data for were not available in the statistical database. Only one company produces nitric acid. Calculation methods, abatement technique and production capacity is based on information achieved directly from the company.
2C3	PFC emissions from aluminium production	Documented process information obtained directly from the company.
2F	Consumption of halocarbons and SF_6	Differences between country specific emission factors and default emission factors from IPCC Guidelines are documented.

All QC measures performed are documented in QC checklists for each CRF code or group of codes. After completion of the initial compilation of the inventory, a QC-team reviews all QC checklists.

1.6.5 Quality control for the overall inventory

When the reporting tables and the NIR are completed, a quality coordinator performs a final quality control before delivery of the inventory to the Swedish EPA.

1.7 General uncertainty evaluation

An uncertainty analysis, excluding LULUCF, has been performed according to the Tier 1 method, described in detail in Annex 7 and IPCC Good Practice Guidance section 6.3.2.

During 2005, a SMED study was performed, aiming at improving the transparency and quality in the present uncertainty estimates in the Swedish National Greenhouse Gas Inventory by making the underlying documentation and structures for uncertainty estimates more consistent and traceable. This will facilitate easier replication and updating of results as well as enable internal and external reviews of assigned uncertainties. To simplify the methodology, there have not been any adjustments for correlation between gases, even though many of them have the same activity data and therefore are correlated. The study is described in Annex 7 and in detail in a SMED report.[6]

The IPCC Good Practice Guidance Tier 1 method is based on emission estimates and uncertainty coefficients for activity data and emission factors. The analysis was done for the sectors Energy, Industrial Processes, Solvent and Other Product Use, Agriculture and Waste. Uncertainty coefficients have in many cases been assigned based on expert judgement or on default uncertainty estimates provided in the IPCC Good Practice Guidance, since not enough background data was available to make actual calculations. Uncertainty estimates have been performed for the base year 1990 and 2007 for direct greenhouse gases, e.g. CO_2, CH_4, N_2O and F-gases.

In the underlying work, sources have been specified on the level where independency is assumed to exist. When reporting the results in the NIR, however, uncertainties are as far as possible presented on the same aggregation level as the key categories. The purpose is to facilitate combined use of the two analyses, since both aims at showing what parts of the inventory are especially important and/or weak. This is very important information when planning future inventories and, above all, using and evaluating the inventory results.

The 2005 study did not include improvement of single uncertainties, for instance by contacting external experts for better information on uncertainties on different sources. Further work considering uncertainties will focus on such improvements.

In conjunction with the Tier 1 uncertainty calculations of emission levels for 1990 and 2007, uncertainty introduced to the trend 1990-2007 is calculated following the IPCC Tier 1 method.

[6] Gustafsson, 2005

1.7.1 Results

The results of the uncertainty calculations according to the Tier 1 uncertainty approach are presented in Annex 7. The Tier 1 calculations of uncertainty in the reported 2007 CO_2 equivalent emissions in Sweden result in combined uncertainty of the national total emissions of 5.4 %, 1.9 %, 5.1 % and 0.4 % for CO_2, CH_4, N_2O and F-gases respectively. The overall uncertainty for 2007 is calculated to be 7.7 %. For 1990, the combined uncertainty of the national total emissions were 5.4 %, 2.8%, 5.3 % and 0.2 % for CO_2, CH_4, N_2O and F-gases respectively. The overall uncertainty for 1990 is calculated to be 8.0 %. These figures neither include corrections for the correlation that may exist between gases (i.e. based on the same activity data), nor include corrections for non-reported sources. Therefore, the actual uncertainty of the estimated emissions per compound and of the aggregated greenhouse gas emissions will be somewhat higher.

It could be noted that estimated overall uncertainties in submission 2008 were 6.5 % for 1990 and 6.0 % for 2006. Uncertainties are higher in this submission. The main reason to this is the revision of emissions from off road vehicles and working machinery that was performed in this submission. New data are based on a detailed bottom-up study. This has improved the accuracy of the inventory significantly, however increasing estimated uncertainties.

The trend of national total greenhouse gas emissions 1990-2007 in Sweden is associated with an uncertainty of 6.4 % (compared to 2.6% in submission 2008). This stems mainly from uncertainty introduced by activity data.

Table 1.6 and Table 1.7 show the ten sources with the largest uncertainty contributions in the Swedish inventory for 2007 and 1990, respectively.

Table 1.6. The ten sources with the largest uncertainty contributions in the Swedish inventory for 2007.

CRF	IPCC source Category	GHG	Emissions 2007	Activity data uncertainty	Emission factor uncertainty	Emission data uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in 2007
			Gg CO_2 e.q.	%	%	%	%	%
1A	Mobile combustion	CO2	24 073	13	7	0	14	5,3
4D	Agricultural soils	N2O	4 744	16	69	0	71	5,2
6A	Solid Waste Disposal on Land	CH4	1 675	30	50	0	58	1,5
4A	Enteric Fermentation	CH4	2 736	5	25	0	25	1,1
1A1a	Public electricity and Heat production	CO2	8 034	1	8	0	8	1,0
1A4b	Residential, Stationary	CH4	265	10	100	0	100	0,4
4B	Manure Management	N2O	478	20	50	0	54	0,4
1B1	Solid fuels	CO2	615	39	15	0	42	0,4
4B	Manure Management	CH4	472	20	50	0	54	0,4
1A2f	Other Manufacturing Industries and Construction, stationary	CO2	3 207	7	4	0	7	0,4

Table 1.7. The ten sources with the largest uncertainty contributions in the Swedish inventory for 1990.

CRF	IPCC source Category	GHG	Emissions 1990	Activity data uncertainty	Emission factor uncertainty	Emission data uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in 1990
			Gg CO_2 e.q.	%	%	%	%	%
4D	Agricultural Soils	N2O	5 248	16	70	0	72	5,3
1A2	Mobile combustion	CO2	21 987	15	7	0	16	5,0
6A	Solid Waste Disposal on Land	CH4	2 874	40	50	0	64	2,6
1A4b	Residential, Stationary	CO2	6 056	18	1	0	18	1,6
4A	Enteric Fermentation	CH4	3 058	5	25	0	25	1,1
1B1	Solid fuels	CO2	789	49	15	0	51	0,6
1A1a	Public electricity and Heat production	CO2	7 691	1	5	0	5	0,6
4B	Manure Management	N2O	728	20	50	0	54	0,5
1A4a	Commercial/Institutional	CO2	2 541	14	1	0	14	0,5
1A2f	Other Manufacturing Industries and Construction, stationary	CO2	4 095	8	1	0	8	0,5

1.8 General assessment of completeness

The inventory covers emissions and sinks in Sweden. All greenhouse gases are covered. The general completeness for each sector is discussed below. Detailed information is presented in Annex 5.

1.8.1 Energy

Estimated emissions are considered to be complete for most sources. There might still be some deficiencies as regards in-house generated fuels in the chemical industry and in smaller companies.

Fugitive emissions, i.e. venting and flaring of liquid and gaseous fuels, are most likely not complete for smaller companies. However, all Swedish plants that flare gas and are included in the European trading scheme in 2005-2007, are accounted for. For smaller plants, data might be included but reported in CRF 1A instead of CRF 1B. Hence, any lack of emission data from flaring is considered to be insignificant. In the Centralized Review of submission 2005, the Expert Review Team (ERT) made the comment that fugitive emissions of CH_4 and CO_2 from transport, refining and storage of oil; transmission and distribution of natural gas are lacking, despite available relevant activity data. From submission 2006 estimates of fugitive emissions of CH_4 from refining are included in the inventory.

1.8.2 Industrial Processes

For most sources, and particularly for the most important ones, the estimates are in accordance with the requirements concerning completeness as laid out in the Good Practice Guidance. However, some exceptions do exist. These are primarily in subsectors with a large number of smaller facilities with minor emissions. .

Data is complete for all greenhouse gases, possibly with the exception of CH_4 for a few sources, e.g. within the chemical industry.

1.8.3 Solvent and other product use

The estimated emissions from solvent and product use are considered to be complete, since a new method was developed during 2005 in order to obtain all activity data concerning the sector from the Products register at the Swedish Chemicals Agency.

The estimated emissions of N_2O are also considered to be complete, since national data from the Products register is used in the inventory.

1.8.4 Agriculture

All relevant agricultural emissions and sources are reported in the inventory. Reindeer, which are normally not considered as a part of the agricultural sector, are included in the inventory. The majority of the country's horses does not belong to farms, but are included in the agricultural sector of the inventory. There are, however, some marginal animal groups, which are not included, such as fur-bearing animals (minks, foxes and chinchillas). These groups are very small and there is no methodology developed for estimating their GHG emissions.

All sales of fertilizers are included in the inventory, also quantities used in other sectors. N-fixing crops used in lay fields, and sludge used as fertilizer is also included. This means that all anthropogenic inputs to agricultural soils are covered.

1.8.5 Land Use, Land Use Change and Forestry

All land areas are inventoried in the field except high mountains, military impediments and urban land. We believe that their relative importance for the Swedish GHG inventory is small.

The reporting of woody biomass stocks refers to above and below ground parts of trees taller than 1.3 m. Smaller trees and other vegetation such as shrubs and herbs are not reported. Emissions from mineralization when extracting peat are now reported, but not yet the below ground biomass of dead stump systems.

1.8.6 Waste

The effects of possible leakage of methane and nitrous oxide from the wastewater treatment processes have not been estimated. All other data are complete.

2 Trends in greenhouse gas emissions

2.1 Description and interpretation of emission trends for aggregated greenhouse gas emissions

Total greenhouse gas emissions in Sweden, calculated as carbon dioxide equivalents, totalled around 65.4 million tonnes (excl. LULUCF) in 2007. Emissions decreased by around 6.5 million tonnes or about 9.1 % between 1990 and 2007. Aggregated greenhouse gas emissions varied over the period but in all cases were below the 1990 level during the period 1999-2007. Emissions decreased by around 1.5 million tonnes between 2006 and 2007, principally due to reduced emissions from the energy sector, the agriculture sector, the waste sector and industrial processes.

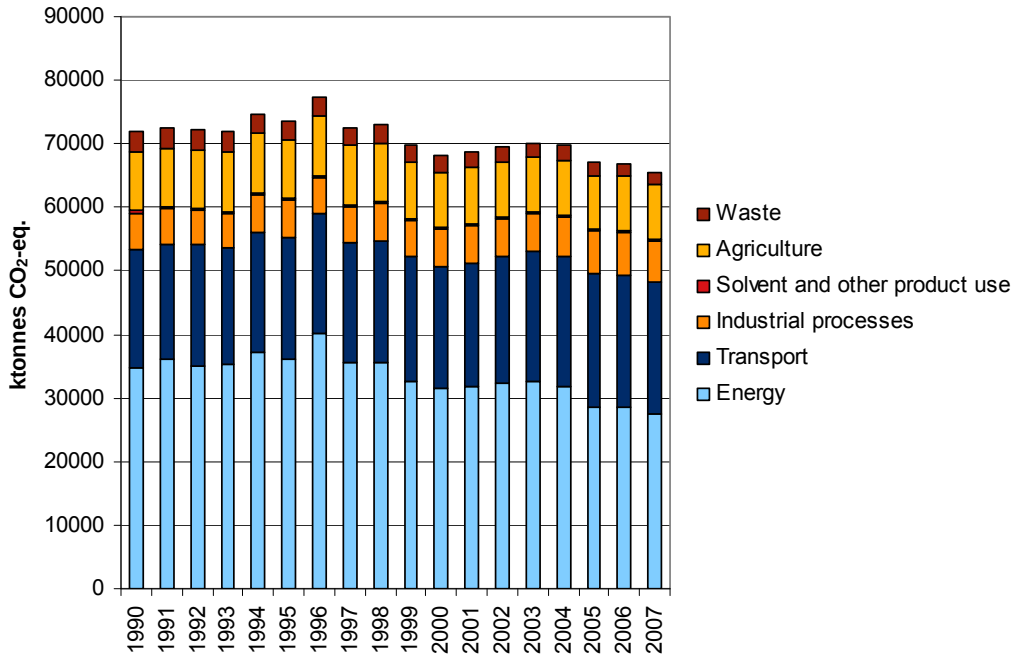

Figure 2.1 Total emissions of all greenhouse gases calculated as CO_2 equivalents from the different sectors.

The Land Use, Land-Use Change and Forestry sector (LULUCF) contributed to a yearly net sink in Sweden, during the period 1990-2007. The size of the sink varied over the period between 21-36 million tonnes of carbon dioxide equivalents, but the trend points towards a somewhat decreasing net sink.

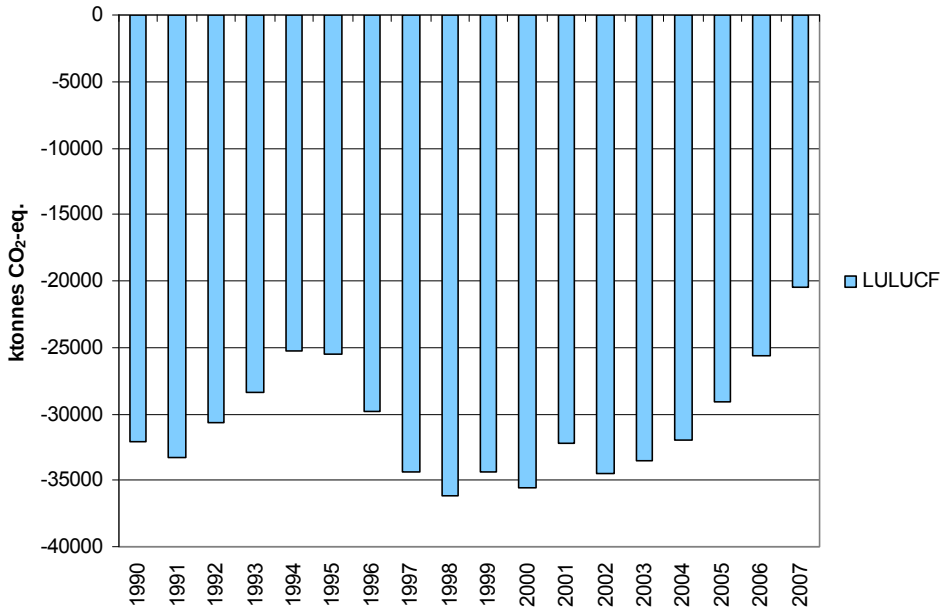

Figure 2.2 Total net removals and emissions from land use, land use change and forestry (LULUCF), calculated as CO_2 equivalents.

GDP growth averaged around 2 % over the period 1990-2007. GDP fell during the early 1990s but average annual growth since 1994 has been just over 3 %. *Aggregated* greenhouse gas emissions have therefore not increased as a result of increased growth in the Swedish economy during the period, and emissions overall have been decoupled from growth. Greenhouse gas emissions (excl. LULUCF) per capita have also decreased, and totalled 7.1 tonnes per capita in 2007, compared with 8.4 tonnes per capita in 1990.

According to Sweden's commitment under the Kyoto Protocol and the EU burden sharing, Sweden's greenhouse gas emissions excluding LULUCF must not exceed 104% of the emissions in the base year. The base year is 1990 for all emissions except fluorinated greenhouse gases, for which it is 1995. The base year's emissions were, when the assigned amount was stipulated in the Initial report on Assigned amount, slightly less than 72,2 million tonnes carbon dioxide equivalents. In 2007 greenhouse gas emissions were around 90% of the base-year level of emissions, which suggests that Sweden will meet its commitment. (Recalculations as a consequence of improved statistics lead to that emissions for the base year in submission 2009 are approximately 72 million tonnes.)

Emissions of greenhouse gases from different sectors of society developed in different directions over the period from 1990 to 2007. The greatest reductions in emissions over the period 1990-2007 took place in the residential and service, agriculture and waste sectors. Increases in emissions occurred principally in the transport sector.

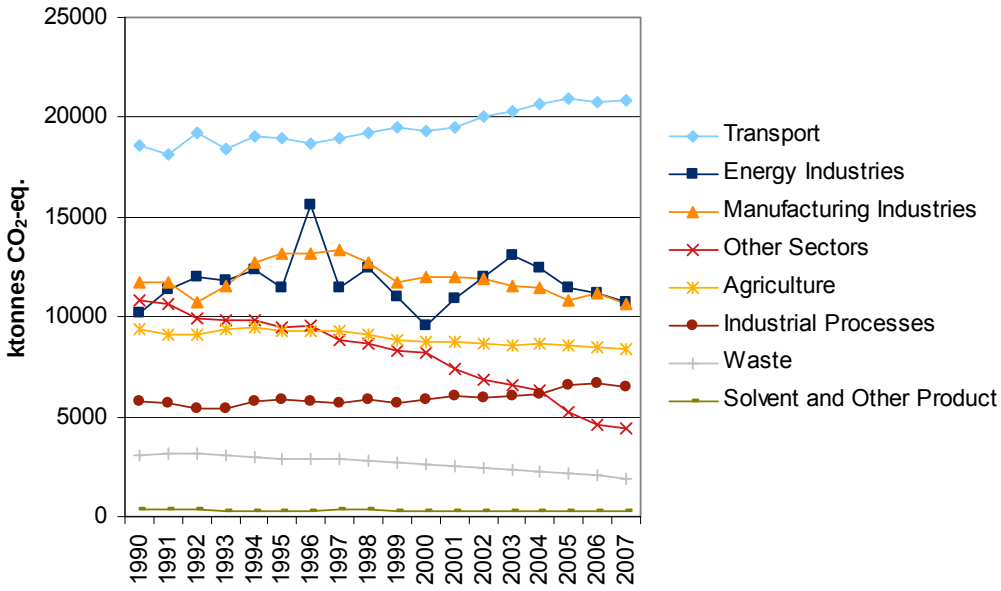

Figure 2.3 Total emissions of all greenhouse gases calculated as CO_2-equivalents from the different sectors.

2.2 Description and interpretation of emission trends in relation to gas

In 2007, emissions (excl. LULUCF) of *carbon dioxide* totalled around 51.6 million tonnes, which is equivalent to around 79 % of aggregated greenhouse gas emissions. Emissions of *methane* were 5.4 million tonnes of carbon dioxide equivalents and account for just over 8% of emissions, while emissions of *nitrous oxide* totalled 7.2 million tonnes, equivalent to around 11%. Only 1.9 % or almost 1.3 million tonnes of carbon dioxide equivalents out of the aggregated greenhouse gas emissions were emissions of *fluorinated greenhouse gases.* The breakdown between the different greenhouses gases was roughly the same over the period 1990-2007.

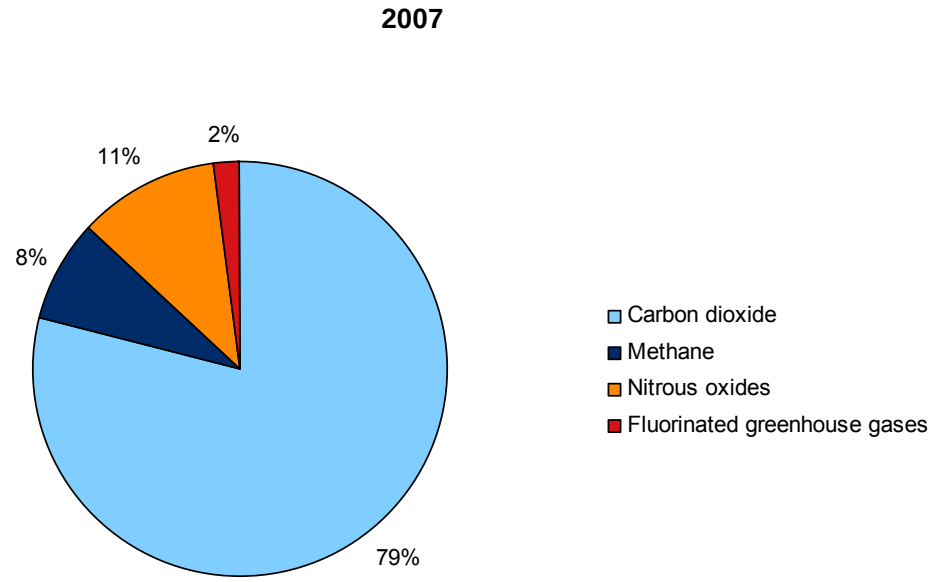

Figure 2.4 Greenhouse gas emissions broken down by gas (2006).

2.2.1 CO_2

In 2007, total *carbon dioxide* emissions in Sweden totalled 51.6 million tonnes, excl. LULUCF. 50 % of carbon dioxide emissions came from the energy sector, 40 % of carbon dioxide emissions came from the transport sector and the remaining 10% came from industrial processes, solvent and other product use and waste. Emissions were 8 % lower in 2007 than in 1990, and it is the energy sector that has shown the greatest reduction.

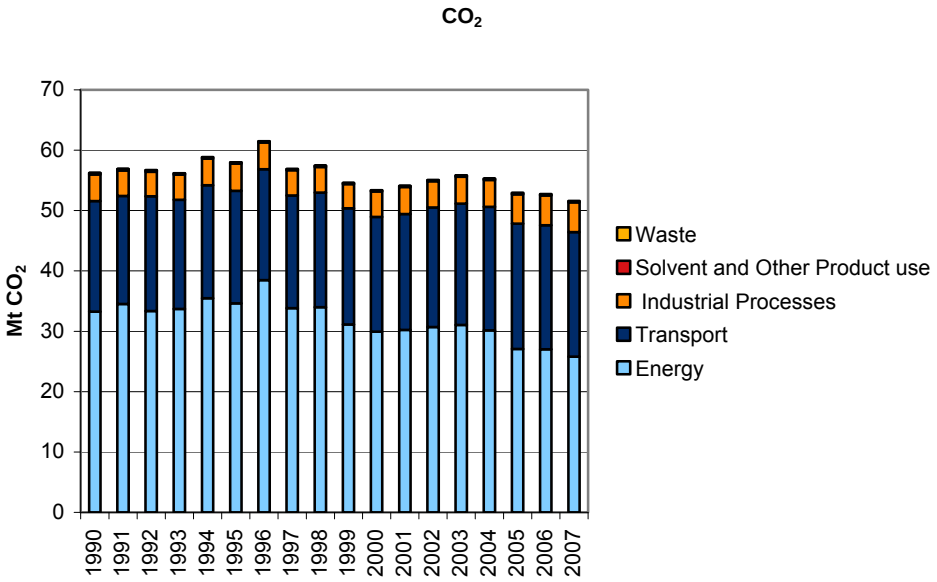

Figure 2.5. Total emissions of CO_2 from different sectors.

2.2.2 CH_4

Emissions of *methane* come primarily from agriculture and landfills, but around 9 % is emitted in the energy and transport sector and from industrial processes. Emissions of methane, excl. LULUCF, totalled around 255 ktonnes in 2007, which is equivalent to around 5.4 million tonnes calculated as carbon dioxide equivalents or just over 8 % of total greenhouse gas emissions. Emissions have fallen by just over 20 % since 1990, largely due to measures taken in the waste sector.

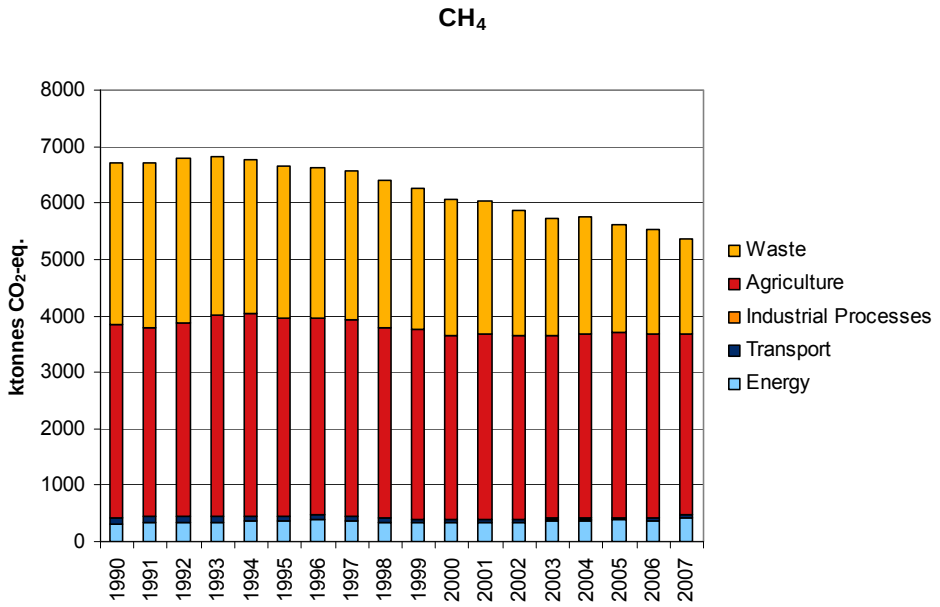

Figure 2.6 Total emissions of CH_4 from different sectors, calculated as CO_2-equivalents.

2.2.3 N_2O

In 2007, emissions of *nitrous oxide* totalled around 23 ktonnes or around 7.2 million tonnes of carbon dioxide equivalents (excl. LULUCF). All sectors produce nitrous oxide emissions, but the emissions came chiefly from the agriculture sector, which accounted for 73 % of emissions. Compared with 1990, emissions have decreased by around 15 %, and it is primarily emissions from the agriculture sector that account for the decrease.

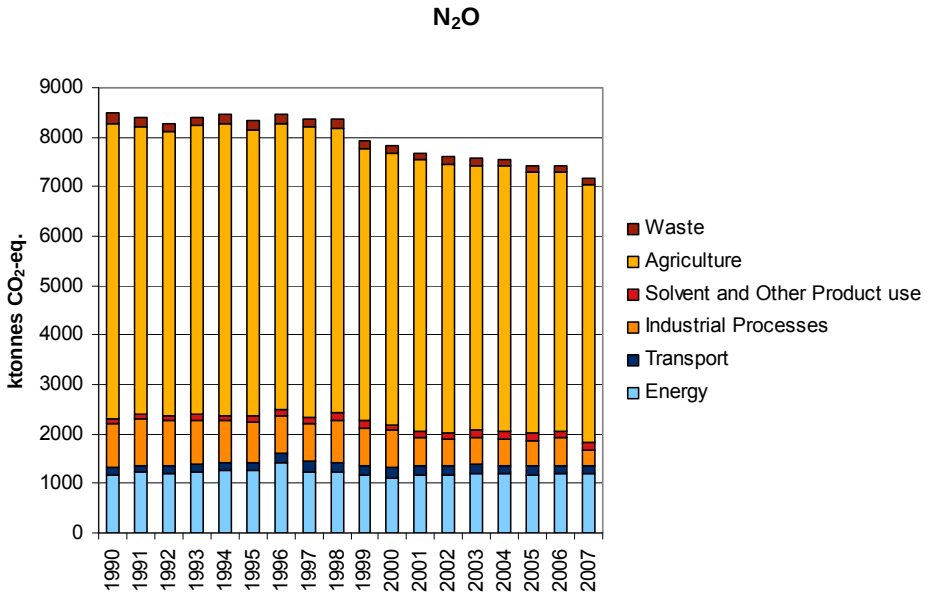

Figure 2.7 Total emissions of N_2O from different sectors calculated as CO_2-equivalents.

2.2.4 Fluorinated greenhouse gases

Emissions of fluorinated greenhouse gases (F-gases) are reported in the industrial processes sector. Total emissions of fluorinated greenhouse gases in 2007 amounted to almost 1.3 million tonnes calculated as carbon dioxide equivalents and account for just under 2 % of total emissions. However, emissions increased by 157 % between 1990 and 2007.

Emissions of HFCs increased in particular, from just under 4 ktonnes of carbon dioxide equivalents in 1990 to around 855 ktonnes in 2007. PFC emissions, on the other hand, have decreased. In 1990 emissions of PFCs amounted to around 377 ktonnes of carbon dioxide equivalents, and in 2007 they had fallen to around 248 ktonnes. Emissions of SF6 varied between 1990 and 2007. In 1990 they totalled around 107 ktonnes and in 2007 they amounted to around 150 ktonnes of carbon dioxide equivalents.

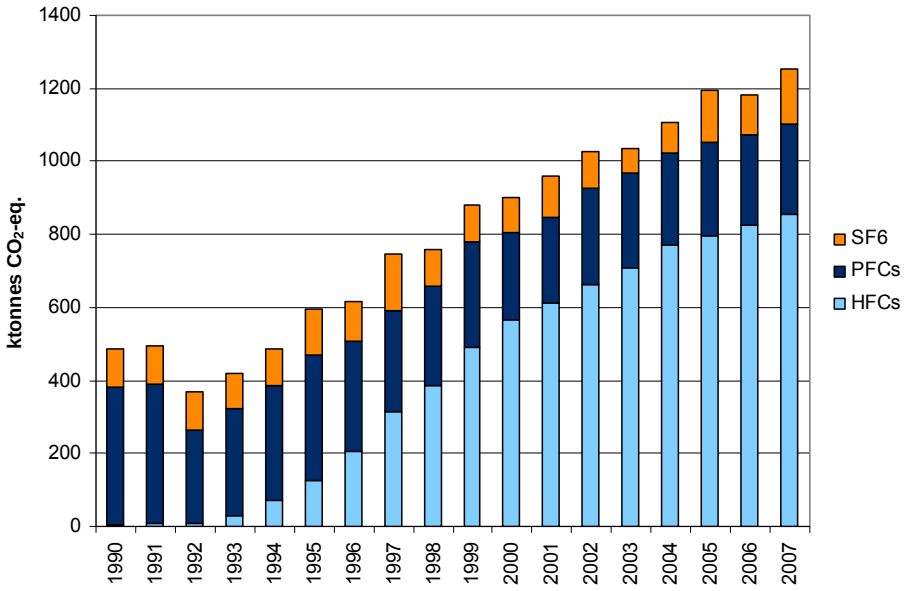

Figure 2.8 Total emissions of SF_6, PFC and HFC, calculated as CO_2-equivalents

2.3 Description and interpretation of emission trends in relation to source

The greatest emissions in 2007 were from the energy, transport and industrial sectors. Emissions from the energy sector made up almost 42% of total greenhouse emissions, in which the energy industry accounted for 16%, industrial combustion for 16%, the residential and service sector for 7% and fugitive emissions and other for around 2.5%. Domestic transport accounted for 32% of total greenhouse gas emissions, agriculture for 13%, industrial processes for 10%, the waste sector for 3% and the use for solvents and other products for 0.5%.

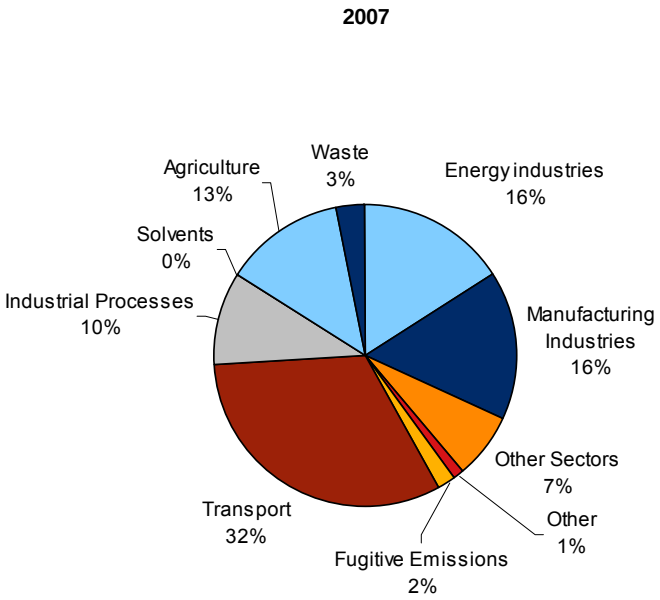

Figure 2.9 Greenhouse gas emissions broken down by sector (2006).

2.3.1 Energy excluding transport

Emissions of greenhouse gases by the energy sector[7] amounted to just over 27 million tonnes of carbon dioxide equivalents in 2007, which is equivalent to almost 42 % of total emissions. Carbon dioxide emissions dominate emissions by the energy sector, while emissions of methane and nitrous oxide are small. Emissions by the energy sector vary depending on temperature and precipitation conditions and the state of the economy, but the trend over the period 1990-2007 was for a slight reduction in emissions. In comparison with 1990, emissions were around 21 % lower in 2007, and the decrease is principally due to the use of oil for heating in the residential and service sector having declined and been replaced principally by district heating based on biomass fuels.

Calculated in terms of carbon dioxide equivalents, total emissions from electricity and district heating production amounted to 8.5 million tonnes, from refineries to 1.9 million tonnes and from industrial combustion to 10.7 million tonnes in 2007. The emissions of the residential and service sector of 4.5 million tonnes include combustion in the residential and service sector and combustion in agriculture, forestry and fisheries. Fugitive emissions from fuels come, for instance, from flaring of gas and refineries and amounted to just under 1.3 million tonnes in 2007 and emissions from other were around 0.3 million tonnes.

[7] Emissions by the energy sector include emissions from the production of electricity and district heating, refineries, manufacture of solid fuels, industrial combustion, fugitive emissions, other and the residential and service sector, including combustion in agriculture, forestry and fisheries

Between 2006 and 2007 a reduction of greenhouse gas emissions is seen in all subsectors within the energy sector. Some reasons could be high oil prices and a lower demand for oil.

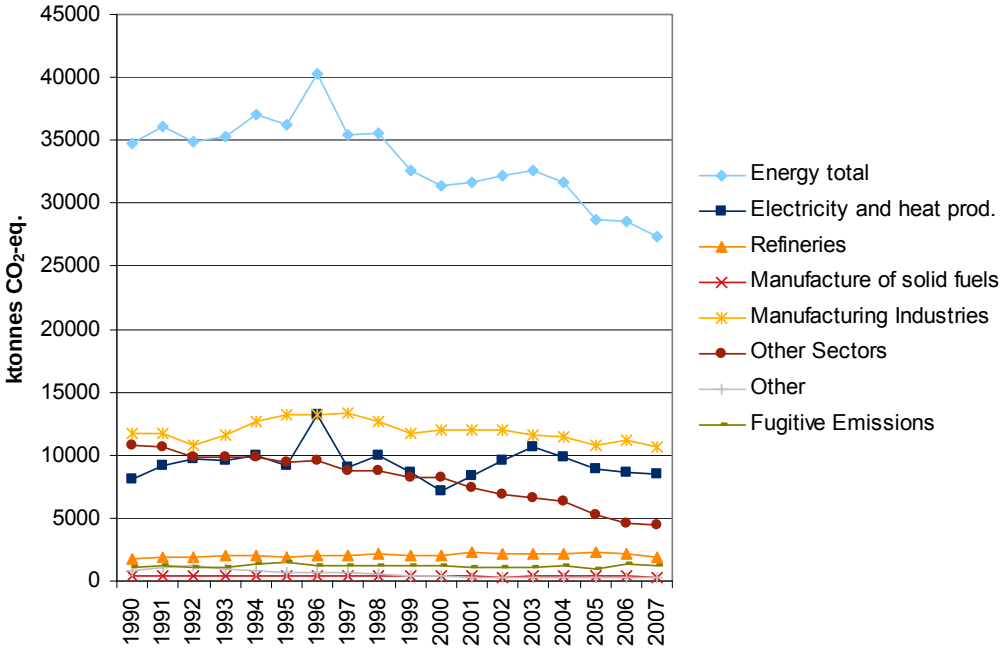

Figure 2.10 Total emissions of all greenhouse gases from the Energy sector, total and per sub-sector.

CARBON DIOXIDE FROM THE ENERGY SECTOR, EXCLUDING TRANSPORT

Energy industries

Emissions of carbon dioxide from the production of electricity and district heating totalled around 8 million tonnes in 2007. Emissions in 1990 totalled around 7.7 million tonnes, but over the period 1990-2007 emissions varied from year to year.

Temperature and precipitation, which vary between years, have an impact on hydropower production and heating needs and thus lead to a variation in emissions between years. This is clearly illustrated by the high emissions in 1996, which was a cold and dry year, and by the low emissions in 2000, which was a warm year with heavy precipitation and thus good availability of hydropower. Emissions are also affected by what energy source is used when there is a shortage of hydropower. The deficient production of hydropower in 1996 was principally offset by increased oil condensing production, while shortage of hydropower in 2003, which was another year of low hydropower production, was largely offset by importing electricity.

During the period, district heating production increased from 34 TWh in 1990 to around 47 TWh in 2007. On the other hand, emissions have not increased significantly as the expansion has principally taken place through increased use of

biomass fuels. Emissions per kWh have instead fallen. Use of biomass fuels, peat and waste in 1990 totalled 10.4 TWh, and it had risen to 36 TWh in 2006. Energy and carbon dioxide taxes have contributed to this trend and in recent years also the electricity certificates system. Use of coal has decreased and been replaced by biomass fuels. On the other hand, the use of oil was fairly stable between 1990 and 2007, although with some variation which can be explained by different temperature conditions from year to year.

Emissions of carbon dioxide from electricity production come from the combustion of fossil fuels in combined heat and power plants, and in some years also from condensing power plants, for example when little hydropower is available. These emissions varied over the period, principally depending on availability of hydropower, but some increase has occurred as a result of increased production in combined heat and power plants with biomass fuels as well as coal, coke and blast-furnace gas, oil and natural gas.

2007 was characterized by a fairly normal inflow to reservoirs in Sweden. The Swedish nuclear power plant reactors had a somewhat lower production than the year before. Simultaneously, electricity use has stabilized in recent years and there was some net importing of electricity. The production of wind power increased substantially from a low level. The fact that production of district heating and heat energy based on bio-fuel etc. was higher in 2007 than in previous years is due to the electricity certificates system which increases profitability of renewable electricity production. All together these factors lead to somewhat lower emissions of carbon dioxide from electricity and district heating in 2007 than 2006.

Production of refined products increased in Sweden during the period, leading to an increase in carbon dioxide emissions from the refineries and fugitive emissions from oil production from 2.0 million tonnes in 1990 to 2.4 million tonnes in 2007 or around 20%. In 2007 emissions were on the contrary lower than in 2006.

Other Sectors

Emissions of carbon dioxide in 2007 were 3.9 million tonnes in the residential and service sector including combustion in agriculture, forestry and fisheries, a decrease of just over 60% in comparison with 1990. The decrease is principally due to a switch from oil to district heating and in recent years also to heat pumps and pellet-fired boilers. Total use of fossil fuels has fallen sharply. Approximately 3 % of detached, semi-detached and terraced houses had oil as their sole source of heating in 2006 while the proportion of houses with combined heating systems in which oil can be used was 3%. The positive trend is principally due to energy and carbon dioxide taxes, rising oil prices and investment grants for connection to the district-heating network. A downward trend in carbon dioxide emissions is therefore visible in this sector, equivalent to around 3 % per year or around 6.4 million tonnes of carbon dioxide in total between 1990 and 2007. The trend in recent years has been for energy consumption for heating per unit of floor area to have fallen for houses and commercial premises but to remain stable in apartment blocks. If conversion losses originating from use by the sector are included, some reduction

can also be seen in this indicator. Causes may be energy efficiency improvements and increased use of heat pumps.

At the same time as carbon dioxide emissions in homes and commercial premises are falling sharply, emissions from energy use in agriculture, forestry and fisheries are increasingly slightly and totalled 1.6 million tonnes in 2007. Emissions here increased by 7 % between 1990 and 2007. The use of machinery constitutes a large part of the emissions and does not follow same development as heating.

Manufacturing industries

Carbon dioxide emissions from industrial combustion were approx. 10 million tonnes in 2007. 1990-2007 emissions decreased by almost 10%, but have varied over the years principally due to economic fluctuations. A few number of energy-intensive industries account for a large portion of carbon dioxide emissions in the sector. The pulp and paper industry accounts for 16% of emissions and the chemical industry accounts for 16%, while the iron and steel industry accounts for 12%.

Viewed over a longer period from 1970 on, industry has reduced its use of oil and increased its use of electricity. However, use of fossil fuels increased by a few TWh between 1992 and 2007. Contributory factors have included increased production and lower energy and carbon dioxide taxes. Use of oil has, however, increased less than production volume due to some improvement in energy efficiency and a switch to electricity and in same cases to biomass fuels. Both specific oil use (kWh per production value at 1991 prices) and specific electricity use almost halved over the period 1992-2006.

From 2006 to 2007 emissions of carbon dioxide decreased by almost 5% from industrial combustion. The reduction arises from emission reductions in pulp and paper industry. Other industrial branch emissions have not changed especially much in recent years. Oil prices sank at the beginning of 2007 but increased substantially during the second half of 2007, which probably has a connection with the reduced emissions in the industry.

EMISSIONS OF METHANE AND NITROUS OXIDE FROM THE ENERGY SECTOR

Only a small proportion of emissions from the energy sector are emissions of methane and nitrous oxide. Approximately 4% of emissions from the energy sector are emissions of nitrous oxide, and approximately 1% are emissions of methane.

Methane emissions from the energy sector excl. Transport have increased by around one third between 1990 and 2007. Almost two-thirds of emissions originate from the residential and service sector, including energy use in agriculture. These emissions have increased during the period, but the greatest percentage increase happened within the electricity and district heating where emissions sharply increased.

Nitrous oxide emissions have been stable between 1990 and 2007.

2.3.2 Transport

Transport's share of emissions has continued to increase and in 2007 was 32 % of the total national greenhouse gas emissions. For the transport sector as a whole, greenhouse gas emissions increased by 12% over the period from 1990 to 2007 inclusive, from 18.6 million to 20.8 million tonnes of carbon dioxide equivalents.

However, in 2006 emissions from the transport sector's national emissions were somewhat lower than 2005 but have increased during 2007. The decrease in 2006 is primarily explained by reductions in domestic aviation and navigation as well as by greenhouse gas emissions from road traffic which only increased by 0.03 %. Emission increasing in 2007 is due to somewhat greater emissions from road traffic by 0.8 %. From 2006 to 2007 the continued reduction of greenhouse gases from domestic aviation by 3 % and navigation 8.9 %.

Greenhouse gas emissions from international bunkering in Sweden continue to increase. This is not included in the Kyoto Protocol commitments and the figures given above. Since 1990 international aviation bunkering in Sweden has increased by 64 % from almost 1.4 to 2.2 Mtonnes and navigation by 233 % from almost 2.3 to 7.5 Mtonnes of carbon dioxide equivalents. The increase of emissions for international bunkering in Sweden between 2006 and 2007 was 9.4 % from aviation and 3.9 % from navigation.

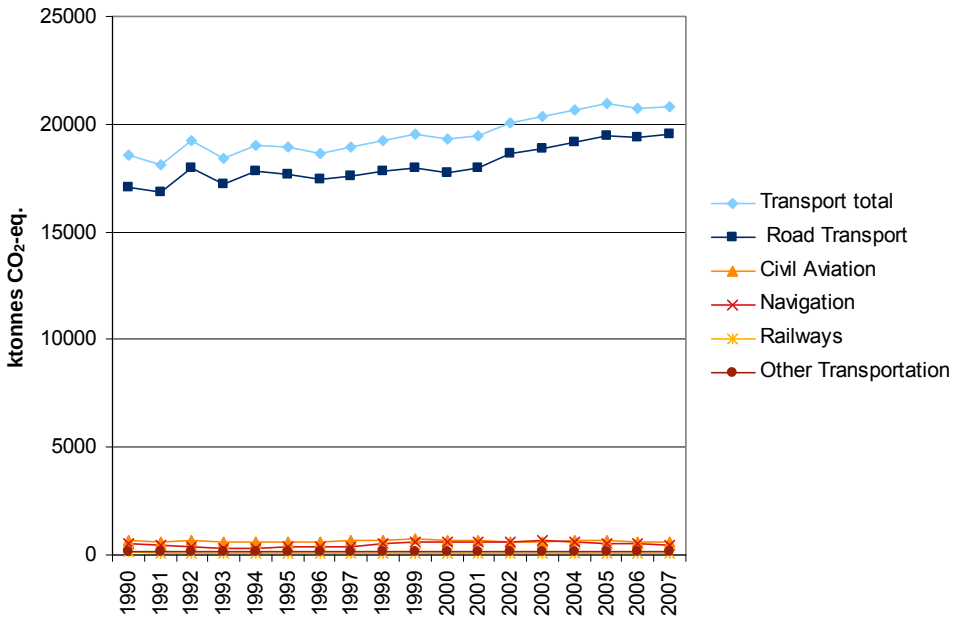

Figure 2.11 Emissions from the transport sector, total and per subsector

EMISSIONS OF CARBON DIOXIDE FROM THE TRANSPORT SECTOR

Carbon dioxide from road traffic accounts for the greatest share of the transport sector's greenhouse gas emissions and were approx. 19.4 million tonnes 2007. From 1990 to 2007 the increase of carbon dioxide was from road traffic 14.8 % and between 2006 and 2007 the increase was 0.8 %. This as is reported in statistics is

only carbon dioxide from fossil fuels. Consequently carbon dioxide from petrol only concerns fossil carbon dioxide while ethanol is not counted.

Diesel consumption for private cars increased by 23 % from 2006 to 2007 or by 4699 TJ while petrol consumption for private cars at the same time decreased by 3442 TJ. Several factors have been significant in limiting carbon dioxide emissions from petrol for road traffic. The use of renewable fuels has increased as carbon-neutral motor fuels have been exempt from energy tax since 2004, as well as not being subject to carbon dioxide tax. The oil companies started large-scale admixture of ethanol in petrol in 2003, which has rapidly led to the situation where almost all petrol sold in Sweden now contains ethanol. Furthermore E85 fuel is sold as a greater part consists of ethanol. Also usage of biogas as fuel is increasing. As an alternative for diesel usage of renewable fuel has begun. Motor fuel taxes, together with the high price of petrol, are judged to have had an impact on a switch from vehicles powered by petrol to diesel or renewable fuels and on change of fuel and to have limited consumption. The total number of what are known as eco-cars has also increased sharply in recent years as a result of several changes in policies that promote their introduction.

It is principally heavy goods vehicles that use diesel, and most of the increase in diesel use is due to increased transport mileage with heavy goods vehicles, but some of the increase is also due to an increased proportion of light goods vehicles and cars running on diesel. Diesel consumption for heavy goods vehicles increased by around 38% between 1990 and 2007, and the increased transport mileage is due to the structural transformation of society entailing specialisation, centralisation and globalisation, which means that freight is being transported ever greater distances.

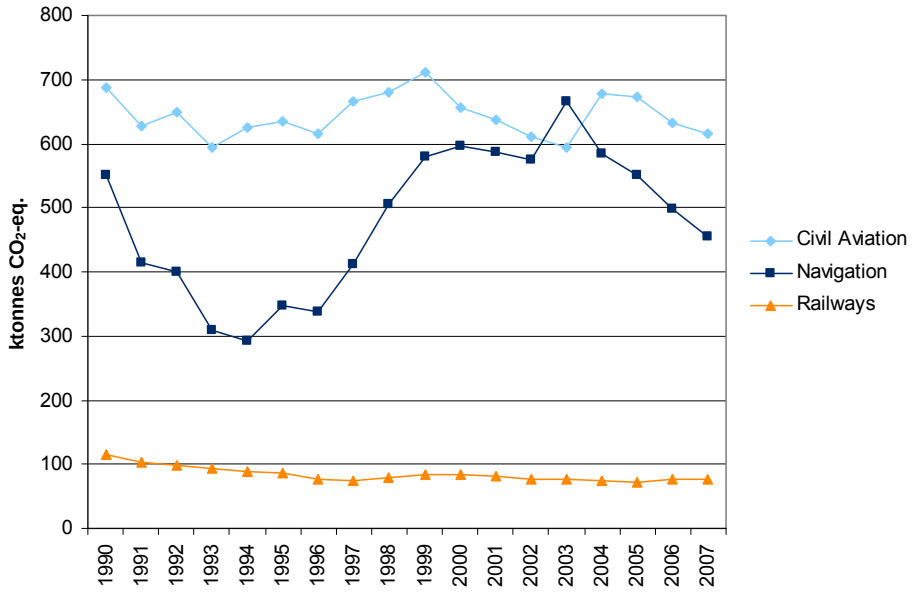

Figure 2.12 Emission from aviation, navigation and railways.

Domestic aviation and navigation emissions of carbon dioxide continue to decrease and are now 10.1 % respective 17.6 % below 1990's levels. Emissions from domestic aviation vary from year to year. Following a sharp increase in 2004, emissions have decreased. Emissions of CO_2 from domestic aviation totalled 673 ktonnes in 1990 and 605 ktonnes in 2007. Domestic aviation has decreased because the share of train and to some extent car journeys has increased. The fact that more people are choosing to travel by train or car rather than flying is considered to be due in part to a decrease in the availability of short-haul air travel and new security requirements and routines reducing the advantages of flying in terms of speed and flexibility. Since Arlanda Airport was integrated into the Swedish railway system, rail travel has proved to be a competitive alternative for both business and private travellers who use Arlanda as a departure point for onward journeys.

Carbon dioxide emissions for domestic navigation are estimated at 445 ktonnes in 2007, which is around 9% lower than in 2006. Emissions by domestic navigation have fallen since 2003. It should be noted at the same time that a variable proportion of domestic marine transport activity uses ship fuel bunkered abroad, which may affect the figures.

Carbon dioxide emissions from the railways have decreased by around 34 % since 1990 and their total level accounts for a marginal share of transport sector emissions.

METHANE AND NITROUS OXIDE FROM THE TRANSPORT SECTOR

Total methane emissions from transport have fallen by 70% since 1990 as a result of better exhaust emission control and were 31 ktonnes of carbon dioxide equivalents in 2007.

The emissions of nitrous oxide from the transport sector were 163 ktonnes in 2007. Emissions of nitrous oxide increased in connection with the shift to cars fitted with catalytic converters. However, changed technology has meant that emissions are decreasing since 2000.

2.3.3 Industrial processes

Emissions from industrial processes come in particular from the production of iron and steel and from the cement and lime industries. Some examples of emission sources are the use of coke in blast furnaces, the use of dolomite and limestone in production in the mineral industry and the use of coal in the reduction of copper. There are also emissions of fluorinated greenhouse gases in this sector. Total emissions from the sector amounted to around 6.5 million tonnes of carbon dioxide equivalents in 2007, which is equivalent to 10 % of aggregated emissions. Carbon dioxide emissions are dominant at around 76 %, followed by fluorinated greenhouse gases with approximately 19 %, nitrous oxide with approximately 5 % and methane with 0.1 %.

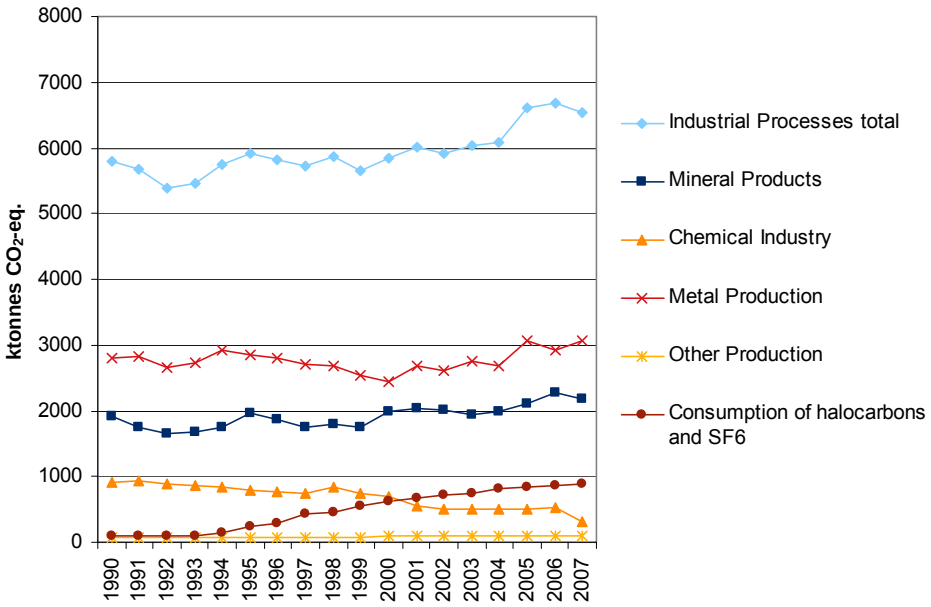

Figure 2.13 Emissions from the Industrial processes sector, total and per subsector.

Emissions in 2007 were almost 13 % higher than in 1990, but total emissions in this sector have varied somewhat since 1990, principally due to variation in production volumes and economic fluctuations. Economic fluctuations may, however, differ for different industries. Emissions from the mineral industry have increased in recent years, for example, while those from the chemical industry have decreased over the same period.

Carbon dioxide emissions from the mineral industry have increased in recent years. This is principally due to an economic upturn in the construction sector, both in Sweden and in other countries to which the cement is exported. However the emissions decreased in 2007 compared to 2006. Production of iron and steel has also increased in recent years due to an increase in demand for iron ore and other iron and steel products on the world market. Also in 2007 the emissions increased compared to 2006. The emissions from the chemical industry have decreased during 1990-2007 and in 2007 the emissions further decreased, mainly because a part of the production in one plant was closed. Total emissions from industrial processes decreased by 2% between 2006 and 2007, principally due to the decrease in the chemical industry and the mineral industry.

FLUORINATED GREENHOUSE GASES (HFC, PFC, SF_6)

Fluorinated greenhouse gases have a number of uses. Most emissions of fluorinated greenhouse gases in Sweden today come from primary aluminium production, leakage from refrigeration and air-conditioning systems, foam plastic manufacturing and foam plastic products. Total fluorinated greenhouse gas emissions in 2007 amounted to around 1250 ktonnes calculated as carbon dioxide equivalents and account for around 1.9 % of total emissions. Emissions of fluorinated gases are showing an increasing trend, however, and increased by 157 % between 1990 and

2007, principally due to a sharp increase in HFC emissions. This is due to HFC in many cases having replaced the ozone-depleting substances CFCs and HCFCs as refrigerants and the number of refrigerating and air-conditioning units, as well as heat pumps, having increased. The emissions of fluorinated greenhouse gases also increased in 2007 by 6% compared to 2006.

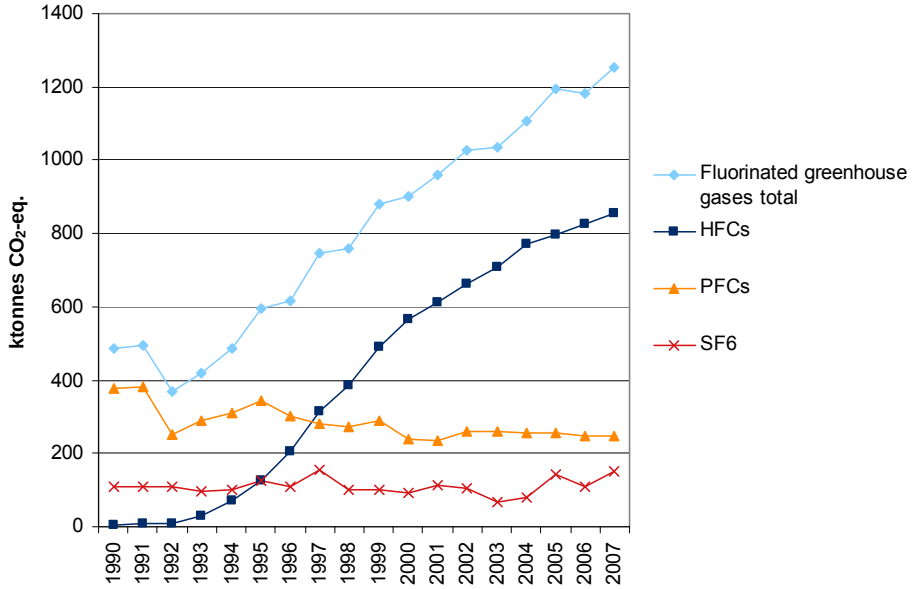

Figure 2.14 Emissions of fluorinated greenhouse gases, total and per gas.

2.3.4 The use of solvents and other products

The use of solvents principally leads to emissions of volatile organic compounds, and the carbon content of these emissions is assumed, according to the reporting guidelines, to be oxidised to carbon dioxide. The use of other products, such as spray cans and gas springs, also leads to emissions of nitrous oxide. Emissions of carbon dioxide and nitrous oxide calculated as carbon dioxide equivalents in 2007 totalled 294 ktonnes, which is around 0.5 % of total emissions. In comparison with 1990, emissions have decreased by around 11 %. Approximately 26 % of carbon dioxide emissions come from paints, but these emissions have been reduced by a shift to water-based paints.

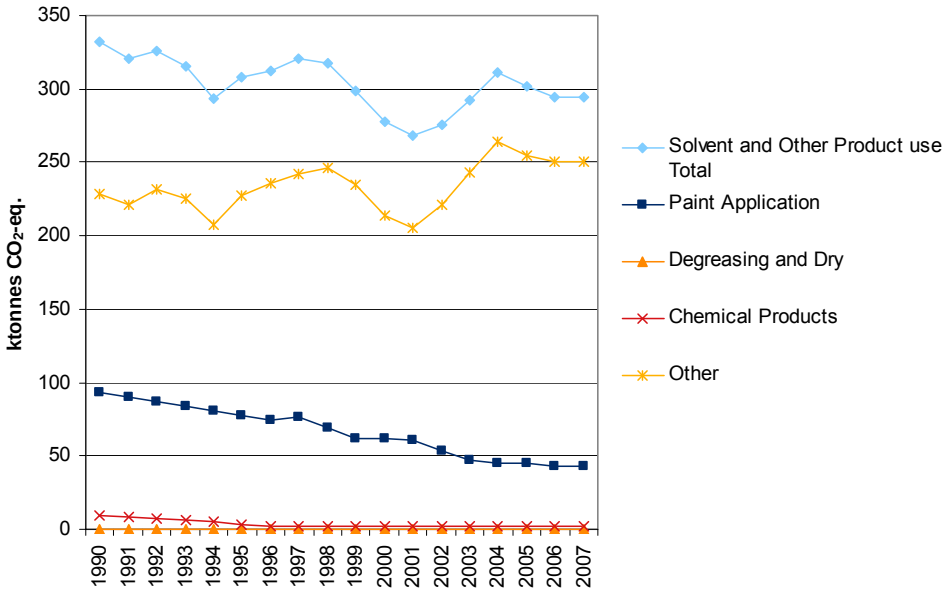

Figure 2.15 Emissions from the use of solvents and other products, total and per subsector.

2.3.5 Agriculture

Agriculture is the largest source of methane and nitrous oxide emissions. Emissions of these greenhouse gases in 2007 amounted to 8.4 million tonnes of carbon dioxide equivalents, of which around 60 % was made up of nitrous oxide and 40 % of methane. In comparison with 2006, emissions have decreased by just over 70 000 tonnes or 0.8 %. This is principally due to two factors: firstly the number of cattle has decreased, resulting in lower methane release, and secondly lower application of nitrogen fertiliser to agricultural land has resulted in decreased release of nitrous oxide. Aggregated emissions decreased by 3.6 % over the period 2000-2007, and they have fallen by 10.1 % since 1990.

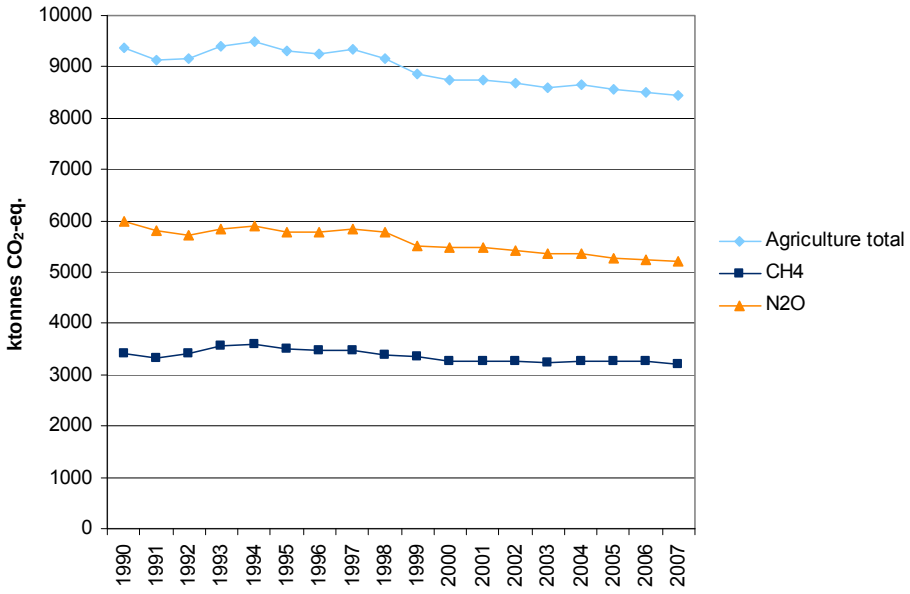

Figure 2.16 Emissions from agriculture, total and per gas.

EMISSIONS OF METHANE FROM AGRICULTURE

Methane emissions come principally from the digestion and manure of cattle, while other types of livestock are of relatively low significance. The most important reason for the decreased emissions is reduced livestock farming. The number of dairy cows decreased from 576 000 in 1990 to 370 000 in 2007. The greatest reduction took place in 1990 and 1991, when a large number of farms abandoned milk production. Some of these changed over to extensive meat production with the aid of government conversion grants, and the number of beef cattle therefore increased during the first half of the 1990s. Following Sweden's accession to the EU in 1995, the EU's Common Agricultural Policy (CAP) stabilised livestock numbers for livestock that have the right for subsidies, for example cattle. The long-term trend is nevertheless for a successive decrease in both cattle and swine, while the number of sheep and chickens for slaughter has increased. Overall, this signifies a decrease in methane emissions from both livestock and their manure. Methane emissions per dairy cow have increased slightly due to increased milk yield, greater quantity of manure and a higher proportion of slurry management, but emissions per produced quantity of milk have fallen slightly at the same time.

EMISSIONS OF NITROUS OXIDE FROM AGRICULTURE

Nitrous oxide emissions come principally from the supply and conversion of nitrogen in soil. Nitrogen is supplied to the soil through the use of farmyard manure and commercial fertilisers, the growing of nitrogen-fixing crops and atmospheric precipitation. Cultivation as such, particularly of peat soils, also results in significant release of nitrous oxide, as does conversion of the nitrogen that leaches to lakes and watercourses. The reduced emissions since 1990 are due to the use of both mineral fertiliser and farmyard manure having decreased. The quantity of farmyard

manure is declining principally as a consequence of the decreasing number of dairy cows. The action programme which has been implemented to lower nitrogen losses from agriculture has to some extent reduced the indirect emissions of nitrous oxide from leached nitrogen and ammonia deposition. The expansion of slurry management for pigs and dairy cows has also reduced emissions. Unlike in the case of methane, nitrous oxide emissions from slurry systems are substantially lower than from traditional solid manure management.

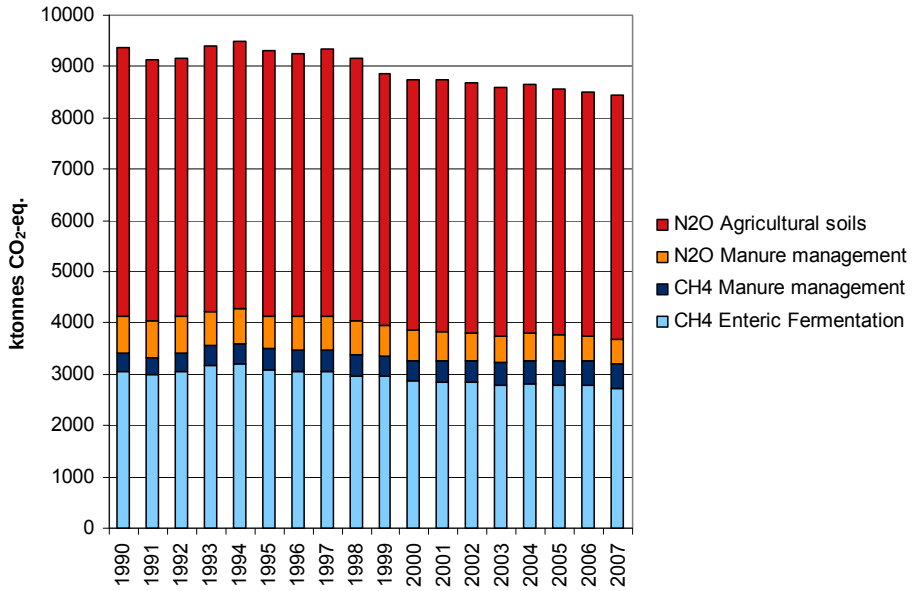

Figure 2.17 Emissions from agriculture, total and per gas and subsector.

2.3.6 Land Use, Land Use Change and Forestry

The Sector Land Use, Land Use Change and Forestry during the period 1990-2007 contribute to a yearly net sink in Sweden. During the period the sink has varied between 21-36 million tonnes of carbon dioxide equivalents but the trend points to a somewhat decreasing sink from the sector. The decreasing sink is mainly due, among other things, to an increase in felling. Over the last few years the sink is decreasing at a somewhat higher rate. This could be due to a severe storm at the beginning of 2005 that brought down a large quantity of forest and the result of this also affects the size of the net sink in the years after 2005, simultaneously as the felling increases. According to Swedish National Board of Forestry statistics, felling ranged between 64 Mm^3 and 95 Mm^3 over the period 1990-2007, with the exception of 2005 when the felling was estimated to 122 Mm^3. However the uncertainty in data gradually increases from 2004 and onwards since the number of sample plots used in the estimate gradually decreases..

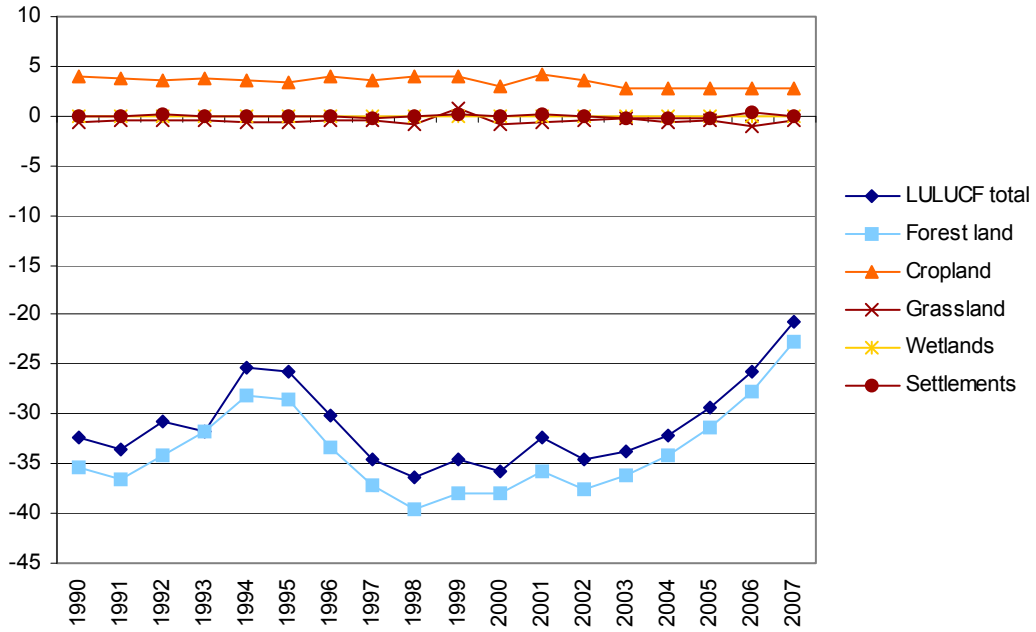

Figure 2.18 Emissions and removals of greenhouse gases from the LULUCF sector

The total size, variation and trend of the net sink, is mainly affected by the carbon stock change in the forest. The carbon stock change in living biomass in the forest affects the most, but emissions from soil organic carbon in the forest are also meaningful. The removal in living biomass in the forest has varied between approx. 20-40 million tones of carbon dioxide, while emissions from soil organic carbon in forest land has varied during the period 1990-2007 between 1.5-7 million tonnes. The cropland is responsible for emissions of carbon dioxide when cultivating organogenic soils and the emissions have varied during the period between 3-4 million tonnes of carbon dioxide. The subsectors grassland, wetlands and settlements account for very small areas compared to the forest land which lead to a higher uncertainty in data. The removal of carbon dioxide in grassland is approx. 0.5 million tonnes of carbon dioxide while the carbon stock change in wetlands and settlements is very small.

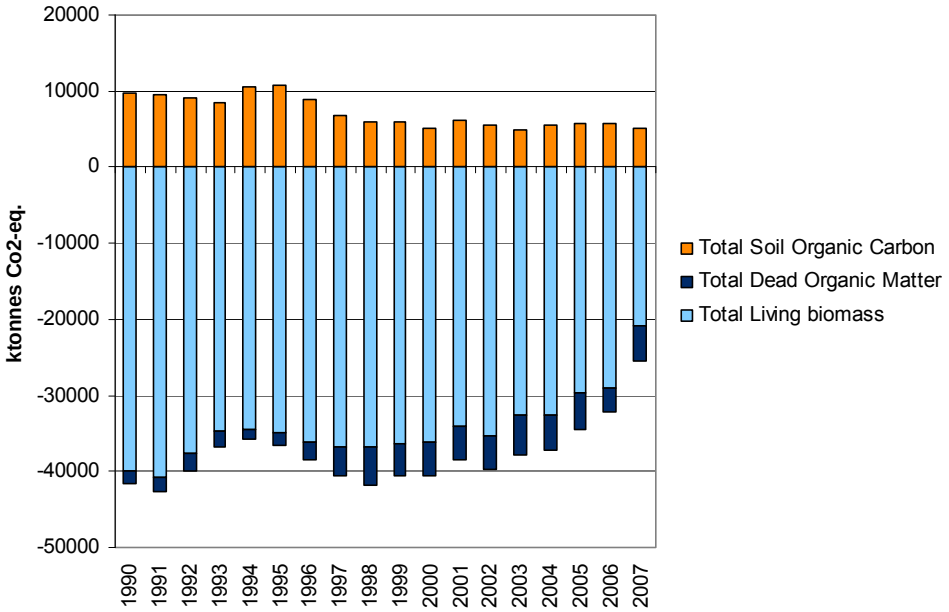

Figure 2.19 Emissions and removals of carbon dioxide from different carbon pools.

The net sink is calculated as the total carbon stock change in the three carbon pools of living biomass, dead organic matter (dead wood and detritus including the humus layer of soil) and soil organic carbon for different land use categories. The carbon pool living biomass and dead organic matter contribute as an aggregate to a net sink, while soil organic carbon account for net emissions. In addition, emissions of N_2O from fertilization and disturbance associated with conversion to cropland, CO_2 emissions from lime application and N_2O, CH_4 and CO_2 from biomass burning are calculated but these emissions are very small. The emissions of CO_2 varied between 50-170 ktonnes, the emissions of CH_4 varied between 2-12 ktonnes and emissions of N_2O varied between 50-115 ktonnes, calculated in carbon dioxide equivalents.

2.3.7 Waste

Total emissions from the waste sector in 2007 amounted to 1.9 million tonnes of carbon dioxide equivalents or 3 % of total greenhouse gas emissions. In comparison with 1990, emissions were around 38 % lower in 2007. Emissions from the waste sector are dominated by methane emissions from landfills, with around 87%, while nitrous oxide emissions from wastewater account for just over 7% and carbon dioxide emissions from incineration of hazardous waste for just over 5 %.

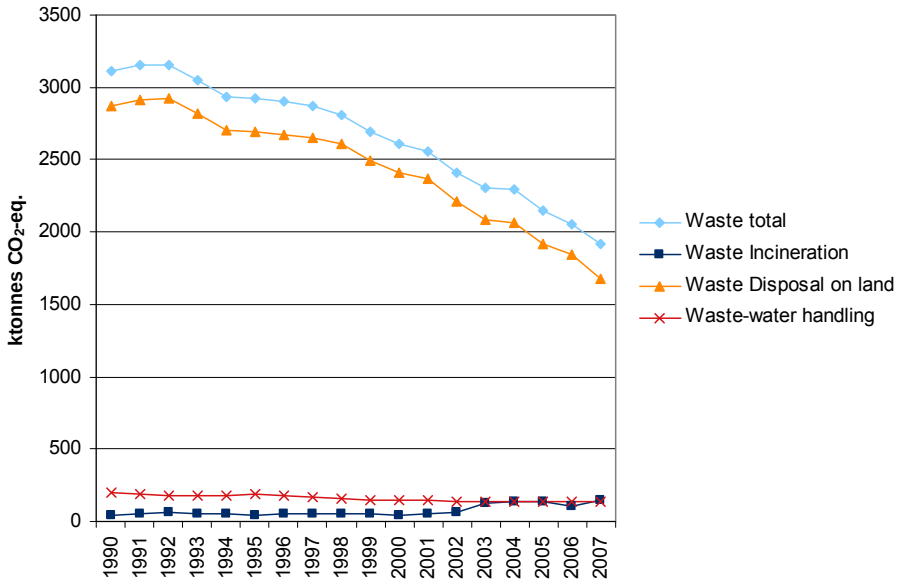

Figure 2.20 Emissions from Waste sector, total and per subsector.

Landfills are the largest source for the emissions of methane gas, after livestock farming, as methane is formed when organic waste is placed on landfills. Methane emissions have declined steadily since the early 1990s, partly because the amount of organic material in landfills has declined and partly due to the increased collection and management of methane gas from landfills.

Several policy instruments have been significant in this trend. During the 1990s there was, for instance, the introduction of producer responsibility for a number of different groups of articles, for example packaging, waste paper, office paper and tyres. It is also believed that the demand for municipal waste planning that was introduced in 1991, has contributed to the expansion of methane collection and to the reduction of the amount of degradable material deposited in landfills.

A tax on landfill waste was introduced in 2000, and bans on the landfill disposal of combustible waste (in 2002) and organic material (in 2005) have subsequently been introduced. These bans have now had an effect. In 2007 the total amount of household waste deposited has decreased by 77 % compared to the level in 2002 and with 87% compared to 1990. Also the landfilling of other waste fractions has decreased significantly. Sludge from the pulp industry has for example previously been the most important industrial organic waste category deposited. Today the sludge from pulp industry is either incinerated or composted. Between 2006 and 2007 the emissions of methane decreased by around 9% and the decrease is mainly due to the bans on landfills disposals.

Nitrous oxide emissions from wastewater handling were around 140 ktonnes of carbon dioxide equivalents in 2007 and accounted for 0.2% of total emissions. Emissions have fallen by 29% since 1990.

Carbon dioxide emissions from incineration of waste were around 103 ktonnes in 2007. Emissions have increased somewhat in recent years in comparison with

the level of emissions from 1990 to 2002. The increase in emissions is due to an increased quantity of waste being incinerated as capacity has increased since 2003.

2.3.8 International bunkers

Emissions of greenhouse gases from international bunkering of fuels amounted to almost 9.8 million tonnes of carbon dioxide equivalents in 2007. This includes refuelling in Sweden by international navigation and international aviation and emissions from this fuel are not included in the reporting of the total emissions from Sweden which are calculated in the Kyoto Protocol commitments. International bunkering of fuel is substantially greater than fuel use for domestic navigation and aviation.

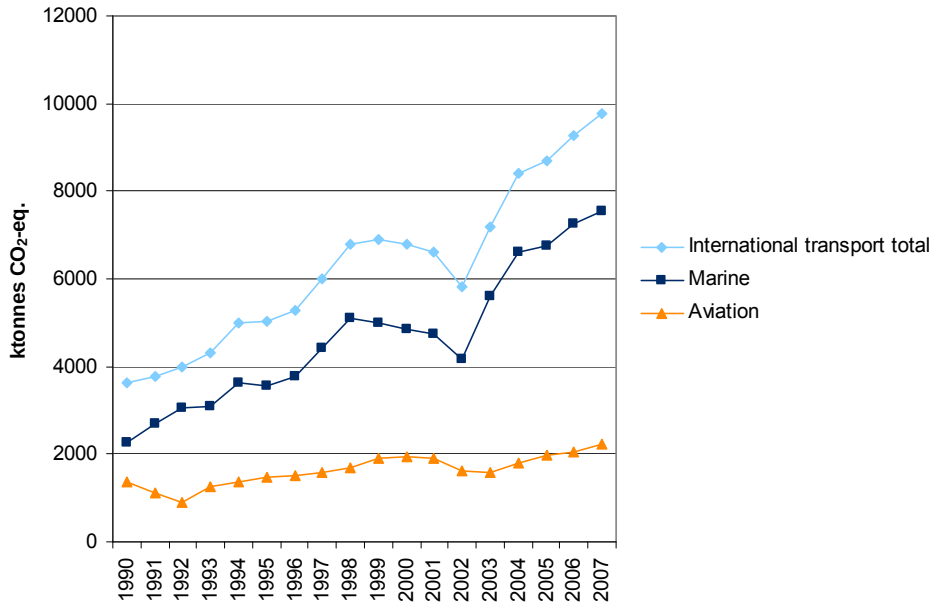

Figure 2.21 Emissions from international bunkers, total and per subsector.

Emissions from international navigation totalled 7.5 million tonnes of carbon dioxide equivalents in 2007. This is an increase of 3.9 % compared with 2006 and just over 233 % since 1990. Part of the explanation is that international freight transport activity has increased due to an increased quantity of freight and globalisation of trade and the systems of production having led to freight being transported over longer distances. Another explanation could be that Swedish refineries are producing low-sulphur Eo2-5, which fulfils strict environmental requirements and this has led to more shipping lines having chosen to refuel in Sweden. The fluctuations in bunkered volumes between different years depends on the price of fuel in Sweden in comparison with other ports in other countries.

Greenhouse gas emissions from the international bunkering of aviation continue to increase and was 2.2 million tonnes of carbon dioxide equivalents in 2007, which was 0.9 million tonnes or 64% higher than 1990 and 9.4% higher than 2006. Emissions from the international bunkering of aviation have varied over time. The

long-term trend is powerfully increasing even if there have been declines at the beginning of 1990s as well as the beginning of the current decade.

2.4 Description and interpretation of emission trends for indirect greenhouse gases and SO_2

2.4.1 NMVOC

Emissions of non-methane volatile organic compounds (NMVOC) totalled around 178 ktonnes in 2007, and emissions have decreased by 49 % in comparison with 1990. The main contributors to NMVOC emissions are solvents-contiang products, road traffic and combustion of wood in households. However,machinery in some industrial activities and use of solvents are also significant for emissions. Road traffic leads to the greatest emissions in the area of transport, but road traffic has also shown the greatest reduction in emissions due to new exhaust emission requirements. Environmental requirements in the new installation of wood-fired boilers and reduced emissions from products containing solvents have also contributed to lower emissions.

NMVOC emissions from the energy sector (excl. transport) totalled around 48 ktonnes in 2007, a decrease of 23 % in comparison with 1990. Most of the decrease occurred in the early 1990s and related to fugitive emissions from oil refineries.

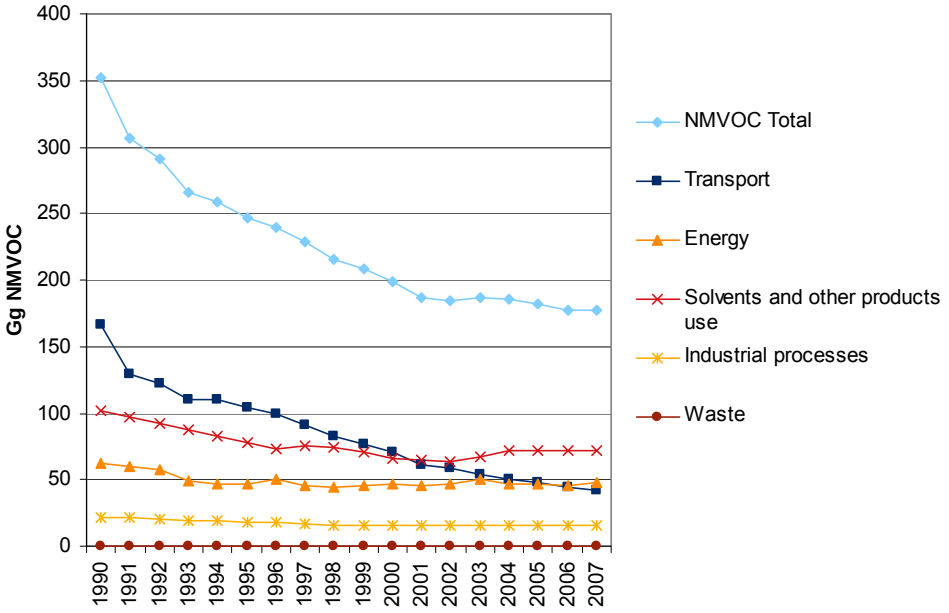

Figure 2.22 Total emissions of NMVOC and emissions from the different sectors.

2.4.2 NO_X

Emissions of nitrogen oxides amounted to around 167 ktonnes in 2007, a decrease of 45 % in comparison with 1990. Nitrogen oxides are formed in all combustion in the energy and transport sectors, and the largest emission sources are road traffic, machinery, navigation and production of electricity and heating.

Emissions of nitrogen oxides from the energy sector totalled just over 65 ktonnes in 2007, a decrease of 34% compared with 1990. The largest sources of emissions are machinery in industry, agriculture and forestry and combustion in the production of electricity and heating and in industry.

19% of emissions in the energy sector in 2007 came from electricity and district heating production. As a result of the NOx charges introduced in the early 1990s and the cleaning measures stimulated as a result, the contribution of the energy sector has also decreased. Some variation is visible over the years which is related to temperature and consequently the need for heating and to precipitation, which affects the need for combustion-based production of electricity. Emissions were therefore lower, for example, in 2000 than in 2003, which was a dry year.

Emissions from machinery in industry account for around one third of emissions of nitrogen oxides by the energy sector (excluding transport). These have decreased by just over 40% during the period 1990-2007. Machinery in agriculture and forestry taken together account for almost 20% of the emissions in the energy sector. There has also been an decrease here in recent years.

Traffic is a large source of emissions of nitrogen oxides, and the emissions come largely from road traffic with 87 ktonnes, but the introduction of catalytic converters in cars and the subsequent successive tightening of exhaust emission requirements have contributed to a general decrease in concentrations of nitrogen oxides in urban areas. Road-traffic emissions of NOx decreased by 3% between 2006 and 2007.

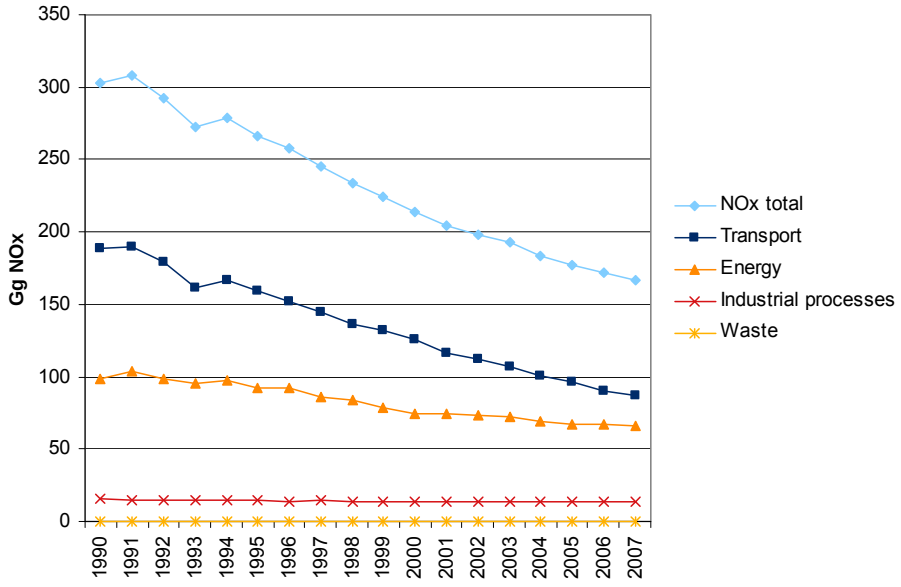

Figure 2.23 Total emissions of NO_X and emissions from the different sectors.

2.4.3 CO

Emissions of carbon monoxide have developed in the same way as NOx emissions. Emissions have decreased from around 938 ktonnes in 1990 to around 566 ktonnes in 2007. 42 % of emissions came from the transport sector and 42% from the 'Other Sectors'.

Energy sector emissions of carbon monoxide increased from around 230 ktonnes in 1990 to around 300 tonnes in 2007. 78 % of emissions from the energy sector came from household energy use.

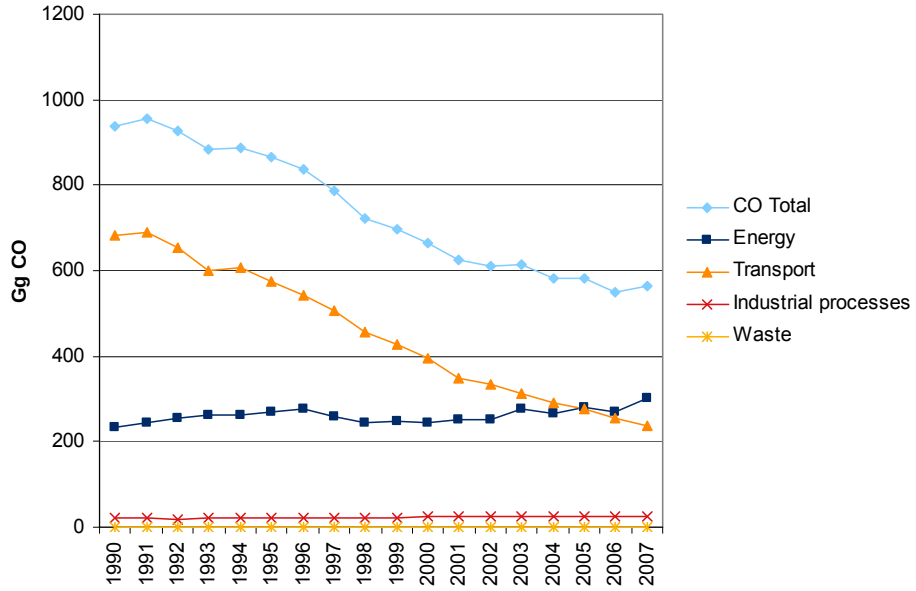

Figure 2.24 Total emissions of CO and emissions from the different sectors.

2.4.4 SO_2

Sulphur dioxide emissions come form the energy, transport and industry sectors and continued to decrease during the 1990s. In 2007, emissions totalled around 34 ktonnes, which is a decrease of 68% compared with 1990. The continued decrease is due to a change-over from fuels with high sulphur levels to low-sulphur fuels, for both vehicles and heating.

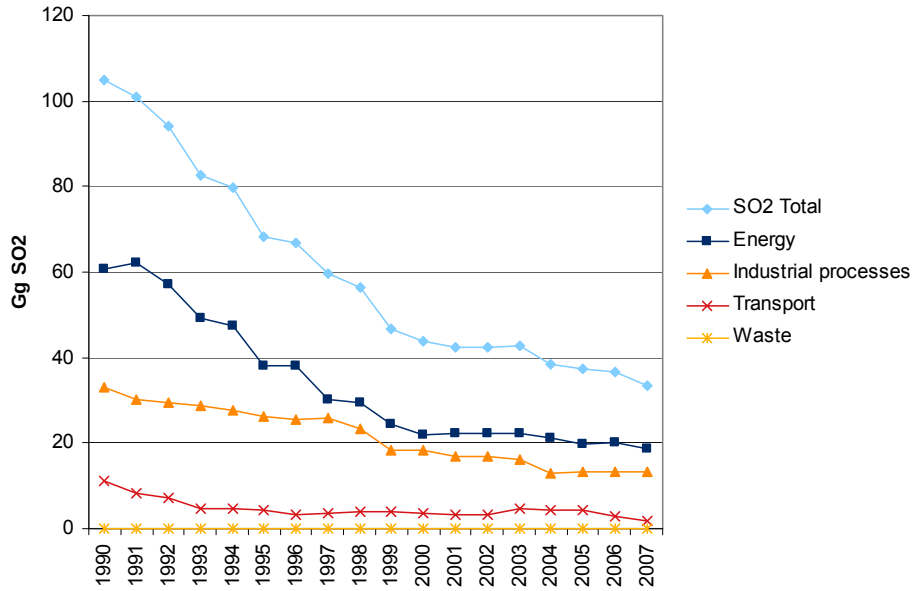

Figure 2.25 Total emissions of SO_2 and emissions from the different sectors.

Energy sector emissions of sulphur dioxide (excl. transport) continued to decrease during the 1990s and in 2007 emissions totalled around 18 ktonnes, a decrease of almost 70 % compared with 1990. The continued decrease is due to a shift from fuels with higher sulphur levels to low-sulphur fuels, both for industry and for production of electricity and district heating. The sulphur tax introduced in 1991 has been significant in this shift. Other factors which contribute to reduced emissions include the consideration of industries under the Environmental Code. Between 2006 and 2007 there was a slight decrease in emissions which can be a result of decreased use of oil in several sectors.

Road traffic emissions of SO_2 have fallen by around 98 % since 1990 as a result of lower sulphur levels in motor fuels, and totalled 0.09 ktonnes in 2007.

Sulphur emissions from domestic navigation have decreased by 72 % since 1990 and are now 1.4 ktonnes due to transferring to oils with lower sulphur content.

3 Energy (CRF sector 1)

3.1 Overview of sector

Energy consumption per capita is high in Sweden compared to other OECD countries. This is because of the availability of natural resources such as forests and hydropower, which led to the early and rapid expansion of energy-intensive industries. Sweden's geographical position, with low mean annual temperatures also explains the high demand for energy for heating. The energy sector, including transport, has long accounted for the major part of Swedish greenhouse gas emissions, and emissions of carbon dioxide dominate overwhelmingly in this sector. However, carbon dioxide emissions per capita are relatively low in Sweden compared with other industrialized nations. This is due to a relatively high use of hydropower and nuclear power and low use of fossil fuels, as well as the use of energy and carbon dioxide taxation for limiting the emissions of carbon dioxide.[8]

In the energy sector, emissions of CO_2 contribute about 96 % of total greenhouse gas emissions (in CO_2 equivalents). The Transport sector is the largest contributor of emissions, followed by Energy Industries and Manufacturing Industries and Construction. Total emissions of CO_2 have varied during the period 1990 to 2007, but in 2007 the emissions are about 10 % lower than in 1990. Emissions of total greenhouse gases from the energy sector have decreased by 9.5 % from 53,313 Gg CO_2 equivalents in 1990 to 48,237 Gg CO_2 equivalents in 2007, mainly due to reduced fossil fuel consumption in the Residential sector.

3.2 Source category description

3.2.1 Public electricity and heat production, CRF 1A1a

This is a key category. All gases are covered.

Swedish production of electricity is characterized by large proportions of hydropower and nuclear energy. Only a small share of electricity production is based on fuels used in conventional power plants. Public electricity and heat use vary between years, due to variations in ambient temperatures for instance. In addition, production of electricity based on fuels depends to a large extent on the actual weather conditions. Years with dry weather and cold winters have a significant effect on the use of fuel in electricity production since less electricity can be produced by means of hydropower and more electricity is needed for heating. The largest emissions from electricity production were thus in 1996, due to very dry and cold weather. In Sweden, electricity and district heating are used to a large extent to heat homes and commercial premises. Increased use of district heating since 1990 to heat homes and commercial/industrial premises has led to increased energy efficiency and thus lower emissions. Emissions of methane and nitrous

[8] Ministry of the Environment, 2001

oxide have increased from electricity and heat production because of the increased burning of biomass fuels.

Electricity is an important energy source in the manufacturing industry, where the most important industries are the pulp and paper and the steel industry.

Production of district heating is currently to a large extent based on biomass and waste. There has been a change from fossil fuels towards biomass since 1990. In 2007, 54 % of all fuels used for district heating were biomass while waste accounted for 21 %. In 1990, 15 % of fuels used were biomass and 15 % was waste. During the same period, there has been a large increase in the use of district heating from 90 PJ (1990) to 165 PJ (2007) but, due to the more frequent use of biomass, greenhouse gas emissions from district heating are at a lower level in 2007 than in 1990.[9]

The number and distribution of Swedish power stations in 2006 are presented in Table 3.1[10].

Changes since 1990 in number of plants and their installed effect have been minor in the electricity sector, but the number of plants that only produce district heating has increased.

Table 3.1. Number and distribution of Swedish energy stations in 2006.

Type of plant	Number of plants	Production GWh
Total power stations	1882	143220
Power generation not based on fuels	1708	62615
- Wind	784	908
- Water	924	61707
Power generation based on fuels	174	80605
- Nuclear power	3	66977
- Power and heat production	171	13628
- Manufacturing industries, ISIC 10-37	40	
- Energy plants, ISIC 40	109	
- Others	22	

3.2.2 Refineries, CRF 1A1b

This is a key category. All gases are covered.

Refineries process crude oil into a variety of hydrocarbon products such as gasoline and kerosene. During the refining process, dissolved gases are separated, some of which may be leaked or vented during processing. Refinery outputs referred to as refined products generally contain negligible amounts of methane and should thus not be estimated according to the IPCC Guidelines. There are five refineries in Sweden. Three of these refineries produce fuel products such as gasoline, diesel and heating oils. The other two refineries mainly produce bitumen products and naphtenic special oils. One facility has a catalytic cracker and four of the facilities have sulphur recovery plants.

[9] All numbers are according to data used in the Greenhouse gas inventory this submission.
[10] Statistics Sweden EN11SM 0701 2008. Data for 2007 are presently not available.

3.2.3 Manufacture of solid fuels and other energy industries, CRF 1A1c

This is a key category. All gases are covered.

Most emissions in this sector arise from two plants belonging to one company, producing coke to be used in blast furnaces for production of iron. The plants are integrated into the iron and steel production industry. Other fuel combustion in manufacturing of solid fuels and all fossil fuel combustion in manufacturing of nuclear power are also included in CRF 1A1c.

3.2.4 Manufacturing Industries and Construction, CRF 1A2

This is a key category. All gases are covered.

A limited number of industries accounts for the majority of industrial energy use, i.e. the pulp and paper industry, iron and steelworks and the chemical industry. Despite rising industrial production, oil consumption has fallen sharply since 1970. This has been possible due to increased use of electricity and improved energy efficiency.

In 2006 there were 46 paper mill plants, 165 sawmills (production capacity >10 000 m^3/year) and 44 pulp industry plants in Sweden. In total, they were producing 11.9 million tonnes of paper, 18.6 million m^3 of sawn timber and 12.4 million tonnes of pulp.[11]

In Sweden, there are three primary steel works that base their production on iron ore pellets procuring either steel or iron powder. There are also 10 secondary steel plants producing steel based on scrap iron. The Swedish iron and steel works produced 3.6 and 1.9 million tonnes of steel, respectively, in total in 2006.[12]

The chemical industry produces a number of different products such as chemicals, plastics, solvents, petrochemical products etc. In total, around 50 plants are included, of which ten use more than 90 % of the energy according to the activity data used for emission calculations for this sector.

3.2.5 Transport, CRF 1A3

This is a key category. All gases are covered.

On average, Swedish citizens travel 48 km per individual per day by various modes of transport. [13] The Swedish road network comprises around 137,000 km of public highways, and road traffic is the dominating mode for both transport of goods and people.[14] Road traffic accounts for the largest increase in CO_2 emissions since 1990, whereas emissions from civil aviation and railways have decreased. The car is the most common mode of transport in Sweden, regardless of purpose, and is used for about 70 % of all journeys.[15] Car travel is also the third most common way of travelling abroad, after air and sea travel.

[11] The Swedish Forest Industries Federation, 2008-09-29
[12] The Swedish Steel Producers´ Association, 2007-09-22
[13] http://www.sika-institute.se 2008-09-29
[14] Ministry of the Environment, 2001.
[15] http://www.sika-institute.se 2008-09-29

Energy use in the transport sector is mainly confined to various oil products such as gasoline, diesel and aviation fuel. Energy use in this sector has been rising since 1970, as a consequence of the overall growth in transport and, hence, the emissions of carbon dioxide have also risen. Since 1990, the use of catalytic converters has increased, resulting in reduced emissions of methane, NMVOC and NO_X, but increased emissions of N_2O.[16]

3.2.6 Other sectors, CRF 1A4

This is a key category. All gases are covered.

CRF 1A4 includes emissions from combustion in the commercial sector, institutions, house-holds, agriculture, forestry and fishing. The largest users of energy are dwellings and premises. In Sweden, the heated area in this sector is 588 million m^2, of which households have a heated area of 425 million m^2 and premises have a heated area of 163 million m^2.[17]

The most common ways of heating these areas are by district heating and electricity. For premises, the area heated with district heating only has increased from 43 % in 1990 to 59 % in 2006, while the area heated with oil only has decreased from 22 % in 1990 to 3 % in 2006. For multi-dwellings, the area heated with district heating only increased from 67 % in 1990 to 77 % in 2002. During the period 2002-2006, the proportion heated with district heating only has been fairly constant, varying between 76 and 78 %. The area heated with oil only in multi-dwellings has decreased from 15 % in 1990 to 2 % in 2006. For one- and two-dwellings, there is a minor increase in the area heated with district heating only (7 % in 1990 to 9 % in 2006). However, for one- and two-dwellings the area heated with oil only has decreased from 13 % in 1990 to 4 % in 2006.[18]

Energy use in agriculture, fishing and forestry has shifted towards more biomass and less liquid fuels during the last five years.

Mobile machinery and off-road vehicles accounted for about 17 % of the energy consumed in Other sectors in 2007.

3.2.7 Other, CRF 1A5

This is a key category. All gases are covered.

CRF 1A5 includes emissions from military transports and pressure levelling losses of natural gas. Emissions from military transports have decreased over the years 1990-2007 due to a decrease in activity.

3.2.8 Fugitive emissions, CRF 1B

This is a key category. All gases are covered.

During all stages from extraction of fossil fuels to final use, escape or release of gaseous fuels, volatile components or absorbed gases may occur. These fugitive emissions are intentional or unintentional escapes and releases of gases from ex-

[16] Ministry of the Environment, 2001.
[17] Statistics Sweden EN16SM0704
[18] Data for latest year not yet available

traction point to final oxidation. In particular, they may arise from the production, processing, transmission, storage and use of fuels, and include emissions from combustion only where it does not support a productive activity (e.g. flaring).

Fugitive emissions in Sweden include flaring of fuels in the iron and steel industry, refineries and the pulp and paper industry, transmission losses of gas works gas, storage and handling of oil in refineries, depots and gasoline distribution.

3.2.9 Memo Items International bunkers, CRF 1C

This sector includes emissions from refuelling in Sweden used for international navigation and international aviation. All gases are covered.

According to IPCC guidelines, international bunkers are not included in national totals. To evaluate Swedish emissions, international bunkers are of course important, especially as international bunkering of fuel is substantially greater than the fuel use for domestic navigation and aviation. Emissions have increased significantly since 1990 due to among other things increased travelling and increased transportation of goods. See also section 2.3.10.

3.3 Methodological issues

Emissions from fuel combustion in Sweden are, if not specifically otherwise stated, determined as the product of fuel consumption, thermal value and emission factors (EF) as shown in Equation 3-1:

Equation 3-1:

$$Emissions_{fuels}\ (unit) = \sum Fuel\ consumption\ (unit) * thermal\ value_{fuels} * EF_{fuels}$$

Different Tiers are used for different sub-sectors as discussed in sections below.

Please note that some fuel types are used in industrial processes rather than for energy purposes. This is the case for black liquor in the paper- and pulp industry and for coal and coke in the metal industry. Emissions from these fuels are thus accounted for under CRF 2 and methods used are described in section 4.

Several recalculations have been carried out in the energy sector, which is described for each code below and in section 3.6.

3.3.1 Public Electricity and Heat Production, CRF 1A1a

The Tier 2 method is used.

Activity data for emissions in CRF 1A1a are taken from quarterly fuel statistics, further described in Annex 2. For this sector, the quarterly fuel statistics are sent to all companies registered as ISIC 40 according to databases used by Statistics Sweden and the response rate is almost 100 %. This provides the inventory with data of very good quality, accurate, complete and consistent and with very low uncertainties. In Sweden the two largest iron and steel producers also comprise energy production plants within the same area. These plants are registered as ISIC 40 and therefore included in CRF 1A1a.

During 2005 it was concluded that one plant combusting waste for energy production was missing in the quarterly fuel statistics used for CRF 1A1a [19]. As a result of this, the time series were revised in submission 2006 resulting in an increase in CO_2 emissions with approximately 20 Gg for the whole time series. Since submission 2007, data from this plant is manually collected to reach complete coverage.

During 2005, the time series for combustion of peat in CRF 1A1a was compared with other relevant data sources from Statistics Sweden, to see if any revisions were necessary. The conclusion was however that no revisions were necessary.

The trend in fuel consumption in this sector varies depending on the production of waterpower and climate variables. The greatest changes in fuel consumption are for biomass fuels, where the consumption has increased significantly due to for instance increased district heating.

3.3.2 Petroleum refining, CRF 1A1b

The Tier 2 method is used.

The statistics for CRF 1A1b are based on a total of seven plants with the Swedish Standard Industrial Classification 232, petroleum refining. Five of these companies are real refineries and they use over 99 % of the energy within the sector and thereby give rise to most of the emissions. The other two plants are oil companies, mainly involved in production of lubricating grease, which means that they are working with products from refineries and therefore should be reported under refineries according to IPCC guidelines.

Activity data for the five refineries has been collected directly from each company for 1990-1999, since the industrial energy statistics and quarterly fuel statistics did not account for all fuels produced within refineries during these years. The corresponding energy content of all fuels has also been collected and individual thermal values have been calculated for each operator and fuel. For 2000-2002, industrial energy statistics were used for all refineries except one in 2000 and 2001, for which data was collected directly from the company in 2000 and from the environmental report in 2001. For 2003, industrial energy statistics were used for all refineries except two, for which data was collected directly from the companies, since data was not yet available in the industrial energy statistics. For 2004, quarterly fuel statistics was used for one plant, the industrial energy statistics for three plants and the environmental report for one plant. As a result of a specific SMED study during 2006[20], data from the EU Emission Trading System (ETS) are used for four refinery plants for 2005 and later years. For the fifth plant data from environmental reports were used. The use of so many different sources for this sector could of course lead to consistency problems. Data used in the inventory is however analysed and no (significant) signs of inconsistency have been found.

[19] Lidén, 2005.
[20] Backman & Gustafsson, 2006

The fuel consumption in this sector is mainly based on liquid fuels and the use has increased due to higher demand of refined products.

It has been noted that combustion of LPG has increased since 2003. In submission 2009, activity data has been carefully studied to verify this increase. As a result of this, activity data for one company was revised for the years 2002-2006. It was found that the reported amounts of LPG were not correct in data from Statistics Sweden. These data were replaced with data from the companys environmental report.

3.3.3 Manufacturing of solid fuels and other energy industries, CRF 1A1c

The Tier 2 method is used.

Emissions from fuel combustion in the manufacturing of solid fuels are reported under CRF 1A1c, in line with IPCC Guidelines. This includes emissions from combustion in coke ovens in the iron and steel industry and emissions from fuel combustion in nuclear power plants.

Activity data is collected from industrial energy statistics for 1990 - 1996 and 2000 - 2002, and from quarterly fuel statistics for 1997 - 1999 and from 2003 onwards. For more details on the surveys see Annex 2. Activity data on combustion of coke oven gas and blast furnace gas in coke ovens is discussed in connection with other emissions from the iron- and steel industry in section 3.3.4.1.

Solid fuel consumption has increased slightly due to higher production of coke caused by higher demand of primary iron and steel.

Consumption of liquid fuels increased with 28 TJ or 65 % 2006 compared to 2005 as a result of one more company being included in the sample survey for this sector. The increase is minor compared to the use of solid fuels in CRF 1A1c.

3.3.4 Iron and steel, CRF 1A2a

The Tier 2 method is used.

For companies with less than 10 employees the Tier 1 method is used, since current data does not allow the Tier 2 methods to be used. Emissions from companies with less than 10 employees are allocated to CRF 1A2f.

Activity data is, if not otherwise stated, collected from industrial energy statistics for 1990-1996 and 2000-2002, and from quarterly fuel statistics for 1997-1999 and 2003 onwards, further described in Annex 2.

Emissions reported from primary steel works and other iron and steel works are reported in both CRF 1A2a and in CRF 2C1 since some emission arises from fuel combustion and some from reducing agents in the process. The text in this section is hence closely connected to the text in the section CRF 2C11 (steel) and CRF 2C12 (pig iron). The trend of the fuel combustion is increasing slightly since 1990 due to higher production of iron and steel products.

The CO_2 implied emission factors for solid fuels in CRF 1A2a are lower than for solid fuels in other industries, since the fuel used is coke oven gas which has a low CO_2 emission factor compared to other solid fuels (see Appendix 19).

3.3.4.1 PRIMARY IRON AND STEEL WORKS

In Sweden, there are two plants for iron and steel production which base the production on iron sinter reduction in a blast furnace process, instead of smelting iron and steel scrap. The plants consist of coke ovens and the coke is, together with some coal, injected in the plants blast furnace cowpers with crude iron to reduce the iron (lower the oxygen content). The process results in pig iron and blast furnace gas. The gas is collected and later used as a fuel in coke ovens, blast furnaces etc. The plants also consist of steel converters in which the pig iron is converted to steel and rolling mills. One of the plants has a power station where in-house gases are used. In Table 3.2 the distribution of fuel consumption and CO_2 emissions in 2007 on different CRF codes for these two plants is shown. As can be seen, only emissions from the total combustion of fuels to produce heat in the steel converter and rolling mill are reported in CRF 1A2a - Iron and steel production. Fuels used in other parts of the plants are reported in other CRF sectors according to Table 3.2. This is further described in each respective section.

Table 3.2. Distribution of fuel consumption and CO_2 emissions in 2007 from iron ore based iron and steel industry in different CRF codes.

Emissions source	Combusted fuels	CRF	Sector	Fuel consumption, %	CO_2 emissions, %
Energy plants within the iron and steel plant area	Coke oven gas and blast furnace gas, oil	1A1a	Public electricity and heat production	4	16
Coke oven	Coke oven gas and blast furnace gas	1A1c	Manufacturing of solid fuels (coke)	7	7
Steel converter and rolling mill	Coke oven gas, propane, oil	1A2a	Iron and steel production	25	24
	Transformations losses of energy in iron and steel industry	1A5a	Other/Stationary	50	
Flaring	Coke oven gas, blast furnace gas and steel converter gas	1B1c	Other fugitive emissions from solid fuels	4	14
Blast furnace	Blast furnace gas	2C1	Pig iron production	11	38

Transformation losses of energy in iron ore based iron and steel industry have been estimated and reported under CRF 1A5a for all years. The energy losses have been estimated as the difference between total energy content in inserted coal in coke ovens according to Statistics Sweden[21] and energy content of combusted fuels giving rise to emissions. Note that transformation losses of energy have nothing to do with emissions. All potential emission sources (gases), produced when coal and coke are combusted, are collected in the plant and later used in other parts of the plant as fuels. Emissions occur not until the different gases are combusted.

[21] Statistics Sweden EN20SM 1990-2007 row 3.9

CO_2 emissions arising from the use of limestone in blast furnaces will create small amounts of pollution when the gas is burned, which should be reported in CRF 2A3 according to the IPCC 1996 Guidelines. However, since these emissions are mixed with those from blast furnace gas, it is hard to estimate the amount of emissions originating from the limestone. Therefore, emissions from combustion of blast furnace gas also include carbon from the use of limestone from two plants. According to the IPCC 2006 Guidelines all emissions within the production, including emission from limestone, should be reported in the production sector, and not in CRF 2A3. Hence, Sweden has decided not to report emissions from limestone used within the iron and steel industry in CRF 2A3 since submission 2006.

3.3.4.2 SECONDARY IRON AND STEEL WORKS

Except for the primary iron ore based iron and steel works, this sector include emissions from for instance electric arc furnaces plants, iron ore pellet plants and iron powder plants. In submission 2005 and submission 2006, data from several plants, included in the EU trading scheme, was revised. These revisions included addition of new activity data that was earlier missing, and revising data that was considered incorrect. The revisions also affected the reporting of emissions from industrial processes (see section 4.4.2.1).[22]

The changes made in submission 2005 and 2006 have resulted in a more consistent and accurate time series and better compliance with the Reference Approach.

In submission 2009 the following revisions have been made:

- Activity data for all fuel combustion in one company has been updated for 2006 with data from Statistics Sweden.
- Activity data for natural gas in one company has been revised for 2004. Now data from the companys environmental report is used, since this has been found to be more accurate according to a recent SMED study[23]
- Correction of fuel type for one company 2002: In submission 2008 and earlier Gas/diesel oil (domestic heating oil) was recorded as residual fuel oil, which is now corrected.

3.3.5 Non-Ferrous Metals, CRF 1A2b

The Tier 2 method is used.

For companies with less than 10 employees the Tier 1 method is used, since current data does not allow the Tier 2 methods to be used. Emissions from companies with less than 10 employees are allocated to CRF 1A2f.

Activity data is taken from industrial energy statistics for 1990-1996 and 2000-2002, and from quarterly fuel statistics for 1997-1999 and 2003-2007. For more details on these surveys see Annex 2. Fuel consumption shows a decreasing trend since 1990. In 1999 there is a large jump in the time series due to increased consumed amounts of natural gas.

[22] Nyström & Cooper, 2005.
[23] Skårman et.al., 2008

In submission 2009, the activity data source for one company is changed for 2006 from the quarterly fuel statistics to the industrial energy statistics, since data will then be more in line with environmental reports and consistent with other years. The industrial energy statistics is also used for 2007 for this company.

3.3.6 Chemicals, CRF 1A2c

The Tier 2 method is used.

For companies with less than 10 employees the Tier 1 method is used, since current data does not allow the Tier 2 methods to be used. Emissions from companies with less than 10 employees are allocated to CRF 1A2f.

Activity data is, with exceptions mentioned below, collected from industrial energy statistics for 1990-1996 and 2000-2002, and from quarterly fuel statistics for 1997-1999 and 2003-2007. For more details on these surveys see Annex 2.

Due to inconsistent time series in the quarterly fuel statistics and industrial energy statistics within this sector, the whole time series was revised in Submission 2004. Contact was taken with several companies resulting in exclusion of incorrect data, exchange of some activity data and inclusion of new activity data. The recalculations resulted in a more accurate and consistent time series, all with plant specific data. Emission data for 2004 and 2005 is mainly based on activity data from the quarterly fuel statistics. For a few plants the industrial energy statistics are considered to be of better quality and therefore used.

The fuel consumption trend is increasing since 1990, especially for liquid fuels, mainly due to increased use within the basic plastic industry.

Note that one major plant in 1A2c is classified as 1A2f in 2000-2001 due to a small shift in type of production (manufacture of plastics belongs to 1A2c while manufacture of plastics products belongs to 1A2f). This temporary shift causes lower emissions in 1A2c for 2000-2001.

In submission 2009, after careful studies of different data sources regarding activity data of consumption of Other petroleum fuels in this sector, it has been found that some of this consumption is in fact methane and methane based gas mixtures. Since this fuel is not oil but more like natural gas, relevant fuel consumption has been recoded as methane and methane based gas mixtures. Since no emission factors for methane and methane based gas mixtures are available, we are using emission factors for natural gas, but of course fuel consumption and emissions are still reported under liquid fuels.

Also in submission 2009, a careful check of the Energy Statistics databases reveals that two companies are combusting hydrogen which is included in the fuel group Other fuels. Fuel type was miscoded in 2006 (coded as biofuels), which is now corrected. Emission factors for hydrogen are not available, but since only emissions of NO_x, N_2O (and NH_3) are possible, all other emissions are set to zero, which implies that these emissions have decreased somewhat in submission 2009.

Emissions from the chemical industries will be further investigated in a separate project in 2009. This study will, among other things, look further into remaining fluctuations for different fuel categories.

3.3.7 Pulp, Paper and Print, CRF 1A2d

The Tier 2 method is used. Emissions from processes in the Pulp, paper and print industry are reported under CRF 2D1 according to IPCC Guidelines. See chapter 4.5.

For companies with less than 10 employees the Tier 1 method is used, since current data does not allow the Tier 2 methods to be used. Emissions from companies with less than 10 employees are allocated to CRF 1A2f.

Activity data is, if not otherwise stated, collected from industrial energy statistics for 1990-1996 and 2000-2002, and from quarterly fuel statistics for 1997-1999 and 2003-2007. For more details on these surveys see Annex 2.

There is no apparent trend in fuel consumption since 1990.

3.3.8 Food Processing, Beverages and Tobacco, CRF 1A2e

The Tier 2 method is used.

For companies with less than 10 employees the Tier 1 method is used, since current data does not allow the Tier 2 methods to be used. Emissions from companies with less than 10 employees are allocated to CRF 1A2f.

Activity data is collected from industrial energy statistics for 1990-1996 and 2000-2002, and from quarterly fuel statistics for 1997-1999 and 2003-2007. For more details on these surveys see Annex 2.

The fuel consumption varies between years. A slight decrease can be observed since 1990.

In submission 2009, for one plant, "Other petroleum fuels" has been recoded as methane and methane-based gas mixtures, as original data shown that this is more correct (see CRF 1A2C above). Consequently, emissions have decreased in this submission.

3.3.9 Other Industries, CRF 1A2f

For emissions from stationary combustion, the Tier 2 method is used with the following exception:

For the construction industry and for companies with less than 10 employees the Tier 1 method is used, since current data does not allow the Tier 2 method to be used.

Emissions from mobile combustion refer to off-road vehicles and other machinery including various mobile vehicles and machines as for example tractors, dumpers, lawn movers, snow mobiles, cranes, trimmers, forklifts and any other mobile machine that run on petroleum fuels. The methodology for estimating emissions is revised in submission 2009 and is considered to correspond to Tier 2. The methodology is quite complex and described in Annex 2.

Emissions from stationary combustion in mining and quarrying and in the manufacturing of various products such as textiles, wearing apparel, leather, wood and wood products, rubber and plastics products, other non-metallic mineral products, fabricated metal products and manufacturing of different types of machinery, are calculated with activity data from the industrial energy statistics for 1990-1996

and 2000-2002, and from the quarterly fuel statistics for 1997-1999 and 2003-2007. For more details on these surveys see Annex 2.

Emissions from all companies with less than 10 employees are estimated and reported under CRF 1A2f. Activity data are collected from Statistics Sweden[24]. Emissions are minor and with current data not possible to separate on different industry sectors.

Emissions from stationary combustion in the construction industry are calculated with activity data from Statistics Sweden.[25]

The fuel consumption varies between years, but has totally decreased slightly since 1990, especially the consumption of liquid and biomass fuels.

Note that one major plant in 1A2c is classified as 1A2f in 2000-2001 due to a small shift in type of production (manufacture of plastics belongs to 1A2c while manufacture of plastics products belongs to 1A2f). This temporary shift causes higher emissions in 1A2f for 2000-2001.

In submission 2009, emissions within this sector during the period 2002-2006 has been partly revised due to a revision of activity data for Other sectors, which includes the construction industry which is included in CRF 1A2F.

Also in submission 2009, for one glassworks plant, it is no longer possible to separate combustion emissions from process emissions. For practical reasons, all data that is available from environmental reports from this plant, namely NO_x and SO_2, are reported in CRF 2A7 and all other emissions are reported in CRF 1A2F.

In submission 2009, emissions from off-road vehicles and working machinery 1990-2006 has been revised following a development project during 2008.

3.3.10 Civil Aviation, CRF 1A3a

Sweden uses the Tier 1 method for CO_2 and Tier 2a for all other gases.

Emissions from aviation in agricultural and forestry sectors are currently reported together with domestic aviation. Emissions from military use of aviation fuels are reported under Other – mobile sources (CRF 1A5b).

Emissions from aviation are calculated using statistics on supply and delivery of petroleum products (see Annex 2), and information from the Swedish Civil Aviation Authority (SCAA) on fuel use and emissions estimates related to the governmental airports in Sweden.

Presently data are provided for a total of 41 airports with regular and/or charted air traffic. The national government administers 19 of these airports, while the remaining 22 are private and/or administered by local government.[26] The traffic routed through governmental airports account for about 90 % of the total fuel consumption within the civil aviation sector. The SCAA publishes information on aviation emissions from these airports in annual environmental reports. Complementary emission calculations are carried out to reach full national coverage including non-governmental airports. SCAA include the traffic from a number of non-governmental airports in their estimates from 2005 and almost all Swedish

[24] Statistics Sweden, EN20SM 1990-2007. See also Annex 2.
[25] Statistics Sweden, EN20SM 1990-2007. See also Annex 2.
[26] Swedish Civil Aviation Authority.

airports from 2006, the methodology for calculating national emissions is however the same for all years.

The fuel consumption and emissions published by the SCAA are calculated by the Swedish Defence Research Agency (FOI). FOI uses statistics on the number of flights between city pairs (domestic and international), type of aircraft, amount of fuel needed for different flights and emissions per fuel on specific flights based on data on aircraft performance during different phases of the flight and the distance between destinations.

To estimate fuel consumption and emissions from domestic landing and take off (LTO) FOI uses two models – HARP (HAsselrot´s Reviewed Pollutions) and PIANO (Project Interactive ANalysis and Optimization). HARP is used for estimating national Times in Mode (TIM) and PIANO is used for calculating the fuel consumption and emissions. Due to the fact that the Swedish airports generally are smaller than international airports in other countries, taxi times are much shorter for domestic flights and climb-out and take-off times are often shorter as well. Hence traffic from Swedish airports needs less fuel and give rise to less emissions compared to the International Civil Aviation Organization (ICAO) standards that the IPCC guidelines follow.[27] For international flights, ICAO standard taxi time has been used for the part of the LTO cycle occurring on international airports.[28]

The results from the emissions calculations are aggregated into four groups: domestic landing and take off (LTO), domestic cruise, international LTO and international cruise. This is in line with the IPCC guidelines and data of good quality exists from 1995 and onwards.

Emissions of CO_2 are based on fuel delivery statistics, national thermal values from Statistics Sweden and emission factors from the Swedish EPA. Quotas for distributing of CO_2 emissions on domestic and international LTO and cruise are based on information on CO_2 emissions from the SCAA. This information is not available for 1990-1994 and is therefore estimated as described by Figure 3.1.

[27] Gustafsson, 2005.
[28] Näs, 2005.

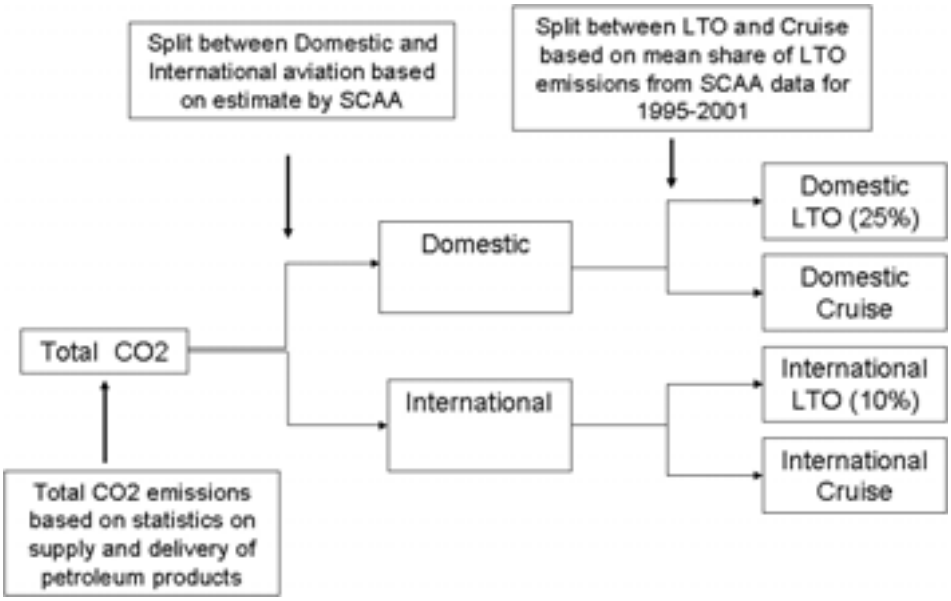

Figure 3.1 Model for estimating Domestic/International LTO/Cruise 1990-1994.

For example, the estimate of domestic emissions for 1990 is calculated based on the share of domestic emissions for 1998 which is approximately 29 %. To adjust for the development of domestic versus international traffic since 1990 the 29 % are multiplied by a factor of approximately 1.16. The factor is supposed to reflect the larger share of domestic traffic in 1990 and is calculated as the share of domestic LTO in 1990 divided by the share of domestic LTO in 1998 (1.156 = 0.724/0.626) based on LTO data from SCAA available in 1998. The share of domestic CO_2 emissions 1990 is then consequently calculated as 1.16 * 0.29 = 34 %. International emissions are estimated as total emissions minus domestic emissions. The distribution of CO_2 emissions for 1991-1994 is estimated using the same method as for 1990.

The last step in estimating emissions from aviation is the split between LTO and Cruise. This is the step that is based on the mean value for LTO cycles for domestic and international flight in 1995-2000, meaning the CO_2 from domestic LTO/total CO_2 from domestic aviation and the equivalent for international traffic.

From 1995 and onwards, emissions of SO_2, NO_x CO and HC are based on information from the SCAA, adjusted to match the delivered amount of aviation fuels. Emissions of NMVOC and CH_4 are estimated based on information on emissions of HC from the SCAA and emission factors from the IPCC guidelines.

N_2O emissions for LTO are estimated using information on the number of LTO cycles from the SCAA together with emission factors from IPCC. N_2O emissions for cruise are based on delivered amounts of fuel for cruise activities estimated by FOI, adjusted to be in line with fuel delivery statistics, together with emission factors according to the IPCC guidelines.

Due to the lack of activity data, all non-CO_2 emissions for 1990-1994 are calculated by SMED in cooperation with the SCAA. Fuel consumption and SO_2 emissions are estimated based on CO_2 emissions. Emissions of CO are calculated by comparing the 1995 relationship between CO and CO_2 and using the same ratio (4.85 % of CO_2 emissions) for 1990-1994. Emissions of NO_X are calculated in a similar way. The ratio is relatively stable over the years and therefore the mean value of 1995-2004 (4.03 % of CO_2 emissions) is used for 1990-1994. Emissions of HC for 1990-1994 are calculated by extrapolation.

SCAA have received information on LTO emissions for 2001 and 2002 from 19 non-governmental airports and estimated CO_2 and NO_X emissions for all non-governmental airports based on this information. Adding together emissions of CO_2 and NO_X from both governmental and non-governmental airports provides a good estimate of the aviation emissions at national level. A comparison between these data and the ones calculated using the Tier 1 method shows good coherence with a variation of only 2-5 %.

3.3.11 Road transport, CRF 1A3b

Emissions of CO_2 and SO_2 from road traffic are based on statistics on supply and delivery of petroleum products (see Annex 2), in accordance with the IPCC Guidelines Tier 1.

Emissions of all other substances, together with input to the national allocation model for diesel for the road traffic sector, are provided by the Swedish National Road Administration (SNRA). SNRA uses the EU road traffic emission model ARTEMIS (Assessment and Reliability of Transport Emission Models and Inventory Systems), further described in Annex 2, for calculating emissions from Swedish road traffic. The ARTEMIS model is based on a bottom-up approach considered to be Tier 2.

Data from the ARTEMIS model are separated by fuel type and four vehicle types: Passenger cars, Light commercial vehicles, Heavy-duty vehicles (including bus) and Mopeds & Motorcycles. Estimated fuel consumption per fuel and vehicle type is used to proportionally allocate national fuel statistics over those categories.

Emissions of CO_2 and SO_2 are then estimated based on the distributed national fuel statistics together with thermal values and CO_2 emission factors from the Swedish energy agency as shown in Appendix 19. Emissions of SO_2 are based on information on the sulphur content of different environmental classes of diesel and gasoline provided by the SNRA, in turn based on estimations made by VTI[29] for 1990-2001, and on fuel analysis from SPI from 2001 and onwards.

Emissions of CH_4, N_2O, NO_x, CO and NMVOC are according to ARTEMIS data adjusted for military transport.

The fuel consumption and CO_2 emissions estimated by the SNRA differ slightly from those reported to the UNFCCC. The SNRA aims to describe what is emitted on Swedish roads, regardless of where the fuel was bought or the nationality of the vehicles. According to IPCC Guidelines, the inventory should only ac-

[29] Swedish Road and Transport Research Institute, 2002.

count for emissions from fuel purchased in Sweden. An overview of the two different objectives is presented in Table 3.3.

Table 3.3. Emissions from road transport reported by the SNRA and in the CRF.

Fuel bought in	Traffic on Swedish roads	Traffic in Sweden, not on roads	Traffic to/from other country	Traffic in other countries
Sweden	CRF 1A3b SNRA	CRF 1A3b	CRF 1A3b * SNRA to the Swedish border	CRF 1A3b *
Other country	SNRA	Not reported	SNRA to the Swedish border	Not reported

* Since the IPCC Guidelines do not consider international bunkers for road transportation, all emissions from road traffic and fuel bought in Sweden are considered to be domestic and thus reported under CRF 1A3b.

Emissions of CO_2 from combustion of gasoline are based on thermal values and country-specific emission factors from Statistics Sweden and the Swedish EPA. Emissions of CO_2 from combustion of diesel are based on thermal values and country-specific emission factors from SPI. Emissions of SO_2 from gasoline and diesel are based on information on the sulphur content of different environmental classes of diesel and gasoline provided by SNRA.

Prior to submission 2007, emissions of SO_2 from diesel and gasoline were based on the maximum allowed sulphur content of different environmental classes. Data on maximum allowed sulphur content was provided by SPI. From submission 2007, emissions of SO_2 are based on the actual sulphur content for the different environmental classes of petrol and diesel fuel. The data on actual sulphur content, provided by SNRA, is based on estimates made by VTI[30] for the years 1990-2001, and on fuel analysis from SPI from 2001 and onwards.

CO_2 and SO_2 from natural gas and biofuels fuels are estimated using statistics on deliveries for natural gas, biogas, ethanol and FAME. Activity data for natural gas is available from 1990, while reliable activity data for biogas exists from 1996 and for ethanol and FAME from 1998. Thermal values and emission factors for ethanol and biogas have been collected from the Swedish Biogas Association. Thermal values and emission factors for FAME are not available but thermal values are assumed to be the same as for diesel and emission factors for CO_2 and SO_2 the same as for natural gas. Emissions of CO_2 from biogas, ethanol (including ethanol admixture) and FAME are reported as biomass and not included in the national totals.

Military transport emissions are reported under CRF 1A5b to be in accordance with the IPCC Guidelines. Military road transport is included in the road traffic emissions estimated by ARTEMIS. To subtract and separate emissions from military transport from emissions from civil road transport, emissions from ARTEMIS for each vehicle type are reduced by an amount equal to the weight of the fuel con-

[30] Ibid.

sumption reported by the Swedish Armed Forces relative to the fuel consumption from national statistics allocated to civil road transport, according to Equation 3-2:

Equation 3-2: $A = B - \sum((C-D)/C*E_i)$

A = Military transport emissions
B = Total ARTEMIS emissions
C = Total fuel consumption National Statistics
D = Military fuel consumption Swedish Armed Forces
E_i = ARTEMIS emissions per vehicle type

- In submission 2009, for road traffic, there are small changes for emissions of all substances 2002-2006 due to minor changes in data from the ARTEMIS model.
- Also in submission 2009, the allocation of gasoline and diesel oil to road traffic and diesel oil to fisheries and domestic navigation has been affected by the revision of emissions from off-road vehicles mentioned above.

3.3.12 Railways, CRF 1A3c

The Tier 1 method is used.

Information on emissions from railways is provided by the Swedish National Rail Administration, as estimates on the amount of diesel consumed as well as estimates on emissions of CO_2, SO_2, NO_x, NMVOC, CH_4, CO and N_2O.

The estimate of diesel consumption is based on fees paid by the rail operators and is considered to be of very high quality. Emission estimates are calculated based on the estimated diesel consumption together with emission factors from three different sources. Emission factors used for calculating CO_2 emissions are supplied by the Swedish Petroleum Institute[31], whereas emission factors used for NO_X and CO estimates are provided by the National Rail Administration. Remaining emissions are calculated based on default emission factors from EMEP/CORINAIR.

In submission 2009, the allocation of diesel oil to railways for all years has been affected by the revision of emissions from off-road vehicles and working machinery mentioned above.

3.3.13 Navigation, CRF 1A3d

Emissions from national navigation are estimated using Tier 1.

Emissions from domestic navigation are calculated based on the amount of fuels that are purchased and consumed in Sweden.[32] Emissions from fuels that are purchased in Sweden but used abroad are reported separately as international bunker emissions. The allocation of emissions from navigation is summarized in Table 3.4.

[31] www.spi.se August 2005
[32] Statistics Sweden EN31SM

Table 3.4. Reporting of emissions from navigation, according to the Good Practice Guidance.

Fuel bought in	Traffic between Swedish harbours	Traffic between Swedish and international harbours	Traffic between two international harbours
Sweden	Domestic, 1A3d	International bunkers, 1C	International bunkers, 1C
Other country	Not included	Not included	Not included

Emissions from gas/diesel oil and residual fuel oils, for 1990-2002, are calculated using emission factors from a SMED study from 2004[33]. Emissions for 2003 and 2004 have been estimated using emissions factors for 2002 while emissions for 2005 and later years have been calculated using emissions factors provided by the Swedish Maritime Administration (SMA). The emission factors provided by the SMA are based on the mentioned study by SMED.

Emissions of CO_2 and SO_2 from leisure boats are calculated based on estimated gasoline consumption together with thermal values and emission factors which are the same as for civil road traffic. Emissions of NO_X, NMVOC, CH_4, CO and N_2O are all based on estimated gasoline consumption together with emission factors from CORINAIR for gasoline.

Emissions of NO_X, NMVOC, CH_4, CO and N_2O from leisure boats also depend on the ratio between 2-stroke and 4-stroke engines. The estimated ratios between the two are based on a study by Statistics Sweden[34] from 2005. The study indicates that there is a larger share of 4-stroke engines in 2004 than in 1990. Based on the assumption that the move towards a larger number of 4-stroke engines has been gradual between since 1990, the ratio for each year between 1990 and 2004 has been estimated by interpolation. From 2005 and onwards, the ratio between 2- and 4-stroke engines is assumed to be the same as for 2004.

The Swedish Maritime Administration also report emissions from domestic navigation. These can however not be compared with emissions from the Swedish national inventory since the former include emissions from the whole Baltic Sea region.

In submission 2009, the allocation of gasoline and diesel oil for all years to road traffic and diesel oil to fisheries and domestic navigation has been affected by the revision of emissions from off-road vehicles and working machinery mentioned above.

3.3.14 Other transportation, CRF 1A3e

Emissions reported under CRF 1A3e refer to emissions from off-road vehicles and other machinery including various mobile vehicles and machines as for example tractors, dumpers, lawn movers, snow mobiles, cranes, trimmers, forklifts and any other mobile machine that run on petroleum fuels. The methodology for estimating emissions is revised in submission 2009 and is considered to correspond to Tier 2. The methodology is quite complex and described in Annex 2.

[33] Cooper and Gustafsson, 2004.
[34] Statistics Sweden, 2005.

Emissions from off-road vehicles and other machinery are also reported under CRF 1A2f, 1A4b and 1A4c, in line with IPCC Guidelines, see Table 3.5.

Table 3.5. Distribution of emissions from off-road vehicles and other machinery

Category	CRF	Definition IPCC Guidelines
Industry	1A2f	The remaining emissions from fuel combustion in industry. This also includes emissions from the construction branch.
Other	1A3e ii	Combustion emissions from all remaining transport activities including ground activities in airports and harbors, and off-road activities not otherwise reported under 1A4c or 1A2f. Including emissions from the public sector.
Residential	1A4b	All emissions from fuel combustion in households. Including emissions from the use of snow mobiles.
Agriculture	1A4c	Emissions from fuel combustion in agriculture and forestry. Highway agricultural transportation is excluded.
Forestry	1A4c	

In submission 2009, emissions from off-road vehicles and working machinery 1990-2006 has been revised following a development project during 2008.

3.3.15 Commercial/institutional, CRF 1A4a

Mobile combustion in this sector is reported included in CRF 1A4b, as it is currently not possible to separate mobile combustion in these two sectors from one another.

For stationary combustion within CRF 1A4a, all activity data is on national level by fuel type and estimated emissions are therefore considered to correspond to Tier 1. The main data source for activity data is premises statistics that is further described in Annex 2.

3.3.15.1 VERIFICATION OF ESTIMATION MODELS AND ALLOCATION METHODS FOR FUEL IN THE OTHER SECTORS

In submission 2005 and earlier, there were large uncertainties in estimation models and allocation methods for fuel in the other sectors and CRF 1A2f, construction. In 2005, a study was performed by SMED, aiming at identifying and analyzing the methods and models applied for each sub-sector and determine whether they were in line with the IPCC guideline recommendations.[35] In addition, each fuel was traced back to its original source in order to determine whether it had been correctly allocated on stationary and mobile combustion.

The results from the study show good agreement with IPCC guideline recommendations. All fuels but biomass had little or no changes in methodologies, and where changes occurred, no significant inconsistencies in fuel consumption time series were detected. However, for biomass, several significant inconsistencies were identified leading to recalculations of activity data and emissions in CRF

[35] Gustafsson, et al. 2005.

1A4a and 1A4b[36]. Due to these recalculations there are obvious inconsistencies between the national energy balances and the national emission inventory data. Furthermore, all fuels proved to be correctly allocated on stationary and mobile combustion. In the Swedish air emission inventory, that means that all diesel oil and gasoline reported under Other sectors in the energy balances are used by mobile combustion, while all the other fuels are related to stationary combustion.

3.3.15.2 ACTIVITY DATA FOR STATIONARY COMBUSTION IN OTHER SECTORS

In the preliminary version of submission 2005, preliminary quarterly fuel statistics, based on fuel delivery statistics, was used to calculate emissions in 2003 from stationary combustion in CRF 1A4, Other sectors and CRF 1A2f, construction. It was however considered to give too high fluctuations compared to the annual statistics. The Swedish EPA therefore decided that prescheduled preliminary annual statistics should be used for the final reference year in the inventory, which was done in the revised version of submission 2005, submission 2006 and submission 2007 for data 2004-2006. These prescheduled preliminary data are inconsistent with the official preliminary annual statistics, reported by Statistics Sweden in the end of each year. The method to use pre-scheduled preliminary annual statistics was reviewed and evaluated in 2007 and presented in a memorandum by SMED[37]. It shows that the pre-scheduled preliminary annual statistics for 2004 and 2005 result in an underestimation of 280 Gg CO_2 and 212 Gg CO_2, respectively, compared to the final annual statistics.

In 2008 all available methods to estimate emissions from stationary combustion in other sectors were overhauled in a SMED study[38]. The main problem is still that the timeline for the GHG inventory is too short for using final data for other sectors and construction for the latest year. All available alternatives have specific problems including higher uncertainties etc discussed in the study. The method that was considered to give the best data was using annual statistics for all years available, and for the latest year make a model estimate of fuel combustion that adjusts the amounts from the year before with the trend in the preliminary quarterly fuel statistics, as exemplified for 2007 in Equation 3-3 below:

Equation 3-3:

Estimate 2007 = Annual statistics 2006* preliminary quarterly fuel statistics 2007/ quarterly fuel statistics 2006

As a consequence of this, emissions from stationary combustion 2002-2006 were revised in this submission. Since emissions for the most recent years are based on this model estimate, uncertainties are a bit higher for this year. Emissions for the most recent years will be revised in next submission when annual statistics are available.

[36] Paulrud et al. 2005.
[37] Gustafsson, 2007b
[38] Lidén and Gerner, 2008

3.3.16 Residential, CRF 1A4b

In this sector both stationary and mobile combustion occur.

Mobile combustion in CRF 1A4a is included in this sector, as it is currently not possible to separate mobile combustion in these two sectors from one another. Emissions from mobile combustion refer to emissions from off-road vehicles and other machinery including various mobile vehicles and machines as for example tractors, dumpers, lawn movers, snow mobiles, cranes, trimmers, forklifts and any other mobile machine that run on petroleum fuels. The methodology for estimating emissions is revised in submission 2009 and is considered to correspond to Tier 2. The methodology is quite complex and described in Annex 2.

For stationary combustion, all activity data is on national level by fuel type and estimated emissions are therefore considered to correspond to Tier 1.

For stationary combustion, the main data sources are One- and two-dwellings statistics, Holiday cottages statistics and Multi-dwellings statistics. Biomass fuel consumption for heating residences are surveyed on the three most common combustion technologies: boiler, stoves and open fire places. Since 1998 biomass activity data is separated on wood logs, pellets/briquettes and wood chips/saw dust. Historical biomass data has been estimated by inter- and extrapolation.

Estimation models and allocation methods for fuel in the Other sectors as discussed in section 3.3.15.1 and use of preliminary data for stationary combustion in other sectors as discussed in section 3.3.15.2 also applies to CRF 1A4b. As a consequence, emissions from stationary combustion 2002-2006 are revised in submission 2009. Emissions for the most recent year will be revised in the next submission when annual statistics are available.

- In submission 2009, emissions from off-road vehicles and working machinery 1990-2006 have been revised following a development project during 2008.

3.3.17 Agriculture/Forestry/Fisheries, CRF 1A4c

In this sector both stationary and mobile combustion occur.

For stationary combustion, all activity data is on national level by fuel type and estimated emissions are therefore considered to correspond to Tier 1.

For stationary combustion, activity data is based on models and results from a survey from 1985 and repeated in 2007 (see Other statistics from Statistics Sweden in Annex 2).

Estimation models and allocation methods for fuel in the Other sectors as discussed in section 3.3.15.1, and use of preliminary data for stationary combustion in other sectors as discussed in section 3.3.15.2 also applies to CRF 1A4c. As a consequence, emissions from stationary combustion 2002-2006 are revised in submission 2009. Emissions for the most recent year will be revised in next submission when annual statistics are available. Note that as a consequence of this revision, emissions from biomass are inconsistent with a sharp increase to a higher level in 2003. There is no information available to improve data from 2002 and earlier years. Emissions in 1990 are considered to be of a sufficient quality as the 1985 survey.

Emissions from off-road vehicles and other machinery including various mobile vehicles and machines as for example tractors, dumpers, lawn movers, snow mobiles, cranes, trimmers, forklifts and any other mobile machine that run on petroleum fuels. The methodology for estimating emissions is revised in submission 2009 and is considered to correspond to Tier 2. The methodology is quite complex and described in Annex 2.

Emissions from Fisheries, CRF 1A4c, were first reported in submission 2006. The estimated fuel consumption is based on a survey on energy consumption within the fishing industry by Statistics Sweden[39] together with data on the Swedish fishing fleets total installed effect in kW from the Swedish Board of Fisheries. The estimate on fuel consumption provided by Statistics Sweden refer to 2005, and for the previous and following years the fuel consumption is estimated by adjusting the 2005 value according to the development in total installed effect.
The emissions factors used to estimate emissions from Fisheries are based on a SMED study from 2005[40], producing emission factors for CO_2, SO_2, NO_x, NMVOC, CH_4 and N_2O for 1990-2004. From 2005 estimates are based on the same consumption estimate and emission factors as for 2004.

Emissions from fisheries are derived under the assumption that the fishing fleet operates using medium speed diesel engines running on marine distillate fuel. The emission abatement technologies used by the fleet (e.g. Selective Catalytic Reduction (SCR) for NO_X reduction) is assumed to be negligible.

- In submission 2009, emissions from off-road vehicles and working machinery 1990-2006 have been revised following a development project during 2008.
- Also in submission 2009, the allocation of gasoline and diesel oil to road traffic and diesel oil to fisheries and domestic navigation has been affected by the revision of emissions from off road vehicles mentioned above.

3.3.18 Other stationary combustion, CRF 1A5a

Methods used in CRF 1A5 are considered to correspond to the Tier 1 method.

3.3.18.1 TRANSFORMATION LOSSES OF ENERGY

Transformation losses of energy in iron ore based iron and steel industry have been estimated and reported under CRF 1A5a for all years. The energy losses have been estimated as the difference between total energy content in inserted coal in coke ovens according to Statistics Sweden[41] and energy content of combusted fuels giving rise to emissions. Note that transformation losses of energy have nothing to do with emissions. All potential emission sources (gases), produced when coal and coke are combusted, are collected in the plant and later used in other parts of the plant as fuels. Emissions occur not until the different gases are combusted.

[39] Statistics Sweden, 2006 ENFT0601.
[40] Cooper et al., 2005a.
[41] Statistics Sweden EN20SM 1990-2006 row 3.9

3.3.18.2 PRESSURE LEVELLING LOSSES OF NATURAL GAS

Reported emissions from natural gas are estimated with data from the statistics on the delivery of gas products (see Annex 2), based on information from wholesale dealers (seven companies in Sweden). The gas is delivered in pipelines and fugitive emissions do not occur, according to wholesale dealers. Some of them report pressure-levelling losses, which are measurement differences when the gas is measured at different temperatures/pressures at different points in the system. Sweden chooses to report these differences, for years they occur, as emissions to avoid underestimation of emissions. The uncertainty in the estimates is by nature very high.

Prior to submission 2006, these emissions were allocated in CRF 1B2b. However, the emissions are not really fugitive, they are just very hard to allocate and thus the emissions are now allocated to CRF 1A5a which refers to emissions from stationary combustion with no further specification on in what sector the combustion took place.

In submission 2008, the transfer loss for gas works gas (CRF 1B2a5) and the pressure levelling losses of natural gas (CRF 1A5a) were mixed up. This has been corrected in submission 2009.

3.3.19 Military transport, CRF 1A5b

Emissions from military transport are based on data on fuel consumption including all military activities and are considered to correspond to Tier 1. Fuel consumption from some more administrative military activities, such as the Swedish Defence Material Administration (FMV), the Swedish Fortification Department (FORTV), the Swedish Defence Research Agency (FOI) and the National Defence Radio Institute (FRA), are not included in the calculations.

CH_4 and N_2O emissions from the military are both based on a top-down approach, using fuel consumption (for aviation and navigation) and a bottom-up approach, using data from the ARTEMIS model (road transport). Hence, estimates are considered to be both Tier 1 and Tier 2. Emissions from military aviation are based on an average of LTO and cruise emission factors. Emissions from military navigation are estimated using emission factors from civil navigation. Emissions from the use of diesel oil by military stationed abroad is reported under Multilateral operations, CRF 1C2.

Military road transport is included in the road traffic emissions estimated by the ARTEMIS model. To subtract and separate emissions from military transport from emissions from civil road transport, emissions according to the ARTEMIS model for each vehicle type are reduced by an amount equal to the weight of the fuel consumption reported by the Swedish Armed Forces relative to the fuel consumption from national statistics allocated to civil road transport, according to:

Equation 3-4: $A = B - \sum((C-D)/C*E_i)$

A = Military transport emissions
B = Total ARTEMIS emissions
C = Total fuel consumption National Statistics
D = Military fuel consumption Swedish Armed Forces
E_i = ARTEMIS emissions per vehicle type

3.3.20 Fugitive emissions from fuels, CRF 1B

3.3.20.1 SOLID FUELS, CRF 1B1

There are no coalmines in Sweden and hence no fugitive emissions from coalmines occur.

SO_2 emissions from quenching and extinction at coke ovens are reported in CFR 1B1b.

Flaring of coke oven gas, blast furnace gas and steel converter gas are reported in CRF 1B1c since submission 2004. The emissions from flaring of these fuels are calculated with Tier 2, i.e. with activity data directly from the plants, in the same way as for emissions from stationary combustion. It should however be noted that uncertainties are still high, since the amount of flared gas are not measured as carefully as combusted gas (this statement is true for any plant).Table 1B1 is not really designed to include flaring, but since CRF 1B2 only refers to liquid and gaseous fuels, it is not possible to report flaring from coke oven gas, blast furnace gas and steel converter gas in CRF Table 1B2.

3.3.20.2 OIL AND NATURAL GAS, CRF 1B2

3.3.20.2.1 Refineries, CRF 1B2A4

Sweden estimates non-CO_2 emissions by using the Tier 2 method.

The Tier 2 method requires data at plant level and Sweden uses data provided by the refineries in their annual environmental reports. Emissions are reported from catalytic cracking (CO, SO_2, NO_X), desulphurisation (SO_2) and from the storage and handling of oil (NMVOC, CH_4). Catalytic cracking occurs at one plant in Sweden. CO emissions from catalytic cracking are calculated as:

$$\mathrm{CO} = \left(\frac{\text{Batched amount of raw material in the cracker}}{\text{Total batched amount of raw material in the plant}} \right) \times \text{Total CO emission for the plant}$$

Due to some operational problems at the plant the total emissions of CO were high for 1997 and 1998 compared to other years.

The emissions of SO_2 from desulphurisation increased in year 2006 compared to previous years due to operational disturbances at one facility.

Fugitive emissions of NMVOC from refineries include emissions from the process area as well as emissions from the refinery harbours when loading tankers. The estimates are mainly based on reported data from the facilities' environmental reports and older reports from the Swedish EPA[42],[43],[44],[45] and Statistics Sweden[46]. The activity data, as crude oil throughput, is known for almost all years. Implied emission factors have been developed, based on reported emissions and known activity data. Reported data for years for which either activity data or emission data is missing have been calculated using the implied emission factors thus developed. In Table 3.6, reported NMVOC emissions as well as activity data can be seen.

The companies have only included the fugitive emissions of CH_4 from storage and handling in their legal environmental reports for later years. Since activity data is known for almost all years, emissions of CH_4 has been calculated for the whole time series using the implied emission factor for each plant. The reported emissions are very uncertain due to limited measurements. In Table 3.6, the reported emissions of CH_4 and also activity data can be seen.

Table 3.6. Throughput of crude oil in refineries and estimated fugitive emissions of NMVOC and CH4 (Mg) 1990-2007 for CRF 1B2A4**.**

Year	Throughput of crude oil Mg	Total emissions of NMVOC Mg	Total emissions of CH_4 Mg
1990	17 330 000	14 408	223
1991	16 590 000	12 900	222
1992	17 870 000	10 961	225
1993	18 723 684	10 311	249
1994	18 192 000	8 933	258
1995	19 430 000	7 643	270
1996	19 850 000	9 661	272
1997	20 100 000	9 749	271
1998	20 254 000	9 507	271
1999	19 483 034	10 350	244
2000	20 253 120	11 568	243
2001	19 592 852	9 795	238
2002	19 313 714	10 195	259
2003	19 661 646	11 602	225
2004	20 611 941	8 957	256
2005	19 919 968	7 691	227
2006	20 012 311	8 269	258
2007	17 671 312	8 877	233

[42] Swedish EPA, 1990.
[43] Swedish EPA, 1994a.
[44] Swedish EPA, 1994b.
[45] Swedish EPA. 1995.
[46] Statistics Sweden. 1996 Emissions to air in Sweden of volatile organic compounds (VOC) 1988 and 1994.

In submission 2009, emissions from combustion of petroleum coke in refineries earlier reported in CRF 1A1b are re-allocated to CRF 1B2A4 to be in line with the IPCC guidelines. This is based on a recent study performed by SMED[47].

In Sweden, one facility for production of hydrogen was started in 2006, which resulted in a sharp increase in emissions from this sector during 2006 and later years.

3.3.20.2.2 Gasoline handling and distribution, CRF 1B2A5

Calculated fugitive emissions of NMVOC from the storage of oil products have been obtained from SPI[48]. Calculations were based on the amount of gasoline handled in the depots. The calculations cover 1990 – 2006 and based on methods given by Concawe 85/54[49] and for the year 2007 on Concawe 03/07[50]. More than 30 depots have been considered during later years. Gas recovery systems and the recovered amount of gas have been considered in the calculations. For some years, for which no data was provided, data were interpolated. Handled amount of gasoline and fugitive emissions of NMVOC from depots for 1990-2007 are presented in Table 3.7.

The calculation of the NMVOC time series for fugitive emissions from gasoline distribution, 1990-2007 (table.3.7), is based on methods given by Concawe[49], including annual national gasoline consumption and assumptions on the share of gasoline evaporated at different stages of the handling procedure, as well as effects of applied abatement technology at gasoline stations[51]. The basic assumptions are presented in Table 3.8.

[47] Skårman, T., Danielsson, H., Kindbom, K., Jernström, M., Nyström, A-K. 2008. Fortsättning av riktad kvalitetskontrollstudie av utsläpp från industrin i Sveriges internationella rapportering. SMED Report 2008

[48] Ljung, 2008, personal communication

[49] Concawe, 1986, Hydrocarbon emissions from gasoline storage and distribution systems, Report No 85/54.

[50] Concawe Report No. 3/07, Air pollutant emission estimation methods for E-PRTR reporting by refineries

[51] Andersson, 2000.

Table 3.7. Handled and distributed amount of gasoline and estimated fugitive emissions of NMVOC (Gg) from storage at depots and at gasoline stations, 1990-2007.

Year	Volume of gasoline m^3	Fugitive emissions of NMVOC at depots Gg	Fugitive emissions of NMVOC at gasoline stations Gg
1990	5 320 700	2.48	13.59
1991	5 396 091	2.22	11.13
1992	5 444 204	2.15	8.54
1993	5 297 811	2.08	4.40
1994	5 382 390	2.01	3.14
1995	5 412 336	1.93	3.16
1996	5 399 878	1.86	3.15
1997	5 360 076	1.77	3.22
1998	5 322 328	1.68	3.19
1999	5 328 572	1.59	3.20
2000	5 287 753	1.50	3.17
2001	5 280 416	1.41	3.17
2002	5 377 027	1.56	3.23
2003	5 351 687	1.57	3.21
2004	5 319 283	1.71	3.19
2005	5 294 863	1.67	3.18
2006	5 126 067	1.60	3.08
2007	5 001 310	1.65	3.00

Table 3.8. Assumptions for calculating fugitive emissions from the handling and distribution of gasoline.

Parameter	Assumption	
Density of gasoline	730 kg/m^3 1990 - 1996 750 kg/m^3 1997 - 2005	
Distribution of gasoline to gas stations	0.16 %	of distributed volume
Spill	0.01 %	of distributed volume
Filling of car tanks	0.18 %	of filled volume
Measures at distribution to gas station	90 %	Efficiency of measures
Measures at filling cars	70 %	Efficiency of measures

The measures at distribution and filling were introduced over a period of time from 1991-1994, to the extent presented in Table 3.9. The amount of gasoline sold at large and small gas stations, respectively, was assumed to be 50/50 for the years 1990-1994. Data on the distributed amounts of gasoline is taken from the ARTEMIS model (Table 3.7). The ARTEMIS model is based on a bottom-up approach considered to be Tier 2.

Table 3.9. Fraction of gasoline stations with technical measures installed

Year	Large gas stations >2000 m^3	Small gas stations
1990	0%	0%
1991	50%	0%
1992	75%	25%
1993	100%	75%
1994 -	100%	100%

3.3.20.2.3 Transfer losses of gas works gas, CRF 1B2A5

Fugitive emissions from gas works gas are reported from the producers of gas works gas to Statistics Sweden and published in Statistics on the delivery of gas products. Cast iron pipelines are used.

In submission 2008, the transfer loss for gas works gas (CRF 1B2a5) and the pressure levelling losses of natural gas (CRF 1A5a) were mixed up. This has been corrected in submission 2009.

Also in submission 2009, emissions are reallocated to this code from CRF 1B2A6.

3.3.20.2.4 Flaring, CRF 1B2C2

Flaring of liquid fuels was estimated and reported for the first time in the Swedish inventory in submission 2005. Data includes flaring of refinery gases at four refineries and one chemical industry, and flaring of LPG at three iron and steel plants and one pulp industrial plant. Data has been collected directly from the plant operators.

In submission 2009, template activity data for one plant for the years 2004-2006 has been replaced by data collected directly from the company.

3.3.21 Memo Items, CRF 1C

3.3.21.1 INTERNATIONAL BUNKERS, CRF 1C1

Emissions from international bunkers for aviation and navigation are not included in the national total, but instead reported separately as a memo item in CRF 1C1, in accordance with the 1996 revised IPCC Guidelines.

International bunkers from navigation are defined as fuels bought in Sweden, by Swedish or foreign-registered ships, and used for transport to non-Swedish destinations. The division on international and domestic fuels is based on information from the monthly survey on supply and delivery of petroleum products. Sweden has not yet had the possibility to verify How well this data corresponds to how international and domestic marine transport is defined in the IPCC Good Practice Guidance has not yet been verified.

International bunkers from aviation are fuels purchased in Sweden and used for flights to destinations abroad. This includes the whole flight cycle, i.e. both LTO and Cruise, see also section 3.3.10 and Annex 4.

3.3.21.2 MULTILATERAL OPERATIONS, CRF 1C2

Emission from multilateral operations are not included in the national total but instead reported separately as a memo item in CRF 1C2, in accordance with the 1996 revised IPCC Guidelines. These emissions are calculated based on information from the military on the amount of fuel purchased in Sweden but used abroad by Swedish forces participating in international operations.

3.4 Uncertainties and time-series consistency

3.4.1 Uncertainty analysis

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. For the energy sector, the largest uncertainties arise from emission factors, especially for N_2O and CH_4.

The distribution of marine distillate fuels and residual fuel oils over domestic and international navigation (bunkers) entail additional uncertainties. The current distribution is provided by the respondents of the survey on supply and delivery of petroleum products, but these are suspected to lack full information on the end-use of all the fuels they provide. Hence, the distribution between domestic and international use might vary considerably for some years. Comparisons made with other data on the fuel consumption from domestic navigation[52] provide considerable differences and may indicate a need to revise the allocation between domestic and international use of fuels. The problem has been identified by the responsible authorities, which plan to look further into this issue in upcoming projects[53].

3.4.2 Time series consistency

The time series are considered to be consistent.

[52] ER 2007:26
[53] ER 2007:26

3.5 Source specific QA/QC and verification

3.5.1 Quality Assurance

A quality system as part of the National System has been developed and is fully operational from January 2006 (Annex 6). For more details see section 1.6.2.

3.5.2 Quality control

All quality procedures according to the Swedish QA/QC plan (including the Manual for SMED:s Quality System in the Air Emission Inventories) have been implemented during the work with this submission.

All Tier 1 general inventory level QC procedures and some specific Tier 2 QC procedures, listed in Good Practice Guidance section 8, have been performed and are documented in checklists. The time series for all revised data have been studied carefully in search for outliers and to make sure that levels are reasonable. Data has, when possible, been compared with information from environmental reports and/or other independent sources. Remarks in review reports from the UNFCCC have been carefully read and when timely possible taken into account. The result are verified by calculating CO_2 emissions with the reference approach, and comparing results with the sectoral approach (see Annex 4).

3.5.3 Verification

In 2005, a survey on fuel consumption in 2004 in the construction sector was carried out by Statistics Sweden on behalf of the Swedish Energy Agency[54]. The results from the survey show little agreement with the fuel consumption estimated in the air emission inventory. The reasons behind the discrepancies have not yet been investigated.

As part of the inventory procedure for submission 2007, a separate study[55] was performed to verify the quality of all fossil fuel combustion-related CO_2-emissions from the largest plants (in terms of CO_2-emissions) in Sweden in 2005. The verification consisted of a comparison of 63 plant-specific data used for the GHG-inventory (energy statistics from the quarterly fuel statistics) with data from the EU Emission Trading System (ETS). The results showed that for 21 plants, accounting for about 50 % of the fossil fuel consumption of the 63 plants included in the study, no significant differences between the two data sources were identified. For a number of plants, large differences occurred between the two data sources. In 2007, 19 of these plants were further surveyed in another study[56]. Again, energy statistics (the quarterly fuel statistics) and ETS data by plant were compared and analyzed.

The results show that the reported fuel amounts differ slightly between the data sets and since ETS data are verified, they are likely to be more correct. Furthermore, on plant level, the national thermal values and emission factors that are used

[54] Statistics Sweden EN0114, 2005
[55] Backman & Gustafsson, 2006
[56] Nyström, 2007

for the GHG inventory are not fully correct. Another deficiency in the quarterly fuel statistics is that unconventional fuels are often grouped and the emission factors of these fuels are associated with very large uncertainties, since they are not specific for the current fuel and plant. Finally, another problem is that some of those unconventional fuels are incorrectly classified. In the ETS some of these fuels are often partly biogenic and should hence be classified as "Other biomass".

In addition, CO_2 emissions 2005 and 2006 from the two largest iron and steel plants in Sweden were given extra attention in submission 2007 and 2008. GHG inventory data, collected by Statistics Sweden, were compared with the ETS data. For 2005, the results showed good coherence (< 5 % difference), whereas for 2006, the results indicate significant differences (> 5 %). It is believed that the divergence occurring for 2006 to a large extent is due to a significantly larger CO_2 emission factor for blast furnace gas in the ETS data.

During 2008, a study[57] has been performed concerning emissions from several industry plants, including the two largest iron and steel plants in Sweden Results show that GHG data could be further improved to be in line with other data sources. The main conclusion is that the emissions need to be reallocated. The reallocation affects CO_2 in CRF 1A1a, 1A1c, 1A2a, 1B1c and 2C1. Moreover, the activity data and CO_2 emissions should be directly obtained from the plants legal environmental reports which may result in an increase in the total emissions of CO_2 from the plants. However, if approved by the Swedish EPA, revisions will be implemented in submission 2010.

3.6 Source specific recalculations

In this section explanations and justifications for recalculations in the energy sector are made, as well as a description of significant implications for the reported emission levels. Table 3.10 shows the percent changes for the GHG emissions by subsector and gas as well as for the total level in the energy sector in 1990 reported in submission 2009 compared to data reported in submission 2008. As can be seen, despite the recalculations, the change on total level for the energy sector is small for all years.

[57] Skårman, T., Danielsson, H., Kindbom, K., Jernström, M., Nyström, A-K. 2008. Fortsättning av riktad kvalitetskontrollstudie av utsläpp från industrin i Sveriges internationella rapportering. SMED Report 2008.

Table 3.10. Recalculations of GHG emissions between submission 2009 and submission 2008 in the energy sector.

Recalculations (Gg CO_2 eq.)									
CRF	**1A1**	**1A2**	**1A3**	**1A4**	**1A5**	**1B1**	**1B2**	**Total CRF 1**	**% CRF 1**
1990	-233	228	143	-456	0	0	232	-85	-0,16%
1991	-204	395	-60	-389	0	0	203	-54	-0,10%
1992	-231	250	229	-582	0	0	230	-104	-0,19%
1993	-253	311	197	-605	0	0	253	-97	-0,18%
1994	-211	277	310	-707	0	0	211	-121	-0,21%
1995	-243	461	78	-627	0	0	242	-89	-0,16%
1996	-245	432	57	-574	0	0	244	-86	-0,15%
1997	-242	306	182	-599	0	0	241	-112	-0,21%
1998	-233	179	320	-628	0	0	231	-130	-0,24%
1999	-252	159	310	-577	0	0	250	-109	-0,21%
2000	-243	139	261	-506	0	0	238	-111	-0,22%
2001	-240	77	325	-524	0	0	237	-125	-0,24%
2002	-396	-20	443	-569	0	0	214	-328	-0,63%
2003	-430	-365	510	-504	0	0	244	-494	-0,93%
2004	-336	-497	635	-8	0	0	245	39	0,07%
2005	-143	-233	669	-423	0	0	231	100	0,20%
2006	-224	-172	562	-194	5	0	631	609	1,23%

CRF 1A1b:
Activity data for one company is revised for the years 2002-2006. Emissions from use of petroleum coke in refineries are reallocated to CRF 1B2A4.

CRF 1A2a:
Activity data for all fuel combustion in one company has been updated for 2006.
Activity data for natural gas in one company is revised for 2004.
Correction of fuel type for one company for 2002

CRF 1A2b:
Activity data source for one company is changed for 2006.

CRF 1A2c:
Correction of fuel type for methane and methane based gas mixtures and hydrogen.

CRF 1A2e:
For one plant, "Other petroleum fuels" has been recoded as methane and methane based gas mixtures.

CRF 1A2f:
Emissions within this sector during the period 2002-2006 have been partly revised. For one glassworks plant, NO_x and SO_2 emissions are reallocated to CRF 2A7 and all other emissions are reported in CRF 1A2F.

CRF 1A2f, 1A4a-c
Activity data for stationary combustion in Other sectors for the years 2002-2006 have been revised.

CRF 1A2f, 1A3e, 1A4b, 1A4c:
Emissions from off-road vehicles and working machinery has been revised for the whole timeseries 1990-2006.

CRF 1A3b, 1A3d, 1A4c:
The allocation of gasoline and diesel oil to road traffic and diesel oil to fisheries and domestic navigation has been affected by the revision of emissions from off-road vehicles..

CRF 1A3b:
For road traffic, there are small changes for emissions of all substances for the years 2002-2006.

CRF 1.AA.5.A\Other non specified
CRF 1.B.2.A.5\Transfer loss gas works gas:
In submission 2008, the transfer loss for gas works gas and the pressure levelling losses of natural gas were mixed up. This has been corrected in submission 2009.

CRF 1B2A4:
Use of petroleum coke in refineries are in this submission moved from CRF 1A1b to CRF 1B2A4. Also, emissions from hydrogen production 2006 (and 2007) is included in this submission.

Updated activity data from the ARTEMIS model leads to slightly revised fugitive emissions of NMVOC at gasoline stations for the years 2002 - 2006.

CRF 1B2A5/1B2A6:
Emissions formerly reported under CRF 1B2A6 are reallocated to CRF 1B2A5.

CRF 1.B.2.C.2.1
Template activity data for one plant for the years 2004-2006 has been replaced by data collected directly from the company.

3.7 Planned improvements

All relevant data are kept under constant review.

For future submissions a number of actions are planned in order to, where appropriate, improve the quality of the inventory for the Energy sector. For submission 2010, a revision of emissions from several industries is planned motivated by a study performed by SMED during 2008[58]. Based on other results published by Paulrudand Fridell (2008)[59], a revision of several emission factors is planned for submission 2010.

[58] Skårman, T., Danielsson, H., Kindbom, K., Jernström, M., Nyström, A-K. 2008. Fortsättning av riktad kvalitetskontrollstudie av utsläpp från industrin i Sveriges internationella rapportering. SMED Report 2008.

[59] Paulrud, S and Fridell, E. Uppdatering av klimatrelaterade emissionsfaktorer. IVL report 2008

4 Industrial processes (CRF sector 2)

4.1 Overview

For Sweden the most important industries within the industrial sector has historically been base industries such as mining, iron and steel industry and pulp and paper industry.Other important industries when considering emissions of greenhouse gases from industrial processes include the cement industry, primary aluminium production and some processes in the chemical industry, e.g. nitric acid production.

Among the industries in this sector, the most important emissions of greenhouse gases are CO_2 from metal production and mineral products, N_2O from nitric acid production and PFCs from primary aluminium production. Greenhouse gas emissions from the industrial processes sector have decreased slightly from 5 792 Gg CO_2 equivalents in 1990 to 5 753 Gg CO_2 equivalents in 2007, a decrease of 0.7 %.

The estimated emissions of fluorinated greenhouse gases consist of emissions from the use of these in various applications, as well as PFC emissions from the primary aluminium production process. No production of halocarbons or SF_6 occurs in Sweden.

The consumption of fluorinated greenhouse gases has increased substantially since 1990. The use as refrigerants in refrigerators, freezers and air-conditioning equipment has contributed the larger share in later years.

Generally four sources of information concerning activity and emission data for the industrial process sector have been used:

- Emission data as reported annually by facilities in legally-required environmental reports to the authorities
- National production statistics or similar information at national level
- Plant specific data from the EU emission trading scheme
- Plant specific data collected by direct contacts with facilities

Under Swedish environmental laws, operators performing environmentally hazardous activities that require a permit by law are compelled to compile and submit an annual environmental report to their supervisory authority. The environmental report consists of three parts:

- Basic identification information about the facility.
- Text section (for example, a description of the facility and the processes, the use of energy, chemicals and raw materials, emissions and conditions in the permit).
- Emission declaration (for example, production data, fuel consumption data, emission data and, in some cases, information on how emission data have been determined).

The data in the environmental reports often originates from measurements or mass balances. The use of default emission factors is limited. Only the operators that exceed the thresholds for the substances listed in Swedish environmental law governing environmental reports[60] are obliged to compile the emission declaration.

The County Administrative Boards audit the data presented in the operators' environmental reports and feed it into an emission database, EMIR. This database includes not only emissions, but also basic information about the facilities, such as their activity code (national code system, adjustment of NACE four digits), IPPC code and permit, location coordinates, etc. The procedure for updating the EMIR database is not regulated by legislation, which results in some inconsistencies in the database.

In cases when there are a large number of companies within a specific sector, and not all environmental reports are available, a combination of information from environmental reports and production statistics at the national level are used to estimate the sector's emissions. The use of emission factors is limited and, when used, they are nationally derived or specific for a facility.

Estimates of CO_2 emissions from industrial processes at national level are calculated on the basis of information on the production and use of raw materials (e.g. limestone, dolomite, carbon electrodes, relevant fuels, etc). The methodologies are in accordance with the IPCC Good Practice Guidance. From 2005 and onwards, data on the production and use of raw materials have been acquired from the EU Emission Trading Scheme (ETS) and through direct contacts with the industries. For facilities included in the ETS, ETS data have been used where the estimates are in accordance with IPCC Good Practice Guidance. For all other facilities, data has been acquired through direct contacts with the industries.

4.2 Mineral products, CRF 2A

4.2.1 Source category description, CRF 2A

Reported emissions include estimates for cement production (2A1), lime production (2A2), limestone and dolomite use (2A3), soda ash use (2A4), asphalt roofing (2A5), road paving with asphalt (2A6), and other (2A7). In the source category other (2A7), non-iron ore mining and dressing plants, glass and mineral wool production, glass production and LECA production are included. Until 1998 also emissions from battery manufacturing are included in code 2A7.

4.2.1.1 CEMENT PRODUCTION, CRF 2A1

Cement production occurs at three facilities in Sweden, with one being dominant. Emission data are obtained from environmental reports, EU ETS and by direct contacts with the facilities. Calculation methods have been discussed with the industry.

[60] NFS 2000:13, Naturvårdsverkets föreskrifter om miljörapport för tillståndspliktiga miljöfarliga verksamheter.

4.2.1.2 LIME PRODUCTION, CRF 2A2

Produced lime is, for instance, used in blast furnaces, in sugar and carbide production and in the pulp and paper industry to bind impurities and purify the produced material. In Sweden, conventional lime is produced at a number of facilities, owned by two companies. There are also industrial plants that produce and use the lime in the production of sugar and pulp.

4.2.1.3 LIMESTONE AND DOLOMITE USE, CRF 2A3

Limestone and dolomite are used in various processes such as glass production, mineral wool production and iron sinter production (further described in 2C13). The use of limestone and dolomite in these processes give rise to emissions of CO_2. Glass is produced at two large facilities and a number of smaller facilities. Five facilities produce glass- and mineral wool. Limestone and dolomite are also used in the production of cement (2A1), lime (2A2) and carbide (2B4).

4.2.1.4 SODA ASH USE, CRF 2A4

Soda ash is used in the production of glass, glass wool, moist snuff and chemicals i.e. detergents, and until 2004 also in flue gas desulphurisation at energy plants. Soda ash is not produced in Sweden.

4.2.1.5 ASPHALT ROOFING, CRF 2A5

Since the end of the 1990's there have only been two companies in Sweden producing asphalt-saturated felt. Production and emission data provided by the manufacturers have been used for developing emission factors for estimations of the NMVOC emissions. No measurements or estimations on CO emissions have been performed by the industry and are consequently reported NE, not estimated, for the whole time-series.

4.2.1.6 ROAD PAVING WITH ASPHALT, CRF 2A6

Large changes have occurred in asphalt paving technology over the last decade, with a gradual change towards use of water-based emulsions instead of solvent-containing bitumen solutions. Industry representatives estimated that the naphtha content in the solutions used for road paving was on average 23 %, 20 %, 17 %, 17 %, 17 % and 20 % in 2002, 2003, 2004, 2005, 2006 and 2007 respectively. In this inventory, only NMVOC emitted in the process of paving the roads is included.

4.2.1.7 OTHER, CRF 2A7

Specified sub-categories under this heading are "Non-Iron ore mining and dressing", "Glass and mineral wool production", "Glass production", "Battery manufacture" and "Light expanded clay aggregate (LECA)".

4.2.1.7.1 Non-Iron ore mining and dressing, CRF 2A7

The only emissions reported for the non-iron ore mining and dressing are, in this submission, NO_X released from use of explosives. Also CO is emitted but no data

concerning the CO emissions are available and the time series 1990 – 2007 is thus reported NE. Estimated emissions from combustion of fuels are included in the Energy sector (CRF 1).

4.2.1.7.2 Glass and mineral wool, CRF 2A7

Glass and mineral wool production occurs at three facilities run by two companies. Before 2004 there were four facilities but one closed down during 2003.

4.2.1.7.3 Glass production, CRF 2A7

In Sweden there is one facility for float glass production, one for container glass and several small facilities for manual glass production. From the float glass production, the total emissions of SO_2 and NO_X from the glass furnace are allocated to 2A7 since a separation in energy related and process related emissions is not possible. From the container glass production, SO_2 emissions originating from the raw material and small amounts of NMVOC are reported. Emissions of CO_2 from the use of limestone and of soda ash in glass production are reported in 2A3 and 2A4 respectively. All other emissions from the glass production facilities are from combustion for energy purposes, and are allocated to the Energy sector (CRF 1).

4.2.1.7.4 Battery manufacturing, CRF 2A7

One battery producer of NiCd-batteries previously used iso-propanol in their processes, which gave rise to emissions of NMVOC. The process was changed in 1998 and, since then, no NMVOC emissions occur from this source.

4.2.1.7.5 Light expanded clay aggregate- LECA production, CRF 2A7

LECA is burnt clay bullets and is made by drying and expanding clay by heating it and adding limestone and other carbon containing material. During the production CO_2 is emitted from the burning of fuels, reported in CRF 1A2f, but CO_2 is also emitted from the clay, the limestone and the other carbon containing material. LECA production occurs at one plant in Sweden. All CO_2 emissions from LECA-production are reported in 2A7.

4.2.2 Methodological issues, CRF 2A

4.2.2.1 CEMENT PRODUCTION, CRF 2A1

All three cement-producing facilities (owned by one company) are covered in the reported estimates and the time series is considered accurate and consistent. Emissions have been estimated based on ETS data as well as direct information from the company. Emissions of NO_X are allocated to the energy sector while SO_2 and CO_2 emissions are allocated to industrial processes, according to the IPCC Guidelines.

The method for calculating emissions of CO_2 from cement production is in line with the Good Practice Guidance (Tier 2) based on clinker production and a cement kiln dust (CKD) correction factor, and the time series is considered to be consistent.

For CO_2 estimates for 1990-2004, the cement company uses the GHG protocol made on initiative by the WRI for the WBCSD (Working Group Cement CO_2 Emissions Inventory Protocol, Version 1.6.), see Facts about the GHG protocol below and on their website[61]. The protocol has been used for all years except 1991-1994 and 1996, since not enough information was provided from the plants. Instead the cement company has reported production and emissions based on mean values from adjacent years for 1991-1994 and 1996. Data that is reported in the protocol to calculate process emissions is clinker, cement and dust production and the use of limestone and raw meal. The process emissions ($MgCO_2$) are then automatically calculated and presented from raw material converted to clinker and from by-pass dust and CKD discarded.

Facts about the GHG protocol
The GHG protocol has been developed to enable companies to uniformly report their emissions of greenhouse gases. Emissions from stationary combustion and from processes are included.
Over 500 experts have developed the protocol and it is used by over 150 companies including industry associations representing pulp and paper, aluminium and cement.
The protocol for CO_2 emissions from the production of cement (WBCSD CSI, version 2.0) can be found on:
http://www.ghgprotocol.org/templates/GHG5/layout.asp?type=p&MenuId=OTAx

4.2.2.1.1 CO_2 (Gg)

Emissions of CO_2 are based on the production of clinker:

Production of cement clinker (kton) * 0.525 (Gg CO_2/ kton clinker = default value in the GHG-protocol) * CKD correction factor.

The company producing cement has provided data on clinker production and total emissions of CO_2 for 1990 - 2004. From 1990 - 2003 the remaining parameters, such as emissions from limestone and dusts, are calculated based on the available information together with the GHG-protocol default emission factor for clinker. In 2004 data for the remaining parameters was acquired through contacts with the

[61] http://www.ghgprotocol.org. 2005-10-20.

cement company. From 2005, data on clinker production and total CO_2 emissions is retrieved from the ETS. The ETS data lack information on emissions from dust. Discussions with the cement producing company indicate that CO_2 emissions from dust are no longer existent at Swedish cement production sites, and there is an ongoing discussion about the accuracy of the current estimates of CO_2 from dust. However, until this issue is resolved, CO_2 emissions from dust from 2005 and onwards are set to the same amount as for 2004.

In Table 4.1 data is shown for clinker production, emissions from production, the calculated emissions from CKD and the resulting CKD correction factor. The CKD correction factor is generally lower than the IPCC default value (1.02) which is line with the conception that dust emission in Sweden are low or non-existent.

The implied emission factor (kton CO_2/kton clinker produced) is due to added emission from CKD a bit higher than 0.525 Gg CO_2/ Gg clinker and also higher than the IPCC Guidelines default value (0.5071 Gg CO_2 /Gg produced clinker) in which emissions from dust are not included.

Table 4.1. Data on production and specific emissions from the production of clinker.

Year	Clinker production	Total CO_2 emissions	CO_2 from clinker	CO_2 from CKD	CO_2 from organic carbon content of raw meal	CKD correction factor
	kton	kton	kton	kton	kton	
1990	2 348	1 272	1 233	13	27	1.010
1991	2 099	1 137	1 102	11	24	1.010
1992	2 007	1 089	1 054	12	23	1.012
1993	2 011	1 092	1 056	13	23	1.013
1994	2 043	1 109	1 073	13	23	1.013
1995	2 405	1 296	1 263	6	27	1.005
1996	2 255	1 225	1 184	15	26	1.013
1997	2 047	1 105	1 075	7	23	1.007
1998	2 105	1 133	1 105	4	24	1.004
1999	2 116	1 139	1 111	4	24	1.004
2000	2 389	1 288	1 254	6	27	1.005
2001	2 472	1 332	1 298	6	28	1.004
2002	2 372	1 280	1 245	8	27	1.007
2003	2 235	1 206	1 173	7	25	1.006
2004	2 386	1 284	1 252	5	27	1.004
2005	2 457	1 341	1 308	5	28	1.004
2006	2 660	1 470	1 435	5	30	1.003
2007	2 493	1 365	1 332	5	28	1,004

To follow the Good Practice Guidance Tier 2 method, information shall also include the CaO content of the clinker and data on non-carbonate feeds to kilns. The cement production company reports the CaO content of the clinker to be approximately 65 %. Data on the non-carbonate feeds to kilns is not available.

Previously reported notation key for Recovery of CO_2 has been changed from NO to NA.

4.2.2.1.2 SO_2 (Gg)

Data on SO_2 emissions from cement production has been obtained directly from the company or from the environmental reports to the authorities. Reported emissions for 2007 have increased compared to previous year and are again at the same level as the years before.

4.2.2.2 LIME PRODUCTION, CRF 2A2

4.2.2.2.1 CO_2 (Gg)

The emissions of CO_2 from the production of lime are based on data from all lime-producing companies in Sweden. Activity data for conventional lime, quicklime and hydraulic lime production is collected from the Swedish lime association and covers all, in total eight plants. For the conventional producers, the emissions of CO_2 are calculated by multiplying the amount of quicklime and dolomite lime with the IPPC´s default emission factors:

0.785 Gg CO_2 / Gg quicklime 0.913 Gg CO_2 / Gg dolomite lime

Activity data also include lime produced in order to purify sugar. This amount is collected through direct contact with the only sugar producing company in Sweden. The calculations of CO_2 emissions are based on the consumed amount of limestone ($CaCO_3$). However, most of the CO_2 emitted from the limestone calcination is recycled into the sugar purification process and not emitted to the atmosphere. The sugar-producing company assumes that the stone they use consists of 97 % lime-stone and that they have recycled an average 87.5 % of the emitted gases between 1990-2004 and 92 % from 2005. The emission factor for limestone ($CaCO_3$) is:

0.44 Gg CO_2/ Gg $CaCO_3$ which is equal to 0.785 Gg CO_2 / Gg CaO

Finally, lime is also produced to recycle cooking chemicals within the pulp and paper industry. This part of the activity data consists of make-up lime estimated based on pulp production data reported by the Pulp and Paper Trade Association. Make-up lime is the part of the lime added in the process that is not recycled. Most of the lime can be reused and only 5 % of the lime needed is new make-up lime. The amount of make-up lime used is about 19.75 ton/ Gg pulp. Emissions are calculated by using emission factors provided by the pulp and paper industry[62] (

[62] Haglind, Ingrid. 2005. Swedish Forest Industries Federation.

Table 4.2). The emission factor has not been updated since 2002.

Table 4.2. Emission factors used for lime production within the pulp and paper industry

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002-07
Emission factor (kton CO_2/kton pulp)	12.9	12.6	12.3	12.0	11.8	11.5	11.2	10.5	10.1	9.7	9.3	8.9	8.7

The UNFCCC expert review team has commented the relatively low implied emission factor (IEF) that the reported Swedish emissions result in. The IEF for the conventional lime production is 0.79 as seen in Table 4.3, but since the reported data also includes emissions from sugar and pulp & paper industry, which recycles lime, the total IEF is hence only around 0.55 kton CO_2/kton lime produced.

Table 4.3. Production of conventional lime and lime in the pulp & paper and sugar industry, together with the estimated implied emission factors for the different kind of lime production.

Year	Conventional production based on limestone	IEF conventional production	Production in sugar industry based on limestone	IEF Sugar industry	Production in pulp and paper industry based on limestone	IEF Pulp and paper industry
	kton	t/t	kton	t/t	kton	t/t
1990	461	0.79	51	0.10	301	0.26
1991	397	0.79	29	0.10	306	0.25
1992	337	0.79	38	0.10	306	0.25
1993	369	0.79	42	0.10	316	0.24
1994	439	0.79	41	0.10	314	0.24
1995	440	0.79	42	0.10	319	0.23
1996	431	0.79	42	0.10	315	0.22
1997	498	0.79	44	0.10	335	0.21
1998	576	0.79	39	0.10	331	0.20
1999	516	0.79	41	0.10	337	0.19
2000	578	0.79	38	0.10	378	0.19
2001	577	0.79	36	0.10	375	0.18
2002	606	0.79	39	0.10	387	0.17
2003	626	0.79	34	0.10	375	0.17
2004	591	0.79	32	0.10	390	0.17
2005	679	0.79	33	0.06	391	0.17
2006	708	0.79	37	0.06	394	0.17
2007	708	0.79	37	0.06	394	0.17

Data reported to the UNFCCC has been compared with national statistics collected from lime producers in a postal survey by Statistics Sweden, in line with the Good Practice Guidance Tier 2.[63] The comparison (Figure 4.1) shows that national statistics are more irregular but for most years the coherence is good. The differences are especially high in 1990-91 and 2000. Unfortunately there are no explanations for these differences. Since data collected for the national inventory are consistent,

[63] Statistics Sweden. Data from the Industrial production database: www.scb.se

i.e. the same plants are included all years, and less volatile than the national statistics, the national inventory data has been chosen for the calculations of CO_2 from lime production.

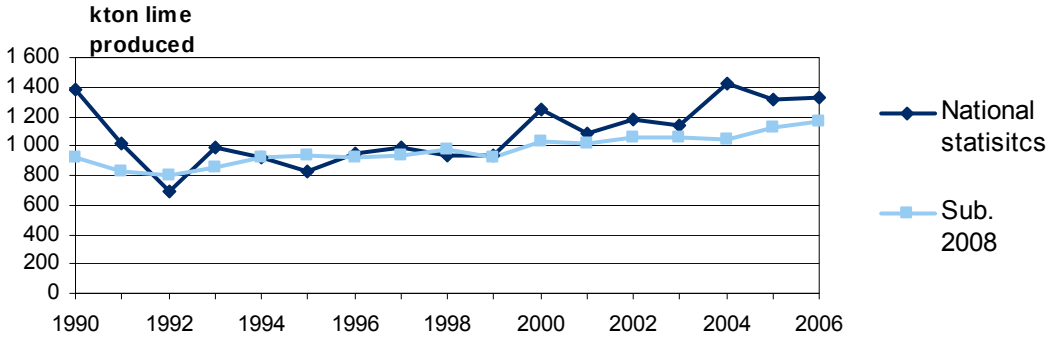

Figure 4.1. National total on produced amount of lime according to data from Statistics Sweden and reported data in CRF 2A2.

Note that quicklime is also produced and used within carbide production. According to the IPCC Guidelines, CO_2 emissions arising from this lime should be reported under CRF 2B4, together with other CO_2 emissions from carbide production. It is not known whether this lime is included in the national statistics in Figure 4.1, but it is most likely not. The reported emissions of CO_2 are considered to be consistent, accurate and complete for the whole time series. Emissions of CO_2 in submission 2009 are the same as in submission 2008 due to the fact that the same activity data as for submission 2008 was used due to some difficulty in recieving transparent activity data. A detailed revision will be made to submission 2010.

It should be noted that the recovered carbon in sugar and pulp industries has been mistakenly reported as CO_2 recovery in earlier submissions. In submission 2009, the CO_2 recovery is reported as NA.

4.2.2.2.2 SO_2 (Gg)

The emissions of SO_2 have been estimated for production of quick lime. Estimates were made for the period 1990 – 2007. The estimations from quick lime production were calculated using emission factors presented in environmental reports by one of the producers[64].

The activity data has been calculated by subtracting figures on amount of limestone used for cement production from statistics on quarried amount of limestone and dolomite[65]. The production of quick lime has been provided by the Swedish Trade Union for Lime Producers[66]. Emissions of SO_2 from quick lime production intended for the pulp and paper industry are not included in the estimates reported in CRF 2A2. Emissions originating from the production of quick lime for the iron and steel industry are from 2000 and henceforth included in CRF 2A2.

[64] Nordkalk, http://www.nordkalk.com
[65] Bergverksstatistik, 1990 – 2007. Geological Survey of Sweden, SGU
[66] Swedish Lime Association, Svenska Kalkföreningen.

4.2.2.3 LIMESTONE AND DOLOMITE USE, CRF 2A3

CO_2 emissions from the use of limestone and dolomite are reported in CRF 2A3 in line with the Good Practice Guidance. The calculations are made by applying the IPCC Guidelines default emission factors for limestone and dolomite for the different production sectors.[67] Emissions arise mainly from production of glass (mainly two big companies), mineral wool (two companies) and ore-based iron pellets (one company). It also includes the use within production of chemical products-detergents (one plant), tile (one plant) and from scrubbers in energy production plants (five companies and eight plants).

Formula for CO_2 emissions from limestone and dolomite:

$$CO_2\ (Gg) = \frac{44.0098}{100.0892} \times f \times limestone\,(Gg)$$

$$CO_2\ (Gg) = \frac{88.02}{184.4} \times f \times dolomite\,(Gg)$$

where *f* is the purity of the limestone and dolomite, set to 0.97 and 1.0 respectively, and 44.0098, 100.0892, 88.02, and 184.4 are the molecular weights. An amount of 900 ton CO_2 per year are added to account for all smaller glass production plants, due to lack of more detailed information. This estimate is based on information from a survey made in the late 1990s by the Swedish EPA on small glass production facilities and represents data from 1997. Two different estimates were made, one based on the consumption of carbonates for the production of glass and crystal, and the other based on the knowledge on the percentage weight loss depending on emitted CO_2, from weight of raw material to produced amount of glass or crystal. Both estimates result in CO_2 emissions of around 900 ton, yearly.

The emissions have increased during the reporting period due to higher limestone and dolomite use in the production of ore-based iron pellets and in the glass industry. This increase is however softened by a decrease in the use within the mineral and glass wool industry and the chemical industry. Decreased emissions from the glass wool industry are partly due to an increased use of recycled materials and thereby less need for limestone and dolomite for raw glass wool production.

Some energy plants have installed scrubbers towards the end of the reporting period leading to increased emissions from limestone and dolomite use.

Data on the use of limestone and dolomite have been acquired from environmental reports, the ETS and through direct contacts with the companies. The time series are considered accurate, consistent and complete for the major companies. It is however likely that there are small companies using limestone and dolomite that are not included in the Swedish inventory. Since a constant is added to account for emissions from small glass producers, emissions from any remaining unknown

[67] IPCC. Revised 1996 Guidelines for National Greenhouse Gas Inventories: Reference Manual section 2.5.2

plants are considered to be very small and would hardly influence the reported emissions.

CO_2 emissions from the use of limestone and dolomite as e.g. slagging agents within the iron and steel industry are reported in the source category where the carbonates are consumed, i.e. CRF 2C1. This is in line with the 2006 IPCC Guidelines. During the 2007 UNFCCC review of the Swedish GHG inventory Sweden was recommended to follow the revised 1996 IPCC Guidelines and account for all limestone and dolomite use in CRF 2A3, until the proposed 2006 IPCC Guidelines are officially adopted. Sweden has chosen not to follow this recommendation since it will require too much resources to alter the current methodology into a methodology that will be not be in line with good practice when the 2006 IPCC Guidelines are adopted, which the current method will be.

4.2.2.4 SODA ASH, CRF 2A4

In 2005 a study was carried out to collect data on soda ash use and calculate CO_2 emissions.[68] From this study it became clear that no production of soda ash occur in Sweden, and is hence reported as NO in the CRF. Activity data consists of soda ash use from ten plants within several areas:

- production of glass, glass wool, moist snuff and chemicals
- until 2004, in flue gas desulphurisation at energy plants

Activity data for the use of soda within water treatment and moist snuff production, by others than the dominant manufacturer, has been estimated based on information from expert organisations[69] and the dominant snuff manufacturer. The emissions are calculated by applying the IPCC Guidelines default emission factors for soda ash for all activity data:

$$CO_2\ (Gg) = \frac{44.0098}{105.9884} \times soda\ ash\ (Gg)$$

Data on the use of soda ash have been acquired from the ETS and through direct contacts with the reporting companies. To verify these data, information is also collected from the Swedish Chemicals Agency (KemI) which has collected data from companies that sell and import soda ash since 1992. A comparison is made between data collected and reported to the UNFCCC and national statistics provided by KemI. The comparison shows that there are discrepancies between the national statistics and the data reported to UNFCCC. The national statistics data after 1998 indicate that on the amount of soda ash usage were higher than that reportet to the UNFCCC. A possible reason for this discrepancy could be that not all soda ash used within i.e. the chemical industry emit CO_2 since some soda ash is bound in the products.

[68] Nyström. 2004. SMED-report: CO2 from the use of soda ash.
[69] The Swedish Chemicals Agency (KemI)

The data used for national GHG estimations from soda ash use and reported to UNFCCC is, compared with the data from national statistics, is believed to be more consistent and complete since the data is collected from the ETS, from the environmental reports of the facilities or by direct contact with the plants.

The time series is consistent and complete for the major plants, but it has to be noted that some facilities using small amounts of soda ash might be missing in the inventory. According to the comparison with data reported to KemI, potential deficits in the data are expected to be small.

4.2.2.5 ASPHALT ROOFING, CRF 2A5

Data on the total Swedish production of asphalt-saturated felt was provided by the producing companies. Emission factors for asphalt roofing manufacture are presented in EMEP/CORINAIR Emission Inventory Guidebook.[70] These are based on studies performed during the 1970s in the USA and presented by EPA.[71] As stated in the guidebook, the level of uncertainty regarding the suggested emission factors is high, and it is recommended that better factors should be developed and used.

After contact with the industry, emission factors based on measurements and calculations made by the manufacturers were developed before submission 2005 for estimating the NMVOC emissions from the Swedish production of asphalt-saturated felt (Table 4.4)[72].

[70] EMEP/CORINAIR Emission Inventory Guidebook: http://reports.eea.eu.int/EMEPCORINAIR4/en
[71] Shrager, Brian and Marinshaw, Richard. 1994. Emission Factor Documentation for AP-42, Section 11.2, Asphalt Roofing, Final Report. For U.S. Environmental Protection Agency , Office for Air Quality Planning and Standards, Emission Inventory Branch. MRI Project No. 4601-01.
[72] Danielsson, H. 2004. SMED report: Investigation on the occurrence of emissions from asphalt roofing in Sweden.

Table 4.4. Estimated emissions of NMVOC from manufacturing of asphalt-saturated felt (CRF 2A5) in Sweden 1990 – 2007.

Year	NMVOC emissions from asphalt roofing, 2A5 Mg
1990	77.7
1991	80.2
1992	79.8
1993	89.5
1994	97.4
1995	98.6
1996	92.4
1997	99.6
1998	99.1
1999	98.4
2000	111.1
2001	112.9
2002	109.2
2003	101.1
2004	113.7
2005	139.7
2006	132.7
2007	142.4

The NMVOC emissions from the production of asphalt-saturated felt originate from the felt saturation and coating processes and from leakage from the asphalt storage tanks, the latter being the dominating source. For the calculation of the NMVOC emissions, separate emission factors were used, 0.068 kg/Mg and 1.56 kg/Mg, respectively. The emission factors are based on measurements/estimations from 2003 and 1997. Previously reported notation keys for activity data have been changed from NE to C.

4.2.2.6 ROAD PAVING WITH ASPHALT, CRF 2A6

Estimates for the early 1990s are taken from investigations and inventories made in the early 1990s. Data for the last five years has been calculated based on information from the asphalt producers on the average amount of solvent (naphtha) in the mixtures used for road paving. The producers have also provided figures on the total amount of road paving mixtures delivered in Sweden. It is assumed that all solvents in the solvent-based bitumen are emitted when used. Emissions of NMVOC reported for the years in mid- and late 1990s were interpolated (Table 4.5). In the calculations no emissions from imported solvent-based bitumen are used. The amount of imported solvent-based bitumen is most likely very small. In 2005 the emission of NMVOC was very high due to the fact that a heavy storm ruined many roads in southern Sweden that had to be restored quickly and solvent-based bitumen was used for this purpose.

Table 4.5. Emissions of NMVOC 1990–2007 from road paving with asphalt.

Year	NMVOC from road paving with asphalt Mg
1990	6 200
1991	5 900
1992	5 600
1993	5 000
1994	4 400
1995	3 800
1996	3 200
1997	2 600
1998	2 000
1999	1 600
2000	1 170
2001	1 080
2002	845
2003	603
2004	920
2005	1 230
2006	750
2007	935

4.2.2.7 OTHER, CRF 2A7

Specified sub-categories under this heading are, “Non-Iron ore mining and dressing”, “Glass and mineral wool production”, “Glass production”, “Battery manufacture” and ”Light expanded clay aggregate (LECA)“.

4.2.2.7.1 Non-Iron ore mining and dressing, CRF 2A7

Data on NO_X emissions from use of explosives within the non-iron ore mining industry are reported 2002 – 2007, but for the years 1990 – 2001 no information is presently available. Data on NO_X emissions are collected from the companies' environmental reports to the authorities.

4.2.2.7.2 Glass and mineral wool production

For glass and mineral wool production, the time series of NMVOC emissions is based on data received from the companies directly or as reported in environmental reports together with earlier total estimates. The emissions of NMVOC consist of formaldehyde and phenol.

Within mineral wool production, the limestone and dolomite used cause process emissions of CO_2 which are allocated to CRF 2A3according to the IPCC Guidelines. For some years however (1990-1995 and 1998-1999), blast furnace slag was used in the process causing CO_2 emissions as well. These emissions are reported in CRF 2A7. Activity data on the slag consumption has been obtained for the mentioned years from the mineral wool producers. The emission factor is 0.04 Gg CO_2 /Gg slag based on that the slag contains 1 % carbon and the CO_2 emissions are calculated by using the formula:

Emissions of CO_2 (Mg) from use of slag = Slag (Mg) * 0.01 * (C content) * 44/12

4.2.2.7.3 Glass production

Emissions of CO_2 from the use of limestone and from the use of soda ash in glass production are reported in CRF 2A3 and 2A4 respectively.

The process-related SO_2 emissions from container and float glass production are reported for the period 1990 – 2007 in CRF 2A7. The reported NO_X emissions originate from the production of float glass. Data has been provided directly by the companies or collected from their environmental reports.

4.2.2.7.4 Battery manufacture

NMVOC emissions from battery manufacture for the period 1990-1998 are compiled from data presented in the companies' environmental reports. The process has changed and no emissions of NMVOC occur after 1998.

4.2.2.7.5 Light expanded clay aggregate (LECA)

Activity and emissions data for 1990 - 2004 is retrieved directly from the production plant, split into emissions from clay and emissions from additives (limestone and other carbon containing material). From 2005 and onwards, the equivalent data is acquired through the ETS and the Swedish LECA producer's annual report.

The implied emission factor may vary somewhat from one year to another because of the specific composition of limestone, clay and additives with different carbon contents. In 2007, the C-content in one of the additives was unusually high which has resulted in comparatively high CO_2-emissions for that year. The use of limestone and other additives has declined in favour of clay which today contributes to about 88 % of all process related CO_2 emissions from LECA production. All CO_2 emissions from LECA production are reported in 2A7. Reported data are considered to be consistent and complete.

4.2.3 Recalculations

4.2.3.1 CRF 2A1

- Previously reported notation key for Recovery of CO_2 has been changed from NO to NA.

4.2.3.2 CRF 2A2

- Previously reported data on Recovery have been removed. The reported data comprised potential CO_2-emissions from recycled lime in processes in sugar and in pulp production. In the UNFCCC reviews the unusually high IEFs from 2A2 have been pointed out. These IEFs, calculated by the secretariat, are based on the sum of reported CO2-emissions and of the reported recovery. Since the IEFs are calculated this way, including the recovery

and not only the emitted CO_2, it has to be further investigated what is supposed to be reported as recovery.

4.2.3.3 CRF 2A4

- Reported notation key for Recovery of CO_2 have been changed from NO to NA.

4.2.3.4 CRF 2A5

- Previously reported notation key for Activity data have been changed from NE to C.

4.2.3.5 CRF 2A7, IRON ORE MINING AND DRESSING

- All emissions from Iron ore mining and dressing, including sinter and pelletizing plants were previously included in 2A7. These have been reallocated to CRF 2C13, Sinter.

4.2.3.6 CRF 2A7

- Data on SO_2 for 2005 from glass production was corrected for one plant.
- NOx for 2005 from non-iron ore mining and dressing has been corrected.

4.2.4 Coming improvements

To submission 2010, a detailed review and if relevant, a revision is planned to improve estimates and allocation of process related CO_2 emissions in CRF 2A.

4.3 Chemical industry, CRF 2B

4.3.1 Source category description CRF 2B

Sources covered in the reporting are nitric acid production (2B2), carbide production (2B4) and other (2B5), which include a large variety of processes in the chemical industry. No ammonia production (2B1) or adipic acid production (2B3) occurs in Sweden.

4.3.1.1 AMMONIA PRODUCTION, CRF 2B1

There is an annual production of about 5 Gg of ammonia in Sweden, according to UN statistics[73]. This ammonia is however not intentionally produced, but is a by-product in one chemical industry producing various chelates and chelating agents, such as EDTA, DTPA and NTA[74]. Emissions from this industry are included in

[73] UN. Commodity Production Statistica Database. Department of Economic and Social Affairs, Statistics Division,. As referred in FCCC Synthesis and Assessment report 2002 Part I.
[74] Kindbom, 2004. SMED report: Investigation on the occurrence of ammonia production in Sweden. 2004-05-11.

CRF code 2B5. Ammonia production, 2B1, is thus reported as NO in the CRF-tables.

4.3.1.2 NITRIC ACID PRODUCTION, CRF 2B2

Production of nitric acid has taken place at three facilities in Sweden during 1990-2000. One of these was shut down in the end of 2000, and a second one was shut down during 2001. Therefore, there is currently only one facility producing nitric acid in Sweden.

4.3.1.3 CARBIDE PRODUCTION, CRF 2B4

Carbide production is carried out at one facility in Sweden. All CO_2 emissions from the industry are included in the code 2B4 (both from energy and process) due to lack of background data. The reported SO_2 emissions represent the process related emissions from the use of coke for production of quick lime for carbide production.

4.3.1.4 OTHER, CRF 2B5

This sub-category includes various chemical industries, such as sulphuric acid production, the pharmaceutical industry, production of base chemicals for plastic industry, various organic and inorganic chemical production and other non specified chemical production, which are not covered elsewhere. Approximately 70 larger industrial facilities are included in the emission estimates. Emissions of CH_4, N_2O, NO_X, CO, NMVOC and SO_2 are reported. It is possible that some emissions of NMVOC reported in CRF 2B5 should be reported in CRF 3C (e.g. pharmaceutical industries), but since it has been difficult to make the distinction clear between process emissions and solvent use, all NMVOC emissions from these facilities have been included in CRF 2B5.

4.3.2 Methodological issues, CRF 2B

4.3.2.1 NITRIC ACID PRODUCTION, 2B2

Activity data, such as the produced amount of nitric acid, has been obtained from the facilities and from official statistics. Emission estimates of N_2O have been reported in the companies' environmental reports or have been provided by the facilities directly. Emission data are not available for all facilities for 1991-1993. Since two plants have been shut down, it is no longer possible to acquire this information. Calculations have therefore been made based on production statistics and an assumed emission factor (Table 4.6). The assumed emission factor of 7 kg/Mg for 1991 - 1993 is based on the calculated emission factors for 1990 and 1994 and is in line with the default factors for nitric acid production presented in Table 4.7 in IPCC Good Practice Guidance. The fluctuations in the calculated total EF for N_2O 1994 - 2002, as can be seen in Table 4.6, is mainly due to fluctuations in one of the facilities. Activity data and reported emissions have been acquired

from previous reporting in e.g. environmental reports from the facility. Since the facility has shut down, it is no longer possible to check previously reported estimates. Beside emissions of N_2O also emissions of NO_X are reported.

Table 4.6. Activity data, emission factors and emissions for N_2O for nitric acid production

Year	Production of nitric acid Gg	Calculated EF (1990 and 1994-2001), kg/Mg	Emissions of N_2O, Gg
1990	374	7.02	2.63
1991	395	7.00*	2.77
1992	380	7.00*	2.66
1993	369	7.00*	2.58
1994	377	6.62	2.50
1995	417	5.48	2.29
1996	400	5.48	2.19
1997	390	5.56	2.17
1998	400	6.10	2.44
1999	383	5.58	2.14
2000	430	4.80	2.06
2001	282	5.48	1.55
2002	263	5.41	1.42
2003	258	5.39	1.39
2004	257	5.37	1.38
2005	264	5.37	1.42
2006	272	5.42	1.47
2007	249	3.16	0.788

*Emission factors have been assumed

The lower level of N_2O emissions from 2001 and onward compared to earlier years is a result of one facility being shut down in late 2000 and a second one during 2001. Emissions for all years, except 1991 - 1993, are as reported from the facilities. The lower level of NO_X emissions in year 2004 is a result of a long lasting leakage of NO_X from one of the production units at the active facility. During 2007 catalytic abatement was installed at one of the production units at the active facility and as a result the emissions of N_2O and NO_X have been reduced compared to previous years.

Documentation has been received from the facility concerning production data, production capacity and abatement measures, emission factors used and the method of estimating emissions as well as uncertainty in emission estimates. However, this information is considered confidential.

4.3.2.2 CARBIDE PRODUCTION, CRF 2B4

Calcium carbide is produced by a high-temperature fusion of coke and lime. This process leads to emissions of CO_2 and SO_2.

Data on produced amount of carbide is provided in the company's environmental report and is used to calculate emission of CO_2. The emission factor used

for the calculation of CO_2 emissions is based on the reported emissions and the amount of carbide produced presented in the 2002 environmental report. In the calculations, emissions from the use of limestone, gas and coke are all included. The emission factor of 1.25 kton CO_2/kton produced carbide is comparable with the IPCC Guidelines default value of 1.37 kton CO_2/kton produced carbide.

The SO_2 emissions reported in CRF 2B4 represent the sulphur content in the coke used for the production of quick lime for the carbide process. The sulphur content of the coke is assumed to be 6 kg/Mg for the whole time series.

During year 2006 the consumption of coke used for the production of quick lime decreased compared to previous years. This affects the reported emissions of SO_2. In 2007, the coke consumtion for production of quick lime increased and consequently the SO_2 emission in 2007 was higher compared to 2006.

4.3.2.3 OTHER, CRF 2B5

The primary information on emissions of CH_4, N_2O, NO_X, CO, NMVOC and SO_2 is as reported by the companies in their environmental reports. A total of approximately 70 facilities are included. In Submission 2005 all emissions were summed up and reported in 2B5 Other non-specified. Since submission 2006 the emissions are presented allocated to six separate categories in 2B5 Other. The time series have been reviewed and are considered to be consistent. Process emissions of CO_2 have not been estimated due to lack of data, but are expected to be minor, considering the processes concerned.

The SO_2 emissions reported in 2B5 decreased dramatically in 2004 in comparison to earlier years. This is due to that in December 2004 one facility for production of viscose staple fibre was shut down. The yearly SO_2 emissions from this facility represented between 8 and 20 % of the totally reported SO_2 emission in CRF 2 – Industrial Processes, 1990 - 2003.

CO-emission from "Other inorganic chemical production" increased from below 200 Mg in 2005 to 500 Mg in 2006. This increase is due to unusually high CO emission in 2006 from one facility producing PVC. In 2007 the CO-emissions were very low from one facility producing PVC.

N_2O-emissions increased in 1999 due to the fact that one facility within ”Pharmaceutical industry” reported higher emissions that year.

CH_4-emissions decreased in 1999 due to a much lower production at one facility.

NH_3-emissions decreased in 2007 due to that one facility is replacing NH_3 from the production.

4.3.3 Recalculations

- No recalculations have been made in submission 2009.

4.3.4 Coming improvements

To submission 2010 a detailed review is planned to improve estimates of process related CO_2 emissions in CRF 2B.

4.4 Metal production, CRF 2C

4.4.1 Source category description, CRF 2C

All sub-categories are covered in the estimates, i.e. iron and steel production (2C1), ferroalloy production (2C2), aluminium production (2C3), SF_6 used in magnesium foundries (2C4) and other (2C5), which consists of estimates for one large non-ferrous smelter plant and one metal recycling plant.

4.4.1.1 IRON AND STEEL PRODUCTION, CRF 2C1

In Sweden, there are three primary iron and steel facilities and about ten steel plants equipped with electric arc furnaces. In total, there are approximately 20 different facilities included in the different estimates. Processes occurring besides the primary processes and secondary steel production are rolling mills, pickling and other steel-related processes. From submission 2009 emissions from two major iron ore mines and three facilities producing pellets in Sweden are reported in 2C13 (reallocated from previous reporting in 2A7). Emissions from a sinter producing facility are also included until 1995, when the production closed down.

4.4.1.2 FERROALLOY PRODUCTION, CRF 2C2

Ferroalloy production is reported for only one facility in Sweden. There is also ferroalloy production at one more plant, but since the main production at this facility is iron and steel, the emissions are reported in CRF 2C1- Iron and steel production.

4.4.1.3 ALUMINIUM PRODUCTION, CRF 2C3

There is one facility that produces primary aluminium in Sweden. The facility consists of two plants. One includes 56 closed pre-baked ovens (CWPB), each of 150 kA, and in the other there are 3 pre-baked ovens and 259 open ovens with Söderberg anodes (VSS). The Söderberg anodes are produced in an electrode pulp factory at the facility.

4.4.1.4 SF_6 USED IN MAGNESIUM FOUNDRIES, CRF 2C4

Four magnesium foundries use SF_6 as a cover gas.

4.4.1.5 OTHER METAL PRODUCTION, CRF 2C5

This sub-category includes CO_2, NO_X and SO_2 emissions from one large smelter producing various non-ferrous metals; copper, lead, zinc etc and CO_2 emissions from one metal recycling company mainly producing lead.

4.4.2 Methodological issues, CRF 2C

4.4.2.1 IRON AND STEEL PRODUCTION, CRF 2C1

Emissions reported from primary steel works and other iron and steel works are reported in both CRF 2C1 and also in CRF 1A2a since some emissions arise from fuel combustion and some from reducing agents in the process. The text in this section is hence closely connected to the text in the section about CRF 1A2a. Generally emissions from combustion of conventional fuels such as residual fuel oil etc. are reported in CRF 1A2a and fuels acting as reducing agents are reported in CRF 2C1.

4.4.2.1.1 Non-CO_2 emissions reported in 2C1

For non-CO_2 emissions, the companies' environmental reports are the main source of information. NO_X, NMVOC and SO_2 emissions emitted from electric arc furnaces are reported in 2C1. NO_X emissions may also arise from pickling and NMVOC emissions from rolling mills. These sources are also included in the estimates.

4.4.2.1.2 CO_2 emissions reported in Steel, CRF 2C11 - Secondary production

The emissions include secondary steel plants using reducing agents such as coke, coal and electrodes in electric arc furnaces. These emissions are not primarily a result of combustion, but are necessary for the process and should hence be reported in CRF 2C1. The reported emissions in CRF 2C11 consist of data from nine plants in 1990-2003 and eight plants from 2004, since one plant shut down its production in 2004. Other plants in this sector do not produce steel and hence do not emit CO_2. In most cases, data from the Swedish enquiry for the Swedish national allocation plan (NAP) for the EU ETS could be used for the years 1998-2002. Data for 1990-1997 and 2003-2004 has been collected directly from the plants. From 2005, the equivalent data are acquired from the ETS, environmental reports and through contacts with the companies.

The Good Practice Guidance method Tier 1 has been used for six of the plants. The Tier 1 method include plant-specific activity data only on carbon-containing input materials since data on outgoing carbon in produced steel and residual products is not available. For these plants, plant specific emission factors for CO_2 were used for all years to get as accurate emission estimates as possible.

For the three remaining plants (two from 2004 and onwards), activity data on reducing agents and emissions are not available for all years. Instead plant specific methods are applied, where activity data on steel production has been used to estimate the emissions for 1990-1997 for two plants, and for 1990-2005 for the third plant.

Limestone or dolomite can also be used to purify the steel. The plants have been asked to report any such usage, but most plants use quicklime or dolomite

lime and not the mineral forms of limestone and dolomite. Only one plant report use of dolomite and this amount is included in the estimates of the CO_2 emissions.

Production and consequently emissions have increased slowly since 1990 due to higher demand of these products. The high production and emissions level in 1990 compared to 1991 is explained by the fact that one plant closed its production in 1991.

4.4.2.1.3 Emissions reported in Pig iron, CRF 2C12- Primary production

Emissions from two pig iron producers and one iron powder producer are included in this sector since they are all primary producers, i.e. bases their production on iron ore pellets. They are also reported together in order to maintain statistics secrecy. Activity data reported is produced amount of pig iron.

4.4.2.1.3.1 Production of iron powder

In Sweden there is one producer of iron ore based iron powder. The emissions of CO_2 are calculated by using the Good Practice Guidance method Tier 2. The method includes plant specific activity data on emissions from carbon-containing input materials such as coke and anthracite and also specific carbon-contents of output iron and rest products for all years. The emissions are hence reported by the plant but are verified by collecting and comparing the carbon contents in the amounts of coke, anthracite and out-put material and compare it between different years and with secondary steel plants that have reported use of the same raw material. Emissions from natural gas are considered to be process related by the plant, but is reported in the Energy sector (CRF 1A2a) since the guidelines does not mention natural gas as process related. To be consistent with calculations of emissions from production of pig iron, limestone used in the production is included in the emissions from the production of iron powder in CRF 2C1.

4.4.2.1.3.2 Production of pig iron

The other two plants reported in this sector are primary steel producing plants with coke ovens, blast furnaces and steel converters. The primary purpose of the use of coal and coke in the blast furnace is to secure oxidation and act as reducing agents, and emissions from combustion of blast furnace gas to produce pig iron in the blast furnace are to be reported as industrial processes from iron and steel production in CRF 2C1, according to the IPCC Guidelines and Good Practice Guidance.

The recommended Tier 2 method, according to the IPCC Guidelines, is to base the calculations on the amount of reducing agent, i.e. injection coal, coke oven coke and petroleum coke used in blast furnaces for the production of iron. Other information needed to use the Tier 2 method is the amount of pig iron and sludge produced as well as the amount used for steel production and produced steel, and the carbon content of all those parts. This information is not provided by the industrial energy statistics or the quarterly fuel statistics (see section 3.3.1.1 and 3.3.1.2 above), or the environmental reports. Another way to make the correct calculations of process emissions from blast furnaces, as Sweden has done, is to base the calcu-

lations on the consumed amount of blast furnace gas, as all emissions from the blast furnace are collected in this gas and emitted when combusting it.

The amount of blast furnace gas is used in the cowpers as activity data when calculating all emissions. Emissions (CO_2, CH_4, NO_X, CO, NMVOC and SO_2) are calculated as the product of fuel consumption, thermal value and emission factors (EF) in the same way as in the Energy sector:

$$\text{Emissions fuels (unit)} = \sum \text{Fuel consumption (unit)} * \text{thermal value fuels} * \text{EFfuels}$$

The thermal value and emission factors are values reported by the plants and are the same as those used and described in the Energy section, described in chapter 3.

The blast furnace gas mainly comes from coke and injection coal, but partly also from lime-stone. According to the IPCC Guidelines 1996, emissions of CO_2 from the use of limestone should be reported separately as process emissions from limestone and dolomite use in CRF 2A3. In the Centralized review from submission 2004 the ERT recommended Sweden to follow the guidelines. However, the proportions of carbon from limestone released as CO_2 and the carbon bound in sludge are not known and besides that, the IPCC Guidelines recommend parties not to exclude these emissions. Hence, all blast furnace gas is reported as process emissions within iron and steel production in CRF 2C1.

Other emissions from these two plants are reported in CRF 1A1a (one of the plants produces electricity), CRF 1A1c (coke production), CRF 1A2a (steel production), 1B1b (quenching and extinction at coke ovens) and CRF 1B1c (flaring of off-gases from the whole plant). This allocation is further described in the Energy section for CRF 1A2a.

During 2008, SMED performed a study on, among other things, how reported emissions from the primary iron and steel plants could be improved. In the study, emissions reported to i.e. UNFCCC were compared to reported emissions in the companies' environmental reports. The comparison showed that reported emissions of CO_2 to UNFCCC did not agree with the emissions reported by the companies in their environmental reports. The main conclusions were that revisions should be made concerning data source and the allocation of emissions. The revisions, if approved by the Swedish EPA (no decision is yet taken) are planned to be implemented in submission 2010. It was not possible to implement the revisions in submission 2009 due to the inventory time cycle applied in Sweden.

When calculating emissions according to the method described above for CRF 2.C.1.2 it has been noticed that consumed amount of blast furnace gas in the blast furnace for years 2005 to 2007 has decreased compared to previous years. Instead the used amount of coke oven gas in the blast furnace has increased. Due to energy optimization in the blast furnace at one plant[75] for later years, 2004 - 2007, the used amount of blast furnace gas in the blast furnace has decreased and the used amount of coke oven gas has increased. As described above, Sweden only include used

[75] A report "Energieffektivisering inom SSAB i Oxelösund under åren 1996 - 2007" produced by "ENET-Steel" (Network for energy efficiency within mining- and steel industry) (ENET-Steel: Report nr 2, September 2007). http://www.enet-steel.se/

amount of blast furnace gas in the blast furnace when estimating emissions of CO_2, i.e. used amount of coke oven gas in the blast furnace is not included in the calculations. As a consequence, the emissions of CO_2 will drop for 2005 - 2007 if the method described above is used. This drop does not reflect reality. Therefore, in order to get better correspondence with the total reported emissions of CO_2 in the companies' environmental reports, the method described above has not been used for year 2005 - 2007. Instead, emissions originating from blast furnace as reported in the environmental reports have been used for these years.

4.4.2.1.4 Iron ore mining, dressing, sintering and iron ore pellets production, CRF 2C13

Emissions of CO_2 from the use of limestone and dolomite within the production of ore based iron pellets are reported in CRF 2A3. Estimated emissions from combustion of fuels are included in the Energy sector (CRF 1).

Emissions considered in CRF 2C13 are SO_2 from the sulphur content in the ore and NO_X emitted as a result of the use of explosives. The use of mining explosives also causes emissions of carbon monoxide, CO[76]. No data concerning the CO emissions is available and the time series 1990 – 2007 is thus reported NE.

Data on production statistics as well as on SO_2 emissions have been supplied by the facilities for the entire time period, 1990 - 2007.

4.4.2.1.5 CO_2 emissions reported in Coke, CRF 2C14

Emissions of CO_2 from the production of coke are reported in CRF 1A1c in line with the IPCC Guidelines.

4.4.2.1.6 CO_2 emissions reported in Other, CRF 2C15

No emissions of CO_2 reported in this sector.

4.4.2.2 FERROALLOY PRODUCTION, CRF 2C2

CO_2 emissions within the production of ferroalloys are plant specific, and are calculated based on the consumed amount of reducing agents (Tier 1a[77]), i.e. electrodes and coke (and in 2003 coal) and their carbon contents. Input data is also the amount of carbon bound in produced ferroalloys. The general distribution of carbon in the incoming and outgoing materials is:

Coke	+	Electrodes	→	Ferroalloys	+	Emissions	+	Particles
95%	+	5%	→	10%	+	89.5%	+	0.5%

To verify the emissions reported by the plant, emissions are calculated based on activity data on coal, coke, electrodes and the amount of carbon in produced ferroalloys and:

[76] Wieland, M.S. 2004.
[77] http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch2wb2.pdf

- emission factors and thermal values used for stationary combustion for coke and coal and information from the company that the electrodes contain 90 % carbon.
- IPCC default factors for coal, coke and electrodes[78].

The formula used is:

$$CO_2\ (Mg) = Coke\ (Mg) \times EF \times Thermal\ value + Coal\ (Mg) \times EF \times Thermal\ value + Electrode\ (Mg) \times C\text{-}content \times \frac{44}{12} - CO_2\ in\ produced\ ferroalloys\ (Mg,\ plant\ data)$$

where 44/12 are the molecule weights of CO_2 and carbon. As can be seen in Table 4.7, the plant specific data are lower than both emissions based on Swedish default EF and emissions estimated with IPCC Guidelines default values. The differences are due to the fact that the carbon content of the coke may vary from one year to another according to the company, and are obviously generally lower than normal Swedish conditions and lower than then IPCC default.

The total amount of carbon in the produced ferroalloys is presented in Table 4.8, and is calculated based on the carbon content in coke, coal, electrodes and dust by the company. The amount of carbon in the produced ferroalloys varies between 0.1 % and 7 %. This carbon is reported under CRF 1.AD.10 - coke and coal.

Data on non-CO_2 emissions has been obtained directly from the company for the whole time series. The reported emissions include NO_X and SO_2 from the process. During 2006 and 2007 one of the units of the facility was in operation for about three months. For this the SO_2 emissions decreased in 2006 and 2007 compared to previous years.

[78] IPCC. Revised 1996 Guidelines for National Greenhouse Gas Inventories: Reference Manual, Table 2.12.

Table 4.7. Total emissions of CO_2 based on plant specific data (reported in the CRF), data based on Swedish EF and thermal values, and based on IPCC Guidelines default values.

Year	Plant specific data, Mg CO_2	Swedish values, Mg CO_2	IPPC default values, Mg CO_2
1990	243	275	295
1991	244	279	299
1992	245	289	310
1993	232	280	300
1994	248	300	322
1995	265	306	328
1996	272	313	336
1997	203	236	253
1998	240	281	302
1999	239	267	287
2000	240	301	323
2001	214	252	271
2002	237	265	285
2003	197	223	239
2004	256	289	310
2005	225	244	262
2006	220	239	257
2007	220	219	235

Table 4.8. Total amount of carbon bound in produced ferroalloys.

Year	-90	-91	-92	-93	-94	-95	-96	-97	-98	-99	-00	-01	-02	-03	-04	-05	-06	-07
Carbon in ferroalloys, Gg	8.4	8.4	8.5	8.3	9.4	8.7	9.3	6.4	8.4	7.9	9.5	7.6	7.7	6.7	8.0	8.0	8.3	8.4

4.4.2.3 ALUMINIUM PRODUCTION, CRF 2C3

Primary aluminium is in Sweden produced in one facility, where both the Prebaked and the Söderberg processes are used. The time series of emissions compiled for primary aluminium production include emissions of CO_2, PFCs, NO_X, CO, NMVOC and SO_2. Reported production statistics and emissions data are based on information in the environmental reports or received directly from the company.

Reported emissions of NO_X are calculated from production statistics using emission factors defined by Swedish EPA[79]. NMVOC emissions are calculated from reported emissions of tar, assuming that 70 % of the tar is emitted as NMVOC[79]. CO emissions were for the first time reported in submission 2008 and are for 2002 - 2007 as reported in the company's environmental reports. For the period 1990 – 2001, the CO emissions are calculated based on production statistics and emission factors provided by the companies as also for the SO_2 emissions during 1990 - 2005. For 2006 and 2007, SO_2 emissions data are based on environmental reports published by the companies.

[79] Ahmadzai, H. Swedish EPA. Personal communication. 2000.

Emission data for CO_2 from the production of primary aluminium 2002 - 2007 are derived through measurements and reported directly by the plants, whereas the emissions for 1990-2001 are calculated based on the mass of coal elements (anodes) such as electrodes, coke etc. and the amount of carbon that is bound in soot. The formula used for CO_2 (Mg) for 1990-2001 is:

$$Mass\ anodes\ (100\%\ C) \times \frac{44}{12} \times (1 - 0.257^{*})$$

* Mass CO_2 bound in soot and rest anodes in 2002

The value for carbon bound in soot and rest anodes (0.257) is based on the reported value for 2002 and has been about the same also the coming years.

For the years from 2002 and onwards the emissions reported by the plant have been verified by also collecting data on amount coal elements used and then calculating the emissions based on the equation above and the results are very comparable.

Since carbon bound in soot has been excluded, the IEF (implied emission factor) values (given as Mg CO_2/ Mg Al produced) are lower than the IPCC Guidelines default emission factors for Pre-baked and Söderberg (1.8 respectively 1.5 kton CO_2/kton produced Al) (Table 4.9). The reason why the IEF varies between years might be that the consumption of anodes in relation to the produced amount of primary aluminium is not absolutely constant.

Table 4.9. Implied emission factor for CO_2 from the production of aluminium.

Year	Aluminium production Gg	Emissions of CO_2 Gg	IEF Gg CO_2/Gg Al
1990	96.3	133.1**	1.38
1991	96.9	133.4	1.38
1992	77.2	100.0	1.30
1993	82.4	120.6	1.46
1994	83.9	119.6	1.43
1995	94.0	129.1	1.37
1996	97.6	137.0	1.40
1997	97.7	136.2	1.40
1998	96.1	139.1	1.45
1999	99.3	139.9	1.41
2000	101.1	144.9	1.43
2001	101.8	138.9	1.36
2002	100.6	146.0	1.45
2003	101.2	146.0	1.44
2004	101.3	140.8	1.39
2005	102.5	143.5	1.40
2006	101.7	142.3	1.40
2007	99.9	139.8	1.40

The two different processes for aluminium production, Prebaked (CWPB) and Söderberg (VSS), have substantially different emission factors for PFCs. Estimates of emissions are based on the number of ovens and the number and duration of anode effects. This activity data is considered to be of good quality.

In earlier submissions than submission 2007, the calculations of emissions of PFCs (CF_4+C_2F_6) were made by the company, according to information from EAA (European Aluminium Association). Emissions of PFC in kg/Mg Al = K x Anode effects in min/oven day, where K=0.12 for Prebaked and K=0.08 for Söderberg. The PFC emissions were assumed to consist of 90 % CF_4 and 10 % C_2F_6.
After recommendation made by the Expert Review Team in the In Country Review in April 2007 the whole time series for CF_4 and C_2F_6 from primary aluminium production has been recalculated to achieve complete agreement with the Tier 2 calculation method described in IPCC Good Practice Guidance (Table 3.9). The function used for the calculations reported in submission 2008 and later is the same as the one used in previous submissions:

$$PFC(Mg) = Al(Gg) \times K \times AE\text{-}minutes/cellday$$

but the slope-factors used in submission 2008 and later (from GPG, Table 3.9) leads to around 13 % lower total PFC emissions expressed as CO_2 eq. in submission 2008 compared to submission 2007 (Figure 4.2).

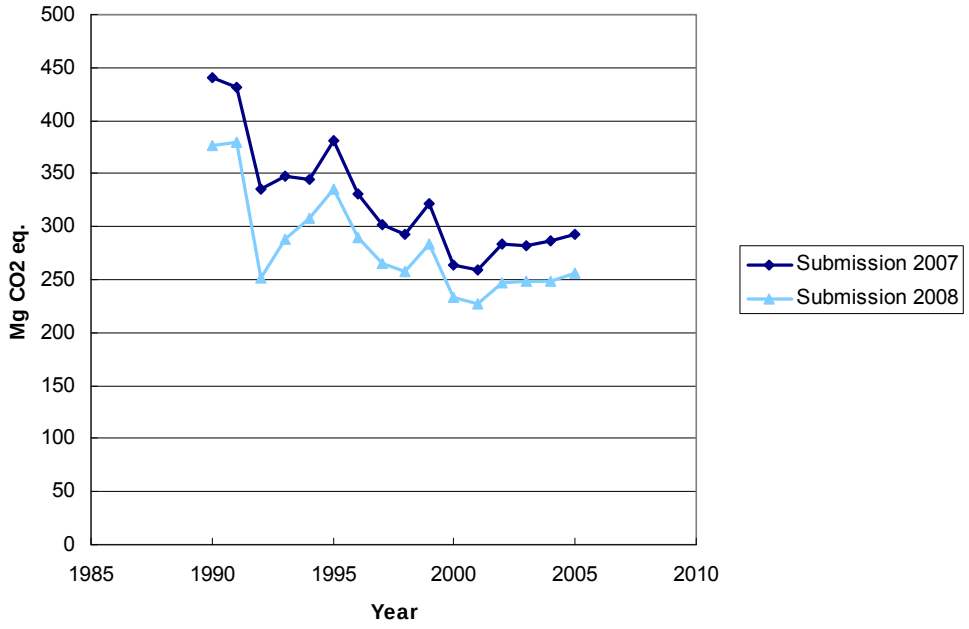

Figure 4.2. Comparison of reported emissions of PFCs from primary aluminum production in submission 2008 vs. submission 2007

Activity data used for the PFC emission calculations, anode effects in min/oven day and production statistics, were provided by the company, and specified for the

Prebaked and Söderberg processes. The reported emissions and calculated Implied Emission Factors are presented in Table 4.10.

As can be seen in Table 4.10 the IEFs shows a declining trend from 1990 to 2007, especially so for CF_4. This reflects the company's ongoing work aiming to reduce the time and frequency of the anode minutes.

Table 4.10. Activity data, emissions of C_2F_8, CF_4 and calculated IEF for aluminum production.

Year	Al production, CWPB, Gg	Al production, VSS, Gg	Total emissions, C_2F_6 Mg	Total emissions, CF_4 Mg	Calculated IEF			
					CWPB kg C_2F_6/Mg	VSS kg C_2F_6/Mg	CWPB kg CF_4/Mg	VSS kg CF_4/Mg
1990	23.4	72.9	3.05	53.66	0.0443	0.0276	0.3444	0.6255
1991	23.4	73.5	3.07	54.04	0.0443	0.0276	0.3444	0.6255
1992	23.4	53.8	1.81	36.15	0.0138	0.0276	0.1075	0.6250
1993	23.2	59.1	1.95	41.61	0.0075	0.0300	0.0585	0.6806
1994	23.1	60.8	2.09	44.44	0.0083	0.0312	0.0644	0.7066
1995	22.8	71.2	2.29	48.25	0.0106	0.0287	0.0827	0.6510
1996	23.0	74.5	1.95	41.81	0.0068	0.0240	0.0526	0.5447
1997	23.2	74.5	1.79	38.26	0.0064	0.0220	0.0497	0.4983
1998	23.2	72.9	1.78	37.20	0.0090	0.0215	0.0702	0.4877
1999	23.2	76.1	1.92	40.81	0.0082	0.0228	0.0636	0.5166
2000	23.0	78.1	1.57	33.58	0.0059	0.0184	0.0460	0.4165
2001	22.9	78.9	1.52	32.80	0.0046	0.0179	0.0362	0.4054
2002	22.9	77.7	1.65	35.77	0.0050	0.0198	0.0386	0.4488
2003	22.8	78.4	1.66	35.90	0.0049	0.0197	0.0381	0.4467
2004	23.3	77.9	1.62	36.01	0.0018	0.0202	0.0138	0.4579
2005	23.6	78.9	1.66	36.93	0.0022	0.0204	0.0171	0.4629
2006	23.6	78.1	1.59	35.21	0.0024	0.0196	0.0188	0.4453
2007	23.3	76.5	1.61	35.54	0.0026	0.0202	0.0205	0.4583

4.4.2.4 SF_6 IN MAGNESIUM FOUNDRIES, CRF 2C4

The total amount of SF_6 used annually in the magnesium foundries is reported as emissions, according to the IPCC Guidelines and Good Practice Guidance. Data is obtained from companies using SF_6. For 2007, as for earlier years, data from the Products register at the Swedish Chemicals Agency was unfortunately not available in sufficient detail to enable crosscheck with data provided by the facilities.

4.4.2.5 OTHER, CRF 2C5

The reported emissions of SO_2 originate from the sulphur content in the raw materials used in one large non-ferrous smelter. The NO_X reported in 2C5 is also emitted from this facility. The company has provided complete time series of SO_2 and NO_X emissions.

Emissions of CO_2 from non-ferrous industries originate from one plant producing copper, lead and zinc, and one metal recycling plant mainly producing lead by melting used batteries and recover the lead. CO_2 emissions from the former plant

are calculated based on the coke used as reducing agent in the process. The company directly reports activity data on coke, coal, limestone, plastics and other raw material, all resulting in CO_2 emissions, as well as carbon content in slag products. The emissions from coal and coke are calculated based on national thermal values (TV) and emission factors (EF). IPCC default value is used for CO_2 emissions from limestone. The equation used for the larger plant is:

$$CO_2\,(Mg) = Coke\,(Mg) \times EF \times Thermal\ value + Coal\,(Mg) \times EF \times Thermal\ \ value$$
$$+ Limestone\,(Mg) \times 0.97 \times \frac{44.0098}{100.0892} + C\ in\ raw\ material\ and\ \ plastics\,(Mg) \times \frac{44}{12}$$
$$- Slag\,(Mg) \times 0.0002 \times \frac{44}{12}$$

The metal recycling plant emits CO_2 from the melting of lead batteries composed of carbon containing plastics (polypropene). The total CO_2 emissions from the plant are reported by the company for all years from 1990. For the years 1990 to 2003 the reported total CO_2 emissions also include energy related emissions. From 2004 the amount of plastics, their carbon content, as well as the CO_2 emission from plastics are known. This information for 2004 is used for estimating the process related CO_2 part of the total CO_2 emissions from the plant for the years 1990 until 2003.

4.4.3 Recalculations

4.4.3.1 CRF 2C11

- CO_2 emissions for 2006 has been updated for one plant.
- Activity data for 2003 has been corrected for one plant
- Emissions of NMVOC have been corrected for one plant for 2001 - 2006 and for another plant for 2001.
- SO_2 emissions from one plant have been corrected for 2000 - 2003
- Emissions of NO_X have been corrected for one plant for 2001 and for one plant for the years 2003 and 2004.
-

4.4.3.2 CRF 2C12

- CO2 emissions for 2005 and 2006 have been updated for two plants.

4.4.3.3 CRF 2C13

- Emissions from iron ore mining, dressing, sinter and iron ore pellets production have been reallocated to 2C13. Previously these emissions were reported in 2A7.
-

4.4.3.4 CRF 2C2

- Corrected activity data for 1994 and 2002.

- Previously reported data on Recovery (carbon bound in the produced ferroalloys) has been removed.

4.4.3.5 CRF 2C3

- Corrected activity data for 1990, 1991, 1993, 1994, 2001, 2003 and 2005.
- Previously reported data on Recovery (carbon bound in soot and rest anodes) has been removed.

4.4.3.6 CRF 2C5/SILICIUM PRODUCTION

- For 1990 notation keys for activity data and emissions of CO_2 and CH_4 has been changed from NO to NE. For NMVOC notation key has been changed from NA to NE for Recovery of CO_2 the notation key has been changed from NO to NA.

4.4.3.7 CRF 2C5/NON-FERROUS METALS

- Previously reported data on Recovery (carbon bound in produced products) has been removed.
- SO_2 emission for 1990 has been corrected. In submission 2008 the emissions from silicium production was by mistake also reported in CRF 2C5/Non-Ferrous Metals
- Notation key for NMVOC has been changed from NA to NE

4.4.4 Coming improvements

In the preparation of submission 2010, a detailed review is planned to improve estimates of process related CO_2 emissions in CRF 2C.

During 2008 a study was performed aiming at comparing emission data for several industry plants (including 2.C.1.2) according to the GHG inventory with data according to the environmental reports. The results show that GHG data could be further improved to be more in line with these other data sources. Revisions, if approved by the EPA (no decision taken yet), are planned to be implemented in submission 2010.

4.5 Other production, CRF 2D

4.5.1 Source category description, CRF 2D

Other production covers emissions from the pulp and paper industry (2D1) as well as estimates from the production of food and drink (2D2).

4.5.1.1 PULP AND PAPER, CRF 2D1

The pulp and paper industry in Sweden is an important source of industrial process emissions. 42 individual pulp and paper facilities are included in the reported emissions, as well as two manufacturers of cardboard. The Kraft process (sulphate) dominates in Sweden but there are also emissions from four sulphite and 16 CTMP

(Chemo Thermo Mechanical Pulp) or TMP (Thermo Mechanical Pulp) facilities reported in CRF 2D, 1990 - 2007.

4.5.1.2 FOOD AND DRINK, CRF 2D2

The food and drink industry is a moderate source of NMVOC in Sweden. The industry consists of beer, wine and liquor producers, bread, sugar, yeast and margarine and solid cooking fat producers, coffee roasters and animal feed producers.

4.5.2 Methodological issues, CRF 2D

Emissions of fossil CO_2 are not estimated for this sector. According to the IPCC Guidelines Reference Manual, emissions of CO_2 from this sector are not likely.

4.5.2.1 PULP AND PAPER, CRF 2D1

Reported emissions from the pulp and paper industry are primarily based on information about production and emissions in the companies' environmental reports. The industrial organisation within this sector has, for several years, cooperated closely with its members in developing sector-specific methods of measuring and calculating emissions, which have resulted in high quality emissions data. The reported emissions of NMVOC do not include therpenes.

The Swedish definition of process emissions includes the combustion of spent cooking liquor which gives rise to emissions of N_2O and CH_4. The cooking liquor contains organic compounds and chemicals and is combusted to recover Na and S, but also to utilise the energy in the cooking liquor. The recovered Na and S (as Na_2CO_3 and Na_2S) are recycled and used in the process again. In submission 2008 and earlier, due to technical reasons, these emissions were reported in CRF 2G. From submission 2008 and onwards, N_2O and CH_4 are reported in 2D1.

The estimated process emissions of CO_2 from quick lime within this industry are allocated to CRF 2A2, where only calculated emissions from the make-up lime is included.

4.5.2.2 FOOD AND DRINK, CRF 2D2

Estimates of NMVOC emissions are based on activity data from different official statistics. For wine the estimation of NMVOC emissions is based on data on sold amount[80] together with figures on import and export[81]. NMVOC emissions from beer production are based on the Swedish annual total production of beer[82] [83]. NMVOC emissions originating from the production of liquors, bread, sugar, yeast, margarine and solid cooking fat, coffee roasters and animal feeds are all based on statistics available at Statistics Sweden's website. For the NMVOC emission estimates, emission factors presented in Table 4.11 were used. Emissions of CO_2 are not estimated but are believed to be minor.

[80] Systembolaget. Försäljningsstatistik. http://www.systembolaget.se/
[81] Statistics Sweden. Data from the Industrial production database. http://www.scb.se/
[82] Carlsberg Sweden. http://www.carlsberg.se
[83] Bryggeriföreningen. http://sverigesbryggerier.se

Table 4.11. NMVOC emission factors for the reported production activities in CRF 2D2 - Food and drink.

Production activity	Emission factor	Unit	Reference
Wine	0.8	kg/1000 litres	84
Beer	0.35	kg/1000 litres	84
Liquors	0.6	kg/1000 litres	EF based on emission and activity data from one producer, 2001
Bread (sponge dough)	8	kg/Mg	84
Bread (white)	4.5	kg/Mg	84
Bread (whole meal and light rye)	3	kg/Mg	84
Bread (dark rye)	0	kg/Mg	84
Cakes	0.1	kg/Mg	84
Biscuits	0.1	kg/Mg	84
Breakfast cereals	0.1	kg/Mg	84
Sugar	10	kg/Mg	84
Yeast	18	kg/Mg	85
Margarine and solid cooking fats	10	kg/Mg	84
Coffee roasting	0.55	kg/Mg	84
Animal feed	0.1	kg/Mg	84

4.5.3 Recalculations

4.5.3.1 CRF 2D1:

- Production data for 2006 corrected for one facility. This correction affects the reported amounts of emitted CH_4, N_2O, CO and NMVOC for 2006.

4.5.3.2 CRF 2D2:

- Activity data, thus affecting reported NMVOC emissions, have been updated for:
  - Beer: Sold amount 2006
  - Liquors: Produced amount 2006
  - Bread: Produced amount 2004-2006
  - Cakes and biscuits: Produced amounts 2006
  - Breakfast cereals: Produced amounts 2006
  - Sugar: Produced amounts 2006
  - Margarine and solid cooking fats: Produced amounts 2006
  - Animal feed: Produced amounts for 2006

84 EMEP/CORINAIR Emission Inventory Guidebook: http://reports.eea.eu.int/EMEPCORINAIR4/en
85 Finnish Environment Institute, 2001. Revised Finnish Non Methane Volatile Organic Compound Emissions- Time series for the years 1998-1999 with Information on the Emissions Sources and Calculation Methods.

- Coffee roasting: Produced amounts 2006
- Yeast: Produced amounts 2006

The Notation key for CO_2 recovery has been changed from NE to NA in submission 2009.

4.5.4 Coming improvements

No major improvements are currently planned.

4.6 Uncertainties and time series consistency CRF 2A-2D

All time series from industrial processes reported in CRF 2A-2D have been reviewed in later years and are considered to be consistent.

4.6.1 Uncertainty estimates for CRF 2A-2D

The uncertainty analysis tables (Tier 1) are presented in Annex 7 and a general description of the uncertainty analysis is presented in section 1.7.

4.7 QA/QC and verification for CRF 2A-2D

As already mentioned in section 1.6.1, Sweden has developed a QA/QC system as an integral part of the national system according to article 5.1 of the Kyoto Protocol. The QA/QC system was fully implemented during 2005.

4.7.1 Quality assurance

An independent review is conducted by experts at the Swedish EPA.

4.7.2 Quality control

All quality procedures according to the Swedish QA/QC plan[86] (Manual for SMEDs Quality System in the Air Emission Inventories) have been implemented during the work with this submission. All Tier 1 general inventory level QC procedures listed in the Good Practice Guidance Section 8 have been performed. According to the Good Practice Guidance, the method of calculating emissions at facilities should be documented. This is currently not done in many cases and will be improved in the future.

4.7.3 Verification

The emissions of CO_2 from 2005 and onwards were estimated using data from the ETS for a number of facilities. ETS data was applied when considered to be in line with IPCC Good Practice Guidance, i.e. when the methodology and the activity data used are equivalent to the method and data used in submission 2006. To en-

[86] Kindbom, K. 2008. SMED-report: Manual for SMEDs Quality System in the Air Emission Inventories, 2008-01-31

sure that ETS and previous data and methods are comparable, companies have been contacted and asked to verify and explain the estimations they have reported to the ETS. In case there has been a mismatch between ETS and previous data, the industries have been asked to provide supplementary data, consistent with the data provided for submission 2006.

4.8 Production of Halocarbons and SF_6, CRF 2E

Production of halocarbons and SF_6 does not occur in Sweden.

4.9 Consumption of Halocarbons and SF6, CRF 2F

All sub-categories are covered in the estimates except solvents (2F5), due to varying and in-consistent information. According to the information available, solvents are estimated to only contribute a very minor share of the emissions of halocarbons, but it has not been possible to quantify the amount.

4.9.1 Source category description, CRF 2F

Use and emissions of halocarbons have increased since 1990, especially in refrigeration and air-conditioning equipment, which is the major source of halocarbon emissions in Sweden. The second largest source is foam blowing (XPS-foam), followed by aerosols and electrical equipment. All remaining sources are comparatively small emitters of fluorinated greenhouse gases.
An overview of actual reported emissions in CRF code 2F are shown in Table 4.12.

Table 4.12. Overview of submitted actual emissions data, Gg CO_2 equivalents.

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
F1	Refrigeration and air conditioning equipment	2.5	5.1	7.3	27	69	120	185	229	287	367	427	475	533	584	629	677	723	771
F2	Foam blowing	NA	NA	NA	NA	NA	NA	12	77	84	99	111	110	104	97	107	87	74	54
F3	Fire extinguishers	NA	NA	NA	NA	NA	NA	NA	0.9	2.3	3.7	5.3	5.1	5.6	5.8	6.1	5.7	6.0	6.0
F4	Aerosols/Metered dose inhalers	1.3	2.6	2.6	2.9	3.1	6.7	8.3	7.1	14	21	22	23	23	24	30	29	24	25
F5	Solvents	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
F6	Other use of ODS substitutes	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
F7	Semiconductor manufacture	NA	1.8	1.8	3.6	5.7	11.4	15.5	17.2	14.8	9.0	8.4	10.5	14.0	10.1	4.2	NO	NO	NO
F8	Electrical equipment	81	81	81	70	70	95	71	106	54	55	32	43	26	22	28	28	22	28
F9	Other	2.5	2.5	2.3	2.3	2.3	3.4	3.5	3.5	5.4	6.7	7.6	9.8	10	9.3	12	14	12	9.1

4.9.2 Methodological issues, CRF 2F

4.9.2.1 POTENTIAL EMISSIONS

Data on bulk imports and exports are obtained from the Products register hosted by the Swedish Chemicals Agency, which did not register these substances until 1995. Estimates of potential emissions for imports and exports were, however, made for all years in the time series, 1990-2004 in a special study in 2005[87]. The method of estimating potential emissions for the following years was made accordingly.

4.9.2.2 ACTUAL EMISSIONS

In estimating the actual emissions, as far as possible, a Tier 2 approach has been used. In Table 4.13, the emission factors and activity data used in the calculations of actual emissions are presented. A model is used for calculating the actual emissions. Changes in accumulated amounts each year resulting from additional amounts of HFC, PFC and SF_6 imported and used within the country, as well as the decline in accumulated stock caused by exports or emissions from operating systems, have been taken into consideration.

[87] Kindbom, K. 2005. Revision of Methodology and Estimated Emissions of Fluorinated grennhouse Gases in Sweden. Report Series SMED Nr 16 2005.

Table 4.13. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of HFCs, PFCs or SF_6, used in calculations of actual emissions in Sweden. Intervals given indicate changes between 1990 and 2007 used in the calculations.

	Fluorinated substances	Lifetime**	Amount installed /unit, kg	Emissions at manufacturing	Emissions per year during use	Remained in product at dis-	Emissions at disposal
Household fridges and freezers	HFCs	20	0.1	2%	1%	90%	5%
Heat pumps	HFCs	20→15	5→1	1%	10→1%	90%	5%
Other refrigeration and air conditioning equipment	HFCs PFC-218	15	*	3.5	7→3.6%	90%	5%
Refrigerated transport	HFCs	10	10→6	4.5%	30→7%	90%	15%
Mobile air-conditioning, lorries	HFCs	6	1.2	1%	15→10%	90%	15%
Mobile air-conditioning, cars	HFCs	11	0.8	1%	15→10%	90%	15%
Mobile air-conditioning, buses	HFCs	12	7	1%	10%	90%	15%
Foam blowing (XPS)	HFCs	> 12	*	35%	Declining	$	NA
Fire extinguishing	HFCs	30	*	0.5%	2% / 0.1%***	95%	1%
Aerosols/ MDI	HFCs	2	*	NA	50%	50%	100%
Semiconductor manufacture	HFCs, PFCs, SF_6	1	*	Tier 1	NA	NA	NA
Electrical insulation and GIS manufacture	SF_6	30	*	12→1.5%	0.6→0.5%	#	NA
Sound proof windows	SF_6	30	*	5-50%##	1%	#	NA
Jogging shoes	SF_6 PFC-218	8	*	NA	NA	100%	25%

* Top-down calculations

$ Calculated according to a declining curve, different for HFC-134a and HFC-152a.

Estimated lifetime at least 30 years, NE.

** Lifetime means the average expected lifetime of a product, not the possible technical lifetime.

*** HFC-227ea 0.1 %, other HFCs 2 %.

Different emissions at different production units.

4.9.2.2.1 Refrigeration and air conditioning equipment, 2F1

Input data for the calculation of actual emissions consists of information from various sources. For heat pumps, air conditioning, mobile air conditioning, refrigeration and freezing equipment, the equipment producers and importers were contacted and have provided information of varying quality. Estimates have been checked with trade associations (KYS and SVEP) and with experts at the Swedish EPA (Ujfalusi, Bernekorn, and Björsell).

The information on refrigerant-related imported amounts of fluorinated gases from the Products register is compared to calculations made in the model, based on assumptions and information from other sources. Since not all sources are possible to trace separately in the inventory, the amounts imported to the country according to the products register is larger than calculated from the individual sources cov-

ered in the model. In order to account for the total volumes of refrigerant-related fluorinated substances, the amount of imported chemical to Sweden, derived from the Products register, is assumed to be the correct data. From these data, the amounts of chemicals already accounted for in other applications, treated separately in the calculations, are subtracted. The resulting remainder of all refrigerant-related HFCs and PFCs from the Products register was allocated as input data in the sub source "other stationary refrigeration". The chemicals concerned are HFC-23, HFC-32, HFC-125, HFC-134a, HFC-143a, HFC-152a and PFC-218 (C_3F_8).

For some sectors within the group, estimates are of high quality while others are of medium or low quality. The sectors contributing the most to the emissions are considered, by expert judgment, to be of medium quality. Due to that data are derived from source-independent national statistics in the Product register, as well as from some end users, it is currently impossible to correctly fill in the CRF background data table asking for domestic, commercial and industrial applications. Consequently, industrial refrigeration as well as stationary air conditioning has been included in commercial refrigeration in CRF table 2(II) F.

4.9.2.2.2 Foam blowing, 2F2

Emission estimates are based on the production and use of XPS foam in Sweden. Data is obtained from the producer on the used amount of HFC-134a and HFC-152a, emissions at production as well as the exported amount of chemicals in products each year. The use of HFCs in this application started in 1996. The company has also provided algorithms to calculate leakage of HFC-134a and HFC-152a during the product lifetime.

The current calculation method provided by the company, used for reporting of emissions, has been compared to the Tier 2 method given in the IPCC Good Practice Guidance (2000).

The basis for the calculation is the amount of HFC-134a and HFC-152a that is introduced into products used in Sweden, and subsequently leached from the products. Beside annual losses from products over time, the reported Swedish emissions in the CRF tables contain emissions from manufacturing. All comparisons presented below only refer to annual losses from products and does not include manufacturing losses.

In the national model, changes in accumulated amounts each year resulting from additional amounts of HFC in new products, as well as the annual decline in accumulated stock caused by emissions from operating systems, are taken into consideration. In order to calculate leakage according to the national method, the specific amount of HFC-134a and HFC-152a introduced in a particular year follows the decline in leakage according to Table 4.14, where the leakage factors for the first 15 years are presented. The factors used in the national method were provided by the manufacturing company.

According to the information provided by the manufacturing company the HFC-134a remains in products for a very long time, while all HFC-152a is emitted during the first 10 years. The default factors from IPCC Good Practice Guidance are presented as comparison. The IPCC Good Practice Guidance methodology does

not distinguish between HFC-species in suggested leakage rates. Furthermore, the Guidelines for estimating these emissions have changed in the 2006 Guidelines, which present separate leakage rates for HFC-134a and HFC-152.

Table 4.14. Leakage factor used for the first 15 years in the national method compared to Good Practice Guidance default factors from GPG Table 3.18

	National method		GPG table 3.18
Year	Leakage factor	Leakage factor	Leakage factor
	HFC-134a	HFC-152a	GPG: HFC
1	0.095	0.659	0.40
2	0.039	0.198	0.03
3	0.030	0.083	0.03
4	0.025	0.035	0.03
5	0.022	0.015	0.03
6	0.020	0.006	0.03
7	0.019	0.003	0.03
8	0.017	0.001	0.03
9	0.016	0.001	0.03
10	0.015	0.000	0.03
11	0.015	0	0.03
12	0.014	0	0.03
13	0.013	0	0.03
14	0.013	0	0.03
15	0.012	0	0.03

The calculated emissions according to the national method and the GPG Tier 2 method are presented in Table 4.15. The calculations were made in a special project[88] where different calculation methods were compared (national method compared to GPG 2000). The GPG Tier 2 default method results in a lower rate of emissions when calculated as emitted tonnes of HFC (Figure 4.3 and Table 4.16). When calculating emissions as CO_2 equivalents, using the annual amount of HFC-134a and HFC-152a, respectively, which remains in products in Sweden, the result is the opposite. The national method in this case results in lower emissions than the GPG-method, due to the differing GWP-values of HFC-134a (1300) and HFC-152a (140).

[88] Kindbom, K. 2005. Revision of Methodology and Estimated Emissions of Fluorinated Greenhouse Gases in Sweden. Report Series SMED Nr 16 2005.

Table 4.15. Estimated emissions of HFCs (Gg CO_2 eq) from products in Sweden using national method and Tier 2 according to GPG, 1996 - 2003.

Emissions	National method		GPG (2000)		Sum of emissions, Gg CO_2 eq	
Gg CO_2 eq	HFC-134a	HFC-152a	HFC-134a	HFC-152a	National method	GPG
1996	1	3	2	2	4	4
1997	6	9	23	5	15	28
1998	11	11	36	5	22	41
1999	16	11	48	5	27	53
2000	18	12	42	5	29	48
2001	19	13	42	7	32	48
2002	20	11	41	5	32	46
2003	21	17	41	9	38	50
Sum	111	87	276	43	198	319

The ratio of HFC-134a to HFC-152a in products in Sweden has not been constant over the years. This means that since expected leakage rates are very different for the two chemicals, the resulting annual emissions from products varies according to chemical composition and product age in the national method. HFC in this application was not used before 1996 in Sweden.

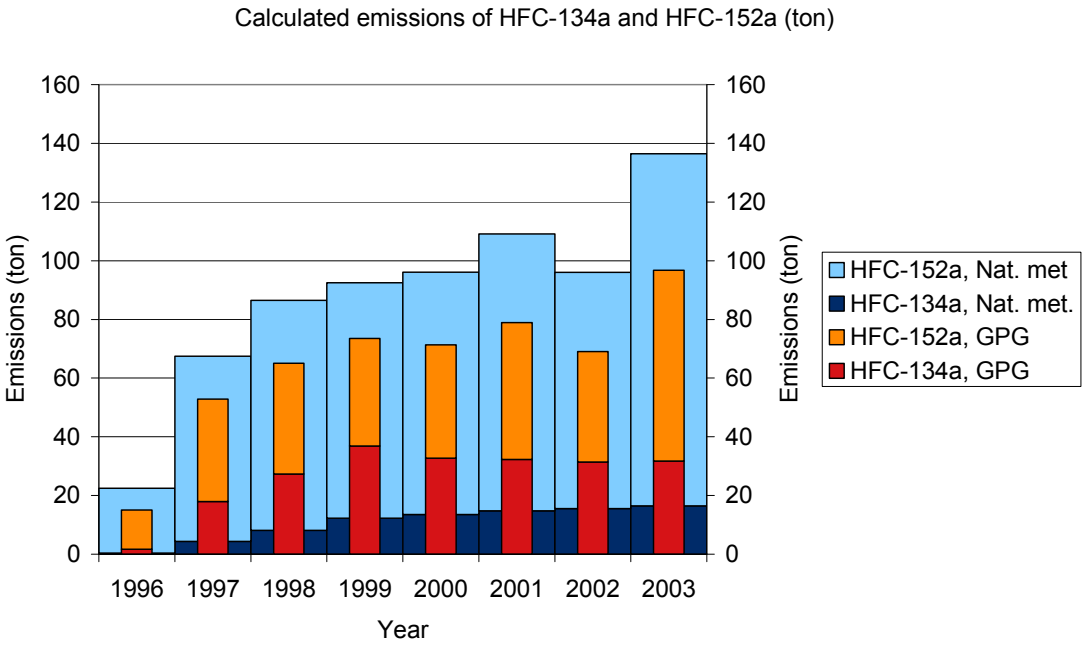

Figure 4.3. Estimated emissions of individual HFC-species (ton) by the national method and the GPG Tier 2 method, 1996 - 2003.

Table 4.16. Calculated total emissions of HFC-134a and HFC-152a (Mg) from products in Sweden according to the national method and according to Good Practice Guidance Tier 2 method, 1996 - 2003.

Year	Emissions of HFC-134a and HFC-152a according to national method (Mg)	Emissions of total HFC according to Good Practice Guidance Tier 2 method (Mg)
1996	22.5	15.1
1997	67.4	52.8
1998	86.5	65.1
1999	92.5	73.5
2000	96.1	71.4
2001	109.1	78.9
2002	96.1	69.0
2003	136.4	96.7
Sum 1995-2003	706.5	522.6

Since the product life time of XPS-foam is very long, several decades, the total amounts of emitted chemical will however in the long run be comparable. The differences due to the different calculation methods lie primarily in estimates of how quickly the chemical is expected to leak from the product. (Figure 4.3 and Table 4.16).

From the above presented comparisons, it has been decided to continue using the national method in Swedish reporting. The reason behind the decisions is two-fold; the national method is species specific, which has a considerable influence on the results, and secondly, due to the change in recommended method and default leakage factors from the Good Practice Guidance (2000) to the 2006 Guidelines, it was concluded to retain the national detailed method.

Uncertainties in 2F2 are the existence of other emissions from foam blowing or products in use in Sweden, which were not estimated due to difficulties in obtaining relevant and reliable background information.

4.9.2.2.3 Fire extinguishers, 2F3

All imports of HFCs to be installed in fire extinguishers are registered at the Swedish Chemicals Agency. Uncertainties are mainly associated with the exported amounts, which are relatively large. From 2001, the use of HFC-227ea in fire extinguishers has been introduced in Sweden. Data has been obtained from the companies supplying such systems. These companies also provided the data included in the inventory.

4.9.2.2.4 Aerosols/metered dose inhalers, 2F4

Emission estimates cover technical aerosols as well as metered dose inhalers. The estimates consist of emissions from production of technical aerosols at one facility, and emissions from the use of imported technical aerosols and metered dose inhalers containing HFCs. The contribution from metered dose inhalers is relatively small, but has increased in later years.

The aerosol manufacturer provided information on the used amount of HFC-134a as well as emissions from production, and exported amounts of HFC-134a in products.

For metered dose inhalers, statistics on the numbers of sold inhalers was received from the Swedish retailer for medical products, Apoteket. Information concerning the content of HFC in the inhalers was provided by the Swedish Medical Products Agency.

The largest uncertainty in this source concerns the amount of HFC-134a imported in technical aerosols for which there are no statistics available. In 2000, a survey was sent to approximately 10 importers of technical aerosol products. The majority of the importers responded to the survey, and provided estimates on the amount of HFC imported each year in technical aerosols. In 2004 an update on estimated import was made for the whole time series, in cooperation with the Swedish Aerosol Association (Svenska Aerosolföreningen). The information from this survey was used to update the time series up to year 2003 at that time.The activity data also includes estimates of e.g. Novelty aerosols.

Data and information from the Products register, hosted by the Swedish Chemicals Agency, could not be used directly for validation and reporting purposes due to confidentiality.

4.9.2.2.5 Solvents, 2F5

Efforts have been made to find national information concerning this sub-category but it has so far not been possible to establish what amounts may be used. A few users were contacted and they provided information that their use of solvents containing PFCs is very limited or non-existent. The company that was said to sell the solvent in Sweden denied doing so. Emissions from solvents are consequently reported as NO, not occurring.

4.9.2.2.6 Other applications using ODS substitutes, 2F6

No other applications are covered in the Swedish inventory.

4.9.2.2.7 Semiconductor manufacture, 2F7

Semiconductor manufacture has in recent years occurred on a commercial scale at only one facility in Sweden. Previously one more facility was located in Sweden, but production was moved abroad. During 2004 the production in the only facility left was also closed down.

Information concerning the annually used amounts of various fluorinated substances has been provided by the company, and as far as possible been compared to information from the Products register at the Swedish Chemicals Agency. Emissions are calculated by using the IPCC Good practice Guidance Tier 1 method.

Emission estimates are judged to be of good quality. Cross-references with the Products register at the Swedish Chemicals Agency could, however, not be made for later years, since the level of detail in the Products register was insufficient.

4.9.2.2.8 Electrical equipment, 2F8.

Estimates of SF_6 emissions actually consist of two different parts, emissions from the production of gas-insulated switchgear (GIS), and emissions from SF_6 installed in distribution systems. The larger part of annual SF_6 emissions in earlier years originated from the manufacture of GIS (Table 4.17), where peak emissions in 1995 and 1997 were due to a leaking valve in 1995 and to rebuilding and accidental leakages in 1997. The SF_6 emissions from production have decreased in later years due to measures taken at the production facility. These estimates, obtained from industry, are of medium to high quality, with better quality in later years. For the early 1990s, assumptions on the emitted amounts of SF_6 from GIS manufacture were made in cooperation with industry. Industry has also provided information concerning the used amount of SF_6 for GIS manufacture, as well as the share of products that are exported from the country, which exceeds 90 % of the production.

Emissions from installed amounts of SF_6 for insulation purposes in operating systems have previously contributed less to the actual annual emissions. In 2001-2002, a questionnaire was sent out to power companies from the trade association Swedenergy[89] (Svensk Energi) asking for the installed amounts of SF_6 in operating equipment, and the replaced amounts of SF_6 during service. The results showed an installed accumulated amount of approximately 80 Mg and an annual leakage rate of 0.6 % (equals the amount replaced from the questionnaire) and these were used as input data in the inventory. For later years, data on replaced amounts of SF_6 in operating systems results in a calculated annual leakage rate of 0.5 % (Swedenergy and power distribution companies).

[89] Swedenergy. Matz Tapper. Personal communication. 2005.

Table 4.17. Calculated emissions and accumulated stock of SF_6 for electrical equipment.

Year	Emissions from GIS manufacture SF_6 Mg	Annual losses SF_6 Mg	Accumulated stock Mg	Total emissions SF_6 Mg
1990	3.0	0.39	65.7	3.4
1991	3.0	0.40	66.8	3.4
1992	3.0	0.41	67.9	3.4
1993	2.5	0.41	69.0	2.9
1994	2.5	0.43	71.2	2.9
1995	3.5	0.46	76.0	4.0
1996	2.5	0.48	80.8	3.0
1997	3.9	0.52	86.7	4.4
1998	1.7	0.56	93.4	2.3
1999	1.7	0.60	100.7	2.3
2000	0.7	0.65	107.9	1.3
2001	1.1	0.69	114.5	1.8
2002	0.35	0.73	121.1	1.1
2003	0.30	0.64	127.6	0.9
2004	0.50	0.67	134.8	1.2
2005	0.47	0.71	143.0	1.2
2006	0.20	0.72	144.7	0.9
2007	0.41	0.77	154.0	1.2

In accordance with the methodology described for deriving amounts of refrigerant chemicals not accounted for, the same procedure was adopted for SF_6. When comparing the amounts of SF_6 accounted for in various applications with data from the Products register, a rather large annual volume of SF_6 remains unallocated. Sources of SF_6 emissions that are covered in the calculations are the use in semi-conductor manufacture, in production of sound-proof windows, in magnesium foundries, in the production of gas-insulated switchgear and as insulation in electrical equipment. Information from the Products register did not indicate that any areas of use have not been covered and are missing from the calculations.

For all sources, except as insulation in electrical equipment, the levels of annual SF_6 consumption is comparatively easy to estimate with some confidence since there are few end-users. It was thus concluded that the amounts of SF_6 not already accounted for elsewhere, most reasonably should be allocated to the electrical equipment source. However, even though information concerning SF_6 in electrical equipment is more difficult to judge concerning completeness, indications from end-users are that the difference between imported amounts according to the Products register and those already accounted for in the calculations seem too large to annually be consumed for electrical insulation. One explanation to the difference could be that there is an underreporting of exported SF_6 from the Products register, where no export at all of SF_6 is registered.

Since the question of the remaining amount of SF_6 at present could not be unambiguously solved, the unaccounted SF_6 from the Products register was allocated to be used as electrical insulation (accumulated stock).

4.9.2.2.9 Other, 2F9

The estimated emissions from the use of SF_6 in jogging shoes and in sound-proof windows are reported in CRF 2F9. No production of SF_6-containing jogging shoes occurs.

For jogging shoes, a more or less rough estimate has been made. It has not been possible to obtain any national data, so a Norwegian estimate was scaled to the Swedish population.[90] According to the results from a study performed in early 2004[91] a phasing out of SF_6 and replacement with PFC-218 was started in 2003.

Manufacturers of windows have provided data on the amount of SF_6 used in the manufacture of barrier gas windows. The manufacturers have also provided estimates of the share of SF_6 emitted in production. These estimates vary considerably between manufacturers, from 5-50 %. The lifetime for shoes is set to 8 years in the national model. The reason for the increase in emissions in later years is the lifetime and the associated time lag for emissions originating from disposal. Calculating a weighted average of the emission factor at production results in a national figure in the order of 30 %, which is in line with the point estimate of 33 % given in the IPCC Good Practice Guidance.

4.9.3 Uncertainties and time series consistency

The uncertainty analysis tables (Tier 1) are presented in Annex 7 and a general description of the uncertainty analysis is presented in section 1.7.
The quality of activity data, such as figures of estimated emissions or amount of fluid used in different applications, is usually better for the later years than for the earlier years of the inventory.

An emission inventory, covering the whole period 1990-1999, was initially performed in 2000,[92] and was updated during 2005[93] for the whole time series 1990-2003. Data for later years have been estimated accordingly. This means that the same method of inventory and of calculation of emissions has been used for each specific sector for the whole period.

4.9.4 QA/QC

All quality procedures according to the Swedish QA/QC plan (Manual for SMEDs Quality System in the Air Emission Inventories) have been implemented during the work with this submission.

To the greatest extent possible, crosschecks are made between activity data obtained independently, for use in the predominantly bottom-up method for calculating actual emissions, and data from the Products register at the Swedish Chemicals Agency.

[90] Weholt, Ø. 1999. Materialstrømsanalyse av SF6. Beregning av potensielt og faktisk utslipp over tid
[91] Kindbom, K. and Skårman, T. 2004. Nya scenarier för fluorerade växthusgaser. U952, Swedish EPA.
[92] Kindbom, K., Haeger Eugensson, M. and Persson, K. 2001. Kartläggning och beräkning av potentiella och faktiska utsläpp HFC, FC och SF6 i Sverige. IVL B-1428.
[93] Kindbom, K. 2005. Revision of Methodology and Estimated Emissions of Fluorinated Greenhouse Gases in Sweden.

4.9.5 Recalculations

4.9.5.1 CRF 2.F POTENTIAL AND ACTUAL EMISSIONS

Due to the recurring one year lag of updating of the data from the Product register from the Swedish Chemicals Agency, data on bulk import and export in 2006 were updated. This results in revised data on potential emissions for 2006. It also results in revised actual emission estimates from stationary refrigeration and air-conditioning equipment (2.F.1) and from electrical equipment (2.F.8) for 2006 due to the calculation system. As described above the remainder of chemicals imported into the country, which have not already been allocated to a specific source, are allocated to 2.F.1 (HFC 23, HFC 32, HFC 125, HFC 134a, HFC 143a and HFC 152a) and 2.F.8 (SF_6).

4.9.5.2 CRF 2.F.1 REFRIGERATION AND AIR-CONDITIONING EQUIPMENT

Revision of activity data for 1993-2006 was made for mobile air conditioning (MAC) since updated and improved information on the number of imported and exported cars, buses and trucks has become available. The results of the revisions are recalculated time series of emissions of HFC-134a for the period 1993 to 2007. The result of the revised calculations for MAC is shown in Table 4.18.

Table 4.18 Changes in estimated emissions from MAC due to revised calculations

	Sub 2009	Sub 2008	Change
Year	GgCO2eq	GgCO2eq	GgCO2eq
1993	2.6	2.6	0.01
1994	9.6	9.7	-0.01
1995	18.3	18.4	-0.08
1996	29.6	29.6	0.01
1997	45.2	45.2	0.03
1998	72.6	72.6	-0.02
1999	123.6	123.6	-0.03
2000	163.4	163.4	0.03
2001	191.7	191.7	0.05
2002	223.0	223	-0.03
2003	258.4	258.4	0.04
2004	298.9	298.9	-0.04
2005	338.7	338.7	-0.04
2006	375.9	375.9	-0.03
2007	414.7		

4.9.5.3 CRF 2.F.1 HEAT PUMPS

Updated information on number of heat pumps installed in Sweden for 2005-2006 was obtained from the trade organisation (Svep). The new information was included in the calculations and as a result the time series of emissions of HFC 32, HFC 125 and HFC 134a are recalculated. The results of the revised calculations are presented in Table 4.19.

Table 4.19 Changes in estimated emissions from heat pumps due to revised calculations

	Sub 2009	Sub 2008	Change
Year	GgCO2eq	GgCO2eq	GgCO2eq
2005	5.5	6.06	-0.55
2006	6.5	7.39	-0.93
2007	6.8		

4.9.5.4 CRF 2.F.4.2 AEROSOLS/ METERED DOSE INHALERS/OTHER

Reported value in submission 2008 on amount of fluid remained in products at decommissioning for HFC 134a for year 2006 has been corrected in submission 2009.

4.9.5.5 CRF 2.FP.3.2 FIRE EXTINGUISHERS

Exported amount of HFC 227ea from fire extinguishers is included in submission 2009. The export started in year 2004. By mistake the export of HFC 227ea from fire extinguishers has not been included in previous submissions.

4.9.5.6 CRF 2.F.5 CONSUMPTION OF HALOCARBONS AND SF6 - SOLVENTS - HFCS, PFCS, SF6

The use of F-gases for use as solvents does not seem to occur, consequently the notation key has been changed from NE to NO.

4.9.6 Coming improvements

No major improvements are currently planned.

4.10 Other, CRF 2G

In previous submissions there was only space provided to include emissions of NO_X, CO, NMVOC and SO_2 from pulp and paper production. The Swedish definition of process emissions also includes the spent cooking liquor (black liquor), which is used in significant amounts in Sweden. Combustion of spent cooking liquor gives rise to emissions of N_2O, CH_4 and biogenic CO_2. The estimated process emissions of N_2O and CH_4 from spent cooking liquor were therefore allocated to the CRF code 2G, other.

In submission 2008 CH_4 and N_2O are reported in CRF 2D1. Biogenic CO_2 from combustion of spent cooking liquor is, as in previous submissions, allocated to and reported in 2G.

Emissions of CO_2 from spent cooking liquor are calculated on the basis of activity data from the industrial energy statistics/quarterly fuel statistics (section 3.3.1.1 and 3.3.1.2), thermal values and emission factors (section 3.3.2 and 3.3.3 and Appendix 19). Since the CRF is not designed to cope with process emissions of CO_2 from biomass, the CO_2 emissions from spent cooking liquor are reported in the documentation box.

4.10.1 Recalculations

- As no activity data or emissions are reported in CRF 2.G Other, notation keys has been changed from NA to NO.

5 Solvent and other product use (CRF sector 3)

5.1 Overview

Estimates reported in this sector include emissions from paint application (CRF 3A), degreasing and dry-cleaning (CRF 3B), chemical products, manufacture and processing (CRF 3C) and other solvent use (CRF 3D). A new method was developed during 2005 in order to obtain all activity data concerning solvent and other product use from the Products register hosted by the Swedish Chemicals Agency. The Products register is a register over chemical products imported to or manufactured in Sweden. Official statistics from the Product register is only available with a two years delay. According to the IPPC Guidelines, NMVOC emissions from production of glue should be allocated to 3C. In the Swedish reporting, these NMVOC emissions are allocated to CRF 2B5, since industries producing glue often produce other chemical products as well, and are classified as chemical industries in the Products register.

5.1.1 Source category description, CRF 3, Solvent and Product Use

5.1.1.1 PAINT APPLICATION, CRF 3A

Includes paints sold for “industrial use” and for “consumer and other professional use”.

5.1.1.2 DEGREASING AND DRY CLEANING, CRF 3B

Includes solvents sold to the laundry and dry cleaning industry. Degreasing is included in CRF 3D.

5.1.1.3 CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING, CFR 3C

Includes solvents sold for car manufacturing, paint industry and rubber industry.

5.1.1.4 OTHER, CRF 3D

Includes solvents sold to the printing industry, for preservation of wood, to leather industry and to textile industry. The code also includes solvents used by other industries not reported separately, and solvents for domestic use. All data concerning NMVOC and CO_2 are reported in CRF 3D5. In CRF 3D4 sold amounts and use of N_2O are reported.

5.1.2 Methodological issues, Solvent and Product Use, CRF 3

A new method was developed during 2005 in order to obtain all activity data concerning solvent and other product use from the Products register hosted by the

Swedish Chemicals Agency. Reliably activity data, for this purpose, can only be obtained from 1995. The Products register is a register over chemical products imported to or manufactured in Sweden. A list of substances defined as NMVOCs, and found in the Products register in quantities over 100 tonnes, has been compiled. The following definition of NMVOC has been used:

"Volatile organic compounds (VOC) mean any organic compound having a vapour pressure of 0.01 kPa or more at 293.15 K, or having a corresponding volatility under the particular conditions of use. The fraction of creosote which exceeds this value of vapour pressure at 293.15 K shall be considered a VOC."[94]

The list includes 360 substances (Cas-nr, name, carbon contents for each substance) and was used for extracting quantities of NMVOC and C in substances found in the Products register for year 2006. The carbon share (C) for each substance defined as NMVOC has been calculated based on the molecular formula. In some cases a mixture of substances are included in the substance list, and for the mixtures the carbon content has been estimated by the Chemicals Agency as 85 % of NMVOC, based on information in the Products register. In those cases when the carbon content can not be derived from the Products register, the default value, given in the 2006 IPCC guidelines[95], of 60 % has been used.

Data extractions have been made for each year from 1995 to 2006. The extractions show for each year:

- The intended use of the product, the type of product (product code)
- Industry to which the product is sold (industry category)
- Quantity NMVOC
- Quantity C

Using the information concerning "product code" and "industry category" in combination, the quantities of NMVOC and C for each year and CRF code were compiled. The quantities of NMVOC used as raw material in processes were identified for each CRF code. Country specific emission factors for solvents used as raw material and for remaining solvents were developed for each CRF code. The emission factors have been developed in order to adjust to the old time series 1988-2001, which were developed by SMED in 2002[96], since they are considered reliable. The emission factors have been developed also considering the application techniques, the reported emissions presented in environmental reports for specific industries, as well as other pathways of release (e.g. waste or water). The emission factors for raw material are set very low, since most of the solvents will not be emitted during production, but will end up in the product.

The sold amount of solvent is not always identical to the amount of solvent used. Therefore the time series has been recalculated using a running average over three years. This leads to need for updating of reported emissions for the latest three years in the time series in every new submission.

[94] COUNCIL DIRECTIVE 1999/13/EC of 11 March 1999 and UNECE Emission Reporting Guidelines
[95] http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_5_Ch5_Non_Energy_Products.pdf
[96] Kindbom, K., Boström, C-Å., Skårman, T., Gustafsson, T. and Talonpoika, M. 2003. Estimated Emissions of NMVOC in Sweden 1988-2001.

Since accurate data for compiling time series for NMVOC and CO_2 from "Solvents and other product use" only can be found in the Products register from 1995, reported emissions for CRF codes 3A-D for 1990 until 1994 were taken from the old time series and in some cases emission data for 1990 - 1994 has been interpolated. Activity data for the latest year, 2007, is not yet official and hence Sweden has chosen to report data from 2006 also for 2007. Data for 2007 will be updated in the next submission.

Emission of CO_2 has been calculated with the following equation:

$$\text{Emission}\,(CO_2) = C_{quantity} \times \text{Emission Factor} \times \frac{44}{12}$$

$C_{quantity}$ is the carbon quantity of the solvents. 44 and 12 are the molecular weights of CO_2 and C, respectively.

Since the method for calculating CO_2 emissions have been changed compared to the method used in previous submissions, the reported emissions of NMVOC for 1990-94 have been related to the NMVOC emissions for 1995. The ratio has been used to calculate the emissions of CO_2 for each CFR code (3A-D).

5.1.2.1 PAINT APPLICATION, CRF 3A

All activity data from 1995 has been obtained from the Products register at the Swedish Chemicals Agency. Emissions from 1988 are taken from the time series that were compiled in a special study concerning NMVOC emissions, which was carried out by SMED in 2002[97]. The emissions for 1990-1994 have been interpolated based on the information from the late 1980´s and known data for 1995. The time series between 1990 and 2007 are presented in Table 5.1, below.

[97] Kindbom, K., Boström, C-Å., Skårman, T., Gustafsson, T. and Talonpoika, M. 2003. Estimated Emissions of NMVOC in Sweden 1988-2001.

Table 5.1. Estimated emissions of NMVOC and CO_2 from paint application 1990-2007.

Year	Emissions of NMVOC	Emissions of CO_2	Sources for emissions of NMVOC
	Mg NMVOC	Mg CO_2	
1990	34613	93553	Interpolated from 1988[97]
1991	33420	90328	-"-
1992	32226	87102	-"-
1993	31033	83877	-"-
1994	29840	80651	-"-
1995	28646	77426	Products register
1996	27191	73954	-"-
1997	27765	76085	-"-
1998	24796	68923	-"-
1999	22146	62273	-"-
2000	22021	62069	-"-
2001	21848	61108	-"-
2002	18934	53264	-"-
2003	16678	47199	-"-
2004	15949	45253	-"-
2005	15880	45015	-"-
2006	15088	42558	-"-
2007	15088	42558	

5.1.2.2 DEGREASING AND DRY CLEANING, CRF 3B

All activity data from 1995 has been obtained from the Products register at the Swedish Chemicals Agency. Emission data for 1988 is based on reported quantities of tetrachloroethylene from the Swedish Chemical Agency. Since not only tetrachloroethylene is included in the time series after 1995, the NMVOC emissions reported 1988 is recalculated using a correction factor based on the proportion of other NMVOCs of the total NMVOC for 1995 (tetrachloroethylene plus 30 %). Emissions between 1990 and 1994 have been interpolated based on the information from the late 1980´s and known data for 1995. The time series between 1990 and 2007 are presented in Table 5.2.

Table 5.2. Estimated emissions of NMVOC and CO_2 from dry cleaning 1990-2007.

Year	Emissions of NMVOC	Emissions of CO_2	Sources for emissions of NMVOC
	Mg NMVOC	Mg CO_2	
1990	771	520	Interpolated from 1988[98]
1991	680	459	-"-
1992	589	397	-"-
1993	499	336	-"-
1994	408	275	-"-
1995	317	214	Products register
1996	292	201	-"-
1997	296	205	-"-
1998	301	213	-"-
1999	242	186	-"-
2000	158	145	-"-
2001	133	134	-"-
2002	122	129	-"-
2003	126	136	-"-
2004	138	144	-"-
2005	136	145	-"-
2006	148	152	-"-
2007	148	152	

5.1.2.3 CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING, CFR 3C

The sector includes emissions from car manufacturing, paint industry and from rubber industry. Emissions from car manufacturing contribute by approximately 50 %, paint industry by 30 % and rubber industry by 20 % of the reported emissions in CRF 3C. Emission data for car manufacturing has been compiled from environmental reports for 1990 and data for 1991-1994 has been interpolated. For paint industry emission data for 1990-1994 has been taken from the old time series given in a special study concerning NMVOC emissions, carried out by SMED in 2002[98]. Emission data for the rubber industry is known for 1988[98]and data for 1990-1994 have been interpolated based on the information from the late 1980´s and known data for 1995. The time series between 1990 and 2007 are presented in Table 5.3.

[98] Kindbom, K., Boström, C-Å., Skårman, T., Gustafsson, T. and Talonpoika, M. 2003. Estimated Emissions of NMVOC in Sweden 1988-2001.

Table 5.3. Estimated emissions of NMVOC and CO_2 from chemical products, manufacture and processing 1990-2007.

Year	Emissions of NMVOC	Emissions of CO_2	Sources for emissions of NMVOC
	Mg NMVOC	Mg CO_2	
1990	3605	9904	Interpolated from 1988[99]
1991	3179	8725	-"-
1992	2712	7444	-"-
1993	2226	6110	-"-
1994	1749	4803	-"-
1995	1335	3664	Products register
1996	960	2542	-"-
1997	985	2486	-"-
1998	1004	2441	-"-
1999	997	2401	-"-
2000	882	2218	-"-
2001	818	2131	-"-
2002	754	1968	-"-
2003	776	2002	-"-
2004	758	1937	-"-
2005	739	1897	-"-
2006	713	1834	-"-
2007	713	1834	

5.1.2.4 OTHER, CRF 3D

Solvents used in printing industry, for preservation of wood, in leather industry and in textile industry have been estimated separately. The code also includes solvents used by other industries not reported separately, and also solvents for domestic use. The printing industry contributes by 8 %, preservation of wood 1 %, leather and textile industry < 1 % and general solvent use 90 % of the total reported emissions in CRF 3D. Emission data for 1988 is known for most industries included in CRF 3D and in most cases the emissions for 1990-1994 have been interpolated based on information from the late 1980´s and known data for 1995. The time series between 1990 and 2007 are presented in Table 5.4. All data concerning NMVOC and CO_2 are reported in CRF 3D5.

[99] Kindbom, K., Boström, C-Å., Skårman, T., Gustafsson, T. and Talonpoika, M. 2003. Estimated Emissions of NMVOC in Sweden 1988-2001.

Table 5.4. Estimated emissions of NMVOC and CO_2 from other solvent use 1990-2007.

Year	Emissions of NMVOC	Emissions of CO_2	Sources for emissions of NMVOC
	Mg NMVOC	Mg CO_2	
1990	63040	138291	Interpolated from 1988[100]
1991	60013	131611	-"-
1992	56589	123772	-"-
1993	53750	117556	-"-
1994	50908	111386	-"-
1995	47481	103559	Products register
1996	44917	97787	-"-
1997	46632	100421	-"-
1998	47762	101948	-"-
1999	47216	99518	-"-
2000	43129	90965	-"-
2001	41598	86753	-"-
2002	44001	93091	-"-
2003	50079	106709	-"-
2004	55115	117548	-"-
2005	55485	117984	-"-
2006	56297	118349	-"-
2007	56297	118349	

5.1.2.4.1 Use of N_2O, CRF 3D

There are two companies in Sweden selling N_2O in gas cylinders. Information on sold amounts was obtained from one of the companies (1990 - 1991) and from the Products register at the Swedish Chemicals Agency (1992 - 2005). The time series of use of N_2O in Sweden are reported in "Other use of N_2O" (3D4) since no background data is available to separate between the source categories "Use of N_2O for Anaesthesia" (3D1) and "N_2O from Aerosol cans" (3D3). Consequently CRF codes 3D1 and 3D3 are both reported as IE. Activity data for the latest year, 2007, is not yet official and hence Sweden has chosen to report data from 2006 also for 2007. Data for 2007 will be updated in the next submission.

5.1.3 Uncertainties and time series consistency

The uncertainty analysis tables (Tier 1) are presented in Annex 7 and a general description of the uncertainty analysis is presented in section 1.7.
The reported time series are considered to be consistent.

5.1.4 QA/QC and verification

All quality procedures according to the Swedish QA/QC plan (Manual for SMEDs Quality System in the Air Emission Inventories) have been implemented during the work with this submission. All Tier 1 general inventory level QC procedures listed in the Good Practice Guidance Section 8 have been performed.

[100] Kindbom, K., Boström, C-Å., Skårman, T., Gustafsson, T. and Talonpoika, M. 2003. Estimated Emissions of NMVOC in Sweden 1988-2001.

5.1.5 Recalculations

CRF 3: Due to use of running average for compiling the NMVOC and CO_2 time series in 3A, 3B, 3C and 3D, the reported emissions for 2004 - 2006 in submission 2008 are updated in submission 2009. Due to some corrections in the combination of "product code" and "industry category" in the calculation model, in combination with the running average, the reported emissions for NMVOC and CO_2 for 2003 are updated in submission 2009. Activity data for CRF 3D5\other \wood preservation (1990-1995), \printing industry (1995), \leather industry (1995) and \textile finishing (1995) has been excluded in submission 2009 and instead the notation key NE has been reported. The reason for the change is that activity data for CRF 3D5\other \other non specified is not available before year 1996.

Recalculations concerning sold amounts and use of N_2O have been performed for 2006, due to the recurring one year lag of updating of the data from the Product register from the Swedish Chemicals Agency.

5.1.6 Coming improvements

No major improvements are planned for the next submission.

6 Agriculture (CRF sector 4)

6.1 Overview

Swedish agriculture has undergone radical structural changes and rationalisations over the past 50 years. One fifth of the Swedish arable land cultivated in the 1950s is no longer farmed. Closures have mainly affected smallholdings and those remaining are growing larger. In 1999, some 31,000 agricultural holdings were livestock farms, 14,000 were purely crop husbandry farms, and only 5,000 were a combination of the two. Livestock farmers predominately engage in milk production and the main crops grown in Sweden are grain and fodder crops.[101] The decrease of agricultural land area has continued since Sweden joined the European Union in 1995 and the acreages of land for hay and silage has increased. Organic farming has increased from 3 % of the arable land area in 1995 to 17 % in 2007.[102]

The total greenhouse gas (GHG) emissions from the Swedish agriculture have decreased by about 10 % since 1990. The largest emissions in this sector are methane (CH_4) from enteric fermentation and nitrous oxide (N_2O) from nitrogen circulation in agricultural land. Carbon dioxide (CO_2) emissions from agricultural land are reported in sector 5- LULUCF in accordance with the IPCC Guidelines.

6.2 Source category description

The size of the animal husbandry sub-sector is the most important factor influencing GHG emissions from agriculture in Sweden. Livestock farming, including farmyard manure management, is the major source of CH_4 emissions. About 87 % derives from enteric fermentation from cattle and the remaining mainly from swine, horses, sheep and reindeer. The total numbers of livestock in Sweden in 1990-2007 are presented in Figure 6.1

[101] Ministry of the Environment, 2001.
[102] Swedish Board of Agriculture, www.sjv.se., http://miljomal.nu/

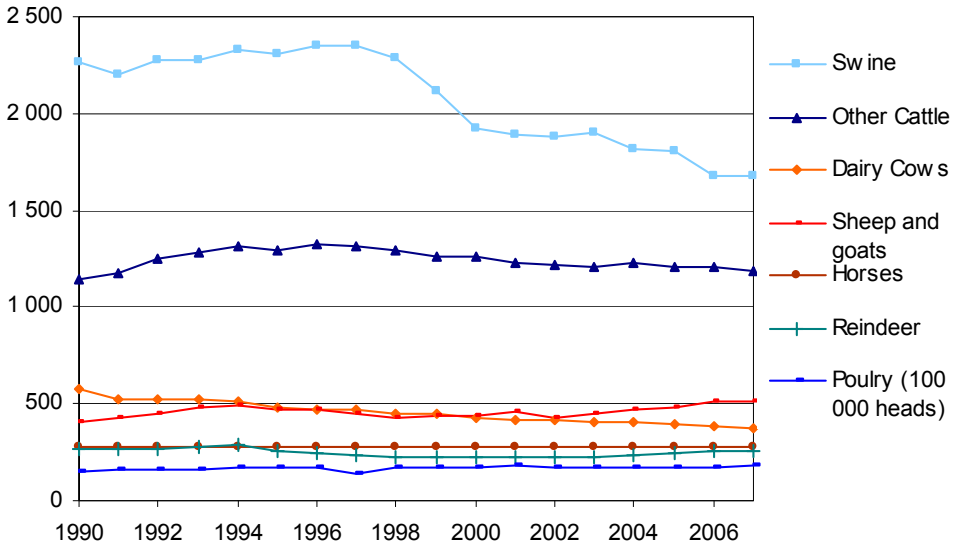

Figure 6.1 Livestock in Sweden 1990-2007, 1000s of head.

Emissions of N_2O derive to a large extent from manure management, use of artificial fertilisers and cultivation of organic soils. The N_2O emissions have decreased since 1990, mainly because of a change from solid manure management to slurry management in dairy and pork production.

Animal feeding plans, soil cultivation methods, choice of crops, timing and method of fertiliser spreading, grassland management, catch crops, length of grazing period, etc. are all factors that may influence in greenhouse gas emissions[103].

6.3 Methodological issues

The methodology used in the GHG inventory is in accordance with the IPCC Guidelines, with some national adaptations. A comparison between the Swedish inventory and the requirements given in IPCC Good Practice Guidance reveals that activity data, methodology and comparability in time series are in line with the IPCC Good Practice Guidance[104]. Activity data is collected from the Official Statistics of Sweden and other data sources such as those stated in section 6.3.4. National emission factors are developed especially for methane emissions from cattle and direct emissions of nitrogen dioxide from addition of fertilisers and manure to agricultural land. Data on nitrogen leaching and ammonia emissions originate from national sources (section 6.3.4.3). Interpolation/ extrapolation are used for years where high quality data on stable periods or waste management systems etc., is not available.

The applicable source subcategories are CRF 4A (Enteric Fermentation), CRF 4B (Manure Management) and CRF 4D (Agricultural Soils). Since there are no rice

[103] Ministry of the Environment, 2001.
[104] A project on quality control was carried out in 2003, as described in section 1.

fields or savannahs in Sweden, emissions from the sub-sources CRF 4C and CRF 4E do not occur. Field burning of agricultural residues is not very common in Sweden and therefore emissions in sub-sector CRF 4F are also reported as not occurring[105].

6.3.1 Enteric Fermentation, CRF 4A

6.3.1.1 METHANE

According to the IPCC Guidelines methodology used, the livestock population in each category is multiplied by an emission factor and the total emission is stated:

$$emissions = \sum_i population_i * EF_i$$

Emission factors (EF_i) for the significant cattle subgroups are national. For reindeer, the IPCC Good Practice Guidance Tier 2 methodology has been applied[106] and for emissions from swine, sheep, goats and horses the IPCC default values are used. Statistics on livestock categories are presented in section 6.3.4.1 and table 6.8 in section 6.3.4.5.

6.3.2 Manure Management, CRF 4B

6.3.2.1 METHANE (INCLUDING EXCRETION FROM GRAZING ANIMALS)

The IPCC Good Practice Guidance Tier 2 methodology for estimating methane from manure management, including excretions from grazing animals, is applied for cattle and swine, and the corresponding Tier 1 methodology is used for other animal groups[107]. The formula for the emission factor for livestock group "i", according to the IPCC Good Practice Guidance IPCC Tier 2 methodology is:

$$emissionfactor_i = VS_i * B_{0i} * 0.67 * \sum_{jk} MCF_{jk} * MS_{ijk}$$

where VS_i is the volatile substance excreted per year, B_{0i} is the maximum methane producing capacity for manure produced by an animal within the livestock group, MCF_{jk} is a conversion factor for methane production, given a manure management system j, where grazing animals are considered as one of the systems, and a climate region k. MS_{ijk} is the fraction of animal manure handled using manure system j in climate region k.

The B_{0i} and MCF factors used are the default values in the IPCC Good Practice Guidance, except for the revised MCF for liquid manure, where the value of 10 % given by IPCC Guidelines, is adopted as a national value. This value is considered

[105] The issue has recently been further analysed in Swedish EPA/SMED 2004.
[106] IPCC Good Practice Guidance, p.4.26.
[107] According to current estimations, cattle and swine produce about 85-90% of the total methane emissions from manure management.

to be a more appropriate for Swedish conditions, firstly because of Sweden's cold climate, and secondly because of the fact that the slurry containers usually have a surface cover[108].

The values reported in the CRF tables are sometimes aggregated after the calculation has been carried out for more specific animal groups. Hence the implied emission factor for "other cattle" will depend not only on different manure management systems and stable periods over the years, but also on the relative composition of the different subgroups. The implied emission factor therefore varies between the reported years.

The Swedish Board of Agriculture provides data from a national database on manure production from cattle and swine (section 6.3.4.4)[109].
Information on waste management systems is collected from the surveys published in the biannual statistical report on the use of fertilisers and animal manure in agriculture[110] and the interpolated values are used for the intermediate years. Three manure management systems are considered apart from grazing animals: liquid systems, solid storage and deep litter (sometimes categorised as "other" in the national inventory). The distribution between the systems for different animal categories is included in a supplementary table in section 6.3.4.4.

National estimates of stable periods for cattle are collected from the statistical report on use of fertilisers and animal manure in agriculture[111]. This information has been available biannually since 1997. Before 1997, the data are extrapolated to 1990.

6.3.2.2 N_2O

The methodology for estimating N_2O from manure management is in accordance with the IPCC Guidelines Tier 2 methodology; it is based on emission factors from the IPCC Guidelines in combination with national activity data. The emissions from different manure management systems are calculated as:

$$emissions = \sum_{system} \left(\sum_{T} N_T * Nex_T * (365 - GrazPeriod_T) / 365 * MS_{(T,S)} \right) * EF_{system} * 44 / 28$$

where N_T is the number of head of livestock in category T in the country, NEX_T is the annual average excretion of N per head of category T in the country, $GrazPeriod_T$ is the grazing period in days for livestock category T, $MS_{(T,S)}$ is the fraction of total annual excretion for each livestock category T managed in manure management system S in the country.

[108] Dustan, 2002.
[109] Swedish Board of Agriculture, 1993. Swedish Board of Agriculture 1995. Swedish Board of Agriculture 2001. The given values are calculated according to the model STANK – "Stallgödselnäring i kretslopp" the official model for input/output accounting on farm level in Sweden (Linder, 2001). STANK is currently being evaluated in a study launched by The European Commission.
[110] Statistics Sweden, MI 30-series.
[111] Statistics Sweden, MI 30-series.

Data on nitrogen production has been derived by the Swedish Board of Agriculture (section 6.3.4.4). Stable period and manure management systems are the same as used in the methane calculations (section 6.3.2.1).

The emission factors are described in section 6.3.5.2. In the CRF tables, where some animal subgroups are aggregated, the implied emission factors (IEFs) may change over the years, depending on the relative size of the respective subgroups aggregated.

6.3.3 Agricultural soils, CRF 4D

6.3.3.1 DIRECT SOIL EMISSIONS, CRF 4D1

6.3.3.1.1 N_2O from synthetic fertilisers

Emissions from fertilisers are calculated as:

$$emissions = N_{FERT} * (1 - Frac_{GASF}) * EF * 44/28$$

where N_{FERT} is the total amount of fertiliser nitrogen consumed annually, and $Frac_{GASF}$ is the fraction that volatilises as ammonia. The statistics on sold quantities of fertilisers are used in the calculations. Sales of fertilisers, recalculated into nitrogen quantities, are published annually by Statistics Sweden[111] and the national estimates are considered to be accurate, according to the quality declaration in the statistical report. The fertiliser sales values are however a bit higher than the estimated use of fertilisers, which is estimated from telephone interviews with farmers. The difference can partly be explained by the use of fertiliser in other sectors such as in horticulture (section 6.5.2).

The estimated emissions are based on mineral fertilisers sold in Sweden and calculated as the nitrogen (N)-content of different types of fertilisers from retailers multiplied by ammonium emission factors (Table 6.1)[112].

[112] CORINAIR, 1998.

Table 6.1. Total N-content of sold fertilisers in Sweden and estimated ammonia emissions, 1990-2007

Year	Sold quantity of fertiliser-N, tonnes (N_{FERT})	N quantity emitted as ammonia, tonnes	Proportion of emitted fertiliser-N ($Frac_{GASF}$)
1990	224 500	2 320	0.010
1991	208 600	2 292	0.011
1992	178 400	2 292	0.013
1993	207 200	3 418	0.016
1994	216 400	4 053	0.019
1995	198 300	3 346	0.017
1996	192 300	2 790	0.015
1997	204 600	2 883	0.014
1998	205 600	2 733	0.013
1999	179 200	2 536	0.014
2000	189 400	2 279	0.012
2001	196 900	2 277	0.012
2002	184 800	2 577	0.014
2003	180 100	1 934	0.011
2004	176 800	2 015	0.011
2005	161 500	1 872	0.012
2006	160 300	1 900	0.012
2007	166 500	1 999	0,012

Swedish Board of Agriculture, Statistics Sweden, MI 30-series, CORINAIR

The proportions of emitted N-content of fertilisers sold in different years are given in Table 6.1. The value varies because of changes in the sold quantities of different types of fertilisers. In Table 6.16 the sold quantities of ammonia-emitting products are shown, which directly explains variations in the $Frac_{GASF}$.

6.3.3.1.2 N_2O from animal manure

To calculate the N_2O from animal manure, the default methodology according to the IPCC Guidelines is used combined with national estimates of N content in manure (section 6.3.4.5) and a national estimation of ammonium-N emissions. The formula is stated:

$$emissions = \sum_T N_T * Nex_T * (365 - GrazPeriod_T)/365 * (1 - Frac_{GASM}) * EF * 44/28$$

where $GrazPeriod_T$ is the grazing period in days and $(365\text{-}GrazPeriod_T)/365$ is the fraction of manure deposited during the stable period. $Frac_{GASM}$ is the national value of the fraction of ammonia-N emissions from animal manure.

The fraction of nitrogen supply emitted as ammonium-N (Table 6.2) is estimated by Statistics Sweden and the Swedish EPA[113]. The estimates are model-based and take into account many factors that influence gas emissions. The methodology, based on data collected on the use of manure from telephone interviews

[113] Statistics Sweden, MI 37-series.

with farmers[114], was developed in the early 1990s[115]. Later, the methodology was extended to take into account more detailed information on the use of manure and manure storage.

Table 6.2. Ammonia-N emissions from manure, fraction.

	1995	1997	1999	2001	2003	2005	2007
Stable manure (FracGASM)	0.33	0.37	0.37	0.33	0,33	0,32	0,33
Manure from grazing animals ("FracGASG")	0.12	0.08	0.08	0.08	0.08	0,08	0,08

Statistics Sweden, MI 37-series.

Emissions from grazing animals (excretion during the grazing period) are calculated in a similar way, but the emissions are attributed to agricultural soils (section 6.3.3.2).

6.3.3.1.3 N_2O from sludge used as fertiliser

N_2O from sewage sludge used as fertiliser is a part of the N_2O emissions from agricultural soils and may be reported, according to the IPCC Good Practice Guidance, if sufficient information is available. Statistics on the use of sewage sludge have been published irregularly and in different reports, but a time series has been created through interpolation and the emissions are reported for the first time in submission 2006 of the GHG inventory. The activity data used is given in table 6.16. The IPCC Guidelines' default factor for ammonia emissions from fertilisers is used to differentiate between direct and indirect emissions. The IPCC Good Practice Guidance's default emission factors for N_2O are used and the emissions are calculated as:

$$emissions = SludgeN * ((1 - Frac_{GASM}) * EF_1 * 44/28,$$

where Sludge-N is the nitrogen in sewage sludge used as fertiliser, $Frac_{GASM}$ is the fraction of nitrogen emitted as ammonia (30 %) and EF_1 is the IPCC Good Practice Guidance's default emission factors for direct soil emissions. The direct emissions from sewage sludge have been reported as an optional category in the CRF.

6.3.3.1.4 N_2O from N-fixing crops in pure stands and in lay land

Nitrogen fixation crops are pasture grounds with features of clover, leguminous crops (cooking and fodder peas, preserved peas, vetches, field beans etc). This nitrogen fixation by leguminous plants is a part of the nitrogen circulation in agricultural soils and the corresponding N_2O emissions are included in the inventory. Data derives from national estimates of nitrogen fixation, which account for regional differences, in combination with the IPCC Good Practice Guidance's default emission factor for direct N_2O emissions. The formula is stated:

[114] Statistics Sweden, 1990.
[115] Rösiö, 1991.

$$emissions = \sum_{crop} production_{crop} * Yield_{crop} * NfixingFactor_{crop} * EF * 44/28,$$

The total production of dry pulses, etc., is given by multiplying the cultivated area, according to the Farm Register, by standard yield. Areas are given in Table 6.12. Note that the indicated low value of about 6,600 hectares of leguminous plant cultivation in 1994 increased rapidly to about 20,200 hectares in 1995. To estimate nitrogen fixation from the atmosphere, a model according to Høgh-Jensen has been used since submission 2006[116]. The model covers fixation from root and stubble as well as transmission to other plants. It has been adapted to account for Swedish conditions[117] and has also been used by others such as the Swedish Board of Agriculture. According to the model the amount of fixed nitrogen is estimated as a part of the total amount of nitrogen in the plant's biomass. This part varies depending on the kind of leguminous plant, the age of the pasture, the number of harvests and, to some extent, the fertilised amount of fertiliser applied.

6.3.3.1.5 N_2O from crop residue

To estimate N_2O from nitrogen circulation in crop residues, the methodology recommended in the IPCC Good Practice Guidance is used combining national activity data on removed residues and other parameters, such as nitrogen content, at crop level with the IPCC Good Practice Guidance's default emission factor for direct N_2O emissions. The formula is stated:

$$emission = \sum_{crop} yield_{crop} * area_{crop} * Fracresidues_{crop} * FracN_{crop} (1 - Fracresiduesremoved_{crop}) * EF * 44/28,$$

where yield is the standard yield, Fracresidues are the crop residues as a fraction of the harvest, FracN is the fraction of nitrogen in crop residues and Fracresiduesremoved is the fraction of crop residues that is removed according to a 1997 field survey[118]. Yet the crop residue used in stables is not excluded because it will circulate back to the field with manure.

When calculating N-circulation in residues from cereal crops, national factors for recalculation from harvest to crop residue and the corresponding N-content based on national measurement data are used[119]. For other crops, a combination of national factors and IPCC default values was used[120]. All factors used for calculating N input with crop residues are given in Table 6.15. Areas of different crops used in the calculations are stated in Tables 6.10 - 6.12. Standard yield[121] of different crops used in the calculations is presented in Tables 6.13 – 6.14.

[116] Høgh-Jensen et al. 2004.
[117] Frankow-Lindberg, 2005.
[118] Statistics Sweden, 1999.
[119] Mattson, 2005.
[120] Swedish EPA/SMED 2005.
[121] Statistics Sweden, 2002e.

6.3.3.1.6 Background emissions of N_2O due to cultivation of organic and mineral soils

Background emissions from agricultural soils are reported both for organic and mineral soils in the Swedish inventory. The estimated area of organic soils is multiplied by the default emission factor in the IPCC Guidelines and a national emission factor has been developed for mineral soils[122]. The formula for estimating the emissions is stated:

$$emissions = \sum_i area_i * EF_i$$

where area is the area of mineral respective organic soils, and EF is the background emissions per hectare. Index i depends on whether the soil is mineral or organic.

The total area of arable land for each year is taken from the Farm Register and the area of organic soils is around 252 600 hectares according to a recent mapping of cultivated organic soils in Sweden[123].

6.3.3.2 ANIMAL PRODUCTION, CRF 4D2

6.3.3.2.1 N_2O from grazing animals

Calculations of N_2O emissions from nitrogen excreted during grazing are carried out according to the methodology in the IPCC Guidelines, but ammonia emissions are considered as well, since national estimates of ammonia from grazing manure are available. This is consistent with the calculation of indirect emissions, the emissions from animal manure and the national methodology for ammonium emissions estimation. The formula is stated as:

$$emissions = \sum_T N_T * Nex_T * GrazPeriod_T / 365 * (1 - Frac_{GASG}) * EF_T$$

where N_T is the number of animals of type T in the country, Nex_T is the N-excretion of animals of type T, $GrazPeriod_T$ is the grazing period for animals of type T, $Frac_{GASG}$ is Ammonium-N emissions (fraction) and EF_T is the emission factor for grazing manure from animals of type T.

The nitrogen content in manure is discussed in section 6.3.4.4. Due to lack of data concerning reindeer, the nitrogen production by sheep is also applied to reindeer. The emission factors used are explained in section 6.3.5.3.

6.3.3.3 INDIRECT EMISSIONS, CRF 4D3

The calculations are carried out according to the methodology in the IPCC Good Practice Guidance, and the activity data, i.e., losses of nitrogen as ammonia and nitrogen leakage, are national.

[122] Klemedtsson, 2001.
[123] Berglund, 2005.

6.3.3.3.1 Deposition of ammonia

In addition to the methodology in the IPCC Guidelines, national data on ammonia emissions and the default emission factor in the IPCC Guidelines are applied. The formula for estimating the emissions is stated:

$$emissions = \left(N_{fert} * Frac_{GASF} + N*Nex*Frac_{GASM} + N*Nex*Frac_{GASG}\right) * EF * 44/28,$$

where N_{fert} is the nitrogen supply by mineral fertiliser and $Frac_{GASF}$ is the corresponding N fraction emitted as ammonia, calculated from sold quantities of different fertilisers and CORINAIR. N*Nex is the total amount of nitrogen excreted from animals, combined with national estimates of $Frac_{GASM}$, the fraction of nitrogen from animal manure emitted as ammonia, and "$Frac_{GASG}$", the fraction of manure from grazing animals emitted as ammonia.

6.3.3.3.2 Nitrogen Leaching and Run-off

The national estimates of nitrogen leaching are calculated from the SOILNDB model[124], which is a part of the SOIL/SOILN model[124]. The simulation model SOIL/SOILN was developed during the 1980s in order to describe nitrogen processes in agricultural soils[125]. Since then the model has been developed and tested on data from controlled leaching experiments, and these tests show that the model estimates leaching from soil with good precision[126]. By using national data on crops, yields, soil, use of fertiliser/manure and spreading time, the leaching is estimated for 22 regions. These regions are based on similarities in agricultural production areas.

For calculating nitrogen leaching in the inventory, the average N leaching per hectare, calculated by the SOILNDB model, is multiplied by the total Swedish area of agricultural soil. The estimated indirect N_2O emission is stated:

$$emissions = area * leachfactor * EF * 44/28$$

The average nitrogen leaching from agricultural soils, the leach factor, estimated to 27 kg N/ha in 1994, is used for 1990-1997. The factor was then updated with new data and the value 23 kg N/ha[126] has been used since 1999. The value used for 1998 is interpolated. No estimate of uncertainty is done, but the used method is considered to be the best available in Sweden, taking many relevant factors with an impact on nitrogen leaching into account. Since statistics on the use of fertilisers and manure are produced every other year,[127] the estimates can be updated at most every second year. However, due to economic reasons, the data has been published intermittently.

To estimate the implied FracLEACH, which is required as additional information in CRF 4D for each reporting year, the leached nitrogen, according to the na-

[124] Johnsson, 1990; Swedish EPA, 2002.
[125] Johnsson et al., 1987.
[126] Swedish EPA, 2002b.
[127] Statistics Sweden, NA 30-series; Statistics Sweden, MI 30-series.

tional model, is divided by the sum of nitrogen in fertilisers and animal production. This quotient varies between 0.2 and 0.25, which is rather close to the IPCC Guidelines' default value of FracLEACH (0.3).

6.3.4 Activity data

6.3.4.1 LIVESTOCK GROUPS AND SUBGROUPS

Livestock is the main contributor to greenhouse gas emissions from agriculture. In Table 6.3 all the livestock subgroups used in the calculations are presented. Mink and foxes are minor contributors to greenhouse gas emissions and are not included in the inventory due to a lack of well-founded emission factors.

The Farm Register provides the main basis for agricultural statistics in Sweden. The Register is administered by the Swedish Board of Agriculture and Statistics Sweden and provides annual information on the total number of animals of different categories on Swedish farms[128]. The information on livestock refers to the situation prevailing in mid-June of that year and thus is considered to be equivalent to a one-year average. Most of the information on livestock numbers comes from the Farm Register, but the distribution of calves (older and younger than 6 months respectively) is model-assisted: 60 % are assumed to be younger than 6 months and the rest are assumed to be over 6 months old.

According to the Farm Register, there are about 95,660 horses on farms in Sweden. However, the total number of horses, including horses used for leisure activities, is estimated to be about 283,000[129]. This larger number has been used for the calculations for all years in submission 2009.

The number of slaughter chickens (mean number of chickens kept during the year) is provided by the Swedish Poultry Meat Association. This estimate is generally higher than the estimate given by the Farm Register, which on the other hand is considered to be too low.

[128] Swedish Board of Agriculture, JO 20-series.
[129] Statistics Sweden, 2006.

Table 6.3. Livestock subgroups used in the calculations.

Categories according to IPCC Guidelines	Sub-categories Enteric Fermentation	Sub-categories Methane from manure management	Sub-categories N_2O from manure management	Sub-categories N_2O from grazing animals
Dairy Cattle (**)	Dairy cows	Dairy cows	Dairy cows	Dairy cows
Non-Dairy Cattle (**)	Beef cows	Beef cows	Beef cows	Beef cows
	Other cattle	Growing animals (12-24 months)	Growing animals (12-24 months)	Growing animals (12-24 months)
		Calves > 6 months	Calves > 6 months	Calves > 6 months(*)
		Calves < 6 months	Calves < 6 months	Calves < 6 months(*)
Swine	Swine	Sows	Sows	NO
		Boars	Boars	
		Pigs for meat production	Pigs for meat production	
		Piglets	Piglets	
Sheep	Sheep	Sheep	Sheep	Sheep
Goats	Goats	Goats	Goats	Goats
Horses (***)	Horses	Horses	Horses	Horses
Poultry	Poultry	Poultry	Laying hens (**)	NO
			Chickens (**)	
			Slaughter Chickens (****)	
Other (*****)	Reindeer	NO	NO	Reindeer

(*) The age distribution of calves is accomplished by using standard values.

(**) Farm Register. (***) Statistics Sweden. (****) Swedish Poultry Meat Association. (*****) Sametinget (The Sami Parliament of Sweden).

6.3.4.2 STATISTICS ON MANURE MANAGEMENT AND USE OF MANURE AND FERTILISERS

Statistics on manure management and the use of manure and fertilisers are collected biannually by Statistics Sweden[130]. Data on stable periods, manure management systems originate from this survey. Since dairy cows are often stabled at night, the data on stable periods for this animal category is combined with an assumption that 45 %[131] of its manure was produced in the stable during the grazing period. Statistics Sweden and the Swedish Board of Agriculture collect statistics on fertiliser sales[132]. A one-time study on how straw and tops from different crops were used was carried out in 1997[133].

6.3.4.3 STATISTICS ON CROPS, YIELDS, SLUDGE AND OTHER DATA

The above mentioned Farm Register also keeps records of areas of different crops (Table 6.10). Estimated standard yields for different crops are published annually

130 Statistics Sweden, MI 30-series.
131 Swedish Board of Agriculture, 2005 – the given value is calculated according to the STANK model – the official model for input/output accounting on farm level in Sweden.
132 Statistics Sweden, MI 30-series; www..sjv.se/net/.
133 Statistics Sweden, 1999.

by the Swedish Board of Agriculture/Statistics Sweden and are a function of crop yields estimated by surveys conducted over the last 15 years[134]. By using standard yields instead of actual yields in the calculations, the time series becomes more regular. Statistics on the use of sludge have been collected intermittently by Statistics Sweden and the Swedish EPA from sewage treatment plants (Table 6.16). The use of sewage sludge in agriculture is low in Sweden. A debate about toxic substances in the end of the 1990s resulted in the food manufacturing industries not accepting crops fertilised by sewage sludge. This forced the Federation of Swedish Farmers to recommend the farmers not to use sewage sludge[135].

When national methodologies are used for official estimates of the environmental impact of agriculture, these are used as an input to the inventory. Ammonia emissions from manure[136] are estimated by Statistics Sweden and nitrogen leaching[137] is estimated by the SLU. Both methodologies use data on manure management practices collected by Statistics Sweden and are thus consistent with national agricultural statistics. To estimate the nitrogen fixation in lay land a national methodology consistent with the national nutrient balances is also used[138].

6.3.4.4 MANURE AND NITROGEN PRODUCTION FROM ANIMALS

The Swedish Board of Agriculture publishes data on manure production from cattle and swine as well as on nitrogen production from most of the animal subgroups included in the inventory[139]. Data on dairy cows for different levels of milk productivity are presented in Table 6.4. Since productivity has increased during the reporting period, the data in Table 6.4 is used for interpolating an accurate mean value for each reporting year in the inventory.

Table 6.4 Manure and nitrogen production from dairy cows.

Animal groups	Manure kg dm/day/head	Nitrogen kg/year/head
Dairy Cows (Milk production 6,000 kg/yr)	5.75	100
Dairy Cows (Milk production 8,000 kg/yr)	6.07	117
Dairy Cows (Milk production 10,000 kg/yr)	6.19	139

The values for manure production per animal in each of the other animal groups are given in Table 6.5. Nitrogen production per animal in each of the other animal subgroups is stated in Table 6.6. Due to more intense swine production, the values for sows and pigs for meat production were updated in 2001.

134 Statistics Sweden, 2002e.
135 Statistics Sweden, Federation of Swedish Farmers, Swedish Board of Agriculture and Swedish EPA 2007.
136 Statistics Sweden, MI 37-series.
137 Swedish EPA, 2002; Swedish EPA, 2002b.
138 Frankow-Lindberg, 2005.
139 Swedish Board of Agriculture, 1993; and Swedish Board of Agriculture, 2001; Swedish Board of Agriculture, 1995; Swedish Board of Agriculture, 2000. The given values are calculated according to the model STANK – the official model for input/output accounting on farm level in Sweden (Linder, 2001).

Table 6.5 Manure production from other animal groups.

Animal groups	Manure production, kg dm/day
Beef cows (*)	2.64 (in stable); 3.64 (during grazing)
Growing animals (12-24 months)	2.6
Calves > 6 months	1.12
Calves < 6 months	0.69
Sows	0.74 (1990-2001); 0,793 (in 2002-2007)
Boars	0.52
Pigs for meat production	0.42
Piglets	0.05

Swedish Board of Agriculture, 1993. Swedish Board of Agriculture, 1995. Swedish Board of Agriculture, 2001.

Table 6.6 Nitrogen production from other animal groups.

Animal groups	Nitrogen kg/year/ Head, 1990-2001	Comment	Updated values on nitrogen prod. used for 2002 - 2007, kg/ year/head	Comment
Beef cows	63			
Growing animals				
12-24 months	47			
Calves > 6 months	28			
Calves < 6 months	28			
Sows	18.5		22.5	
Boars	13			
Pigs for meat production	9.5	2.5 prod. cycles/ year	10.8	3 prod. cycles / year
Piglets	0.5		0.5	
Sheep	13	Ewes incl. 1.5 lambs		
Lambs	0			
Goats	13			
Kids	0			
Horses	50	Mean value for all animals		
Laying hens and turkeys	0.64			
Chickens	0.28	2.5 prod. cycles/ year		
Slaughter Chickens	0.29	6.5 prod. cycles/ year		

Values are calculated according to the STANK model (Swedish Board of Agriculture)

6.3.4.5 ACTIVITY DATA – SUPPLEMENTARY TABLES

Table 6.7 Stable periods for cattle, months.

Year	Dairy cows	Beef cows	Steers and bulls	Heifers	Calves	Sheep, horses, goats	Rein-deer	Poultry, Swine
1990	7.2	6.2	7.6	6.5	7.8	6	0	12
1991	7.2	6.2	7.6	6.5	7.8	6	0	12
1992	7.2	6.2	7.6	6.5	7.8	6	0	12
1993	7.2	6.2	7.6	6.5	7.8	6	0	12
1994	7.2	6.2	7.6	6.5	7.8	6	0	12
1995	7.2	6.2	7.6	6.5	7.8	6	0	12
1996	7.2	6.2	7.6	6.5	7.8	6	0	12
1997	(*) 7.2	(*) 6.2	(*) 7.6	(*) 6.5	(*) 7.8	6	0	12
1998	7.2	6.2	7.6	6.5	7.8	6	0	12
1999	(*) 7.2	(*) 6.2	(*) 7.6	(*) 6.5	(*) 7.8	6	0	12
2000	7.7	5.8	7.9	6.1	7.6	6	0	12
2001	(*) 7.1	(*) 5.6	(*) 7.9	(*) 6.0	(*) 7.3	6	0	12
2002	7.1	5.6	7.9	6.0	7.3	6	0	12
2003	(*) 6.9	(*) 5.3	(*) 7.6	(*) 6.1	(*) 7.4	6	0	12
2004	6.9	5.3	7.6	6.1	7.4	6	0	12
2005	(*) 6.9	(*) 5.4	(*) 7.9	(*) 5.5	(*) 7.3	6	0	12
2006	6.9	5.4	7.9	5.5	7.3	6	0	12
2007	(*) 7.2	(*) 5.2	(*) 8.3	(*) 5.7	(*) 8.0	6	0	12

(*) Statistics Sweden, 2008. Other values are standard values, or interpolated /extrapolated.

Table 6.8 Population size of different animal groups (1000s heads).

Year	Dairy cows	Non-Dairy Cattle			Swine				Sheep		Horses	Goats		Other	Poultry		
	Dairy Cows	Beef cow	Growing animals (12-24 months)	Calve	Sow	Pig for meat production	Piglet	Boar	Sheep	Lamb	Horse (*)	Goat (***)	Kid (***)	Reindeer	Laying hen	Chicken	Slaughter Chicken (**)
1990	576	75	543	524	221	1276	758	8.6	162	244	283	2.9	1.4	271	6400	2200	6600
1991	528	98	543	537	219	1239	736	8.3	168	251	283	3.2	1.6	271	6100	2600	7000
1992	526	136	565	548	225	1283	763	8.3	180	267	283	3.5	1.8	271	6100	2200	7600
1993	525	154	549	581	241	1272	756	7.9	189	282	283	3.5	1.8	280	5800	1900	7600
1994	509	165	561	592	241	1264	815	8.2	196	288	283	3.5	1.8	284	5900	2200	8200
1995	482	157	596	542	237	1300	768	7.6	195	266	283	3.5	1.8	253	6100	1800	8500
1996	466	164	617	543	273	1303	765	6.9	203	266	283	3.5	1.8	241	5700	2200	8700
1997	468	169	614	530	269	1313	764	5.8	195	247	283	3.5	1.8	239	2700	1900	9400
1998	449	170	611	509	255	1293	733	4.8	187	234	283	3.5	1.8	227	5400	2200	9400
1999	449	165	600	499	220	1239	651	4.2	194	244	283	3.5	1.8	227	5600	2200	9400
2000	428	167	589	500	202	1146	566	4.2	198	234	283	3.5	1.8	221	5700	1700	9500
2001	418	166	573	494	212	1089	586	3.9	208	244	283	3.5	1.8	221	5700	1700	10450
2002	417	169	553	499	208	1096	574	3.4	197	229	283	3.5	1.8	220	4700	1500	10600
2003	403	165	527	512	204	1127	567	3.9	210	238	283	3.7	1.8	229	4500	1500	10402
2004	404	172	539	514	192	1095	528	3.1	220	246	283	3.7	1.8	239	5000	1600	10502
2005	393	177	527	508	185	1085	538	2.7	222	249	283	3.7	1.8	251	5100	1700	10064
2006	388	178	530	496	184	1002	492	2,6	244	262	283	3,7	1,8	261	4500	1600	10670
2007	370	186	516	489	179	1015	480	2,5	242	267	283	3,7	1,8	255	5328	1753	10710

Most data from the Farm register, Swedish Board of Agriculture and Statistics Sweden. (*) Estimated total of horses in all sectors 2005, by Statistics Sweden. (**) Swedish Poultry Meat Association. (***) Data on goats were available until 1992, this data have been extrapolated.

Table 6.9 Waste management systems, fraction of liquid systems.

Year	Dairy cattle	Other cattle	Pigs for meat production	Other swine	Sheep, goats, horses, reindeer	Poultry
1990	0.23	0.17	0.44	0.44	0	0.25
1991	0.23	0.17	0.44	0.44	0	0.25
1992	0.23	0.17	0.44	0.44	0	0.25
1993	0.29	0.22	0.58	0.58	0	0.25
1994	0.29	0.22	0.58	0.58	0	0.25
1995	0.31	0.23	0.63	0.63	0	0.25
1996	0.31	0.23	0.63	0.63	0	0.25
1997	(*) 0.33	(*) 0.16	(*) 0.8	(*) 0.24	0	0.25
1998	0.33	0.16	0.8	0.24	0	0.25
1999	(**) 0.39	(**) 0.14	(**) 0.82	(**) 0.26	0	0.25
2000	0.39	0.14	0.82	0.26	0	0.25
2001	(***) 0.44	(***) 0.15	(***) 0.86	(***) 0.31	0	0.25
2002	0.44	0.15	0.86	0.31	0	0.25
2003	(****) 0.46	(****) 0.14	(****) 0.88	(****) 0.38	0	0.25
2004	0.46	0.14	0.88	0.38	0	0.25
2005	(*****) 0.50	(*****) 0.15	(*****) 0.87	(*****) 0.33	0	0.25
2006	0.50	0.15	0.87	0.33	0	0.25
2007	(******) 0,55	(******) 0,14	(******) 0.94	(******) 0.47	0	0.25

(*) Statistics Sweden, 1998. (**) Statistics Sweden, 2000b. (***) Statistics Sweden, 2002b. (****) Statistics Sweden, 2004. (*****) Statistics Sweden, 2006. (******) Statistics Sweden 2008, Other values are standard values, or interpolated /extrapolated.

Table 6.9 continued Waste management systems, fraction of deep litter systems.

Year	Dairy cattle	Other cattle	Pigs for meat production	Other swine	Sheep, goats, reindeer	Horses	Poultry
1990	0,01	0,10	0,02	0,11	0	0,04	0,2
1991	0,01	0,10	0,02	0,11	0	0,04	0,2
1992	0,01	0,11	0,02	0,11	0	0,04	0,2
1993	0,01	0,11	0,02	0,11	0	0,04	0,2
1994	0,01	0,11	0,02	0,11	0	0,04	0,2
1995	0,01	0,11	0,02	0,11	0	0,04	0,2
1996	0,01	0,11	0,02	0,11	0	0,04	0,2
1997	0,01	0,11	0,02	0,11	0	0,04	0,2
1998	0,01	0,11	0,02	0,11	0	0,04	0,2
1999	0,01	0,12	0,01	0,07	0	0,04	0,2
2000	0,01	0,12	0,01	0,07	0	0,04	0,2
2001	0	0,16	0,01	0,12	0	0,04	0,2
2002	0	0,16	0,01	0,12	0	0,04	0,2
2003	0,01	0,18	0,01	0,11	0	0,04	0,2
2004	0,01	0,18	0,01	0,11	0	0,04	0,2
2005	0,01	0,20	0,01	0,22	0	0,04	0,2
2006	0,01	0,20	0,01	0,22	0	0,04	0,2
2007	0,01	0,21	0	0,12	0	0,04	0,2

(*) Statistics Sweden, 1998. (**) Statistics Sweden, 2000b. (***) Statistics Sweden, 2002b. (****) Statistics Sweden, 2004. (*****) Statistics Sweden, 2006. (******) Statistics Sweden 2008, Other values are standard values, or interpolated /extrapolated.

Table 6.10 Areas of different crops used in the calculations (hectares).

Year	Winter wheat	Spring wheat	Winter rye	Winter barley	Spring barley	Oats	Mixed grain	Triticale
1990	320 120	29 595	73 460	(*) -	492 027	387 823	32 628	(**) -
1991	225 330	33 387	43 239	(*) -	490 896	364 272	40 337	(**) -
1992	233 678	36 647	34 597	(*) -	454 097	360 859	47 420	(**) -
1993	271 818	32 581	46 390	(*) -	420 437	321 961	35 330	35 330
1994	212 095	39 722	38 957	29 536	443 489	341 415	25 421	42 526
1995	222 304	39 076	39 693	26 220	427 115	278 322	27 124	44 577
1996	292 170	42 392	33 558	22 061	446 503	283 588	34 230	61 694
1997	299 594	44 588	29 416	15 272	467 628	315 465	30 247	66 473
1998	359 024	39 021	34 617	15 949	429 011	311 467	26 972	66 751
1999	209 641	65 777	24 507	11 883	470 104	305 658	33 022	32 586
2000	353 201	48 364	34 533	12 997	398 227	295 544	45 328	40 728
2001	354 495	44 670	34 403	9 577	387 922	278 174	25 370	39 642
2002	285 249	54 350	24 395	6 386	410 456	295 002	22 623	30 809
2003	364 058	47 290	24 366	6 345	362 127	279 808	25 235	44 661
2004	349 823	53 585	24 402	5 268	392 006	229 696	18 697	52 195
2005	295 325	59 430	21 386	5 356	373 208	200 122	18 857	50 292
2006	317 603	43 333	23 454	5 691	309 444	206 055	17 430	55 406
2007	323 182	38 367	24 716	8 274	318 407	207 909	15 317	53 914

Statistics from the Farm Register. (*) Before 1994, statistics on winter barley and spring barley revised as one crop. (**) Before 1993, statistics on Triticale was included in Mixed grain.

Table 6.11 Areas of different crops used in the calculations (hectares).

Year	Sugar beets	Winter rape	Spring rape	Winter turnip rape	Spring turnip rape	Table potatoes	Potatoes for starch prod.
1990	38 502	84 598	44 203	9 068	30 035	27 305	8 866
1991	47 963	75 724	41 046	8 089	26 362	28 269	8 807
1992	51 287	51 364	56 519	3 145	26 366	30 414	8 791
1993	51 287	74 460	46 203	2 455	22 370	27 815	8 469
1994	53 353	46 035	53 033	1 746	27 647	25 449	7 539
1995	57 518	56 084	23 311	1 587	23 661	27 630	7 371
1996	59 223	21 737	18 976	811	23 869	27 577	9 060
1997	60 459	22 888	19 475	1 787	19 432	26 732	9 081
1998	58 737	23 159	16 705	1 470	13 238	25 133	8 567
1999	59 881	19 626	31 273	1 206	23 784	24 422	8 391
2000	55 484	24 870	12 112	1 395	9 791	23 610	9 293
2001	54 834	19 900	13 591	857	10 425	23 776	8 460
2002	54 820	31 219	21 943	1 899	12 408	23 142	8 589
2003	50 100	23 352	26 670	817	7 734	21 923	8 617
2004	47 625	37 496	36 715	1 244	8 343	23 015	8 656
2005	49 182	34 997	38 578	1 460	7 116	22 081	8 372
2006	44 184	47 638	35 148	1138	6 270	20 212	7 966
2007	40 682	50 341	33 044	1 117	3 341	20 330	8 032

Table 6.12 Areas of different crops used in the calculations (hectares).

Year	Lay (*)	Lay for seed	Green forage	Pasture ground (**)	Peas and peas for fodder	Peas for conservation	Brown beans	Total area of arable land	Total Area of Lay (*****) ha
1990	727 590	10 753	39 698	190 503	32 742	(****) -	(****) -	2 845 000	778 000
1991	696 069	10 418	33 509	239 818	23 327	(****) -	(****) -	2 790 000	740 000
1992	708 384	8 791	2 896	292 825	14 059	(****) -	(****) -	2 768 000	720 000
1993	748 094	7 863	23 137	314 458	8 720	(****) -	(****) -	2 780 000	779 000
1994	757 000	8 241	23 000	314 666	6 598	(****) -	(****) -	2 780 000	788 000
1995	766 776	7 907	23 695	276 927	11 959	8 578	709	2 767 000	798 000
1996	750 085	7 854	22 268	247 369	17 713	8 821	690	2 811 000	780 000
1997	746 832	8 470	24 443	234 677	32 742	9 028	921	2 799 000	780 000
1998	742 068	9 013	21 935	221 418	49 150	8 524	938	2 784 000	773 000
1999	760 227	8 165	21 867	198 091	30 053	8 752	872	2 747 000	790 000
2000	760 227	8 465	21 867	198 091	27 892	8 525	835	2 694 184	791 000
2001	750 200	10 300	26 400	179 400	29 928	8 862	756	2 705 982	787 000(***)
2002	759 419	12 439	32 387	181 604	31 959	8 909	717	2 679 900	804 245
2003	769 200	12 306	31 748	164 100	28 942	9 121	767	2 668 586	813 254
2004	770 412	12 329	35 715	164 359	33 116	9 318	767	2 660 643	818 456
2005	803 920	12 847	39 628	192 670	31 285	8 874	707	2 703 057	856 395
2006	816 400	15 151	42 463	206 270	26 180	8 954	646	2 660 424	874 014
2007	831 390	14 276	46 482	190 400	19 198	8 824	535	2 647 700	892 148

From 2000 the Farm Register does not differentiate between pasture (**) and lay (*). Therefore, values are imputed or taken from other studies. (***) Statistics Sweden, 2002b. (****) Before 1995, statistics on all groups of peas and beans were aggregated. (*****) Total area of lay= lay + lay for seed + green fodder.

Table 6.13 Standard yield of different crops used in the calculations, total weight (including water), kg/hectare.

Year	Winter wheat	Spring wheat	Winter rye	Spring barley	Oats	Mixed grain	Triticale	Sugar beets	Winter rape	Spring rape
1990	5 818	4 918	4 195	3 911	3 866	3 305	5 818	44 843	2 748	1 777
1991	5 929	4 948	4 242	3 947	3 872	3 323	5 929	45 272	2 758	1 762
1992	6 040	4 979	4 288	3 982	3 879	3 341	6 040	45 701	2 767	1 746
1993	6 151	5 009	4 335	4 018	3 885	3 359	6 151	46 130	2 776	1 731
1994	6 207	5 012	4 398	4 036	3 869	3 359	6 207	46 446	2 777	1 715
1995	6 262	5 014	4 461	4 053	3 853	3 360	6 262	46 762	2 777	1 699
1996	6 393	5 078	4 600	4 103	3 882	3 394	5 434	46 985	2 752	1 679
1997	6 477	5 151	4 705	4 153	3 897	3 421	5 505	46 838	2 735	1 680
1998	6 592	5 021	5 010	4 136	3 714	3 336	5 603	46 686	2 681	1 607
1999	6 503	5 017	5 103	4 153	3 710	3 342	5 528	46 637	2 638	1 657
2000	6 446	5 059	5 204	4 137	3 658	4 431	6 446	46 300	2 609	1 720
2001	6 408	5 134	5 348	4 168	3 685	4 517	6 408	46 249	2 607	1 809
2002	6 351	5 176	5 448	4 204	3 747	3 976	6 351	46 416	2 634	1 910
2003	6 376	5 265	5 561	4 266	3 823	4 045	6 376	46 626	2 717	2 008
2004	6 231	5 227	5 526	4 245	3 853	4 049	6 231	46 661	2 789	2 062
2005	6 196	5 282	5 567	4 248	3 880	4 064	6 196	46 389	2 887	2 141
2006	6 169	5 201	5 515	4 201	3 870	4 036	6 196	47 193	3 027	2 175
2007	6128	5042	5561	4 184	3 869	4 027	6 128	47 990	3 147	2 214

Swedish Board of Agriculture, Statistics Sweden, JO 15-series

Table 6.14. Standard yield of different crops used in the calculations, total weight (inc. water), kg/hectare

Year	Winter turnip rape	Spring turnip rape	Table potatoes	Potatoes for starch prod.	Lay	Green fodder
1990	1 821	1 587	29 194	36 045	6 920	5 000
1991	1 804	1 578	29 769	36 502	6 958	5 000
1992	1 787	1 570	30 343	36 958	6 996	5 000
1993	1 770	1 562	30 918	37 415	7 034	5 000
1994	1 747	1 558	31 409	37 585	7 077	5 000
1995	1 724	1 555	31 900	37 754	7 120	5 000
1996	1 682	1 542	31 817	37 651	7 216	5 000
1997	1 622	1 533	31 832	37 613	7 287	5 000
1998	1 523	1 420	34 910	39 706	7 287	5 000
1999	1 474	1 431	35 598	40 665	7 287	5 000
2000	1 471	1 451	35 146	40 401	7 340	5 000
2001	1 444	1 483	34 608	40 268	7 340	5 000
2002	1 390	1 511	33 866	39 812	7 340	5 000
2003	1 415	1 553	33 436	39 368	7 340	5 000
2004	1 440	1 573	32 461	38 530	7 340	5 000
2005	1 496	1 596	31 536	38 426	7 340	5 000
2006	1 586	1 590	30 976	38 367	7 340	5 000
2007	1 655	1 583	30 493	37 982	7 340	5 000

Swedish Board of Agriculture, Statistics Sweden, JO 15-series

Table 6.15. Data used for calculating nitrogen input in crop residues.

Crop	Fraction of crop residues removed (ResiduesRemoved)	Fraction of N in crop residues, per cent of dm (FracN)	Fraction residues in relation to harvest, (FracResidues)	Dry matter content, fraction
Winter wheat	0,06	0,51	0,87	0,85/0,86
Spring wheat	0,06	0,44	0,96	0,85/0,86
Winter rye	0,09	0,6	1,08	0,85/0,86
Winter barley	0,23	0,51	0,87	0,85/0,86
Spring barley	0,12	0,77	0,83	0,85/0,86
Oats	0,12	0,73	0,89	0,85/0,86
Mixed grain	0,18	0,67	0,98	0,85/0,86
Triticale	0,06	0,6	1,08	0,85/0,86
Sugar beets	0,09	2,25	0,66	0,85
Winter rape	0,02	1,07	0,47	0,91
Spring rape	0,02	1,07	0,47	0,91
Winter turnip rape	0,02	1,07	0,47	0,91
Spring turnip rape	0,02	1,07	0,47	0,91
Table potatoes and Potatoes for starch prod.	0	1,1	0,40	0,20
Lay	0	1,3	0,25	0,84
Lay for seed	0,49	1,3	0,94	0,84
Green fodder	0	1,3	0,25	0,84
Pasture ground	0	1,3	0,40	0,67
Peas, Peas for fodder and brown beans	0,02	1,42	1,50	0,85
Peas for conservation	0	1,42	1,50	0,85

Swedish EPA/SMED 2005.

Table 6.16. Sold quantity of ammonia emitting fertilisers and nitrogen in sludge used as fertilizers

Year	N in sold fertilisers, tonnes	Ammonium Nitrate, AXAN, N26, N27, N28, tonnes of product	N-solution, tonnes of product	Urea, tonnes of product	NPK, tonnes of N	NP, tonnes of N	NK, tonnes of N	Sludge, tonnes of N.
1990	224 500	225 387	10 089	5 932	64 600	11 000	0	(**) 1 180
1991	208 600	237 612	6 498	4 683	52 100	11 000	3 700	1 180
1992	178 400	179 234	8 837	2 980	45 400	8 500	3 000	1 180
1993	207 200	200 004	5 257	3 501	46 100	9 800	3 300	1 180
1994	216 400	167 150	7 820	3 061	55 900	12 300	3 000	(**) 1 433
1995	198 300	182 486	11 193	1 955	51 050	13 451	2 912	(*) 2 304
1996	192 300	158 613	5 949	1 474	48 000	14 000	2 500	2 304
1997	204 600	175 558	4 399	1 104	51 500	15 900	2 300	2 304
1998	205 600	209 463	2 631	889	53 723	14 286	2 033	(*) 2 027
1999	179 200	166 077	3 111	745	50 092	14 619	1 746	2 027
2000	189 400	205 869	3 772	655	51 600	11 400	2 200	(*) 1 735
2001	196 900	235 495	2 036	553	54 000	11 300	3 000	1 735
2002	174 400	189 709	638	446	49 800	9 900	2 000	1 735
2003	180 100	238 828	1 083	382	53 900	10 600	2 200	595
2004	176 800	240 553	4 928	475	54 500	11 900	1 800	595
2005	161 500	273 036	3 364	519	59 000	8 400	1 600	754
2006	160 300	267 754	3 164	225	57 800	8 500	1 800	975
2007	166 500	285 064	0	271	61 100	5 300	2 000	1 322

Statistics on fertilisers from Swedish Board of Agriculture, 2008 and Statistics Sweden, 2008. (*) Statistics Sweden 1997b and Statistics Sweden 2001. (**) from Statistics Sweden 1992 and Statistics Sweden 1995. Other values are expert judgements.

Table 6.17 Average milk production per dairy cow

Year	Dairy cows in country, number of head(*)	Dairy cows in the official control activity, number of head (**)	Produced milk per head in official control activity, kg/head/yr (**)	Produced milk per head, not in official control activity (**)	Average milk production per head, kg/yr (***)
1990	576 000	421 780	7 319	5 330	6 786
1991	528 000	388 860	7 376	5 280	6 824
1992	526 000	367 452	7 376	5 400	6 780
1993	525 000	376 126	7 740	5 600	7 133
1994	509 000	383 124	8 011	6 100	7 538
1995	482 000	390 146	8 083	6 200	7 724
1996	466 000	382 511	8 033	6 150	7 696
1997	468 000	380 760	8 209	6 250	7 844
1998	449 000	380 567	8 298	6 258	7 987
1999	449 000	378 623	8 377	6 300	8 051
2000	428 000	368 350	8 537	6 430	8 243
2001	418 000	360 364	8 742	6 627	8 450
2002	417 000	354 801	8 784	6 665	8 468
2003	403 000	346 133	8 939	6 750	8 506
2004	404 000	332 367	8 994	6 750	8 596
2005	393 000	332 367	8 994	6 750	8648
2006	388 000	318 986	9 283	6 750	8832
2007	370 000	298 865	9 412	6750	8902

(*) Farm Register, (**) Swedish Dairy Association. (***) Calculated value.
Some values were not updated for submission 2007 or 2008.

6.3.5 Emission factors

6.3.5.1 METHANE FROM ENTERIC FERMENTATION, CRF 4A

A national methodology based on feed energy requirements expressed as metabolisable energy[140] is used in the Swedish inventory to estimate emission factors for dairy cows, beef cows and other cattle. The calculations for dairy cows were revised some years ago[141]. The emission factors for other cattle groups were also re-evaluated, using the same methodology[141]. The conclusion led to a decision to use the emission factor, 50 kg CH_4/head and year, a value close to the IPCC Good Practice Guidance default value for non-diary cattle (48 kg CH_4/head and year). Due to the recommendation of the ERT during the in-country visit in Sweden in 2007, CH_4 emission factors for beef cows and reindeer were revised to 78.0 kg CH_4/head and year and 19.9 kg CH_4/head and year, respectively.

The initial steps in estimating emission factors for cattle according to the Swedish method is similar to the procedure recommended in section 4 of the IPCC Good Practice Guidance for enhanced characterisation of feed intake estimates (Tier 2 methodology). The energy requirements for maintenance, growth, lactation and pregnancy are estimated, but expressed as metabolisable energy (MJ/day) instead

[140] Lindgren, 1980; Murphy, 1992; Bertilsson, 2002.
[141] Bertilsson, 2001.

of as net energy, as in IPCC Good Practice Guidance[142]. The metabolisable energy requirement is then recalculated to digestible energy, using the formula[143]:

Metabolisable energy (% of digestible energy) = 83.2 + 2.53*L – 0.045 * G – 0.184* Rp

where L is the total feed intake expressed as multiples of maintenance energy, G is the share (%) of roughage in the feed and Rp is the crude protein concentration (%) of the feed.

The digestible energy is used to calculate the methane conversion rate using the formula[144]:

Methane conversion rate (% methane of digestible energy) = 15.7 – 0.030 * SK – 1.4 * L

where SK is the digestibility of the feed (% of gross energy) and L is the total feed intake expressed as multiples of maintenance energy. The emission factor is calculated with the formula:

Emission factor (kg CH_4/head and year) = (SE * Ym / 55.65) * 365

where SE is the digestible energy (MJ/head and day) and Ym is the methane conversion rate (% of digestible energy). For dairy cows the calculation is performed for a lactation period of 305 days and a non-lactating period of 60 days, which are summed up to give the CH_4 total emissions per animal during a whole year.

The default values in the IPCC Guidelines are used for the less significant animal groups[145] and for these groups the development of a national emission factor has not been given priority. For reindeer, where the IPCC Guidelines do not provide default values, an emission factor is calculated according to the IPCC Guidelines methodology using a Finnish value of gross energy requirements.[146] The emission factors used for dairy cattle and other animal groups are collected in Table 6.18.

[142] Spörndly, 1999.
[143] Lindgren, 1980.
[144] Lindgren, 1980.
[145] According to current estimations, “other animal groups” produce less then 10 % of the total methane that results from enteric fermentation.
[146] Statistics Finland, 2007

Table 6.18 Methane from animals, used emission factors.

Livestock subgroups	Kg CH_4/ head/year	Method
Dairy cows in 1990, average milk production 6786 kg/yr/head	120.3	(*)
Dairy cows in 1995, average milk production 7724 kg/yr/head	126.4	(*)
Dairy cows in 2002, average milk production 8468 kg/yr/head	127.7	(*)
Dairy cows in 2007, average milk production 8902 kg/yr/head	132,0	(*)
Beef cows	78	(****)
Growing animals (12-24 months)	50	(****)
Calves	50	(****)
Swine	1.5	Tier 1 (**)
Sheep	8	Tier 1 (**)
Goats	5	Tier 1 (**)
Horses	18	Tier 1 (**)
Poultry	No fermentation assumed	(**)
Reindeer	19.9	(***)

The emission factor is related to milk production and calculated from Spörndly, 1999 and Bertilsson, 2001.

(**) IPCC Guidelines. (***)IPCC Good Practice Guidance, Tier 2. (****)Bertilsson, 2001.

6.3.5.2 MANURE MANAGEMENT, CRF 4B

The emission factors are calculated as a function of national activity data for manure production, stable periods and animal manure management systems (AWMS), etc. Parameters that are used to estimate methane and N_2O emissions depend on the specific AWMS. Very little research has been carried out in Sweden on GHG emissions from manure management, but a study on research results from countries with a similar climate has been carried out[147]. The only national value chosen is the MCF for liquid manure, which is set to 10 %, as was stated in the IPCC Guidelines[147]. All other parameters, due to the lack of information needed to determine national values, are default values from the IPCC Guidelines.

6.3.5.3 DIRECT SOIL EMISSIONS, CRF 4D1

For estimating direct soil emissions, the IPCC Good Practice Guidance encourages parties to use country-specific emission factors for N_2O from agricultural fields, where possible. A suggested alternative is to use factors from other countries with comparable management and climatic conditions. In order to update the information from research, a literature study was carried out, requested by the Swedish EPA[148]. The study includes documented N_2O emission measurements carried out in Sweden, in other countries in northern Europe and in Canada. National emission factors for Sweden are suggested where sufficient data are available.

The study shows that the emissions are generally higher following the application of manure compared to mineral N fertilisers and suggests emission factors of

[147] Dustan, 2002.
[148] Klemedtsson, 2001.

2.5 % of added manure N and 0.8 % of added fertiliser N. A lower value than the IPCC Good Practice Guidance default value of 1.25 % for mineral fertiliser N has also been suggested in a synthesis of literature data[149].

Background emissions from mineral soils, which includes the long-term effects of nitrogen in organic matter accumulating in the soil, is also described in the report. This is an anthropogenic effect of previous farming activities and the suggested emission factor is 0.5 kg N_2O-N ha^{-1}.

Based on this study the national emission factors given in Table 6.19 are applied in the Swedish inventory. For nitrogen supply from fertilisers, a national emission factor, 0.8 % N_2O-N of N-supply, is used[150]. For nitrogen supply from manure, a national emission factor of 2.5 % emissions of N-supply is used[150]. The background emissions from the cultivation of mineral soils have also been included in the inventory with the national emission factor of 0.5 kg N_2O-N ha-1. For other direct soil emissions, default values from the IPCC Guidelines are used.

Table 6.19 National emission factors for sources of direct N_2O-emissions from agricultural soils.

Source	EF in IPCC Guidelines	Applied EF
Mineral fertilizer	1.25 % of N	0.8 % of N
Manure	1.25 % of N	2.5 % of N
Background emissions from mineral soils	..	0.5 kg N_2O-N ha^{-1}

The background emissions from organic soils vary with different crops[151]. They are considered to be higher from ploughed soils than from pasture or lay[151] lands and the suggested emission factors are 1 and 6 kg N_2O-N ha^{-1}, respectively. The IPCC Guidelines' default value is however implemented in the inventory since a Swedish/Finnish research group concluded that not enough data exists to generate different emission factors for different management and soil types[152].

6.3.5.3.1 N_2O from grazing animals

For N_2O emissions from N excreted on permanent pastures, an emission factor of 1 % N_2O-N/kg nitrogen excreted is used. Very scarce information is available on emissions from unfertilised pastures, but according to data in the IPCC Guidelines - Reference Manual, page 4.97 - the emissions from unfertilised grasslands in New Zealand range from 0.2 to 1 %. Furthermore, it is stated on the same page of the manual that nitrogen losses as N_2O are probably low in cold and dry climates - a statement considered to support the lower emission factor for grass-lands. The nitrogen content per dry matter of manure from grazing animals is assumed to be equal to that of stable manure and equal in grassland and pastures[153].

149 Lægreid and Aastveit, 2002.
150 Klemedtsson, 2001.
151 Klemedtsson, 2001.
152 Klemedtsson et al., 1999.
153 Statistics Sweden, 2003c.

6.3.5.4 INDIRECT SOIL EMISSIONS, CRF 4D1

For indirect soil emissions, the IPCC Good Practice Guidance default emission factors are used. The IPCC Good Practice Guidance stresses the lack of knowledge on a global scale and the extreme variability in the suggested emission factors and parties are not encouraged to use national values unless rigorously documented and previewed country-specific values have been developed.

6.3.5.5 OVERVIEW OF EMISSION FACTORS

Table 6.20 Emission factor for CH_4.

Enteric Fermentation	**Emission factor kg CH_4/animal/yr**	**Note**
Dairy Cows	120-130	1
Non-Dairy Cattle (Beef cows)	78	9
Non-Dairy Cattle (other then Beef cows)	50	2
Sheep	8	4
Goats	5	4
Horses	18	4
Swine	1.5	4
Reindeer	19.9	8
Poultry	0	3
Manure management	**Emission factor**	
MFC solid manure(*)	1 % of B_0	4
MFC liquid manure(*)	10 % of B_0	5
MFC deep litter(*)	39 % of B_0	4
Dairy Cattle - volatile solid (VS)	1 937 kg VS/animal/yr	6
Dairy Cattle - B_0(**)	0.24 m^3 CH_4/kg VS	4
Dairy Cattle - Emission per animal	16 kg CH_4/animal/yr	7
Non-Dairy Cattle – volatile solid (VS)	625 kg VS/animal/yr	6
Non-Dairy Cattle – B_0	0.17 m^3 CH_4/kg VS	4
Non-Dairy Cattle – emission/animal(***)	5.6 kg CH_4/animal/yr	7
Swine – volatile solids (VS)	110 kg VS/animal/yr	6
Swine - B_0**	0.45 m^3 CH_4/kg VS	4
Swine – emission per animal(***)	3 kg CH_4/animal/yr	7
Sheep – emission	0.19 kgCH_4/animal/yr	4
Goats – emission	0.12 "	4
Horses – emission	1.40 "	4
Poultry – emission	0.08 "	4

(*)MCF = Methane Conversion Factor. (**) B0 = maximum methane producing capacity for manure. (***) Weighted value – more than one animal category. 1) National, Bertilsson (2001). 2) National. 3) No fermentation assumed. 4) IPCC Guidelines. 5) National, Dustan 2002. 6) National – STANK. 7) Calculated – 2002. 8) Statistics Finland, 2007. 9) National, Bertilsson, 2007.

Table 6.21 Emission factor for N_2O

Manure management	Emission factor	Note
Waste Management System	% N_2O-N of N-supply	
Liquid manure	0.1	2
Solid manure	2	2
Deep litter	2	2

Direct emissions from soils	Emission factor	Note
	% N_2O-N of N-supply	
Mineral fertiliser	0.8	1
Manure	2.5	1
Crop residue	1.25	2
N-fixing Crops	1.25	2
Animal Excretion – grassland(*)	2	2
Animal Excretion – pasture(**)	1	3
Background emission due to cultivation	Kg N_2O-N/ha/yr	
Cultivation of Histosoils	8	2
Cultivation of Mineral Soils (***)	0.5	1
Indirect emissions from soils		
Deposition of N from Swedish agriculture	1 % of emitted N	2
Leached nitrogen	2.5 % of leaching	2

(*) Refers to arable land. (**) Excreted N from cattle: 80 % to pasture, 20 % to grazing land. (***) Refers to excretion-N from cattle (120 %), sheep/goats (100 %), horses (100 %), reindeer = sheep (100 %). 1) National, Klemedtsson, 2001. 2) IPCC Guidelines. 3) National.

6.4 Uncertainties and time series consistency

The uncertainty analysis tables (Tier 1) are presented in Annex 7 and a general description of the uncertainty analysis is presented in section 1.7.

Although much activity data in the agricultural sector is estimated from extensive surveys, with high quality estimates at national level, the sector contributes to a large part of the total estimated uncertainty (Table 1.3). This is because the methodology in the agricultural sector is mainly affected by uncertain emission factors, which seem to be generally difficult to estimate. Estimated indirect N_2O emissions are among the most uncertain in the whole methodology. Direct N_2O emissions from agricultural fields are calculated with an error of about 80 % in the emission factor, as stated by the IPCC Good Practice Guidance. The disaggregating of direct emissions from manure and mineral fertilisers, respectively, in the Swedish inventory may reduce some of the variability but direct emissions from agricultural soils are still one of the most uncertain in the inventory. Emissions from manure management have an estimated error of about 50 %. Methane from enteric fermentation may be a bit more certain with an error of about 30 %. The time series in the agricultural sector are calculated consistently but the data needed are not always available for every year covered by the inventory. In cases where statistics are not produced annually, interpolation and extrapolation are necessary tools for the imputation of estimates. This further increases the uncertainty.

6.5 QA/QC and verification

6.5.1 Quality Assurance and Quality Control

Sweden has developed a QA/QC system which was implemented from submission 2006. All quality procedures according to the Swedish QA/QC plan (Manual for SMED's Quality System in the Air Emission Inventories) have been implemented during the work completed in conjunction from submission 2008.

6.5.1.1 REDUCING COMPILING ERRORS

The emission estimates in the agricultural sector depend on a set of calculations, one for each sub-source, which use several data matrices and many parameters described in the methodological overview, etc. The calculations are programmed in the SAS system in order to achieve consistent estimates for the whole time series. Hence, when applicable, the same matrices or factors needed are used for more than one sub-source. Double-checking inputs and crosschecking between years have been used for eliminating errors.

The basic steps for preparing the inventory and doing the calculations, along with the SAS program, are stated in a working document.

6.5.2 Verification

6.5.2.1 NUTRIENT BALANCES IN SWEDEN

Regional nitrogen and phosphorus balances for Swedish agriculture have been calculated, according to the soil surface method,[154] since the late 1990s. Table 6.22 shows nitrogen added and nitrogen removed for the whole of Sweden as estimated for 2005[155].

Table 6.22 Nitrogen added and removed for the whole of Sweden as estimated for 2005.

Input and output of nitrogen in arable land by source in 2001, tonnes			
Nitrogen added:	360 480	Nitrogen removed:	233 150
Sources:		Sources:	
Chemical fertiliser	155 320	Yield	228 180
Stable manure (*)	101 490	Harvested plant residues	4 970
Grazing manure	41 720		
Sewage sludge	1 210	Surplus:	127 330
Seed	4 270		
Biological fixation (**)	31 970	Leaching	52 180
Deposition	24 490	NH3-N from fertilisers and manure	38 210

(*) After losses of ammonia from ventilation, storage and application on the fields and from grazing periods. (**) From N-fixing crops, including clover in lay

[154] Statistics Sweden, 2003c.
[155] Statistics Sweden, 2007c.

The difference between "nitrogen-added" and "nitrogen-removed" results in a surplus containing ammonia losses from the fields, leaching, denitrification and the build-up of nutrients in the soil. The leaching is derived from the SOIL-SOILN model[154].

6.5.2.2 SOLD FERTILISERS VS. USED FERTILISERS

Two related parameters are the amount of nitrogen in sold fertiliser, estimated by the sales statistics, and the nitrogen in used fertilisers, estimated from interviews with farmers. Sales statistics are collected annually by the Swedish board of agriculture and Statistics Sweden[156]. Data has been collected in the same way from the larger producers and retailers since the early 1960s. Statistics on the use of fertiliser and manure have been collected biannually since the end of the 1980s[156]. The estimated nitrogen content in sold products has, until 1997, been about 15 % higher than the nitrogen in the estimated used products. In 2007, this difference was only 6 %[156].

The two estimates should be about the same, at least in the long run. The difference may be due to storage and/or the fact that estimation methods are affected by different error types. The sales statistics also contain quantities sold for use outside the agricultural sector and are therefore expected to result in a higher figure.

The user statistics provide valuable information about the use of fertilisers in different crops and regions, but the sales statistics are considered to give a more accurate estimate of total use. Therefore, the latter have been used in the GHG inventory. Another advantage of the sales statistics is that they are updated annually.

6.6 Recalculation

The stable period for cattle is revised for the whole time series. The method for calculating it has been refined in the underlying survey. Some other minor updates of data has been performed.

6.7 Coming improvements

The used data for area cropland (table 6.10 – 6.12) and also for the total agricultural land do not correspond to the data used in the LULUCF sector since two different data sources are used (official statistics versus the Swedish National Forest Inventory). This data will be investigated together with the Swedish Board of Agriculture (i.e. the responsible authority for statistics on use of agricultural land) and the Swedish University of Agricultural Sciences with the aim to use the identical data in the two sectors.

156 Statistics Sweden, MI 30-series.

7 Land Use, Land-Use Change and Forestry (CRF sector 5)

7.1 Overview

7.1.1 Background

The Swedish UNFCCC-reporting of the LULUCF-sector is adapted to the CRF-tables[157] using the IPCC-reporting instructions[158]. All carbon pools reported in this year's CRF tables are recalculated from the base year (1990) and reports data by year up to 2007. A statistically representative, systematic grid of permanent monitoring plots provides unbiased estimates of the areas of all land-use categories and it is possible to trace, in a consistent manner, both gross and net land-use transfers from the base year onward. Data from these plots are also the major source of information used to quantify changes in the various carbon pools. The stock change method is used for the most important pools: living biomass, dead organic matter and soil organic carbon, and the measurements are based on repeated measurements on permanent sample plots. Emissions and removals resulting from land-use management are considered. Non-CO_2 emissions such as nitrous oxide (N_2O) and methane (CH_4) are also completely reported.

Compared to previous submission:

- The reporting of living biomass and land use 1990-2003 is now based on about 30000 instead of about 24000 permanent sample plots. Years 2004, 2005, 2006 and 2007 are based on about 24000, 18000, 12000 and 6000 sample plots, respectively. From submission 2009, changes in the living biomass pool for the period 1990-2003 will no longer be gradually updated. This is because estimates are now based on all re-inventoried sample plots (in total approximately 30000). To improve the accuracy and due to a five-year inventory cycle, each submission estimates of the five most recent years will be re-calculated
- Changes in the soil organic carbon pool on drained organic forest soils are from now on based on the area of drained organic forest and national emission factors.
- An error influencing the estimates of living biomass and land use (submission 2008) has been identified and corrected in a resubmission of the crf and NIR 2008. The cause and consequences of this error are described in the resubmitted report. Actions to avoid a similar error in future reporting have been implemented.

[157] Decision 13/CP.9, Annex I
[158] Intergovernmental Panel on Climate Change, 2003

7.1.2 Results

The whole land and fresh-water area is monitored and the land-use categories Forest land, Cropland, Grassland and Settlements are assumed managed. A limited area of Wetlands, used for peat extraction, is also assumed managed. Compared to submission 2008, the land use matrix (Table 7.1) is now based on about 30000 instead of 24000 sample plots. However, the area estimates are very similar and for land use classes larger than 200 000 ha deviate less than 3 % between the two submissions. For the UNFCCC reporting, still Forest land is the most important land-use category. The gross and net conversions indicate that conversions from Forest land to Settlements are frequent.

Table 7.1 Land Use Categories 1990, 2003 and gross and net land use transfers 1990-2003 (based on about 30000 permanent sample plots inventoried 1983-2007). The carbon stock of Forest land in the mountain area[159] (915 000 ha) is not monitored in the field and changes in the carbon pools for this area are not reported.

	"From"	"To" Year 2003					
Area [1000 ha]	Year 1990	Forest Land	Crop-Land	Grass-Land	Wet-land	Settle-ments	Other Land
Forest land	28194	27977	3	19	23	146	26
Cropland	3085	65	2928	30	3	59	0
Grassland	500	35	35	412	3	11	3
Wetlands	7215	50	0	3	7067	9	87
Settlements	1717	59	13	6	4	1623	12
Other land	4410	25	0	1	31	2	4350
Sum after transfers		28212	2979	471	7131	1850	4477

Most of the carbon stock originates from Forest land. The largest carbon stocks are found in the living biomass and soil organic carbon pools. Also the largest annual change in stock is found on Forest land and the largest stock change is the change in the living biomass pool (Table 7.2). A net removal of the living biomass pool is reported for every year during the period. This removal shows a slight decreasing trend.

The dead organic matter pool has been a net sink during the reported period while the soil organic carbon pool is a source. However, some soils act as sources whereas others act as sinks (Table 7.3). The major source is the emission from drained Histosols (organic soils), both on Forest land and on Cropland. An area of about 4.5 Mha of the Forest land was considered as Histosols and close to 20 % (ca. 1 Mha) of the Histosols can be assumed disturbed by drainage. The Cropland area on Histosols is estimated to ca. 250 kha and all of that area is drained.

[159] Löfgren, 1998

Table 7.2 Carbon stock changes expressed as CO_2-equivalents. Summary of living biomass, dead organic matter (DOM) and soil organic carbon (SOC) per land use category; submission 2009 (minus = removal)

Year	CO_2-equivalents [M ton per year]														
	Forest land			Cropland			Grassland			Wet-	Settl-	Total			
	Living biomass	DOM	SOC	Living biomass	DOM	SOC	Living biomass	DOM	SOC	SOC	Living biomass	Living biomass	DOM	SOC	Total
1990	-39,6	-1,7	5,8	0,1	-0,02	3,8	-0,6	0,00	-0,1	0,04	-0,1	-40,2	-1,7	9,6	-32,3
1991	-40,4	-1,9	5,6	-0,1	-0,02	3,8	-0,4	0,00	-0,1	0,04	-0,1	-41,0	-1,9	9,4	-33,6
1992	-37,1	-2,2	5,2	-0,2	-0,02	3,7	-0,3	0,01	-0,1	0,04	0,2	-37,4	-2,3	8,8	-30,8
1993	-34,2	-2,2	4,5	-0,1	-0,02	3,8	-0,4	0,00	-0,1	0,04	0,0	-34,6	-2,2	8,3	-28,6
1994	-34,0	-1,2	6,9	-0,1	-0,02	3,6	-0,5	0,00	-0,1	0,04	-0,1	-34,7	-1,2	10,4	-25,4
1995	-34,1	-1,6	7,1	-0,3	-0,02	3,7	-0,5	-0,01	0,0	0,05	0,0	-35,0	-1,6	10,8	-25,7
1996	-35,9	-2,3	4,7	-0,1	-0,02	4,0	-0,3	0,01	-0,2	0,04	-0,1	-36,4	-2,3	8,6	-30,1
1997	-36,4	-3,9	2,9	-0,2	-0,02	3,6	-0,3	0,02	-0,2	0,05	-0,2	-37,0	-3,9	6,3	-34,7
1998	-36,0	-5,0	1,5	-0,2	-0,01	4,1	-0,6	0,05	-0,3	0,04	0,0	-36,8	-5,0	5,4	-36,4
1999	-35,2	-4,2	1,5	-0,2	-0,01	4,1	-0,6	0,04	-0,3	0,06	0,2	-35,8	-4,2	5,4	-34,6
2000	-35,3	-4,3	1,5	-0,4	-0,01	3,3	-0,5	0,03	-0,3	0,06	0,0	-36,3	-4,3	4,7	-35,9
2001	-33,2	-4,3	1,6	-0,4	-0,01	4,4	-0,5	0,02	-0,2	0,06	0,1	-33,9	-4,3	5,8	-32,4
2002	-35,0	-4,3	1,6	-0,2	-0,01	3,8	-0,3	0,04	-0,2	0,06	-0,1	-35,6	-4,3	5,2	-34,7
2003	-32,7	-5,2	1,8	-0,2	-0,01	2,9	0,0	0,04	-0,2	0,06	-0,2	-33,1	-5,2	4,5	-33,8
2004	-31,9	-4,7	2,4	-0,3	-0,01	3,0	-0,5	0,05	-0,2	0,05	-0,1	-32,9	-4,7	5,3	-32,3
2005	-29,1	-4,9	2,6	-0,3	0,00	2,9	-0,3	0,03	-0,2	0,06	-0,1	-29,9	-4,9	5,4	-29,4
2006	-27,3	-3,2	2,6	-0,3	0,00	3,0	-1,0	0,03	-0,2	0,04	0,4	-28,2	-3,2	5,4	-25,9
2007	-20,3	-4,7	2,1	-0,3	0,00	2,9	-0,2	0,05	-0,2	0,06	-0,1	-20,9	-4,6	4,8	-20,7

Table 7.3 Annual removals (-) and emissions from the soil organic carbon pool according to crf 5 A, B, C and D .

	CO_2-equivalents [M ton per year]					
	Forest land		Cropland		Grass-land	Wetland
year	Mineral soils	Organic soils	Mineral soils	Organic soils	Mineral soils	Organic soils
1990	-1.6	7.5	0.12	3.72	-0.09	0,04
1991	-1.9	7.5	0.11	3.71	-0.11	0,04
1992	-2.3	7.5	0.01	3.70	-0.13	0,04
1993	-3.0	7.5	0.08	3.73	-0.11	0,04
1994	-0.7	7.6	-0.11	3.69	-0.08	0,04
1995	-0.4	7.6	0.00	3.70	-0.05	0,05
1996	-2.9	7.6	0.22	3.75	-0.15	0,04
1997	-4.8	7.6	-0.20	3.77	-0.23	0,05
1998	-6.1	7.6	0.39	3.75	-0.29	0,04
1999	-6.1	7.6	0.40	3.73	-0.26	0,06
2000	-6.1	7.7	-0.29	3.63	-0.26	0,06
2001	-6.1	7.7	0.61	3.77	-0.25	0,06
2002	-6.1	7.7	0.06	3.72	-0.24	0,06
2003	-6.0	7.7	0.11	2.74	-0.23	0,06
2004	-5.3	7.8	0.20	2.75	-0.20	0,05
2005	-5.1	7.7	0.14	2.74	-0.21	0,06
2006	-5.1	7.7	0.23	2.76	-0.21	0,04
2007	-5.5	7.6	0.15	2.75	-0.23	0,06

Table 7.4 Annual emissions from non-carbon pools expressed as CO_2-equivalents

Year	CO_2-equivalents [M ton]						
	Fertilization	To Cropland	Liming	Biomass burning			Total
	CRF 5 I	CRF 5 III	CRF 5 IV	CRF 5 V			
	N_2O	N_2O	C	CO_2	N_2O	CH_4	
1990	0,057	0,022	0,170	0,018	<0.001	0,002	0,269
1991	0,033	0,027	0,134	0,017	<0.001	0,002	0,214
1992	0,024	0,029	0,109	0,017	<0.001	0,002	0,180
1993	0,021	0,035	0,130	0,018	<0.001	0,002	0,205
1994	0,018	0,038	0,156	0,017	<0.001	0,002	0,232
1995	0,021	0,042	0,169	0,017	<0.001	0,002	0,252
1996	0,019	0,045	0,193	0,018	<0.001	0,002	0,277
1997	0,015	0,049	0,174	0,096	0,001	0,009	0,344
1998	0,016	0,050	0,131	0,005	<0.001	<0.001	0,202
1999	0,020	0,050	0,156	0,032	<0.001	0,003	0,262
2000	0,020	0,054	0,156	0,032	<0.001	0,003	0,265
2001	0,017	0,058	0,137	0,033	<0.001	0,003	0,248
2002	0,011	0,061	0,131	0,053	<0.001	0,005	0,262
2003	0,014	0,067	0,128	0,066	0,001	0,006	0,281

2004	0,017	0,073	0,122	0,059	0,001	0,005	0,278
2005	0,025	0,077	0,117	0,055	0,001	0,005	0,279
2006	0,027	0,086	0,091	0,133	0,001	0,012	0,351
2007	0,037	0,078	0,119	0,026	0,000	0,002	0,263

Emissions of CO_2, N_2O and CH_4 from sources other than living biomass, organic matter and soils are relatively small. Emissions from i) direct N_2O emissions from nitrogen fertilization, ii) N_2O emissions from disturbance associated with land-use conversion to Cropland, iii) CO_2 emissions from agricultural lime application, and iv) GHG-emissions from biomass burning are quite limited in Sweden (Table 7.4). The total emission shows no obvious trend but instead a quite stable emission less than 0.4 M ton CO_2-equivalents every year during the period 1990-2007. Among the categories, the largest emissions originate from liming. Sweden does not report N_2O emissions from drainage of soils.

7.2 Source category 5A, 5B, 5C, 5D, 5E and 5F

7.2.1 Definition of land use categories

Sweden has defined Forest land according to the Global Forest Resources Assessment (FRA) 2005[160]. Forest land is land with a tree crown cover (or equivalent stocking level) of more than 10 percent, with a minimum area of 0.50 hectare and the trees should be able to reach a minimum height of 5 m at maturity *in situ*. However, there are two small discrepancies between the FRA 2005 definition and the definition implemented in the Swedish inventory. In the Swedish inventory permanent forest roads (width>5m) are not considered Forest land and no minimum width to constitute Forest land is considered (note that the strict terms of 11/CP.7 does neither mention the minimum width nor the forest roads, FCCC/CP/2001/13/Add.1, p 58). All Forest land is considered managed, i.e. even protection of forests in reserves is considered as management. Cropland is defined as regularly tilled agricultural land and all Cropland is assumed managed. Grassland is defined as agricultural land that is not regularly tilled and all Grassland is assumed managed. Generally, Wetlands is assumed unmanaged and is defined as mires and areas saturated by fresh water. A Wetland area of about 10 000 ha is used for peat extraction and assumed managed. Settlements are defined as infrastructure components such as roads and railways, power lines within forests, municipality areas, gardens and gravel pits. All Settlements are assumed managed. Other land is defined as impediments (waste land) and most of the mountain area in northwest Sweden and all Other land is assumed unmanaged. Land-use categories are monitored by the Swedish National Forest Inventory (NFI[161]). Management status of the reported land-use categories are summarized in Table 7.5.

[160] Food and Agriculture Organization of the United Nations, 2004
[161] Ranneby et al., 1987

Table 7.5 Management status of different land-use categories. An area could only be classified as belonging to one land-use category and the predominant land-use decides to which category.

Land Use Category	Abbreviation	Management status
Forest land	F	Managed
Cropland	C	Managed
Grassland	G	Managed
Wetlands	W	Unmanaged or Managed (small area)
Settlements	S	Managed
Other land	O	Unmanaged

7.2.1.1 THE CONNECTION BETWEEN NATIONAL AND REPORTED LAND USE CATEGORIES

The reported land use categories are based on 16 original national land use categories monitored by the Swedish National Inventory of Forests (RIS). For example in year 2000 the area of Forest land was estimated to 27 414 000 ha. Using national land use categories, this refers to 22 749 000 ha Productive Forest land (national category 01), 1 678 000 ha Mire (04), 520 000 ha Rock Surface (05), 268 000 ha Sub alpine Coniferous Woodland (06), 376 000 ha High Mountain (07), 1 615 000 ha Protected Area, Nature Reserve (11) and 208 000 ha to other categories (Table 7.6). Whatever national land use category registered, observe that if the international land use category (FRA 2005) is registered as Forest land, then the area is reported as Forest land.

Table 7.6 National Land Use Categories, their connection to the UNFCCC/KP Land Use Categories and their potential importance for carbon reporting. A=all land FAO Forest land, B=large areas FAO Forest land

National Land Use Category	UNFCCC/KP-Land Use Category	Carbon Stock In Living Biomass of Trees [T gram] Year 2000	Area [1000 ha] Year 2000	Additional Explanation
Productive Forest land (01)	F	1047	22749	Land which hosts a potential yield of stem-wood exceeding one cubic metre per hectare and year (A).
Grazing Land (02)	G	5,7	494	Not regularly cultivated.
Arable Land (03)	C	1,5	3052	Regularly cultivated
Mire (04)	W	35,6	4588	Land which hosts a potential yield of stem-wood lower than one cubic metre per hectare and year (B).
Rock Surface (05)	O	16,4	896	Rocky or stony areas. (B)
Sub alpine Coniferous Woodland (06)	F	8,2	307	Land-zone usually located between (01) and (07). (A)
High Mountain (07)	O	Low	3010	Usually unstocked or sparsely stocked. (B)
Climatic Impediment (08)	O	0,7	48	Usually located in flat terrain in northern Sweden. (B)
Road and Railroad (09)	S	0,5	445	For permanent use. Not only roadway and rail but also other connected areas as embankments and ditches.
Power line Within Forest (10)	S	0,2	145	Minimum width 5 m, otherwise Productive Forest land (01)
Protected Area, Nature Reserve (11)	(F)	Medium	3967	This land use category was left out 2003 and is thereafter included in the remaining land use categories.
Military Impediment (12)	S	Low	69	Could not be inventoried for security or safety reasons.
Urban Land (13)	S	Low	1185	Settlements of many different kinds.
Other land (14)	S	2,1	115	Different kinds of land that is not covered by Other land use categories. Examples: gravel pits, halting places and slalom slopes
Water (not sea) (15)	W	0	4009	Lakes, rivers, creeks, canals, pounds etc. Minimum width of 2 m.
Sea (16)	-	-	-	To check if the total land area is constant.
Total		1118	45080	

7.2.1.2 CONSISTENCY IN REPORTING LAND USE CATEGORIES

From a carbon-reporting point of view, the NFI has monitored land-use categories in a quite consistent way since 1983. Based on permanent sample plots, it is possible to trace both gross and net land-use transfers from 1983 onward. On Forest land, it is also possible to decide former land-use (Cropland or Grassland) before the base year (1990). All land areas are inventoried in the field except high mountains, military impediments and urban land (section 7.2.1.1). These latter land-use categories are only inventoried for area by remote sensing. It is assumed that their relative importance for the Swedish carbon budget is negligible.

A few inconsistencies in assessing land-use categories over time have been identified and corrected. Before year 2003, protected areas ("Protected Area, Nature Reserve"; section 7.2.1.1) constituted a national land-use category that was not regularly field inventoried. From 2003 onwards this land is included in other land-use categories. Starting in 1990 the changes in carbon pools in former "protected areas" is assumed to be zero and from 2003 potential changes will be reported based on field inventory data. The FRA 2005 definition of Forest land was introduced in the field inventory in 1998 and therefore, before that year, land-use categories have to be re-determined. A few inconsistencies in assessing land-use categories over time have been identified and corrected. How former protected areas are handled, the re-determination of land-use categories and the methodology for correcting inconsistencies in assessing land-use categories over time are described in more detail in the methodology section.

7.2.2 Definition of carbon Pools, CRF 5A, 5B, 5C, 5D, 5E and 5F

7.2.2.1 LIVING BIOMASS

The reported carbon refers to the biomass of all living trees with a height of at least 1.3 m. Thus, small trees, shrubs and other vegetation, such as herbs are not included in the figures. Both aboveground and belowground biomasses are reported. Aboveground biomass is defined as living biomass above stump height (1 % of tree height). Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*) and birch (*Betula pendula* and *Betula pubescens*) constitute about 92 % of the standing volume[162]. Broad-leaved species constitute most of the remaining 8 %. Belowground biomass is defined as living biomass below stump height (1 % of tree height) down to a root diameter of 2 mm (fine roots, <2 mm, are operationally defined as belonging to the dead organic matter pool or in the soil organic carbon pool). The living biomass is reported for all field inventoried land-use categories. The reported figures are estimated consistently, by the same monitoring design using the same functions, from the base year onward.

[162] Swedish University of Agricultural Sciences, 2004

7.2.2.2 DEAD ORGANIC MATTER

Dead organic matter includes the carbon pools dead wood and litter. Dead wood is defined as fallen dead wood or snags. Dead wood should have a minimum "stem diameter" of 100 mm and a length of at least 1.3 m. The dead wood is reported for all relevant field inventoried land-use categories. Litter includes all non-living biomass not classified as dead wood, lying dead, in various states of decomposition above the mineral or organic soil. This includes the litter, fumic, and humic layers. Live fine roots (<2 mm), are included in litter if found in the O horizon since they cannot be distinguished separately during sampling. Coarse litter is defined as dead organic material with a "stem diameter" between 10-100 mm and originating from dead trees. Fine litter from the previous season or earlier is regarded as part of the O horizon and sampled. Below-ground dead wood originating from stump and root systems of dead trees are not reported this year (section 7.7.1).

7.2.2.3 SOIL ORGANIC CARBON

Data for soil organic carbon on forest land and grassland includes all carbon in the mineral soil below the litter, fumic and humic layers and all organic carbon in soils classified as Histosols[163]. The carbon pool considered is soil organic carbon down to a depth of 0.5 m measured from top of the mineral soil or, alternatively, from the soil surface when the soil is classified as a Histosol. For the land-use categories Forest land and Grassland the calculation of changes is primarily based on soil sampling combined with pedotransfer functions and for histosols on emission factors. For the land-use category Cropland the soil organic carbon pool is defined as the top soil layer. The calculation of changes in mineral soils is based on modelling[164] and in agricultural organic soils (Histosols) on the mean annual subsidence rates modified by crop type.

7.2.3 Emissions of N_2O, CO_2 and CH_4, CRF 5(I), 5(II), 5(III), 5(IV) and 5(V)

7.2.3.1 DIRECT N_2O EMISSIONS FROM N FERTILIZATION, CRF 5(I)

Middle aged or older forest stands on mineral soils are sometimes fertilized to increase the forest production. In 1990, the fertilized forest area was estimated at 69 200 ha[165]. Since then, the annual fertilized area has decreased to about 20 000 ha in 1997-2004. In 2007, this area had increased to about 45 000 ha. The underlying data (areas) are based on an annual questionnaire sent to approximately 150 large-scale forest companies and constitute Official Statistics of Sweden collected by the Swedish Forest Agency. Large-scale forestry, defined as forest companies with more than 10 employees or owners of more than 5000 ha Forest land, contributes with 98.5 % of fertilizer related emissions of N_2O. Consequently, small-scale

[163] Food and Agriculture Organization of the United Nations, 1994.
[164] Andrén & Kätterer, 2001
[165] National Board of Forestry, 2004

forestry is assumed to contribute with approximately 1.5 % of the emissions. To estimate the total annual emission, area figures are multiplied with normal average spread amount of fertilizer N per hectare. The normal average spread amount per hectare is obtained from companies that are carrying out the fertilization in practice (there are only a few companies in this business).

7.2.3.2 N_2O EMISSION FROM DRAINAGE OF SOILS, CRF 5(II)

According to UNFCCC (decision 13/CP.9), reporting emissions of nitrous oxide from drainage (N_2O-direct $N_{drainage}$) is optional. One reason for that is the limited understanding of the processes controlling the emissions. No N_2O emissions from drainage of soils will be reported this year, but some preliminary studies indicate that reliable methods may be available in a few years.

7.2.3.3 N_2O EMISSIONS FROM DISTURBANCE ASSOCIATED WITH LAND-USE CONVERSION TO CROPLAND, CRF 5(III)

Due to more intensive soil management on Cropland, the transfer of other land-use to Cropland is usually associated with a temporary increase in the mineralization of organic matter. Part of the released N may be converted to N_2O through denitrification. Land converted to Cropland is reported as belonging to the conversion class for twenty years (if no secondary conversion occurs). An area of about 1000-8000 ha is annually reported in the class land converted from Forest land to Cropland and about 15000-70000 ha as land converted from Grassland to Cropland. The area of other land-use conversions to Cropland is negligible.

7.2.3.4 CARBON FROM AGRICULTURAL LIME APPLICATION, CRF 5(IV)

Lime is used for soil improvement in both agriculture and horticulture to mitigate acidification that is caused by the export of biomass, acidifying fertilizers and acid rain. The reported figures are based on quantities sold for agricultural and horticultural purposes plus lime from sugar mills and steel production. The quantities are separated into dolomite ($CaMg(CO_3)_2$) and limestone ($CaCO_3$), where dolomite and Mg-lime are reported as dolomite and all other categories are reported as limestone. All categories are supposed to contain 100 % dolomite/limestone except residual lime from sugar production which is assumed to contain 65 % limestone due to a water content of approximately 35 %. The accuracy of estimates of the sold quantities is assumed to be high and constitutes Official Statistics of Sweden[166]. Separate default IPCC emission factors are used for limestone and dolomite, respectively.

7.2.3.5 N_2O, CH_4 AND CO_2 FROM BIOMASS BURNING, CRF 5(V)

Terrestrial fires are very rare in Sweden. Wildfires have been monitored by the Swedish Rescue Services Agency since 1996[167] and the area of wildfires has varied from 400 to 6400 ha yr^{-1}. Controlled burning after clear-cutting to improve regen-

[166] Statistics Sweden, 2004
[167] Swedish Rescue Services Agency, 2004

eration of trees is monitored by a full record from 1990 and onwards (Swedish Forest Agency). Controlled burning for nature conservation is monitored from 2006. An area of approximately 1000-3000 ha is now annually burned after clear cutting and 400-1400 ha is now annually burnt for nature conservation. The Swedish Rescue Services Agency reports the annual area of wildfires for three different land categories: "Forest", "Sparsely covered by trees" and "No tree cover". The definition of "Forest" almost corresponds to the national definition of forest. "Sparsely covered by trees" are areas sparsely covered by trees such as mires, forest in the mountain area and parks. "No tree cover" is land with no trees such as agricultural land, open areas but also some mires. The assumed former stock on burned areas is based on above-ground figures of living and dead biomass inventoried by the NFI by matching national definitions to the definition by the Swedish Rescue Services Agency. The area of wildfires is probably slightly underestimated since the reported figures only include actual turnouts by the fire brigade. The accuracy of the burned amount of carbon per land category is probably low. This is due to a lack of knowledge about the burned stock in typically burned forests.

7.3 Methodological issues

7.3.1 CRF-tables 5A, 5B, 5C, 5D, 5E and 5F

7.3.1.1 BASE METHODOLOGY

Sweden reports CRF-tables 5A-5F according to the IPCC stock change method. Since the estimates are based on representative allometric single tree regression functions or on direct measurements, a low risk of bias is assumed. The stock change method is combined with a sample-based inventory design and it's possible to estimate errors of the estimates. Fortunately, the Swedish National Inventory of Forests (RIS[168]) has monitored the most relevant carbon pools before the base year (1990) and onward. Another advantage is that this has been undertaken by using permanent sample plots, with access to all land, and thus it is possible to monitor both gross and net land-use conversions for the six land-use categories in a consistent and transparent manner.

[168] Swedish University of Agricultural Sciences, 2005

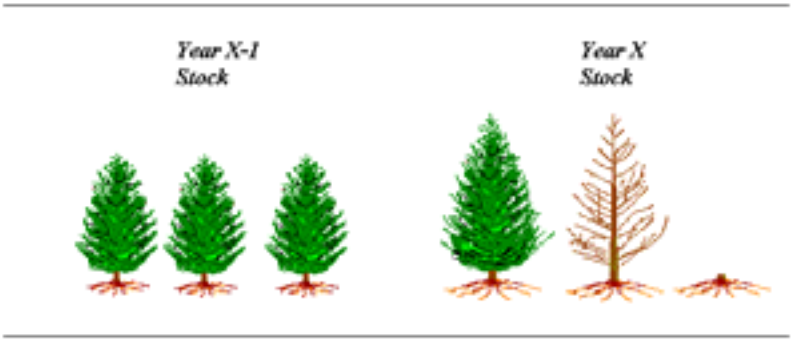

Figure 7.2 For year X, the net emissions/removals are reported as the difference in stock between year X and X-1 (The stock change method)

7.3.1.2 THE LULUCF-REPORTING DATABASE

The reporting database is based on permanent sample plots inventoried by RIS. In total, around 40000 permanent sample plots were laid out during the period 1983-1987 covering the whole country. Thus all land and fresh-water areas are monitored. The permanent sample plots have been re-inventoried at intervals of 5-10 years. The land-use of each plot (or sub-plot for plots divided in two or more land use classes) is described from the year of the first inventory and every year thereafter. The land-use of years between inventories has been interpolated. Before 2006 there were no information of when a land use transfer occurred between two consecutive inventories, so before that year a land use conversion is assumed to occur at a random year between inventories. From 2006 the year of land use conversions is judged in field (the re-inventory cycle is five years from 2003). Biomass pools for years between inventories are interpolated by linear interpolation. Plots without a full record have been removed from the reporting database and therefore the original number of sample plots has been reduced by about 25 % to about 30 000.

All figures for all plots are assumed to be correct and final for the reporting years 1990-2003. Due to a five-year inventory cycle, estimates of the five most recent years will be re-calculated in each submission . Theoretically, both the current and the re-calculated reporting will be unbiased. However, the accuracy will be better in the latter case.

7.3.1.3 THE SWEDISH NATIONAL INVENTORY OF FORESTS

The Swedish National Inventory of Forests (RIS[169]) consists of the Swedish National Forest Inventory (NFI[170]) and The Swedish Forest Soil Inventory (MI[171]). The NFI and the MI are integrated in the same sample design, using the same sample plots. However, the sampling interval of the soil inventory is longer since processes in the soil are much slower than in the living biomass. The NFI plots are re-inventoried every fifth year and MI plots every tenth year. Moreover, top soil cores are only taken at every second sample plot and lower soil horizons are only sam-

[169] Swedish University of Agricultural Sciences, 2005
[170] Ranneby et al., 1987
[171] Swedish University of Agricultural Sciences, http://www-markinventeringen.slu.se/

pled on every fourth sample plot. The reported data of changes in the living biomass and dead wood pools are based on the NFI and changes in the litter and soil organic carbon pools on the MI.

The NFI is an annual, systematic, cluster-sample inventory of Sweden's forests. Each year roughly a thousand survey sample clusters are inventoried in the field. One third of the clusters are temporary and two thirds are permanent. Only permanent sample plots are used for the UNFCCC/KP reporting. The clusters are distributed all over the country in a pattern that is denser in the southern part of Sweden than in the north. The clusters (tracts) are square-shaped with sample plots along each side. There are between four and eight sample plots in each cluster, depending on geographical region. Each year, about 6000 permanent survey sample plots are inventoried in the field. On each circular sample plot, with a radius usually of 10 or 20 m, information is collected about the trees, the stand and the site. The focus of the NFI is on monitoring forests for timber production and environmental protection.

The MI uses the 10-m radius sampling plot. On that plot, MI records general site variables, describes the soil and humus type, performs litter and soil sampling and carries out a vegetation inventory of the bottom and field layer. Depending on the humus type classification the O, H and A horizon are sampled using an augur. The mineral soil is sampled in different layers according to the distance from the soil surface and to some extent depending on the soil type. From 2003 and onwards the soil sampling has been harmonized with an ongoing European inventory, i.e. Biosoil and soil samples are taken at fixed depths throughout the profile.

7.3.1.4 SAMPLE BASED ESTIMATIONS

The sample frame consists of a map covering the whole land and fresh water area of Sweden. A sea archipelago zone where islands covered by vegetation might occur is also included in the frame (but no sea area is reported). The frame is divided into about 30 strata and a specific number of sample units are sampled per stratum. Each cluster (tract) of sample plots is assumed to be the sample unit. The inventoried area of a tract will represent a large area in the estimations of area weight and the sum of all represented areas will be equal to the total county area.

Whole plots or plot parts may change land use category by time but the total tract area will always represent the same area. At the county level, the reported value of a change in a carbon pool (for example a change in the living biomass pool for land use category Forest land remaining Forest land) will be estimated by a ratio estimator[172]. Finally the reported value on national level is estimated as the sum of the county values.

Sweden will only report “human induced” carbon changes, where “human induced” has the interpretation of “managed”, i.e. the biomass stock change on unmanaged land are set to zero. However, the “actual” stock on unmanaged land is considered when calculating stock changes after conversions between unmanaged and managed land and vice versa. All areas, managed or unmanaged, are reported.

[172] Thompson, 1992

7.3.1.5 LAND USE TRANSFERS CRF-TABLES 5A, 5B, 5C, 5D, 5E AND 5F

Land-use transfers are assumed to occur at a random year between two consecutive inventories but from the inventory year 2006 the year of conversion is judged in field. Every plot that is converted to another land-use category is reported for 20 years in the land-use transfer class. After 20 years the plot will be reported in the class to which it was transferred. If a second land-use conversion occurs within the 20 years, the counting starts all over again and the second transfer is reported for 20 years in the land-use transfer class as in the first example. It is also possible to trace back some of the land-use transfers that occurred up to 20 years before 1983 and consequently it is also possible to decide how many years a sample plot has belonged to a certain land-use category and what land-use category it was converted from.

Protected areas were not regularly field inventoried until year 2003 when the variable "Protective Area, Nature Reserve" was excluded from the NFI. Since 2003 the protected land areas have been included in other land-use categories. Therefore formerly protected areas have been given the same land-use category/biomass pools as estimated since the 2003 inventory.

As mentioned, the FRA 2005 definition of Forest land was introduced in 1998. Therefore, land-use categories have to be re-determined for the period 1990-1997. There are two main types of redetermination cases which are handled as follows:

1. If the land-use category for a sample plot was registered as Forest land at the first inventory after 1997 and the national land-use category (see Table 7.6) had been the same at all earlier inventories since 1990, the plot are assumed to have always belonged to the land-use category Forest land.
2. If the land-use category was registered as Forest land at the first inventory after 1997 and the national land-use category (see Table 7.6) had changed since 1990, the first land-use category are assumed to remain until the year of conversion. If at consecutive inventories after that, the land-use category belonged to the same land-use category, the plot is assumed to belong to the category Forest land all years after the year of conversion.

Two types of inconsistently classified land-use transfers have been identified and corrected:

1. Inconsistency over time in applying land-use category definitions.
2. Inconsistency in delineating borders between plots divided into more than one land-use category.

One example of the first type is when at different inventories, the land-use category of a sample plot has been classified as Forest land at the first inventory, as Wetland at the next inventory and then again as Forest land at the third inventory without traces of human activities. A case like this is corrected so that the land-use category is assumed to be Forest land on all three occasions. Another example of the first type is when a recreation forest close to a city has been converted from Settlements

(section 7.2.1.1, national land-use category 13, "Urban land") to Forest land and the new land-use category consists of old trees. This has been corrected so the land-use is assumed as Forest land on both occasions. One example of the second type is when the delineation of a divided plot, representing more than one land-use category, has been changed at the re-inventory due to personal judgments rather than due to actual changes. These land-use changes should not be registered as ARD-activities and have been corrected by keeping the newer delineation, usually if the assumed incorrect new delineation deviates approximately less than 0.75 m^2 from the old delineation. If the affected area is larger, the new delineation is assumed to be correct. Rules for automatic and manual corrections of inconsistencies and the actual corrections are saved and could be verified on request.

7.3.1.6 METHODOLOGY LIVING BIOMASS CRF 5A, 5B, 5C, 5D, 5E AND 5F

A national methodology (Tier 3) is used. The aboveground biomass per fractions is estimated by applying Marklund's[173] biomass functions to calliper and sample trees on permanent sample plots of the NFI[174]. The below-ground biomass is estimated by using Peterssons and Ståhl's[175] biomass functions on biomass data from the same trees as for the aboveground biomass. The conversion factor 0.49 is used to convert biomass to carbon[176]. Estimates of the annual change in the carbon pools are based on repeated measurements. Consequently, the stock change of for example year 2000 is calculated as the difference in stock between year 2000 and year 1999.

7.3.1.7 METHODOLOGY DEAD ORGANIC MATTER CRF-TABLES 5A, 5B, 5C, 5D, 5E AND 5F

A national methodology (Tier 3) is used to estimate the dead organic matter pool. The pool includes different sub-pools that are estimated slightly differently. The reported stock change is the annual average change in the trend in carbon stock of the pool between 1993 and 2004 except for the dead wood and coarse litter. The inventory of dead wood began in 1995 (for northern Sweden, 1994) and this year's reporting is based on up to approximately 24000 sample plots inventoried in 1995/1999, 1996/2000, 1997/2001 and 1998/2002 and re-inventoried in 2004, 2005, 2006 and 2007, respectively. The carbon content in dead wood was calculated using conversion factors from volume per decay class to biomass for the species Norway spruce and Scots pine. The volume is measured by the NFI. Below-ground dead wood originating from stump and root systems of dead trees is not reported in submission 2009.

The carbon in the litter pool is estimated based on three different sources (i) coarse litter (ii) annual litter fall and (iii) litter < 2 mm. Coarse litter is defined as dead organic material with a "stem diameter" between 10-100 mm and originating from dead trees. Coarse litter is not inventoried but calculated as 15 % of the

[173] Marklund, 1987 and 1988
[174] Ranneby et al., 1987
[175] Petersson and Ståhl, 2006
[176] National Board of Forestry, 2000

aboveground dead wood. Litter fall is calculated using empirical functions based on tree stand properties and litter fall for deciduous species by biomass functions based on leaf biomass. This fraction of litter is regarded as an annual pool. The remaining part of this pool after one year is included in the O horizon and thus measured by the soil inventory. The fine litter (< 2 mm) is estimated by sampling the O or H horizon sample which is taken on an area basis, weighed and analysed for carbon content for further details, see annex 3.

7.3.1.8 METHODOLOGY SOIL ORGANIC CARBON CRF 5A, 5B, 5C, 5D, 5E AND 5F

The soil organic carbon pool is estimated using different approaches depending on the land use. For Forest land and Grassland mineral soils estimates are based on repeated soil sampling in combination with pedotransfer functions. For organic forest and grassland soils the changes are based on emission factors and area estimates of different sub-categories. For Cropland the ICBM model[177] is used to predict changes in the soil organic carbon stock on mineral soils and an estimation of the subsidence to calculate the change on organic soils.

7.3.1.9 FOREST LAND AND GRASSLAND ON MINERAL SOILS CRF 5A AND 5C

The method is a Tier 3 method. The estimates are based on repeated measurements on the NFI plots of several variables. The basic function used to determine the amount of carbon in a soil layer is based on the amount of carbon in a certain soil layer and the fraction of fine earth. The amount of fine earth is dependent on the bulk density and amount of gravel, stones and boulders in the soil (for further details, see annex 3):

7.3.1.10 FOREST LAND AND GRASSLAND ON ORGANIC SOILS CRF 5A AND 5C

The method is a Tier 2 method. Changes in the organic carbon pool are calculated as the difference between annual below ground litter input and the heterotrophic respiration. Annual litter production is derived from the National Forest Inventory and the emission factors for drained and undisturbed organic forest soils are based on studies from Sweden and Finland (for further details see annex 3)

7.3.1.11 CROPLAND ON MINERAL SOILS CRF 5B

The method to estimate the carbon balance of agricultural soils is a Tier 3 method. The carbon changes in the mineral soil are calculated based on data from eight agricultural production regions using the model ICBM-region. The ICBM model is described in Andrén & Kätterer[178]. The calculations are based on daily weather data, annual crop harvest statistics, the use of manure in each region and the results

[177] Andrén & Kätterer, 2001
[178] Andrén & Kätterer, 2001.

from a nationwide survey of agricultural soils including data on carbon content and texture[179].

7.3.1.12 CROPLAND ON ORGANIC SOILS CRF 5B

The method to estimate the carbon balance of organic agricultural soils is a Tier 2 method. A national emission factor for cropland on organic soils is used to calculate the mean annual carbon loss per cm soil subsidence. The emission factor is modified according to crop type. The relative area proportion of the different crop types and the total area of organic soils under agricultural production was estimated in a national survey in 2005[180].

7.3.1.13 CO_2 EMISSION FROM MINERALIZATION WHEN EXTRACTING PEAT CRF 5D

The method used to estimate CO_2 emission from peat extraction areas is a Tier 1 approach. A limited area of Wetlands (10000 ha) used for peat extraction is considered managed and reported under Wetlands remaining Wetlands. The reported CO_2 emissions refer to mineralization when extracting peat for fuel and agricultural purposes. The emitted CO_2 [M ton•yr^{1}] is calculated as the product of the extracted area and an emission factor (for further details see annex 3).

Peat extraction is only ongoing on part of the production area. The peat extraction is usually proceeding many years on the same production area until this area is closed down and restored. Former managed peat land is usually restored by saturation by water or by conversion to Forest land. The water saturation will probably stop most carbon mineralization and Wetlands converted to Forest land is reported under Wetlands converted to Forest.

7.3.2 CRF 5(I), 5(II), 5(III), 5(IV) and 5(V)

7.3.2.1 DIRECT N_2O EMISSIONS FROM N FERTILIZATION, CRF 5(I)

A Tier 1 methodology is used and the reported figures refer to $N_2O_{direct\ fertilizer}$ (of N). All fertilization is assumed to occur on Forest land remaining Forest land. In year 1990 nitrate of lime ($Ca(NO_3)_2$) was the dominant fertilizer but thereafter the fertilizer have been based on 50 % NO_3-N and 50 % NH_4-N. The reported annual $N_2O_{direct\ fertilizer}$ [Gg•yr^{-1}] is calculated as the product of the applied amount and the emission factor (for further details see Annex 3).

7.3.2.2 N_2O EMISSIONS FROM DRAINAGE OF SOILS, CRF 5(II)

Not reported (optional).

[179] Eriksson 1997,1999
[180] Berglund and Berglund, 2005

7.3.2.3 N_2O EMISSIONS FROM DISTURBANCE ASSOCIATED WITH LAND USE CONVERSION TO CROPLAND, CRF 5(III)

A Tier 1 methodology is used. The reported annual N_2O emission from disturbance associated with land use conversion to Cropland (N_2O_{conv} [Gg•yr^{-1}]) is calculated according to equation 3.3.15 in IPCC GPG for LULUCF (IPCC[181]) (for further details see Annex 3).

7.3.2.4 CARBON FROM AGRICULTURAL LIME APPLICATION, CRF 5(IV)

Methodology level Tier 1-2 is used for reporting carbon emissions from liming. The reporting is based on consumption studies[182] and all liming is assumed to occur on Cropland remaining Cropland. The reported annual carbon emission from agricultural lime application (C_{lime}; [Gg•yr^{-1}]) is calculated as the product of the applied lime and the emission factors (see Annex 3 for further details).

7.3.2.5 EMISSIONS FROM BIOMASS BURNING, CRF 5(V)

A Tier 1 methodology and IPCC default emission factors are used. All land categories are monitored but the reported emission is assumed to occur only on Forest land remaining Forest land and on Grassland remaining Grassland. Calculations are based on the amount of biomass per area, burned area and emission factors (for further details see Annex 3).

7.4 Uncertainties and time series consistency

7.4.1 Uncertainties

Inventory agencies may apply national methods for estimating the overall uncertainty. Since the Swedish reporting system of the LULUCF-sector mainly is based on sampling, a national method is chosen. Uncertainties from reported estimates arise from random and systematic errors. Random errors dominate for the living biomass, dead organic matter and soil organic pools and systematic errors for other pools. For estimated annual emissions and removals, a summary of uncertainties is found in Table 7.7. The random errors could be estimated by statistical theory but systematic errors are often hard to quantify. Generally for Sweden, the systematic error induced by activity data is small compared to the error due to use of incorrect emission factors. Systematic errors could also arise from missing or overlapping pools. Systematic errors are subjectively judged with help from experts and from default error values according to IPCC[183].

[181] Intergovernmental Panel on Climate Change, 2003
[182] Statistics Sweden, 2004
[183] Intergovernmental Panel on Climate Change, 2003

Table 7.7 Estimated annual net emissions/removals and their corresponding uncertainty (2•relative "standard error"). For categories Living biomass, Dead organic matter and Soil organic carbon, standard errors are based on random sampling. For other categories, standard errors refer to biases that are assumed. Assuming GWP=1 for CO_2, 310 for N_2O and 21 for CH_4, the uncertainty level for the total net removal is estimated to 39 %. Combined uncertainties are calculated according to IPCC, minus=removal

	Emission/Removal [Gg•yr^{-1}]			2·Relative Standard [%]		
Category	CO_2	N_2O	CH_4	CO_2	N_2O	CH_4
Living biomass	-20946	-	-	29	-	-
Dead organic matter	-4621	-	-	70	-	-
Soil organic carbon	4845	-		35	-	-
Direct N fertilization, 5 (I)	-	0.119	-	-	50	-
Drainage of soils, 5 (II)	-	NE	-	-	NE	-
Conversion Cropland, 5 (III)	-	0.253	-	-	100	-
Agricultural lime application, 5 (IV)	119	-	-	50	-	-
Biomass burning, 5 (V)	26	0.001	0.113	50	75	75
All	-20578	0.373	0.113	39	87	75

7.4.2 Living biomass, CRF 5A, 5B, 5C, 5D, 5E and 5F

The estimated accuracy of the living biomass pool depends mainly on the sample design of the NFI. Results from the control inventory of the NFI indicate that measurement errors, registration errors and errors caused by the instruments (callipers) could be assumed to be close to zero. Potential bias induced by incorrectly specified models and an unrepresentative derivation data are ignored. Estimates for reporting years 1990-2003 are based on approximately 30000 sample plots and with a corresponding estimated relative standard error of 11% (or 3 M ton CO_2-equivalents). Estimates for reporting years 2004, 2005, 2006 and 2007 are based on approximately 24000, 18000, 12000 and 6000 sample plots, respectively. Consequently, the relative sample error increases from 2003 onwards. Estimates of the five most recent years will gradually be updated at each submission. The re-calculation is motivated by obtaining a smaller sampling error. Still, the expected values of former and re-calculated estimates are the same.

7.4.3 Dead organic matter, CRF 5A, 5B, 5C, 5D, 5E and 5F

Estimates of dead organic matter are based on sampled data from the litter pool and dead wood pool from the NFI and the MI. The sample error for the entire dead organic matter pool is calculated similarly to the living biomass calculation and is given in Table 7.7. There is probably a small error in the estimates of dead wood due to incorrect measured volumes and due to errors connected to the conversion from volume to carbon. Coarse litter is calculated as 15 % of the dead wood. The error of this proportion might be large since the knowledge of the relation between the amount of dead wood and coarse litter is poor. Compared to submission 2008 accuracy has improved since the reported figures now are based on more repeated measurements of permanent sample plots (1995 to 2005) and O horizon samples (1993-1996 to 2003-2005), and because we are now also basing the estimate on

interpolated values for years between inventories. The accuracy will increase in the future when the estimates will be based on more data from repeated measurements.

7.4.4 Soil organic carbon, CRF 5A, 5B, 5C, 5D, 5E and 5F

The sample error for the soil organic carbon pool is calculated similarly to the living biomass calculation and is given in Table 7.7 The problems associated to the estimates of changes in the soil carbon pool is of the same nature as the ones described for the dead organic matter pool above, and significant improvements are expected when the proportion of repeated measurements will increase. Another problem associated to our methodology is the risk of systematic errors in the sampling and analysis of data. Since there are rather small changes in large pools even a small systematic error may cause a trend in the material. From 2003 the sampling methods of soil samples have been changed compared to earlier inventories in order to avoid subjective judgments in sampling, e.g. regarding determination of soil horizon boundaries. This might give rise to problems of comparability between inventories but should improve the quality of the data by reducing future risks of systematic errors. Significant efforts are made to check data and to remove possible sources of error in the field data collection. The uncertainty in activity data (area) for CO_2 emission from drained forest land is judged to 25 % and errors in the emisson factor to 25 % as well. The uncertainty in activity data (area) for CO_2 emission from mineralization when extracting peat is judged to 25 % and the uncertainty due to errors in the emission factor chosen is judged to 300 %. The high error of the EF is based on the fact that i) the variation between different emission factors is significant[184], and ii) the underlying data of the EF does not perfectly match the target population[185,186].

7.4.5 Other CO_2 emissions, CRF 5(IV) and 5(V)

The reported CO_2 emission from agricultural lime application is based on consumption studies and the design is regarded as a total inventory with no random error. The error due to activity data is probably small and the reason for this is high quality data on quantities of limestone and dolomite sold. It is assumed that the error due to the use of incorrect emission factors used might be quite large. The reported uncertainty is based on a default error from IPCC[187].

Uncertainties from biomass burning arise from the errors in the estimated area that is burned and in the emission factors used. The emitted amounts per area unit depend on the biomass stock before the fire and the proportion of this biomass that actually is burned. The error of the estimated burned area is probably quite small but the knowledge of emitted amount per area is quite poor. The reported uncertainty is based on a default error from IPCC.

[184] Statistics Sweden, 2002
[185] Kasimir-Klemedtsson et al., 2000
[186] Sund et al., 2000
[187] Intergovernmental Panel on Climate Change, 2003

7.4.6 N_2O and CH_4 emissions, CRF 5(I), 5(III) and 5(V)

Generally for all N_2O and CH_4 emissions, the error in activity data is small compared to the error due to incorrect emission factors.

For N_2O emissions from N-fertilization, the error due to activity data is judged to 3 % of the emission (the Swedish Forest Agency) and the default total error to 25%. However, a recommendation is that emission factors chosen should be within the range 0.25 % to 6 % and the interpretation is that a badly chosen emission factor could lead to an error that is much larger than 25 %. Based on this information a total error of 50 % for N_2O emissions from N-fertilization is suggested.

The accuracy of estimates of N_2O emissions from disturbance associated with land-use conversion to Cropland is assumed lower than for N_2O emissions from N-fertilization. This because, it is assumed that the error of the activity data (ΔC from mineralization) is higher and due to a potential error from an incorrect C:N-ratio chosen. The uncertainly level is based on this reasoning and on IPCC default values (IPCC).

Following the same reasoning as for CO_2 emissions from biomass burning, the uncertainty of N_2O and CH_4 emissions from biomass burning are assumed to be 75 %, (Managing uncertainties: A.1.4).

7.4.7 Completeness

It is assumed that all categories have been reported only once. Theoretically Sweden has the possibility to report the pool of below-ground dead stump systems, but this has not yet been done. The cuttings have gradually increased since 1990[188], so today this pool is probably a net sink. Harvested wood products are not reported and factoring out has not been considered.

7.4.8 Time series consistency and verification

The estimates of living biomass were incorrect in the original submission 2008. Since the rebsubmission was based on the same dataset as this submission there are no discrepancies in the data between the submissions.

7.5 QA/QC

7.5.1 Quality assurance

The quality assurance system of the data collection within RIS used for the UNFCCC and Kyoto reporting has been described by the Swedish University of Agricultural Sciences[189] and a detailed description of routines is under development. These routines were improved during 2006 cooperating with SLU. SLU also works closely with the Swedish EPA to enhance the QA/QC. For this submission, quality assurance has been carried out in an internal review by experts at SLU. A

[188] National Board of Forestry, 2004
[189] Karltun, E., Stendahl, J., Löfgren, O. 2005.

national review has been carried out by representatives for the Swedish Forest Agency and Swedish Board of Agriculture.

7.5.2 Quality control

An internal quality control has been performed following level Tier 1, (Table 5.5.1 in Good Practice Guidance 2003).

For reported activity data, descriptions of definitions, description of underlying models, description of sampling design and emission factors used were studied and no errors were found. This was also valid for descriptions of land areas, eventual transcription errors and references. Both calculations and units of estimates were cross checked and seem reasonable. Data from the NFI constitute official statistics of Sweden and were not checked. All data (and methodologies used) is archived by the SLU.

7.6 Recalculations

The living biomass pool, land use areas and areas subject to land use transfers have been recalculated to improve accuracy and are now based on up to 30000 instead of 24000 sample plots. The pools dead organic carbon and soil organic carbon have been recalculated for the whole time series from 1990 to 2007 due to (i) introduction of more reinventoried sample plots, and (ii) due to a change in methodology for drained organic soils. The reported emission from nitrogen fertilization of year 2006 has been recalculated due to more accurate underlying area-data. As a result from updating all land use areas, every N_2O emission from disturbance associated with land use conversion to Cropland have been recalculated. Year 2006 for emissions from biomass burning, wildfires has been updated (a large fire were not included in submission 2008). The area used for peat-extraction of year 2006 is updated to 6200 ha.

7.7 Coming improvements

7.7.1 Improvements of estimated pools

Gradually, the reporting of the living biomass pool, the dead wood pool, and land use will be based on up to 30000 sample plots. This will improve the accuracy of the estimated emissions or removals. The reporting of the soil organic pool will also be based on more sample plots, but since the re-inventory cycle is longer and since the sample intensity for soil data is lower than for biomass, the final sample design will be based on less than 30000 sample plots. The coarse litter pool might be monitored with a methodology similar to the one used for the below-ground dead wood (section 7.7.1). Emissions from the litter pool is not considered for fires and the emission factor used for controlled burning in nature reserves might lead to overestimations of the emissions. The reporting of pools will be slightly different for the Kyoto Protocol by subdividing the pools living biomass, dead organic matter and soil organic carbon into five sub-pools based on the current methodology. These five pools will match differently to land use classes. Sweden has chosen forest management under article 3.4. in the Kyoto protocol and since all forest land is assumed to be managed, this is supposed to be the most important reporting

activity. The reporting of afforestation, reforestation and deforestation is mandatory and is also assumed important for the Swedish reporting.

7.7.2 Methodology

For reporting under the Kyoto Protocol during the commitment period 2008-2012, it is permitted to recalculate figures until year 2014, then 100 % of the 30000 plots, 100 %, 80 %, 60 % and 40 % will be used for the reporting of years 2008, 2009, 2010, 2011 and 2012, respectively (Table 7.9). In theory, this will lead to unbiased estimates but with a gradually lower accuracy of the estimates.

Table 7.9 A single sample plot will be inventoried in one of ten inventory intervals. Blue background refers to measurements and in 2014 only plots of type 1, 2, 9 and 10 have a full re-inventoried record 2008-2012. Final re-calculated figures will be based on all sample plots for years 2008 and 2009, on 80 % of the plots 2010, on 60 % of the plots 2011 and on 40 % of the plots 2012.

1	2	3	4	5	6	7	8	9	10
2008	2008	2008	2008	2008	2008	2008	2008	2008	2008
2009	2009	2009	2009	2009	2009	2009	2009	2009	2009
2010	2010			2010	2010	2010	2010	2010	2010
2011	2011					2011	2011	2011	2011
2012	2012							2012	2012
2013	2013								

8 Waste (CRF sector 6)

8.1 Overview

In this sector, the most important emissions of greenhouse gases are those of CH_4 from solid waste landfills. A minor category is N_2O from wastewater handling. Emissions of CO_2, NO_X, SO_2 and NMVOC are reported from waste incineration. For both CH_4 and N_2O together, the trend over the last ten years has been a constant reduction of emissions by about 30 % (based on CO_2 equivalents). These trends can be explained by the decreasing quantities of organic waste deposited at landfills interacting with an until 2003 increasing quantity of recovered CH_4. There has also been a reduction in the quantity of nitrogen discharged from municipal wastewater treatment plants from the mid 1990s when nitrogen treatment in wastewaster treatment plants in Sweden was developed.

8.2 Source category description

8.2.1 Solid waste disposal on land, CRF 6A

8.2.1.1 WASTE TREATMENT IN SWEDEN

Waste management in Sweden has developed over recent years. Legislation, such as the implementation of EU directives and national tax policies in the waste management field, has forced and encouraged investments in new technical solutions and treatment methods.

The most important change is the implementation of section 26 of the Waste Collection and Disposal Ordinance, concerning combustible waste, and section 27 of the prohibition on separated combustible waste in landfills. These were implemented on January 1st 2002. The section of the Ordinance prohibiting the deposition of organic waste as landfill was implemented on January 1st 2005.

During the 1990s, the amount of deposited waste decreased significantly, due to the implementation of waste treatment policies. This is especially notable for household waste, which is the largest contributor of greenhouse gases of all waste categories. Only 4.0 % of the generated household waste (in Sweden also refered as “Municipal waste”) was deposited in 2007. The remaining part was converted into fuel (46.4 %) or recycled (36.8 %) or treated biologically (11.9 %).

In 2007 there were about 140 active landfill sites for municipal waste in Sweden, according to Avfall Sverige – Swedish Waste Management. The number of sites receiving more than 50 tonnes of waste has decreased by about 160 sites since 1994. In 2007, landfill gas was extracted at 70 landfills of which 60 were active landfills.

Depositing has become an expensive solution for the disposal of waste. Since January 1st 2000, there is taxation on depositing, currently 435 SEK per ton of

waste liable to taxation. This action is presumed to have contributed to reducing the amount of deposited municipal waste (section 8.2.1.2). The trend is expected to continue in the future because of actions such as the ongoing comprehensive extension of the treatment capacity of Swedish incineration plants for household waste (with energy recovery) and the implementation of the legislation mentioned above.

8.2.1.1.1 Biogas production and utilization

According to a survey[190] by the Swedish Energy Agency, the production of biogas in Sweden 2006 was 1 213 GWh (or 87.0 Gg in methane) to be compared with 1 239 GWh (or 88.9 Gg in methane) in 2005. In 2006, 28 % of the produced energy from biogas was produced at landfills. The biogas production decreased by 16 % from 2005 to 2006, mainly because of the amounts of deposited organic waste decreased significantly the past years, due to the implementation of waste treatment policies. Biogas from landfills is mainly used for heating but also for production of electricity. None of this gas is used as vehicle fuel because of the difficulties to upgrade the gas to sufficient quality. Ca 18 % of the biogas produced at landfills was flared.

8.2.1.2 EMISSION ESTIMATES

The decrease in deposited waste quantities reduces the potential of methane emissions from landfills. Figure 8.1 shows the methane emissions calculated by the IPCC default model and the IPCC First Order Decay (FOD) model respectively.

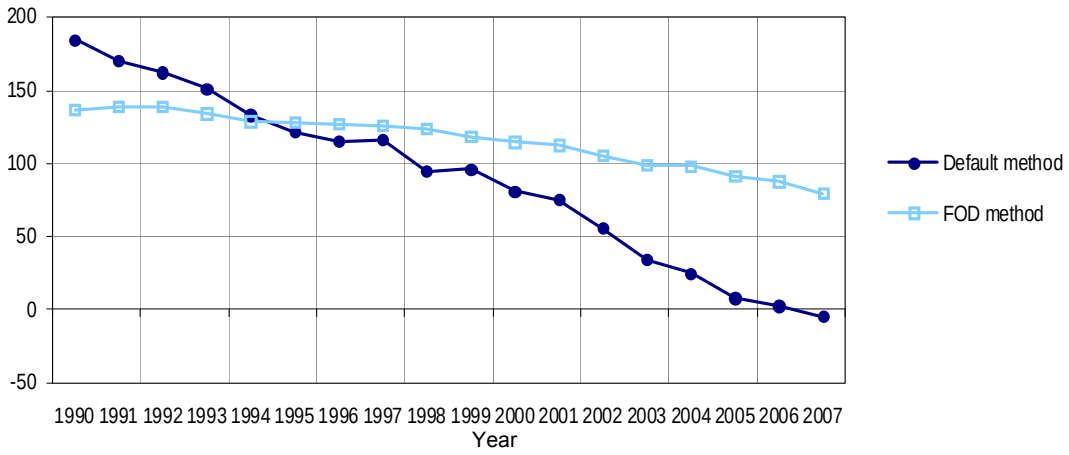

Figure 8.1 Emission of methane from Swedish landfills 1990-2007, estimated by the two IPCC methodologies, (Gg CH_4.)

The two methods are not really comparable. According to the default model, there is a rapid decrease that immediately follows the decrease in deposited waste. By using this model, the annual landfill gas potential is calculated, rather than the actual gas emissions. The gas emission value for 2007 is negative (-4.7 Gg) since the quantity of recovered gas exceeds the landfill gas potential for waste deposited

[190] Swedish Energy Agency, 2008

the same year. The FOD model, on the other hand, uses a time factor representing the delay in methane production, which results in a slower decrease of emitted methane. The estimates of the FOD model are used in the Swedish National GHG Inventory. In Table 8.1, the estimates from the FOD model and the deposited amount of municipal solid waste (MSW) are presented.

Table 8.1 Methane emission from Swedish landfills according to IPCC Default and FOD methods. Deposited MSW*, Sludges and Total, 1990-2007

Year	Gas emissions Default method Gg CH_4	Gas emissions FOD method Gg CH_4	Deposited MSW* in 1000 tonnes	Deposited sludge from wastewater handling and pulp industry in 1000 tonnes	Total deposited waste** in 1000 tonnes
1990	185	137	2323	1400	5563
1991	170	139	2223	1262	5161
1992	162	139	2203	1174	4977
1993	151	134	2199	1086	4824
1994	133	129	2166	860	4547
1995	122	128	1974	850	4330
1996	115	127	1856	880	4145
1997	116	126	1842	975	4203
1998	95	124	1678	700	3868
1999	96	119	1756	620	3853
2000	81	115	1529	587	3720
2001	76	113	1488	514	3488
2002	56	105	1338	341	3006
2003	34	99	1034	223	2688
2004	25	98	810	113	2380
2005	8	92	541	58	2067
2006	3	88	424	39	1944
2007	-5	80	316	39	1852

* Includes household and similar waste, park and garden waste, industry- and non-industry specific waste (organic fractions), construction and demolition waste (organic fraction).

** Includes household and similar waste, park and garden waste, industry- and non-industry specific waste (organic and inorganic fractions), construction and demolition waste (organic and inorganic fractions) and sludge from wastewater handling and pulp industry.

8.2.1.3 WASTE STATISTICS IN SWEDEN

The Swedish EPA made the first national survey in Sweden in 1980, collecting data on deposited waste (only for household waste and similar). Statistics Sweden collected similar data in 1985, 1990 and 1994. Since 1994, Avfall Sverige – Swedish Waste Management (former RVF) has carried out an annual survey on deposited waste. Thus, household waste is the best documented waste category, with high quality data available since 1980. Household waste is also the most important category for methane production in landfills. Statistics on deposited sludge from households and park and garden waste are available since 1990. Standard values on fractions of deposited household waste from 1970 and 1975 are also available at Avfall Sverige.

Statistics on biological waste from industry are much scarcer. There is information on industrial waste from the 1980s but biological fractions were not specified. The official statistics from 1993 and 1998 on waste from manufacturing do not emphasize generation and treatment of organic waste. Dedicated studies on quantities and treatment of biological waste from industry were carried out in 1993 and 1996 by the Swedish EPA. According to these studies, deposited sludge from the pulp industry has previously been the most important organic deposited industrial waste category. This waste category is also documented by surveys, carried out regularly until 2000 by the Swedish EPA. Today the sludge from the pulp industry is incinerated and composted.

8.2.1.4 WASTE CATEGORIES

8.2.1.4.1 Household waste, sludge and garden waste

Table 8.2 summarizes the available statistics on household waste, sludge from waste water treatment and garden waste. Interpolation is used for the intermediate years. Before 1990, park/garden waste and sludge from households are assumed to be directly proportional to the population, with the same proportion as in 1990.

Table 8.2 Deposited household waste, sludge and garden waste (1000 tonnes).

Year	Household waste (and similar)	Sludge from waste water treatment, wet weight	Garden waste
1980 [1]	1 450	..	..
1985 [2]	1 040	..	..
1986 [3]	1 020	..	..
1988 [4]	1 080	..	..
1990 [5]	1 400	900	70
1994 [6]	1 380	610	80
1995 [7]	1 200	540	60
1996 [8]	1 110	470	70
1997 [8]	1 150	455	50
1998 [9]	1 020	490	45
1999 [10]	972.5	490	45
2000 [11]	869.5	345	53
2001 [12]	880	330	44
2002 [13]	820	215	40
2003 [14]	575	155	33
2004 [15]	380	102	0*
2005 [16]	210	58	0*
2006 [17]	226	39	0*
2007 [18]	187	39**	0*

1) Swedish EPA, 1983. 2) Statistics Sweden, 1988; RVF. 3) RVF, 1988. 4) RVF, 1990. 5) Statistics Sweden, 1992. 6-16) RVF, 1996-2006. 17-18) Avfall Sverige, 2007- 2008

* Included in household waste from reference year 2004. ** Estimate

The composition of household waste has been investigated in many studies over the years. Ohlsson[191] presents a historic overview of Swedish investigations, the first of which was carried out in 1977. The time series indicates a rather constant composition of components, except the paper content, which declines during the 1990s. The chosen composition[192] for 1990 and 1995 are presented in Table 8.3. The composition in the years between the surveys is interpolated. It should be pointed out that this type of analysis contains an unknown variation, and the source of error may be large. Ohlsson also shows that different studies may differ greatly in methods and results.

In 2005, another overview of household waste composition was published.[193] Different fractions of household waste from southern Sweden have been analysed with the same methodology in 3 different years (1997, 2000 and 2004), see further in Table 8.3

Table 8.3 Content of Swedish household waste, %.

	1990	1995	1997	2000	2004
A, Paper and textiles	33	28	23	25	18
B, Garden/park waste, and diapers	14	14	14	11	13
C, Food waste	40	40	41	39	43
D, Wood	1	1	1	1	1

In Sweden the section of the Ordinance prohibiting the deposition of organic waste as landfill was implemented on January 1st 2005. The impact of the new legislation on the DOC content of deposited household waste has not yet been investigated and documented, but the waste composition has probably changed as a result of increasing separation of waste at the treatment plants before landfilling. Organic fractions are separated and the waste treatment plants need permissions in order to deposit organic waste.

8.2.1.4.2 Industrial waste

As noted above, statistics on deposited industrial waste are not divided into organic waste categories. Therefore special studies of organic waste are considered to be the most important information sources of industrial waste categories. In 2004 a study on depositing of organic waste was carried out on contract for the Swedish EPA.[194] The estimates have been made with information from many different sources, such as national statistics, screening inspections of waste content, information on capacity of energy recovery from waste and extrapolation back in time using the industries part of Gross National Product (GNP). The study shows that

[191] Ohlsson, 1998 and REFORSK, 1998
[192] Ohlsson, 1998
[193] RVF, 2005
[194] Profu, 2004.

great amounts of paper and wood have been deposited in construction and demolition waste, as well as in the category of "non specific" industrial waste.
The first study on "specific" organic industrial waste was published in 1993;[195] the waste groups found to generate methane in landfills are presented in Table 8.4. The most important subgroup here is sludge from the pulp industry and the other subgroups are mainly from the food industry. The deposited gas potentials stated in the report are based on literature studies and rotting experiments. The gas potentials are used in the methane calculations for 1990.

Table 8.4 Organic industrial waste, early 1990s (Swedish EPA, 1993).

Waste category	Produced quantity, 1000 tonnes/yr	Deposited fraction, %	Deposited quantity, 1000 tonnes/yr	Gas potential, Mm_3 CH_4/yr
Sludge from pulp industry	1000	50	500	31.5
Carcasses	8	35	2.8	0.63
Waste from slaughterhouses	40	5	2	0.45
Sludge from slaughterhouses	45	8	3.6	0.28
Entrails	30	5	1.5	0.09
Manure from slaughterhouses	10	5	0.5	0.03
Draff	5.5	0.5	0.0275	0.03
Waste from sugar beet industry	100	0.5	0.5	0.02
Waste from potato industry	46	0.5	0.23	0.01
Returned bread	13	3	0.39	0.11
Mycelia waste	2	1	0.02	0.01
Scrows waste	5.5	100	5.5	0.8
Waste from fishing industry		50	0	0.5
Whey	1 000	0	0	0
Tinned foods industry	53	50	26.5	1.55
Total:				
Sludge from pulp industry			500	31.5
Other			43.6	4.5

Data on deposited sludge from the pulp industry is available from a survey carried out annually from 1994 up to year 2000 by the Swedish EPA. In 2004, data on deposited sludge from the pulp industry is taken from the Swedish Forest Industries Federation. Data for the intermediate years have been interpolated. The reports contain detailed information on waste and waste treatment for each pulp and paper producer. Intermediate values (1991-1993) are interpolated (Table 8.5).

[195] Swedish EPA, 1993

Table 8.5 Values of deposited wastewater sludge from the pulp industry, wet weight.

Year	Quantity 1000 tonnes/year
1990	500[1]
1994	250[2]
1995	310[3]
1997	520[4]
1998	210[5]
1999	130[6]
2000	242[7]
2001	184[8]
2002	126[8]
2003	68[8]
2004	10,5[9]
2005	0[10]
2006	0[11]
2007	0[12]

1) Swedish EPA, 1993. 2) Swedish EPA, 1995. 3) Swedish EPA, 1996b. 4) Swedish EPA, 1998b. 5) Swedish EPA, 1999. 6) Swedish EPA, 2000. 7) Swedish EPA, 2001. 8) Value interpolated no similar survey carried out. 9-12) Swedish Forest Industries Federation, 2005, 2006, 2007 and 2008, respectivley.

A study on organic industry-specific waste was published in 1996[196]. In accordance with the report, the deposited waste categories are presented in Table 8.6. The gas potentials were calculated by Sweco Viak.

Table 8.6 Organic Industrial Waste 1996.

Waste category	Deposited quantity, 1000 tonnes/yr	Gas potential, Mm3 CH_4/yr
Waste from slaughterhouses	22.5	0.88
Waste from potato and vegetable industries	11.5	0.64
Total:	34	1.52

Swedish EPA, 1996

The final gas potential is used as gas potentials in the methane calculations for 1996 and later. Using the two reports, values are interpolated between 1990 and 1996.

In addition to the gas potentials from these industries, the gas potentials for paper and cardboard waste from industry, which is not included in the referred reports, have to be added. Information on these gas potentials is extracted from a survey (Waste from the manufacturing and minerals extraction industries in 1998) done by the Swedish EPA and Statistics Sweden.[197] In 1998, about 6,000 tonnes of paper and wrapping material were deposited. This quantity is added each year to the industrial waste already noted.

[196] Swedish EPA, 1996
[197] Statistics Sweden, 2000

8.2.2 Waste water handling, CRF 6B

There are 500 wastewater treatment plants in Sweden dimensioned for treating wastewater for more than 2,000 people. 95 % of the wastewater is treated mechanically, chemically and bio-logically. In some larger plants, or plants with sensitive recipients, special nitrogen treatment is performed. In Sweden, there are approximately one million people not connected to a municipal treatment plant. Those people are instead mainly connected to smaller plants or have a private plant with varying standards.[198] Considerable quantities of heat and bio-energy are recovered from sewage and wastewater.[199] The rest of the methane generated in the wastewater treatment process may be insignificant[200] because of flaring, but is reported as NE (not estimated) in the CRF tables. The effects of leakage of methane and nitrous oxide from the wastewater treatment processes has not been investigated enough to draw any conclusions. Methane generated from landfilling of sludge from waste water handling is reported as IE (included elsewhere) because it is included in CRF 6A.

8.2.2.1.1 Biogas production and utilization

According to a survey[201] by the Swedish Energy Agency the production of biogas in Sweden, 2006 was 1 213 GWh (or 87.0 Gg in methane) to be compared with 1 239 GWh (or 88.9 Gg in methane) in 2005. In 2006, 48 % of the produced energy from biogas was produced at wastewater treatment plants. The biogas production increased by 4 % from 2005 to 2006. Biogas from wastewater treatment plants is mainly for internal use but also for production of electricity, heating, vehicle fuel and for local gas distribution networks. Ca 14 % of the biogas produced at wastewater treatment plants was flared.

8.2.3 Waste incineration, CRF 6C

Emissions from incineration of hazardous waste, and in later years also MSW and industrial waste, from one large plant are reported in CRF 6C. Emissions from other MSW incineration plants combusting waste for energy purposes are included in CRF 1.

8.3 Methodological issues

For the whole waste category, the methodology and time series consistency are in line with the Good Practice Guidance.

[198] Swedish EPA & SMED, 2003
[199] Ministry of the Environment, 2001.
[200] Marklund S, Luleå kommun, 2006
[201] Swedish Energy Agency, 2008

8.3.1 Solid Waste Disposal on Land, CRF 6A

8.3.1.1 MANAGED WASTE DISPOSAL ON LAND, CRF 6A1

The method used for estimating methane emissions from municipal solid waste is the Tier 2 methodology, the IPCC First Order Decay model, with a slightly different time factor and with some estimates on the national gas potentials. The time factor year i, is calculated as:

$$\begin{cases} 1 - e^{-0,5k}, & i = 0 \\ e^{-k(i-0,5)} \cdot (1 - e^{-k}), & i = 1, 2, \ldots \end{cases}$$, where k is the generation rate constant.

This model corresponds to the assumption[202] that all waste is deposited on 1 July, which is approximately equivalent to a uniformly distributed deposition.

Comparisons between the suggested IPCC gas potentials and Swedish estimates show that the IPCC values tend to be higher, but considering the large methodological uncertainties, which is the same in both cases, the difference should be within a reasonable interval.

Historical data has been extrapolated five half-life periods back in time, which means that, for the calculations of 1990, all deposited gas potentials since 1952 are considered. All available historical information on national deposited quantities is used in the calculation. The quality of data on household waste is high since 1980, but data on organic industrial waste is scarce. The consequence is that many assumptions on historical deposited waste quantities have been made, which have greater impact on the calculated emissions in 1990 than in 2007.

8.3.1.1.1 Methane potentials

IPCC values for gas potentials are used for the different fractions of household waste, as well as garden waste. As noted above, these values are somewhat higher than Swedish estimates, but lie within a reasonable interval.

The IPCC gives no gas potential for deposited sludge (already treated, for example, by rotting) from wastewater treatment. The content of Degradable Organic Carbon (DOC) in sludge from wastewater treatment is approximately 7 percent.[203] The gas potential of the sludge is reduced by 50 % because it is treated.[204] By using formulas given in Good Practice Guidance the gas potential can be calculated to 24 kg/tonnes of sludge.

For wastewater sludge from the pulp industry, a national value of 45 kg methane /tonnes of waste is used.[205] Gas potentials in waste from the food industry are presented in section 8.2.1.

[202] Statistics Sweden, 2005
[203] Recounted from RVF, 1996.
[204] Sweco Viak, 2000.
[205] Swedish EPA, 1993.

8.3.1.1.2 Recovered gas

Since gas recovery can be of importance for the final emissions of methane, Good Practice Guidance recommends formulas that subtracts the recovered gas from the produced gas. In Sweden the first plant for biogas extraction from landfills was started in 1983. The business has increased until 2003 when gas was recovered in 72 plants. Since 2004 70 gas plants has been in operation, but the amount of recovered gas is now constantly decreasing because of the dramatic reduction of landfilling of organic waste. Information on recovered gas (in energy units) is provided by Avfall Sverige and converted to quantity (in tonnes) by Statistics Sweden (Table 8.7).

Table 8.7 Used values on recovered gas, tonnes.

Year	Recovered gas
1982	0 [1]
1983	NE [2]
1990	12 000 [3]
1991	12 210 [3]
1992	14 430 [3]
1993	20 800 [4]
1994	27 500 [4]
1995	30 000 [4]
1996	30 000 [5]
1997	30 000 [5]
1998	30 000 [5]
1999	33 000 [5]
2000	34 000 [5]
2001	32 400 [5]
2002	35 947 [5]
2003	36 449 [5]
2004	30 135 [5]
2005	29 418 [5]
2006	24 567 [6]
2007	24 553 [7]

1) No gas recovery. 2) 1st plants started. 3) Swedish EPA/RVF. 4) RVF, 1996c. 5) RVF, 1997-2006. 6) Avfall Sverige, 2007. 7) Avfall Sverige, 2008

8.3.1.1.3 Other parameters

The Methane Correction Factor for modern Swedish landfills is equal to one unit (Table 8.8). Waste management was centralised during the 1970s. Before 1980, landfills were smaller and presumably less compact. Information that helps establish the MCF factor (cover material, mechanical compacting and levelling of waste) is missing. For calculations before 1980 the IPCC default value 0.6 was used. The IPCC default value 50 % is used for the methane content in landfill gas (F) (Table 8.8). The value of DOC_F 0.5 have been chosen according to IPCC meth-

odology. The oxidation factor is estimated to be 10 %, and the half-life of the methanogenesis is 7.5 years.[206]

Table 8.8 Other used parameters in the methane emission calculations.

Parameter	Value	Motivation
MCF - 1979	0.6	IPCC Default
MCF 1980 -	1	Well managed(*)
F	50 %	IPCC Default
DOCF	0.5	IPCC Default
OX	10 %	National(**)
t½	7.5 years	National(***)

(*) Swedish EPA, 1999b, (**) Swedish EPA, 1997b, (***) Swedish EPA, 1993b.

Until about 1975, waste burning at landfills was a common waste treatment method, but it ceased about five years later. There is no information on the waste fraction that was burned, except that burning was practiced at 311 of the 847 landfills in 1975.[207] An assumption is therefore made that before 1976, 37 % of all deposited household waste was burned.

8.3.1.2 UNMANAGED WASTE DISPOSAL SITES, CRF 6A2

There are today no unmanaged landfills for municipal solid waste in use.

8.3.1.2.1 Used statistics on deposited waste

Table 8.9a-b and 8.10 shows the data used in the calculations of methane emissions from solid waste disposal on land.

Table 8.9a Overview over used statistics on deposited waste and interpolated/-extrapolated values: Solid waste.

Year	Standard value: Household waste/ citizen (kg)	Fraction deposited household waste	Fraction of burned household waste on landfills	Deposited household waste and similar, 1000 tonnes	Deposited park and garden waste, 1000 tonnes	Deposited organic industrial waste(**), 1000 tonnes	Deposited industrial waste (not industry specific), organic fraction(**), 1000 tonnes	Deposited construction and demolition waste, organic fraction(**), 1000 tonnes
1952	290	76%	37%	992	58	56	207	63
1953	290	76%	37%	998	59	56	211	64
1954	290	76%	37%	1005	59	56	215	66
1955	290	76%	37%	1012	59	56	220	68
1956	290	76%	37%	1018	60	56	226	70
1957	290	76%	37%	1024	60	56	232	71
1958	290	76%	37%	1030	60	56	234	73
1959	290	76%	37%	1035	61	56	239	75

[206] Börjesson, 2000
[207] Swedish EPA, 1983.

Table 8.9b Continued overview over used statistics on deposited waste and interpolated/extrapolated values: Solid waste.

Year	Standard value: Household waste/ citizen (kg)	Fraction deposited household waste	Fraction of burned household waste on landfills	Deposited household waste and similar, 1000 tonnes	Deposited park and garden waste, 1000 tonnes	Deposited organic industrial waste(**), 1000 tonnes	Deposited industrial waste (not industry specific), organic fraction(**), 1000 tonnes	Deposited construction and demolition waste, organic fraction(**), 1000 tonnes
1960	290	76%	37%	1041	61	56	250	77
1961	290	76%	37%	1049	62	56	260	78
1962	290	76%	37%	1056	62	56	272	80
1963	290	76%	37%	1064	62	56	280	82
1964	290	76%	37%	1072	63	56	301	83
1965	290	76%	37%	1079	63	56	316	85
1966	290	76%	37%	1088	64	56	325	87
1967	290	76%	37%	1096	64	56	330	89
1968	290	76%	37%	1105	65	56	345	90
1969	290	76%	37%	1114	65	56	349	92
1970	290	76%(*)	37%	1122	66	56	364	94
1971	290	76%	37%	1126	66	56	369	96
1972	290	76%	37%	1129	66	56	372	97
1973	290	66%	37%	984	66	56	391	99
1974	290	66%	37%	987	67	56	406	101
1975	290	66%(*)	37%(*)	990	67	56	409	103
1976	290	66%	30%	1109	67	56	452	116
1977	290	66%	22%	1229	67	56	483	131
1978	290	58%	15%	1186	67	56	517	145
1979	290	58%	7%	1292	68	56	593	162
1980			0%	1450(*)	68	56	628	177
1981				1400	68	56	632	179
1982				1300	68	56	627	182
1983				1200	68	56	551	158
1984				1100	68	56	579	161
1985				1040(*)	68	56	595	163
1986				1020(*)	68	56	602	165
1987				1050	69	56	615	168
1988				1080(*)	69	56	624	170
1989				1240	70	56	630	172
1990				1400(*)	70(*)	56	622	175
1991				1390	72	57.1	567	137
1992				1390	75	58.2	554	126
1993				1390	77	59.3	558	115
1994				1380(*)	80(*)	60.3	564	82
1995				1200(*)	60(*)	61.4	571	82
1996				1110(*)	70(*)	62.5	536	78
1997				1150(*)	50(*)	62.5	495	85
1998				1020(*)	45(*)	62.5	477	73
1999				972.5(*)	45(*)	62.5	580	96

Table 8.9c Continued overview over used statistics on deposited waste and interpolated/extrapolated values: Solid waste.

Year	Standard value: Household waste/ citizen (kg)	Fraction deposited household waste	Fraction of burned household waste on landfills	Deposited household waste and similar, 1000 tonnes	Deposited park and garden waste, 1000 tonnes	Deposited organic industrial waste(**), 1000 tonnes	Deposited industrial waste (not industry specific), organic fraction(**), 1000 tonnes	Deposited construction and demolition waste, organic fraction(**), 1000 tonnes
2000				869.5(*)	53(*)	62.5	473	71
2001				880(*)	44(*)	62.5	439	62
2002				820(*)	40(*)	62.5	370	45
2003				575(*)	33(*)	62.5	323	40
2004				380(*)	0(***)	62.5	321	47
2005				210(*)	0(***)	62.5	231	37
2006				226(*)	0(***)	62.5	100	36
2007				187(*)	0(***)	62.5	30	37

(*) Taken from statistical sources. Other values are interpolated or extrapolated.

(**) Estimate.

(***) Included in household waste from reference year 2004.

Table 8.10a Overview over used statistics on deposited waste and interpolated/extrapolated values: Sludge, wet weight.

Year	Deposited sludge from waste water treatment, 1000 tonnes	Deposited sludge from pulp industry, 1000 tonnes
1952	748	500
1953	753	500
1954	759	500
1955	764	500
1956	768	500
1957	772	500
1958	777	500
1959	781	500
1960	786	500
1961	791	500
1962	797	500
1963	803	500
1964	809	500
1965	814	500
1966	821	500
1967	827	500
1968	834	500
1969	840	500
1970	847	500
1971	849	500
1972	852	500

Table 8.10b Continued overview over used statistics on deposited waste and interpolated/extrapolated values: Sludge, wet weight.

Year	Deposited sludge from waste water treatment, 1000 tonnes	Deposited sludge from pulp industry, 1000 tonnes
1973	855	500
1974	857	500
1975	860	500
1976	862	500
1977	865	500
1978	867	500
1979	869	500
1980	871	500
1981	872	500
1982	873	500
1983	874	500
1984	875	500
1985	876	500
1986	881	500
1987	885	500
1988	890	500
1989	895	500
1990	900(*)	500(*)
1991	800	462
1992	750	424
1993	700	386
1994	610(*)	250(*)
1995	540(*)	310(*)
1996	470(*)	410(*)
1997	455(*)	520(*)
1998	490(*)	210(*)
1999	490(*)	130(*)
2000	345(*)	242(*)
2001	330(*)	184
2002	215(*)	126.3
2003	155(*)	68
2004	102(*)	10.5(*)
2005	58(*)	0(*)
2006	39(*)	0(*)
2007	39	0(*)

(*) Taken from statistical sources. Other values are interpolated or extrapolated.

8.3.1.2.2 Composition on deposited waste

Table 8.11 illustrates the estimated composition on deposited waste 1990-2007.

Table 8.11 Composition of deposited waste, percent.

Year	Paper	Food	Plastic	Glass	Textile	Napkins	Sludge from waste water	Sludge from pulp industry	Wood	Other inert	Other organic
1990	7.1	13.5	2.1	0.6	0.7	1.3	16.2	9.0	0.3	34.9	14.3
1991	7.4	14.6	2.2	0.7	0.8	1.5	15.5	9.0	0.3	34.5	13.6
1992	7.5	15.4	2.3	0.7	0.8	1.5	15.1	8.5	0.3	34.2	13.7
1993	7.5	16.1	2.4	0.7	0.8	1.6	14.5	8.0	0.4	34.1	14.0
1994	7.7	17.2	2.6	0.8	0.9	1.7	13.4	5.5	0.4	35.8	14.2
1995	6.8	15.8	2.4	0.7	0.8	1.6	12.5	7.2	0.3	36.9	15.1
1996	6.3	15.9	2.3	0.7	0.8	1.5	11.3	9.9	0.3	36.1	14.8
1997	5.6	16.0	2.5	0.7	0.8	1.6	10.8	12.4	0.3	35.5	13.8
1998	5.4	15.6	2.4	0.7	0.8	1.5	12.7	5.4	0.3	41.0	14.2
1999	5.2	15.0	2.3	0.7	0.8	1.5	12.7	3.4	0.3	40.7	17.5
2000	5.4	13.5	2.5	0.8	0.7	1.2	9.3	6.5	0.2	45.5	14.6
2001	5.8	14.2	2.7	0.8	0.8	1.2	9.5	5.3	0.2	45.2	14.4
2002	6.3	15.5	2.9	0.9	0.9	1.3	7.2	4.2	0.2	46.9	13.8
2003	5.0	13.0	2.3	0.7	0.7	1.1	5.8	2.5	0.1	55.4	13.5
2004	2.8	10.4	1.8	0.4	0.4	0.9	4.3	0.4	0.1	63.1	15.5
2005	1.9	7.8	1.2	0.2	0.2	0.6	2.8	0.0	0.1	72.2	13.0
2006	2.2	8.7	1.3	0.3	0.3	0.6	2.0	0.0	0.1	77.5	7.0
2007	1.9	8.1	1.2	0.2	0.2	0.5	2.1	0.0	0.1	82.0	3.6

8.3.2 Waste water handling, CRF 6B

National activity data on nitrogen in discharged wastewater from municipal wastewater treatment plants and industries are used, in combination with a model estimating nitrogen in human sewage from people not connected to municipal wastewater treatment plants.

The general formula to calculate the emissions is:

$$\left(N_{WastewaterTreatmentPlants} + N_{Industry} + PROTEIN * Nr_{People} * 0.16\right) * EF * 44/28$$

where $N_{WastewaterTreatmentPlants}$ and $N_{Industry}$ are the nitrogen in discharged wastewater from municipal wastewater treatment plants (including industries without internal wastewater treatment) and other industries (with internal wastewater treatment) respectively. IPCC's default emission factor , 1 % N_2O-N/N, is used as emission factor (EF) for the discharges from all three sources (Wastewater treatment plants, Industries and unconnected households).

8.3.2.1 MUNICIPAL WASTEWATER TREATMENT PLANTS

The formula is: $N_{WastewaterTreatmentPlants} * EF * 44/28$

$N_{WastewaterTreatmentPlants}$ is magnified by 10 %, in order to compensate for wastewater from small treatment plants, not included in the statistics.

8.3.2.2 INDUSTRIES WITH INTERNAL WASTEWATER TREATMENT

The formula is: $N_{Industry} * EF * 44/28$

The sector covers; Pulp and paper industry, Oil refineries, Chemical industry, Iron and steel industry, Food manufacturing industry and Engineering industry (see further in Table 8.12 below).

8.3.2.3 HOUSEHOLDS NOT CONNECTED TO MUNICIPAL WASTEWATER TREATMENT PLANTS

The formula is: $\left(PROTEIN * Nr_{People} * 0.16\right) * EF * 44/28$

PROTEIN is the annual per capita consumption per person/year (National value: 32.85[208]), NrPeople is the number of people not connected to municipal wastewater treatment plants, and 0.16 is the fraction of nitrogen in proteins.

[208] National Food Administration, 2002

Table 8.12 Discharges of nitrogen from municipal wastewater treatment plants, pulp and paper industry and some coastal industries, tonnes.[209]

Year	Municipal wastewater-treatment plants (*)	Pulp and paper industry	Oil refineries	Chemical industry	Iron and steel industry	Food manufac-turing industry	Engineering industry
1990	26 200	5 500	..	..	..	..	..
1992	25 310	3 630	..	..	..	..	..
1994	..	3 200	..	..	..	..	..
1995	25 940	3 844	80	385	70	0	..
1997	..	3 433	..	..	..	..	..
1998	21 376	3 307	78	423	230	1	0
1999	..	3 042	..	..	..	..	..
2000	18 977	3 241	38	361	114	109	..
2001	..	3 014	..	..	..	..	..
2002	18 036	3 169	68	268	72	3	..
2003	..	3 162	..	..	..	..	..
2004	17 779	3 039	30	224	54	11	..
2005	..	3 222	..	..	..	..	..
2006	18 347	3 200	39	144	74	17	..
2007	..	2825					

(*) From treatment of domestic, commercial and industrial waste water.

According to Swedish environmental protection law, all municipal wastewater treatment plants designed for more than 2,000 person equivalents, including industry, need to report their discharges in legal environmental reports delivered to their supervision agency. Statistics are published every other year by the Swedish EPA.[210] The statistics exclude municipal wastewater treatment plants designed for fewer than 2,000 person equivalents. These were surveyed in 1999, and were found to represent about 6 % of the total discharged nitrogen, which is compensated for using a “1.1 factor” in the above formula.

The statistics also exclude almost 1 million people in rural areas, who are not connected to municipal wastewater treatment. However, the nitrogen from these people is accounted for in the formula as well, through the model estimate of nitrogen production. The calculated IEF for N_2O from human sewage (kg N_2O-N/kg sewage N produced) in CRF Reporter is using the Swedish total population value instead of the one million people mentioned above that are not connected to municipal wastewater treatment. As a result all values of the N_2O IEF for 'Human sewage' have been identified as outliers in Synthesis & Assessment Part II submission 2008. By using the correct population value, the IEF will be 1 % (0.01) which is the IPCC default emission factor that Sweden are using.

[209] MI 22 SM, Swedish EPA and SMED, NV 4657, NV 4434, NV 4657, NV 4924, NV 4987, NV 5114, Swedish Forest Industries Federation.
[210] Statistics Sweden, MI 22 SM, Swedish EPA and SMED.

8.3.3 Waste incineration, CRF 6C

Emissions from incineration of hazardous waste, and in later years also MSW and industrial waste, from one large plant are reported in CRF 6C. Reported emissions are for the whole time series obtained from the facility's Environmental report or directly from the facility on request. CO_2, SO_2 and NO_X are measured continuously in the fumes at the plant. In 2003 capacity was increased substantially at the plant by taking one new incinerator into operation. The new incinerator incinerates a mixture of MSW, industrial waste and hazardous waste. As a consequence of increased capacity, the emissions from 2003 are increased compared to earlier years. Only a minor part (less than 0.5 %) of the total amount of MSW incinerated for energy purposes in Sweden are incinerated in the facility included in 6C. All other emissions from incineration of MSW are reported in CRF 1.

Emissions reported are CO_2, NO_X, SO_2 and NMVOC. The CO_2 emission of biogenic origin of the MSW fraction of the waste, has since 2003 (when the incineration capacity increased dramatically, in order to treat MSW) been estimated using published information[211]. In the facility's environmental report the total amounts of incinerated waste as well as the amount of incinerated municipal waste are presented. Also the total CO_2 emission from incineration of waste is given. In a report published by the Swedish Waste Management Association (2003)[211] the information is given that approximately 70 % of the emitted CO_2 from incineration of municipal waste have biogenic origin. For the estimates we have assumed the same carbon content in hazardous, industrial and MSW waste.

According to information from the facility, occasional measurements concerning CH_4 and N_2O have been performed. The CH_4 measurement showed very low or non-detectable amounts. For N_2O the occasional measurements showed levels giving emissions in the approximate order of 0.2 Mg N_2O/year. For correct estimates more background data (measurements) has to be available. Sweden has therefore decided to report CH_4 and N_2O as NE.

8.4 Uncertainties and time series consistency

The uncertainty analysis table (Tier 1) are presented in Annex 7 and a general description of the uncertainty analysis is presented in section 1.7.

Because of the simplifications in the used top-down model and the difficulties in estimating many of the parameters, the estimated emissions in the waste sector are uncertain. The time dependency in methane production makes the model estimate further dependent on assumptions of waste management from earlier years. The uncertainty is highest in 1990 and then decreases, mainly due to better and more frequent activity data on household waste during the 1990s. The section of the Ordinance prohibiting deposition of organic waste as landfill was implemented on January 1st 2005. It has led to higher uncertanties since the data on DOC has

[211] The Swedish Association of Waste Management. RVF rapport 2003:12 (in Swedish). Förbränning av avfall. Utsläpp av växthusgaser jämfört med annan avfallsbehandling och annan energiproduktion.

not been updated during the last years to cover the changes. The DOC from the year 2005 is probably overestimated.

IPCC Guidelines suggest that the error in estimated methane generation potential may be about 15 % given high quality data and 50 % given poor data on methane generation, per ton of waste. The uncertainty in statistics on deposited waste may be 10 %, if the waste is weighted, or more than 200 % if the data quality is poor. The errors in estimated methane recovery will probably be small, according to the Good Practice Guidance. Given these standard uncertainty ranges and applying the simple error propagation formula, a total error of estimated methane emissions of about 20 % would be achievable, in the best case, given high quality data. According to Good Practice Guidance there is some extra uncertainty in the methane generation rate constant [-40 %, 300 %], and in the oxidation factor, if oxidation is assumed. An assessment of the confidence interval for the Swedish methane estimate from landfills would be around 50-60 % for 2007 Swedish waste statistics on household waste, in particular, are now of high quality, but the estimates are still dependent on lower quality data and extrapolations from earlier years. Furthermore, statistics on different waste fractions in household waste, and especially industrial waste, are still of lower quality. The quality of parameters based on IPCC default values may also be low, since they rely on older research, and data from Swedish on-site measurements is not yet extensive enough for verification.

The statistics of discharges from municipal wastewater treatment plants are biased from sources of inaccuracy such as under coverage, non-response or no observations and sample errors “within” the treatment plants. No objective methods of calculating accuracy measures have been developed, but data on nitrogen is considered to have a margin of inaccuracy of well under 10 % at national level. The inaccuracy in the emission factor is estimated to be at least 50 %, according to Good Practice Guidance. This results in an overall inaccuracy exceeding 50 % annually, and more for years where activity data have been extrapolated.

The time series in the waste sector are calculated consistently, and when statistics are not produced annually, interpolation and extrapolation have been necessary tools for imputation.

8.5 QA/QC and verification

8.5.1 Quality Assurance and Quality Control

All quality procedures according to the Swedish QA/QC plan (Manual for SMED:s Quality System in the Air Emission Inventories) have been implemented during the work with this submission.

8.5.2 Verification of data and reducing compiling errors

Statistics Sweden and the IVL has on behalf of the Swedish EPA scrutinized the activity data (quantities of deposited; household waste, park and garden waste,

sludge from waste water treatment) used for calculations. The accuracy in these activity data is judged to be good.

8.6 Recalculations

In submission 2009 the following recalculations were performed:

8.6.1 CRF 6B

Discharges of nitrogen from oil refineries, the chemical industry, the iron and steel industry and the food manufacturing industry were revised for the year 2004 resulting in 2.7 % lower emissions of N_2O for CRF 6B1 Industrial wastewater.

Discharges of nitrogen from oil refineries, the chemical industry, the iron and steel industry and the food manufacturing industry were revised for the year 2006 resulting in 3.8 % lower emissions of N_2O for CRF 6B1 Industrial wastewater.

Discharges of nitrogen from municipal wastewater treatment plants were revised for the year 2006 resulting in 2.5 % higher emissions of N_2O for CRF 6B2 Domestic and commercial wastewater.

General efforts in the interpolation work has been performed for years for which no statistics are available. This has resulted in smoother changing emission of N_2O for the time series in 6B Wastewater handling.

8.7 Coming improvements

No improvements are planned in this sector for submission 2010.

9 Other sectors

Not applicable in Sweden.

10 Recalculations and improvements

The explanations and justifications for recalculations included in this submission and performed since the submission April 15, 2008 are given in the sector chapters together with descriptions on the implications for the emission levels, refer to:

Energy	Section 3.6
Industrial processes,	
Mineral Production,	Section 4.2.3
Chemical industry	Section 4.3.3
Metal Production	Section 4.4.3
Other Production	Section 4.5.3
Consumption of Halocarbons and SF6	Section 4.9.5
Solvents and other products use	Section 5.1.5
Agriculture	Section 6.6
LULUCF	Section 7.6
Waste	Section 8.6

Since the last submission, recalculations of GHG emissions for several years have been carried out throughout the inventory (Table 10.1). The recalculations are due to comments in the ongoing progress to make the inventory be fully in line with the IPCC Good Practice Guidance and implement recommendations from the review teams. The recalculations include new methods, emission factors, thermal values and activity data. Some recalculations are due to discovered errors in earlier inventories during the work with the present inventory.

Table 10.1 Recalculations of GHG emissions between submission 2009 and submission 2008 by CRF sector.

Year	Recalculations (Gg CO_2 eq.)					
	CRF 1	CRF 2	CRF 3	CRF 4	CRF 5	CRF 6
1990	-85.37	-	-	-23.62	-	-
1991	-54.33	-	-	-22.39	-	-6.94
1992	-103.83	-	-	-22.61	-	-
1993	-97.28	-0.07	-	-21.96	-	0.08
1994	-120.54	0.08	-	-22.16	-	2.25
1995	-88.53	0.69	-	-21.88	-	-
1996	-86.05	0.45	-	-20.79	-	-8.83
1997	-112.36	0.44	-	-21.46	-	-3.92
1998	-130.38	0.44	-	-21.04	-	-
1999	-108.93	0.44	-	-16.09	-	-6.70
2000	-110.60	0.44	-	-15.61	-	-
2001	-124.76	0.44	-	-32.39	-	-3.04
2002	-327.78	0.44	-	-32.02	-	-
2003	-493.90	0.44	-	4.61	-	-0.91
2004	38.68	0.44	-0.44	4.19	-	-0.45
2005	100.14	1.58	-1.75	-2.61	-	0.96
2006	608.80	4.17	-9.07	-1.23	-	2.38

10.1 Implications on emission trends

The total emissions of GHG have changed in all years due to recalculations in the inventory. Below a more specific description of implications for each GHG due to recalculations will be discussed.

10.1.1 CO_2

Emissions of CO_2 are recalculated for all years for the Energy sector. The main changes for the Energy sector are caused by the revision of off-road vehicles and working machinery and the revision 2002-2006 for stationary combustion in other sectors. It should be noted that, there has been no recalculation made in the LULUCF sector between the revised submission 2008 and this submission

10.1.2 CH_4

Emissions of CH_4 are recalculated for all years 1990-2006. Minor recalculations have been performed for all years in the Energy and in the Agricultural sectors. The recalculations have resulted in small annual decreases from 1990-2002 and to small annual increases in 2003-2006. The main changes for the Energy sector are caused by the revision of off-road vehicles and working machinery and the revision 2002-2006 for stationary combustion in other sectors.

10.1.3 N_2O

Slight reductions for all years, 1990-2006 in the emissions of N_2O result from recalculations in the Energy sector, due to the revision of off-road vehicles and working machinery and the revision 2002-2006 for stationary combustion in other sectors, in the Agricultural sector, except for a few years with slightly increased emissions and in the LULUCF-sector with very minor emission changes. Recaculations in the LULUCF sector are based on changes in the land-use conversion statistics.

In the Waste sector the activity data on discharges of nitrogen has been updated. General efforts in the interpolation work has been performed for years were no statistics are available. In most of the cases this has resulted in lower emissions and in general in smoother changing emissions of N_2O for the time series in 6B Wastewater handling.

10.2 Recalculations and other changes made in response to the review process

In April 2007, Sweden was visited by an expert review team and several comments and recommendations from the team lead to revisions of the inventory data in submission 2008. Since the inventory time cycle in Sweden is planned for a national independent review of the inventory, this inventory for submission 2009 is already compiled in mid-november 2008. The preliminary result of the centralized review in 2008, taking place in October, can thus only be taken into account as minor recaluclations and changes in response to the review process. In the following sections the recalculations and other changes in data and in the NIR made in response to the review process are described briefly.

10.2.1 General

In this submission no general improvements were made in response to the review process.

10.2.2 Energy

In this submission no specific recalulcations were made in response to the review process.

10.2.3 Industrial processes

In this submission no specific recalulcations were made in response to the review process.

10.2.4 Solvents and other products use

In this submission no specific recalulcations were made in response to the review process.

10.2.5 Agriculture

In this submission no specific recalulcations were made in response to the review process.

10.2.6 LULUCF

In this submission no specific recalulcations were made in response to the review process.

10.2.7 Waste

In this submission no specific recalulcations were made in response to the review process.

In the consistency report it was noted that the emissions of N_2O in sector 6B2a Domestic and commercial waste water were decreasing between 1996-1998 and 1999-2000, whereas the remaining time series is rather constant. The reason is that the national data on discharges of nitrogen from municipal wastewater treatment plants (and from other industries) are not produced on a yearly basis, but every second or third year. Due to the lack of interpolation and extrapolation it seemed like the remaining time series were constant. The reason has been that the observations has been imputated for the following years with no observations. In submission 2009 general efforts in the interpolation work has been performed for years were no statistics are available. This has resulted in smoother changing emission of N_2O for the time series in 6B Wastewater handling.

11 References

Section 1

Swedish EPA, 2003-05-26. www.naturvardsverket.se

UNFCCC. 12 June 2002. Guidelines on reporting and review of greenhouse gas inventories from parties included in annex 1 to the convention (implementing decisions 3/cp.5 and 6/CP.5).

2002/358/EC

Section 3

Andersson, Kjell. 2000. Rapportering av luftutsläpp till CORINAIR 1994 -1999. Swedish EPA.

Backman, H. & Gustafsson, T. 2006. Verification of activity data within the energy sector for the reporting to the UNFCCC, EU Monitoring Mechanism, CLRTAP and the EU NEC Directive using data from the EU Emission Trading Scheme. SMED report 2006

Concawe, 1986, Hydrocarbon emissions from gasoline storage and distribution systems, Report No 85/54.

Cooper, D. and Gustafsson, T., 2004, Methodology for calculating emissions from ships: 2 Emission factors for 2004 reporting. SMED report 5:2004

Cooper, D., Flodström, E., Gustafsson, T., and Jernström, M. 2005. Emission factors, fuel consumption and emission estimates for Sweden's fishing fleet 1990-2004. SMED report 2005

ER 2007:26. Energianvändning för inrikes sjöfart 2006. Energimyndigheten 2007

Gustafsson, T., Olsson, B., Rönnbacka, M. 2005. Review of activity data in the Other sector – CRF 1A2f, construction and CRF 1A4, Other. 1. Pilot study. SMED report 2005

Gustafsson, T. 2005. Comparative study of Swedish emission factors for aviation with the IPCC default factors. SMED report 2005.

Gustafsson, T. 2007b. Utvärdering av uppsnabbad preliminär energistatistik för Övrigsektorn. (eng. Evaluation of the prescheduled preliminary annual statistics for the Other sector.). SMED report 2007

Lidén, Utredning om avfallsförbränning 2005, Statistics Sweden 2005

Lidén, M & Gerner, A 2008. Översyn av metodik för beräkningar av stationära utsläpp från Övrigsektorn. (eng. Overhaul of methodology for estimating emissions from stationary combustion in Other sectors) SMED Memorandum 2008.

Ljung, Leif, 2003. Swedish Petroleum Institute, personal communication.

Ministry of the Environment Sweden. 2001. Sweden´s third national communication on Climate change, Ds 2001:71

Nyström, A-K. 2007. Study of differences in plant data between the Energy Statistics and the EU Emission Trading Scheme. SMED report 2007

Nyström, A-K & Cooper, D. 2005. Use of data from the EU emission trading scheme for reporting to EU Monitoring Mechanism, UNFCCC and CLRTAP. SMED report.

Näs, A. 2005. Swedish Defence Research Agency (FOI). Personal communication.

Paulrud, S, Kindbom, K, Cooper, D, Gustafsson, T. 2005. Methane emissions from residential biomass combustion. SMED report 17:2005

Paulrud, S and Fridell, E. Uppdatering av klimatrelaterade emissionsfaktorer. IVL report 2008

Skårman, T., Danielsson, H., Kindbom, K., Jernström, M., Nyström, A-K. 2008. Fortsättning av riktad kvalitetskontrollstudie av utsläpp från industrin i Sveriges internationella rapportering. SMED Report 2008.

Statistics Sweden, 1990-2007. EN11SM: El- gas- och fjärrvärmeförsörjning (Electricity supply, district heating and supply of natural gas and gasworks gas). Energy Statistics.

Statistics Sweden, 1990-2007. EN16SM: Energistatistik för småhus, flerbostadshus och lokaler, Jämförande uppgifter (Summary of energy statististics for dwellings and non-residential premises) Energy Statistics.

Statistics Sweden, 1990-2007. EN20SM: Årliga energibalanser (Yearly Energy Balance Sheets). Energy Statistics.

Statistics Sweden, 1990-2007. EN31SM: Bränslen, leveranser och förbrukning av bränsle (Fuels. Deliveries and consumption of fuels). Energy Statistics.

Statistics Sweden, 1996 Emissions to air in Sweden of volatile organic compounds (VOC) 1988 and 1994. Statistical appendix. (Utsläpp till luft i Sverige av flyktiga organiska ämnen (VOC) 1988 och 1994. Statistikbilaga.)

Statistics Sweden, 2005. Båtlivsundersökningen 2004 (Leisure boats survey 2004).

Statistics Sweden, 2005. EN0114: Energianvändning inom byggsektorn 2004 (Energy use in construction sector 2004). Energy Statistics.

Statistics Sweden, 2006. ENFT0601: Energianvändning inom fiskesektorn 2005 (Energy consumption in the fishery sector 2005)

Swedish Civil Aviation Authority, www. luftfartsstyrelsen.se. September 2006.

Swedish EPA. 1990. Emissions to air from refineries. (Utsläpp till luft från raffinaderier - emissioner och åtgärdsförslag). Report 3816.

Swedish EPA. 1994a. Emissions to air of volatile organic compounds 1992, report 4312.

Swedish EPA. 1994b. Emissions to air and water from chemical industry 1992, report 4336.

Swedish EPA. 1995. Emissions to air and water from chemical industry 1993, report 4462.

Swedish Petroleum Institute, www.spi.se August 2005

Swedish Road and Transport Research Institute. 2002. EMV – Indata, rättning och viss uppdatering.

Swedish Road and Transport Research Institute, 2008-09-29. www.sika-institute.se,

The Swedish Forest Industries Federation. 2008-09-29. www.skogsindustrierna.org.

The Swedish Steel Producers' Association. 2007-09-22. www.jernkontoret.se.

Section 4

Ahmadzai, H. Swedish EPA. Personal communication. 2000.

Bergverksstatistik, 1990 – 2007. Geological Survey of Sweden, SGU

Bryggeriföreningen. http://www.sverigesbryggerier.se

Carlsberg Sweden. http://www.carlsberg.se

Danielsson, H. 2004. SMED report: Investigation on the occurrence of emissions from asphalt roofing in Sweden.

EMEP/CORINAIR Emission Inventory Guidebook: http://reports.eea.eu.int/EMEPCORINAIR4/en

ENET-steel. 2007. Energieffektivisering inom SSAB i Oxelösund under åren 1996-2007. Report number 2, September 2007. http://www.enet-steel.se

Finnish Environment Institute. 2001. Revised Finnish Non Methane Volatile Organic Compound Emissions - Time Series for the Years 1998-1999 with Information on the Emissions Sources and Calculation Methods

Haglind, Ingrid. 2005. Swedish Forest Industries Federation.

IPCC. Revised 1996 Guidelines for National Greenhouse Gas Inventories: Reference Manual section 2.5.2

IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories: Reference Manual, Table 2.12.

IPCC. 2000. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories.

IPCC 2006 Guidelines. www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_5_Ch5_Non_Energy_Products.pdf

Kindbom, K. Haeger Eugensson, M. Persson, K. 2001. Kartläggning och beräkning av potentiella och faktiska utsläpp av HFC, FC och SF_6 i Sverige. IVL B-1428

Kindbom, 2004. SMED report: Investigation on the occurrence of ammonia production in Sweden. 2004-05-11.

Kindbom, K. 2008. SMED-report: Manual for SMEDs Quality System in the Air Emission Inventories, 2008-01-31

Kindbom, K. 2005. Revision of Methodology and Estimated Emissions of Fluorinated Greenhouse Gases in Sweden. Report Series SMED Nr 16 2005.

Kindbom, K. and Skårman, T. 2004. Nya scenarier för fluorerade växthusgaser. U952, Swedish EPA.

Nordkalk, http://www.nordkalk.com

Nyström, A-K. 2004. SMED report: CO2 from the use of soda ash.

Shrager, Brian and Marinshaw, Richard. 1994. Emission Factor Documentation for AP-42, Section 11.2, Asphalt Roofing, Final Report. For U.S. Environmental Protection Agency , Office for Air Quality Planning and Standards, Emission Inventory Branch. MRI Project No. 4601-01.

Skårman, T,. Danielsson, H., Kindbom, K., Jernström, M., Nyström, A-K. 2008. Fortsättning av riktad kvalitetskontrollstudie av utsläpp från industrin i Sveriges internationella rapportering. SMED Report 2008.

Statistics Sweden. Data from the Industrial production database: www.scb.se.

Swedish EPA. NFS 2000:13, Naturvårdsverkets föreskrifter om miljörapport för tillståndspliktiga miljöfarliga verksamheter.

Swedenergy. Matz Tapper. Personal communication. 2005.

Swedish Lime Association, Kalkföreningen

Systembolaget. Försäljningsstatistik. http://www.systembolaget.se/

The National Institute of Public Health (NIPH)

The Swedish Chemicals Agency (KemI)

The Swedish Refrigeration Foundation (KYS). Personal communication.

Ujfalusi, M. Swedish EPA. Personal communication.

UN. Commodity Production Statistica Database. Department of Economic and Social Affairs, Statistics Division,. As referred in FCCC Synthesis and Assessment report 2002 Part I.

Weholt, Ø. 1999. Materialstrømsanalyse av $SF6_6$. Beregning av potensielt og faktisk utslipp over tid.

Wieland, Michael S. 2004. Work-Principle Model for Predicting Toxic Fumes of Nonideal Explosives

WRI- World Resource Institute, WBCSD- World Business Council for Sustainable Development

www.ghgprotocol.org. 2005-10-20.

Section 5

COUNCIL DIRECTIVE 1999/13/EC of 11 March 1999 and UNECE Emission Reporting Guidelines

Kindbom, K., Boström, C-Å., Skårman, T., Gustafsson, T. and Talonpoika, M. 2003. Estimated Emissions of NMVOC in Sweden 1988-2001.

The Swedish Chemicals Agency (KemI).

Section 6

Berglund Ö. Berglund K. 2005. Kartering av odlade organogena jordar i Sverige med hjälp av digitali-serade databaser. Swedish University of Agricultural Sciences. Dept of Soil Sciences. Division of hydrotechnics.

Bertilsson, J. 2001. Utvärdering av beräkningsmetodik för metanavgång från nötkreatur. SLU, Swedish University of Agricultural Sciences. Department of Animal Nutrition and Management. (A re-view of methodology for estimating methane emission from cattle). Unpublished report to the Swedish Environmental Protection Agency.

Bertilsson, J. 2002. Methane emissions from enteric fermentation – effects of diet composition. Danish Institute of Agricultural Sciences, Plant Production no. 81 October 2002

Bertilsson, J. 2007. Methane emissions from suckler cows. SLU, Swedish University of Agricultural Sciences. Department of Animal Nutrition and Management. Unpublished report to the Swedish Environmental Protection Agency.

CORINAIR. 1998. Emission Inventory Guidebook, CORINAIR 'CORe INventory of AIR emissions', a project performed since 1995 by the European Topic Centre on Air Emissions under contract to the European Environment Agency.

Dustan A. 2002. Review of methane and nitrous oxide emission factors for manure management in cold climates. JTI – Swedish Institute of Agricultural and Environmental Engineering, Uppsala. Report 299.

Frankow-Lindberg. 2005. Bestämning av klöverandel I slåttervall, Swedish University of Agricultural Sciences, Uppsala.

Høgh-Jensen et al. 2004. An empirical model for quantification of symbiotic nitrogen fixation in grass-clover mixtures, Agricultural Systems 82, 2004

Johnsson H., Bergström, L. Jansson P.-E. and Paustian, K. 1987. Simulated nitrogen dynamics and losses in a layered agricultural soil. Agric. Ecosystems Environ. 18, 333-356

Johnsson H. 1990. Nitrogen and Water Dynamics in Arable Soil. Swedish University for Agricultural Sciences. Department of Soil Sciences Reports and Dissertations 6.

Kasimir Klemedtsson Å. 2001. Metodik för skattning av jordbrukets emissioner av lustgas (Methodol-ogy for estimating the emissions of nitrous oxide from agriculture). Swedish Environmental protection Agency. Report 5170.

Klemedtsson L, Kasimir Klemedtsson Å, Esala M and Kulmala A. 1999. Inventory of N_2O emission from farmed European peatlands. In: A. Freibauer and M. Kaltschmitt (eds) Approaches to Greenhouse Gas Inventories of Biogenic Sources in Agriculture. IER, Stuttgart.

Lægreid M and Aastveit H. 2002. Nitrous oxide emissions from field-applied fertilizers. Danish Insti-tute of Agricultural Sciences, Plant Production no. 81 October 2002

LBR, the register of holdings in agriculture and forestry (the farm register) provides the main basis for the agricultural statistics in Sweden. Results are published by Statistics Sweden. Results on use of arable land are published in series J 10 SM, and results on livestock are published in series J 20 SM. 1991-2007. www.sjv.se

Linder J. 2001. STANK- the official model for input/output accounting on farm level in Sweden. In: Element balances as a sustainable tool. Workshop in Uppsala, March 16-17, 2001. JTI-Swedish Institute of Agricultural and Environmental Engineering. Report 281.

Lindgren E. 1980. Skattning av energiförluster i metan och urin hos idisslare (Estimates of energy losses in methane and urine for ruminant animals). Swedish University of Agricultural Sci-ences, Dept of livestock physiology, Report 47.

Mattson L. 2005. Halmskörden, hur stor är den? Swedish University of Agricultural Sciences Dept of Soil Sciences, Soil Fertility and Plant Nutrition

Ministry of the Environment Sweden, Ds 2001:71. 2001. Sweden´s third national communication on Climate change.

Murphy M. 1992. Växthusgasutsläpp från husdjur (Greenhouse gas emissions from livestock). Swedish Environmental Protection Agency. Report 4144.

Odling i balans. 1996. Växtnäringsbalans i jordbruket (Nutrient balances in agriculture).

Rösiö G. 1991. Ammoniakutsläpp till luft från gödsel m m i Sverige. Nordisk statistisk sekretariat. Tekniske rapporter 56.

Sametinget, The Sami Parliament of Sweden, 2006. www.sametinget.se

Spörndly R. (ed). 1999. Fodertabeller för idisslare 1999 (Feed tables for ruminant animals). Swedish University of Agricultural Sciences. Department of Animal Nutrition and Management. Report 247.

Statistics Finland, 2007. Greenhouse gas emissions in Finland 1990-2005. National Inventory Report to the UNFCCC April 15th 2007.

Statistics Sweden, 1990. Gödselmedel i jordbruket 1987/88. Tillförsel till åkergrödor (Use of fertilisers and manure in agriculture 1987/88). Statistical report Na 30 SM 9001.

Statistics Sweden, 1997b. Utsläpp till vatten och slamproduktion 1995 (Discharges to water and sludge production in 1995), MI 22 SM 9701.

Statistics Sweden, 1998. Gödselmedel i jordbruket 1996/97 (Use of fertilisers and animal manure in 1996/97). Statistical report Na 30 SM 9803.

Statistics Sweden, 1999. Utnyttjande av halm och blast från jordbruksgrödor 1997 (Utilization of straw and tops from agriculture crops in 1997). Statistical report MI 63 SM 9901.

Statistics Sweden, 2000. Kväve- och fosforbalanser för svensk åkermark och jordbrukssektor 1999 (Nitrogen and phosphorus balances in arable land and agricultural sector 1999). Statistical report Mi 40 SM 0101.

Statistics Sweden, 2000b. Gödselmedel i jordbruket 1998/99 (Use of fertilisers and animal manure in 1998/99). Statistical report MI 30 SM 0002.

Statistics Sweden, 2000c. Utsläpp till luft av ammoniak i Sverige 1999 (Emission to air of ammonia in Sweden from agriculture and other antropogenic sources in 1999). Statistical report MI 37 SM 0001.

Statistics Sweden, 2001. Utsläpp till vatten och slamproduktion 2000 (Discharges to water and sludge production in 2000), MI 22 SM 0101.

Statistics Sweden and Federation of Swedish Farmers. 2001. Miljöredovisning för svenskt jordbruk 2000.

Statistics Sweden, 2002. Utsläpp av ammoniak till luft i Sverige 2001 (Emission of ammonia to air in Sweden 2001). Statistical report MI 37 SM 0201. www.scb.se

Statistics Sweden, 2002b. Gödselmedel i jordbruket 2000/01 (Use of fertilisers and animal manure in agriculture 2000/01). Statistical report MI 30 SM 0202. www.scb.se

Statistics Sweden, 2002c. Försäljning av mineralgödsel för jord- och trädgårdsbruk under 2000/01 (Sales of fertilisers for agricultural and horticultural purposes in 2000/01). Statistical report MI 30 SM 0201.

Statistics Sweden, 2002e. Standard yields, Statistical reports, series JO 15 SM. www.scb.se

Statistics Sweden, 2003. Försäljning av mineralgödsel för jord- och trädgårdsbruk under 2001/02 (Sales of fertilisers for agricultural and horticultural purposes in 2001/02). Statistics Sweden, MI 30 SM 0301. www.scb.se

Statistics Sweden, 2003c. Kväve- och fosforbalanser för svensk åkermark och jordbrukssektor 2001 (Nitrogen and phosphorus balances in arable land and agricultural sector 2001). Statistical re-port MI 40 SM 0301. www.scb.se

Statistics Sweden, 2003d. Utsläpp av ammoniak till luft i Sverige 2003 (Emission of ammonia to air in Sweden 2003). Statistical report MI 37 SM 0401. www.scb.se

Statistics Sweden, 2004. Gödselmedel i jordbruket 2002/03 (Use of fertilisers and animal manure in agriculture 2002/03). Statistical report MI 30 SM 0403. www.scb.se

Statistics Sweden, 2004c. Försäljning av mineralgödsel för jord- och trädgårdsbruk under 2002/03 (Sales of fertilisers for agricultural and horticultural purposes in 2002/03). Statistical report MI 30 SM 0401.

Statistics Sweden, 2006. Yearbook of agricultural statistics 2006.

Statistics Sweden, 2006b. Gödselmedel i jordbruket 2004/05 (Use of fertilisers and animal manure in agriculture 2004/05). Statistical report MI 30 SM 0603. www.scb.se

Statistics Sweden, 2006c. Försäljning av mineralgödsel för jord- och trädgårdsbruk under 2004/05 (Sales of fertilisers for agricultural and horticultural purposes in 2004/05). Statistical report MI 30 SM 0601.

Statistics Sweden, Federation of Swedish Farmers, Swedish Board of Agriculture and Swedish EPA 2007. Hållbart Jordbruk 2007 (Sustainable agriculture 2007).

Statistics Sweden, 2007b. Utsläpp av ammoniak till luft i Sverige 2005 (Emission of ammonia to air in Sweden 2005). Statistical report MI 37 SM 0701. www.scb.se

Statistics Sweden, 2007c. Kväve- och fosforbalanser för jordbruksmark och jordbrukssektor 2005 (Nitrogen and phosphorus balances in arable land and agricultural sector 2005). Statistical report MI 40 SM 0701. www.scb.se

Statistics Sweden, 2008. Gödselmedel i jordbruket 2006/07 (Use of fertilisers and animal manure in agriculture 2006/07). Statistical report MI 30 SM 0803. www.scb.se

Statistics Sweden, 2008c. Försäljning av mineralgödsel för jord- och trädgårdsbruk under 2006/07 (Sales of fertilisers for agricultural and horticultural purposes in 2006/07). Statistical report MI 30 SM 0801.

Statistics Sweden, 2008b. Yearbook of agricultural statistics 2008.

Svensk Fågel, Swedish Poultry Meat Association. 2008 www.svenskfagel.se.

Svensk Mjölk, Swedish Dairy Association. 2008. www.svenskmjolk.se

Swedish Board of Agriculture. 1993. Gödselproduktion, lagringsbehov och djurtäthet i olika djurhållningssystem med grisar (Manure production, storage and animal density for different pig prod-cuction systems). Swedish Board of Agriculture. Report 1993:20.

Swedish Board of Agriculture. 1995. Gödselproduktion, lagringsbehov och djurtäthet vid nötkreaturshållning (Manure production, storage and animal density in cattle breeding). Swedish Board of Agriculture. Report 1995:10.

Swedish Board of Agriculture. 2000. Riktlinjer för gödsling och kalkning 2001. Swedish Board of Agriculture. Report 2000:22.

Swedish Board of Agriculture. 2001. Gödselproduktion, lagringsbehov och djurtäthet I olika djurhållningssystem med grisar (Manure production, storage and animal density for different pig prodcuction systems). Swedish Board of Agriculture. Report 2001:13.

Swedish Board of Agriculture. 2003. Sales statistics on fertilisers, www.sjv.se/net/

Swedish Board of Agriculture. 2006. Livestock in June 2005. Final results. Statistical report JO 20 SM 0601. www.sjv.se

Swedish Board of Agriculture. 2008. Sales statistics on fertilisers, unpublished

Swedish EPA. 2002. TRK Tranport – Retention – Källfördelning. Belastning på havet. Swedish EPA. Report 5247.

Swedish EPA. 2002b. Kväveläckage från svensk åkermark. Beräkning av normalutlakning för 1995 och 1999. Swedish EPA. Report 5248.

Swedish EPA/SMED 2004. Field Burning of Crop Residues. SMED report 2005.

Swedish EPA/SMED 2005. A review of Swedish crop residue statistics used in the greenhouse gas inventory. SMED report 2005.

Section 7

Andrén, O. and Kätterer, T. 2001. Basic principles for soil carbon sequestration and calculating dynamics country-level balances including future scenarios. - In: Lal et al. Assessment methods for soil carbon. Lewis Publishers, pp. 495 - 511

Berg, B., Johansson, M-B., Tjarve, I., Gaitneks, T., Rokjanis, B., Beier, C., Rothe, A., Bolger, T., Göttlein, A. and Gertsberger, P. 1999a. Needle litterfall in a northern European spruce forest transect. Reports in Ecology and Forest Soils, Report 80, Department of forest Soils, Swedish university of agricultural Sciences, Uppsala, Sweden. 36 pp.

Berg, B., Albrektsson, A., Berg, M.P., Cortina, J., Johansson, M-B., Gallardo, A., madeira,M., Pausaa,J., Kratz,W., Vallejo, R., and McClaugherty, C. 1999b. Amounts of litterfall in some pine forests in a European transect, in particular Scots pine. Ann. For. Sci. 56:625-639.

Berglund, K. 1989. Ytsänkning av mosstorvjord. Swedish University of Agricultural Sciences, Dept. of Soil Sciences, Division of hydrotechnics. Report 89:3. (In Swedish).

Berglund, K. and Berglund, Ö. 2005. Odlad organogen jord i Sverige 2003- areal och grödfördelning uppskattad med hjälp av digitaliserade databaser. Naturvårdsverket dnr 721-3859-04Mm

Food and Agriculture Organization of the United Nations. 1994. World Reference Base for Soil Resources. FAO, Rome.

Food and Agriculture Organization of the United Nations. 2004. Global Forest Resources Assessment Update 2005 ─ Terms and Definitions. Food and Agriculture Organization of the United Nations, Forestry Department, Forest Resource Assessment Programme. Working Paper 83/E, Rome 2004.

Intergovernmental Panel on Climate Change. 2000. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Penman, J., Kruger, D., Galbally, I., Hiraishi, T., Nyenzi, B., Emmanuel, S., Buendia, L., Hoppaus, R., Martinsen, T., Meijer, J., Miwa, K., and Tanabe K. (Eds.). IPCC/OECD/IEA/IGES, Hayama, Japan.

Intergovernmental Panel on Climate Change. 2003. Good Practice Guidance for Land Use, Land-Use Change and Forestry. Penman, J., Gytarsky, M., Hiraishi, T., Krug T., Kruger, D., Pipatti, R., Buendia, L., Miwa, K., Ngara, T., Tanabe, K., and Wagner, F. (Eds.). IPCC/OECD/IEA/IGES, Hayama, Japan. ISBN 4-88788-003-0.

Johansson,T. 1999. Biomass equations for determining fractions of pendula and pubescent birches growing on abandoned farmland and some practical implications. Biomass and Bioenergy, 16:223-238.

Karltun, E., Stendahl, J., Löfgren, O. 2005. Sveriges Lantbruksuniversitets kvalitétssystem för försörjningen av grunddata till klimatrapporteringen enligt Kyotoprotokollet.

Kasimir-Klemedtsson, Å., Nilsson, M., Sundh, I., Svensson, B., 2000. Växthusgasflöden från myrar och organogena jordar. Naturvårdsverket, Rapport 5132. ISBN 91-620-5132.

Kjeldahl, J.G.C.T. 1883. Neue methode zur bestimmung des stickstoffs in organischen körpern. [A new method for the estimation of nitrogen in organic compounds]. Zeitschrift für analytische Chemie, 22, 366-382. (In German).

Löfgren, P. 1998. Skogsmark, samt träd- och buskmark inom fjällområdet. Sveriges Lantbruksuniversitet, Institutionen för skoglig resurshushållning och geomatik, rapport 34. 13 sidor ISSN 1401-1204.

Marklund, L.G. 1987. Biomass functions for Norway spruce in Sweden. Swedish University of Agricultural Sciences, Department of Forest Survey, report 43. 127p. ISSN 0348-0496.

Marklund, L.G. 1988. Biomassafunktioner för tall, gran och björk i Sverige. Sveriges Lantbruksuniversitet, Institutionen för skogstaxering, rapport 45. 73 sidor ISSN 0348-0496.

National Board of Forestry. 2000. Skogliga konsekvensanalyser 1999. Skogsstyrelsen, Jönköping 2000. 331 sidor. ISSN 1100-0295.

National Board of Forestry. 2004. Statistical yearbook of forestry 2004. National Board of Foresty, Jönköping 2004. ISSN 0491-7847.

Petersson, H., and Ståhl, G. 2006. Functions for Below Ground Biomass of Pinus sylvestris, Picea abies, Betula pendula and B. pubescens in Sweden. Scandinavian Journal of Forest Research, 21(Suppl 7): 84-93.

Ranneby, B., Cruse, T., Hägglund, B., Jonasson, H., and Swärd, J. 1987. Designing a new national forest survey for Sweden. Studia Forestalia Suecica 177, 29 p.

Sandström, F., Petersson, H., Kruys, N., and Ståhl, G. 2007. Biomass conversion factors (density and carbon concentration) by decay classes for dead wood of Pinus sylvestris, Picea abies and Betula spp. in boreal forests of Sweden. Forest Ecology and Management, 243: 19-27.

Statistics Sweden. 2002. Torv 2001 – Produktion, användning, miljöeffekter. SCB, Sveriges Officiella Statistik, Statistiska Meddelanden MI 25 SM 0201. ISSN 1403-8978. In Swedish.

Ståhl, G., Boström, B., Lindkvist, H., Lindroth, A., Nilsson, J., and Olsson, M., 2003. Methodological options for quantifying changes in carbon pools in Swedish forests. SLU, Department of forest resource management and geomatics. Working paper 118. ISSN 14021-1204.

Statistics Sweden. 2004. Sales of lime for agricultural and horticultural purposes, and for lakes and woodlands in 2003. Statistics Sweden, MI 30 SM 0402. ISSN 1403-8978. In Swedish.

Swedish Rescue Services Agency. 2004. Räddningstjänst i siffror. Rapport I99-114, 128 s. In Swedish.

Sundh, I., Nilsson, M., Mikkelä, C., Granberg, G., Svensson, B.H., 2000. Fluxes of methane and carbon dioxide on peat-mining areas in Sweden. Ambio 29, no 8: 499-503.

Svenska Torvproducentföreningen. 2006. Torvåret 2005 – Statistik över Sveriges Torvproduktion 2005. Sammanställd av Svenska Torvproducentföreningen, In Swedish

Swedish University of Agricultural Sciences. 2004. Forestry statistics 2004. Official statistics of Sweden, Swedish University of Agricultural Sciences, Umeå 2004. 124 p. ISSN 0280-0543. In Swedish.

Swedish University of Agricultural Sciences. 2005. RIS Fältinstruktion 2005 ─ Riksinventeringen av skog. SLU, Institutionen för Skoglig Resurshushållning och Geomatik och Institutionen för Skoglig Marklära. In Swedish.

Thompson, S.K. 1992. Sampling. Wiley Series in Probabilty and Mathematical Statistics, USA, 343 p. ISBN 0-471-54045-5.

Viro, 1952. On the determination of stoniness. Comm. Inst. For. Fenn. 40:1-19.

Section 8

Avfall Sverige, 2007. Swedish Waste Management 2007. Årsskrift från Avfall Sverige. Swedish Association of Waste Management. www.avfallsverige.se.

Avfall Sverige, 2007. Oral communication. Mikael Johnsson, Avfall Sverige. Swedish Association of Waste Management.

Avfall Sverige, 2008. Swedish Waste Management 2008. Årsskrift från Avfall Sverige. Swedish Association of Waste Management. www.avfallsverige.se.

Avfall Sverige, 2008. Oral communication. Mikael Johnsson, Avfall Sverige. Swedish Association of Waste Management.

Börjesson G. 1997. Methane Oxidation in Landfill Cover Soils, Gunnar Börjesson, Department of Microbiology Uppsala.

Börjesson G. 2000. Oral communication. Gunnar Börjesson, Department of Microbiology Uppsala.

Börjesson, G., Svensson, B. Samuelsson J. and Galle B. 2003. AVF 03/1. Slutrapport

STEM projekt nr P10856-2. Metan från avfallsupplag i Sverige. Statens Energimyndighet 2003-01-23.

Galle, B., Samuelsson. J., Svensson, BH., Börjesson, G. 2001. Measurements of methane emissions from landfills using a time correlation tracer method based on FTIR absorption spectroscopy. Environemntal Science & Technology 35 (1):21-25.

Marklund S. 2006. Oral communication. Stefan Marklund, Luleå kommun.

Ministry of the Environment Sweden, Ds 2001:71, 2001. Sweden´s third national communication on Climate change.

National Food Administration. 2002. www.slv.se.

Ohlsson T. 1998. Plockanalys av hushållsavfall, metoder och trender, Tommy Ohlsson, 1998:226 CIV, Luleå University of Technology.

Profu. 2004. Deponering av olika avfallstyper i Sverige. Profu rapport 2004-01-30.

REFORSK 1998. Plockanalys av hushållens säck- och kärlavfall. En studie i sex svenska kommuner. Report FoU 145.

REFORSK. 2001. Karaktärisering av avfall från svenska hushåll, K. Report FoU 155.

RVF. 1986. Statistik Svensk avfallshantering. Swedish Association of Waste Management. Report 88:5.

RVF. 1990. Svensk avfallshantering 1990. Swedish Association of Waste Management. Report 90:9.

RVF. 1996. Svenska deponier idag, kartläggning av miljöskydd, avgifter och mängder. Swedish Association of Waste Management. Report 96:5.

RVF. 1996b. Beskrivning av biologiskt avfall. Vägledning vid val av biologisk behandlingsmetod. Swedish Association of Waste Management. Report 96:8.

RVF. 1996c. Deponigas, teknik och produktion vid svenska anläggningar. Swedish Association of Waste Management. Report 96:5

RVF. 1997. Deponering i Sverige. Swedish Association of Waste Management. Report 97:8.

RVF. 1998. Avfallsanläggningar med deponering. Swedish Association of Waste Management. Report 98:9.

RVF. 1999. Avfallsanläggningar med deponering. Swedish Association of Waste Management. Report 99:5.

RVF. 2000. Avfallsanläggningar med deponering. Swedish Association of Waste Management. Report 00:14.

RVF. 2001. Avfallsanläggningar med deponering. Statistik 2000. Swedish Association of Waste Management. Report 01:11.

RVF. 2002. Swedish Waste Management 2002. Årsskrift från RVF. Swedish Association of Waste Management. www.rvf.se.

RVF. 2003. Swedish Waste Management 2003. Årsskrift från RVF. Swedish Association of Waste Management. www.rvf.se.

RVF. 2003. Förbränning av avfall. Utsläpp av växthusgaser jämfört med annan avfallsbehandling och annan energiproduktion. Swedish Association of Waste Management. Rapport 2003:12 (in Swedish). ISSN 1103-4092.

RVF. 2004. Swedish Waste Management 2004. Årsskrift från RVF. Swedish Association of Waste Management. www.rvf.se.

RVF. 2005. Swedish Waste Management 2005. Årsskrift från RVF. Swedish Association of Waste Management. www.rvf.se.

RVF. 2005. Oral communication. Anders Hedenstedt, Thomas Rihm, RVF. Swedish Association of Waste Management.

RVF. 2005. Trender och variationer i hushållsavfallets sammansättning. Swedish Association of Waste Management. RVF 2005:05. ISSN 1103-4092

RVF. 2006. Swedish Waste Management 2006. Årsskrift från RVF. Swedish Association of Waste Management. www.rvf.se.

Statistics Sweden, 1988. Avfall och återvinning i kommunal regi 1985 (Waste and recovery in municipalities in Sweden 1985). Statistical report Na 28 SM 8801.

Statistics Sweden, 1992. Avfall och återvinning i kommunal regi 1990 (Waste and recovery in municipalities in Sweden 1990). Statistical report Na 28 SM 9201.

Statistics Sweden, 1995. Industrins avfall och returråvaror 1993 (Waste and returnable raw materials from the industry 1993). Statistical report Na 28 SM 9501.

Statistics Sweden, 1995b. Avfall och återvinning i kommunal regi 1994 (Waste and recovery in municipalities in Sweden 1994). Statistical report Na 28 SM 9502.

Statistics Sweden, 2000. Avfall från tillverkningsindustrin och utvinning av mineraler 1998 (Waste from the manufacturing and minerals extraction industries in 1998). Statistical report MI 28 SM 0001.

Statistics Sweden, 2000b. Återvinning och bortskaffande av avfall 1998 (Recovery and disposal of waste 1998). Statistical report MI 28 SM 0002.

Statistics Sweden, 2002. Utsläpp till vatten och slamproduktion 2000 (Discharges to water and sludge production in 2000), MI 22 SM 0101.

Statistics Sweden, 2004. Utsläpp till vatten och slamproduktion 2002 (Discharges to water and sludge production in 2002), MI 22 SM 0401.

Statistics Sweden, 2007. Utsläpp till vatten och slamproduktion 2004 (Discharges to water and sludge production in 2004), MI 22 SM 0701.

Statistics Sweden, 2008. Utsläpp till vatten och slamproduktion 2006 (Discharges to water and sludge production in 2006), MI 22 SM 0801.

Sweco Viak, Oral communication, 2000.

Swedish Energy Agency, 2008. Produktion och användning av biogas år 2006. Report ER 2008:02

Swedish EPA. 1975. Avfallsanläggningar i Sverige. Swedish EPA. Report 1975:11.

Swedish EPA. 1983. Avfallsanläggningar i Sverige, Statistik och sammanställningar. Swedish EPA. Report PM 1652.

Swedish EPA. 1988. Svensk avfallshantering – Nuläge och problem. Swedish EPA. Report 3480.

Swedish EPA. 1993. Deponigasgenerering: Underlag för riktlinjer. Swedish EPA. Report 4158.

Swedish EPA. 1993b. Metangas från avfallsupplag (Methane from Landfills). Swedish EPA. Report 4271.

Swedish EPA. 1994. Lustgasutsläpp från kommunala reningsverk (N_2O-emissions from municipal waste water treatment plants). Swedish EPA. Report 4309.

Swedish EPA. 1995: Skogsindustrins utsläpp till vatten och luft, samt avfallsmängder (Emissions and waste from the forest industry). Swedish EPA. Report 4434.

Swedish EPA. 1996. Flöden av organiskt avfall. Swedish EPA. Report 4611.

Swedish EPA. 1996b. Skogsindustrins utsläpp till vatten och luft, samt avfallsmängder 1995. Swedish EPA. Report 4657.

Swedish EPA. 1997. Metangas från avfallsupplag, underlag för statistik, Magnus Montelius, Krets-loppsavdelningen. Swedish EPA PM 970205, 1997. (Unpublished)

Swedish EPA. 1997b: Sverige mot minskad klimatpåverkan. Swedish EPA. Report 4786.

Swedish EPA. 1998. Skogsindustrins utsläpp till vatten och luft samt avfallsmängder energiförbrukning 1996. Swedish EPA. Report 4869.

Swedish EPA. 1998b. Skogsindustrins utsläpp till vatten och luft samt avfallsmängder och energiförbrukning 1997. Swedish EPA. Report 4924.

Swedish EPA. 1999. Skogsindustrins utsläpp till vatten och luft samt avfallsmängder och energiför-brukning 1998. Swedish EPA. Report 4987.

Swedish EPA. 1999b. Gas Emission from Land fills, An overview of issues and research needs. AFR 264.

Swedish EPA. 2000. Skogsindustrins utsläpp till vatten och luft samt avfallsmängder och energiför-brukning 1999. Swedish EPA. Report 5114.

Swedish EPA. 2001. Skogsindustrins utsläpp: avfallsmängder och energiförbrukning 2000. Swedish EPA. Report 5154.

Swedish EPA and SMED. 2002, Data om hushållsavfall

Swedish EPA and SMED. 2003. Avloppsrening i Sverige.

Swedish EPA and SMED. 2006. Rening av avloppsvatten i Sverige år 2004.

Swedish Forest Industries Federation. 2005. Oral communication. Ingrid Haglind.

Swedish Forest Industries Federation. 2006. Oral communication. Ingrid Haglind.

Swedish Forest Industries Federation. 2007. Oral communication. Ingrid Haglind.

Swedish Forest Industries Federation. 2008. Oral communication. Ingrid Haglind.