National Inventory Report 2010
Sweden

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

SWEDISH ENVIRONMENTAL
PROTECTION AGENCY

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 2010. It contains national greenhouse gas emission inventories for the period 1990 to 2008, 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.

This inventory is coordinated, on behalf of the Swedish Ministry of Environment, by 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 2010. 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 2008, 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 knappt 64 miljoner ton år 2008 med ca 6 % osäkerhet (Tabell S 1), vilket är en minskning med 2,2 miljoner ton jämfört med 2007. Utsläppen har minskat med 11,7 %, eller ca 8,5 miljoner ton, mellan 1990 och 2008. Osäkerheten är beräknad till $\pm$ 2,5 % i trenden, dvs. minskningen ligger i intervallet 9,2-14,2 %. 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 14,7 miljoner ton koldioxidekvivalenter 2008. Sänkans storlek har

varierat under perioden 1990-2008, men trenden pekar mot en något minskande sänka. (Tabell S 1).

Utsläppen av koldioxid var 50,42 miljoner ton år 2008 vilket är 11 % 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 5,1 miljoner ton 2008 räknat som koldioxidekvivalenter (Tabell S 1). Sedan 1990 har utsläppen av metan minskat med ca 24 %, vilket främst beror på åtgärder inom avfallssektorn.

2008 var totala utsläppen av lustgas nästan 7,2 miljoner ton räknat som koldioxidekvivalenter (Tabell S 1), vilket är en minskning med ca 16 % 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) 2008 var ca 1,23 miljoner ton uttryckt i koldioxidekvivalenter (Tabell S 1). Detta innebär en ökning av utsläppen med 151 % 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	2008
	CO_2 equivalent (Gg)																		
CO_2 incl. netto CO_2 från LULUCF	25 491	24 041	27 169	29 886	35 223	34 779	32 641	23 173	21 198	19 444	17 686	20 958	21 246	23 488	29 936	32 928	35 857	37 361	35 606
CO_2 excl. netto CO_2 från LULUCF	56 615	57 059	56 883	56 569	59 091	58 521	62 016	57 372	58 067	55 154	53 888	54 642	55 693	56 379	55 869	53 328	52 943	52 291	50 416
CH_4 incl. CH_4 från LULUCF	6 733	6 719	6 806	6 855	6 778	6 692	6 658	6 606	6 432	6 284	6 103	6 073	5 896	5 760	5 782	5 655	5 568	5 341	5 101
CH_4 excl. CH_4 från LULUCF	6 732	6 717	6 804	6 853	6 777	6 690	6 656	6 598	6 432	6 281	6 100	6 070	5 891	5 754	5 776	5 650	5 556	5 339	5 088
N_2O incl. N_2O från LULUCF	8 683	8 597	8 497	8 598	8 660	8 531	8 656	8 566	8 555	8 121	8 049	7 885	7 807	7 790	7 774	7 628	7 685	7 378	7 355
N_2O excl. N_2O från LULUCF	8 603	8 536	8 445	8 541	8 602	8 467	8 591	8 501	8 489	8 050	7 974	7 809	7 733	7 708	7 687	7 530	7 578	7 264	7 234
HFCs	4	8	10	30	74	127	204	312	385	489	564	612	665	711	774	803	835	870	917
PFCs	377	380	252	291	312	343	303	280	272	291	241	236	261	258	254	257	245	248	225
SF6	107	109	108	97	100	127	108	153	99	102	94	111	104	69	81	142	111	151	83
Totalt (incl. LULUCF)	41 396	39 853	42 842	45 756	51 147	50 598	48 569	39 091	36 942	34 730,	32 736	35 875	35 979	38 077	44 601	47 413	50 302	51 349	49 287
Totalt (excl. LULUCF)	72 438	72 808	72 503	72 381	74 955	74 275	77 879	73 215	73 745	70 366	68 861	69 480	70 347	70 880	70 441	67 711	67 268	66 163	63 963

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	2008
	CO_2 equivalent (Gg)																		
Energi	53 203	53 922	54 060	53 691	55 850	54 998	58 885	54 182	54 759	51 801	50 312	51 012	51 934	52 915	52 023	49 644	49 294	48 520	46 676
Industriprocesser	6 265	6 094	5 634	5 764	6 215	6 579	6 363	6 351	6 531	6 548	6 735	6 732	6 881	6 609	7 002	6 931	6 943	6 880	6 793
Användning av lösningsmedel och andra produkter	332	320	326	315	293	309	312	321	318	299	278	269	276	292	311	303	297	284	284
Jordbruk	9 515	9 304	9 316	9 551	9 653	9 455	9 410	9 486	9 314	9 016	8 923	8 899	8 834	8 750	8 800	8 667	8 666	8 549	8 470
Markanvändning, förändrad markanvändning och skogsbruk	-31 042	-32 956	-29 661	-26 625	-23 808	-23 676	-29 309	-34 124	-36 803	-35 636	-36 125	-33 606	-34 368	-32 803	-25 841	-20 298	-16 966	-14 814	-14 676
Avfall	3 122	3 168	3 168	3 059	2 944	2 934	2 909	2 875	2 822	2 702	2 614	2 569	2 423	2 314	2 305	2 166	2 068	1 929	1 740

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 46,7 miljoner ton i koldioxidekvivalenter 2008 (Tabell S 2), vilket är ca 73 % av de totala utsläppen. Utsläpp av koldioxid från trafiken ökade med 11% från 1990 till 2008. Den ökande trenden har mattats av sedan 2003. Utsläppen av koldioxid har 2008 minskat som en följd av e.g., den ekonomiska nedgången som inleddes hösten 2008. Utsläpp från individuell uppvärmning av byggnader fortsätter att minska. Detta innebär att energisektorn inklusive transporter har minskat sina utsläpp med ca 12,3 % år 2008 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 18 % och lustgas med ca 5 %. De totala utsläppen från industriprocesser var omkring 6,8 miljoner ton koldioxidekvivalenter år 2008 (Tabell S 2), vilket motsvarar omkring 10 % av totala utsläppen. Totala utsläppen från industriprocesser minskade med drygt 1% mellan 2007 och 2008. Sedan 1990 har de totala utsläppen i denna sektor varierat, vilket framför allt beror på att produktionsvolymerna varierar med ekonomiska cykeln. 2008 var utsläppen 8,4 % högre än 1990.

Användningen av Lösningsmedel och andra produkter ger huvudsakligen upphov till utsläpp av flyktiga organiska ämnen, lustgas och en del koldioxid. 2008 var utsläppen av koldioxid och lustgas knappt 0,3 miljoner ton uttryckt i koldioxidekvivalenter (Tabell S 2), vilket utgör 0,44 % av de totala växthusgasutsläppen. Jämfört med 1990 har utsläppen i denna sektor minskat med 14 %. Omkring 25 % 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. 2008 var de totala utsläppen från jordbrukssektorn 8,5 miljoner ton uttryckt i koldioxidekvivalenter (Tabell S 2), vilket är en minskning med ca 11 % jämfört med 1990. Utsläpp av metan kommer framför allt från boskapens matsmältningsprocesser och avföring. De viktigaste anledningar till de minskade utsläppen är en minskad boskapshållning och en minskad tillämpning av mineral gödselmedel i jordbruket. 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 14,7 miljoner ton koldioxidekvivalenter år 2008 (Tabell S 2). Sänkans storlek har varierat under perioden 1990-2008, men trenden pekar mot en något minskande sänka som beror främst på, bland annat till ökad avverkning.

Kommentar [mlu1]: Kom ihåg att ta bort!!!

Deponier av fast avfall är den näst största källan till utsläpp av metan. 2008 var de totala utsläppen från avfallssektorn knappt 1,74 miljoner ton (Tabell S 2) uttryckt i koldioxidekvivalenter, vilket motsvarar ca 2,7 % av de totala utsläppen. Detta är en minskning på 44 % 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 173 kton 2008 (Tabell S 4), vilket är en minskning med ca 51 % jämfört med 1990. De huvudsakliga källorna till NMVOC är vägtrafik, vedeldning inom bostadssektorn och produkter innehållande lösningsmedel, . 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	2008
NO_X	304	309	295	274	280	268	261	246	235	224	212	203	197	191	182	176	171	165	156
CO	939	958	929	886	889	867	840	789	723	698	665	627	611	614	584	582	550	552	521
NMVOC	353	307	291	267	259	247	240	229	216	208	200	188	185	187	186	183	179	180	173
SO_2	105	102	94	82	80	69	67	60	56	47	42	41	40	41	37	36	36	33	31

Utsläppen av kväveoxider (NO_x) var ca 156 kton 2008 (Tabell S 4), vilket är en minskning med ca 49 % 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 kväveoxidutsläpp från energisektorn.

Utsläppen av kolmonoxid (CO) har minskat från 939 kton 1990 till 521 kton 2008 (Tabell S 4), en reducering på knappt 44 %. Omkring 42% av utsläppen kommer från transportsektorn och 40% från "övriga sektorer".

Utsläppen av svaveldioxid (SO_2) har minskat från 105 kton 1990 till 31 kton 2008 (Tabell S 4), en reducering på ca 71 %. Minskningen beror framför allt på en övergång till lågsvavelhaltiga bränslen, både för vägtrafik och uppvärmning. Svavelskatt, 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 2010 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 2008, 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 almost 64 million tonnes for 2008 with an uncertainty of about 6 % (Table ES 1), which is a decrease of 2,2 million tonnes compared to 2007. Emissions have fallen by about 11,7 % or approximately 8,5 million tonnes between 1990 and 2008. The uncertainty in the trend is a percentage point range relative to the inventory trend and should be interpreted as

± 2.5 %. Aggregated emissions varied over the period but were in all cases below the 1990 level during the period 1999-2008.

The net removals by sinks for the land use, land use change and forestry (LULUCF) sector amounted to approximately 14,7 million tonnes carbon dioxide equivalents in 2008. (Table ES 1). The size of the sink varied over the period 1990-2008, but the trend points towards a somewhat decreasing sink.

Emissions of CO_2 were around 50,42 million tonnes in 2008, which is about 11 % 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 arise mainly from agriculture and landfill sites, and were approximately 5,1 million tonnes, expressed in CO_2-equivalents, in 2008 (Table ES 1). Since 1990, emissions have decreased about 24 %, primarily due to measures implemented in the waste sector.

In 2008, the total emissions of nitrous oxide were around 7.2 million tonnes, expressed in CO_2-equivalent (Table ES 1), a reduction of 16 % compared to 1990. Emissions arise mainly 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 2008 were approximately 1,23 million tonnes expressed in carbon dioxide equivalents (Table ES 1). This corresponds to an increase of about 151 % 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	2008
	CO_2 equivalent (Gg)																		
CO_2 incl. net CO_2 from LULUCF	25 491	24 041	27 169	29 886	35 223	34 779	32 641	23 173	21 198	19 444	17 686	20 958	21 246	23 488	29 936	32 928	35 857	37 361	35 606
CO_2 excl. net CO_2 from LULUCF	56 615	57 059	56 883	56 569	59 091	58 521	62 016	57 372	58 067	55 154	53 888	54 642	55 693	56 379	55 869	53 328	52 943	52 291	50 416
CH_4 incl. CH_4 from LULUCF	6 733	6 719	6 806	6 855	6 778	6 692	6 658	6 606	6 432	6 284	6 103	6 073	5 896	5 760	5 782	5 655	5 568	5 341	5 101
CH_4 excl. CH_4 from LULUCF	6 732	6 717	6 804	6 853	6 777	6 690	6 656	6 598	6 432	6 281	6 100	6 070	5 891	5 754	5 776	5 650	5 556	5 339	5 088
N_2O incl. N_2O from LULUCF	8 683	8 597	8 497	8 598	8 660	8 531	8 656	8 566	8 555	8 121	8 049	7 885	7 807	7 790	7 774	7 628	7 685	7 378	7 355
N_2O excl. N_2O from LULUCF	8 603	8 536	8 445	8 541	8 602	8 467	8 591	8 501	8 489	8 050	7 974	7 809	7 733	7 708	7 687	7 530	7 578	7 264	7 234
HFCs	4	8	10	30	74	127	204	312	385	489	564	612	665	711	774	803	835	870	917
PFCs	377	380	252	291	312	343	303	280	272	291	241	236	261	258	254	257	245	248	225
SF_6	107	109	108	97	100	127	108	153	99	102	94	111	104	69	81	142	111	151	83
Total (incl. LULUCF)	41 396	39 853	42 842	45 756	51 147	50 598	48 569	39 091	36 942	34 730,	32 736	35 875	35 979	38 077	44 601	47 413	50 302	51 349	49 287
Total (excl. LULUCF)	72 438	72 808	72 503	72 381	74 955	74 275	77 879	73 215	73 745	70 366	68 861	69 480	70 347	70 880	70 441	67 711	67 268	66 163	63 963

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	2008
	CO_2 equivalent (Gg)																		
Energy	53 203	53 922	54 060	53 691	55 850	54 998	58 885	54 182	54 759	51 801	50 312	51 012	51 934	52 915	52 023	49 644	49 294	48 520	46 676
Industrial Processes	6 265	6 094	5 634	5 764	6 215	6 579	6 363	6 351	6 531	6 548	6 735	6 732	6 881	6 609	7 002	6 931	6 943	6 880	6 793
Solvent and Other Product Use	332	320	326	315	293	309	312	321	318	299	278	269	276	292	311	303	297	284	284
Agriculture	9 515	9 304	9 316	9 551	9 653	9 455	9 410	9 486	9 314	9 016	8 923	8 899	8 834	8 750	8 800	8 667	8 666	8 549	8 470
Land Use, Land-Use Change and Forestry	-31 042	-32 956	-29 661	-26 625	-23 808	-23 676	-29 309	-34 124	-36 803	-35 636	-36 125	-33 606	-34 368	-32 803	-25 841	-20 298	-16 966	-14 814	-14 676
Waste	3 122	3 168	3 168	3 059	2 944	2 934	2 909	2 875	2 822	2 702	2 614	2 569	2 423	2 314	2 305	2 166	2 068	1 929	1 740

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 46,7 million tonnes,expressed as carbon dioxide equivalents, in 2008 (Table ES 2), which is equivalent to 73 % of the total emissions. From 1990 to 2008 there was 11 % increase of carbon dioxide from road traffic. However, the increasing trend has been moderated since 2003. In 2008 the emissions have decreased as a result of e.g., the economic downturn that began in the autumn of 2008.

Emissions from individual combustion in buildings are decreasing. This means that the energy sector, including transport, has decreased its GHG emissions with 12,3 % in 2008 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 18 % and nitrous oxide with 5 %. Total emissions from industrial processes in 2008 were approximately 6,8 million tonnes expressed as carbon dioxide equivalents (Table ES 2), which is approximately 10 % of the total emissions. The total emissions from industrial processes decreased by just over 1 % between 2007 and 2008. Since 1990, total emissions in this sector have varied, primarily because production volumes vary with economic cycles. In 2008 emissions were 8,4 % 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 2008, emissions of carbon dioxide and nitrous oxide expressed in carbon dioxide equivalents were almost 0.3 million tonnes (Table ES 2), which corresponds to 0,44 % of the total greenhouse gas emissions. Compared to 1990, emissions have decreased with about 14 %. About 25 % 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 2008, total greenhouse gas emissions expressed in carbon dioxide equivalents were 8,5 million tonnes (Table ES 2), a decrease with about 11 % compared to 1990. Methane emissions arise primarily from the digestive processes of cattle and from their manure. The most important reasons for the reduced emissions are reduced livestock keeping and reduced application of N-fertilisers in agriculture.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 14,7 million tonnes in 2008 (Table ES 2). The size of the sink varied over the period 1990-2008, but the trend points towards a somewhat decreasing sink, which is mainly due to an increase in felling.

Solid waste landfills are the second largest source of emissions of methane. In 2008, total emissions from the waste sector were 1,74 million tonnes (Table ES 2) expressed as carbon dioxide equivalents or about 2,7 % of the total GHG emissions. This is a reduction of 44 % 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 173 ktonnes in 2008 (Table ES 4), a decrease of 51 % compared to 1990. The main contributors to NMVOC emissions are road traffic, wood combustion in the residential sector and solvents-contiang products.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	2008
NO_X	304	309	295	274	280	268	261	246	235	224	212	203	197	191	182	176	171	165	156
CO	939	958	929	886	889	867	840	789	723	698	665	627	611	614	584	582	550	552	521
NMVOC	353	307	291	267	259	247	240	229	216	208	200	188	185	187	186	183	179	180	173
SO_2	105	102	94	82	80	69	67	60	56	47	42	41	40	41	37	36	36	33	31

Emissions of nitrogen oxides (NO_x) were about 156 ktonnes in 2008 (Table ES 4), a reduction of 49 % 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 939 ktonnes in 1990 to 521 ktonnes in 2008 (Table ES 4), a reduction of about 44 %. About 42 % of emissions came from the transport sector and 40% from the 'Other Sectors'.

Emissions of sulphur dioxide (SO_2) have decreased from 105 ktonnes in 1990 to 31 ktonnes in 2008 (Table ES 4), a reduction of about 71 %. 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 2010. The report contains information on Sweden's inventories for all years from 1990 to 2008 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

[1] 2002/358/EG

as greenhouse gases than carbon dioxide, which means that they still make a considerable 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.

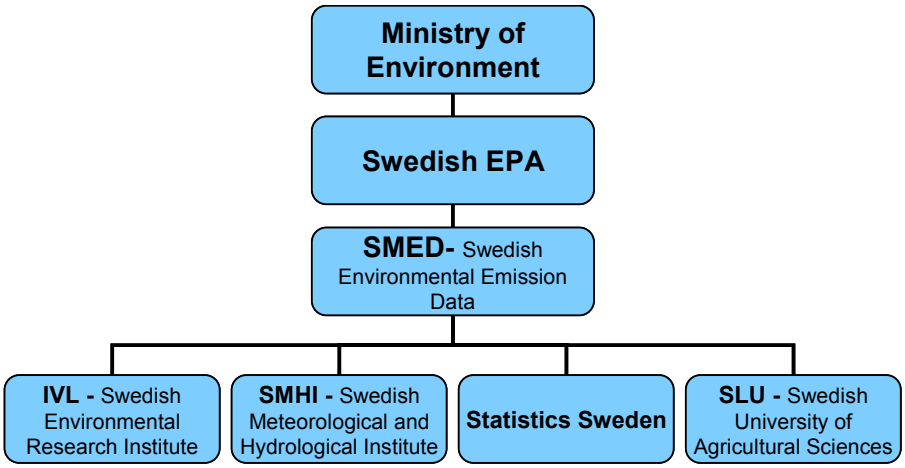

Figure 1.1. The Swedish inventory system.

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 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, an independent research and consultant company in the areas of energy, environment and waste management, 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 1990-2008 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, European Union Emission Trading Scheme (EU ETS)[2], environmental reports[3], 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

[2] See Annex 8.1

[3] See Annex 8.3

Gas Inventories (IPCC Guidelines)[4] and, in general, in line with IPCC´s Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (Good Practice Guidance)[5] and IPCC's Good Practice Guidance for Land Use, Land-Use Change and Forestry (GPG-LULUCF)[6]. Some parts of the methodologies are taken directly from the IPCC Guidelines, the Good Practice Guidance and the EMEP/CORINAIR Emission Inventory Guidebook (CORINAIR).[7] Information from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines)[8] is used in some parts of the inventory.

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 aluminum 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.
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

[4] The IPCC Guidelines can be found at: http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm

[5] The Good Practice Guidance can be found at: http://www.ipcc-nggip.iges.or.jp/public/gp/english/

[6] The GPG-LULUCF can be found at: http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.html

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

[8] The 2006 IPCC Guidelines can be found at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

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.

1.5 Key categories

According to 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 GPG-LULUCF for the LULUCF sector section 5.4 and Good Practice Guidance section 7.2. The resulting key categories including LULUCF are presented in Appendix 21A according to the format of CRF table 7. Corresponding background tables, according to tables 7.A1 - 7.A2 of the Good Practice Guidance are presented in Appendix 21B. The methodology is discussed in detail in Annex 2.

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 2008 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 2008. They contribute with 30.03 % and 10.94 %, respectively, of the national total and are the top two on the level assessment list for all years.

Table 1.2. Key categories 2008 in terms of level assessment, excluding LULUCF

IPCC category	GHG	Emissions 2008	Contribution to the national total emissions 2008
		Gg CO_2 eq	
1A3b. Road Transportation	CO2	19 208	30.03%
1A1a. Public electricity and Heat production	CO2	6 996	10.94%
4D. Agricultural Soils	N2O	4 816	7.53%
1A2f. Other Manufacturing Industries and Construction	CO2	4 514	7.06%
2C. Metal Production	CO2	2 981	4.66%
4A. Enteric Fermentation	CH4	2 713	4.24%
1A1b. Petroleum Refining	CO2	2 193	3.43%
2A. Mineral Products	CO2	2 159	3.38%
1A2a. Iron and Steel	CO2	2 088	3.26%
1A4c. Agriculture/Forestry/Fisheries	CO2	1 767	2.76%
1A2d. Pulp, Paper and Print	CO2	1 549	2.42%
6A. Solid Waste Disposal on Land	CH4	1 465	2.29%
1A2c. Chemicals	CO2	1 421	2.22%
1A4b. Residential	CO2	1 211	1.89%
2F. Consumption of Halocarbons and SF6	HFCs	917	1.43%
1A4a. Commercial/Institutional	CO2	831	1.30%
1B2. Oil and Natural Gas	CO2	794	1.24%
1A3a. Civil Aviation	CO2	626	0.98%
1A2e. Food Processing, Beverages and Tobacco	CO2	491	0.77%
4B. Manure Management	N2O	476	0.74%
4B. Manure Management	CH4	464	0.73%
1A3d. Navigation	CO2	443	0.69%
1A1a. Public electricity and Heat production	N2O	390	0.61%
1A2f. Other Manufacturing Industries and Construction	N2O	340	0.53%

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 2008, 22 key categories in terms of trend have been identified, excluding LULUCF (Table 1.3). The Energy Sector (CRF 1) contributes with the majority (14 categories) of categories, while Industrial Processes (CRF 2), Agriculture (CRF 4) and Waste (CRF 6) account for 5, 2 and 1 categories, respectively.

In 2008, the sources with the most significant increase in trend since 1990 are CO_2 from Road transport (1A3b), followed by emissions of HFCs from Consumption of Halocarbons and SF6 (2F), contributing with 20.42 % and 4.75 % to the

overall trend, respectively. Road transport has been on the top-ten list every year 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 2008 contributing 22.28 % and 7.32 % 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 5.58 % contribution.

Table 1.3. Key categories 2008 in terms of trend assessment, excluding LULUCF

IPCC category	GHG	Emissions 1990	Emissions 2008	Contribution to the emission trend 1990-2008
		Gg CO_2 eq	Gg CO_2 eq	
1A4b. Residential	CO2	6 220	1 211	22.28%
1A3b. Road Transportation	CO2	17 309	19 208	20.42%
1A4a. Commercial/Institutional	CO2	2 533	831	7.32%
6A. Solid Waste Disposal on Land	CH4	2 874	1 465	5.58%
2F. Consumption of Halocarbons and SF6	HFCs	4	917	4.75%
1A2a. Iron and Steel	CO2	1 638	2 088	3.34%
2A. Mineral Products	CO2	1 721	2 159	3.33%
1A1b. Petroleum Refining	CO2	1 778	2 193	3.24%
1A5. Other	CO2	801	161	2.84%
1B2. Oil and Natural Gas	CO2	304	794	2.74%
1A2f. Other Manufacturing Industries and Construction	CO2	5 670	4 514	2.56%
2B. Chemical Industry	N2O	832	276	2.39%
1A4c. Agriculture/Forestry/Fisheries	CO2	1 536	1 767	2.14%
1A2c. Chemicals	CO2	1 146	1 421	2.13%
1A2d. Pulp, Paper and Print	CO2	2 186	1 549	1.98%
1A1a. Public electricity and Heat production	CO2	7 493	6 996	1.98%
1A2e. Food Processing, Beverages and Tobacco	CO2	948	491	1.80%
2C. Metal Production	CO2	3 075	2 981	1.38%
4B. Manure Management	N2O	728	476	0.87%
4B. Manure Management	CH4	349	464	0.81%
1A1a. Public electricity and Heat production	N2O	304	390	0.63%
2C. Metal Production	PFCs	377	223	0.57%

A detailed description of the methodology used in the analysis is provided in Annex 2 and the complete analysis of Sweden's key source categories is presented in Appendix 21B.

1.5.3 Level and trend assessment including LULUCF

Table 1.4 shows the additional LULUCF-key categories 2008 for level and trend when including the LULUCF sector in the national inventory. Emissions/removals of CO_2 were found to be key for one or more years for Forest land (5A), Cropland (5B) 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 2008 for both level and trend. A negative value indicates a net removal. (Total emissions/ removals refer to absolute values)

IPCC category	GHG	Emissions/ Removals 1990	Emissions/ Removals 2008	Contribution to the level of national total emissions/-removals, including LULUCF 2008	Contribution to the trend of emissions/removals, including LULUCF 1990-2008
		Gg CO_2 eq	Gg CO_2 eq		
5A. Forest land	CO_2	-35819,18	-20932,76	22.96%	41.24%
5B. Cropland	CO_2	4129,58	2886,77	3.17%	3.86%
5E. Settlements	CO_2	1183,57	3039,82	3.33%	3.10%
5C. Grassland	CO_2	-657,04	134,05	(no key category)	1.74%

1.6 Information on QA/QC

1.6.1 Background

This section presents the general QA/QC plan for the Swedish GHG inventory[9]. The current system complies with the Tier 1 procedures outlined in the Good Practice Guidance. 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 collec-

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

tion of improvement needs from all stages of the annual inventory cycle. This results 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 aluminum 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 Good Practice Guidance section 6.3.2. According to the IPCC Guidelines, uncertainty estimates are an essential part of an emission inventory. They should be derived for each variable used in the inventory (measured emissions, activity data and emission factors) and aggregated into uncertainty estimates in total national emissions and emission changes over time (trends). The 2006 IPCC Guidelines identify that: "An uncertainty analysis should be seen, first and foremost, as a means to help prioritise national efforts to reduce the uncertainty of inventories in the future, and guide decisions on methodological choice".

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.[10]

The 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 Good Practice Guidance, since not enough background data was available to make actual statistical uncertainty calculations. Hence, care should be taken when interpreting and assessing the uncertainty results.

Uncertainty estimates have been performed for the base year 1990 and 2008 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.

[10] Gustafsson, 2005

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 2008, uncertainty introduced to the trend 1990-2008 is calculated following the IPCC Tier 1 method.

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 2008 CO_2 equivalent emissions in Sweden result in combined uncertainty of the national total emissions of 2.2%, 1.8%, 5.4 % and 0.4 % for CO_2, CH_4, N_2O and F-gases respectively. The overall uncertainty for 2008 is calculated to be 6.1%. For 1990, the combined uncertainties of the national total emissions were 2.2 %, 2.8%, 5.4 % and 0.2 % for CO_2, CH_4, N_2O and F-gases respectively. The overall uncertainty for 1990 is calculated to be 6.5 %. 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 2009 were 8.0 % for 1990 and 7.7 % for 2007, which means that the estimated overall uncertainties are lower in this submission. The main reason to this is the revision of emissions from off-road vehicles and working machinery that was performed in submission 2009. In this model, the uncertainties were originally assessed on a highly disaggregated level and assumed to be very high. In submission 2010, it was concluded that the activity data uncertainty and the emission factor uncertainty for CO_2 should in fact be the same for off-road vehicles as for other mobile sources, as the total fuel deliveries are known with a low uncertainty, and the carbon content in the fuel is the same regardless of in which sector it is combusted. Furthermore, there is an ambition to overlook the estimated uncertainties for CH_4 and N_2O in this model estimates to submission 2011, as these might be too high as well.

The trend of national total greenhouse gas emissions 1990-2008 in Sweden is associated with an uncertainty of 2.5 % (compared to 6.4% in submission 2009). This stems mainly from uncertainty introduced by activity data. The uncertainty in the trend is a percentage point range relative to the inventory trend and should be interpreted as ± 2.5% to the estimated percentage difference between total GHG emissions 1990 and 2008, i.e. there is a 95% probability that the decrease in GHG emissions in Sweden 1990 to 2008 is between 9.2% and 14.2%.

Table 1.6 and Table 1.7 show the ten sources with the largest uncertainty contributions in the Swedish inventory for 2008 and 1990, respectively.

Table 1.6. The ten sources with the largest uncertainty contributions in the Swedish inventory for 2008.

CRF	IPCC source Category	GHG	Emissions 2008	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in 2007
			Gg CO_2 eq.	%	%	%	%
4D	Agricultural Soils	N_2O	4 816	16	69	0	71
1A	Mobile combustion	CO_2	23 889	3	4	0	5
6A	Solid Waste Disposal on Land	CH_4	1 465	30	50	0	58
4A	Enteric Fermentation	CH_4	2 713	5	25	0	25
1A1a	Public electricity and Heat production	CO_2	6 996	1	8	0	8
4B	Manure Management	N_2O	476	20	50	0	54
2F	Consumption of Halocarbons and SF6	HFC	917	11	26	0	28
4B	Manure Management	CH_4	464	20	50	0	54
1A1b	Petroleum Refining	CO_2	2 193	9	5	0	10
1A2a	Iron and Steel	CO_2	2 088	3	10	0	11

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	Combined uncertainty	Combined uncertainty as % of total national emissions in 1990
			Gg CO_2 eq.	%	%	%	%
4D	Agricultural Soils	N_2O	5 380	16	71	0	72
6A	Solid Waste Disposal on Land	CH_4	2 874	40	50	0	64
1A4b	Residential, Stationary	CO_2	6 037	18	1	0	19
1A	Mobile combustion	CO_2	22 393	2	3	0	4
4A	Enteric Fermentation	CH_4	3 058	5	25	0	25
4B	Manure Management	N_2O	728	20	50	0	54
1A1a	Public electricity and Heat production	CO_2	7 493	1	5	0	5
1A4a	Commercial/Institutional	CO_2	2 533	14	1	0	14
1A2f	Other Manufacturing Industries and Construction, stationary	CO_2	4 095	8	1	0	8
1A4b	Residential, Stationary	CH_4	232	10	99	0	99

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. Emissions of CH_4 and N_2O from liquid biofuels used in road transportation and military transportation are however not estimated. There might also still be some lack in completeness as regards in-house generated fuels in the chemical industry and in smaller companies.

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 temporary grass 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/removals from below ground biomass of dead stump systems are not yet reported.

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 64 million tonnes (excl. LULUCF) in 2008. Emissions decreased by almost 8.5 million tonnes or 11.7 % between 1990 and 2008. The uncertainty in the trend is a percentage point range relative to the inventory trend and should be interpreted as ± 2.5%. Aggregated greenhouse gas emissions varied over the period but in all cases were below the 1990 level during the period 1999-2008. Since 2003 the emissions has been reduced every year compared to the previous year. Emissions decreased by 2.2 million tonnes between 2007 and 2008, principally due to reduced emissions from the industry, transport, the residential and service sector and the waste sector.

During the autumn of 2008, an economic downturn began that has affected a number of sectors. For example, the recession has meant that many industrial sectors have reduced production, with diminished emissions as a consequence. Transportation has also been affected since the scope of goods transports has lessened.

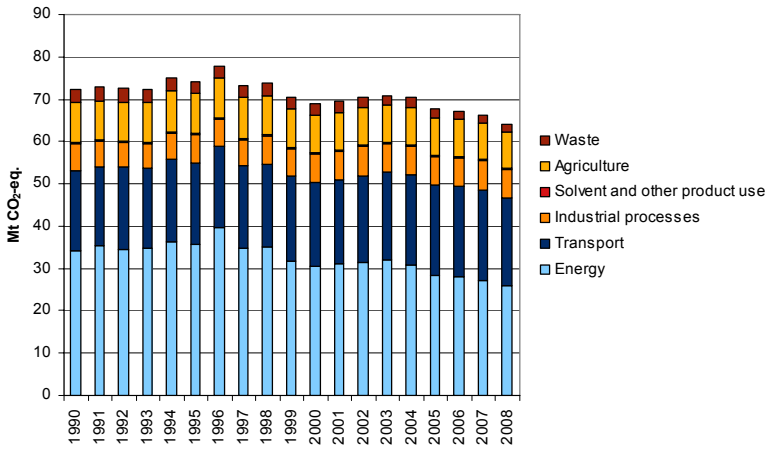

Figure 2.1 Total emissions of all greenhouse gases calculated as CO_2 equivalents from the different sectors.

The Land Use, Land-Use Change and Forestry sector (LULUCF) contributed to a yearly net sink in Sweden, during the period 1990-2008. The size of the sink varied over the period between 15-37 million tonnes of carbon dioxide equivalents, but the trend points towards a somewhat decreasing net sink.

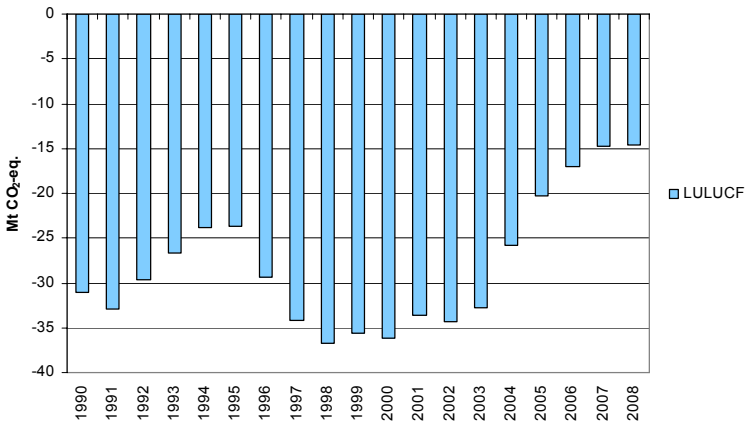

Figure 2.2 Total net removals and emissions from land use, land use change and forestry (LULUCF), calculated as CO_2 equivalents.

GDP growth averaged around 2 % over the period 1990-2008. The GDP was falling at the start of the 1990s, but has been increasing by an average of 3 % per year since 1994, excepting 2008, when the growth slowed. Despite economic growth of nearly 50 % since 1990, emissions of greenhouse gases have still been able to be reduced. Even per capita emissions of greenhouse gases (excl. LULUCF) have gone down, from 8.4 tonnes per person in the year 1990 to 6.9 tonnes per person in 2008.

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 72,2 million tonnes carbon dioxide equivalents, when the assigned amount was established. This means that Sweden's emissions of greenhouse gases will be allowed to comprise a maximum of 75 million tonnes per year on average for 2008-12. In 2008 greenhouse gas emissions were around 64 million tonnes or 89 % of the base-year level of emissions, which suggests that Sweden will meet its commitment.

Emissions of greenhouse gases from different sectors of society developed in different directions over the period from 1990 to 2008. The greatest reductions in emissions over the period 1990-2008 took place in the residential and service, agriculture, waste and some industrial sectors. Increases in emissions occurred principally in the transport sector and in certain industrial sectors. The emissions have however been reduced or moderated in a number of sectors in the year 2008 in consequence of the economic downturn that began in the autumn of 2008.

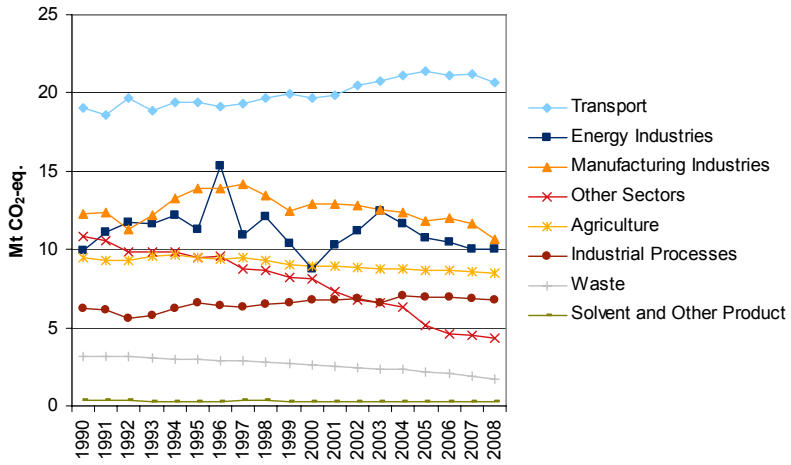

Figure 2.3 Total emissions of all greenhouse gases calculated as CO_2-equivalents from the different sectors.

2.2 Description and interpretation of emission trends in relation to gas

In 2008, emissions (excl. LULUCF) of *carbon dioxide* totalled 50.4 million tonnes, which is equivalent to 79% of aggregated greenhouse gas emissions. Emissions of *methane* were 5.1 million tonnes of carbon dioxide equivalents and account for 8% of emissions, while emissions of *nitrous oxide* totalled 7.2 million tonnes, equivalent to 11%. Only 2% or 1.2 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 1990-2008.

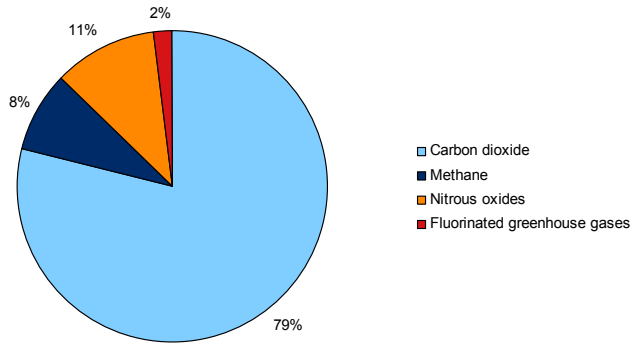

Figure 2.4 Greenhouse gas emissions broken down by gas (2008).

2.2.1 CO_2

In 2008, total *carbon dioxide* emissions in Sweden totalled 50.4 million tonnes, excl. LULUCF. 48 % of carbon dioxide emissions came from the energy sector, 41 % of carbon dioxide emissions came from the transport sector and the remaining 11% came from industrial processes, solvent and other product use and waste. Emissions were 11 % lower in 2008 than in 1990, and it is the energy sector that has shown the greatest reduction.

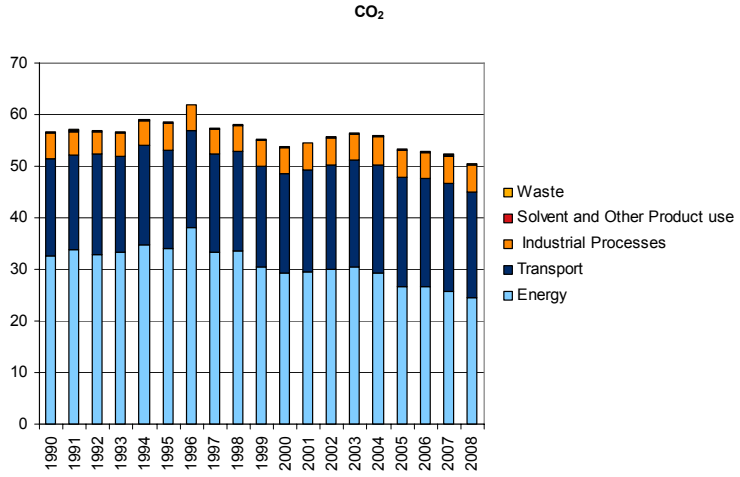

Figure 2.5. Total emissions of CO_2 from different sectors.

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 242 ktonnes in 2008, which is equivalent to 5.1 million tonnes calculated as carbon dioxide equivalents or 8 % of total greenhouse gas emissions. Emissions have fallen by 24 % since 1990, largely due to measures taken in the waste sector.

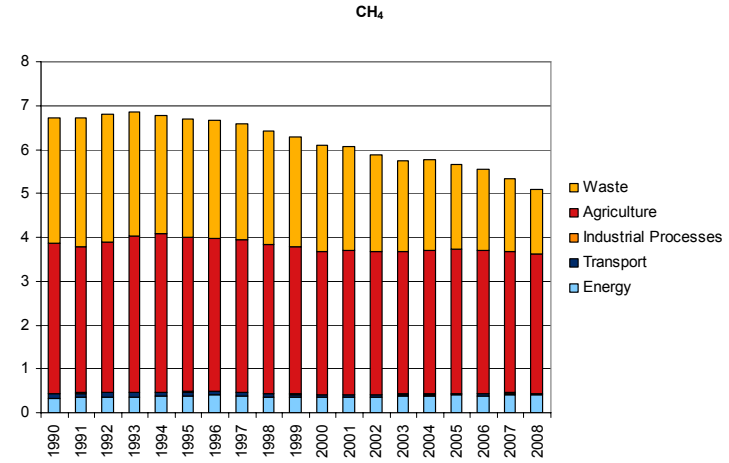

Figure 2.6 Total emissions of CH_4 from different sectors, calculated as CO_2-equivalents.

2.2.3 N_2O

In 2008, emissions of *nitrous oxide* totalled 23 ktonnes or 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 16 %, and it is primarily emissions from the agriculture sector that account for the decrease.

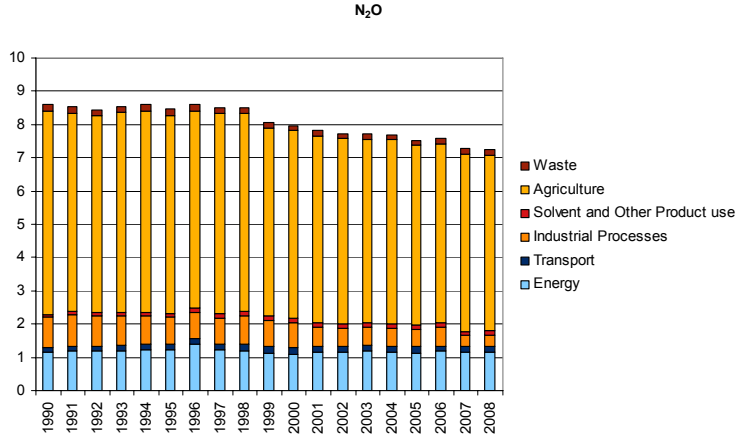

Figure 2.7 Total emissions of N_2O from different sectors calculated as CO_2-equivalents.

Fluorinated greenhouse gases

Emissions of fluorinated greenhouse gases (F-gases) are reported in the industrial processes sector. Total emissions of fluorinated greenhouse gases in 2008 amounted to 1.2 million tonnes calculated as carbon dioxide equivalents and account for 2 % of total emissions. However, emissions increased by 151 % between 1990 and 2008.

Emissions of HFCs increased in particular, from just under 4 ktonnes of carbon dioxide equivalents in 1990 to 917 ktonnes in 2008. PFC emissions, on the other hand, have decreased. In 1990 emissions of PFCs amounted to 377 ktonnes of carbon dioxide equivalents, and in 2008 they had fallen to 225 ktonnes. Emissions of SF6 varied between 1990 and 2008. In 1990 they totalled 107 ktonnes and in 2008 they amounted to 83 ktonnes of carbon dioxide equivalents.

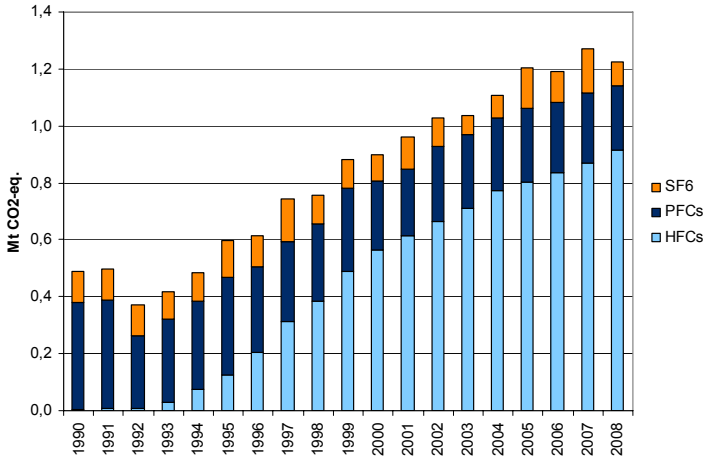

Figure 2.8 Total emissions of SF_6, PFC and HFC, calculated as CO_2-equivalents

2.3 Description and interpretation of emission trends in relation to source

The greatest emissions in 2008 were from the energy, transport and industrial sectors. Emissions from the energy sector made up 41% of total greenhouse emissions, in which the energy industry accounted for 16%, industrial combustion for 17%, the residential and service sector for 7% and fugitive emissions and other for 1.5%. Domestic transport accounted for 32% of total greenhouse gas emissions, agriculture for 13%, industrial processes for 11%, the waste sector for 3% and the use for solvents and other products for 0.5%.

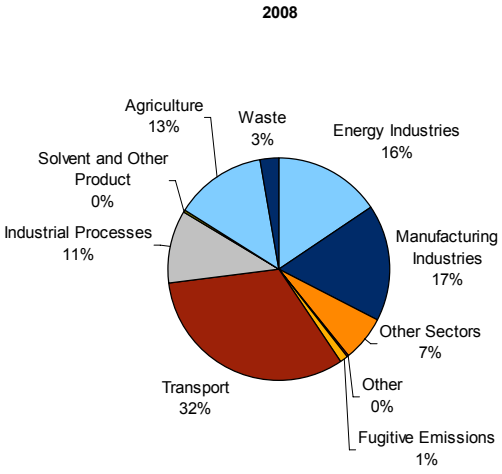

Figure 2.9 Greenhouse gas emissions broken down by sector (2008). (Note that 0% means a share lower than 0.5%.)

2.3.1 Energy excluding transport

Emissions of greenhouse gases by the energy sector[11] amounted to 26 million tonnes of carbon dioxide equivalents in 2008, which is equivalent to 41 % 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 1990-2008 was for a slight reduction in emissions. In comparison with 1990, emissions were 24 % lower in 2008, 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 7.5 million tonnes, from refineries to 2.2 million tonnes and from industrial combustion to 10.7 million tonnes in 2008. The emissions of the residential and service sector of 4.3 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 refineries and amounted to 0,8 million tonnes in 2008 and emissions from other were 0.2 million tonnes.

Between 2007 and 2008 a reduction of greenhouse gas emissions is seen in all subsectors within the energy sector, except refineries. Underlying causes for the reduction are among other things the economic downturn, existing measures and high fuel prices.

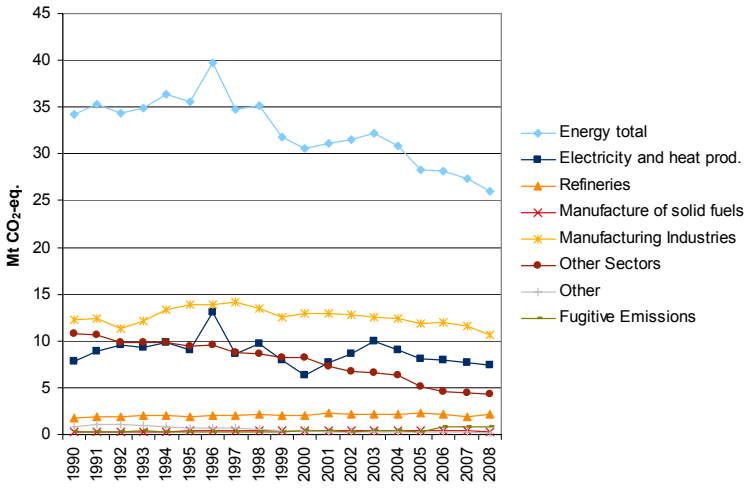

Figure 2.10 Total emissions of all greenhouse gases from the Energy sector, total and per subsector.

[11] 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

CARBON DIOXIDE FROM THE ENERGY SECTOR, EXCLUDING TRANSPORT

Electricity and heat production

Emissions of carbon dioxide from the production of electricity and district heating totalled around 7 million tonnes in 2008. Emissions in 1990 totalled 7.5 million tonnes, but over the period 1990-2008 emissions varied from year to year. However since 2003 a slight downward trend in emissions can be seen.

Temperature and precipitation conditions, have an impact on hydropower production and heating needs in individual years 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. The emissions were also affected by the increased iron and steel production that occurred since 1990, since residual gases are used for producing electricity as well as for district heating.

During the period 1990-2008, district heating production increased by more than 30 %. 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 around 10 TWh, and it had risen to around 35 TWh in 2007. Energy and carbon dioxide taxes, fossil fuel prices and the EU emissions trading scheme have, among other things, contributed to this trend.

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. Some increase in emissions from electricity production, based on combustion, 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 and natural gas.

2008 was characterized by a high 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 taken together some net export of electricity was possible. The production of wind power increased substantially in 2008 from a low level. The production of district heating and heat energy based on bio-fuel etc. was higher in 2008 than in previous years. All together these factors lead to somewhat lower emissions of carbon dioxide from electricity and district heating in 2008 than 2007.

Refineries

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 1.8 million tonnes in 1990 to 2.2 million tonnes in 2008

or around 23 %. Emissions were higher in 2008 than for 2007, having increased by 15 % in comparison with 2007, however the increase was mostly due to a substantial plant shutdown in 2007 for purposes of performing maintenance repairs. In comparison with 2006, the emissions increased by a good 1%. The emissions from refineries are also reported in the fugitive emissions sector and in 2006-2008 the total emissions from refineries was higher than the previous years as a new installation was started.

Other Sectors

Emissions of carbon dioxide in 2008 were 3.8 million tonnes in the residential and service sector including combustion in agriculture, forestry and fisheries, a decrease of 63% in comparison with 1990. The reduction is due to emissions of carbon dioxide from houses and commercial premises having dropped from almost 8.8 million tonnes in the year 1990 to 2 million tonnes in the year 2008 in consequence of a switch from oil to district heating and in recent years also to heat pumps and pellet-fired boilers. Approximately 3 % of detached, semi-detached and terraced houses had oil as their sole source of heating in 2008 while the proportion of houses with combined heating systems in which oil can be used was 2%. This means that the use of oil has practically been phased out soon in this sector. 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 4 % per year or around 6.7 million tonnes of carbon dioxide in total between 1990 and 2008. Even the energy consumption for heating per unit of floor area to have fallen for houses and commercial premises.

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 almost 1.8 million tonnes in 2008. Emissions here increased by 15 % between 1990 and 2008.

Manufacturing industries

Carbon dioxide emissions from industrial combustion were 10.2 million tonnes in 2008. 1990-2008 emissions decreased by 13%, but have varied a little 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 iron and steel industry accounts for 21% of emissions, the pulp and paper industry accounts for 15% and the chemical industry accounts for 14%. Some decrease in emissions can be seen in recent years, principally due to reduced emissions from the pulp and paper industry but also other industries have reduced emissions. The EU emissions trading scheme, the electricity certificate system and fuel prices have contributed to this trend.

Viewed over a longer period from 1970 on, industry has reduced its use of oil and increased its use of electricity. Between 1998 and 2007 the use of oil has been reduced by 15 %. Even the specific oil use (kWh per production value at 2000

prices) and specific electricity use have been reduced during the period 1990-2008, by almost 70% and around 55 % respectively.

From 2007 to 2008 emissions of carbon dioxide decreased by just over 8% from industrial combustion. Reductions are occurring in a majority of industries and range between 5 and nearly 25 %. Among other things high oil prices and coal prices in the beginning of 2008 and diminishing production volumes caused by the recession in the end of 2008 are reasons for the reduced emissions.

Fugitive emissions and Other

Emissions from fugitive emissions sector come for example from refineries. Emissions was 0.8 million tonnes of carbon dioxide equivalent in 2008. Emissions from "Other" (principally military emissions) decreased between 1990 and 2008 and totalled just under 0.2 million tonnes of carbon dioxide equivalents in 2008.

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 21 % between 1990 and 2008. The increased emissions are principally due to increased use of biofuels in the residential and service sector and in the production of electricity and district heating. Almost two-thirds of emissions originate from the residential and service sector, including energy use in agriculture. These emissions have increased by 2 % during the period. The greatest percentage increase has however happened within the electricity and district heating where emissions sharply increased.

Nitrous oxide emissions have been stable between 1990 and 2008.

2.3.2 Transport

Domestic transport was responsible for 32 % of total greenhouse gas emissions in 2008. The emissions of greenhouse gases from domestic transport were 9 % higher in 2008 compared to 1990, an increase from 19 million to 20.7 million tonnes of carbon dioxide equivalents. Greenhouse gas emissions from road traffic was 19.4 million tonnes, from domestic aviation 0.6 million tonnes, from domestic navigation 0.5 million tonnes, from railways 0.1 million tonnes and from other machinery 0.2 million tonnes.

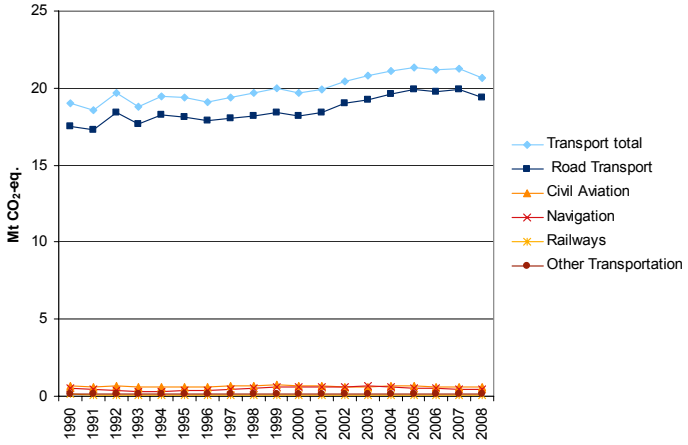

Figure 2.11 Emissions from the transport sector, total and per subsector

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 19.2 million tonnes 2008. From 1990 to 2008 the increase of carbon dioxide was from road traffic 11 %. The increasing trend has been moderated since 2003. In 2008 the emissions have however decreased by the economic downturn that began in the autumn of 2008.

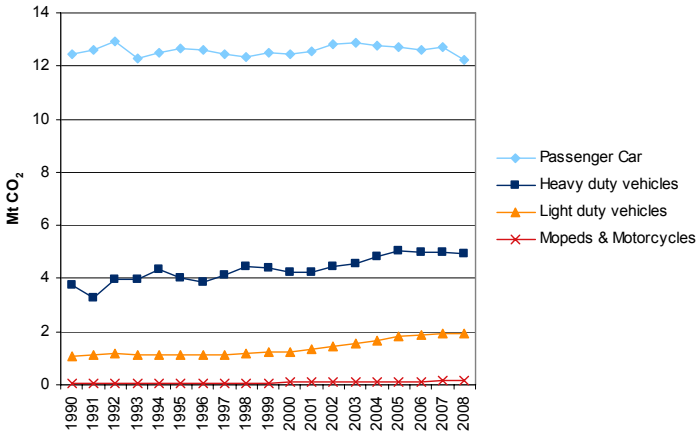

Figure 2.12 Emissions of CO_2 from different vehicle categories. Note that the emissions from different vehicle categories are based on transport mileage and not fuel consumption.

Emissions from road traffic have increased during the period spanning 1990-2008, primarily in consequence of increased transport milage with heavy vehicles as well as an increased share of light lorries and passenger cars using diesel. The increased transport mileage with heavy vehicles is due to the structural transformation of society entailing specialisation, centralisation and globalisation, which means that freight is being transported ever greater distances.

The increased emissions from increased consumption of diesel for road traffic is counteracted by lowered petrol consumption. Several factors have been significant in limiting carbon dioxide emissions from petrol for road traffic. Among other things, the fuel taxes coupled with a high petrol price have contributed to a transition to renewable fuels and to limiting consumption. 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, the use of renewable fuels is increasing principally ethanol, FAME and biogas. 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. The reduced emissions from passenger cars in 2008 are also due to reduced distance covered.

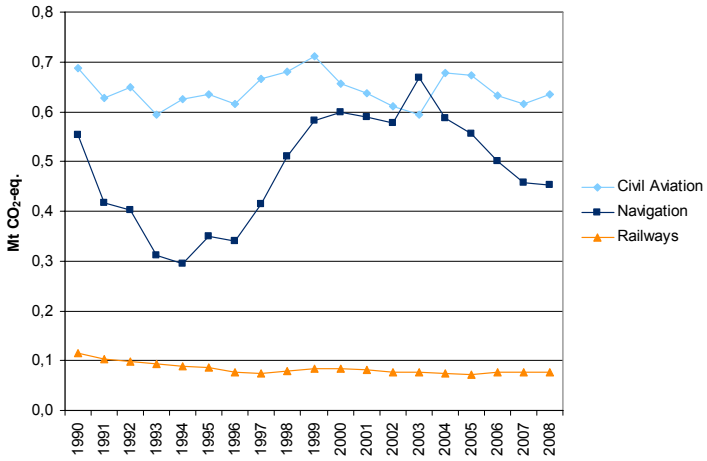

Figure 2.13 Emission from aviation, navigation and railways.

In 2008, emissions of carbon dioxide from domestic aviation was 0.6 million tonnes, which is 7 % lower than the level for the year 1990. However the emissions have varied during the period. The emissions increased sharply in 2004 but then decreased for some years. 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.

Carbon dioxide emissions for domestic navigation are estimated at 0.4 million tonnes in 2008, which is around 18% lower than in 1990. Emissions by domestic navigation have fallen since 2003.

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 73% since 1990 as a result of better exhaust emission control and were 0.03 million tonnes of carbon dioxide equivalents in 2008.

The emissions of nitrous oxide from the transport sector were almost 0.2 million tonnes in 2008. 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 6.8 million tonnes of carbon dioxide equivalents in 2008, which is equivalent to 11 % of aggregated emissions. Carbon dioxide emissions are dominant at around 76 %, followed by fluorinated greenhouse gases with approximately 18 %, nitrous oxide with approximately 5 % and methane with 0.2 %.

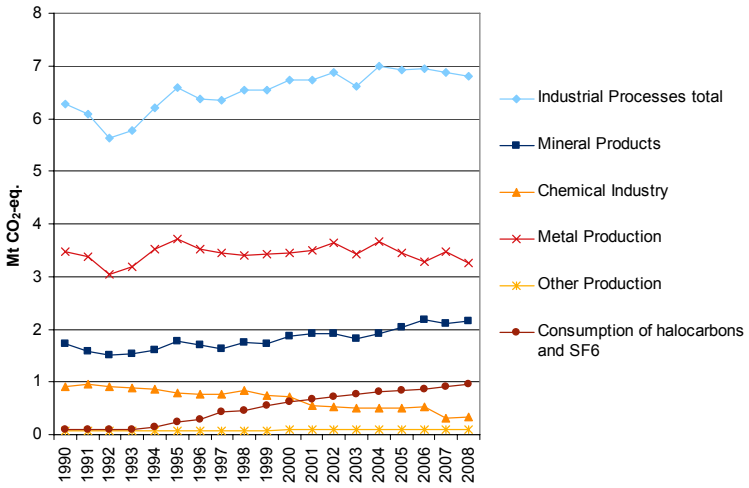

Figure 2.14 Emissions from the Industrial processes sector, total and per subsector.

Emissions in 2008 were just over 8 % 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. The development 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.

The increasing carbon dioxide emissions from the mineral industry in recent years is principally due to an economic upturn in the construction sector, both in Sweden and in other countries to which the cement is exported. Emissions also increased in 2008 in consequence of increased production, because the demand was large. Emissions from the iron and steel industry have been at about the same level during the period spanning 1990-2008. Emissions from this industry are also reported however in the energy sector, which means that emissions from the iron and steel industry are not fully reflected in this sector. Total emissions from the iron and steel industry have increased by around 25% during the entire period spanning 1990-2008, and the emissions have increased most in recent years. The emissions from the chemical industry have decreased by almost 65 % during 1990-2008. For 2007 and 2008, emissions have been very low in comparison with preceding years. This is primarily due to a new treatment technology having been installed that has resulted in reduced emissions of nitrous oxide in the nitric acid production. Total emissions from industrial processes decreased by just over 1 % between 2007 and 2008, principally due to the decrease in the metal 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 2008 amounted to 1.2 million tonnes calculated as carbon dioxide equivalents and account for 2 % of total emissions. Emissions of fluorinated gases are showing an increasing trend, however, and increased by 151 % between 1990 and 2008, 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.

In 2008, emissions of fluorinated greenhouse gases were reduced by slightly more than 3 % in comparison with 2007, which is due to reduced emissions of PFC and SF6. One explanation for these emissions declining is an EU regulation that was introduced in 2006. The regulation involves certain fluorinated greenhouses gases being forbidden at various points in time between 2006-2009.

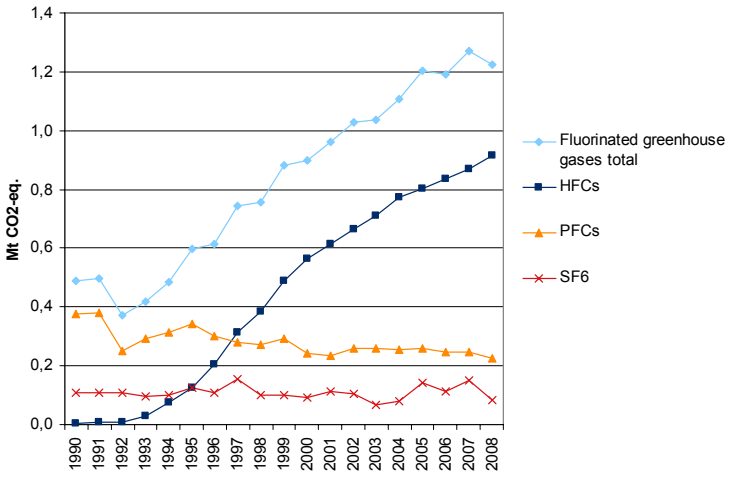

Figure 2.15 Emissions of fluorinated greenhouse gases, total and per gas.

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 2008 totalled 0.3 million tonnes, which is 0.4 % of total emissions. In comparison with 1990, emissions have decreased by 14 %. Approximately 25 % of carbon dioxide emissions come from paints, but these emissions have been reduced by a shift to water-based paints.

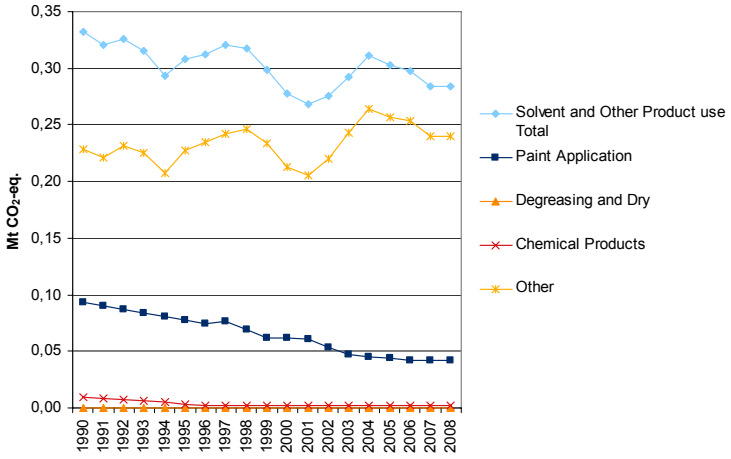

Figure 2.16 Emissions from the use of solvents and other products, total and per subsector.

2.3.5 Agriculture

Agriculture is the largest source of methane and nitrous oxide emissions. Emissions of these greenhouse gases in 2008 amounted to 8.5 million tonnes of carbon diox-

ide equivalents, of which around 60 % was made up of nitrous oxide and almost 40 % of methane. In comparison with 2007, emissions have decreased by around 1 %. Aggregated emissions decreased by 5 % over the period 2000-2008, and they have fallen by 11 % since 1990. 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.

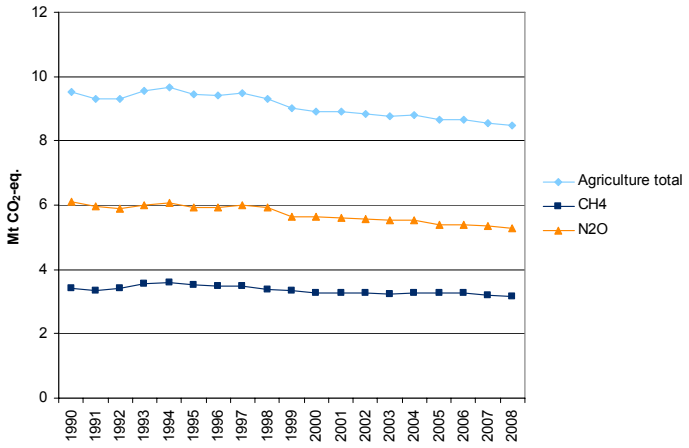

Figure 2.17 Emissions from agriculture, total and per gas.

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 357 000 in 2008. A large 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.

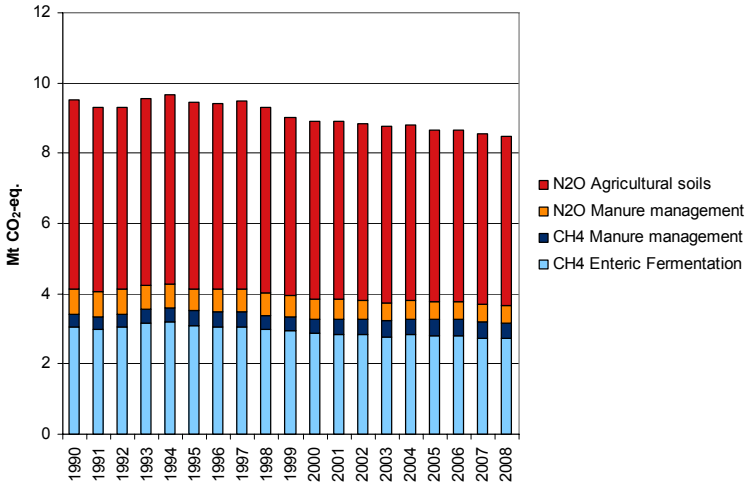

Figure 2.18 Emissions from agriculture, total and per gas and subsector.

2.3.6 Land Use, Land Use Change and Forestry - LULUCF

The Sector Land Use, Land Use Change and Forestry (LULUCF) during the period 1990-2008 contribute to a yearly net sink in Sweden. During the period the sink has varied between 15-37 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 96 Mm^3 over the period 1990-2008, with the exception of 2005 when the felling, including wood felled by storms, was estimated to 122 Mm^3. However the uncertainty is greater in data for 2005-08 since all sample plots for these years have not been inventoried.

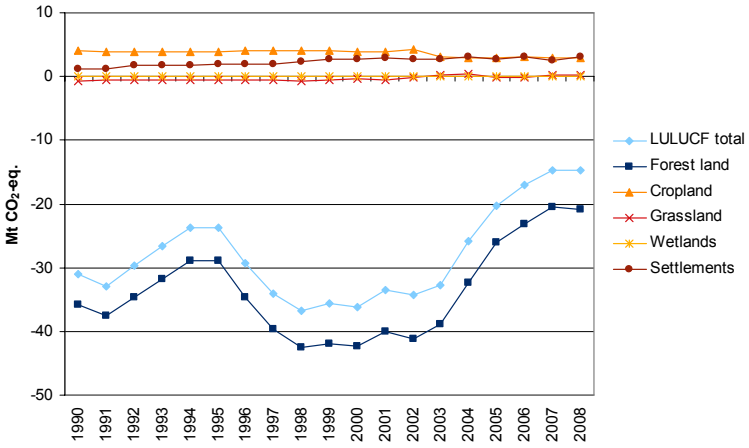

Figure 2.19 Emissions and removals of greenhouse gases from the LULUCF sector

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 approximatey 20-40 million tones of carbon dioxide, while emissions from soil organic carbon in forest land has varied during the period 1990-2008 between 0.2-9 million tonnes. The cropland is responsible for emissions of carbon dioxide when cultivating organogenic soils. The emissions have varied during 1990-2008 between around 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 carbon stock change in grassland and wetlands is small. Emissions from settlements have been in the range of 1-3 million tonnes of carbon dioxide during the period spanning 1990-2008.

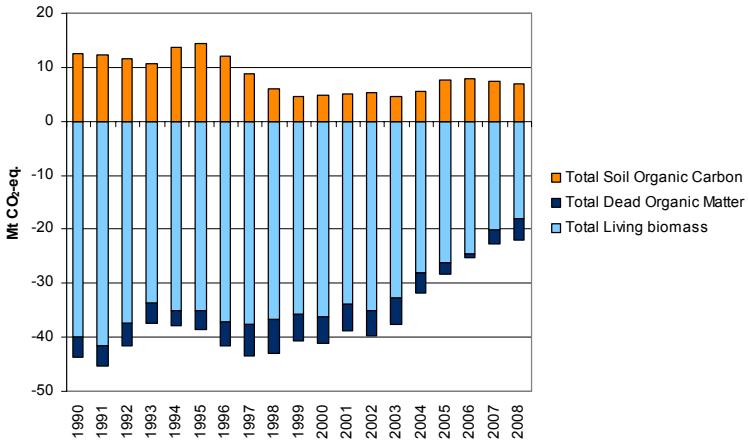

Figure 2.20 Emissions and removals of carbon dioxide from different carbon pools.

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. Annual emissions from these categories of CO_2 varied between 130-270 ktonnes, the emissions of CH_4 varied between 0.5-13 ktonnes and emissions of N_2O varied between 50-120 ktonnes per year, calculated in carbon dioxide equivalents.

2.3.7 Waste

Total emissions from the waste sector in 2008 amounted to almost 1.8 million tonnes of carbon dioxide equivalents or almost 3 % of total greenhouse gas emissions. In comparison with 1990, emissions were around 44 % lower in 2008. Emissions from the waste sector are dominated by methane emissions from landfills, with around 84%, while nitrous oxide emissions from wastewater account for around 8 % and carbon dioxide emissions from incineration of hazardous waste for around 7 %.

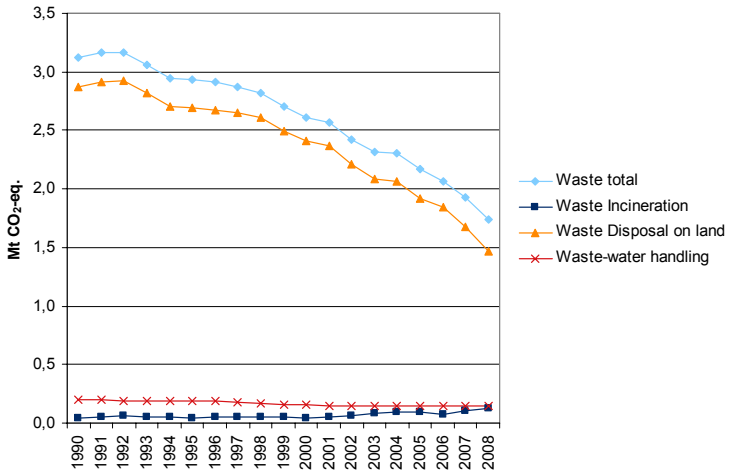

Figure 2.21 Emissions from Waste sector, total and per subsector.

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 2008 the total amount of household waste deposited has decreased by 83 % compared to the level in 2002 and with 90% 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 2007 and 2008 the emissions of methane decreased by almost 13 % and the decrease is mainly due to the bans on landfills disposals.

Nitrous oxide emissions from wastewater handling were just over 0.1 million tonnes of carbon dioxide equivalents in 2008 and accounted for 0.2% of total emissions. Emissions have fallen by 28% since 1990 due to improved sewage treatment.

Carbon dioxide emissions from incineration of waste were around 0.1 million tonnes in 2008. 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 around 9.5 million tonnes of carbon dioxide equivalents in 2008. 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.

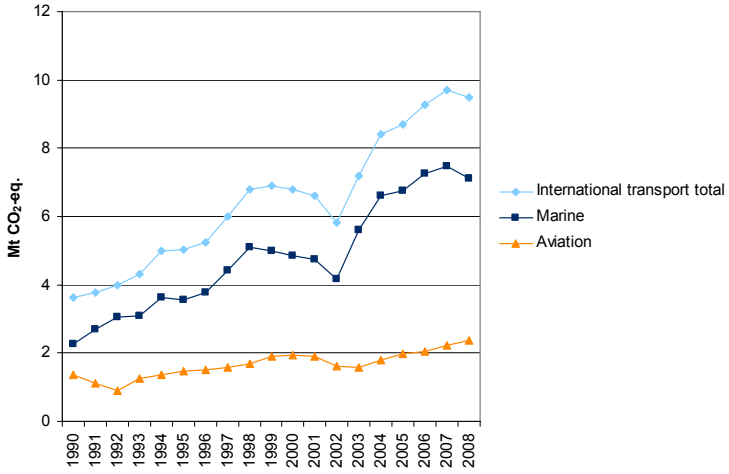

Figure 2.22 Emissions from international bunkers, total and per subsector.

Emissions from international navigation totalled 7.1 million tonnes of carbon dioxide equivalents in 2008. This is an decrease of 5 % compared with 2007 but an increase of 214 % 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 also depends on the price of fuel in Sweden in comparison with other ports in other countries. The reduced emissions from international navigation between 2007 and 2008 are primarily a consequence of the economic downturn during the autumn of 2008 that reduced the transport of goods.

Greenhouse gas emissions from the international bunkering of aviation continue to increase and was 2.4 million tonnes of carbon dioxide equivalents in 2008, which was around 1 million tonnes or 76 % higher than 1990 and 7 % higher than 2007. 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 173 ktonnes in 2008, and emissions have decreased by 51 % in comparison with 1990. Road traffic and combustion of wood in households dominate emissions, but machinery, some industrial activity 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 45 ktonnes in 2008, a decrease of 28% in comparison with 1990. Most of the decrease occurred in the early 1990s and related to fugitive emissions from oil refineries.

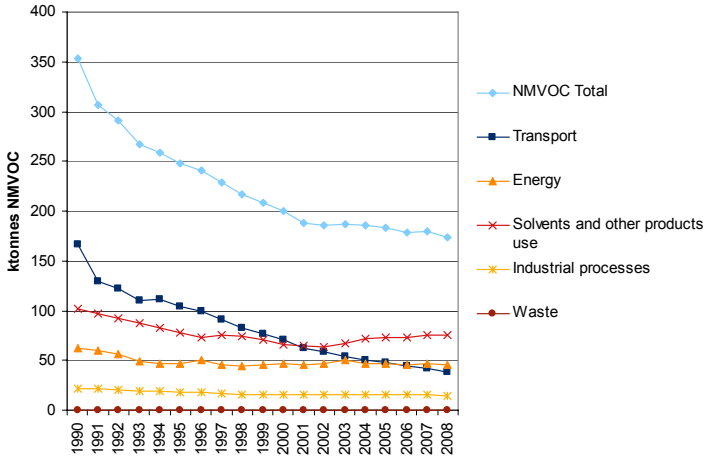

Figure 2.23 Total emissions of NMVOC and emissions from the different sectors.

2.4.2 NO_X

Emissions of nitrogen oxides amounted to around 156 ktonnes in 2008, a decrease of 49 % 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 NOx from the energy sector, excluded transport, totalled just over 60 ktonnes in 2008, a decrease of 36% 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.

21 % of emissions in the energy sector in 2008 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 31 % of emissions of nitrogen oxides by the energy sector (excluding transport). These have decreased by 37% during the period 1990-2008. Machinery in agriculture and forestry taken together account for 19% 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 70 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 60 % between 1990 and 2008 and by 9% between 2007 and 2008.

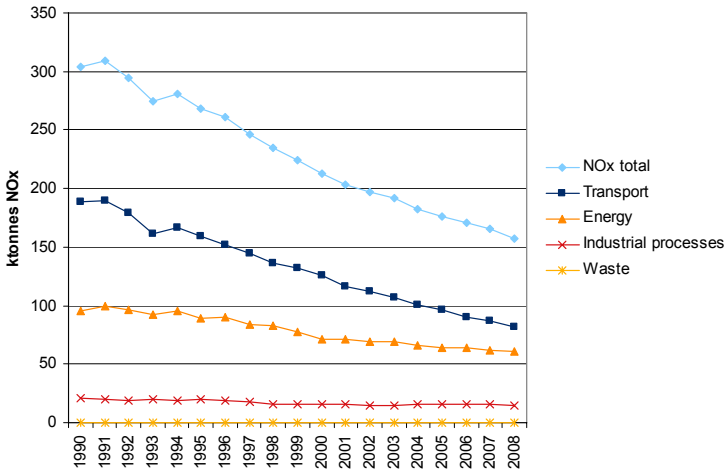

Figure 2.24 Total emissions of NO_X and emissions from the different sectors.

2.4.3 CO

Emissions of carbon monoxide have developed in the same way as NOx emissions. Emissions have decreased from 939 ktonnes in 1990 to 521 ktonnes in 2008. 42 % of emissions came from the transport sector and 40% from the 'Other Sectors'.

Energy sector emissions of carbon monoxide increased from around 234 ktonnes in 1990 to around 280 tonnes in 2008. 75 % of emissions from the energy sector came from household energy use.

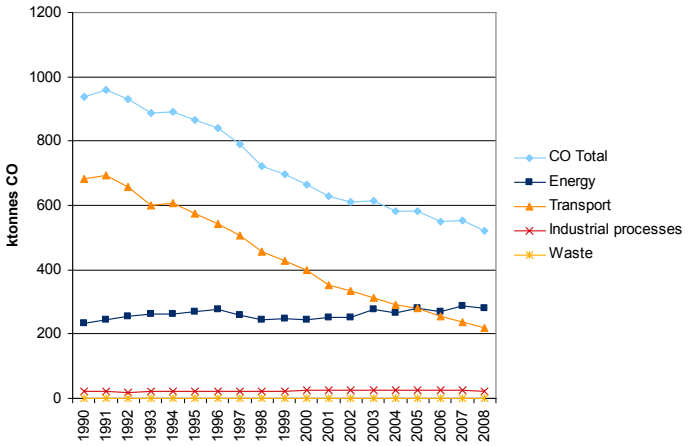

Figure 2.25 Total emissions of CO and emissions from the different sectors.

2.4.4 SO_2

Sulphur dioxide emissions come form the energy, transport and industry sectors and continued to decrease during the 1990s. In 2008, emissions totalled 31 ktonnes, which is a decrease of 71% 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.

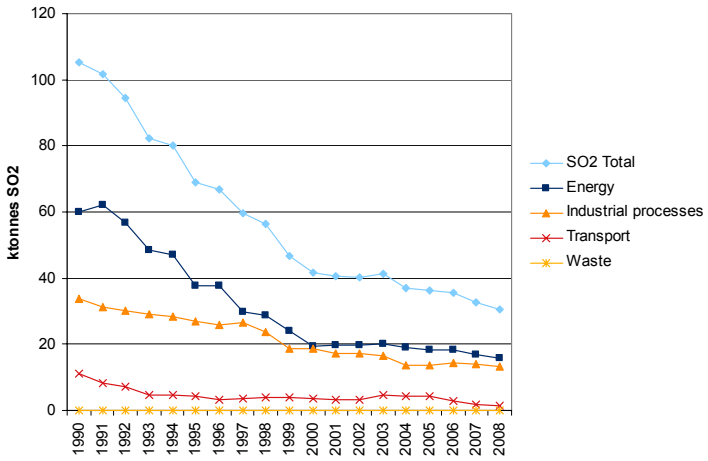

Figure 2.26 Total emissions of SO_2 and emissions from the different sectors.

Energy sector emissions of sulphur dioxide (excl. transport) continued to decrease during the 1990s and in 2008 emissions totalled 16 ktonnes, a decrease of 74 % 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 2007 and 2008 there was a slight decrease in emissions which can be a result of decreased use of oil in several sectors.

Road traffic emissions of SO2 have fallen by 98% since 1990 as a result of lower sulphur levels in motor fuels, and totalled 0.09 ktonnes in 2008. Sulphur emissions from domestic navigation have decreased by 77 % since 1990 and are now 1.2 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.[12]

It can be seen in Figure 3.1 that in the energy sector, emissions of CO_2 contribute about 96 % of total greenhouse gas emissions (in CO_2 equivalents). Emissions of total greenhouse gases from the energy sector have decreased by 12.3 % from 53,219 Gg CO_2 equivalents in 1990 to 46,676 Gg CO_2 equivalents in 2008, mainly due to reduced fossil fuel consumption in the residential sector (CRF 1A4).

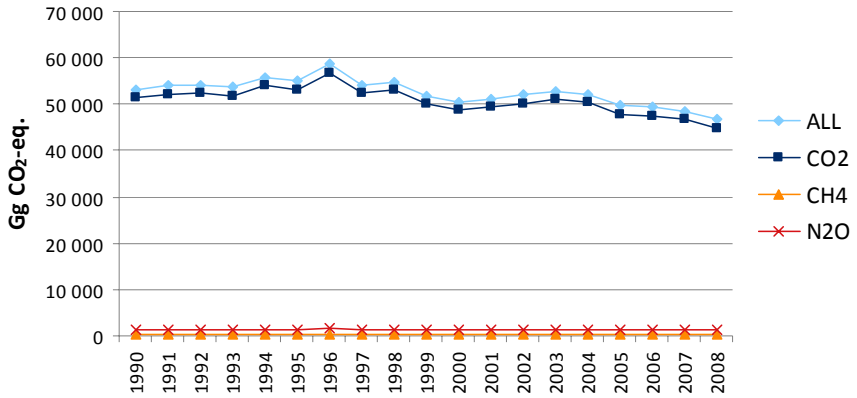

Figure 3.1. Total emissions of all greenhouse gases calculated as CO_2 equivalents from CRF 1 Energy.

[12] Ministry of the Environment, 2001

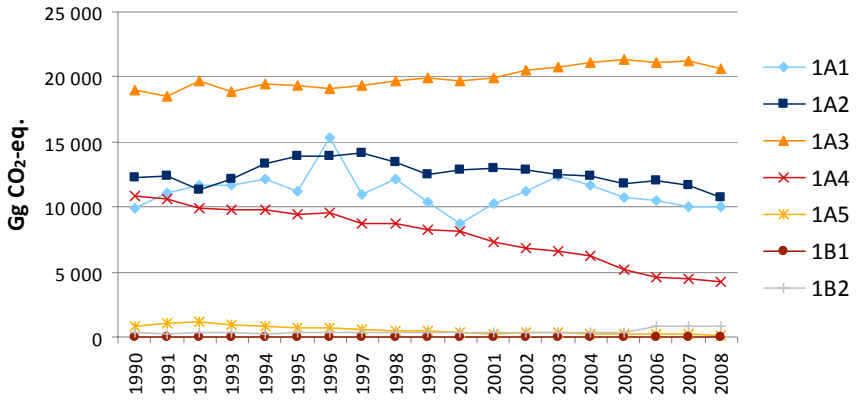

Figure 3.2. Total emissions of all greenhouse gases calculated as CO_2 equivalents from the different sub-sectors within the Energy sector.

1A1 Energy industries. 1A2 Manufacturing industries and construction. 1A3 Transport. 1A4 Other sectors. 1A5 Other. 1B1 Solid fuels (fugitive). 1B2 Oil and natural gas (fugitive).

As shown in Figure 3.2, the transport sector (CRF 1A3) accounts for the largest, and increasing, part of the GHG emissions from the energy sector. Emissions from public electricity and heat production (CRF 1A1) varies mainly because of temperature variations between years. Emissions from energy consumption in the manufacturing industry (CRF 1A2) are decreasing slightly. As mentioned earlier, the emissions from residential heating (CRF 1A4) are decreasing due to reduced consumption of fossil fuels. The recent increase in fugitive emissions from oil and natural gas (CRF 1B2) is caused by a new hydrogen production facility put into operation at one of the oil refineries in 2006.

3.2 Source category description

3.2.1 Public electricity and heat production, CRF 1A1a

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.1.

Table 3.1. Summary of source category description, CRF 1A1a.

CRF	Gas	Key Category Assessment 2008			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1A1a	CO_2	x	x		T2	CS	Yes
	CH_4				T2	CS	Yes
	N_2O	x	X		T2	CS	Yes

CS Country Specific. T2 Tier 2.

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 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 2008, 58 % 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 171 PJ (2008) but, due to the more frequent use of biomass, greenhouse gas emissions from district heating are at a lower level in 2008 than in 1990.[13]

The number and distribution of Swedish power stations in 2006 are presented in Table 3.2[14]. 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 3.2. Number and distribution of Swedish energy stations in 2007.

Type of plant	Number of plants	Production GWh
Total power stations	2100	148 557
Power generation not based on fuels	1927	67 697
- Wind	1022	1432
- Water	905	66 265
Power generation based on fuels	173	80860
- Nuclear power	3	66969
- Power and heat production	170	13891
- Manufacturing industries, ISIC 10-37	44	
- Energy plants, ISIC 40	114	
- Others	12	

[13] All numbers are according to data used in the Greenhouse gas inventory this submission.

[14] Statistics Sweden EN11SM 0701 2008. Data for 2007 are presently not available.

3.2.2 Refineries, CRF 1A1b

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.3.

Table 3.3. Summary of source category description, CRF 1A1b.

CRF	Gas	Key Category Assessment 2008			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1A1b	CO_2	x	X		T2	CS	Yes
	CH_4				T2	CS	Yes
	N_2O				T2	CS	Yes

CS Country Specific. T2 Tier 2.

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 naphthenic special oils. One facility has a catalytic cracker and a hydrogen production plant and four of the facilities have sulphur recovery plants.

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

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.4.

Table 3.4. Summary of source category description, CRF 1A1c.

CRF	Gas	Key Category Assessment 2008			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1A1c	CO_2				T2	CS	Yes
	CH_4				T2	CS	Yes
	N_2O				T2	CS	Yes

CS Country Specific. T2 Tier 2.

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

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.5.

Table 3.5. Summary of source category description, CRF 1A2.

CRF	Gas	Key Category Assessment 2008			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1A2a	CO_2	x	x		T2,T3	CS, PS	Yes
	CH_4				T2	CS	Yes
	N_2O				T2	CS	Yes
1A2b	CO_2				T2	CS	Yes
	CH_4				T2	CS	Yes
	N_2O				T2	CS	Yes
1A2c	CO_2	x	x		T2	CS	Yes
	CH_4				T2	CS	Yes
	N_2O				T2	CS	Yes
1A2d	CO_2	x	x		T2	CS	Yes
	CH_4				T2	CS	Yes
	N_2O				T2	CS	Yes
1A2e	CO_2	x	x		T2	CS	Yes
	CH_4				T2	CS	Yes
	N_2O				T2	CS	Yes
1A2f	CO_2	x	x		T1,T2	CS	Yes
	CH_4				T1,T2	CS	Yes
	N_2O	x			T1,T2	CS	Yes

CS Country Specific. PS Plant Specific. T1 Tier 1. T2 Tier 2. T3 Tier 3.

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 2008 there were 43 paper mill plants, 170 sawmills (production capacity >10 000 m^3/year) and 43 pulp industry plants in Sweden. In total, they were producing 11.7 million tonnes of paper, 17.5 million m^3 of sawn timber and 12.1 million tonnes of pulp.[15]

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 3.4 and 1.8 million tonnes of steel, respectively, in total in 2008.[16]

[15] The Swedish Forest Industries Federation, 2009-09-29

[16] The Swedish Steel Producers´ Association, 2009-09-29

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 uses more than 90 % of the energy according to the activity data used for emission calculations for this sector.

3.2.5 Transport, CRF 1A3

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.6.

Table 3.6. Summary of source category description, CRF 1A3.

CRF	Gas	Key Category Assessment 2008			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1A3a	CO_2	x			CS, T1, T2, M	CS	Yes
	CH_4				CS, M, T1, T2	CR, CS, D, M	Yes
	N_2O				CS, M, T1, T2	CR, CS, D, M	Yes
1A3b	CO_2	x	x		CS, T1, T2, M	CS	Yes
	CH_4				CS, M, T1, T2	CR, CS, D, M	No, see Annex 5
	N_2O				CS, M, T1, T2	CR, CS, D, M	No, see Annex 5
1A3c	CO_2				T1	CS	Yes
	CH_4				T1	CR, CS, D, M	Yes
	N_2O				T1	CR, CS, D, M	Yes
1A3d	CO_2	x			T1	CS	Yes
	CH_4				T1	CR, CS	Yes
	N_2O				T1	CR, CS	Yes
1A3e	CO_2				CS, T1, T2, M	CS	Yes
	CH_4				CS, M, T1, T2	CR, CS, D, M	Yes
	N_2O				CS, M, T1, T2	CR, CS, D, M	Yes

CS Country Specific. CR CORINAIR. T1 Tier 1. T2 Tier 2. M Model. D Default.

On average, Swedish citizens travel 48 km per individual per day by various modes of transport. [17] 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.[18] 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

[17] http://www.sika-institute.se 2008-09-29

[18] Ministry of the Environment, 2001.

used for about 70 % of all journeys.[19] Car travel is also the third most common way of travelling abroad, after air and sea travel.

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.[20]

3.2.6 Other sectors, CRF 1A4

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.7.

Table 3.7. Summary of source category description, CRF 1A4.

CRF	Gas	Key Category Assessment 2008			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1A4a	CO_2	x	x		T1,T2	CS	Yes
	CH_4				T1,T2	CS	Yes
	N_2O				T1,T2	CS	Yes
1A4b	CO_2	x	x		T1,T2	CS	Yes
	CH_4				T1,T2	CS	Yes
	N_2O				T1,T2	CS	Yes
1A4c	CO_2	x	x		T1,T2	CS	Yes
	CH_4				T1,T2	CS	Yes
	N_2O				T1,T2	CS	Yes

CS Country Specific. T1 Tier 1. T2 Tier 2.

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 585 million m^2, of which households have a heated area of 426 million m^2 and premises have a heated area of 159 million m^2.[21]

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 66 % in 2007, while the area heated with oil only has decreased from 22 % in 1990 to 3 % in 2007. 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 %. In 2007 this proportion increased to 82%. The

[19] http://www.sika-institute.se 2008-09-29

[20] Ministry of the Environment, 2001.

[21] Swedish Energy Authority: ES 2009:06 Summary of energy statistics for dwellings and nonresidential premises for 2007

area heated with oil only in multi-dwellings has decreased from 15 % in 1990 to 1 % in 2007. For one- and two-dwellings, there is a minor increase in the area heated with district heating only (7 % in 1990 to 9 % in 2007). However, for one- and two-dwellings the area heated with oil only has decreased from 13 % in 1990 to 3 % in 2007.[22]

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

Mobile machinery and off-road vehicles accounted for about 31 % of the energy consumed in Other sectors in 2008.

3.2.7 Other, CRF 1A5

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.8.

Table 3.8. Summary of source category description, CRF 1A5.

CRF	Gas	Key Category Assessment 2008			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1A5	CO_2		x		T1	CS	Yes
	CH_4				T1	CS	No, see Annex 5
	N_2O				T1	CS	No, see Annex 5

CS Country Specific. T1 Tier 1.

CRF 1A5 includes emissions from military transports and pressure levelling losses of natural gas. Emissions from military transports have decreased over the years 1990-2008 due to a decrease in activity.

3.2.8 Fugitive emissions, CRF 1B

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.9.

Table 3.9. Summary of source category description, CRF 1B.

CRF	Gas	Key Category Assessment 2008			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1B1	CO_2				T2	CS	Yes
	CH_4				T2	CS	Yes
	N_2O				T2	CS	Yes
1B2	CO_2	x	x		T1, T2, T3	D, CS, PS	Yes
	CH_4				T1, T2	CS, PS	Yes
	N_2O				T1, T2	CS	Yes

CS Country Specific. PS Plant Specific. T1 Tier 1. T2 Tier 2. T3 Tier 3. D Default

[22] Data for latest year not yet available

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 extraction 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, the chemical 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.
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.

In submission 2010, emissions from energy plants integrated with the iron and steel industry are reallocated to CRF 1A2a, as a part of the revision of emissions from primary iron and steel works. This is discussed in chapter 3.3.4.1 and in detail in chapter 4.4.2.1.2.2.

3.3.2 Petroleum refining, CRF 1A1b

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[23], data from the EU Emission Trading System (ETS) are used for four refinery plants for 2005 and later years. For refinery gas, emission factors reported to the ETS are used for 2008. 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.

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 was 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

[23] Backman & Gustafsson, 2006

Sweden. These data were replaced with data from the company's environmental report.

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

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. The methodology for estimating emissions from the iron and steel industry has been thoroughly revised in submission 2010. The new methodology is described in chapter 3.3.4.1 and in detail in chapter 4.4.2.1.2.2.

Activity data for nuclear power plants 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. 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 has decreased since 2006 and the consumption of biomass is small and fairly constant.

3.3.4 Iron and steel, CRF 1A2a

During 2009, a new methodology was applied for the two largest primary iron and steel works. This is described in detail in chapter 4.4.2.1.2.2.

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 2C1.1 (secondary steel) and CRF 2C1.2 (primary pig iron and steel). 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 higher than for solid fuels in other industries, since a large proportion of the fuel used is blast furnace gas which has a high carbon content compared to other solid fuels. See also chapter 4.4.2.1.2.2.

3.3.4.1 PRIMARY IRON AND STEEL WORKS

In Sweden, there are two plants for integrated primary iron and steel production, i.e. basing their production on iron ore pellets. The integrated iron and steel production consists of material flows between coke oven, blast furnace and steelworks, and in one plant, rolling mill (see Figure 4.7 in section 4.4.2.1.2.2). Emis-

sions from fuel combustion (oils, LPG and recovered energy gases, i.e. coke oven gas and blast furnace gas) used in the rolling mills and for in-house power and heat production is allocated to this sub-sector (Table 3.10) in accordance with the IPCC Guidelines. For comparison, the allocation used in submission 2009 is also provided in the table.

Table 3.10. Allocation of fuel consumption and CO_2 emissions in 2008 from iron ore based iron and steel industry on different CRF codes.

CRF	CRF sub 2009	Plant station	Fuel consumption 2008 (TJ)	CO_2 emissions 2008 (Gg)
1A1c	1A1c	Coke Oven	4352	314
1A2a	1A1a, 1A2a	Combustion in Rolling Mills + Power and Heat Production	6139	1201
1A5a	1A5a	Transformations losses of energy in iron and steel industry	35482	NA
1B1c	1B1c	Flare in Coke Oven (COG)	96	4
2C1.2	1B1c, 2C1.2	Blast Furnace + Steelworks (including Flaring of BFG and LD-gas)	NA	2069
Total				3588

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[24] 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.

3.3.4.2 SECONDARY IRON AND STEEL WORKS

Except for the primary iron ore based iron and steel works, this sector includes emissions from for instance electric arc furnaces plants, iron ore pellet plants and iron powder plants. It can be noted that combustion of coke is reported in this sector for 1990-1992 and 2008. This is due to the fact that one facility that uses coke for energy production was classified as a secondary iron and steel plant in 1990-92 and 2008, but in the years in-between the production was described as “other manufacturing of metal items” and hence allocated to CRF 1A2f.

3.3.5 Non-Ferrous Metals, CRF 1A2b

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 2003-2008. For more details on these surveys see Annex 2. Fuel consumption shows a decreasing trend

[24] Statistics Sweden EN20SM 1990-2007 row 3.9

since 1990. In 1999 there is a large jump in the time series due to increased consumed amounts of natural gas.

3.3.6 Chemicals, CRF 1A2c

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 2003-2008. For more details on these surveys see Annex 2.

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

The large increase in combustion of solid fuels and biomass in 2008 is caused by a reclassification of one major plant from 1A2f to 1A2c in 2008 due to a small shift in type of production (manufacture of plastics belongs to 1A2c while manufacture of plastics products belongs to 1A2f). Before 2001 the plant was also allocated to 1A2c.

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. For one facility, ETS data is used for 2008 for activity data and CO_2-emissions for this fuel. The plant specific emission factor is about 32% lower than the national emission factor used for other facilities and earlier years, and as a result of this, emissions are lower (and more accurate) than for 2007. This activity exists for 2000 and later years, and hence future revisions regarding this activity will not affect the emissions in the base year 1990. ETS data is available for 2005 and later years, and CO_2 emissions from this activity will eventually be revised in submission 2011 as part of a planned project dedicated to the chemical industry. In this project, the activity data time series for all fuel types and all facilities within the chemical industry will be thouroughly reviewed.

3.3.7 Pulp, Paper and Print, CRF 1A2d

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 2003-2008. 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

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 2003-2008. For more details on these surveys see Annex 2.

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

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 was 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 2003-2008. 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[25]. 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.[26]

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 2001-2007 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 2001-2007 and explains the quite large decrease in fuel consumption in 1A2f between 2007 and 2008.

[25] Statistics Sweden, EN20SM 1990-2008. See also Annex 2.

[26] Statistics Sweden, EN20SM 1990-2008. See also Annex 2.

Since 2007, 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.

For 2008, activity data for the three plants within the cement production industry is taken from the EU ETS system.

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.[27] 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 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 lower emissions compared to the International Civil Aviation Organization (ICAO) standards

[27] Swedish Civil Aviation Authority.

that the IPCC guidelines follow.[28] For international flights, ICAO standard taxi time has been used for the part of the LTO cycle occurring on international airports.[29]

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.

During 2007, the Swedish Transport Agency responded to the governmental call to reduce response burden on statistical compilations. As a result, private aviation as well as educational training flights and military are no longer covered in the calculations of emissions. The emissions mostly affected are CO, HC and N_2O.

Emissions of CO_2 are based on fuel delivery statistics, national thermal values from Statistics Sweden and emission factors from the Swedish EPA. New emission factors were delivered in time for the submission of 2010, covering CO_2 emission from jet kerosene and aviation gasoline. 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.

Quotas for distributing CO_2 emissions on domestic and international LTO and cruise are not available for 1990-1994 and is therefore estimated as described by Figure 3.1.

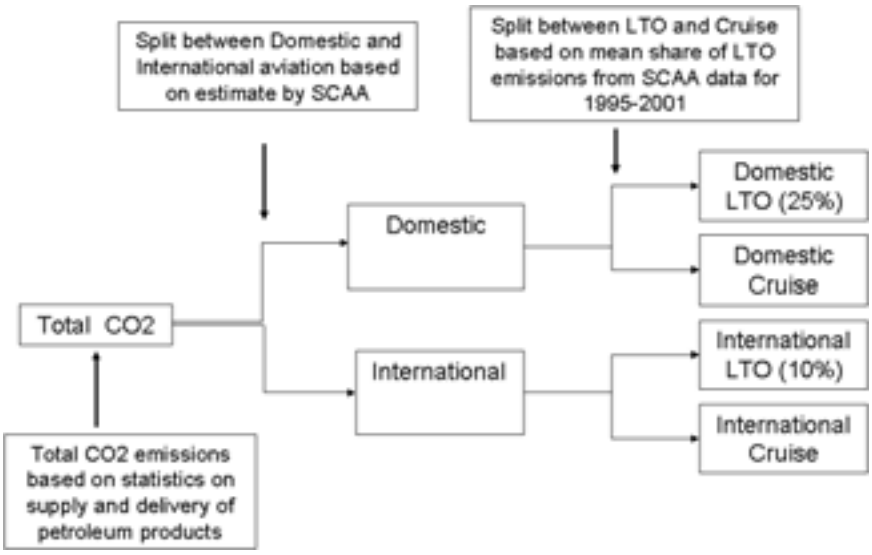

Figure 3.1 Model for estimating Domestic/International LTO/Cruise 1990-1994.

For example, domestic emissions for 1990 were calculated based on the share of domestic emissions for 1998 which is approximately 29 %. The reason for choosing 1998 relates to the trend analysis conducted. The percentages between 1995

[28] Gustafsson, 2005.

[29] Näs, 2005.

and 1998 vary from 29-30%, i.e. they are very stabile. The data for later years show an impact of society's development and international flights receive a higher share compared to previous years and are not representative for earlier years. The share of domestic/international LTO for the years 1990-1994 (data that are known from the SCAA) has a much higher influence on the estimated emissions than the choice of year 1995-1998.

In order 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 20. 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[30] 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 account for emissions from fuel purchased in Sweden. An overview of the two different objectives is presented in Table 3.11.

Table 3.11. 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.

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

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[31] 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, as well as for natural gas have been provided from the SEPA. 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 consumption 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

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, HC and N_2O.

[31] Ibid.

The majority of all railway traffic in Sweden runs on electricity. Only a small part runs on other fuel sources and in Sweden it is diesel fuel. According to IPCC's guidelines emissions related to the use of electricity for railway should not be included in this sector.

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[32], 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 2010, 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.[33] 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 3.12.

Table 3.12. 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[34]. 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

[32] www.spi.se August 2005

[33] Statistics Sweden EN31SM

[34] Cooper and Gustafsson, 2004.

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[35] 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 2010, 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 was revised in submission 2009 and is considered to correspond to Tier 2. The methodology is quite complex and described in Annex 2.
Emissions from off-road vehicles and other machinery are also reported under CRF 1A2f, 1A4b and 1A4c, in line with IPCC Guidelines, see Table 3.13.

Table 3.13. 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 harbours, 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	

[35] Statistics Sweden, 2005.

In submission 2009, emissions from off-road vehicles and working machinery 1990-2006 were revised following a development project during 2008. Due to this new methodology the emission factors change yearly.

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.[36] 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 1A4a and 1A4b[37]. 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 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

[36] Gustafsson, et al. 2005.

[37] Paulrud et al. 2005.

[38] Lidén and Gerner, 2008

considered to give the best data was using annual energy balances for all years when 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

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.

Since 2002, and in particular since 2004, the consumtion of biomass fuels has increased in this sector. This is partly explained by the general shift from liquid to biomass fuels in recent years. However, a data check performed in 2009 showed that the data for biomass use in the commercial/institutional sector in the energy balances might not be complete. This will be further investigated before submission 2011.

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 was 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.

The consumption of biomass, liquid fuels and gaseous fuels within this sector was higher in 2007 than in 2006 and 2008. Since data for 2008 is considered preliminary (see section 3.3.15.2), it is difficult to draw any firm conclusions from this fact. A minor investigation of different data sources for this sector will be performed before submission 2011.

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. The sharp increase in use of biomass in 2003 is due to a revision in submission 2009, where improved data was used for 2003 and later years. 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 was 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.

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

[39] Statistics Sweden, 2006 ENFT0601.

[40] Cooper et al., 2005a.

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.

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.

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.

A special estimation for the use of FAME was conducted by the military for the years 1999-2002. None has been done for the other years.

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:

[41] Statistics Sweden EN20SM 1990-2006 row 3.9

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 from the coke oven is reported in CRF 1B1c since submission 2004. Starting in submission 2010, flaring of blast furnace gas in the blast furnace and steel converter gas in the steel converter are reported under CRF 2C1. For details on this recalculation, see chapter 4.4.2.1.2.2. 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 in CRF Table 1B2.

3.3.20.2 OIL AND NATURAL GAS, CRF 1B2

3.3.20.2.1 Hydrogen production plants at refineries, CRF 1B2A1

According to 2006 IPCC Guidelines, emissions from hydrogen production plants should be reported in this sector. Since 2006, one such facility is in operation in Sweden. In submission 2009, Sweden reported the emissions from this facility in CRF 1B2A4, but they have been reallocated to 1B2A1 in submission 2010. Both CO_2 and non-CO_2 emissions are estimated using the Tier 2 method. Activity data as consumed amount of fossil gases (e.g. butane) and CO_2 emissions are taken from the company's report to the EU ETS system. Non-CO_2 emissions are calculated with this plant specific activity data and national emission factors for butane.

3.3.20.2.2 Transport, CRF 1B2A3

In Sweden, crude oil is transported to and from the country by tankers. In response to recommendations from the UNFCCC expert review teams, Sweden estimates for the first time in the 2010 submission inventory emissions of CH_4 from transport of

crude oil. National statistics on imported and exported amounts of crude oil available from Statistics Sweden is used as activity data. The activity data is corresponding to the data in the Reference Approach. As no reliable country-specific measurements are carried out, the IPCC Guidelines default emission factor (745 kg CH_4/PJ) for Western Europe is applied. Fugitive emissions of CO_2 from transport of crude oil are considered to be not applicable (NA) in Sweden as no default IPCC emission factor for tankers is available.

3.3.20.2.3 Refineries, CRF 1B2A4

Sweden estimates both CO_2 and 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:

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

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 3.14, 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 3.14, the reported emissions of CH_4 and also activity data can be seen.

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[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.

Table 3.14. Throughput of crude oil in refineries and estimated fugitive emissions of NMVOC and CH4 (Mg) 1990-2008 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	16 430 000	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	19 910 000	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	17 706 518	8 877	233
2008	20 420 061	8 505	263

In submission 2009, emissions from combustion of cracker coke in refineries earlier reported in CRF 1A1b were reallocated to CRF 1B2A4 to be in line with the IPCC guidelines. This is based on a recent study performed by SMED[47]. The cracking reactions produce some carbonaceous material (referred to as *coke*) that deposits on the catalyst and very quickly reduces the catalyst reactivity. The catalyst is regenerated by burning off the deposited coke. Hence the combustion is not carried out for energy purposes and thus the emissions should not be reported in CRF 1A.

3.3.20.2.4 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 and 2008 on Concawe 03/07[50]. More than 30 depots have been considered during later years. Gas recovery systems and

[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] Brännström, 2009, 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

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 1990-2008 are presented in Table 3.7.

The calculation of the NMVOC time series for fugitive emissions from gasoline distribution, 1990-2008 (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 3.16.

Table 3.15. Handled and distributed amount of gasoline and estimated fugitive emissions of NMVOC (Gg) from storage at depots and at gasoline stations, 1990-2008.

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	5 377 355	1.56	3.23
2003	5 351 942	1.57	3.21
2004	5 319 104	1.71	3.19
2005	5 295 211	1.67	3.18
2006	5 128 491	1.60	3.08
2007	5 006 028	1.65	3.00
2008	4 795 633	1.16	2.88

Table 3.16. 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 - 2008	
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

[51] Andersson, 2000.

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 3.17. 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%

3.3.20.2.5 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 2009, emissions were reallocated to this code from CRF 1B2A6.

3.3.20.2.6 Venting, CRF 1B2C1

In submission 2010, emissions are reported for the first time using the Tier 1 approach and default emissions factors from the 2000 Good Practice Guidance. For emissions of CH_4, the maximum value of the default EF is chosen to avoid any risk of underestimating the emissions.

3.3.20.2.7 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. Emissions in this CRF category varies quite widely between years due to large variations in the amount of refinery gases that needs to be flared each year. Data has been collected directly from the plant operators. For the years 2005 and later, data from the EU ETS system has been used when possible. Data from the EU ETS system are verified against data from environmental reports and vice versa. In submission 2010 EU ETS data have been analyzed carefully. It was concluded that the notation key for flaring of natural gas (NE in earlier submissions) could be changed, since no such flaring could be found in the EU ETS data and all plants that might be flaring are included in the EU ETS. There is a slight possibility that some flaring of natural gas is reported included in the flaring

of liquid fuels. Because of this the notation key IE is used rather than NO, referring to emissions reported under CRF 1.B.2.C.2.1 Oil.

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 Good Practice Guidance.

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.

In submission 2010 the consumption of diesel has been revised for the year 2007 affecting the emission calculations. The reason is that one company had double reported the amount of bunkered diesel in the statistics. All emissions are affected of by revision as the consumption of diesel was reduced by half the amount of previous reporting.

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.

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-

[52] ER 2007:26
[53] ER 2007:26
[54] Statistics Sweden EN0114, 2005
[55] Backman & Gustafsson, 2006

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 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] was 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 was that the emissions needed 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. These revisions have been implemented in submission 2010 and are described in chapter 3.3.4.

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 3.18 shows the recalculation differences for the GHG emissions by sub-sector well as for the total level in the energy sector reported in submission

[56] Nyström, 2007

[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.

2010 compared to data reported in submission 2009. As can be seen, despite the recalculations, the change on total level for the energy sector is small for all years.

Table 3.18. Recalculations of GHG emissions between submission 2010 and submission 2009 in the energy sector.

Recalculation differences, submission 2010/2009 (Gg CO_2 eq.)									
CRF	1A1	1A2	1A3	1A4	1A5	1B1	1B2	Total CRF 1	% CRF 1
1990	-262	564	445	-22	-44	-786	-6	-110	-0.21%
1991	-298	577	455	-23	-46	-936	-2	-273	-0.50%
1992	-283	541	464	-23	-33	-748	-3	-85	-0.16%
1993	-232	580	441	-23	1	-715	-3	48	0.09%
1994	-183	612	446	-25	1	-1 092	1	-240	-0.43%
1995	-202	732	455	-29	1	-1 107	-1	-151	-0.27%
1996	-198	676	449	-33	1	-953	17	-40	-0.07%
1997	-507	787	439	-31	1	-883	2	-191	-0.35%
1998	-367	757	427	-33	1	-844	10	-48	-0.09%
1999	-641	750	429	-30	1	-861	3	-349	-0.67%
2000	-784	870	423	-26	1	-857	4	-370	-0.73%
2001	-710	900	424	-30	0	-772	3	-185	-0.36%
2002	-839	867	429	-28	0	-765	3	-333	-0.64%
2003	-747	928	426	-30	0	-668	2	-88	-0.17%
2004	-778	865	417	-31	0	-833	3	-356	-0.68%
2005	-699	955	413	-33	0	-573	2	66	0.13%
2006	-643	807	402	-38	0	-575	-5	-51	-0.10%
2007	-714	974	395	52	0	-612	188	283	0.59%

0 equals value less than 0.5.

CRF 1, general:

- The thermal values and CO_2 emission factors for natural gas have been revised for the years 2002 and later, thanks to availability of new data from the Danish Energy Authority. Year specific thermal values and emission factors are used.[58] The result is a minor increase in CO_2 emissions from use of natural gas of 0.02 to 1.6% depending on year.
- The CO_2 emission factor for gas works gas has been revised from 77.5 kg/GJ to 52.0 kg/GJ. The new emission factor is based on frequent measurements performed by the only producer of gas works gas in Sweden.[59] Depending on the consumption of this fuel each year, the recalculation accounts for a reduction of between 38 and 59 Gg CO_2 per year of the total emissions in CRF 1A and 1B.
- The N_2O emission factor for petroleum coke, i.e. cracker coke, has been revised from 0.02 kg/GJ to 0.0006 kg/GJ.[60] This affects the GHG emissions in CRF 1A2 and 1B2 and the total reduction is between 12 and 28 Gg CO_2-eqv depending on the consumption of petroleum coke each year.

[58] www.energinet.dk and Paulrud, Fridell & Stripple 2009.

[59] Paulrud, Fridell & Stripple 2009

[60] Ibid

- Thermal values and CO_2 emission factors for gasoline have been revised from 31.4 GJ/m^3 to 32.78 GJ/m^3 (thermal values) and from 72.6 kg/GJ to 72.0 kg/GJ (emission factors)[61]
- Thermal values and CO_2 emission factors for biogas have been revised from 39.74 GJ/1000m^3 to 35.3 GJ/1000m3 (thermal values) and 56.5 kg/GJ to 56.1 kg/GJ (emission factors) [62]
- Thermal values and CO_2 emission factors for ethanol have been revised from 22.46 GJ/m^3 to 22.77 GJ/m^3 (thermal values) and from 56.6 kg/GJ to 67.1 kg/GJ (emission factors) [63]
- Thermal values and CO_2 emission factors for FAME have been revised from 35.3 GJ/m^3 to 33 GJ/m^3 (thermal values) and 56.5 kg/GJ to 75.6 kg/GJ (emission factors) [64]
- Thermal values and CO_2 emission factors for aviation gasoline have been revised from 31.81 GJ/m^3 to 31.45 GJ/m^3 (thermal values) and from 72.3 kg/GJ to 70 kg/GJ (emission factors) [65]
- Thermal values and CO_2 emission factors for jet kerosene have been revised from 34.5 GJ/m^3 to 35.28 GJ/m^3 (thermal values) and from 73.1 kg/GJ to 71.5 kg/GJ (emission factors) [66]
- Activity data for use of diesel for stationary combustion 2007 has been revised due to use of erroneous enumeration factors in submission 2009. The result of this is a reallocation of around 55 Gg CO_2-eqv from stationary to mobile combustion.

CRF 1A1a:

- In earlier submissions, some emissions from the integrated iron and steel industry were allocated to CRF 1A1a. In submission 2010, these emissions are reallocated to CRF 1A2a. This is related to the revision of process emissions from the iron- and steel industry discussed in section 3.3.4 and 4.4.2.1.2.2.
- Activity data for landfill gas 2006 has been revised. A data check performed in 2009 showed that activity data for this fuel for 2006 were erroneous in submissions 2008 and 2009. The result is -85 Gg CO_2 –eqv 2006.

CRF 1A1b:

- In earlier submissions, consumption of other fuels was reported for the emission year 2005. Data checks have shown that this was incorrect, why in submission 2010 this fuel consumption and the related emissions, in total 0.41 Gg CO_2-eqv, have been reallocated to liquid fuels.

CRF 1A1c:

[61] Ibid
[62] Ibid
[63] Ibid
[64] Ibid
[65] Ibid
[66] Ibid

- All emissions from the two largest iron and steel plants, which account for the majority of the emissions in this sector, were profoundly revised due to a change in methodology following a SMED project described in chapter 3.3.4 and 4.4.2.1.2.2.

CRF 1A2a:

- All emissions from the two largest plants all years were profoundly revised due to a change in methodology following a SMED project described in chapter 3.3.4 and 4.4.2.1.2.2.
- Activity data for natural gas 2002-2007 was revised for one company. This has only minor effects on the total emissions within this sector.

CRF 1A2b:

- All emissions from use of coke were reallocated to CRF 2C5, since it was discovered that these emissions are in fact process emissions.

CRF 1A2d:

- Emissions of NO_X and SO_2 for pulp and paper plants the years 2000-2007 have been revised to be more in line with the emissions reported by the companies in their annual environmental reports. Since the environmental reports do not provide any information on emissions per fuel type, but only total emissions from combustion of fuels, a mean enumeration factor calculated as (emissions reported in the environmental reports)/(activity data from energy statistics * national EF) has been used for all fuels.

CRF 1A2e:

- Activity data for landfill gas 2006 has been revised. A data check performed in 2009 showed that activity data for this fuel 2006 was erroneous in submissions 2008 and 2009. The result is -12 Gg CO_2 –eqv 2006.

CRF 1A2f, 1A4a-c:

- Activity data for liquid fuels at small companies has been revised for 2007. The reason is that data for these industries are not ready in time for the GHG inventory, and thus preliminary data is estimated by a model. Hence, in every new submission, the activity data for the second latest year is revised.

CRF 1A2f, 1A3e, 1A4b, 1A4c:

- Emissions from off-road vehicles and working machinery have been revised for the whole times series 1990-2008 due to a new methodology.

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 1B1c:

- Flaring of BFG and LD gas is reallocated to CRF 2C1.2 due to a change in methodology following a SMED project described in chapter 3.3.4 and 4.4.2.1.2.2.

CRF 1.B.2.A.5\Transfer loss gas works gas:

- The emission factor for CO_2 has been revised for the whole time series.67

CRF 1B2A1, 1B2A4:

- Emissions from hydrogen production plants are reallocated from CRF 1B2A4 to 1B2A1 in submission 2010.
- In submission 2009, CO_2 from combustion of cracker coke was by mistake not reported for 2007. This has been corrected in submission 2010, resulting in an increase of 185 Gg CO_2 in submission 2010 compared to submission 2009.
- Data for throughput of crude oil in refineries is slightly revised for the years 1991, 1996 and 2007 due to updated data from one refinery.

CRF 1B2A5:

- Updated activity data from the ARTEMIS model has lead to slightly revised fugitive emissions of NMVOC at gasoline stations for the years 2002 - 2007.

CRF 1B2C1:

- Emissions are estimated using Tier 1 and default EF for all years.

CRF 1B2C2:

- Notation key changed from NE to IE after a careful study of ETS data.

CRF 1C

- The consumption of diesel has been revised for the year 2007 affecting the emission calculations. The reason is that one company had double reported the amount of bunkered diesel in the statistics.

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 2011, the revision of emissions from several industries motivated by a study performed by SMED during 2008[68] is planned to be continued. Based on other results published by Paulrud, Fridell and Stripple (2009)[69], a revision of several emission factors is planned for submission 2011. Some of the recommended revisions have been made already in submission 2010.

[67] Paulrud, Fridell & Stripple, 2009

[68] 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.

[69] Paulrud, Fridell Stripple. Uppdatering av klimatrelaterade emissionsfaktorer. IVL report 2nd edition 2009

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 aluminum production, consumption of fluorinated greenhouse gases and some processes in the chemical industry.

Greenhouse gas emissions from the industrial processes sector have increased with 524 Gg CO_2 equivalents from 6,264 Gg CO_2 equivalents in 1990 to 6,793 Gg CO_2 equivalents in 2008, an increase of 8.4% (Figure 4.1). The trend is mainly due to increased emissions of HFCs (+913 Gg CO_2 equivalents) and CO_2 (+327 Gg) and decreased emissions of N_2O (-538 Gg CO_2 equivalents) and PFCs (-152 Gg CO_2 equivalents). In Figure 4.1 it can be seen that in 2008, CO_2 is by far the largest contributor among the greenhouse gases in this sector, accounting for 76.4% of the GHG emissions. Emissions of HFCs are the second largest greenhouse gas in 2008, accounting for 13.5% of the sector emissions.

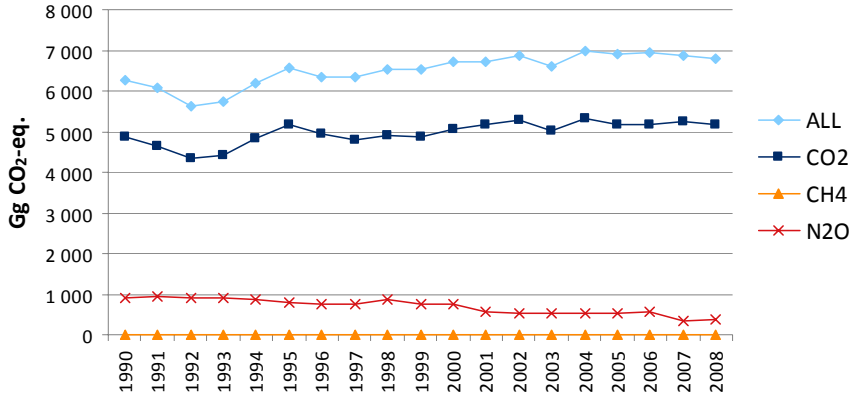


Figure 4.1. Total emissions of all greenhouse gases calculated as CO_2 equivalents from CRF 2 Industrial processes.

Among the industries in this sector, metal production (CRF 2C) is the largest contributor in 2008 with 3,252 Gg CO_2 equivalents, or 47.9% of the sector emissions, and compared to 1990 there is a slight reduction in greenhouse gas emissions of about 6.5% (Figure 4.2).

In Figure 4.2 it can be seen that greenhouse gas emissions from mineral products (CRF 2A) in 2008 amounted to 2,159 Gg CO_2 equivalents, or 25.4% of the sector emissions. This is an increase in greenhouse gas emissions since 1990 of 438

Gg CO_2 equivalents, mainly due to increased production of lime and clinker. For chemical industry (CRF 2B), greenhouse gas emissions have decreased with 570 Gg CO_2 equivalents since 1990 and amounted to 338 Gg CO_2 equivalents in 2008. The reduction is closely linked to N_2O emissions from nitric acid production.

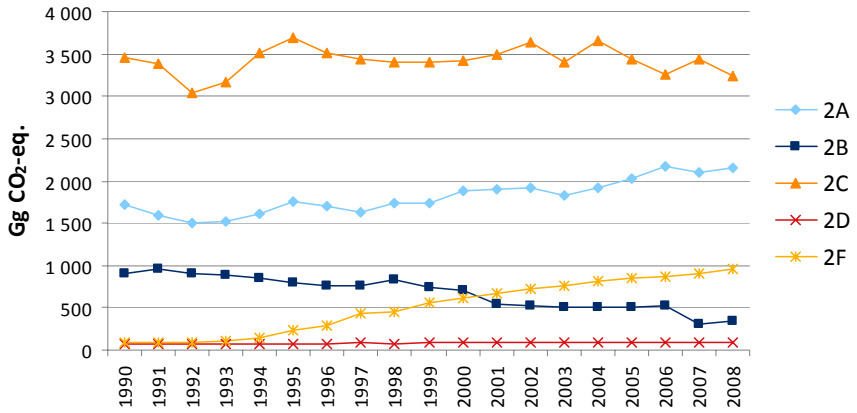


Figure 4.2. Total emissions of all greenhouse gases calculated as CO_2 equivalents from the different Industrial processes sub-sectors.

2A Mineral products. 2B Chemical industry. 2C Metal production. 2D Other production. 2F Consumption of Halocarbons and SF_6.

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 aluminum production process. No production of halocarbons or SF_6 (CRF 2E) occurs in Sweden. The consumption of fluorinated greenhouse gases (CRF 2F) has increased substantially, 867 Gg CO_2 equivalents, since 1990 (Figure 4.2). The use as refrigerants in refrigerators, freezers and air-conditioning equipment has contributed to the larger share in later years.

Process emissions from pulp and paper in other production (CRF 2D) do not contribute significantly to the emissions of greenhouse gases in Sweden.

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), glass production (2A7.1), non-iron ore mining and dressing plants, glass and mineral wool production, LECA production and production of roofing tiles, bricks and ceramics are included. Until 1998 also emissions from battery manufacturing are included in code 2A7. The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.1.

Table 4.1. Summary of source category description, CRF 2A.

CRF	Gas	Key Category Assessment 2008			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2A	CO_2	x	x		D, CS, T2	D, CS, PS	No, see Annex 5
	CH_4				NA	NA	NA
	N_2O				NA	NA	NA

D Default. CS Country Specific. T2 Tier 2. PS Plant-specific.

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.

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.

4.2.1.3 LIMESTONE AND DOLOMITE USE, CRF 2A3

Limestone and dolomite are used in various processes such as mineral wool production and iron sinter production (further described in 2C1.3). The use of limestone and dolomite in these processes give rise to emissions of CO_2. Three facilities produce glass- and mineral wool. Limestone and dolomite are also used in the production of cement (2A1), lime (2A2), carbide (2B4) and glass (2A7.1).

4.2.1.4 SODA ASH USE, CRF 2A4

Soda ash is used in the production of glass wool, moist snuff and chemicals i.e. detergents, and until 2004 also in flue gas desulphurisation at energy plants. Soda ash is also used in production of glass (2A7.1). 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 % in 2002 and 19 % in 2008. 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 “Glass production (2A7.1)”, “Non-Iron ore mining and dressing”, “Glass and mineral wool production”, “Battery manufacture” and ”Light expanded clay aggregate (LECA), roofing tile, brick, and ceramics production“.

4.2.1.7.1 Glass production, CRF 2A7.1

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 2A7.1 since a separation into 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 soda ash in glass production are from submission 2010 reported in 2A7.1. In earlier submissions CO_2 from the use of limestone and of soda ash in glass productions were reported under 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).

4.2.1.7.2 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 – 2008 is thus reported NE. Estimated emissions from combustion of fuels are included in the Energy sector (CRF 1).

4.2.1.7.3 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.

4.2.1.7.4 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), roofing tile, brick and ceramics production, CRF 2A7

In this sub-code under 2A7 Sweden report CO_2 emissions from production of clay based materials such as LECA, roofing tiles, bricks and ceramics. During the production CO_2 is emitted from the burning of fuels, reported in CRF 1A2f, but CO_2 originating from the clay, the limestone and from other carbon containing material is also emitted. Reported CO_2 represents the emissions from totally five facilities of which one is dominating. All CO_2 emissions from raw material used 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 SO_2 and CO_2 are allocated to industrial processes, according to the IPCC Guidelines. Emissions of NO_x have been reallocated from the energy sector (1A2f) to industrial processes. The reason for this is that there is a lack of correct emission factors due to the fact that the companies use such a large variety of waste as fuel. The use of different waste as fuel varies within and between years.

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[70]. 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, aluminum and cement.

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

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 (Gg) * 0.525 (Gg CO_2/ Gg clinker = default value in the GHG-protocol) * CKD correction factor+ CO_2 from organic carbon content of raw meal

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 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 4.2 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 (Gg CO_2/Gg clinker produced) is due to added emissions from the organic carbon content of raw meal and 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 and from organic carbon content of raw meal are not included.

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 %. For the years from 2005 the reported CO_2 emissions are based on analysis of the CaO content in the clinker. Data from 2008 and 2009 shows a variation in CaO content between 63.9 to 67.6%. Data on the non-carbonate feeds to kilns is not available.

Table 4.2. 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
	Gg	Gg	Gg	Gg	Gg	
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
2008	2 644	1 425	1 390	5	30	1.003

4.2.2.1.2 NO_X (Gg)

Emissions of NO_X have been reallocated from the energy sector (1A2f). Data on NO_X emissions from cement production has been obtained directly from the company or from the environmental reports to the authorities.

4.2.2.1.3 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 2008 have decreased compared to previous year.

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 activity data on produced amounts of quicklime and hydraulic lime and dolomitic lime.

Activity data on used amounts of limestone for production of lime for sugar production are obtained directly from the sugar producing company. All other ac-

tivity data are collected from the Swedish Lime Association and The Swedish Lime Industry[71], and represents the total production of lime in conventional lime mills, and limestone used for the production of lime within the pulp and paper industry.

All emission factors used are as presented in the 2006 IPCC Guidelines and the purity of the limestone is set to 95% for the production of lime in conventional lime mills and within the pulp and paper industry. The corresponding figure for dolomite is 100%. The purity of the limestone used in the sugar industry is 97%, as reported by the sugar producing company.

4.2.2.2.1.1 Sugar industry

For determining activity data and emissions of CO_2 within the sugar industry, the amounts of limestone for the production of quicklime are used. The quantities are obtained directly from the sugar producing company for the years 1999 – 2008. For years prior to 1999 no data on used amounts of limestone are available. For those years the amounts of limestone used for production of quicklime are estimated using the quantity of coke used for lime production 1990 – 1998, together with the average ratio coke/limestone for the years 1999 to 2002. According to the company the used limestone consists to 97% of $CaCO_3$.

In the production of sugar, lime is used for purification of the juice. Lime is added to the raw juice and some impurities are precipitated. In the carbonisation step CO_2 is bubbled through the juice and most of the remaining lime is precipitated as $CaCO_3$. The precipitated "limestone" is sold and used within agricultural activities. Information from the company gives that around 88% of the lime used were precipitated as $CaCO_3$ between 1990 and 2004. For later years this share has increased and in 2008 more than 94% of the lime used is precipitated to $CaCO_3$.

In earlier submissions the whole amount of lime produced and used within the sugar industry were reported as activity data without taking into account that a large amount of the produced lime is precipitated as $CaCO_3$ in the carbonation process. In submission 2010 only the part of CaO which is not recovered as $CaCO_3$ is reported as activity data.

In Table 4.3 the used amounts of limestone, the amounts of produced lime and emitted CO_2, the precipitated $CaCO_3$, and the reported activity data and CO_2 emissions from lime production within the sugar industry is presented.

[71] Swedish Lime Association and The Swedish Lime Industry, Svenska Kalkföreningen, personal communication

Table 4.3. Limestone used, amount of produced lime and emitted CO_2, precipitated $CaCO_3$ and reported activity data and CO_2 emissions from lime production within the sugar industry

Year	Used amounts of limestone	Amount of lime produced	CO_2 from lime production	Precipitated share of lime	Precipitated amount of lime	Reported Activity Data (lime)	Reported CO_2 emissions
	Gg	Gg	Gg	%	Gg	Gg	Gg
1990	94.7	51.4	40.4	87.5%	45.0	6.4	5.0
1991	53.2	28.9	22.7	87.5%	25.3	3.6	2.8
1992	70.1	38.1	29.9	87.5%	33.3	4.8	3.7
1993	77.2	42.0	33.0	87.5%	36.7	5.2	4.1
1994	74.6	40.5	31.9	87.5%	35.5	5.1	4.0
1995	76.4	41.5	32.6	87.5%	36.3	5.2	4.1
1996	76.7	41.7	32.7	87.5%	36.5	5.2	4.1
1997	81.2	44.1	34.6	87.5%	38.6	5.5	4.3
1998	71.9	39.1	30.7	87.5%	34.2	4.9	3.8
1999	75.3	40.9	32.1	87.5%	35.8	5.1	4.0
2000	70.0	38.0	29.9	87.5%	33.3	4.8	3.7
2001	66.2	35.9	28.2	87.5%	31.4	4.5	3.5
2002	71.0	38.5	30.3	87.5%	33.7	4.8	3.8
2003	63.2	34.3	27.0	87.5%	30.0	4.3	3.4
2004	58.5	31.8	25.0	87.5%	27.8	4.0	3.1
2005	60.9	33.1	26.0	92.0%	30.4	2.6	2.1
2006	68.1	37.0	29.1	92.0%	34.0	3.0	2.3
2007	48.6	26.4	20.7	91.3%	24.1	2.3	1.8
2008	57.3	31.1	24.4	94.4%	29.4	1.7	1.4

4.2.2.2.1.2 Pulp and paper industry

Previous reporting of activity data and CO_2 emissions from lime production within the pulp and paper industry have led to comments and recommendation from the UNFCCC Expert Review Team (ERT). The comments concern the methodology used and Sweden has been recommended to improve the reporting of activity data and CO_2 emissions. In order to improve the reporting of activity data and associated CO_2 emissions, detailed data from the Swedish Lime Association and The Swedish Lime Industry[72] have been used in submission 2010.

Detailed data on the quantities of lime used as make-up lime in the pulp and paper industry, and quantities of limestone and dolomite used for production of make-up lime, have been obtained from the Swedish Lime Association and The Swedish Lime Industry for the years 1995 – 2008. For the years before 1995, the amounts of make-up lime consumed are estimated using the average ratio between the quantity of make-up lime used and kraft pulp produced for the period 1995 – 2008 and corresponding production data for 1990 – 1994. Earlier information on

[72] Swedish Lime Association and The Swedish Lime Industry, Svenska Kalkföreningen, personal communication

the need for make-up lime has indicated that it would be less than 20 kg per Mg. New information from a small number of Swedish pulp and paper industries shows that the need may vary considerably, from less than 10 kg per Mg to over 30 kg per Mg[73]. The data used in submission 2010 gives an average need of 20 kg make-up lime per Mg kraft pulp and can therefore be considered reliable to use to estimate the need for make-up lime to the pulp industry for years before the 1995. Similarly, the amount of CO_2 emitted is estimated for 1990 – 1994 using the average ratio between emitted CO_2 and used amounts of make-up lime for the period 1995 – 2008 (Table 4.4).

Table 4.4. Produced amounts of kraft pulp, IEF (Make-up lime used per produced amounts of kraft pulp), IEF (CO_2 emitted per produced make-up lime) and reported activity data and CO_2 emissions from make-up lime production for the pulp and paper industry

Year	Produced amounts of kraft pulp	IEF (Make-up lime/kraft pulp)	IEF (CO2/Make-up lime)	Reported Activity Data (Make-up lime)	Reported CO2 emissions
	Gg	Gg/Gg	Gg/Gg	Gg	Gg
1990	5 944	0.020**	0.7457**	118.7*	88.5*
1991	6 129	0.020**	0.7457**	122.4*	91.3*
1992	6 113	0.020**	0.7457**	122.1*	91.0*
1993	6 310	0.020**	0.7457**	126.0*	94.0*
1994	6 270	0.020**	0.7457**	125.2*	93.4*
1995	6 377	0.019	0.7458	119.4	89.0
1996	6 298	0.020	0.7458	125.1	93.3
1997	6 704	0.020	0.7458	131.7	98.2
1998	6 615	0.021	0.7458	141.7	105.7
1999	6 735	0.023	0.7458	152.8	114.0
2000	7 557	0.018	0.7457	138.1	103.0
2001	7 505	0.016	0.7456	123.4	92.0
2002	7 627	0.018	0.7457	139.3	103.9
2003	7 877	0.018	0.7456	143.0	106.6
2004	7 773	0.018	0.7455	142.4	106.1
2005	7 784	0.022	0.7456	172.0	128.3
2006	7 828	0.020	0.7455	156.5	116.7
2007	7 835	0.024	0.7457	188.6	140.7
2008	7 635	0.022	0.7458	164.7	122.8

*estimated

** average ratio for 1995 - 2008

4.2.2.2.1.3 Other production of lime

The conventionally produced amounts of lime reported in earlier submissions included by mistake amounts of lime used within the pulp and paper industry. These

[73] Håkan Stripple, IVL Swedish Environmental research Institute, personal communication

amounts resulted thus in a double-counting of activity data and CO_2 emissions in 2A2. The detailed data from the Swedish Lime Association and The Swedish Lime Industry[74] have lead to a revision of reported activity data and CO_2 emissions in submission 2010. The revision affects the reported activity data and also the reported CO_2 emissions.

Table 4.5. Produced amounts of quick lime and dolomitic lime, emitted CO_2 and IEF (CO_2 emitted per produced quick lime and dolomitic lime) in conventional lime mills.

Year	Reported Activity Data (quick lime and dolomitic lime, excluding lime in sugar and pulp industry)	Reported CO_2 emissions (excluding emissions in sugar and pulp industry)	IEF (CO_2/quick lime + dolomitic lime)
	Gg	Gg	Gg/Gg
1990	264.3	201.1	0.7609
1991	263.3	200.4	0.7609
1992	226.0	172.0	0.7609
1993	247.9	188.6	0.7609
1994	324.0	246.5	0.7609
1995	258.4	196.4	0.7599
1996	261.7	198.9	0.7599
1997	327.5	248.9	0.7599
1998	454.6	345.5	0.7599
1999	437.7	332.6	0.7599
2000	403.9	306.0	0.7576
2001	388.4	296.0	0.7622
2002	447.9	339.7	0.7586
2003	437.5	331.8	0.7584
2004	444.9	335.6	0.7543
2005	495.6	375.6	0.7578
2006	543.7	412.1	0.7581
2007	530.5	402.6	0.7590
2008	541.4	409.6	0.7566

The new activity data reported in 2A2 have been compared with national statistics from Statistics Sweden in line with the Good Practice Guidance Tier 2.[75] The comparison (Figure 4.3) shows that national statistics are more irregular but for most years the coherence is good. The differences are especially high in 1998, 1999 and from 2003 and onwards. The national statistics are based on national surveys mainly aiming at collecting data for economical statistics. In these surveys not all facilities are included and for those the produced amounts are estimated, which might lead to over- or underestimations of, in this case, produced amounts of lime.

[74] Swedish Lime Association and The Swedish Lime Industry, Svenska Kalkföreningen, personal communication

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

Since data collected for the national inventory are consistent and less volatile than the national statistics, the national inventory data has been chosen for the calculations of CO_2 from lime production.

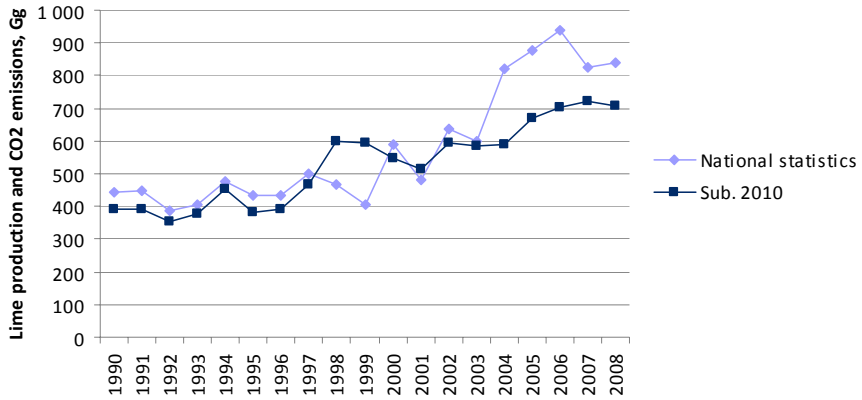


Figure 4.3. National total on produced amount of lime according to data from Statistics Sweden and reported data in CRF 2A2.

Quick lime 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 4.3, but it is most likely not.

When comparing the activity data and CO_2 emissions reported in submission 2009 with the corresponding figures in submission 2010, it is clear that the revision of the reported data mainly affects reported activity data, but that the revision also affects the reported CO_2 emissions (Figure 4.4). In submission 2010 reported activity data in 2A2 is between 43 and 67% of reported figures in submission 2009. The corresponding figures for reported CO_2 emissions in submission 2010 are between 58 and 95%. The reduction of reported CO_2 emissions in 2A2 between submission 2009 and submission 2010 is partly due to the earlier double-counting of emissions from lime used within the pulp and paper industry. This double-counting represents for the years 1995 to 2007 between 80 to 130 Gg per year.

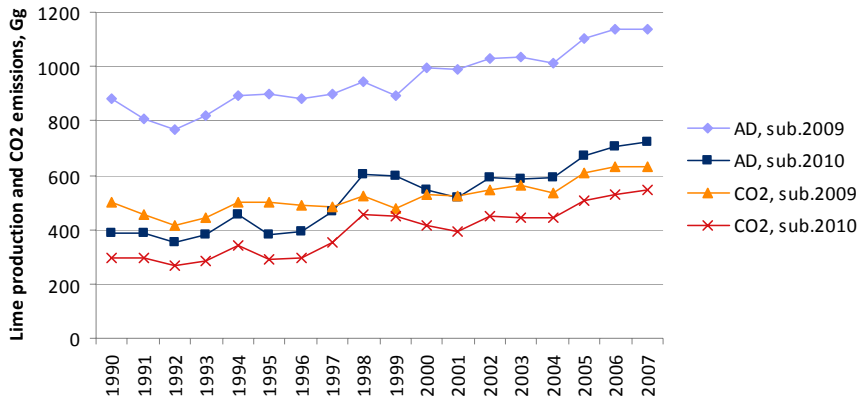


Figure 4.4. Reported Activity and CO_2 emission data in 2A2 submission 2009 compared to revised reported data in submission 2010.

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 – 2008. The estimations from quick lime production were calculated using emission factors presented in environmental reports by one of the producers[76]. The emission factor provided by the lime producer is substantially higher for 2008 than for earlier years. This results in an increase of reported SO_2 emissions for 2008 compared to earlier years.

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.

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. The reported activity data and CO_2 emissions represent limestone and dolomite use within facilities producing glass and mineral wool, iron pellets and chemical products, and also use of limestone and dolomite for flue gas purification in energy producing facilities. The calculations are made by applying the IPCC Guidelines default emission factors for limestone and dolomite[77].

Formulas for CO_2 emissions from limestone and dolomite:

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

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

[76] Nordkalk, http://www.nordkalk.com

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

where *f* is the purity of the limestone and dolomite, set to 97% and 100% respectively.

The Revised 1996 IPCC Guidelines[78] state that all use of limestone and dolomite and corresponding CO_2 emissions are to be allocated to CRF 2A3. Sweden has chosen to not report CO_2 emissions from the use of limestone and dolomite in primary and secondary production of steel (2C1.1, 2C1.2), in other metal production (2C5), in production of clay based products (2A7) and in glass production (2A7.1), in accordance with the Revised 1996 IPCC Guidelines[78]. In the case of limestone and dolomite use within the production of glass, the reallocation of CO_2 emissions from 2A3 to 2A7.1 is due to recommendations from the EC Internal review in 2009. Emissions of CO_2 from use of limestone and dolomite for the production of clay based products are reported in 2A7. This is due to the fact that emissions originating from the use of limestone and dolomite seldom are separately reported in the ETS, but rather reported together with other carbon containing raw materials. In Table 4.6 the Swedish allocation of CO_2 from use of limestone and dolomite is presented.

According to the IPCC Guidelines, emissions of CO_2 from the use of limestone should be reported separately as process emissions from limestone and dolomite use in CRF 2A3. Since the Centralized review from submission 2004 the ERT has repeatedly recommended Sweden to follow the guidelines. As the CO_2 emissions from limestone and dolomite are small (<1 per cent of the plants total CO_2 emissions) it is not considered to be good practice to spend resources obtaining underlying data to separate these emissions. Hence Sweden choose to include these CO_2 emissions in CRF 2C1.2.

Table 4.6. Allocation of CO_2 emissions due use of limestone and dolomite according to Revised 1996 IPCC Guidelines, in previous submission and in submission 2010.

Allocation	Energy producing facilities (flue gas desulphurisation)	Cement production	Lime production	Glass production	Other mineral products (glass and mineral wool)	Other mineral products (clay based products)	Calcium carbide production	Other chemical industry	Secondary steel production	Primary iron and steel production	Iron sinter production	Other metal production
according to Revised 1996 IPCC Guidelines	2A3	2A1	2A2	2A3	2A3	2A3	2B4	2A3	2A3	2A3	2A3	2A3
in previous submission	2A3	2A1	2A2	2A3	2A3	2A3 & 2A7	2B4	2A3	2C1.1	2C1.2	2A3	2C5
in current submission	2A3	2A1	2A2	2A7.1	2A3	2A7	2B4	2A3	2C1.1	2C1.2	2A3	2C5

[78] IPCC. Revised 1996 Guidelines for National Greenhouse Gas Inventories

In Table 4.7 the use of limestone and dolomite, and corresponding CO_2 emissions, for glass production, primary iron and steel production and other metal production are presented for 2005, 2006, 2007 and 2008. In relation to the amounts reported in 2A3, the yearly amounts not included in 2A3 represents around 35% of the total use of limestone and dolomite in Sweden 2005 – 2008.

Table 4.7. Used amounts of limestone and dolomite for production of glass, primary steel production and other metal production, 2005 – 2008.

Year	Glass production		Other mineral products (clay based products)		Secondary steel production		Primary iron and steel production		Other metal production	
	AD, Gg	CO_2, Gg	AD, Gg	CO_2, Gg	AD, Gg	CO_2, Gg	AD, Gg	CO_2, Gg	AD, Gg	CO_2, Gg
2005	68	31.7	*	*	*	*	70	29.9	5	2.1
2006	73	33.7	*	*	*	*	68	29.0	4	1.7
2007	72	33.6	*	*	*	*	56	23.9	5	2.1
2008	73	33.7	*	*	*	*	74	31.6	4	1.7

* not possible to separate CO_2 from limestone/dolomite for included facilities

Table 4.8. Used amounts of limestone and dolomite and corresponding CO_2 emissions

	Reported Activity data (limestone and dolomite)	Reported CO_2 emissions	CO_2 emissions in energy producing facilities (flue gas desul-phurisation)	CO_2 emissions in Other min-eral products (glass and mineral wool)	CO_2 emissions in Other chemical industry	CO_2 emissions in Iron sinter production
	Gg	Gg	%	%	%	%
1990	194	90.4	11.5	26.1	20.1	42.2
1991	214	99.9	14.0	22.2	18.9	44.9
1992	208	97.4	16.3	21.2	16.9	45.6
1993	180	83.8	15.3	17.4	20.5	46.8
1994	177	82.3	16.8	19.8	17.6	45.8
1995	214	100.2	14.2	17.9	13.8	54.1
1996	223	104.3	15.8	16.4	14.7	53.1
1997	218	101.8	13.0	14.2	15.3	57.5
1998	186	87.2	14.7	12.1	12.5	60.7
1999	205	95.0	12.6	12.2	10.7	64.6
2000	245	113.3	9.5	15.1	8.0	67.4
2001	254	115.9	11.7	14.5	6.6	67.3
2002	244	112.0	16.3	11.1	5.3	67.3
2003	248	113.2	16.9	9.7	6.0	67.3
2004	260	118.9	14.3	8.5	4.9	72.4
2005	248	113.4	13.8	9.8	4.6	71.8
2006	235	106.3	16.2	11.2	5.8	66.8
2007	261	119.1	13.0	10.0	5.2	71.7
2008	284	129.6	10.7	10.1	4.8	74.4

A comparison between activity data and CO_2 emissions reported in submission 2009 and the corresponding figures in submission 2010 is presented in Figure 4.5. As can be seen the reported activity data and corresponding CO_2 emissions are reduced in submission 2010 compared to in submission 2009. The main reason for this is the reallocation of emissions from glass production from 2A3 to 2A7.1.

Reported data in submission 2009 covered the use of limestone and dolomite for flue gas desulphurisation in seven energy producing facilities. In submission 2010 another three facilities have been included in the inventory, which to some degree compensates the reduction of reported CO_2 emissions in 2A3. One of these "new" energy producing facilities represents in submission 2010 between 30% and 60% of the reported CO_2 emissions from the use of limestone and dolomite for flue gas desulphurisation.

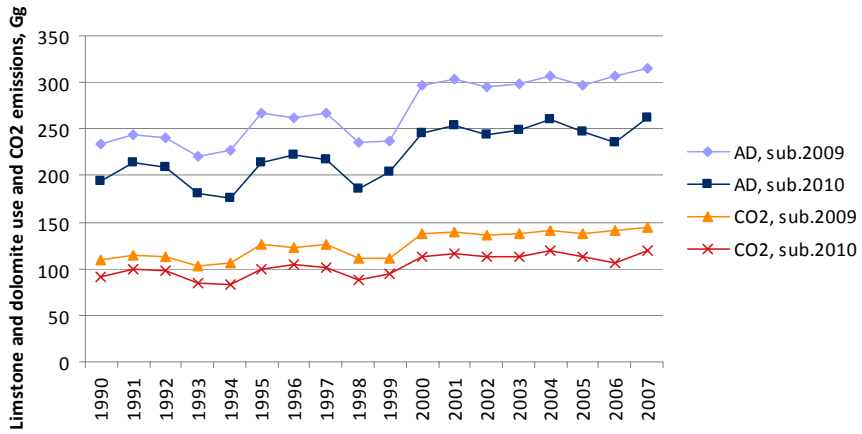


Figure 4.5. Reported Activity and CO_2 emission data in 2A3 submission 2009 compared to revised reported data in submission 2010.

The emissions have increased during the reporting period due to higher limestone and dolomite use in the production of ore-based iron pellets. 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.

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. It is however possible that there are small facilities using limestone and dolomite which may perhaps not are included in the Swedish inventory.

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.[79] 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 wool, moist snuff and chemicals
- until 2004, in flue gas desulphurisation at energy plants

As for the use of limestone and dolomite, the emissions and activity data concerning use of soda ash within the glass industries have been reallocated to 2A7.1 due to recommendations from the EC Internal review in 2009. This reallocation reduces the reported CO_2 emissions by approximately 50% in the early 1990s and by over 90% for the last years. The reason for the large effect on reported emissions in later years is due to large changes in the use of soda ash in one chemical industry. This industry spent during the early 1990s considerable amounts of ash, and has since 1997 sharply reduced their consumption. In the beginning of the new millenium this industry stopped using soda ash resulting in emissions of CO_2.

In Figure 4.6 a comparison between activity data and CO_2 emissions reported in submission 2009 and the corresponding figures in submission 2010 is presented.

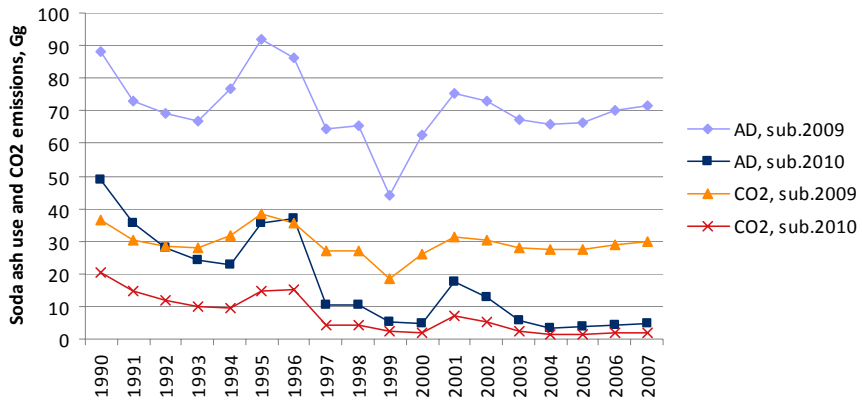


Figure 4.6. Reported Activity and CO_2 emission data in 2B4.2 submission 2009 compared to revised reported data in submission 2010.

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[80] and the dominant snuff manufacturer. The emissions are calculated by applying the IPCC Guidelines default emission factors for soda ash for all activity data:

[79] Nyström. 2004. SMED-report: CO2 from the use of soda ash.

[80] The Swedish Chemicals Agency (KemI)

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

Data on the use of soda ash have been acquired from the ETS and through direct contacts with the reporting companies.
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.

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.[81] These are based on studies performed during the 1970s in the USA and presented by EPA.[82] 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)[83].

Table 4.9. Estimated emissions of NMVOC from manufacturing of asphalt-saturated felt (CRF 2A5) in Sweden 1990 – 2008.

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

[81] EMEP/CORINAIR Emission Inventory Guidebook: http://reports.eea.eu.int/EMEPCORINAIR4/en

[82] 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.

[83] Danielsson, H. 2004. SMED report: Investigation on the occurrence of emissions from asphalt roofing in Sweden.

Year	NMVOC emissions from asphalt roofing, 2A5 Mg
2000	111.1
2001	112.9
2002	109.2
2003	101.1
2004	113.7
2005	139.7
2006	132.7
2007	142.4
2008	138.6

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 Data for the years 2002 – 2008 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. These roads needed to be restored quickly and solvent-based bitumen was used for this purpose.

Table 4.10. Emissions of NMVOC 1990–2008 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

Year	NMVOC from road paving with asphalt Mg
2000	1 170
2001	1 080
2002	845
2003	603
2004	920
2005	1 230
2006	750
2007	935
2008	855

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), roofing tile, brick, and ceramics production“.

4.2.2.7.1 Glass production, CRF 2A7.1

Emissions of CO_2 from the use of limestone and from the use of soda ash in glass production are reported in CRF 2A7.1 together with CO_2 emissions from other carbon containing raw material. Of the reported total CO_2 emissions in 2A7.1, approximately 44% is caused by the use of soda ash and 55% on the use of limestone and dolomite. The remaining CO_2 is emitted as a result of use of other carbon containing raw materials.

The process-related SO_2 emissions from container and float glass production are reported for the period 1990 – 2008 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.

Activity data and emissions are mainly collected from the ETS or from the facilities yearly environmental reports. For small glass production plants a constant amount of 0.9 Gg CO_2 per year, and corresponding amount of limestone, is added. 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 0.9 Gg, yearly.

4.2.2.7.2 Non-Iron ore mining and dressing, 2A7

Data on NO_X emissions from use of explosives within the non-iron ore mining industry are reported 2002 – 2008, 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.

4.2.2.7.3 Glass and mineral wool production, 2A7

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 2A3 according 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

4.2.2.7.4 Battery manufacture, 2A7

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), roofing tile, brick and ceramics production, 2A7

Activity and emissions data for LECA production 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.

For roofing tile, brick and ceramics production, activity and emission data from 2005 and onwards is acquired through the ETS. CO_2 emissions from the use of limestone were for one of the facilities in earlier submissions included in 2A3, but no CO_2 emissions from the use of other carbon containing raw materiel were included in the inventory in submission 2009.

The data in the ETS does not always separate between emissions from limestone/dolomite use and CO_2 emissions from other raw material needed for the production. In order to as far as possible report an accurate total process-related CO_2 emission for the facilities included in this 2A7 sub-code, Sweden have chosen to report all CO_2 emissions in 2A7.

As there is a lack of data before 2005, the reported emissions for 2005 are extrapolated for 1990-2004.

As activity data reported in this 2A7 sub-code produced amounts of LECA is reported due to lack of activity data for remaining facilities. 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 for LECA production was unusually high which

has resulted in comparatively high CO_2-emissions for that year. The use of limestone and other additives in LECA production has declined in favour of clay which today contributes to about 88 % of all process related CO_2 emissions from LECA production. The facility producing LECA corresponds to around 75% of yearly reported CO_2 emissions in this 2A7 sub-code.

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. The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.11.

Table 4.11. Summary of source category description, CRF 2B.

CRF	Gas	Key Category Assessment 2008			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2B	CO_2				D	PS	Yes
	CH_4				CS	PS	No, see Annex 5
	N_2O		x		CS, T2	PS	No, see Annex 5

D Default. CS Country Specific. T2 Tier 2. PS Plant-specific.

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[84]. 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[85]. Emissions from this industry are included in 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.

[84] UN. Commodity Production Statistica Database. Department of Economic and Social Affairs, Statistics Division,. As referred in FCCC Synthesis and Assessment report 2002 Part I.

[85] Kindbom, 2004. SMED report: Investigation on the occurrence of ammonia production in Sweden. 2004-05-11.

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 4.12). 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 Good Practice Guidance. The fluctuations in the calculated total EF for N_2O 1994 - 2002, as can be seen in Table 4.12, 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.
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.

Table 4.12. 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
2008	266	3.26	0.87

*Emission factors have been assumed

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 Gg CO_2/Gg produced carbide is comparable with the IPCC Guidelines theoretical emission factor of 1.37 Gg CO_2/Gg produced calcium 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 consumption for production of quick lime increased and consequently the SO_2 emission in 2007 was higher compared to 2006. For 2008 the reported SO_2 emission is in the same order of magnitude as in 2007.

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.

In Sweden there is one company producing carbon black. In submission 2010, CH_4 emissions are added from 1990 and onwards based on production data from the company’s environmental reports and IPCC Guidelines default EF (11 g/kg production). Due to data confidentiality, emissions are added under 2B5 (Other inorganic chemical production).

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), aluminum 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. The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.13.

Table 4.13. Summary of source category description, CRF 2C.

CRF	Gas	Key Category Assessment 2008			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2C	CO_2	x	x		CS, D, T2	CS, PS	Yes
	CH_4				CS	CS	No, see Annex 5
	N_2O				NA	NA	NA
	PFCs		x		T2	CS	Yes
	SF_6				D	D	Yes

D Default. CS Country Specific. T2 Tier 2. PS Plant-specific.

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 and onwards, 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 ALUMINUM PRODUCTION, CRF 2C3

There is one facility that produces primary aluminum in Sweden. The facility consists of two plants. One of the plants includes 56 closed pre-bake ovens (CWPB), each of 150 kA. The other plant consisted until the beginning of 2008 of three pre-bake ovens and 259 open ovens with Söderberg anodes (VSS) ,which are produced in an electrode pulp factory at the facility. During 2008, 98 of the Söderberg ovens have been rebuilt to pre-bake ovens and in December 2008 the remaining Söderberg ovens were shut down.

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

Process emissions arising from reducing agents in the primary steel works and secondary iron and steel works are reported in CRF 2C1. As the plants also generate emissions from fuel combustion (CRF 1A1c and CRF 1A2a) and fugitive emissions (CRF 1B1c), the text in this section is closely connected to the text in the corresponding section in the energy chapter.

In the Swedish inventory, emissions from primary iron and steel production and secondary steel production are reported separately and fed into the CRF Reporter under 2C1.2 Pig iron and 2C1.1 Steel, respectively. This enables process emissions from the two integrated iron and steel production plants in Sweden to be reported together (2C1.2 Pig iron), and thus not introducing further sources of uncertainty due to additional data handling.

4.4.2.1.1 Secondary steel production, CRF 2C1.1

The reported CO_2 emissions include emissions from reducing agents such as coke, coal and electrodes in electric arc furnaces in secondary steel plants. These emissions are not primarily a result of combustion, but are necessary for the process and should hence be reported in CRF 2C1. Reported CO_2 emissions also include emissions from the use of limestone and dolomite in secondary steel industry.

In submissions prior to submission 2010, the reported CO_2 emissions in CRF 2C1.1 included data from nine plants in 1990-2003 and eight plants from 2004, since one plant was shut down in 2004. In submission 2010 another two secondary steel industries have been included in the reported CO_2 time series. Other plants with non-CO_2 emissions reported 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, from the facilities environmental reports and through contacts with the companies.

Data in the ETS also includes information on other sources for process-related CO_2 emissions as well as information concerning carbon bound in products, slag,

etc. Prior to submission 2010, these emissions were not included for all facilities. For those, estimates of missing CO_2 emissions are performed using ETS data for 2005 – 2008 and production data for years before 2005. All CO_2 emissions presented for the facilities in ETS 2005 – 2008 are included in 2C1.1 in submission 2010.

Reported CO_2 emissions in submission 2010 are for all facilities except the one which closed down in 2004 based on data in the ETS, and reported CO_2 emissions can therefore be classified to follow the Good Practice Guidance method Tier 2. According to the ETS guidelines, reported emissions shall be based on all carbon input to and carbon output from the process. For the remaining facility plant specific methods are applied.

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.

The revision of the CO_2 time series in CRF 2C1.1 results in a yearly increase of reported emissions between 4 and 11%, when compared to submission 2009. The CO_2 emission in 2008 was around 7% lower compared to 2007.

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 2C1.1. 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 Primary iron and steel production, CRF 2C1.2

In Sweden there are three producers of primary iron and steel, i.e. the basis of their production is iron ore pellets. Two plants produce pig iron and steel, and one plant iron sponge and iron powder.

4.4.2.1.2.1 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 by-products for all years. The emissions are as reported by the plant but are verified by collecting and comparing the carbon contents in the amounts of coke, anthracite and out-put material. CO_2 emissions from natural gas used for production of reduction gas used in the process are considered to be process-related and are in submission 2010 reported in 2C1.2. The remaining amounts of natural gas used by the facility are considered as energy-related and the corresponding emissions are reported in the Energy sector (CRF 1A2a). 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 2C1.2. Activity data reported is produced amount of direct-reduced iron (iron sponge).

4.4.2.1.2.2 Production of primary pig iron and steel

The other two plants reported in this sector are primary iron and steel producing plants as part of integrated 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 the associated emissions are to be reported as industrial processes from iron and steel production in CRF 2C1, according to the Revised 1996 IPCC Guidelines and Good Practice Guidance.
In previous submissions, the emissions of greenhouse gases were estimated mainly based on information on consumed amounts of energy gases (coke oven gas, blast furnace gas and LD-gas) from Statistics Sweden, but also on information reported by the plants in their environmental reports. The recommended Tier 2 method, according to the IPCC Guidelines, is however to base the calculations of CO_2 emissions on carbon mass-balances in order to reduce the risk of double counting or omitting CO_2 emissions. As a response to recommendations from UNFCCC expert review teams, in submission 2010, all emissions from the two plants are reviewed and revised.

The carbon contents of external input materials such as coking coal, coke, injection coal, limestone, etc., are balanced against final output materials; coke[86], pig iron[86], steel, tar, sludge, slag, etc. The remaining carbon contents are accounted for as CO_2 emissions:

$$CO_2\ emissions_{Total\ CRF\ 1\ and\ 2} = \left[\sum_i \left(MI_i * C_i \right) - \sum_p \left(MO_p * C_p \right) \right] * 44/12$$

where,

MI_i = External carbon material input *i* fed into any part of the integrated processes (t).
MO_p = Final carbon material output *p* (t).
C_x = Carbon content of material input or output *x* (t C/t material *x*).

Figure 4.7 gives an overview of the input and output materials, the carbon flows between the different processes (plant stations), and the CO_2-emitting sources.

In the coke ovens (battery), coking coal is turned into coke through dry distillation. During the process, coke oven gas (COG) and by-products are formed. The coke oven gas is purified through several procedures and used as fuel in other plant stations, but smaller amounts are also flared. Produced amounts of coke are fed into the blast furnace together with injection coal to act as reduction agent when pig iron is produced from iron ore pellets. Limestone is added to extract slag and other by-products from the pig iron. Besides pig iron and by-products, blast furnace gas (BFG) is produced in the process. The main use for the blast furnace gas is to heat up the cowpers (and in one plant used in the coke oven), but some excess gas is released through flaring.

[86] If put in stock or sold externally

In the steelworks, pig iron is transformed into various qualities of steel depending on the demand. Dolomite, pig iron, carbide, etc., are added depending on the different metallurgic processes. LD-gas is produced in the steel converter and used as fuel or flared. Some steel is treated in the rolling mills where LGP and different oils are used as fuel.

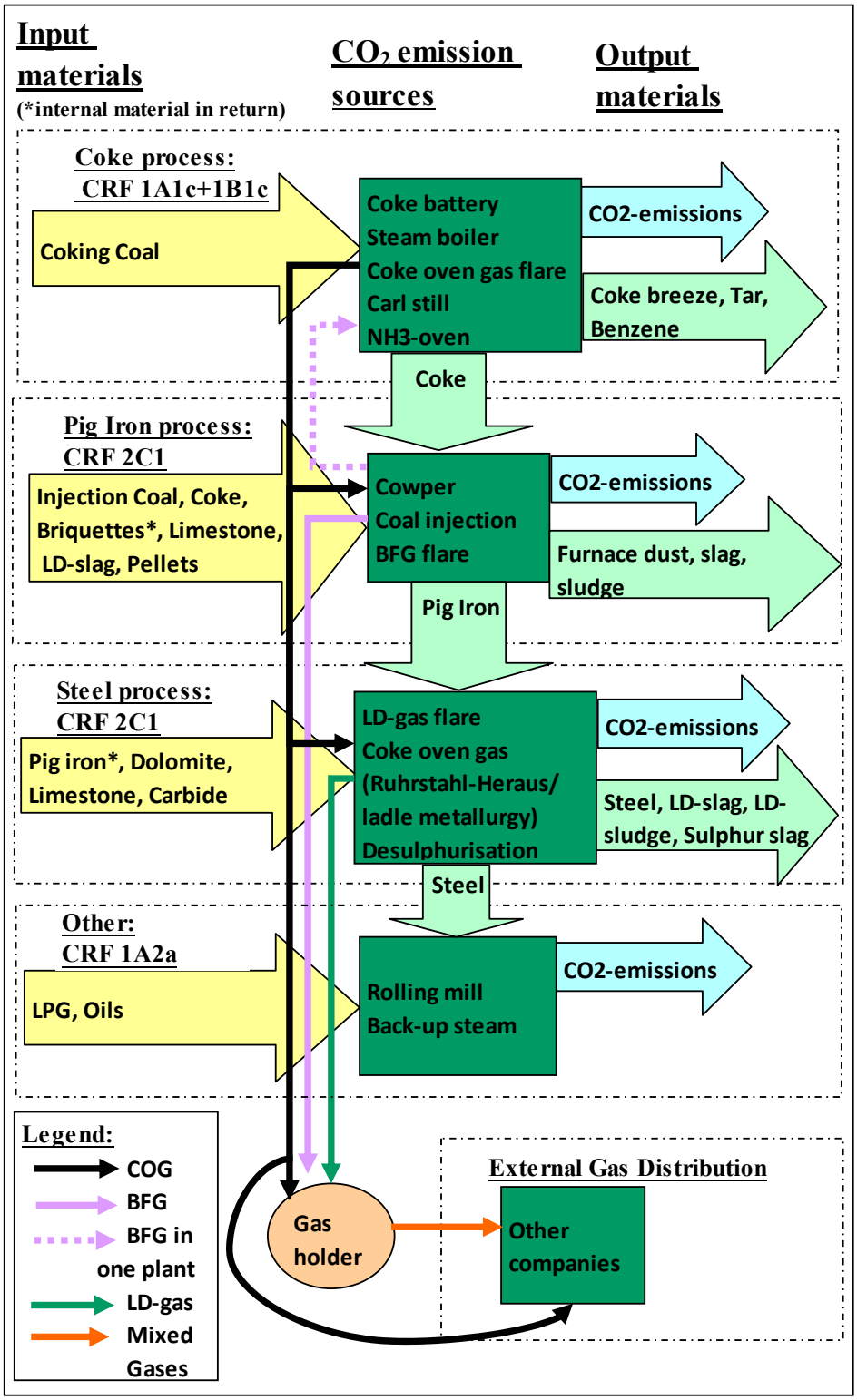


Figure 4.7. Carbon flow chart of integrated primary iron and steel plants in Sweden

Considerable amounts of energy gases (coke oven gas, blast furnace gas and LD-gas) from the different processes are collected in a gas holder and sold to external consumers.

During the whole process from raw material to final product, emissions of CO_2 are released. The allocation of both plants total CO_2 emissions on plant stations and consequently CRF sub-sector is based on detailed mass-balances (

Table 4.14). For comparison, the allocation used in submission 2009 is also provided in the table.

Table 4.14. CO_2 emission allocation 2008 in integrated primary iron and steel production.

CRF	CRF sub 2009	Plant station	CO_2 emissions 2008 (Gg)
1A1c	1A1c	Coke Oven	314
1A2a	1A1a, 1A2a	Combustion in Rolling Mills + Power and Heat Production	1201
1B1c	1B1c	Flare in Coke Oven (COG)	4
2C1.2	1B1c, 2C1.2	Blast Furnace + Steelworks (including Flaring of BFG and LD-gas)	2069
Total			3588

According to the IPCC Guidelines, emissions of CO_2 from the use of limestone should be reported separately as process emissions from limestone and dolomite use in CRF 2A3. Since the Centralized review from submission 2004 the ERT has repeatedly recommended Sweden to follow the guidelines. As the CO_2 emissions from limestone and dolomite are small (<1 per cent of the plants total CO_2 emissions) it is not considered to be good practice to spend resources obtaining underlying data to separate these emissions. Hence Sweden choose to include these CO_2 emissions in CRF 2C1.2.

Activity data (amount of pig iron produced) on integrated pig iron and steel production along with CO_2 emissions and consumed amounts of energy gases (coke oven gas, blast furnace gas and LD-gas) and other fuels, are reported by the plants in the environmental reports since 2003. Mass-carbon balances and associated CO_2 emissions are also reported to the EU-ETS since 2005. For some years, CO_2 emissions to the EU-ETS did not include all plant stations (rolling mills), and additional information from the plants was obtained in order to ensure that no omissions occurred. Since 2008 CO_2 emissions reported by the plants in their environmental reports and to the EU ETS are the same. From 2003 information on activity data and emissions for all plants (CRF 1A1c, 1A2a, 1B1c and 2C1.2) are taken from the environmental reports. Amounts of pig iron produced 1990-2002 were obtained directly from both plants, together with total CO_2 emissions 1990-2002 for one of the plants. For the other plant, CO_2 emissions 1990-2002 are calculated using its pig iron production 1990-2002 and an average CO_2 IEF 2003-2007. Allocation of CO_2 emissions on different sub-categories (CRF 1A1c, 1A2a, 1B1c and 2C1.2) are based on the plant specific average distributions 2003-2007.

Consumed amounts of different energy gases and other fuels 1990-2002 are derived by applying the Good Practice Guidance surrogate method using the average values 2003-2007 and the CO_2 emissions as the surrogate parameter. Activity data reported in CRF Reporter in CRF 2C1.2 is produced amount of primary pig iron.

Emissions of CH_4, N_2O, NMVOC and CO are not reported in the plants' environmental reports. In the Swedish inventory these emissions are instead estimated from consumed amounts (including flared amounts) of energy gases multiplied by country-specific emission factors (see Appendix 20). Emissions of CH_4, NMVOC and CO from coke oven gas, blast furnace gas and LD-gas in the blast furnace and steel converter are allocated to CRF 2C1.2, whereas emissions of N_2O are assumed to be not applicable (NA) in this sub-category, in accordance with the IPCC Guidelines. Emissions of NO_x and SO_2 are based on detailed plant information from the environmental reports.

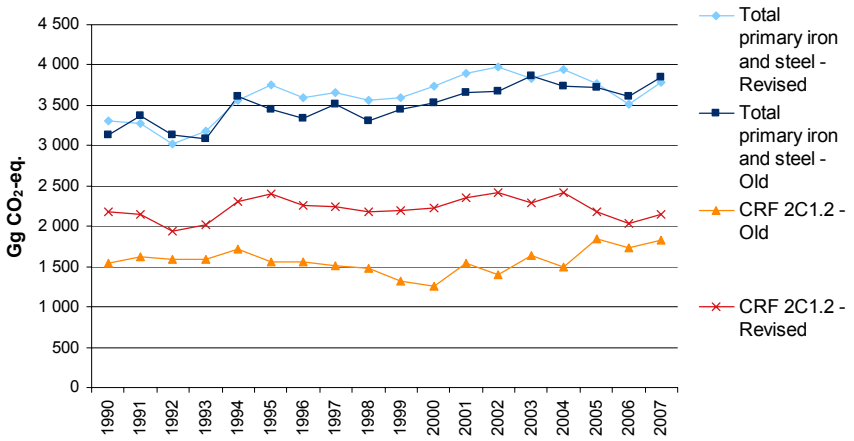
There is an obvious decrease in CO_2 IEF since 1990 (Table 4.15) for primary pig iron and steel production, from 0.80 Gg CO_2/kt iron in 1990 to 0.58 Gg CO_2/kt iron in 2008. This is due to the undertaking of several energy efficiency measures, e.g. increased temperature in the blast furnaces, increased recycling of energy gases and by-products,[87] leading to decoupling between CO_2 emissions and primary pig iron production in Sweden.

Table 4.15. CO_2 implied emission factors (IEF) for primary pig iron production

Year	CO_2 IEF (Gg CO_2/kt primary pig iron produced)
1990	0.80
1991	0.77
1992	0.71
1993	0.71
1994	0.76
1995	0.78
1996	0.72
1997	0.73
1998	0.69
1999	0.68
2000	0.70
2001	0.65
2002	0.65
2003	0.61
2004	0.62
2005	0.58
2006	0.57
2007	0.56
2008	0.58

[87] ENET-Steel, 2007.

The recalculations of greenhouse gas emissions from the two integrated primary iron and steel production plants in Sweden 1990-2007 had a minor impact on their total emissions, but due to reallocation of emissions between categories, emissions from processes in CRF 2C1.2 increased all years. Emissions in 2C1.2 are about 640 Gg CO_2 equivalents higher in 1990 and about 330 Gg CO_2 equivalents higher in 2007 in submission 2010 compared to submission 2009. The overall changes for the two plants are 174 Gg CO_2 equivalents higher in 1990 and 53 Gg CO_2 equivalents lower in 2007.



4.4.2.1.3 Iron ore mining, dressing, sintering and iron ore pellets production, CRF 2C1.3

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 2C1.3 are CO_2 from the use of organic binder, 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[88]. No data concerning the CO emissions is available and the time series 1990 – 2008 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 - 2008. Organic binder has been used in one of the facilities starting at 2002 and data on used amounts and emission factors for CO_2 have been supplied by the company.

4.4.2.1.4 CO_2 emissions reported in Coke, CRF 2C1.4

Emissions of CO_2 from the production of coke are reported in CRF 1A1c and emissions of CO_2 from the use of coke in blast furnaces are reported in CRF 2C1.2 in line with the IPCC Guidelines.

[88] Wieland, M.S. 2004.

4.4.2.1.5 CO_2 emissions reported in Other, CRF 2C1.5

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[89]), 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:

- 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 electrodes90.

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, there are differences in the plant specific data and emissions based on Swedish default EF and emissions estimated with IPCC Guidelines default values. The differences are due to the fact that - according to the company - the carbon content of the coke may vary from one year to another.
The total amount of carbon in the produced ferroalloys is presented in Table 4.17, 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.
CH_4 emissions from production of FeSi alloys are reported from submission 2010 and calculated based on FeSi alloy production (Tier 2[91])

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 proc-

[89] http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch2wb2.pdf

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

[91] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Table 4.8

ess. 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.

Table 4.16. 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, Gg CO_2	Swedish values, Gg CO_2	IPCC default values, Gg CO_2
1990	243	244	263
1991	244	248	268
1992	245	258	278
1993	232	249	269
1994	248	266	286
1995	265	274	295
1996	272	279	301
1997	203	213	229
1998	240	250	270
1999	239	238	257
2000	240	266	287
2001	214	225	242
2002	237	237	255
2003	197	198	214
2004	256	260	280
2005	225	214	231
2006	220	209	225
2007	220	188	203
2008	194	164	177

Table 4.17. 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	-08
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	7.4

4.4.2.3 ALUMINUM PRODUCTION, CRF 2C3

Primary aluminum 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 aluminum 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[92]. NMVOC emissions are calculated from reported emissions of tar, assuming that 70 % of the tar is emitted as NMVOC[92]. CO emissions were for the first time reported in submission 2008 and

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

are for 2002 - 2008 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, 2007 and 2008, SO_2 emissions data are based on environmental reports published by the company.
Emission data for CO_2 from the production of primary aluminum 2002 - 2008 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 (0.234 – 0.282).

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.

Due to the fact that the carbon bound in soot is not included in the reported CO_2 emissions in 2C3, the IEF (implied emission factor) values in the Swedish inventory (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 Gg CO_2/Gg produced Al) (Table 4.18).

The two different processes for aluminum 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.

Table 4.18. Implied emission factor for CO_2 for the production of aluminum.

Year	Aluminum production Gg	Emissions of CO_2 Gg	IEF Gg CO_2/Gg Al
1990	96	133	1.4
1991	97	133	1.4
1992	77	100	1.3
1993	82	121	1.5
1994	84	120	1.4
1995	94	129	1.4
1996	98	137	1.4
1997	98	136	1.4
1998	96	139	1.4
1999	99	140	1.4
2000	101	145	1.4
2001	102	147	1.4
2002	101	146	1.5
2003	101	146	1.4
2004	101	141	1.4
2005	103	144	1.4
2006	102	142	1.4
2007	100	140	1.4
2008	82	114	1.4

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 4.19.

As can be seen in Table 4.19 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. For 2008 it can be seen that the IEF for C_2F_6 as well as for CF_4 from the pre-bake ovens are higher compared to 2007. According to the company the reason for this is due to initial start up problems with the new pre-bake ovens.

Table 4.19. 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
2008	23.9	57.8	1.83	31.74	0.0058	0.0203	0.0454	0.4607

4.4.2.4 SF_6 IN ALUMINUM AND MAGNESIUM FOUNDRIES, CRF 2C4

The total amount of SF_6 used annually in the magnesium foundries (CRF 2C4.2) is reported as emissions, according to the IPCC Guidelines and Good Practice Guidance. Data is obtained from companies using SF_6. For 2008, 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.

In Sweden, no SF_6 is used in aluminum foundries (CRF 2C4.1) as far as known, and thus reported as not occurring (NO).

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.

4.5 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). The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.20.

Table 4.20. Summary of source category description, CRF 2D.

CRF	Gas	Key Category Assessment 2008			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2D	CO_2				NA	NA	NA
	CH_4				CS	CS	Yes
	N_2O				CS	CS	Yes

CS Country Specific.

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. One of these facilities shut down during 2008. 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 - 2008.

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 production within this industry are allocated to CRF 2A2. 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[93] together with figures on import and export[94]. NMVOC emissions from beer production are based on the Swedish annual total production of beer[95] [96]. 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 4.21 were used. Emissions of CO_2 are not estimated but are believed to be minor.

[93] Systembolaget. Försäljningsstatistik. http://www.systembolaget.se/

[94] Statistics Sweden. Data from the Industrial production database. http://www.scb.se/

[95] Carlsberg Sweden. http://www.carlsberg.se

[96] Bryggeriföreningen. http://sverigesbryggerier.se

Table 4.21. 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	97
Beer	0.35	kg/1000 litres	97
Liquors	0.6	kg/1000 litres	EF based on emission and activity data from one producer, 2001
Bread (sponge dough)	8	kg/Mg	97
Bread (white)	4.5	kg/Mg	97
Bread (whole meal and light rye)	3	kg/Mg	97
Bread (dark rye)	0	kg/Mg	97
Cakes	0.1	kg/Mg	97
Biscuits	0.1	kg/Mg	97
Breakfast cereals	0.1	kg/Mg	97
Sugar	10	kg/Mg	97
Yeast	18	kg/Mg	98
Margarine and solid cooking fats	10	kg/Mg	97
Coffee roasting	0.55	kg/Mg	97
Animal feed	0.1	kg/Mg	97

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.

[97] EMEP/CORINAIR Emission Inventory Guidebook: http://reports.eea.eu.int/EMEPCORINAIR4/en

[98] 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.

4.7.2 Quality control

All quality procedures according to the Swedish QA/QC plan[99] (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 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 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 ensure 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. The summary of the latest

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

key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.22.

Table 4.22. Summary of source category description, CRF 2F.

CRF	Gas	Key Category Assessment 2008			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2F	HFCs	x	x		CS, T2	CS, D, PS	Yes
	PFCs				CS	CS, D	Yes
	SF_6				CS, D	CR, D, PS	Yes

D Default. CS Country Specific. T2 Tier 2. PS Plant-specific. CR CORINAIR.

An overview of actual reported emissions in CRF code 2F are shown in Table 4.23.

Table 4.23. 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	2008
F1	Refrigeration and air conditioning equipment	2.5	5.1	7.3	27	70	120	183	228	286	366	427	476	533	586	633	683	732	786	832
F2	Foam blowing	NA	NA	NA	NA	NA	NA	12	77	84	99	111	110	104	97	107	87	74	54	53
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	6.1	6.0	7.6
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	26
F5	Solvents	NE	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	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	NO
F8	Electrical equip-ment	81	81	81	70	70	95	71	106	54	55	32	43	26	22	28	28	22	29	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	7.5

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[100]. 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 4.24, the emission factors and activity data used in the calculations of actual emissions are presented. A model is used for calculating the actual emis-

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

sions. 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.

Table 4.24. 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 the last inventory year 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 covered 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 Good Practice Guidance.

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 4.25, 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 Good Practice Guidance are presented as comparison. The 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 IPCC Guidelines, which present separate leakage rates for HFC-134a and HFC-152.

Table 4.25. 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		Good Practice Guidance 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 Good Practice Guidance Tier 2 method are presented in Table 4.26. The calculations were made in a special project[101] where different calculation methods were compared (national method compared to Good Practice Guidance). The Good Practice Guidance Tier 2 default method results in a lower rate of emissions when calculated as emitted tonnes of HFC (Figure 4.8 and Table 4.27). 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 Good Practice Guidance method, due to the differing GWP-values of HFC-134a (1300) and HFC-152a (140).

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

Table 4.26. 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		Good Practice Guidance		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.

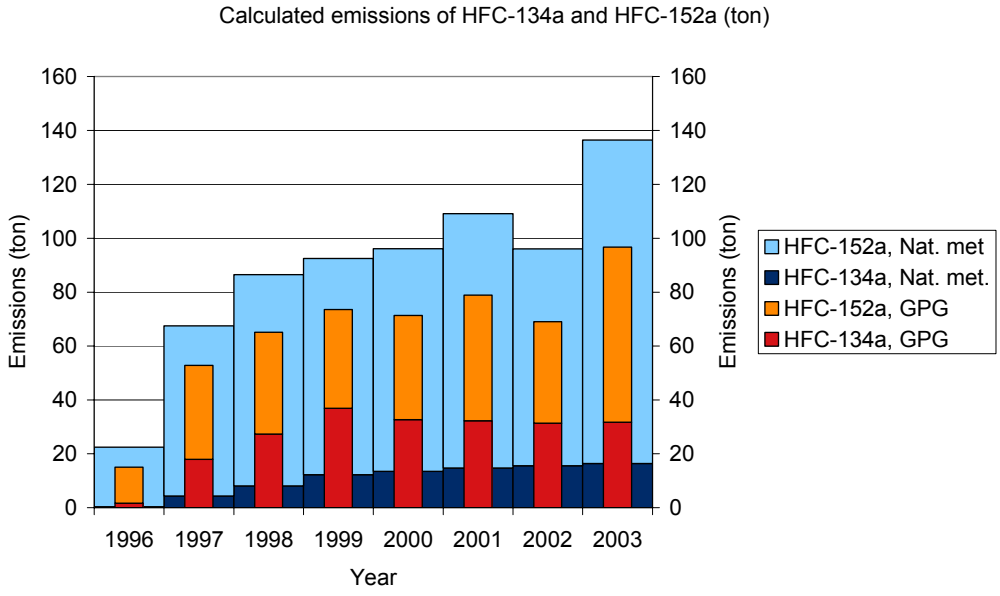


Figure 4.8. Estimated emissions of individual HFC-species (ton) by the national method and the Good Practice Guidance (GPG) Tier 2 method, 1996 - 2003.

Table 4.27. 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 4.8 and Table 4.27).

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 to the 2006 IPCC 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 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 4.28), where emissions in 1995 and 1997 peak 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[102] (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).

[102] Swedenergy. Matz Tapper. Personal communication. 2005.

Table 4.28. 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	0.74	148.7	0.9
2007	0.41	0.81	162.9	1.2
2008	0.32	0.85	170.0	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 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.[103] According to the results from a study performed in early 2004[104] 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 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,[105] and was updated during 2005[106] 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.

4.9.3.1 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 2007 are updated. This results in revised data on potential emissions for 2007. 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 2007 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

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[103] Weholt, Ø. 1999. Materialstrømsanalyse av SF6. Beregning av potensielt og faktisk utslipp over tid

[104] Kindbom, K. and Skårman, T. 2004. Nya scenarier för fluorerade växthusgaser. U952, Swedish EPA.

[105] 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.

[106] Kindbom, K. 2005. Revision of Methodology and Estimated Emissions of Fluorinated Greenhouse Gases in Sweden.

allocated to 2.F.1 (HFC 23, HFC 32, HFC 125, HFC 134a, HFC 143a and HFC 152a) and 2.F.8 (SF_6).

4.9.4 QA/QC

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.

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.

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 and onwards, CH_4 and N_2O are reported in CRF 2D1.

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 20). 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.

4.11 Source-specific recalculations

In this section explanations and justifications for recalculations in the industrial processes sector are made, as well as a description of significant implications for the reported emission levels. Table 4.29 shows the recalculation differences for the GHG emissions by sub-sector as well as for the total level in the sector reported in submission 2010 compared to data reported in submission 2009.

Table 4.29. Recalculations of GHG emissions between submission 2010 and submission 2009 in the industrial processes sector.

Recalculation differences, submission 2010/2009 (Gg CO_2 eq.)						
CRF	**2A**	**2B**	**2C**	**2F**	**Total CRF 2**	**% CRF 2**
1990	-198	7	663		472	8.16%
1991	-151	6	552		407	7.15%
1992	-140	6	384		250	4.65%
1993	-149	7	452		310	5.67%
1994	-152	8	607	1	463	8.06%
1995	-205	8	870	-1	672	11.38%
1996	-184	8	725	-2	547	9.40%
1997	-125	9	749	-2	632	11.05%
1998	-62	9	727	-1	673	11.48%
1999	-18	8	896	-1	886	15.64%
2000	-108	9	988	0	888	15.20%
2001	-123	9	836	0	723	12.03%
2002	-90	8	1 041	1	961	16.23%
2003	-110	9	678	2	578	9.59%
2004	-81	9	975	4	908	14.89%
2005	-91	8	394	6	317	4.80%
2006	-97	9	350	10	271	4.06%
2007	-73	8	397	16	348	5.32%

0 equals value less than 0.5.

CRF 2A1

- Emissions of NO_X have been reallocated from the energy sector (1A2f). Time series (1990-2008) for NO_X emissions have been added. Time series for SO_2 have been revised for the period 1990-2000 due to new information from the company.

CRF 2A2

- In response to ERT recommendations, the reported CO_2 emissions and activity data is revised for the whole time series. This also affects reported emissions of SO_2. In earlier submissions there was a double-counting of lime used within the pulp and paper industry. New and more detailed data are used in the current submission. Reported CO_2 emission for 1990 in submission 2010 is around 200 Gg lower than in submission 2009. Corresponding figure for 2007 is 84 Gg.

CRF 2A3

- After recommendations from the EC Internal review, CO_2 emissions originating from use of limestone and dolomite within the glass industry have

been reallocated from 2A3 to 2A7.1, and reported together with all other process-related CO_2 emissions from glass production. In submission 2010 another three facilities using limestone/dolomite for flue gas desulphurisation is included. Reported CO_2 emission in submission 2010 is around 20 Gg lower compared to reported emission in submission 2009.

CRF 2A4

- Due to recommendations from the EC Internal review, CO_2 emissions from the use of soda ash in the glass industry are reallocated from 2A4.2 to 2A7.1 in submission 2010. Reported CO_2 emission in submission 2010 is around 20 Gg lower compared to reported emission in submission 2009.

CRF 2A7

- After recommendations from the EC Internal review, CO_2 emissions from use of limestone, dolomite and ash soda in glass production, previously reported in 2A3 and 2A4.2, are reported in 2A7.1 in submission 2010. Reported CO_2 emissions in 2A7.1 is for 1990 39 Gg and for 2008 61 Gg.
- From submission 2010, all CO_2 emissions originating from clay, limestone and other carbon containing material in the production of roofing tiles, bricks and ceramics are reported in 2A7. Reported CO_2 emissions in submission 2010 are for the whole time series around 2 Gg higher in comparison to submission 2009.

CRF 2B5

- In response to ERT recommendations, CH_4 emissions from carbon black production from 1990 and onwards is added to 2B5 Other inorganic chemical production for the first time in the 2010 submission, resulting in 8 Gg CO_2 eq. higher emissions.

CRF 2C1

- CO_2 emission time series 1990 – 2007 has been updated for 2C1.1. CO_2 emissions from two more facilities are included in the inventory. CO_2 from carbon containing raw material, not earlier included in the inventory has been added for five facilities. The updated CO_2 time series are between 6 and 19 Gg higher in submission 2010 compared to submission 2009.
- Minor adjustments in 2C1.1 of reported NO_X for 2004 – 2006, NMVOC 2001 – 2003 and SO_2 for 2000 – 2007.
- In response to the ERT recommendations, emissions from integrated primary iron and steel production are reviewed, leading to recalculations for all years. Emissions in 2C1.2 are about 640 Gg CO_2 eq. higher in 1990 and about 330 Gg CO_2 eq. higher in 2007 in submission 2010 than in submission 2009. Note that most of the changes in emissions are due to reallocations from the energy sector. The overall changes for the two plants are 175 Gg CO_2 emissions higher in 1990 and 52 Gg CO_2 emissions lower in 2007.
- In submission 2010 CO_2 emissions from natural gas for reduction gas production within primary iron and steel industry are included in 2C1.2.

CRF 2C2

- CH_4 emissions from production of FeSi alloys are reported in submission 2010. The calculations are based on FeSi alloy production and default emission factors according to the 2006 IPCC Guidelines.

CRF 2C3

- Emissions of CO_2 are updated for 2001 due to new data on used amounts of carbon containing raw material.

CRF 2C5

- Emissions of CO_2 from coke used as reduction agent are for one facility re-allocated from 1A2b to 2C5. Emissions of CO_2 from use of coal and coke are for another facilitiy revised 2004-2007 due to incorrect data handling. Emissions of CO_2 in the 2010 submission are about 15 - 40 Gg higher compared to submission 2009.

CRF 2D1

- Minor corrections are made of reported NO_X for 2002 – 2003 and SO_2 for 2004 – 2007.

CRF 2D2

- Activity data, thus affecting reported NMVOC emissions, have been up-dated for:
    - Wine: Sold amount 2007, Import 2005-2007, Export 2007
    - Beer: Sold amount 2006-2008
    - Liquors: Produced amount 2002-2004, 2007
    - Bread: Produced amount 2007
    - Cakes and biscuits: Produced amounts 2007
    - Breakfast cereals: Produced amounts 2007
    - Sugar: Produced amounts 2007
    - Margarine and solid cooking fats: Produced amounts 2007
    - Animal feed: Produced amounts for 2007
    - Coffee roasting: Produced amounts 2007
    - Yeast: Produced amounts 2007

CRF 2F

- Emissions of HFC 32, HFC 125, HFC 134a and HFC 143a from heat pumps are recalculated 1994-2007 due to new detailed information on the types of heat pumps in Sweden 1990-2007 and updated number of heat pumps installed in Sweden from 2000 and onwards from the Swedish trade organisation (Svep). Emissions are 6.5 Gg CO_2 eq. higher in 2007 in the 2010 submission than the 2009 submission.
- Emissions deriving from the consumption of Halocarbons and SF_6 in 2007 are updated due to new information from the Products register hosted by the Swedish Chemicals Agency. Recalculated emissions are 9.2 Gg CO_2 eq. higher for 2F.

4.12 Planned improvements

All relevant data are kept under constant review.

5 Solvent and other product use (CRF sector 3)

5.1 Overview of sector

This chapter describes emissions from solvents and other product use. Use of solvents and products containing solvents result in emissions of non-methane volatile organic compounds (NMVOC), which is regarded as an indirect greenhouse gas as it over a period of time will oxidise to CO_2 when emitted to the atmosphere.

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 3D5). Other use of N_2O (CRF 3D4) includes evaporative emissions of N_2O arising from other types of product use. This includes N_2O emissions from anaesthesia and aerosol cans.

Emissions of total greenhouse gases from the solvent and other product use sector (CRF 3) have decreased by 15 % from 332 Gg CO_2 equivalents in 1990 to 284 Gg CO_2 equivalents in 2008 (see Figure 5.1). The decline can largely be explained by a reduction in the use of solvents in CRF 3A (paint application) due to a shift to water-based paints, which contain a smaller fraction of solvents compared to solvent-based paints.

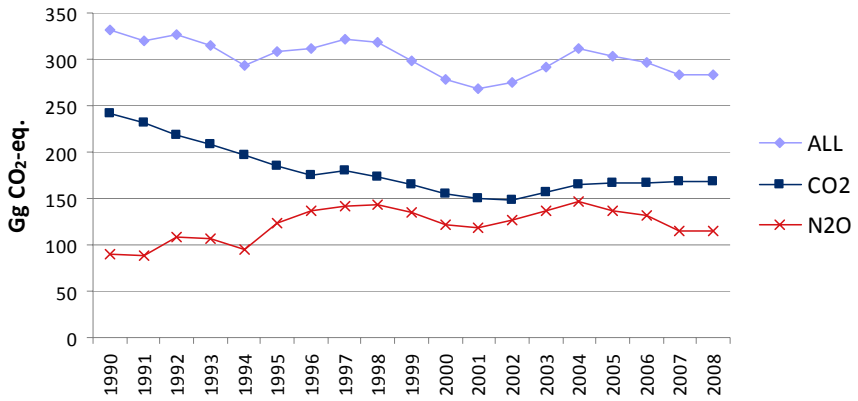

Figure 5.1. Total emissions of all greenhouse gases calculated as CO_2 equivalents from CRF 3 Solvent and Other product use.

The major sources of CO_2 emission from solvents in CRF sector 3 are CRF 3D5 (other solvent use) and CRF 3A (paint application) (see Figure 5.2). CO_2 emissions in CRF 3D5 have decreased by 9 % from 138 Gg CO_2 equivalents in 1990 to 126 Gg CO_2 equivalents in 2008. CO_2 emissions in CRF 3A have decreased by 55 % from 94 Gg CO_2 equivalents in 1990 to 42 Gg CO_2 equivalents in 2008.

In Figure 5.2 it can be seen that the use of N_2O (CRF 3D4) has increased with 27 % from 90 Gg CO_2 equivalents in 1990 to 115 Gg CO_2 equivalents in 2008.

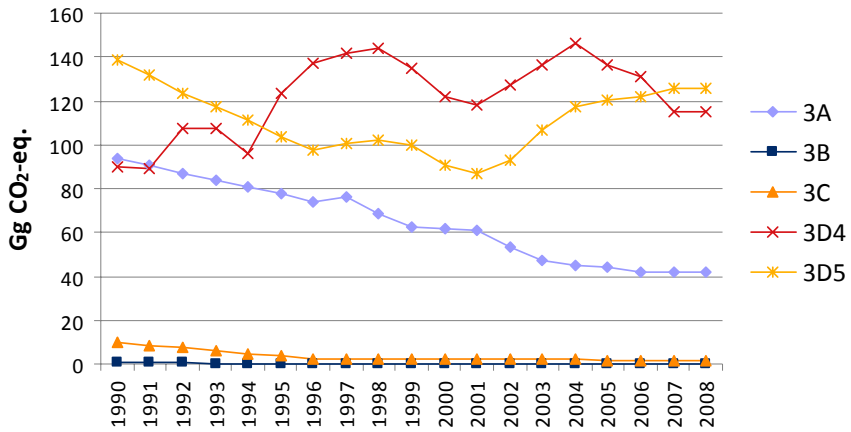

Figure 5.2. Total emissions of all greenhouse gases calculated as CO_2 equivalents from the different Solvent and Other product use sub-sectors.

3A Paint application. 3B Degreasing and dry-cleaning. 3C Chemical products, manufacture and processing. 3D4 Other use of N_2O. 3D5 Other solvent use.

5.2 Source category description

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), are presented in Table 5.1.

Table 5.1. Summary of source category description, CRF 3.

CRF	Gas	Key Category Assessment 2008			Method	EF	All sources estimated
		Level	Trend	Qualitative			
3A	CO_2				CS	CS	Yes
3B	CO_2				CS	CS	Yes
3C	CO_2				CS	CS	Yes
3D	CO_2				CS	CS	Yes
3D	N_2O				CS	CS	Yes

CS Country Specific.

5.2.1 Paint application, CRF 3A

Includes paints sold for “industrial use” and for “consumer and other professional use”.

5.2.2 Degreasing and Dry cleaning, CRF 3B

Includes solvents sold to the laundry and dry cleaning industry. Degreasing is included in CRF 3D.

5.2.3 Chemical products, Manufacture and Processing, CFR 3C

Includes solvents sold for car manufacturing, paint industry and rubber industry.

5.2.4 Other, CRF 3D

All data concerning solvents, NMVOC and CO_2, are reported in CRF 3D5. CRF 3D5 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. In CRF 3D4 sold amounts and use of N_2O are reported. Due to confidentiality, data for 3D1 - Use of N_2O for Anaesthesia and 3D3 – N_2O from Aerosol cans cannot be reported separately.

5.3 Methodological issues

In 2005 a new method for estimating emissions from Solvent and Other Product Use was developed by SMED in cooperation with the Swedish Chemicals Agency[107]. The method is more complete, accurate and transparent, and data can easily be updated on a yearly basis. The Swedish method is consumption-based with a product-related approach. With the new method emissions are calculated with activity data from the Products Register hosted by the Swedish Chemicals Agency, and country specific emissions factors.

The Products Register is a register over chemical products imported to or manufactured in Sweden. Official statistics from the Products Register is only available with a two years delay.

5.3.1 Substance list

A list of substances defined as NMVOCs, and found in the Products Register in quantities over 100 tonnes, has been compiled. The threshold of 100 tonnes is based on the fact that substances found in the Products Register in quantities less than 100 tonnes are equivalent to 0.03 % of the total solvent sales of 400 000 tonnes. 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."[108]

The list includes 382 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 2007. 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 Swedish Chemicals Agency as 85 % of NMVOC, based on information in the Products Register. In those cases

[107] Skårman, Tina. et al., 2006, Revised Method for Estimating Emissions of NMVOC from Solvent and Other Product Use in Sweden. SMED Nr 18 2006

[108] COUNCIL DIRECTIVE 1999/13/EC of 11 March 1999 and UNECE Emission Reporting Guidelines

when the carbon content cannot be derived from the Products Register, the default value, given in the 2006 IPCC guidelines, of 60 % has been used.

5.3.2 Activity data

The sold amount of solvents and solvent based products, (production + import – export), is derived from the Products Register at the Swedish Chemicals Agency. When a company is reporting to the Products Register it should be stated, among other things, to which industrial sectors the product is sold, and the intended use of the product.

The substance list has been used to extract quantities of NMVOC and C in substances found in the Products Register. Due to confidentiality, data cannot be delivered on substance level. Consequently, data are delivered on product and industrial category level. An advantage of making a more targeted selection like this on product and industry category, is that the risk that chemicals are double-reported in the Products Register is minimized. Hence it is highly unlikely that the same chemical will appear in a particular product that is sold twice to the same industrial sector.

Data extractions have been made for each year from 1995 to 2007, since reliable activity data, for this purpose, can only be obtained from 1995. The extractions show for each year:

- The intended use of the product and the type of product (product code)
- Industry to which the product is sold (industry category)
- Quantity NMVOC
- Quantity C

The extractions from the Products Register for 1995-2007 have been used in order to compile a connection diagram with all combinations of "product codes" and "industry categories". For all combinations, decisions whether to include or exclude from reporting are based on expert judgements in order to avoid double-counting of reported emissions within other sectors. The industries that are excluded in the extractions from the Products Register are considered to be reported in CRF 1, 2 or 6. If the combination should be included, its specific CRF code has been decided. Furthermore, it has to be determined if the product is used as raw material or not. The quantities of NMVOC used as raw material in processes have been identified and treated separately from remaining quantities for each CRF code, due to that most of the solvents used as raw material will not be emitted. An Excel macro has been written in order to compile time series with quantities of NMVOC and C for each sub-code within CRF sector 3.

The sold amount of solvent is not always identical to the amount of solvent used, i.e. stock of solvents. Therefore activity data has been recalculated using a running average over three years. This leads to the need for updating of reported emissions for the latest three years in the time series in every new submission.

5.3.3 Emission factors

Country specific emission factors for solvents used as raw material and for remaining solvents were developed for each reported activity within each CRF code (see Annex 3.3). The emission factors have been based on the old emission time series 1988-2001, which were developed by SMED in 2002[109]. The old time series were mostly based on information in earlier national reports, investigations and estimations of national NMVOC emissions. These investigations were dedicated specific emission inventories focusing on NMVOC, which is why they are still to be considered as 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.

5.3.4 Emissions

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[109] and in some cases emission data for 1990 - 1994 has been interpolated.

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.

As 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) according to the Good Practice Guidance overlap method[110].

Activity data for the latest year, 2008, is not yet official and hence Sweden has chosen to report data for 2007 also for 2008. Data for 2008 will be updated in the next submission.

5.3.4.1 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, carried out

[109] Kindbom, K., Boström, C-Å., Skårman, T., Gustafsson, T. and Talonpoika, M. 2003. Estimated Emissions of NMVOC in Sweden 1988-2001.

[110] Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories http://www.ipcc-nggip.iges.or.jp/public/gp/english/7_Methodological.pdf

by SMED in 2002[111]. The emissions for 1990-1994 have been interpolated based on the information from the late 1980´s and known data for 1995.

5.3.4.2 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. After 1995 also other substances for degreasing and dry cleaning are included. Of the total amount of NMVOC used within CRF 3B these "non tetrachloretylene" substances stand for approximately 30%. As 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 solvents used within CRF 3B includes a lower carbon share compared to the solvents used in the other sub-codes within CRF 3.

5.3.4.3 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[111]. Emission data for the rubber industry is known for 1988[111] and data for 1990-1994 have been interpolated based on the information from the late 1980´s and known data for 1995.

5.3.4.4 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.

5.3.4.5 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

[111] Kindbom, K., Boström, C-Å., Skårman, T., Gustafsson, T. and Talonpoika, M. 2003. Estimated Emissions of NMVOC in Sweden 1988-2001.

Products Register at the Swedish Chemicals Agency (1992 - 2007). 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, 2008, is not yet official and hence Sweden has chosen to report data from 2007 also for 2008. Data for 2008 will be updated in the next submission.

5.4 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.

The reported time series are considered to be consistent, except for last year (2008) where data for previous year (2007) has been reported. This procedure has been raised by the ERT several times. The reason of procedure is due to the fact that activity data from the Product Register is not official at the time data is needed to be able to perform the calculations and report in a timely manner.

5.5 QA/QC and verification

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. All Tier 1 general inventory level QC procedures listed in the Good Practice Guidance Section 8 have been performed.

5.6 Source-specific recalculations

In this section explanations and justifications for recalculations in the solvent and other product use sector are made, as well as a description of significant implications for the reported emission levels. Table 5.2 shows the recalculation differences for the GHG emissions by sub-sector as well as for the total level in the sector reported in submission 2010 compared to data reported in submission 2009.

Table 5.2. Recalculations of GHG emissions between submission 2010 and submission 2009 in the Solvent and Other product use sector.

Recalculation differences, submission 2010/2009 (Gg CO_2 eq.)						
CRF	**3A**	**3B**	**3C**	**3D**	**Total CRF 3**	**% CRF 3**
2004	0			0	0	0.00%
2005	-1	0	0	3	1	0.44%
2006	0	0	0	4	3	1.05%
2007	-1	0	0	-9	-10	-3.47%

0 equals value less than 0.5.

CRF 3:

- Recalculations concerning NMVOC and CO_2 3A, 3B, 3C and 3D5 have been performed for year 2007, due to the recurring one year lag of updating of the data from the Product Register from the Swedish Chemicals Agency.
- Due to use of running average for compiling the NMVOC and CO_2 time series in 3A, 3B, 3C and 3D5, the reported emissions for 2005 - 2007 in submission 2009 are updated in submission 2010.
- 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 2004 are updated in submission 2010.
- Recalculations concerning sold amounts and use of N_2O have been performed for 2007, due to the recurring one year lag of updating of the data from the Product Register from the Swedish Chemicals Agency.

5.7 Coming improvements

No major improvements are planned for the next submission.

6 Agriculture (CRF sector 4)

6.1 Overview of sector

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.[112] 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 16 % in 2008.[113]

The total greenhouse gas (GHG) emissions from the Swedish agriculture have decreased by 11 % since 1990, from 9,515 Gg Gg CO_2 equivalents to 8,470 Gg CO_2 equivalents (Figure 6.1). In Figure 6.2 it can be seen that the largest emissions in this sector are methane (CH_4) from enteric fermentation (CRF 4A) and nitrous oxide (N_2O) from nitrogen circulation in agricultural land (CRF 4D). Carbon dioxide (CO_2) emissions from agricultural land are reported in sector 5- LULUCF in accordance with the IPCC Guidelines.

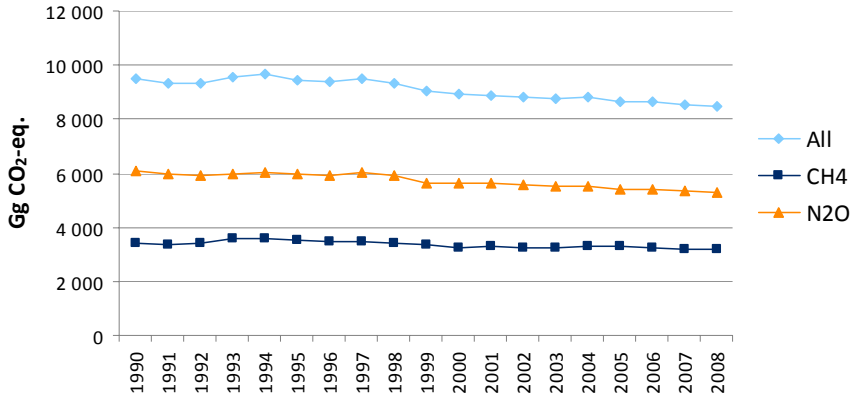

Figure 6.1. Total emissions of all greenhouse gases calculated as CO_2 equivalents from CRF 4 Agriculture.

[112] Ministry of the Environment, 2001.

[113] Swedish Board of Agriculture, www.sjv.se., http://miljomal.nu/

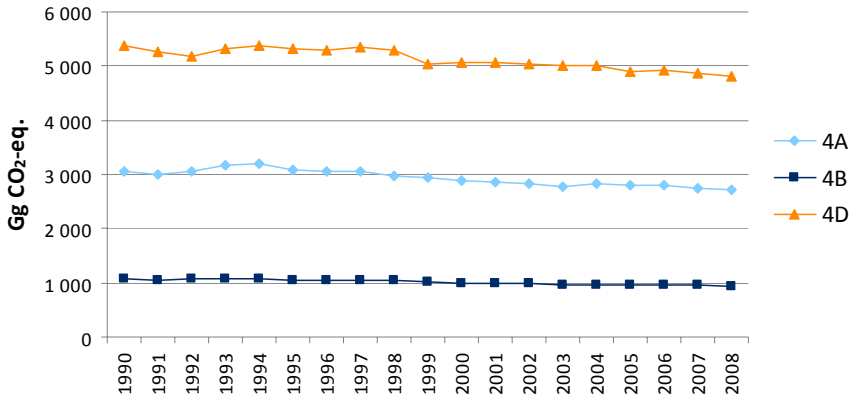

Figure 6.2. Total emissions of all greenhouse gases calculated as CO_2 equivalents from the different agricultural sub-sectors. There are no emissions from 4.C or 4.E-G.
4A Enteric fermentation. 4B Manure management. 4D Agricultural soils.

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. From the total emission of CH_4 about 74 % derives from enteric fermentation from cattle. The total numbers of livestock in Sweden in 1990-2008 are presented in Figure 6.3.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), are presented in Table 6.1.

Table 6.1. Summary of source category description, CRF 4. There are no emissions from 4.C or 4.E-G.

CRF	Gas	Key Category Assessment 2008			Method	EF	All sources estimated
		Level	Trend	Qualitative			
4.A	CH_4	x	x		CS, T1, T2	CS, D	Yes
4.B	CH_4	x	x		T1, T2	CS, D	Yes
	N_2O	x	x		T2	CS	Yes
4.D	N_2O	x	x		CS, T1, T1a, T1b, T2	CS, D	Yes

6.2.1.1 ENTERIC FERMENTATION, CRF 4.A

Emissions of methane from enteric fermentation.

6.2.1.2 MANURE MANAGEMENT, CRF 4.B

Emission of methane and nitrous oxide from manure management.

6.2.1.3 AGRICULTURAL SOILS, CRF 4.D

Includes direct soil emissions from fertilizers and manure, from N-fixing crops, crop residues, histosols and use of sewage sludge as fertilizer, emissions from pasture, range and paddock manure, and indirect emissions from atmospheric deposition and nitrogen leaching and run-off. Emissions from cultivation of mineral soils are also included in this category.

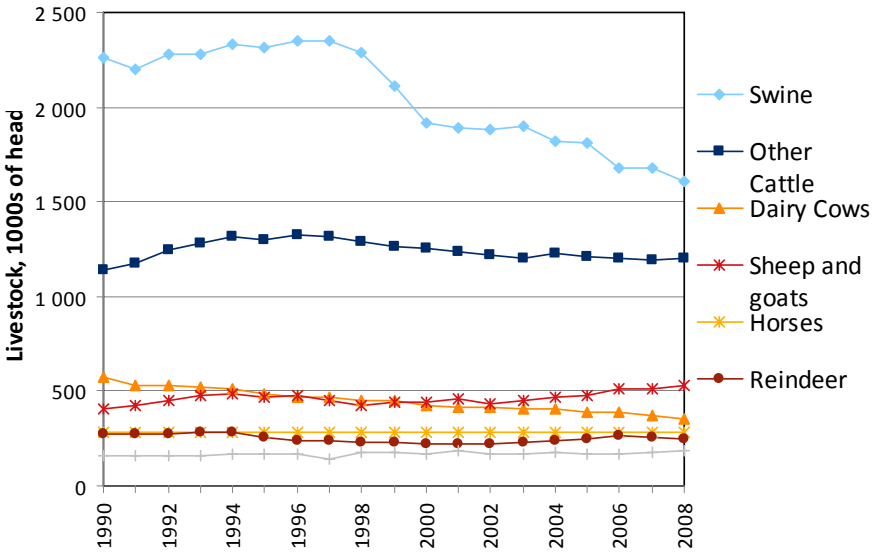

Figure 6.3. Livestock in Sweden 1990-2008, 1000s of head.

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 liquid manure 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[114].

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 Good Practice Guidance reveals that activity data, methodology and comparability in time series are in line with the Good Practice Guidance[115]. 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

[114] Ministry of the Environment, 2001.

[115] A project on quality control was carried out in 2003, as described in section 1.

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 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[116].

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 Good Practice Guidance Tier 2 methodology has been applied[117] and for emissions from swine, sheep, goats and horses the IPCC default values are used. Statistics on livestock categories are presented inTable 6.4.

6.3.2 Manure Management, CRF 4B

6.3.2.1 METHANE (INCLUDING EXCRETION FROM GRAZING ANIMALS)

The 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[118]. The formula for the emission factor for livestock group "i", according to the Good Practice Guidance 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

[116] The issue has recently been further analysed in Swedish EPA/SMED 2004.

[117] IPCC Good Practice Guidance, p.4.26.

[118] According to current estimations, cattle and swine produce about 85-90% of the total methane emissions from 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 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 to be a more appropriate for Swedish conditions, firstly because of Sweden's cold climate, and secondly because of the fact that the liquid containers usually have a surface cover[119].

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)[120].
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[121] 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 6.3.4.5.

National estimates of stable periods for cattle are collected from the statistical report on use of fertilisers and animal manure in agriculture[122]. 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:

$$emissions = \sum_{system} \left(\sum_{T} N_T * Nex_T * (365 - GrazPeriod_T) / 365 * MS_{(T,S)} \right) * EF_{system} * 44 / 28$$

[119] Dustan, 2002.

[120] 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.

[121] Statistics Sweden, MI 30-series.

[122] Statistics Sweden, MI 30-series.

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.
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[122] 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 6.2)[123].

[123] CORINAIR, 1998.

Table 6.2. Total N-content of sold fertilisers in Sweden and estimated ammonia emissions, 1990-2008

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	1 992	0,012
2008	186 500	2 231	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 6.2. The value varies because of changes in the sold quantities of different types of fertilisers. In Table 6.19 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 6.3.4.4) 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 6.3) is estimated by Statistics Sweden and the Swedish EPA[124]. The estimates are model-based and take into account many factors that influence gas emissions. The meth-

[124] Statistics Sweden, MI 37-series.

odology, based on data collected on the use of manure from telephone interviews with farmers[125], was developed in the early 1990s[126]. Later, the methodology was extended to take into account more detailed information on the use of manure and manure storage.

Table 6.3. Ammonia-N emissions from manure, fraction.

	1995	1997	1999	2001	2003	2005	2007	2008
Stable manure (FracGASM)	0.33	0.33	0.33	0.33	0,33	0,32	0,33	0,33
Manure from grazing animals ("FracGASG")	0.12	0.08	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 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 6.19.
The IPCC Guidelines' default factor for ammonia emissions from fertilisers is used to differentiate between direct and indirect emissions. The 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 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 temporary grass

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 re-

[125] Statistics Sweden, 1990.
[126] Rösiö, 1991.

gional differences, in combination with the Good Practice Guidance's default emission factor for direct N_2O emissions. The formula is stated:

$$emissions = \sum_{crop} production_{crop} * Yield_{crop} * NfixingFactor_{crop} * EF * 44/28,$$

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 6.13, Table 6.14 and Table 6.15. To estimate nitrogen fixation from the atmosphere, a model according to Høgh-Jensen has been used since submission 2006[127]. The model covers fixation from root and stubble as well as transmission to other plants. It has been adapted to account for Swedish conditions[128] 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 Good Practice Guidance is used combining national activity data on removed residues and other parameters, such as nitrogen content, at crop level with the 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[129]. 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[130]. For other crops, a combination of national factors and IPCC default values was used[131]. All factors used for calculating N input with crop residues are given in Table 6.18. Areas of different crops used in the calculations are stated in Table 6.13, Table 6.14 and Table 6.15. Stan-

[127] Høgh-Jensen et al. 2004.
[128] Frankow-Lindberg, 2005.
[129] Statistics Sweden, 1999.
[130] Mattson, 2005.
[131] Swedish EPA/SMED 2005.

dard yield[132] of different crops used in the calculations is presented in Table 6.16 and Table 6.17.

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[133]. 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 249 800 hectares according to a recent mapping of cultivated organic soils in Sweden[134].

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.

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[132] Statistics Sweden, 2002e.

[133] Klemedtsson, 2001.

[134] Berglund, 2005.

6.3.3.3 INDIRECT EMISSIONS, CRF 4D3

The calculations are carried out according to the methodology in the Good Practice Guidance, and the activity data, i.e., losses of nitrogen as ammonia and nitrogen leakage, are national. See Sweden's Informative Inventory Report (IIR) for a detailed explanation of the calculations of volatilization ratios of ammonia.

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[135], which is a part of the SOIL/SOILN model[135]. The simulation model SOIL/SOILN was developed during the 1980s in order to describe nitrogen processes in agricultural soils[136]. 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[137]. 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[137] have 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

[135] Johnsson, 1990; Swedish EPA, 2002.
[136] Johnsson et al., 1987.
[137] Swedish EPA, 2002b.

impact on nitrogen leaching into account. Since statistics on the use of fertilisers and manure are produced every other year,[138] 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 national 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 6.4 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[139]. 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[140]. This larger number has been used for the calculations for all years in submission 2010.

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.

[138] Statistics Sweden, NA 30-series; Statistics Sweden, MI 30-series.
[139] Swedish Board of Agriculture, JO 20-series.
[140] Statistics Sweden, 2006.

Table 6.4. 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[141]. 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 %[142] 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[143]. A one-time study on how straw and tops from different crops were used was carried out in 1997[144].

141 Statistics Sweden, MI 30-series.

142 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.

143 Statistics Sweden, MI 30-series; www..sjv.se/net/.

144 Statistics Sweden, 1999.

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. Estimated standard yields for different crops are published annually by the Swedish Board of Agriculture/Statistics Sweden and are a function of crop yields estimated by surveys conducted over the last 15 years[145]. 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 6.19). 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[146].

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[147] are estimated by Statistics Sweden and nitrogen leaching[148] 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 temporary grass a national methodology consistent with the national nutrient balances is also used[149].

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[150]. Data on dairy cows for different levels of milk productivity are presented in Table 6.5.

Table 6.5. 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

As productivity has increased during the reporting period, the data in Table 6.5 is used for interpolating an accurate mean value for each reporting year in the inventory.

145 Statistics Sweden, 2002e.

146 Statistics Sweden, Federation of Swedish Farmers, Swedish Board of Agriculture and Swedish EPA 2007.

147 Statistics Sweden, MI 37-series.

148 Swedish EPA, 2002; Swedish EPA, 2002b.

149 Frankow-Lindberg, 2005.

150 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).

The values for manure production per animal in each of the other animal groups are given in Table 6.6. Nitrogen production per animal in each of the other animal subgroups is stated in Table 6.7. Due to more intense swine production, the values for sows and pigs for meat production were updated in 2001.

Table 6.6. 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 2002-2008)
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 6.7. Nitrogen production from other animal groups.

Animal groups	Nitrogen kg/year/ Head, 1990-2001	Comment	Updated values on nitrogen prod. used for 2002 - 2008, 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 6.8. 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	7.2	5.8	7.6	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
2008	7.2	5.2	8.3	5.7	8.0	6	0	12

(*) Statistics Sweden. Other values are standard values, or extrapolated.

Table 6.9. 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 pro-duction	Piglet	Boar	Sheep	Lamb	Horse (*)	Goat (***)	Kid (***)	Rein-deer	Lay-ing hen	Chick-en	Slaugh-ter Chick-en (**)
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
2008	357	196	513	492	167	974	465	2,5	251	273	283	3,7	1,8	245	5546	1649	10770

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. (****) Between 1995 and 1996 there was an increase in number of sows by 13 %. The reason for this sudden increase is that as from this year also uncovered gilts are included in this group.

Table 6.10. 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
2008	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 6.11. Waste Management Systems, fraction of solid systems.

Year	Dairy cattle	Other cattle	Pigs for meat production	Other swine	Sheep, goats, reindeer	horses	Poultry
1990	0,52	0,32	0,54	0,45	0,5	0,48	0,55
1991	0,52	0,32	0,54	0,45	0,5	0,48	0,55
1992	0,52	0,32	0,54	0,45	0,5	0,48	0,55
1993	0,46	0,27	0,4	0,31	0,5	0,48	0,55
1994	0,46	0,27	0,4	0,31	0,5	0,48	0,55
1995	0,44	0,26	0,35	0,26	0,5	0,48	0,55
1996	0,44	0,26	0,35	0,26	0,5	0,48	0,55
1997	0,41	0,33	0,17	0,65	0,5	0,48	0,55
1998	0,41	0,33	0,17	0,65	0,5	0,48	0,55
1999	0,35	0,31	0,18	0,67	0,5	0,48	0,55
2000	0,35	0,31	0,18	0,67	0,5	0,48	0,55
2001	0,31	0,26	0,13	0,58	0,5	0,48	0,55
2002	0,31	0,26	0,13	0,58	0,5	0,48	0,55
2003	0,27	0,24	0,11	0,51	0,5	0,48	0,55
2004	0,27	0,24	0,11	0,51	0,5	0,48	0,55
2005	0,23	0,20	0,05	0,44	0,5	0,48	0,55
2006	0,23	0,20	0,05	0,44	0,5	0,48	0,55
2007	0,20	0,22	0,06	0,41	0,5	0,48	0,55
2008	0,20	0,22	0,06	0,41	0,5	0,48	0,55

(*) 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 6.12. 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	0.02	0.2
1991	0.01	0.10	0.02	0.11	0	0.02	0.2
1992	0.01	0.11	0.02	0.11	0	0.02	0.2
1993	0.01	0.11	0.02	0.11	0	0.02	0.2
1994	0.01	0.11	0.02	0.11	0	0.02	0.2
1995	0.01	0.11	0.02	0.11	0	0.02	0.2
1996	0.01	0.11	0.02	0.11	0	0.02	0.2
1997	0.01	0.11	0.02	0.11	0	0.02	0.2
1998	0.01	0.11	0.02	0.11	0	0.02	0.2
1999	0.01	0.12	0.01	0.07	0	0.02	0.2
2000	0.01	0.12	0.01	0.07	0	0.02	0.2
2001	0	0.16	0.01	0.12	0	0.02	0.2
2002	0	0.16	0.01	0.12	0	0.02	0.2
2003	0.01	0.18	0.01	0.11	0	0.02	0.2
2004	0.01	0.18	0.01	0.11	0	0.02	0.2
2005	0.01	0.20	0.01	0.22	0	0.02	0.2
2006	0.01	0.20	0.01	0.22	0	0.02	0.2
2007	0.01	0.21	0	0.12	0	0.02	0.2
2008	0.01	0.21	0	0.12	0	0.02	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 6.13. 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
2008	311 632	49 915	27 581	10 396	395 367	227 588	15 955	49 287

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 6.14. 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 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
2008	36 778	61 860	24 359	834	2 453	19 590	7 293

Table 6.15. Areas of different crops used in the calculations (hectares).

Year	Temporary grass (*)	Temporary grass for seed	Green forage	Pasture ground (**)	Peas incl fodder	Peas for conservation	Brown beans	Total area arable land	Total area of temporary grass (*****) ha
1990	727 590	10 753	39 698	190 503	32 742	(****) -	(****) -	3 092 853	778 000
1991	696 069	10 418	33 509	239 818	23 327	(****) -	(****) -	3 083 238	740 000
1992	708 384	8 791	2 896	292 825	14 059	(****) -	(****) -	3 075 190	720 000
1993	748 094	7 863	23 137	314 458	8 720	(****) -	(****) -	3 064 192	779 000
1994	757 000	8 241	23 000	314 666	6 598	(****) -	(****) -	3 059 905	788 000
1995	766 776	7 907	23 695	276 927	11 959	8 578	709	3 055 559	798 000
1996	750 085	7 854	22 268	247 369	17 713	8 821	690	3 050 373	780 000
1997	746 832	8 470	24 443	234 677	32 742	9 028	921	3 045 872	780 000
1998	742 068	9 013	21 935	221 418	49 150	8 524	938	3 036 034	773 000
1999	760 227	8 165	21 867	198 091	30 053	8 752	872	3 020 870	790 000
2000	760 227	8 465	21 867	198 091	27 892	8 525	835	3 012 928	791 000
2001	750 200	10 300	26 400	179 400	29 928	8 862	756	3 005 397	787 000(***)
2002	759 419	12 439	32 387	181 604	31 959	8 909	717	2 995 930	804 245
2003	769 200	12 306	31 748	164 100	28 942	9 121	767	2 990 816	813 254
2004	770 412	12 329	35 715	164 359	33 116	9 318	767	2 980 831	818 456
2005	803 920	12 847	39 628	192 670	31 285	8 874	707	2 936 464	856 395
2006	816 400	15 151	42 463	206 270	26 180	8 954	646	2 987 499	874 014
2007	831 390	14 276	46 482	190 400	19 198	8 824	535	2 887 829	892 148
2008	870 740	14 260	44 619	183 380	17 414	7 343	498	2 656 241	929 619

From 2000 the Farm Register does not differentiate between pasture (**) and temporary grass (*) → values are imputed or taken from other studies. (***) Statistics Sweden, 2002b. (****) Before 1995 statistics on peas&beans were aggregated. (*****) Total area of temporary grass= temporary grass+temporary grass for seed+green fodder.

Table 6.16. 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	6 128	5 042	5 561	4 184	3 869	4 027	6 128	47 990	3 147	2 214
2008	6 184	4 966	5 580	4 280	3 997	3 245	4 849	49 129	3 214	2 217

Swedish Board of Agriculture, Statistics Sweden, JO 15-series

Table 6.17. 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.	Temporary grass	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
2008	1 709	1 534	29 857	37 315	7 340	5 000

Swedish Board of Agriculture, Statistics Sweden, JO 15-series

Table 6.18. 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
Temporary grass	0	1,3	0,25	0,84
Temporary grass 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 6.19. Sold quantity of ammonia emitting fertilisers and nitrogen in sludge used as fertilizers

Year	N in sold fertilis-ers, tonnes	Ammonium Nitrate, AXAN, N26, N27, N28, tonnes of prod-uct	N-solu-tion, tonnes of product	Urea, tonnes of prod-uct	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	(*) 1 758
2001	196 900	235 495	2 036	553	54 000	11 300	3 000	1 171
2002	174 400	189 709	638	446	49 800	9 900	2 000	593
2003	180 100	238 828	1 083	382	53 900	10 600	2 200	692
2004	176 800	240 553	4 928	475	54 500	11 900	1 800	796
2005	161 500	273 036	3 364	519	59 000	8 400	1 600	1 053
2006	160 300	267 754	3 164	225	57 800	8 500	1 800	1 322
2007	167 100	285 064	0	271	61 100	5 300	2 000	1 322
2008	186 500	360 415	13	235	71 029	3 931	1 805	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 6.20. 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	8 648
2006	388 000	318 986	9 283	6 750	8 832
2007	369 646	298 865	9 412	6 750	8 902
2008	357 194	293 939	9 322	6 750	8 867

(*) 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[151] 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[152]. The emission factors for other cattle groups were also re-evaluated, using the same methodology[152]. The conclusion led to a decision to use the emission factor, 50 kg CH_4/head and year, a value close to the 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 reindeers were revised to 78.0 kg CH_4/head and year and 19.9 kg CH_4/head and year, respectively.

For dairy cows during the lactation period Sweden uses a method were we first calculate the metabolisable energy (MJ/day) from the energy requirements for maintenance and lactation. The metabolisable energy is then used to estimate di-

[151] Lindgren, 1980; Murphy, 1992; Bertilsson, 2002.

[152] Bertilsson, 2001.

gestible energy, and from this the emission of methane is calculated using the methane conversion rate.
This is a review of the different stages in the calculation for dairy cows during the lactation period. Metabolisable energy (MJ/day) is calculated using the formula from Spörndly 1999:

Metabolisable energy (MJ/day) =1.11 × (62 + Milk Production/day × 5) - 13.6

Metabolisable energy is then converted to digestible energy using the formula[153]:

Metabolisable energy (% of digestible energy) = 83.2 + 2.53×L – 0.045×G – 0.184×Rp

Methane conversion rate of digestible energy is calculated using the formula[154]:

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. Finally the actual emission of methane is estimated with the formula:

Emission of methane (Kg/day) = (Digestible energy × Methane conversion rate) / 55.65

For the year 2008 this resulted in an emission of 392 g of methane per day for milk cows during the lactation period. The lactation period is estimated to 305 days per year. To calculate emission per day for dry cows during the non-lactation period we us a similar method. Here there are only constant factors so the value does not change between years. For dry cows we use the value 201 g of methane per day. Hence, the final emission from milk cow per head and year is then calculated from the emission during the lactation and the non- lactation period.

From these variables it is possible to calculate gross energy intake (GE) and the methane conversion rate for gross energy (Y_m) that are used in the CRF-tables despite that we do not actually use them in the calculation of the emission. For this we use the formulas:

Gross energy intake (GE) = ((Digestible energy during lactation × 305 + Digestible energy for dry cows × 60)/365) / SK

Methane conversion rate (Y_m)= CH_4/head/year × 55.65 / (GE × 365)

However, for the moment we do only report Y_m in CRF-table and use a constant value for GE.

[153] Lindgren, 1980.
[154] Lindgren, 1980.

The default values in the IPCC Guidelines are used for the less significant animal groups[155] 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.[156] The emission factors used for dairy cattle and other animal groups are collected in Table 6.21.

Table 6.21. 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 2008, average milk production 8867 kg/yr/head	131,7	(*)
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. (***)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[157]. The only national value chosen is the MCF for liquid manure, which is set to 10 %, as was stated in the IPCC Guidelines[157]. All other parameters, due to the lack of information needed to determine national values, are default values from the IPCC Guidelines.

[155] According to current estimations, “other animal groups” produce less then 10 % of the total methane that results from enteric fermentation.

[156] Statistics Finland, 2007

[157] Dustan, 2002.

6.3.5.3 DIRECT SOIL EMISSIONS, CRF 4D1 & 4D4

For estimating direct soil emissions, the 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[158]. 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 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[159].

Background emissions from mineral soils, which include the long-term effects of nitrogen in organic matter accumulating in the soil, are 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 6.22 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[160]. For nitrogen supply from manure, a national emission factor of 2.5 % emissions of N-supply is used[160]. 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.

Table 6.22. 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[161]. They are considered to be higher from ploughed soils than from pasture or temporary grass[161] 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[162].

[158] Klemedtsson, 2001.
[159] Lægreid and Aastveit, 2002.
[160] Klemedtsson, 2001.
[161] Klemedtsson, 2001.
[162] Klemedtsson et al., 1999.

6.3.5.4 N_2O FROM GRAZING ANIMALS, CRF 4D2

For N_2O emissions from N excreted on permanent pastures, an emission factor of 1.8 % N_2O-N/kg nitrogen excreted is used for dairy cattle and 1 % for the other animal groups. 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[163].

6.3.5.5 INDIRECT SOIL EMISSIONS, CRF 4D3

For indirect soil emissions, the Good Practice Guidance default emission factors are used. The 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.

[163] Statistics Sweden, 2003c.

6.3.5.6 OVERVIEW OF EMISSION FACTORS

Table 6.23. Emission factor for CH_4.

Enteric Fermentation	Emission factor kg CH_4/animal/yr	Note
Dairy Cows	118-132	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 6.24. 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
Manure during grazing (Dairy Cows)	1.8	3
Manure during grazing (Other)	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

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 1.6 and Table 1.7). 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 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,[164] since the late 1990s. Table 6.25 shows nitrogen added and nitrogen removed for the whole of Sweden as estimated for 2005[165] (this is the most recent calculation).

Table 6.25. 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 temporary grass.

[164] Statistics Sweden, 2003c.

[165] 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[164].

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[166]. 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[166]. 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 %[166].

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.

166 Statistics Sweden, MI 30-series.

6.6 Recalculation

In this section explanations and justifications for recalculations in the agricultural sector are made, as well as a description of significant implications for the reported emission levels. Table 6.26 shows the recalculation differences for the GHG emissions by sub-sector as well as for the total level in the sector reported in submission 2010 compared to data reported in submission 2009.

Table 6.26. Recalculations of GHG emissions between submission 2010 and submission 2009 in the agricultural sector.

Recalculation differences, submission 2010/2009 (Gg CO_2 eq.)							
CRF	4A	4B	4D1	4D3	4D4	Total CRF 4	% CRF 4
1990		0	-11	82	61	132	1.39%
1991		0	-11	96	72	158	1.70%
1992		0	-11	101	76	166	1.78%
1993		0	-11	94	70	153	1.60%
1994		0	-11	92	69	150	1.56%
1995		0	-11	95	71	155	1.64%
1996		0	33	61	59	153	1.63%
1997		0	33	64	61	158	1.66%
1998		0	33	60	62	154	1.66%
1999		0	32	60	67	159	1.76%
2000		0	31	70	75	176	1.97%
2001		0	-20	89	74	146	1.64%
2002		0	-22	90	78	145	1.64%
2003		0	-10	90	79	159	1.82%
2004		0	-10	90	79	159	1.81%
2005		0	-9	66	58	114	1.32%
2006		0	-9	92	80	164	1.89%
2007		0	-8	67	59	118	1.38%

0 equals value less than 0.5.

In earlier submissions the agricultural sector and the LULUCF sector have been using different sources for the statistics of total agricultural land (the Swedish agricultural subsidy system versus the Swedish National Forest Inventory). Consequently they have not matched perfectly. As from now we have harmonized data and use the value from Swedish National Forest Inventory also for the agricultural sector. The whole time series from 1990 has been updated. This results in an increase of the emissions from the agricultural sector because the estimation of total agricultural land is somewhat higher in the Swedish National Forest Inventory.

In submission 2009 the activity data on nitrogen excretion per animal management system was reported 1000 times too low for cattle, swine and poultry. This did however not affect the estimated emissions. This is corrected in submission 2010.

6.7 Coming improvements

No major improvements are presently planned for submission 2011.

7 Land Use, Land-Use Change and Forestry (CRF sector 5)

7.1 Overview of sector

Sweden reports carbon stock changes and greenhouse gas emissions from Forest land, Cropland, Grassland and Settlements and associated land-use transfers. These land use categories are considered managed. Except for a small area used for peat extraction, Wetlands and Other land are considered unmanaged and only areas are reported. The reporting also includes CO_2, N_2O and CH_4 emissions associated with nitrogen fertilization of Forest land, land conversions to cropland, liming and biomass burning.

In 2008 the net removal from the LULUCF-sector was estimated to ca 15 M ton CO_2, which should be compared to a net emission from all other sectors of 65 M ton CO_2. The gross removal originating from tree growth in Sweden corresponds to more than 160 M ton CO_2 per year.

Since 2010 is the first year of reporting under the Kyoto Protocol, Sweden now reports data and supplementary information for 2008. The supplementary information required for the reporting under the Kyoto Protocol is found in section 7.8-7.13 in this chapter.

Forest is the major land-use category in Sweden. The total forest area (FAO definition) 2008 is 28.0 million hectares, which is equivalent to 62% of the total land and fresh water area of the country. The forest area has not changed significantly since 1990. The productive forests (producing >1 m^3 stem wood per hectare and year), on which most of the reported changes in carbon pools occur, is 23.0 million hectares[167]. Harvest of trees is more or less restricted to productive forests and this area has decreased since 1990, as a result of the establishment of nature reserves. Increased demand for forest products has lead to a continuous increase in felling during the reported period (1990-2008), while the growth rate only increased moderately. However, still the growth is larger than the drain – defined as harvest and self mortality. As a consequence of changes mentioned above, the increase in the stock or the forest carbon sink has declined in Sweden.

The land use and land-use change matrix (Table 7.1) is based on about 30000 sample plots. For the UNFCCC reporting, Forest land is the most important land-use category. The gross and net conversions indicate that conversions from Forest land to Settlements are frequent.

[167] SLU, 2009

Table 7.1 Land Use Categories 1990, 2004 and gross and net land use transfers 1990-2004 (based on about 30000 permanent sample plots inventoried 1983-2008). The carbon stock of Forest land in the mountain area[168] (915 000 ha) is not monitored in the field and changes in the carbon pools for this area are not reported.

	"From"	"To" Year 2004					
Area [1000 ha]	Year 1990	Forest Land	Crop-Land	Grass-Land	Wet-land	Settle-ments	Other Land
Forest land	28211	27974	3	19	41	146	27
Cropland	3092	72	2920	33	4	62	0
Grassland	506	41	40	404	3	12	5
Wetlands	7221	67	0	3	7049	8	94
Settlements	1713	64	16	7	7	1604	15
Other land	4401	31	0	1	29	0	4340
Sum after transfers		28249	2981	467	7134	1831	4481

The largest carbon stocks are found in the living biomass and soil organic carbon pools on Forest land, and the largest annual stock change is the change in the living biomass pool (Figure 7.1 and 7.2). A net removal of CO_2 due to increases in the living biomass pool is reported for every year during the period. This removal shows a decreasing trend due to increased felling and some severe storms that occured 2005 and 2006.

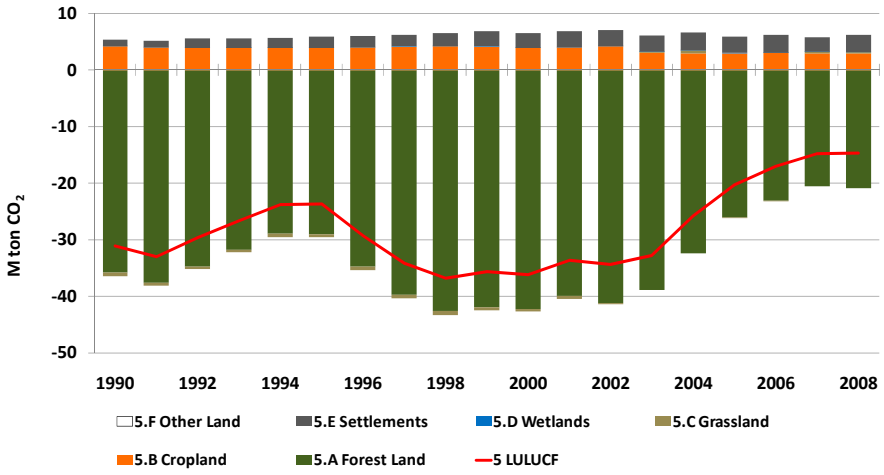

Figure 7.1. Uptake/emissons of GHG in the LULUCF sector from different land-use categories.

Except for a few years the dead organic matter pool has been a net sink during the reported period while the soil organic carbon pool is a source. Some soils act as sources whereas others act as sinks. The major source is the emission from drained organic soils (Histosols) 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 M ha) of the Histosols can be assumed to be drained. The Cropland area on Histosols is

[168] Löfgren, 1998

estimated to ca. 250 kha and all of that area is drained. The area is decreasing since the total cropland area in Sweden is decreasing.There is considerable variation between years in the soil organic carbon pools over the period. These variations are caused by random variation in the sample. Since the total pool is huge and the changes in the pool comparatively small the figures are sensitive to random variation when small changes are multiplied by large areas. It should be noted that a change of 0.1% in the pool is equivalent to more than 3 Mton CO_2. Thus, the variation in the time series should not be overinterpreted.

Emissions of CO_2, N_2O and CH_4 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. 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. A summary of emissions/ removals is found in Table 7.2.

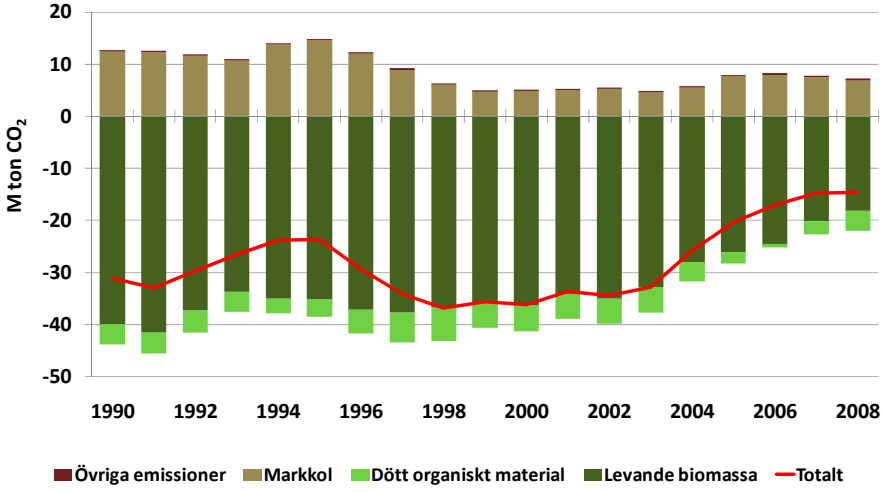

Figure 7.2. Uptake/emissons of GHG in the LULUCF sector from different carbon pools.

Table 7.2a Summary of carbon pool changes in living biomass (LB), dead organic matter (DOM) and soil organic carbon (SOC) per land use category.

7.2 a	Carbon pool changes (minus=removal) [M ton CO_2]															
	Forest land				Cropland				Grassland				Wet-land	Settlement		
Year	LB	DOM	SOC		LB	DOM	SOC		LB	DOM	SOC		SOC	LB	DOM	SOC
			Min.	Org.			Min.	Org.			Min.	Org.				
1990	-39,5	-4,1	-2,3	10,0	0,1	0,0	0,1	3,8	-0,6	-0,1	-0,2	0,2	0,0	0,0	0,3	0,8
1991	-41,0	-4,2	-2,5	10,0	-0,1	0,0	0,1	3,8	-0,4	-0,1	-0,2	0,2	0,0	-0,1	0,4	0,9
1992	-37,0	-4,5	-3,2	10,1	-0,1	0,0	0,1	3,7	-0,3	-0,1	-0,2	0,2	0,0	0,2	0,5	1,0
1993	-33,2	-4,2	-4,3	10,1	-0,1	0,0	0,0	3,8	-0,4	-0,1	-0,2	0,2	0,0	0,0	0,5	1,2
1994	-34,4	-3,3	-1,4	10,1	-0,1	0,0	0,0	3,7	-0,5	-0,1	-0,2	0,2	0,0	-0,1	0,6	1,3
1995	-34,5	-3,8	-0,8	10,1	-0,2	0,0	0,1	3,8	-0,4	-0,2	-0,2	0,2	0,0	0,0	0,6	1,4
1996	-36,6	-5,0	-3,4	10,2	-0,1	0,0	0,1	3,8	-0,3	-0,3	-0,3	0,2	0,0	-0,1	0,7	1,5
1997	-37,0	-6,2	-6,8	10,2	-0,1	0,0	0,2	3,8	-0,4	-0,2	-0,3	0,2	0,0	-0,2	0,7	1,5
1998	-36,1	-6,9	-9,8	10,1	-0,1	0,0	0,3	3,8	-0,6	-0,1	-0,2	0,2	0,0	0,0	0,7	1,6
1999	-35,1	-5,7	-11,3	10,2	-0,1	0,0	0,2	3,8	-0,6	0,0	-0,1	0,2	0,1	0,2	0,8	1,7
2000	-35,5	-5,8	-11,3	10,2	-0,4	0,0	0,3	3,7	-0,6	0,0	-0,1	0,2	0,1	0,1	0,8	1,8
2001	-33,2	-5,8	-11,3	10,3	-0,3	0,0	0,2	3,9	-0,6	0,0	-0,1	0,2	0,1	0,1	0,9	1,9
2002	-34,4	-5,8	-11,4	10,3	-0,2	0,0	0,3	3,8	-0,4	0,0	-0,1	0,2	0,1	-0,1	0,9	2,0
2003	-32,3	-6,0	-11,0	10,3	-0,2	0,0	0,2	2,8	0,0	0,1	0,0	0,2	0,1	-0,2	0,9	2,0
2004	-28,0	-4,8	-10,1	10,3	-0,3	0,0	0,2	2,8	0,1	0,1	0,0	0,2	0,0	0,2	0,9	2,0
2005	-24,9	-3,3	-8,1	10,2	-0,4	0,0	0,3	2,8	-0,7	0,3	0,2	0,2	0,1	-0,1	0,9	2,0
2006	-23,7	-1,8	-7,9	10,1	-0,3	0,0	0,3	2,9	-0,9	0,3	0,2	0,3	0,0	0,3	0,8	2,0
2007	-19,3	-3,5	-7,9	10,1	-0,4	0,0	0,2	2,9	-0,4	0,2	0,2	0,3	0,1	0,0	0,7	1,8
2008	-17,3	-4,9	-9,0	10,1	-0,3	0,1	0,2	2,8	-0,6	0,1	0,3	0,2	0,1	0,0	0,8	2,2

Table 7.2b Summary of carbon pool changes in living biomass (LB), dead organic matter (DOM) and soil organic carbon (SOC) and other sources (minus = removal). The total LULUCF removals are expressed as CO_2-equivalents.

7.2 b	Total carbon pool changes [M ton CO_2]			Other emissions [M ton substance]						Total LULUCF
				Fert. 5 (I)	To CL 5 (III)	Liming 5 (IV)	Biomass burning 5 (V)			
Year	LB	DOM	SOC	N_2O	N_2O	CO_2	CO_2	N_2O	CH_4	[M ton CO2-eq]
1990	-40,0	-3,8	12,5	2E-04	7E-05	0,17	0,019	6E-07	8E-05	**-31,0**
1991	-41,5	-3,9	12,3	1E-04	9E-05	0,13	0,018	5E-07	8E-05	**-33,0**
1992	-37,3	-4,2	11,7	8E-05	9E-05	0,11	0,018	5E-07	8E-05	**-29,7**
1993	-33,7	-3,8	10,7	7E-05	1E-04	0,13	0,018	5E-07	8E-05	**-26,6**
1994	-35,0	-2,8	13,8	6E-05	1E-04	0,16	0,018	5E-07	8E-05	**-23,8**
1995	-35,1	-3,4	14,5	7E-05	1E-04	0,17	0,018	5E-07	8E-05	**-23,7**
1996	-37,1	-4,6	12,1	6E-05	1E-04	0,19	0,019	6E-07	8E-05	**-29,3**
1997	-37,7	-5,7	8,9	5E-05	2E-04	0,17	0,10	3E-06	4E-04	**-34,1**
1998	-36,8	-6,3	6,1	5E-05	2E-04	0,13	0,00	2E-07	2E-05	**-36,8**
1999	-35,7	-4,9	4,7	6E-05	2E-04	0,16	0,03	1E-06	1E-04	**-35,6**
2000	-36,3	-4,9	4,8	6E-05	2E-04	0,16	0,03	1E-06	1E-04	**-36,1**
2001	-34,0	-4,8	5,0	5E-05	2E-04	0,14	0,03	1E-06	1E-04	**-33,6**
2002	-35,0	-4,8	5,2	4E-05	2E-04	0,13	0,05	2E-06	2E-04	**-34,4**
2003	-32,7	-5,0	4,6	4E-05	2E-04	0,14	0,07	2E-06	3E-04	**-32,8**
2004	-28,0	-3,7	5,6	6E-05	2E-04	0,12	0,06	2E-06	3E-04	**-25,8**
2005	-26,1	-2,1	7,7	8E-05	2E-04	0,13	0,05	2E-06	2E-04	**-20,3**
2006	-24,6	-0,7	7,9	9E-05	3E-04	0,09	0,13	4E-06	6E-04	**-17,0**
2007	-20,1	-2,5	7,5	1E-04	2E-04	0,13	0,03	8E-07	1E-04	**-14,8**
2008	-18,1	-3,8	6,9	2E-04	2E-04	0,10	0,14	4E-06	6E-04	**-14,7**

7.2 Source and sink category description 5A, 5B, 5C, 5D, 5E and 5F

7.2.1 Description of Key categories

A summary of the key category description is found in Table 7.3. For reporting of all carbon pools and tables CRF 5A, 5B, 5C and 5E, Sweden uses methodology Tier 3 and country specific emissions factors. Most land under 5D and 5F are considered unmanaged and not reported. The reported land under 5D refers to quite limited emissions from peat extraction. Emissions from categories 5I, 5III, 5IV and 5V are reported but for some categories it is not possible to separate emissions into land use categories. Category 5II, Non-CO_2 emissions from drainage of soils and wetlands, is not reported.

7.2.2 Definition of land use categories

Sweden has defined Forest land according to the Global Forest Resources Assessment (FRA) 2005[169]. 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.

[169] Food and Agriculture Organization of the United Nations, 2004

Table 7.3. Summary of key category description, CRF 5. If no emissions/ removals are associated with a category, this category is not showed. Emissions/ removals from CRF-tables 5I - 5V are very small and included in CRF 5A – 5F. All pools and emissions are reported except 5II.

CRF	Gas	Key Category Assessment 2008			Method	EF
		Level	Trend	Qualitative		
5A	CO_2[1,3]	x	x		T3	CS
	N_2O				T1 (5V)	CS (5V)
	CH_4				T1 (5V)	CS (5V)
5B	CO_2[2]	x	x		T3	CS
	N_2O				T1 (5IV)	D (5IV)
5C	CO_2[3]		x		T3	CS
	N_2O				T1 (5V)	CS (5V)
	CH_4				T1 (5V)	CS (5V)
5D	CO_2				T1	CS
5E	CO_2	X	X		T3	CS

[1]=5I included, no key category, T1, CS; [2]=5III included, no key category, T1, D; [3]=5V included, no key category, T1, CS

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 Decision 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. However, ca 10 000 ha of the Wetland area is used for peat extraction and therefore 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. All Other land is assumed unmanaged. Land-use categories are monitored within the Swedish National Forest Inventory (NFI[170]).

7.2.2.1 THE CONNECTION BETWEEN NATIONAL AND REPORTED LAND USE CATEGORIES

The reported land use categories are based on 16 national land use categories monitored by the Swedish National Inventory of Forests (RIS). For example in year 2000 the area of Forest land, according to the definition of forest described above, was estimated to 27 414 000 ha. This corresponds 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

[170] Ranneby et al., 1987

Mountain (07), 1 615 000 ha Protected Area, Nature Reserve (11) and 208 000 ha to other categories, using the national land use categories (Table 7.4). Note that the international land use category (FRA 2005) Forest land is superior to all other land use categories.

Table 7.4 National Land Use Categories, their connection to the UNFCCC Land Use Categories and their potential importance for carbon reporting. A=all land is considered FAO Forest land, B=large areas are considered 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 stemwood 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 stemwood 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	

7.2.2.2 CONSISTENCY IN REPORTING LAND USE CATEGORIES

The NFI has monitored land-use categories in a reasonably consistent way since 1983. Based on permanent sample plots, it is possible to trace both gross and net land-use transfers from 1983 and onwards. On Forest land, it is also possible to determine former land-use (i.e. Cropland or Grassland) before the base year (1990). All land areas are included in the field inventory except high mountains 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 historical inconsistencies in the land-use categoriy assesment have been identified and corrected. Before year 2003, protected areas ("Protected Area, Nature Reserve"; section 7.2.1.1) were not regularly inventoried. From 2003 and onwards this areas are included in other land-use categories. Usually there are data from at least one field inventory of "protected areas" before 1990, but sometimes no data are available. If no data area available, the change in carbon pools in former "protected areas" is assumed to be zero from 1990 to 2002. 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 land-use categories in earlier inventories has been re-determined. A description on the treatment of former protected areas, re-determination of land-use categories and the methodology for correcting inconsistencies in the land-use category assessment are described in more detail in the methodology section.

7.2.3 Definition of carbon Pools, CRF 5A, 5B, 5C, 5D, 5E and 5F

7.2.3.1 LIVING BIOMASS

The reported carbon pool changes refer 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[171]. 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 pool is reported for all land-use categories assessed in the field inventory.

7.2.3.2 DEAD ORGANIC MATTER

The dead organic matter pool includes the carbon pools dead wood and litter. Dead wood is defined as fallen dead wood or snags. Dead wood should have a minimum

[171] Swedish University of Agricultural Sciences, 2004

"stem diameter" of 100 mm and a length of at least 1.3 m. The dead wood is reported for all relevant 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 separated 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. Below-ground dead wood originating from stump and root systems of dead trees are not reported (section 7.7.1).

7.2.3.3 SOIL ORGANIC CARBON

The soil organic carbon pool on forest land and grassland includes all carbon in the mineral soil below the litter, fumic and humic layers in mineral soils and all organic carbon in soils classified as Histosols[172]. 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.

7.2.4 Emissions of N_2O, CO_2 and CH_4, CRF 5(I), 5(II), 5(III), 5(IV) and 5(V)

7.2.4.1 DIRECT N_2O EMISSIONS FROM N FERTILIZATION, CRF 5(I)

To increase the forest production, some middle aged or older forest stands on mineral soils are occasionally fertilized. In 1990, the fertilized forest area was estimated to 69 200 ha[173]. Since then, the annual fertilized area has decreased to about 20 000 ha in 1997-2004. In 2008, this area had increased to about 60 000 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 are 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 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 amount of fertilizer N spread per hectare. The normal average amount N spread per hectare is obtained from companies that are carrying out the fertilization in practice (there are only a few companies in this business).

7.2.4.2 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

[172] Food and Agriculture Organization of the United Nations, 1994.
[173] National Board of Forestry, 2004

drainage of soils will be reported this year, but some preliminary studies indicate that reliable methods may be available in a few years.

7.2.4.3 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). The accumulated area converted from Forest to Cropland during 20 years is 10000 ha and the area converted from Grassland to Cropland about 60000 ha. The area of other land-use conversions to Cropland is negligible.

7.2.4.4 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[174]. Separate default IPCC emission factors are used for limestone and dolomite, respectively.

7.2.4.5 N_2O, CH_4 AND CO_2 FROM BIOMASS BURNING, CRF 5(V)

Forest fires are very rare in Sweden. Wildfires have been monitored by the Swedish Rescue Services Agency since 1996[175] and the area of wildfires has varied from 400 to 6400 ha yr^{-1}. Controlled burning after clear-cutting to improve regeneration 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 400-2000 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 productive 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

[174] Statistics Sweden, 2004

[175] Swedish Rescue Services Agency, 2004

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. The Swedish National Inventory of Forests (RIS[176]) has monitored the most relevant carbon pools before the base year (1990) and onward. A particular 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.

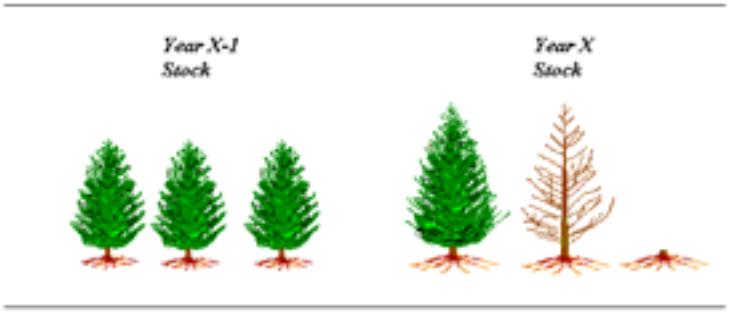

Figure 7.3 For year X, the net emissions/removals are reported as the difference in stock between year X and X-1 (The stock change method)

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

[176] Swedish University of Agricultural Sciences, 2005

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 (see Table 10 in Annex 3).
Before 2006 the time of a land use transfer between two consecutive inventories was not assessed. Therefore 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 absolute for the reporting years 1990-2004. 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 of these years 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[177]) consists of the Swedish National Forest Inventory (NFI[178]) and The Swedish Forest Soil Inventory (MI[179]). 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 sampled 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 (Figure 7.4 and 7.5). 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 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. Each cluster consists of four to eight sample plots, 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.

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[177] Swedish University of Agricultural Sciences, 2005

[178] Ranneby et al., 1987

[179] Swedish University of Agricultural Sciences, http://www-markinventeringen.slu.se/

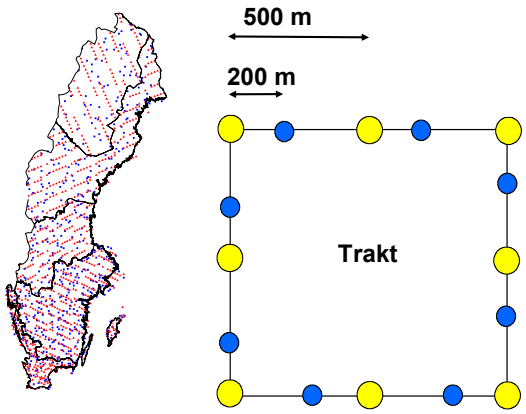

Figure 7.4 Covering whole Sweden, each year a permanent sample grid (red) is re-inventoried and a temporary sample grid (blue) is inventoried. To be able to trace both gross and net land use transfers, only permanent sample plots are used in the reporting. When estimating changes of e.g. C, the accuracy is also higher using permanent then when using temporary sampling plots. Each red dot represents a cluster of sample plots (Trakt) and within Trakt the yellow plots are used for the inventory while the blue plots are used for validation of harvests (estimates on up to one year old stumps).

Figure 7.5 The sample plots are covering all relevant land use. On this example map in the left panel, plots are located on e.g. Forest land, Cropland, Wetlands and some plots are divided into more than one land use category. On the plots, measurements are made to estimate standing biomass of trees. If at the next re-inventory, the trees remains and has been growing the plot represents a sink but if they have been harvested the plot represents a source (stock change method). Volume of dead wood per decay classes are also measured on the plot. Soil samples from different soil horizons are sampled and analyzed for C concentration and other properties. Litter is partly estimated using data from the plot and partly modeled. Observe that the shape of tracts differs by county.

The soil inventory uses the 10-m radius sampling plot. On that plot, general site variables are recorded, the soil and humus type described and litter and soil layers are sampled. 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.

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.

The land use of whole plots or parts of plots may change 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 the land use category Forest land remaining Forest land) will be estimated by a ratio estimator[180]. 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.

7.3.1.5 LAND USE TRANSFERS CRF-TABLES 5A, 5B, 5C, 5D, 5E AND 5F

From 1990 until 2005 land-use transfers are assumed to occur at a random year between two consecutive inventories. From the inventory year 2006 and onwards 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. In the reporting database it is possible to trace some of the land-use transfers that occurred up to 20 years before 1983 and consequently it is 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 already at the start of the reporting period (1990).

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.

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 Ta-

[180] Thompson, 1992

ble 7.4) 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 7.4) 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 land use changes 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[181] biomass functions to calliper and sample trees on permanent sample plots of the NFI[182]. The below-ground biomass is estimated by using Peterssons and Ståhl's[183] biomass functions on biomass data from the

[181] Marklund, 1987 and 1988

[182] Ranneby et al., 1987

[183] Petersson and Ståhl, 2006

same trees as for the aboveground biomass. The conversion factor 0.49 is used to convert biomass to carbon[184]. 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 carbon stock of the pool between 1993 and 2006 (values for 2007 and 2008 are extrapolated) 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 a trend using data from this inventory. 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. Belowground dead wood originating from stump and root systems of dead trees is not reported in submission 2010.

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 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[185] 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.

[184] National Board of Forestry, 2000

[185] Andrén & Kätterer, 2001

7.3.1.8.1 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):

7.3.1.8.2 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)

7.3.1.8.3 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[186]. The calculations are based on daily weather data, annual crop harvest statistics, the use of manure in each region and the results from a nationwide survey of agricultural soils including data on carbon content and texture[187](for further details see annex 3).

7.3.1.8.4 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[188](for further details see annex 3). The area has been linked to the changes in total cropland area so that decreasing cropland area proportionally affects the area of cropland on organic soils.

7.3.1.9 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

[186] Andrén & Kätterer, 2001.

[187] Eriksson 1997,1999

[188] Berglund and Berglund, 2005

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 land.

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).

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[189]) (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[190] 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

[189] Intergovernmental Panel on Climate Change, 2003

[190] Statistics Sweden, 2004

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 7.5. 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[191].

Table 7.5 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	-18133	-	-	30	-	-
Dead organic matter	-3827	-	-	70	-	-
Soil organic carbon	6900	-		35	-	-
Direct N fertilization, 5 (I)	-	0.158	-	-	50	-
Drainage of soils, 5 (II)	-	NE	-	-	NE	-
Conversion Cropland, 5 (III)	-	0.229	-	-	100	-
Agricultural lime application, 5 (IV)	104	-	-	50	-	-
Biomass burning, 5 (V)	145	0.004	0.632	50	75	75
All	-15309	0.391	0.632	39	83	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 1990-2004 are based on approximately 30000 sample plots and with a corresponding estimated relative standard error of 15% (or 3 M ton CO_2-

[191] Intergovernmental Panel on Climate Change, 2003

equivalents). Estimates for reporting years 2005, 2006, 2007 and 2008 are based on approximately 24000, 18000, 12000 and 6000 sample plots, respectively. Consequently, the relative sample error increases from 2005 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 2009 accuracy has improved since the reported figures now are based on more repeated measurements of permanent sample plots. For changes in carbon in the O-horizon the measurements are based on samples from 1993-1997 (first inventory) and from 2003-2006 (second inventory), while dead wood measurements are from the period 1995 to 2005. We are now also basing the estimate on interpolated values for years between inventories. The accuracy will increase in the future when more data from repeated measurements will be accessible.

One of the major difficulties in reporting changes in DOM and SOC is that the pool is very large and the changes small in comparison to the pool. As seen in Figure 7.6 the reported changes are considerable in terms of carbon and they do have an impact on the national carbon budget. However, the annual changes are still only in the order of 1 ‰ of the pool and can hardly be detected in the right panel. When tested statistically the changes are not significant at p=0.05 and the system is sensitive to systematic errors like small changes in data collection between inventories.

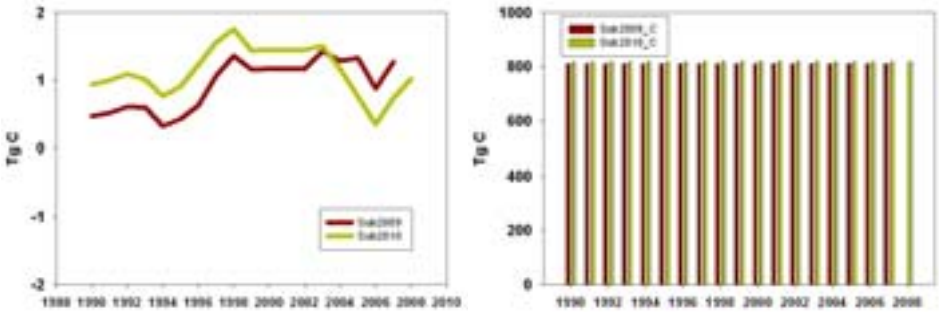

Figure 7.6 The reported change in dead organic matter carbon (left panel) and the stock (right panel) for Forest remaing Forest from submission 2009 and 2010.

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 7.5. 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[192], and ii) the underlying data of the EF does not perfectly match the target population[193,194].

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 coefficient from IPCC[195].

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 coefficient from IPCC.

7.4.6 N_2O and CH_4 emissions, CRF 5(I), 5(III) and 5(V)

[192] Statistics Sweden, 2002

[193] Kasimir-Klemedtsson et al., 2000

[194] Sund et al., 2000

[195] Intergovernmental Panel on Climate Change, 2003

Generally for all N_2O and CH_4 emissions, the error in activity data is small compared to the error due to errors associated to the emission factors.
For N_2O emissions from N-fertilization, the error due to activity data is judged to 3 % (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 to be lower than for N_2O emissions from N-fertilization. This is because it is assumed that the error of the activity data (ΔC from mineralization) is higher and due to a large potential error in the selected C:N-ratio . The uncertainly level is based on this reasoning and on IPCC default values (IPCC).

According to the points raised in the discussion above on uncerntainties in 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[196], 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 time series of change in carbon stock for the living biomass pool is quite consistently measured from 1990 and onwards. The trend was validated by the default method (growth minus drain) but not the level of the trend. We assume that most of the discrepancy could be explained by the quite crude biomass expansion factors applied using the default method. The time series for the dead wood pool extrapolates data in the beginning of the period and this because the inventory did not begin until the mid 1990th. Due to a relative high sampling error, a trend is reported and it is quite difficult to match emissions/removals from dead wood to the correct year. The dead wood pool constitutes a sink and this could partly be explained by that increasing amounts of dead wood and snags have been left after harvest, however, no proper validation has been made.

The time series of the dead organic matter pool is consistently measured since 1993 with only minor changes in sampling methodology. The soil organic carbon has been sampled annually since 1993. In 2003 a revision of sampling methodology was made to harmonize sampling with international monitoring programs. Studies on the effects of these changes in sampling have not revealed any systematic differences with respect to soil carbon pool estimates. The time series for dead

[196] National Board of Forestry, 2004

organic matter and soil organic carbon in forests have been compared to results from two process-oriented models. Models and measurements agreed well in estimation of the soil carbon pool and in the direction of change, but there where small changes with respect to the rate of change between the models and the measurements[197].

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[198] 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 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 judged as reasonable. Original 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 (also valid for areas per land use category), land use areas and areas subject to land use transfers have been recalculated for the years 2005-2007 to improve accuracy and each estimate are now based on 6000 more sample plots. The consequence of this re-calculation is a reduced carbon sink for recent years. Minor corrections of single plots have been made and that is why also small deviations from former submissions occur also for years 1990-2004. The pools dead organic carbon and soil organic carbon have been recalculated for the whole time series from 1990 to 2008 due to introduction of more re-inventoried sample plots. For the first time DOC and SOC pools are reported for land-use transfer categories. This has resulted in an increased emission of ca. 1 Mton yr^{-1} for Land

[197] Ortiz C., Lundblad M., Liski J., Stendahl, J., Karltun, E., Lehtonen, A. and Gärdenäs, A. 2009.
[198] Karltun, E., Stendahl, J., Löfgren, O. 2005.

converted to Settlement. This emission is based on estimated emission factors for different type of conversions (see Appendix 20.2, Section 1.6.2.9) Recalculations occur also for non-carbon pools, but these re-calculations are very small and have no practical influence on the accounting. Emissions from N fertilization (5I) have been corrected for year 2007 (underlying data from the Forestry agency have been improved). Due to recalculated estimates of areas, also the emissions from disturbance associated with land use conversion to Cropland (5III) have been updated. Emissions from controlled burning (5V) have been corrected for year 2007 (underlying data from the Forestry agency has been improved). Some rounding errors have been corrected (general for both carbon and non-carbon pools).

7.7 Coming improvements

7.7.1 New pools

The below-ground dead wood pool will be included in future reporting. This will be made for individual trees by estimating the below-ground biomass when a tree dies on root or is cut. Thereafter the decomposition is modelled by decay rates. Mortality could be monitored on plot basis since management activities are registered between inventories. If, for example, a plot has been thinned between two consecutive inventories, trees that have been cut during the period could individually be traced.

7.7.2 Unofficial reporting of HWP

This year, Sweden unofficially reports emissions/removals from Harvested Wood Products (HWP) using the Production approach (PA) as described in the IPCC-guidelines from 2006 (IPCC 2006). Thus, emissions from HWP are estimated as changes in the carbon pool of HWP in use originating from Swedish forests.

The IPCC default model Tier 1 is used (IPCC 2006). Input data arise from FAO (FAOSTAT) based on production and trade of primary products during 1961-2007, and calculations are made using the excel spread sheet model (EXPHWP) provided by IPCC (2006).

In EXPHWP the primary products are divided into two subcategories: wooden products and paper products. Each year's carbon pool per category is calculated as inflow of new carbon plus carbon remaining from previous years. Using the PA approach, the inflow constitutes of the domestic production – where the harvest is consumed does not influence on the accounting.

A first-order decay is assumed, i.e. it is proportional to the produced amount, and is calculated using half-time (number of years until 50% is consumed) as input variable.

Half-time for primary wooden products (sawn wood and panels) was set to 15 years and half time for primary paper products were set to 1 year. Default values on conversion factors and development of the carbon pool prior to 1961 are used.

According to the estimates the removals of carbon dioxide from the atmosphere into HWP varied between 0.5 and 5.1 M ton/yr during 1990-2007.

Table 7.6 Estimated annual net emissions/removals from Harvested Wood Products using the Production approach. Underlying data are based on figures originating from FAO for years 1961-2007. A Tier 1 methodology is used (IPCC, 2006). The figures are not included in the official reporting.

HWP, PA, [M ton CO_2]																	
1990	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07
-2.6	-0.5	-0.6	-1.8	-2.0	-2.7	-2.6	-3.1	-2.0	-1.2	-2.6	-2.3	-2.5	-2.9	-3.0	-5.1	-4.5	-4.9

7.7.3 The below Improvements of estimated emissions/removals

Gradually, the reporting of the living biomass pool, the dead wood pool, and the 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 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 ca 5000 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 currently not considered in the estimates of biomass burning and the emission factor used for controlled burning in nature reserves might lead to overestimations of the emissions.

7.8 Supplementary Information under Article 7, paragraph 1 of the Kyoto Protocol for the Land Use, Land-Use Change and Forestry Sector

This section fulfils the requirements of information on the LULUCF-sector set out in Decision 15/CMP.1 relating to the preparation of information required under Article 7 of the Kyoto Protocol. The structure of this annex is based on the structure of Annex I to Decision 15/CMP.1, but begins with background information mainly originating from Sweden's Initial report under the Kyoto Protocol. It includes also one section about uncertainty analysis and one about key-category analysis.

7.8.1 Background Information

7.8.1.1 DEFINITION OF FOREST (FOREST LAND)

For reporting purposes under the Kyoto Protocol, Forest land is defined, according to the FAO definition, as land with a tree crown cover (or equivalent stocking level) of more than 10 %, an area of more than 0.5 ha and a minimum height of 5 m (same definition as under the UNFCCC). Both crown cover and height refers to at maturity *in situ*. Assessed land that meets the forest criteria above but where other land-use is predominating is not considered Forest land. Tree-rows narrower than 10 m are not considered forests. Roads and power-line routes within forests are considered forest only if they are narrower than 5 m. This definition is consistent with former reporting and to other national bodies such as the FRA 2005. However, to be able to trace both gross and net land use transfers, only permanent sample plots are used in the reporting under the UNFCCC and the KP while both temporary (only visited once) and permanent (fixed position and re-inventoried) sample plots are used for most other national reportings. In both cases the expected values of estimates are the same but estimates might vary from sample-randomness.

All Forest land is assumed managed. Thus, the definition of Forest land and the assumption that all Forest land is managed are consistent with reporting under the UNFCCC. The same underlying data – using only permanent sample plots – are the same for the two reportings.

7.8.1.2 ELECTED ACTIVITIES UNDER ARTICLE 3.4

For the accounting of LULUCF-activities under article 3.4 during the first commitment period, Sweden has elected Forest management (FM). FM is defined as activities on Forest land. Land under Afforestation/ Reforestation (AR) has usually secondary classification FM (always if reported under Forest remaining Forest or conversion to Forest under the UNFCCC). Theoretically, land under Deforestation

can have secondary classification FM (if reported under Forest remaining Forest or conversion to Forest under the UNFCCC) but this far such land does not exist.

7.8.1.3 ACCOUNTING PERIODICITY

For the activities under Article 3.3 as well as for FM under Article 3.4, Sweden intends to account for the entire commitment period (and not on annual basis during the commitment period).

7.8.2 General Information to be Reported for Activities under Article 3, Paragraph 3, and Any Elected Activities under Article 3, Paragraph 4 (Decision 15/CMP.1, annex paragraph 6 a-e)

7.8.2.1 INFORMATION ON HOW INVENTORY METHODOLOGIES HAVE BEEN APPLIED TAKING IN ACCOUNT ANY IPCC GOOD PRACTICE GUIDANCE, 6(A)

The same institutional arrangements, national system and corresponding QA/QC procedures as for the UNFCCC reporting are used. However, the reporting differs only for the LULUCF-sector and this section focuses on differensces in aggregating underlying data between the UNFCCC– and the KP-reporting.

The same underlying methodology as for the UNFCCC reporting is used for the reporting under the KP of the LULUCF-sector (see NIR chapter 7). In other words the estimates of emissions/ removals and areas are based on permanent sample plots using data from sample plots inventoried by the Swedish National Inventory of Forests covering all land and fresh water areas. A major difference from the UNFCCC reporting is that the carbon pool living biomass is separated into above ground and below ground living biomass and that the dead organic matter pool is separated into dead wood and litter and reported separately under the KP. Only emissions/ removals on land under the activities AR, D and FM are reported under the KP. ARD land is accumulated from 1990 using permanent sample plots covering all land and fresh water areas. Precedence conditions are: D, AR and FM. Once land is reported under D, after 1990, this land could never leave the D-category and the corresponding valid for AR, except if land under AR is considered deforested (this far no such area has been identified). Changes in carbon pools on ARD-land are reported for years 2008-2012.

Land under FM is accumulated from1990 and changes in carbon pools are reported on such land 2008-2012. If land under FM is converted from Forest land to unmanaged land (non-human induced) e.g. Wetlands or Other land before 2008, this land will not be reported 2008-2012. If land under FM is converted from Forest land to unmanaged land from 2008, this land will be reported under FM 2008-2012. After deforestation, former land under FM will be reported under D. Such conversion is valid at any time after 1990. N-fertilization is only applied in middle aged or older forests and is reported under FM. Emissions associated with land use conversions from Forest land to Cropland are reported under D. Emissions from biomass burning is only observed on land under FM. N_2O emissions from drainage of soils is not reported (voluntary). Liming has not been observed on land reported

under the KP. In summary Sweden has followed decision 16/CMP.1 and the Good Practice Guidance (2003), (mainly chapter 4.2).

7.8.2.2 GEOGRAPHICAL LOCATION OF BOUNDARIES FOR AREAS ENCOMPASSING ACTIVITIES UNDER ARTICLE 3, 6(B)

Sweden uses a geographical boundary encompassing units of land (Reporting method 1) and has adopted approach 3 (Table 4.2.2 in GPG LULUCF 2003) for reporting emissions/ removals under article 3 of the KP (Figure 7.6). In practice a sample frame of approximately 30000 permanent sample plots is covering all relevant managed land in Sweden (see NIR chapter 7). The sample frame is divided into about 30 strata and the distance between sample units within stratum is based on autocorrelation. A five-year inventory cycle is used and each year about 6000 sample plots are inventoried over the whole country. Each sample plot has an identification code and a registered geographical position (confidential from sampling reasons). A certain year, each sample plot could only represent one activity (D, AR or FM) or none. The status of activities on sample plots could be traced back from the current year to the base year (1990; Figure 7.7).

Figure 7.6 The location of sample plots partly or completely reported under ARD (1990-2008) **6(b)(i)**. Every plot under AR but no under D has secondary classification FM **6(b)(ii)**. Thousands of sample plots within the country border represent FM **6(b)(iii)**. From sampling reasons, the exact geographical position of each plot is confidential. However, on request a list of sample plots is open for the review team (in country review). A certain year, each specific sample plot could only be reported under AR, D, FM or not be reported at all. The methodology used minimizes the risk of overlaps. The sample frame is permanent and there is minimal risk to by accident exclude plots from the inventory.

7.8.2.3 THE SPATIAL ASSESSMENT UNIT USED FOR DETERMINING THE AREA OF ACCOUNTING FOR AFFORESTATION, REFORESTATION AND DEFORESTATION, 6(C)

The "Spatial assessment unit", that is the same as for the UNFCCC-reporting, should be used for determining the area of accounting for ARD. "Spatial assessment unit" is defined as the minimum area used to detect a land use conversion. Sweden will monitor land use transfers based on field measurements using circular sample plots (radius 10 m). If any part of a plot is converted from one land use category to another, it can be detected. Thus, the "Spatial assessment unit" will be a sample plot part and activities down to an area of 0 m^2 could be detected. The same "Spatial assessment unit" has consistently been used in both the UNFCCC and the KP-reporting. The Swedish definition of "Spatial assessment unit" has no connection to "patch area"[199]. The ARD and FM-activities are based on land use.

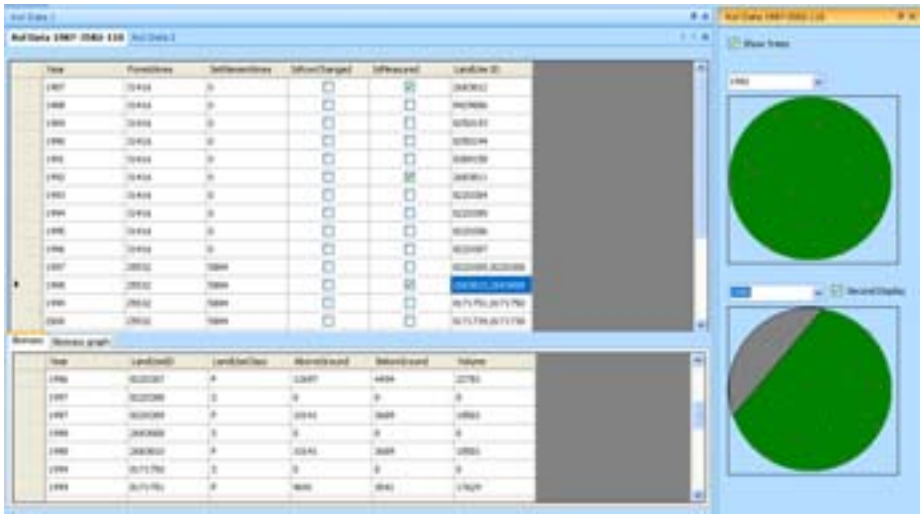

Figure 7.7 Between 1996 and 1997 a certain sample plot was partly converted from Forest land to Settlements (in this case to a road) and consequently the "grey" part of the plot should be reported under D. The "Spatial assessment" is here part of a plot (radius 10 m). Observe that the "Spatial assessment unit" has nothing to do with e.g. the minimum area of land to constitute Forest land (instead the minimum area refers to a definition of land). In practice, activities usually have a minimum area and in this example this minimum area coincides with the minimum area of the "spatial assessment unit".

[199] There is no minimum limit for detecting ARD, but two other concepts –valid for all Parties– are central for the estimated ARD-areas. These concepts are the minimum "patch areas" for land use and for activities. A common minimum patch area of Forest land is a piece of land spanning at least 0.5 ha. If part of Forest land with an exact area of 0.5 ha is converted to another land use class also the remaining area has to switch land use. The aggregation of all pieces of land is dependent on the minimum "patch area" decided per land use category. For example, the minimum "patch area" for Settlements for Sweden is very small and can be the delineated area covered by a shed surrounded by trees. The minimum "patch area" for other land use categories is 0.02 ha. Areas under activities usually are based on "patch areas" for national land use categories and then the second concept might be neglected. However, it is possible to also define minimum "patch areas" for activities –different from the ones for land use.

7.8.2.4 INFORMATION ON ANTHROPOGENIC GREENHOUSE GAS EMISSIONS BY SOURCES AND REMOVALS BY SINKS RESULTING FROM ACTIVITIES UNDER ARTICLE 3, PARAGRAPHS 3 AND 4, 6(D)

Emissions/ removals originating from the activities Afforestation and Reforestation (AR) and Deforestation (D) are estimated by area sampling and are quite uncommon in Sweden (Table 7.6 and 7.7). When based on the full set of approximately 30 000 permanent sample plots, the accumulated estimated ARD-area always increases by time, but for the most recent years this might not always be the case. This is due to the five-year inventory cycle used with estimates for the five recent years based on approximately 30 000 down to 6000 sample plots. The expected values of estimates based on the partly different samples are statistically independent of sample size used but the sample error decreases by sample size. To improve the accuracy of estimates, every year data for the five recent years are recalculated. The IPCC recommends this five-year inventory cycle and to recalculate data when the intention is to improve accuracy. Sweden has elected the activity Forest management (FM) under Article 3.4 of the Kyoto Protocol (KP). The KP-reporting under FM and AR harmonize with the UNFCCC-reporting under Forest land and land converted to Forest land. Due to a slow growth rate in boreal forests, land under AR will not be considered harvested during the first commitment period[200] and these juvenile forests are not fertilized. Forest fires –both natural and wildfires– are uncommon and, this far, has not been registered on ARD-land. N_2O emissions from disturbance associated with land use conversion from Forest land to Cropland are reported under D. Emissions from N fertilization and biomass burning is reported under FM. N_2O emissions from drainage of soils is not reported (voluntary). Liming has not been observed on land under the KP.

Table 7.6 The accumulated area under activities AR, D and F and the approximate number of sample plots each estimate is based on.

[M ha]	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
AR	0.00	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.08	0.10	0.11	0.12	0.14	0.15	0.16	0.19	0.21	0.22	0.26	0.35
D	0.00	0.01	0.02	0.04	0.06	0.07	0.08	0.09	0.10	0.11	0.13	0.14	0.15	0.17	0.17	0.18	0.17	0.18	0.18	0.20
FM		28.2	28.2	28.2	28.2	28.2	28.2	28.2	28.1	28.1	28.1	28.1	28.1	28.1	28.1	28.1	27.9	27.7	27.6	27.6
Plots	30’	30’	30’	30’	30’	30’	30’	30’	30’	30’	30’	30’	30’	30’	30’	30’	24’	18’	12’	6’

Table 7.7 Emissions (minus)/ removals (plus), CO_2 [M ton] from reported carbon pools in AR, D and FM for the first year in the commitment period (2008).

[M ton]	Above ground biomass	Below ground biomass	Dead wood	Litter	Soil organic carbon
AR	1.10	0.36	0.03	0.96	-0.31
D	-0.47	-0.16	0.002	-0.92	-0.84
FM	11.6	4.23	2.19	1.24	-0.7

[200] The concept “harvest” is important when a party claims to offset emissions from land under harvested AR-land (e.g. FCCC/KP/CMP/2005/8/Addd.3 p.6) but no definition of “harvest” has been found. So Sweden assumes that “harvest” refers to emissions at final felling and such AR-land is not expected to exist in Sweden during the first commitment period.

7.8.3 Information on carbon pools, not accounted for, 6(e)

Sweden accounts for all carbon pools (aboveground biomass, belowground biomass, litter, dead wood and soil organic carbon).

7.8.4 Information on Factoring Out Anthropogenic Greenhouse Gas Emissions from LULUCF Activities, 7(a)-(c)

Sweden argue that the issue of "factoring out" was solved during negotiations with the cap for FM (indeed, a footnote of par. 7 "recognizes that the intent of the appendix to the annex to decision 16/CMP.1 is to factor out the effects described in paragraph 7 (a)–(c) of these guidelines for the first commitment period"). So Sweden has indirectly "factored out" 7 (a)-(c) by the cap for FM but no direct "factoring out" has been made. Moreover, sound science for a direct "factoring out" does not exist and no methodology has been adopted.

7.8.5 Specific information related to activities under Article 3, paragraph 3, 8 (a)-(c)

7.8.5.1 INFORMATION THAT DEMONSTRATES THAT ACTIVITIES UNDER ARTICLE 3, PARAGRAPH 3, BEGAN ON OR AFTER 1 JANUARY 1990 AND BEFORE 31 DECEMBER 2012, AND ARE DIRECTLY HUMAN-INDUCED, 8 (A)

Sweden defines D as land use conversions from Forest land (all managed) to Cropland, Grasslands or Settlements (all land under these three categories are assumed managed). AR is defined as land use conversions in the opposite direction (Figure 7.8). Land use categories are strictly defined (see NIR chapter 7) and land use conversions are observed in field using the by IPCC recommended five-year inventory cycle. The approximately 30 000 permanent sample plots where first inventoried in field before the base year (1990) and have thereafter been re-inventoried in a consistent way (Figure 7.7). If the land use of a sample plot or part of a sample plot is considered conversed between consecutive inventories the exact year of conversion is estimated from properties on the sample plot (site, stand and vegetation properties). This is valid from 2006. The years 1990-2006, the conversion year between consecutive inventories is randomly assumed. AR on former Cropland, Grasslands and Settlements are connected with an active decision. Normally regeneration is following after the land conversion. All AR land is by national legislation considered as Forest land and the same definition of Forest land is used in the Forestry act as for the carbon reporting.

Figure 7.8 D is defined as land use conversions from Forest land (managed) to another managed land use class (all Cropland, Grasslands and Settlements are assumed managed). AR are defined as land use conversions in the opposite direction (C, G or S to F)

7.8.5.2 INFORMATION ON HOW HARVESTING OR FOREST DISTURBANCE THAT IS FOLLOWED BY THE RE-ESTABLISHMENT OF A FOREST IS DISTINGUISHED FROM DEFORESTATION, 8 (B)

Final felling is a natural step in the rotation cycle of forestry. If final felling has been identified between two consecutive inventories this is not enough to classify the plot as D. However, if a new road is located on the former Forest land, then the plot is considered D (national sub-categories of Settlements are found in NIR chapter 7). The emission from "loss of biomass" is matched to the conversion year. Suppose final felling has occurred on a plot between two consecutive inventories with no sign of D, but at the next re-inventory D is confirmed, then the year of D is "re-calculated" to match the "loss of biomass" to the conversion year. About 200 000 ha Forest land is annually losing its forest cover as a natural step in the forest rotation cycle.

7.8.5.3 INFORMATION ON EMISSIONS AND REMOVALS OF GREENHOUSE GASES FROM LANDS HARVESTED DURING THE FIRST COMMITMENT PERIOD FOLLOWING AFFORESTATION AND REFORESTATION ON THESE UNITS OF LAND SINCE 1990, 8 (C)

Due to the slow growth and long rotation cycle in boreal forestry, harvests on AR-land will probably not occur during the first commitment period and Sweden will not claim to, by a potential removal from FM, offset emissions originating from harvested AR-land.

7.8.6 Specific information related to any elected activities under Article 3, paragraph 4, 9 (a),(c)-(d)

7.8.6.1 DEMONSTRATION THAT ACTIVITIES UNDER ARTICLE 3, PARAGRAPH 4, HAVE OCCURRED SINCE 1 JANUARY 1990 AND ARE HUMAN INDUCED, 9 (A)

The activity FM is assumed to occur on all Forest land and first classification of FM is reported under Article 3.4 FM (land under AR usually has secondary classification FM). Land under activity FM is accumulated from 1990 but could leave this category for D at any time and from the reporting, if converted to unmanaged land by degradation (Wetlands or Other land) before 2008. According to IPCC, after 2008 land could only leave this class for D. The area under FM is quite stable (Table 7.9.1). All land use categories, including Forest land, are consistently monitored in field before the base year (1990) and onwards. Therefore it is possible to trace back all land use categories and land use conversions to at least 1990. "Human induced" is assumed equivalent with "managed" and all Forest land is assumed managed. The definition used coincides with definition of Forest land according to the Forestry act.

7.8.6.2 INFORMATION THAT DEMONSTRATES THAT EMISSIONS BY SOURCES AND REMOVALS BY SINKS RESULTING FROM ELECTED ARTICLE 3, PARAGRAPH 4, ACTIVITIES ARE NOT ACCOUNTED FOR UNDER ACTIVITIES UNDER ARTICLE 3, PARAGRAPH 3, 9 (C)

Each sample plot has an identification code and geographical position (confidential for sampling reasons). A certain year, a sample plot could only represent one activity (D, AR or FM) or none. Different checks have been made to avoid overlaps but also too avoid incorrect exclusions of activities.

7.8.6.3 INFORMATION THAT INDICATES TO WHAT EXTENT THE ANTHROPOGENIC GREENHOUSE GAS REMOVAL BY SINKS OFFSETS THE DEBIT INCURRED UNDER ARTICLE 3, PARAGRAPH 3

The current situation indicates that the total potential small net emission from ARD will be offset by FM. Observe that this issue is not yet valid for Sweden because Sweden intends to account for the entire commitment period (and not on annual basis during the commitment period).

7.8.7 Uncertainty estimates

Estimates of carbon stock changes are based on the same underlying data as the reporting under the UNFCCC. These estimates originate mainly from a sampling design with the intention to keep systematic errors as low as possible. The systematic error is reduced by using representative functions, by direct measurements in field and at laboratory. We assume that the major source of uncertainty arise from random variation. The sampling error is estimated using statistical theory for living biomass and partly for other carbon pools (all Tier 3). A consistent methodology for estimating carbon pools has been used from 1990 and onwards. Therefore, we expect the uncertainty to be the same for all years where all sample units are used to estimate the annual change. The uncertainties for other categories, are assumed.

Table 7.7 Estimated and assumed uncertainty for KP-activities. (Uncertainty=2•relative "standard error"). Combined uncertainty is approximately 40% per activity

		2·Relative Standard Error [%]		
Activity	**Category**	**CO_2**	**N_2O**	**CH_4**
FM	Living biomass	30	-	-
	Dead organic matter	70	-	-
	Soil organic carbon	35	-	-
	Direct N fertilization, 5 (I)	-	50	-
	Biomass burning, 5 (V)	50	75	75
AR	Living biomass	30	-	-
	Dead organic matter	70	-	-
	Soil organic carbon	35	-	-
D	Living biomass	30	-	-
	Dead organic matter	70	-	-
	Soil organic carbon	35	-	-
	Conversion Cropland, 5 (III)	-	100	-

7.8.8 Key category analysis for Article 3.3 activities and Forest management

A qualitative key category analysis has been made (IPCC 2003, p 5.38-5.40). Carbon dioxide emissions for land use categories Forest land, Cropland, Grassland and Settlements are considered key categories under the UNFCCC. Emissions under categories 5I-5V are never identified as key categories for any gas under the UNFCCC. In 2008, Forest land and conversion to Forest land under the UNFCCC represent the same land as the activities Forest management and Afforestation/Reforestation. Therefore only carbon dioxide for Forest management is considered a key category under the KP. Observe that all carbon pools are reported using Tier 3 under the KP. Only very limited emissions from non-carbon pools are relevant under the KP. These are not considered as key categories and reported using Tier 1.

7.8.9 KP LULUCF Tables NIR1, NIR2, and NIR3

Carbon stock changes are reported for all carbon pools but since AR and D are quite uncommon "NO" is reported for some non-carbon pools. Methodologies for "Drainage of soils under forest management" are found in an appendix of the IPCC Good Practice Guidance (2003) and are therefore voluntary to report. Sweden has chosen not to report this emission until methodologies based on sound science are published and adopted by the IPCC.

TABLE NIR 1. SUMMARY TABLE

Activity		Change in carbon pool reported[1]					Greenhouse gas sources reported[2]						
		Above-ground	Below-ground	Litter	Dead wood	Soil	Fertilization[3]	Drainage	Land-use conversion to croplands	Liming	Biomass burning[4]		
							N_2O	N_2O	N_2O	CO_2	CO_2	CH_4	N_2O
3.3	AR	R	R	R	R	R	NO			NO	NO	NO	NO
	D	R	R	R	R	R			R	NO	NO	NO	NO
3.4	FM	R	R	R	R	R	R	NE		NO	R	R	R
	CM	NA	NA	NA	NA	NA			NA	NA	NA	NA	NA
	GM	NA	NA	NA	NA	NA				NA	NA	NA	NA
	Rev.	NA	NA	NA	NA	NA				NA	NA	NA	NA

(1) Indicate R (reported), NR (not reported), IE (included elsewhere) or NO (not occurring), for each relevant activity under Article 3.3 or elected activity under Article 3.4. If changes in a carbon pool are not reported, it must be demonstrated in the NIR that this pool is not a net source of greenhouse gases. Indicate NA (not

(2) Indicate R (reported), NE (not estimated), IE (included elsewhere) or NO (not occurring) for greenhouse gas sources reported, for each relevant activity under Article 3.3 or elected activity under Article 3.4. Indicate NA (not applicable) for each activity that is not elected under Article 3.4. Explanation about the use of nota-

(3) N_2O emissions from fertilization for Cropland Management, Grazing Land Management and Revegetation should be reported in the Agriculture sector. If a Party is not able to separate fertilizer applied to Forest Land from Agriculture, it may report all N_2O emissions from fertilization in the Agriculture sector.

(4) If CO_2 emissions from biomass burning are not already included under changes in carbon stocks, they should be reported under biomass burning; this also includes the carbon component of CH_4. Parties that include CO_2 emissions from biomass burning in their carbon stock change estimates should report IE (included elsewhere).

Table NIR 1.1 Additional information

Parameter	Range	Selected value
Minimum land area	0.05 - 1 ha	0.50
Minimum crown cover	10 - 30 %	10.00
Minimum height	2 - 5 m	5.00

Table NIR 2. LAND TRANSITION MATRIX

Areas and changes in areas between the previous and the current inventory year [1], [2], [3]

		Article 3.3 activities		Article 3.4 activities				Other [5]	Total area at the beginning of the current inventory year[6]
		Afforestation and Reforestation	Deforestation	Forest Management (if elected)	Cropland Management (if elected)	Grazing Land Management (if elected)	Revegetation (if elected)		
		(kha)							
Article 3.3 activities	Afforestation and Reforestation	263,95	0,00						263,95
	Deforestation		178,81						178,81
Article 3.4 activities	Forest Management (if elected)		20,66	27 549,44					27 570,10
	Cropland Management[4] (if elected)	NA	NA		NA	NA	NA		NA
	Grazing Land Management[4] (if elected)	NA	NA		NA	NA	NA		NA
	Revegetation[4] (if elected)	NA			NA	NA	NA		NA
Other [5]		84,21	0,00	94,64	NA	NA	NA	16 832,97	17 011,83
Total area at the end of the current inventory year		348,16	199,47	27 644,09	NA	NA	NA	16 832,97	45 024,69

[1] This table should be used to report land area and changes in land area subject to the various activities in the inventory year. For each activity it should be used to report area change between the previous year and the current inventory year. For example, the total area of land subject to Forest Management in the year preceding the inventory year, and which was deforested in the inventory year, should be reported in the cell in column of Deforestation and in the row of Forest Management.

[2] Some of the transitions in the matrix are not possible and the cells concerned have been shaded.

[3] In accordance with section 4.2.3.2 of the IPCC good practice guidance for LULUCF, the value of the reported area subject to the various activities under Article 3.3 and 3.4 for the inventory year should be that on 31 December of that year.

[4] Lands subject to Cropland Management, Grazing Land Management or Revegetation which, after 2008, are subject to activities other than those under Article 3.3 and 3.4, should still be tracked and reported under Cropland Management, Grazing Land Management or Revegetation, respectively.

[5] "Other" includes the total area of the country that has not been reported under an Article 3.3 or an elected Article 3.4 activity.

[6] The value in the cell of row "Total area at the end of the current inventory year" corresponds to the total land area of a country and is constant for all years.

8 Waste (CRF sector 6)

8.1 Overview of sector

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 all greenhouse gases together, the trend over the last ten years has been a constant reduction of emissions (Figure 8.1). The trend can be explained by decreasing quantities of organic waste deposited at landfills in combination with that until 2003 increasing quantities of CH_4 was recovered. 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 wastewater treatment plants in Sweden was developed. CO_2 from waste incineration is a small source of greenhouse gases and contributes to the total greenhouse gas emissions in 2008 with 7%.

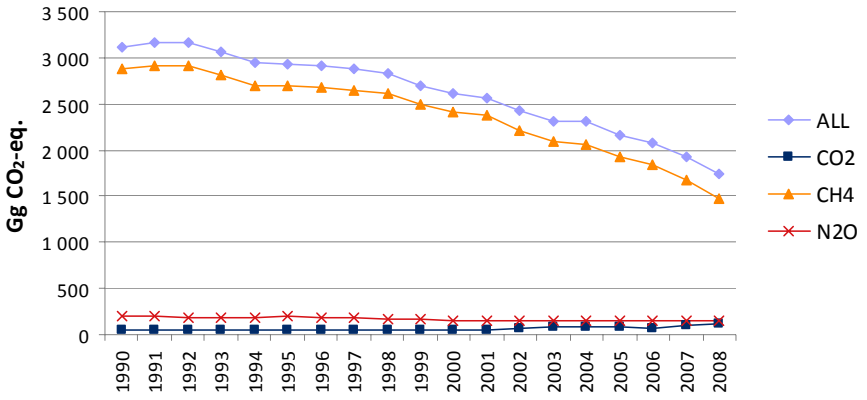

Figure 8.1. Total emissions of all greenhouse gases calculated as CO_2 equivalents from CRF 6 Waste.

Figure 8.2 shows that greenhouse gas emissions from the Waste sector largely come from solid waste disposal on land (CRF 6A). Of totally reported greenhouse gas emissions in the Waste sector, CH_4 in sub-sector 6A represents between 93% and 86% of totally reported greenhouse gases 1990 – 2008.

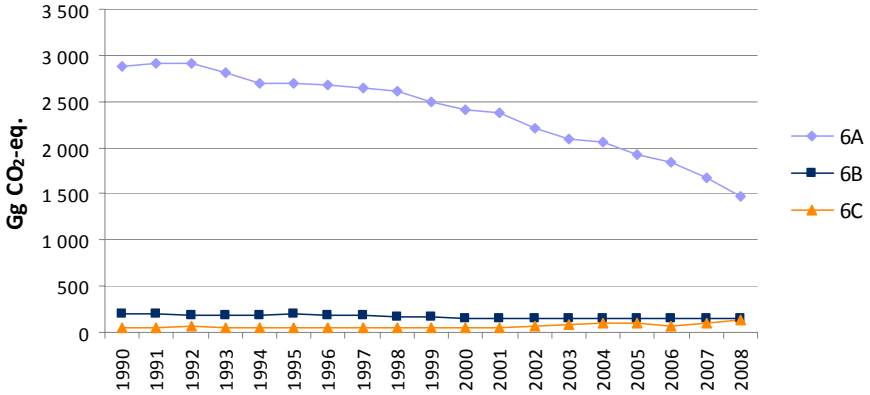

Figure 8.2. Total emissions of all greenhouse gases calculated as CO_2 equivalents from the different Waste sub-sectors.

8.2 Source category description

8.2.1 Solid waste disposal on land, CRF 6A

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 8.1.

Table 8.1. Summary of source category description, CRF 6A1.

CRF	Gas	Key Category Assessment 2008			Method	EF	All sources estimated
		Level	Trend	Qualitative			
6A	CO_2				NA	NA	NA
	CH_4	X	X		T2	CS	Yes
	N_2O				NA	NA	NA

CS Country Specific. T2 Tier 2.

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 3.0 % of the generated household waste (in Sweden also referred as "Municipal waste") was deposited in 2008. The remaining part was incinerated (49 %) or recycled (35 %) or treated biologically (13 %).

In the end of 2008 a new EU regulation for deposition came into force and since then the number of landfills for municipal waste has decrease significantly in Sweden from 140 active landfill sites in 2007 to only 80 in 2008 according to the trade association Avfall Sverige – Swedish Waste Management. In 2008, landfill gas was extracted at 57 landfills whereof 47 were active landfills.

Depositing has become an expensive solution for disposal of waste. Since January 1st 2000, there is taxation on depositing, currently 435 SEK[201] 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[202] by the Swedish Energy Agency, the production of biogas in Sweden in 2006 was totally 1 213 GWh (or 87.0 Gg in methane). In 2006, 28 % of the produced energy from biogas was produced at landfills. The biogas production decreased by 16 % from 2005 to 2006, mainly due to that 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. About 18 % of the biogas produced at landfills was flared in 2006.

8.2.1.2 EMISSION ESTIMATES

The decrease in deposited waste quantities reduces the potential of methane emissions from landfills. Figure 8.3 shows the methane emissions calculated by the IPCC default model and the IPCC First Order Decay (FOD) model respectively.

[201] SFS 1999:673

[202] Swedish Energy Agency, 2008

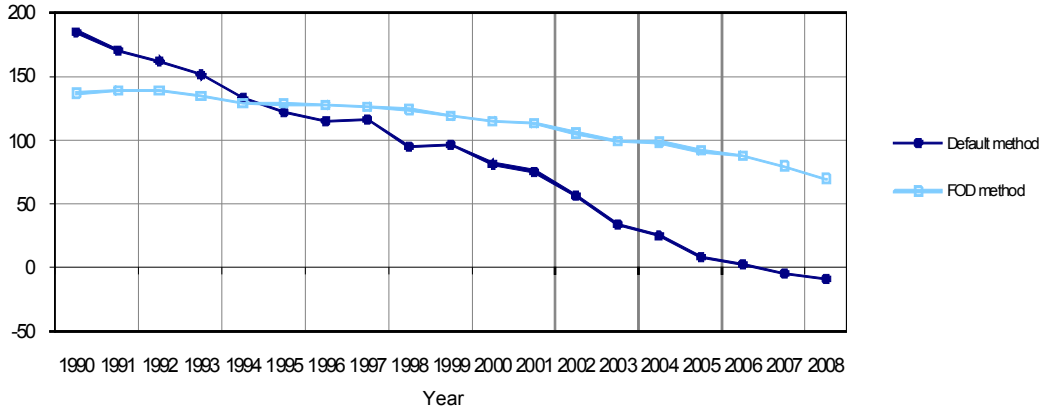

Figure 8.3 Emission of methane from Swedish landfills 1990-2008, estimated by the two IPCC methodologies, (Gg CH_4.)

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 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 8.2, the estimates from the FOD model and the deposited amount of municipal solid waste (MSW) are presented.

Table 8.2 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
2008	-9	65	272	39	1832

* 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, the 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 the Swedish Waste Management.

Statistics on organic waste from industries are much scarcer. There is information on industrial waste from the 1980s but organic 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 sludge from the pulp industry is incinerated and composted.

There are no time series of data available on landfilled organic industrial waste (except from data on sludge from pulp industry). Time series of data on organic industrial waste from the food industry could perhaps in the future be provided from the Swedish reports according to the European Waste Statistic Regulation.

8.2.1.4 WASTE CATEGORIES

8.2.1.4.1 Household waste, sludge and garden waste

Table 8.3 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 8.3 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*
2008	140	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. 17-19) Avfall Sverige, 2007- 2009

* Included in household waste from reference year 2004. ** Estimate

The composition of household waste has been investigated in many studies over the years. Ohlsson[203] 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[204] 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.[205] 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 8.4.

Table 8.4. 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. Special studies of organic waste are considered to be the most important information sources of industrial waste categories. In 2004 a study on deposition of organic waste was carried out by Profu and financed by the Swedish EPA.[206] 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

[203] Ohlsson, 1998 and REFORSK, 1998
[204] Ohlsson, 1998
[205] RVF, 2005
[206] 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;[207] the waste groups found to generate methane in landfills are presented in Table 8.5. The most important subgroup here is sludge from the pulp industry and the other subgroups are mainly from the food industry. The 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 8.5 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 slaughter houses	40	5	2	0.45
Sludge from slaughter-houses	45	8	3.6	0.28
Entrails	30	5	1.5	0.09
Manure from slaughter-houses	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 8.6).

[207] Swedish EPA, 1993

Table 8.6 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]
2005-2008	0[10]

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.

A study on organic industry-specific waste was published in 1996[208]. In accordance with the report, the deposited waste categories are presented in Table 8.7. The gas potentials were calculated by Sweco Viak.

Table 8.7 Organic Industrial Waste 1996.

Waste category	Deposited quantity, 1000 tonnes/yr	Gas potential, Mm3 CH_4/yr
Waste from slaughter houses	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. By 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 industries, 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) made by the Swedish EPA and Statistics Sweden.[209] 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.

[208] Swedish EPA, 1996

[209] Statistics Sweden, 2000

8.2.2 Waste water handling, CRF 6B

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 8.8.

Table 8.8. Summary of source category description, CRF 6B.

CRF	Gas	Key Category Assessment 2008			Method	EF	All sources estimated
		Level	Trend	Qualitative			
6B	CO_2				NA	NA	NA
	CH_4				-	-	No, see Annex 5
	N_2O				CS	D	Yes

CS Country Specific. D Default.

There are 500 wastewater treatment plants in Sweden with treatment capacity for more than 2,000 personal equivalents. 95 % of the wastewater is treated mechanically, chemically and biologically. In some larger plants, or plants with sensitive recipients, special nitrogen treatment is performed. There are also a number of smaller plants or private plants of varying standard.[210] In Sweden, there are approximately 1.3 million people not connected to a municipal treatment.

Considerable quantities of heat and bioenergy are recovered or from sewage and wastewater.[211] Most of the remaining amounts of the methane generated in the wastewater treatment plants are flared. Methane generated from wastewater treatment and sludge treatment at the wastewater treatment plants are reported as "Not estimated" (NE).

The leakage of methane and nitrous oxide from the wastewater treatment processes and sludge treatment processes has not been investigated enough to draw conclusions about the effects it may have on the national emissions.

8.2.2.1.1 Biogas production and utilization

According to a survey[212] 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. Approximately 14 % of the biogas produced at wastewater treatment plants was flared in 2006.

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

[210] Swedish EPA & SMED, 2003

[211] Ministry of the Environment, 2001.

[212] Swedish Energy Agency, 2008

other MSW incineration plants combusting waste for energy purposes are included in CRF 1. The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), are presented in Table 8.9.

Table 8.9. Summary of source category description, CRF 6C.

CRF	Gas	Key Category Assessment 2008			Method	EF	All sources estimated
		Level	Trend	Qualitative			
6C	CO_2				T3	PS	Yes
	CH_4				T2	PS	Yes
	N_2O				T2	PS	Yes

PS Plant Specific. T2 Tier 2. T3 Tier 3.

8.3 Methodological issues

For the whole waste category, the methodology and time series consistency are in line with the Good Practice Guidance.

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[213] 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.

[213] Statistics Sweden, 2005

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.[214] The gas potential of the sludge is reduced by 50 % because it is treated.[215] 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.[216] Gas potentials in waste from the food industry are presented in section 8.2.1.

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 subtract 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 deposition 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 8.10).

[214] Recounted from RVF, 1996.
[215] Sweco Viak, 2000.
[216] Swedish EPA, 1993.

Table 8.10 Recovered landfill 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]
2008	26 979[8]

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) Avfall Sverige, 2009

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 8.11). The value of DOC_F 0.5 has been chosen according to IPCC methodology. The oxidation factor is estimated to be 10 %, and the half-life of the methanogenesis is 7.5 years.[217]

[217] Börjesson, 2000

Table 8.11 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.[218] 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 8.12- Table 8.14 shows the data used in the calculations of methane emissions from solid waste disposal on land.

[218] Swedish EPA, 1983.

Table 8.12 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
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

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
1998				1020(*)	45(*)	62.5	477	73
1999				972.5(*)	45(*)	62.5	580	96
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
2008				140(*)	0(***)	62.5	31	38

(*) Taken from statistical sources. Other values are interpolated or extrapolated.

(**) Estimate.

(***) Included in household waste from reference year 2004.

Table 8.13 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 8.14 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(*)
2008	39	0(*)

(*) Taken from statistical sources. Other values are interpolated or extrapolated.

8.3.1.2.2 Composition on deposited waste

Table 8.15 Illustrates the estimated composition on deposited waste 1990-2008.

Table 8.15 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
2008	1.6	6.9	0.9	0.2	0.2	0.4	2.1	0.0	0	83.9	3.8

8.3.2 Waste water handling, CRF 6B

8.3.2.1 NITROUS OXIDE (N_2O)

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).

IPCC Guidelines suggest an emission factor of 1% (N_2O-N/kg sewage N discharged sewage effluent) for sewage nitrogen that enters rivers and estuaries (Good

Practice Guidance, Table 4.18), while the N_2O emissions associated with sewage treatment and land disposal are considered to be negligible. There is no Swedish research that will motivate a national emission factor concerning discharged sewage nitrogen.

8.3.2.1.1 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.

8.3.2.1.2 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).

8.3.2.1.3 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[219]), NrPeople is the number of people not connected to municipal wastewater treatment plants, and 0.16 is the fraction of nitrogen in proteins.

[219] National Food Administration, 2002

Table 8.16 Discharges of nitrogen from municipal wastewater treatment plants, pulp and paper industry and some coastal industries, tonnes.[220]

Year	Municipal wastewater-treatment plants (*)	Pulp and paper industry	Oil refineries	Chemical industry	Iron and steel industry	Food manu-facturing 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	..	..	..	..	..
2008	..	2830	..	..	..	..	..

(*) 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.[221] 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.

Sweden has better data on emissions in tonnes than in cubic metres for industrial waste water handling. One reason is that large quantities of the waste water output are actually cooling water, not process water, and therefore not relevant. It is often confusing for the reporting companies which quantity/quantities of wastewater that should be reported. Also, discharges in tonnes are more relevant than in cubic meters. This is the reason why Sweden has chosen to publish data of discharges of nitrogen in tonnes in Table 8.16.

The statistics also exclude approximately 1.3 million people in rural areas, who are not connected to municipal wastewater treatment. Until submission 2009, Sweden estimated this population to almost 1 million people. The new estimate is based on new data[222] for 1995, 2000 and 2005. The mean of these data is approx. 1 264

[220] MI 22 SM, Swedish EPA and SMED, NV 4657, NV 4434, NV 4657, NV 4924, NV 4987, NV 5114, Swedish Forest Industries Federation.

[221] Statistics Sweden, MI 22 SM, Swedish EPA and SMED.

[222] Statistics Sweden MI 11 SM 0701, Korrigerad version

000 people, which is rounded up to 1.3 million people in the calculations to compensate for suspected underestimation for year 1995. Sweden can not see any national trend or variations over the years that are significant enough to apply in the calculations, since the data for 1995 (1 205 686 people) is likely an underestimation, and 2000 (1 296 757 people) and 2005 (1 291 299 people) are very similar. 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 is using.

8.3.2.2 METHANE (CH_4)

8.3.2.2.1 Methane emissions from wastewater treatment

Sweden reports NE (not estimated) for methane emissions from waste water handling in the CRF tables because of lack of data. The default method presented in Good Practice Guidance (Box 5.1) has been suggested by the ”Decision Tree for CH_4 emissions from Domestic Wastewater Handling” for calculating emissions from private or smaller plants. The population (variable **P**) connected to this category of plants are at the moment not properly estimated, but improvements are expected in the near future.

8.3.2.2.2 Methane emissions from sludge treatment

Methane emissions from sludge treatment in 6B1 (Industrial Waste Water) and 6B2 (Domestic and Commercial Wastewater) has previously been reported as ”Included elsewhere” (IE) since sludge used do be deposited at landfills. The methane emissions from unintentional leakage of methane from the treatment of sludge (anaerobic digestion) at the wastewater treatment plants are not estimated because lack of sufficient data on a national level.

There are indications that the leakage is insignificant because of flaring. A study[223] on two wastewater treatment plant in Stockholm shows that this leakage is between 4 % and 7 % of the gas production for these plants. If these plants are representative for all 138 wastewater treatment plants with anaerobic digestion in Sweden, then the national methane emission estimate for the year 2006 could be within the interval 1.74 Gg to 3.14 Gg for sludge treatment.

In submission 2010 Sweden has changed the notation key from ”IE” to ”NE” in order to follow the recommendations from ERT.

[223] Stockholm Vatten, 2004

8.3.2.3 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. 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, CH_4, N_2O, 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[224]. Total amounts of incinerated waste as well as the amount of incinerated municipal waste have been obtained by the company. Also the total CO_2 emissions from incineration of waste are as reported by the company. In a report published by the Swedish Waste Management Association (2003)[224] 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 company reports CH_4 emission around 1.1 Mg for 2008. This information, together with information of incinerated amounts of waste 1990 until 2007, has been used for estimating a complete time series for emissions of CH_4 in CRF 6C. In submission 2010 also N_2O from waste incineration is reported for the whole time series 1990 – 2008. The estimates are based on occasional measurements of the N_2O concentrations in the flue gas made by the company together with information on yearly flue gas volumes 2003 - 2008. For 1990 until 2002 the volumes are not known and for these years the flue gas volumes have been estimated using the average of the ratios between volumes and incinerated amounts of waste for 2003 to 2008. Activity data and emission factors used for the CH_4 and N_2O estimates are presented in Table 8.17.

[224] 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.

Table 8.17. Activity data and emission factors used for estimations of CH_4 and N_2O emissions in CRF 6C.

Year	Total amounts of incinerated waste	Flue gas volume	N_2O	CH_4
	Gg	1000 m^3	EF, g/1000 m^3	IEF, kg/Gg
1990	30	220 674*	15.00	7.73
1991	35	257 453*	15.00	7.73
1992	35	257 453*	15.00	7.73
1993	31	230 972*	15.00	7.73
1994	34	247 419*	15.00	7.73
1995	33	240 637*	15.00	7.73
1996	25	181 386*	15.00	7.73
1997	29	209 890*	15.00	7.73
1998	29	212 156*	15.00	7.73
1999	29	213 307*	15.00	7.73
2000	28	205 778*	15.00	7.73
2001	31	228 934*	15.00	7.73
2002	33	240 887*	15.00	7.73
2003	122	789 438	15.00	7.73
2004	130	881 100	15.00	7.73
2005	126	1 099 338	15.00	7.73
2006	122	902 039	15.00	7.73
2007	140	915 032	15.00	7.73
2008	146	1 189 691	15.00	7.73

* = estimated volume

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 uncertainties since the data on DOC has 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 apply-

ing 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 2008 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 Source-specific recalculations

In this section explanations and justifications for recalculations in the waste sector are made, as well as a description of significant implications for the reported emission levels. Table 8.18 shows the recalculation differences for the GHG emissions

by sub-sector as well as for the total level in the sector reported in submission 2010 compared to data reported in submission 2009.

Table 8.18. Recalculations of GHG emissions between submission 2010 and submission 2009 in the waste sector.

Recalculation differences, submission 2010/2009 (Gg CO_2 eq.)					
CRF	6A	6B	6C	Total CRF 6	% CRF 6
1990		8	1	9	0.28%
1991		8	1	9	0.28%
1992		8	1	9	0.28%
1993		8	1	9	0.29%
1994		8	1	9	0.30%
1995		8	1	9	0.30%
1996		8	1	9	0.29%
1997		8	1	9	0.30%
1998		8	1	9	0.31%
1999		8	1	9	0.32%
2000		8	1	9	0.33%
2001		8	1	9	0.34%
2002		8	1	9	0.36%
2003		8	4	11	0.49%
2004		8	4	12	0.51%
2005		8	5	13	0.60%
2006		8	4	12	0.58%
2007		8	4	12	0.62%

CRF 6A1

- In line with the recommendations from the ERT emissions of CO_2 from Solid waste disposal on land (CRF 6A1) combustion are reported as NO instead of NE, since there is no on-site combustion of waste on Swedish landfills since the 1970´s.

6B1 and 6B2

- In response to the review process, recalculations have been done for N_2O from human sewage. Previously Sweden used the figure 1 million people (people in rural areas, who are not connected to municipal wastewater treatment) as activity data in the calculations. As new data[225] recently has been published for 1995, 2000 and 2005, a new estimate has been calculated based on the mean of these data, approximately 1 264 000 people. The mean is rounded up to 1.3 million people in the calculations to compensate for the suspected underestimation for year 1995. Sweden can not see any national trend or variations over the years that are significant enough to apply in the calculations, since the data for 1995 (1 205 686 people) is likely an underestimation, and 2000 (1 296 757 people) and 2005 (1 291 299 people) are very similar. The recalculations has resulted

[225] Statistics Sweden MI 11 SM 0701, Korrigerad version

in higher emissions of N_2O for 1990-2007, 0.024778 Gg (or 30 % of the previously emissions reported for N_2O from human sewage).

- The notation keys for methane emissions from sludge treatment in 6B1 (Industrial Waste Water) and 6B2 (Domestic and Commercial Wastewater) has been changed the notation key from ”IE” to ”NE” in order to follow the recommendations from ERT.
- In NIR, it was reported that the methodology is in line with Good Practice Guidance, the Tier 2 methodology was used for calculating CH_4 emission from SWDs on Land. In CRF “SUMMARY 3 SUMMARY REPORT FOR METHODS AND EMISSION FACTORS USED” the methodology was reported as T3 (Tier 3), when in fact there are no Tier 3 (T3) methodology in IPCC Guidelines and Good Practice Guidance. As 2006 IPCC Guidelines are not officially in use at the moment, Tier 3 should not be reported. It has been changed to Tier 2.

6C

- In earlier submissions CH_4 and N_2O from waste incineration were reported as NE. Inresponse to ERT recommendations, emissions of CH_4 and N_2O are added in the 2010 submission for the whole time series.

8.7 Source-specific planned improvements

No major improvements are planned in this sector to submission 2011.

9 Other sectors

Not applicable in Sweden.

10 Recalculations and improvements

Since the last submission, recalculations of GHG emissions for several years have been carried out throughout the inventory. The recalculations are due to comments and implemented recommendations from the national and international review teams in the ongoing progress to make the inventory be fully in line with the IPCC Guidelines and the Good Practice Guidance. 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.

10.1 Explanations and justifications for recalculations

The explanations and justifications for the recalculations made in this submission since the submission by April 15, 2008, together with descriptions on their implications for the emission levels, are given in the sector chapters according to:

Energy	Section 3.6
Industrial processes	Section 4.11
Solvents and other products use	Section 5.6
Agriculture	Section 6.6
LULUCF	Section 7.6
Waste	Section 8.6

10.2 Implications for emission levels

This section provides a general description for each sector of the major recalculations made. The implications for emission levels of GHG emissions by sector are presented in Table 10.1.

10.2.1 Energy, CRF 1

In the energy sector, recalculations have been made for the entire time series 1990-2007. The largest implication on sector total emission levels occurs due to the revised method for estimating emissions from the integrated iron and steel production plants, and in particular the reallocation of fugitive emissions from flaring of gases (CRF 1B1c) to the industrial processes sector. In addition, the increased thermal value for gasoline significantly affects the sector total GHG emission levels.

10.2.2 Industrial industries, CRF 2

The revised method for estimating emissions from the integrated iron and steel production plants, including the results of the reallocation of fugitive emissions from flaring of gases to the industrial processes sector (CRF 2C1.2), is the main reason for the increased GHG emission levels in CRF 2. A reduction of GHG emissions occurs in the sector due to the elimination of the previous double-

counting of CO_2 emissions from lime use in the pulp and paper industry (reported in CRF 2A2).

10.2.3 Solvents and other products use, CRF 3

In this sector, the update of the Swedish Chemicals Agency data for 2007 results in minor decrease of GHG emissions.

10.2.4 Agriculture, CRF 4

In order to harmonize data between the agricultural sector and LULUCF, information on the area of arable land in the agricultural sector is now taken from the Swedish National Forest Inventory instead of the previous source the Swedish Agricultural Subsidy System. The recalculations resulted in increased GHG emission levels for the entire time series 1990-2007.

10.2.5 LULUCF, CRF 5

A substantial contribution to the changes in the levels of the reporting is that Sweden for the first time reports dead organic matter and soil organic matter on land-use change categories. Reporting of emission from Histosols have also been improved which resulted in some level changes. A major part of the large differences in the total removals from 2004 and onwards is the result of the annual update of the reporting data base which results in recalculated emission levels in the carbon pools from 2004 to2007.

10.2.6 Waste, CRF 6

Recalculations in this sector have been made for the entire time series 1990-2007. The emissions of N_2O from human sewage (CRF 6B2.2) were increased due to updated information on the number of citizens not connected to municipal water treatment. In addition, emissions of CH_4 and N_2O from waste incineration are added for the first time in submission 2010.

Table 10.1. Recalculations of GHG emissions between submission 2010 and submission 2009 by CRF sector.

Recalculation difference														
Year	Total (excl LULUCF)		CRF 1		CRF 2		CRF 3		CRF 4		CRF 5		CRF 6	
	Gg CO_2 eq.	%	Gg CO_2 eq.	%	Gg CO_2 eq.	%	Gg CO_2 eq.	%	Gg CO_2 eq.	%	Gg CO_2 eq.	%	Gg CO2 eq.	%
1990	504	0.70%	-110	-0.21%	472	8.16%			132	1.41%	-1011.0	3.2%	9	0.28%
1991	301	0.41%	-273	-0.50%	407	7.15%			158	1.73%	-388.9	1.2%	9	0.28%
1992	340	0.47%	-85	-0.16%	250	4.65%			166	1.81%	-994.1	3.2%	9	0.28%
1993	520	0.72%	48	0.09%	310	5.67%			153	1.63%	-1771.5	6.2%	9	0.29%
1994	382	0.51%	-240	-0.43%	463	8.06%			150	1.58%	-1408.3	5.6%	9	0.30%
1995	685	0.93%	-151	-0.27%	672	11.38%			155	1.67%	-1781.5	7.0%	9	0.30%
1996	668	0.87%	-40	-0.07%	547	9.40%			153	1.65%	-536.7	1.8%	9	0.29%
1997	608	0.84%	-191	-0.35%	632	11.05%			158	1.69%	-194.1	0.6%	9	0.30%
1998	787	1.08%	-48	-0.09%	673	11.48%			154	1.68%	-595.3	-1.6%	9	0.31%
1999	704	1.01%	-349	-0.67%	886	15.64%			159	1.79%	-1283.6	-3.7%	9	0.32%
2000	702	1.03%	-370	-0.73%	888	15.20%			176	2.01%	-521.7	-1.5%	9	0.33%
2001	693	1.01%	-185	-0.36%	723	12.03%			146	1.67%	-1439.0	-4.5%	9	0.34%
2002	782	1.12%	-333	-0.64%	961	16.23%			145	1.67%	-71.0	0.2%	9	0.36%
2003	660	0.94%	-88	-0.17%	578	9.59%			159	1.86%	-746.5	2.2%	11	0.49%
2004	723	1.04%	-356	-0.68%	908	14.89%	0	0.00%	159	1.84%	-6192.4	19.3%	12	0.51%
2005	511	0.76%	66	0.13%	317	4.80%	1	0.44%	114	1.34%	-8841.2	30.3%	13	0.60%
2006	398	0.60%	-51	-0.10%	271	4.06%	3	1.05%	164	1.92%	-8621.1	33.7%	12	0.58%
2007	751	1.15%	283	0.59%	348	5.32%	-10	-3.47%	118	1.40%	-5646.0	27.6%	12	0.62%

10.3 Implications for emission trends

The total emissions of GHG have changed for all inventory years due to the recalculations. Below a more detailed description is presented of implications for emission trends due to recalculations of the base year emissions and the last recalculated year's emissions. Note that this section does not include implications for emission trends in the LULUCF sector. In Table 10.2 it can be seen that compared to the estimated assigned amounts, the base year emissions in submission 2010 are about 395 Gg CO_2 equivalents higher.

Table 10.2. Difference between Assigned Amount and Base Year emissions submission 2010 by GHG

GHG	Assigned Amount (Gg CO_2 eq.)	Base Year* emissions Submission 2010 (Gg CO_2 eq.)	Difference between Base Year emissions Submission 2010 and Assigned Amount (Gg CO_2 eq.)
CO_2	56 301.08	56 614.95	313.87
CH_4	6 719.22	6 731.68	12.46
N_2O	8 534.73	8 603.18	68.44
F-gases	596.61	596.65	0.04
Total**	72 151.65	72 546.45	394.81

*1995 for F-gases and 1990 for other GHG emissions (excluding LULUCF)

Based on submission 2010, the estimated GHG emissions in Sweden decreased by 11.8% between the base year (72,438 Gg CO_2 equivalents) and 2008 (63,963 Gg CO_2 equivalents). In Table 10.3 it can be seen that in submission 2009 the trend from the base year to 2007 shows a 9.2% decrease. It can also be seen that the recalculation of GHG emissions in submission 2010 reduced the downward trend between the base year and 2007 by 248 Gg CO_2 equivalents or 0.41 % compared to submission 2009.

Table 10.3. Impact on emission trends due to recalculations of GHG emissions between submission 2010 and submission 2009 by GHG

Trend Base Year* to 2007						
GHG	Submission 2009		Submission 2010		Difference between submission 2010 and submission 2009	
	Gg CO_2 eq.	%	Gg CO_2 eq.	%	Gg CO_2 eq.	% points
CO_2	-4 636.00	-8.24%	-4 323.90	-7.64%	312.10	0.60%
CH_4	-1 351.78	-20.15%	-1 392.73	-20.69%	-40.95	-0.54%
N_2O	-1 299.63	-15.33%	-1 339.19	-15.57%	-39.56	-0.24%
F-gases	656.13	109.86%	672.39	112.69%	16.26	2.83%
Total**	-6 631.29	-9.20%	-6 383.44	-8.80%	247.85	0.41%

*1995 for F-gases and 1990 for other GHG emissions (excluding LULUCF)

10.4 Recalculations and other changes made in response to the review process

As the inventory time cycle in Sweden is planned for a national independent review of the inventory, submission 2010 is already compiled in mid-October 2009. The preliminary result of the centralized review in 2009, taking place in October, can thus only be taken into account as minor recalculations 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 UNFCCC review process are described briefly and referenced to relevant sections to the NIR.

Table 10.4. Recalculations and other changes made in response to the UNFCCC review process.

Review[226]	Sector	Paragraph and recommendation in report (shortened)	Actions as a result of ERT recommendations
submission 2006	Energy	23, 37. Categories not estimated	Fugitive emissions of CH_4 from transport of crude oil are estimated in submission 2010 and added to CRF 1B2a iii Transport, whereas CO_2 emissions in the same category is considered to be not applicable (NA) in Sweden (see NIR 3.3.20). 1B2c Flaring: In submission 2010, all emissions are estimated. All plants where flaring occurs are part of the EU ETS system, and according to this data no flaring of natural gas occurs. If natural gas is included in the "burning gas" sometimes reported to the EU ETS, the emissions are estimated but reported as IE (in flaring of liquid fuels).
submission 2007/2008	Energy, Industrial processes, Waste	19, 32, 80. Categories not estimated	1B2c Flaring: In submission 2010, all emissions are estimated. All plants where flaring occurs are part of the EU ETS, and according to this data no flaring of natural gas occurs. If natural gas is included in the "burning gas" sometimes reported to the EU ETS, the emissions are estimated but reported as IE (in flaring of liquid fuels). CH_4 from Carbon Black added all years (see NIR 4.3.3)
submission 2006	Energy	34. Improve explanations on fluctuating trend for fugitive emissions of refinery gas in Petroleum refining	Text in NIR section 3.3.20.2.5 clarified in submission 2010
submission 2006	Energy	36. The allocation of fuel between civil aviation and aviation bunkers is not transparently described in the NIR, especially for the period 1990–1994.	A more detailed description is provided in NIR submission 2010 section 3.3.10
submission 2007/2008	Energy	27. The CO_2 IEF for diesel decreased due to the change in the mix of the different types of diesel in Sweden. The ERT recommends that Sweden provide explanations in its next NIR, together with the specific carbon content values of Swedish MK1 and MK3 diesel.	In submission 2010, these specific carbon content values are shown in Appendix 20.

[226] FCCC/IRR/2006/SWE and FCCC/ARR/2008/SWE

submission 2007/2008	Energy	30. The ERT recommends that Sweden provide specific information in its next NIR on how technology improvements influence the CH_4 EFs from biomass burning.	In submission 2010, extensive information on this issue is included in NIR Annex 2. Very detailed information is provided in Paulrud et al, 2005: Methane emissions from residential biomass combustion. This report can be provided to the ERT if required.
submission 2006	Energy	32 Methodology for Iron and steel industry	Addressed in submission 2010. Emissions have been revised for all years and reported in accordance with IPCC Guidelines (see NIR section 4.4.2.1.2.2)
submission 2007/2008	Energy and Industrial processes	28, 29, 33, 35, 36. Sweden uses a CS-method to estimate and allocate CO_2 emissions from pig iron production, not in line with the good practice guidance as this method allocates all CO_2 emissions to the output (i.e. the blast furnace), rather than using an input based CO_2 calculation method.	Addressed in submission 2010. Emissions have been revised for all years and reported in accordance with IPCC Guidelines (see NIR section 4.4.2.1.2.2)
submission 2007/2008	Industrial processes	37. Inconsistency in IEF since 2005 is not explained in the NIR. Sweden is encouraged to provide the time series for the content of calcium oxide (CaO) in clinker to validate the single average value (65%) for the whole period.	Addressed in submission 2010. Before 2005 the company used the default EF 0.525 for the estimates. From 2005, CO_2 emissions are based on analysis on the CaO content in the clinker. Data from 2008 and 2009 show a CaO content variation between 63.9 to 67.6%. See NIR 4.2.2.1
submission 2007/2008	Industrial processes	38. The ERT recommends that Sweden improves the transparency of the reporting of the methodology used to estimate the CO_2 removals in the pulp and paper industry.	Addressed in submission 2010. Reported data is revised in submission 2010. The revised time series affects reported activity data as well as CO_2 emission data. See NIR section 4.2.2.2
submission 2007/2008	Industrial processes	40. The ERT encourages Sweden to correct and improve its reporting in the NIR, and to improve the transparency of the applied approach by adding an allocation table of the annual amounts of limestone used and emissions for each category.	Reported data in 2A3 is revised in submission 2010. An allocation table is added in the NIR and activity and emission data is provided for 2005 - 2008. See NIR section 4.2.2.3
submission 2007/2008	Industrial processes	41. For CO_2 and N_2O from solvent and other product use, Sweden reported identical emission estimates for 2005 and 2006 in its 2008 submission. The ERT recommends that Sweden improve its data collection procedures in order to estimate final emissions in a timely manner.	Not implemented in submission 2010 but addressed in NIR section 5.1.3
submission 2006	Agriculture	52. Break in time series 1995	Addressed in submission 2010. In the footnote to Table 6.9 an explanation to this is added.

submission 2006	Agriculture	54. Background data on enteric fermentation for cattle in CRF tables not consistent with calculations.	Addressed in submission 2010. The paragraph concerning the method for the calculations of enteric fermentation has been revised
submission 2006	Agriculture	61. Sweden does not provide sufficient information in the NIR about the volatilization ratios of ammonia (NH_3) and nitrogen oxide (NO_X) from the use of synthetic fertilizers and the application of animal manure.	Reference in NIR section 6.3.3.3 is clarified in submission 2010
submission 2007/2008	Agriculture	46. The ERT recommends that Sweden re-examine the preparation of table 4.B(b) to ensure that it accounts for all N excretion for the estimation of N2O from manure management and for the quantification of N input for manure applied to soils and excretion on pasture range and paddock (table 4.Ds1). The ERT also recommends that Sweden ensure that its QA/QC procedures provide for accurate and correct completion of CRF tables in the agricultural sector.	This was due to a miscount that resulted in some incorrect activity data in submission 2009. It did, however, not affect the estimate of the actual emissions. This is corrected in submission 2010.
submission 2007/2008	Agriculture	51. The ERT recommends that Sweden ensure the consistency of information between CRF tables 4.B(b) and 4.D	This was a consequence of the error mentioned above and is thus corrected in submission 2010.
submission 2007/2008	Agriculture	52. Sweden does not provide sufficient information in the NIR on the volatilization ratios of ammonia (NH_3) and nitrogen oxide (NO_X) from the use of synthetic fertilizers, and the application of animal manure.	Reference in NIR section 6.3.3.3 is clarified in submission 2010.
submission 2006	LULUCF	70. Estimate CO_2 emissions from land converted to wetland.	Addressed in submission 2010. No longer reported unmanaged.
submission 2007/2008	LULUCF	55. The ERT recommends that Sweden improve the transparency of its inventory by providing all the necessary documentation and information in its future submissions, in accordance with the IPCC good practice guidance for LULUCF.	Figures have been introduced to make it easier for the reviewer to follow the quite complicated sample design use. The text is continuously improved. See NIR section 7.3.1.3. Estimators are moved to Appendix to NIR.
submission 2007/2008	LULUCF	56. The ERT recommends that Sweden consider the use of notation keys NO or IE either for gains or losses when the stock change method is applied.	Sweden is following this advice from submission 2010.
submission 2007/2008	LULUCF	60. The total area of organic soil reported in the LULUCF sector does not match the area of cultivated organic soils reported in the agriculture sector (CRF table 4.Ds1).	In submission 2010, the reporting of total cropland areas in the agriculture sector (CRF 4) has been revised to be consistent with the reporting in the LULUCF sector. The area of cultivated organic soils still differ due to differences in data sources. We will correct this inconsistency in submission 2011.

submission 2007/2008	LULUCF	63. Sweden reports a net carbon increase for the living biomass (except 1991) and dead organic matter pools for all years. The ERT recommends that Sweden provide an explanation for this trend in its next NIR in order to improve the transparency of its reporting.	The transparency in describing this issue has improved in submission 2010. See NIR section 7.1.
submission 2007/2008	LULUCF	66. With the exception of the years 2002, 2003 and 2005 Sweden reports a net carbon increase in living biomass associated with land-use change from forest land to grassland. The ERT recommends that Sweden provide an explanation for the outlined trend in its next NIR.	The transparency in describing this issue has improved in submission 2010. See NIR section 7.1.
submission 2007/2008	LULUCF	67. With the exception of the years 1992 and 2006, Sweden reports a net carbon increase in living biomass associated with land-use change from forest land to settlements. To improve the transparency, the ERT recommends that Sweden provide an explanation for the outlined trend in its next NIR.	The transparency in describing this issue has improved in submission 2010.
submission 2007/2008	LULUCF	68. Sweden has not been able to separate emissions from organic and mineral soils (CRF table 5 (III)). The ERT recommends that Sweden improve its methodology in order to be able to report the two soil categories separately.	Categories are reported separately in submission 2010.
submission 2006	Waste	75. The ERT recommends that Sweden provide further information on the utilization of gas recovery in its next NIR.	In submission 2010, the use of recovered gas are described in NIR section 8.2.1.1.1.
submission 2006	Waste	79. The ERT recommends that Sweden use the notation key “not estimated” (“NE”) for CH_4 emissions from wastewater treatment, instead of “included elsewhere” (“IE”), in CRF table 6.B.	In submission 2010, the notation key NE is reported for CH_4 emissions. See NIR section 8.3.2.2.2.
submission 2007/2008	Waste	72. The ERT recommends that Sweden include in its next NIR information on time series for industrial organic waste in order to provide a more complete picture of municipal solid waste AD.	No data are currently available, which has been further described in the NIR of submission 2010. See NIR section 8.2.1.3
submission 2007/2008	Waste	73. CO_2 emissions from solid waste disposal on land could be better reported using the notation key NO.	In submission 2010, the notation key NO is reported for CO_2 emissions. See NIR section 8.6
submission 2007/2008	Waste	74. CH_4 emissions from wastewater treatment have been reported as NE	In submission 2010, further description in this matter is provided in the NIR section 8.3.2.2.1
submission 2007/2008	Waste	75. The ERT recommends that Sweden change the notation key from IE to NE for the emissions from sludge resulting from treatment during the wastewater handling process.	In submission 2010, the notation key NE is reported for CH_4 emissions. See NIR section 8.3.2.2.2

submission 2007/2008	Waste	76. Clarifications on methodology Wastewater handling needed in NIR	In submission 2010, justifications have been made in NIR section 8.3.2
submission 2007/2008	Waste	80. CH_4 and N_2O emissions from waste incineration are reported as 'NE'. The ERT recommends that Sweden calculate these emissions (however insignificant) using IPCC default EFs, rather than wait for the outcome of actual measurements.	Estimates of N_2O and CH_4 emissions are included in submission 2010. See NIR section 8.3.2.3

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

Paulrud, S, Fridell, E, Stripple, H. Uppdatering av klimatrelaterade emissionsfaktorer. IVL report 2nd edition 2009

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.

Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories http://www.ipcc-nggip.iges.or.jp/public/gp/english/7_Methodological.pdf. 2009-10-07.

Kindbom, K., Boström, C-Å., Skårman, T., Gustafsson, T. and Talonpoika, M. 2003. Estimated Emissions of NMVOC in Sweden 1988-2001.

Skårman, Tina. et al., 2006, Revised Method for Estimating Emissions of NMVOC from Solvent and Other Product Use in Sweden. SMED Nr 18 2006.

The Swedish Chemicals Agency (KemI).

2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 3. Industrial Processes and Product Use Chapter 5: Non-Energy Products from Fuels and Solvent Use. http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_5_Ch5_Non_Energy_Products.pdf (2009-10-07)

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. Kalt-

schmitt (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 nötkreatursh̊llning (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.

Avfall Sverige, 2009. Swedish Waste Management 2008. Årsskrift från Avfall Sverige. Swedish Association of Waste Management. www.avfallsverige.se.

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.

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.

Statistics Sweden, 2008, Statistik för vattendistrikt och huvudavrinningsområden 2005 (Statistical data for water districts and main drainage area 2005), MI11SM0701, Korrigerad version,

Stockholm Vatten, 2004, Metanförluster vid avloppsreningsverken i Henriksdal och Bromma, rapport nr 22,

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.

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