National Inventory Report 2011 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 2011 and it is written in line with the guidlines of the Annotated outline of the National Inventory Report including reporting elements under the Kyoto Protocol. It contains national greenhouse gas emission inventories for the period 1990 to 2009, 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

(Summary in Swedish)

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. Det långsiktiga målet 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 2011. 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 2009, inklusive beskrivningar av metoder, datakällor, osäkerheter, den kvalitetssäkring och kvalitetsstyrning (QA/QC) som görs och en trendanalys.

De elektroniska data, såsom emissioner, aktivitetsdata och emissionsfaktorer som UNFCCC efterfrågar återfinns i CRF-tabeller tillsammans med denna rapport.

S 2. Sammanfattning av nationella utsläpp och upptag samt trender, inklusive KP-LULUCF

S 2.1 Växthusgaser

Totala utsläppet av växthusgaser i Sverige, uttryckt i koldioxidekvivalenter, var ca 59,8 miljoner ton år 2009 med ca 7 % osäkerhet (Tabell S 1), vilket är en minskning med ca 3,5 miljoner ton jämfört med 2008. Utsläppen har minskat med ca 17 %, eller ca 12,5 miljoner ton, mellan 1990 och 2009. Osäkerheten är beräknad till $\pm$ 2,4 % i trenden, dvs. minskningen ligger i intervallet 14,9-19,7 %. Sedan 1999 har de totala utsläppen av växthusgaser legat på lägre nivå än 1990.

Nettoupptaget för sektorn Markanvändning, Förändrad markanvändning och Skogsbruk (LULUCF) har beräknats till ca 40 miljoner ton koldioxidekvivalenter 2009 (Tabell S 1). Den årliga förändringen i sänkan är otroligt liten i förhållande till poolernas (levande biomassa, dött organiskt material och markkol) storlekar. Beräkningarna är på grund av detta behäftad med stora osäkerheter. Osäkerheterna tillsamman med metodutveckling kan ge stora utslag på de årliga värdena och mellan submissionerna.

Utsläppen av koldioxid var 46,6 miljoner ton år 2009 vilket är ca 17,7 % lägre jämfört med 1990 (Tabell S 1). Energisektorn, inklusive transporter, står för ca 92 % av de totala koldioxidutsläppen och är därmed den största källan till koldioxidutsläpp i Sverige. Koldioxid står för ca 78 % av de totala utsläppen av växthusgaser.

Metanutsläpp kommer framför allt från jordbruk och avfallsdeponier och var ca 5 miljoner ton 2009 räknat som koldioxidekvivalenter (Tabell S 1). Sedan 1990 har utsläppen av metan (CH_4) minskat med ca 25 %, vilket främst beror på åtgärder inom avfallssektorn och jordbruksektorn.

2009 var totala utsläppen av lustgas (N_2O) ca 7 miljoner ton räknat som koldioxidekvivalenter (Tabell S 1), vilket är en minskning med ca 16 % jämfört med 1990. Utsläpp av lustgas kommer huvudsakligen från jordbrukssektorn, men också från energiproduktion, industriprocesser och hantering av avloppsvatten. Jordbrukssektorn står för den största delen av minskningen.

Totala utsläppen av fluorerade gaser (PFCs, HFCs och SF_6) 2009 var ca 1 miljon ton uttryckt i koldioxidekvivalenter (Tabell S 1). Detta innebär en ökning av utsläppen med 115 % jämfört med 1990. Ökningen beror främst på att ozonförstörande ämnen ersatts av HFCs.

S 2.2 KP-LULUCF

Sverige rapporterar under Kyoto protokollet, artikel 3.3 och 3.4 för andra året i rad. För dessa aktiviteter har Sverige valt att bokföra för hela perioden (och ej på årsbasis). Aktiviteterna under artikel 3.3, nybeskogning /återbeskogning (AR), är ovanliga i Sverige. Sedan 2008 har arealen nybeskogad/återbeskogad mark inte ökat utan är konstant. Upptaget för alla poolerna har beräknats till 0,98 miljoner ton CO_2 ekvivalenter 2009. Andelen mark som avskogats, (D), har ökat något från 2008. Det totala utsläppet 2009 har beräknats till 3,52 miljoner ton CO_2 ekvivalenter. Under artikel 3.4 har Sverige valt bokföring för skogsbruk. För denna aktivitet är upptaget ca 43 miljoner ton CO_2 ekvivalenter 2009. Rapporteringen under Kyotoprotokollet artikel 3.3 och 3.4 harmonierar med UNFCCC rapporteringen för skogsmark och mark som konverterats till skogsmark (arean).

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

UTSLÄPP AV VÄXTHUS-GASER CO2 eq.(Gg)	CO_2 incl. net CO_2 from LULUCF	CO_2 excl. net CO_2 from LULUCF	CH_4 incl. CH_4 from LULUCF	CH_4 excl. CH_4 from LULUCF	N_2O incl. N_2O from LULUCF	N_2O excl. N_2O from LULUCF	HFCs	PFCs	SF_6	Total (incl. LULUCF)	Total (excl. LULUCF)
1990	11 157	56 646	6 817	6 816	8 416	8 336	4	377	107	26 878	72 286
1991	10 083	57 091	6 803	6 801	8 328	8 267	8	380	109	25 710	72 656
1992	14 213	56 917	6 890	6 888	8 228	8 176	10	252	108	29 702	72 352
1993	17 802	56 609	6 938	6 937	8 328	8 272	30	291	97	33 486	72 235
1994	18 978	59 122	6 862	6 860	8 390	8 333	74	312	100	34 716	74 801
1995	18 509	58 544	6 776	6 774	8 259	8 195	127	343	127	34 140	74 109
1996	20 521	62 044	6 741	6 740	8 386	8 321	204	303	108	36 263	77 720
1997	14 636	57 390	6 690	6 681	8 296	8 231	312	280	153	30 367	73 046
1998	16 040	58 091	6 516	6 515	8 282	8 217	385	272	99	31 595	73 580
1999	15 296	55 180	6 368	6 365	7 847	7 776	489	291	102	30 392	70 203
2000	12 751	53 913	6 186	6 183	7 775	7 701	564	241	94	27 611	68 696
2001	17 030	54 669	6 156	6 153	7 611	7 535	612	236	111	31 757	69 317
2002	16 606	55 714	5 980	5 975	7 528	7 454	665	261	104	31 145	70 174
2003	19 689	56 400	5 844	5 838	7 514	7 432	711	258	69	34 086	70 710
2004	23 809	55 786	5 865	5 860	7 498	7 411	774	254	81	38 280	70 165
2005	21 924	53 187	5 738	5 733	7 362	7 264	804	257	142	36 228	67 387
2006	22 155	52 924	5 654	5 641	7 425	7 319	835	245	111	36 425	67 076
2007	21 963	51 897	5 415	5 413	7 121	7 007	870	248	151	35 769	65 586
2008	19 577	49 876	5 207	5 194	7 194	7 067	912	225	84	33 198	63 358
2009	6 332	46 621	5 085	5 082	7 159	7 031	932	35	82	19 625	59 784

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

KÄLLOR TILL OCH SÄNKOR AV VÄXTHUSGASER CO2 equiv.	Energi	Industriprocesser	Användning av lösnings-medel och andra produk-ter	Jordbruk	Markanvändning, förändrad markan-vändning och skogsbruk	Avfall
1990	53 181	6 318	332	9 237	-45 408	3 217
1991	53 899	6 150	320	9 024	-46 946	3 263
1992	54 036	5 691	326	9 036	-42 650	3 263
1993	53 671	5 824	315	9 271	-38 750	3 154
1994	55 825	6 272	293	9 372	-40 085	3 039
1995	54 972	6 627	309	9 172	-39 969	3 029
1996	58 858	6 417	312	9 129	-41 457	3 004
1997	54 157	6 393	321	9 204	-42 680	2 971
1998	54 734	6 580	318	9 029	-41 985	2 919
1999	51 779	6 597	299	8 729	-39 811	2 799
2000	50 288	6 783	278	8 636	-41 085	2 712
2001	50 989	6 782	269	8 610	-37 560	2 667
2002	51 908	6 924	276	8 544	-39 029	2 522
2003	52 886	6 655	292	8 462	-36 624	2 414
2004	51 889	7 048	311	8 512	-31 885	2 405
2005	49 440	6 988	303	8 390	-31 159	2 266
2006	49 238	6 974	299	8 395	-30 651	2 170
2007	48 043	6 934	286	8 289	-29 817	2 035
2008	46 087	6 837	295	8 292	-30 159	1 846
2009	44 538	5 031	295	8 192	-40 159	1 727

S 3. Översikt över utsläppsberäkningar och trender sektorsvis, inklusive KP-LULUCF

S 3.1 Växthusgaser

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	
	-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 från energisektorn varierar på grund av temperatur- och nederbördsförhållanden samt det ekonomiska konjunkturläget men trenden för perioden 1990-2009 är minskande utsläpp. Utsläppen av växthusgaser från energisektorn inklusive transporter var ca 44,5 miljoner ton i koldioxidekvivalenter 2009 (Tabell S 2), vilket är ca 74 % av de totala utsläppen. Utsläpp av växthusgaser från trafiken ökade med 7 % från 1990 till 2009. Utsläppen av växthusgaser har under 2009 minskat som en följd av t ex den ekonomiska ned-

gången som inleddes hösten 2008. Utsläpp från individuell uppvärmning av byggnader fortsätter att minska beror främst på att användningen av olja för uppvärmning i bostads- och servicesektorn har minskat och att fjärrvärmen blir alltmer baserad på biobränslen. Detta innebär att energisektorn inklusive transporter har minskat sina utsläpp med ca 16 % år 2009 jämfört med 1990.

För industriprocesser är koldioxid den dominerande växthusgasen med 71 %, sedan kommer fluorerade växthusgaser med 21 % dikväveoxid med ca 8 % och metan med 0,2 %. Utsläppen kommer framför allt från produktion av järn och stål samt mineralindustrin. De totala utsläppen från industriprocesser var omkring 5 miljoner ton koldioxidekvivalenter år 2009 (Tabell S 2), vilket motsvarar drygt 8 % av totala utsläppen. Totala utsläppen från industriprocesser minskade med 1,8 miljoner ton koldioxidekvivalenter eller ca 26 % mellan 2008 och 2009. De minskade utsläppen 2009 beror främst på en minskad produktion främst inom metallindustrin till följd av den ekonomiska nedgången som startade 2008 och fördjupades 2009.

Sedan 1990 har de totala utsläppen i denna sektor varierat, vilket framför allt beror på att produktionsvolymerna varierar med ekonomiska cykeln. 2009 var utsläppen 20 % lägre än 1990.

Användningen av Lösningsmedel och andra produkter ger huvudsakligen upphov till utsläpp av flyktiga organiska ämnen (VOCs), lustgas (N_2O) och en del koldioxid. 2009 var utsläppen av koldioxid och lustgas knappt 0,3 miljoner ton uttryckt i koldioxidekvivalenter (Tabell S 2), vilket utgör ca 0,5 % av de totala växthusgasutsläppen. Jämfört med 1990 har utsläppen i denna sektor minskat med 11 %. Omkring 21 % 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 lustgas och metan. 2009 var de totala utsläppen från jordbrukssektorn knappt 8,2 miljoner ton uttryckt i koldioxidekvivalenter (Tabell S 2) varav drygt 60 % utgjordes av N_2O och nästan 40 % av CH_4. Det är en minskning med ca 11 % jämfört med 1990. Utsläpp av metan kommer framför allt från boskapens matsmältningsprocesser och fekalier. De viktigaste anledningar till de minskade utsläppen är en minskad boskapshållning och en minskad tillämpning av mineralgödsel-medel 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.

Beräkningarna av nettoupptaget för sektorn markanvändning, förändrad markanvändning och skogsbruk, LULUCF under 2009 visar på en större nettosänka jämfört med föregående år (Tabell S 2). Ökningen av sänkans storlek beror både på den metodik som används, revidering av arealen för jordbruksmarken och mindre skogsavverkning som en följd till den ekonomiska nedgången. Under 2009 var det endast 20 % av provytorna som inventerats för att beräkna sänkan. Det innebär att underlaget för statistiska beräkningar av sänkans storlek har en stor inbyggd osäkerhet och beräkningar för kommande år kan ge betydligt förändrade resultat.

Av avfallssektorns utsläpp under 2009 dominerar metanutsläppen från avfallsdeponier med ca 79 % medan lustgas från avloppsvatten står för 9 % och koldioxidutsläppen från förbränning av farligt avfall för 6%. 2009 var de totala utsläppen från avfallssektorn drygt 1,7 miljoner ton (Tabell S 2) uttryckt i koldioxidekvivalenter, vilket motsvarar knappt 3 % av de totala utsläppen. Utsläppen från sektorn har minskat med 46 % jämfört med 1990. Utvinning av deponigas, deponiförbud och deponiskatter är huvudorsakerna till utsläpps-minskningen.

Totala utsläpp av växthusgaser uppgick 2009 till ca 59,8 miljoner ton koldioxidekvivalenter varav utsläpp ej inkluderade i utsläppshandel stod för 42,3 miljoner ton. Detta innebär att de svenska utsläppen år 2009 var 17 % lägre än för basåret vilket innebär att Sverige kommer att kunna uppfylla sina åtaganden med god marginal.

S 3.2 KP-LULUCF

I och med att aktiviteterna under artikel 3.3 (beskogning och avskogning) är ovanliga är det svårt att uttala sig om skillnader mellan år. Nettoupptag respektive emissioner ligger på ungefär samma nivåer som 2008.

När det gäller aktiviteten skogsbruk under artikel 3.4 så har nettoinlagringen ökat jämfört med 2008. Framförallt beroende på att avverkningarna har minskat.

S 4. Översikt av utsläppsberäkningar och trender för indirekta växthusgaser och SO2

Utsläpp av flyktiga organiska ämnen (NMVOC) var ca 180 kton 2009 (Tabell S 4), vilket är en minskning med 49 % 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	2009
NO_X	303	308	294	274	280	267	260	245	234	224	212	202	196	191	182	175	170	164	155	150
CO	939	959	930	886	890	868	840	789	723	699	666	627	611	614	584	582	550	544	533	536
NMVOC	353	307	291	267	259	247	240	229	217	209	200	188	186	188	186	184	182	183	181	180
SO_2	105	101	94	82	80	69	67	60	56	47	42	41	40	41	37	36	36	33	30	30

Utsläppen av kväveoxider (NOx) var ca 150 kton 2009 (Tabell S 4), vilket är en minskning med ca 50 % jämfört med 1990. Vägtrafikens utsläpp av NOx har minskat med 62 % mellan 1990 och 2009 och med 5 % mellan 2008 och 2009. 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 536 kton 2009 (Tabell S 4), en reducering på ca 43 %. Omkring 96 % av utsläppen kommer från energisektorn varav 40 % kommer från transport.

Utsläppen av svaveldioxid (SO_2) har minskat från 105 kton 1990 till knappt 30 kton 2009 (Tabell S 4), en reducering på ca 72 %. 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 (GHG) 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 2011 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 2009, 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 and emission factors in the Common Reporting Format (CRF) requested by the UNFCCC are provided together with this report.

ES 2. Summary of National Emissions and Removal Related Trends, including KP-LULUCF

ES.2.1 GHG inventory

Total greenhouse gas emissions in Sweden, expressed in carbon dioxide equivalents, were about 59,8 million tonnes for 2009 with an uncertainty of about 7 % (Table ES 1), which is a decrease of 3,5 million tonnes compared to 2008. Emissions have fallen by about 17 % or approximately 12,5 million tonnes between 1990 and 2009. The uncertainty in the trend is a percentage point range relative to the inventory trend and should be interpreted as ± 2.4 %,

that is emissions have decreased by 14.9% - 19.7 %. Aggregated emissions varied over the period but were in all cases below the 1990 level during the period 1999-2009.

The net uptake of the land use, land-use change and forestry (LULUCF) has been estimated at 40 million tonnes carbon dioxide equivalent in 2009 (Table S1). The annual change of the sink is very small compared to the size of pools (living biomass, dead organic matter and land-based carbon). For this reason, the estimations are associated with uncertainties. The uncertainties and change of methods can result in substantial effects on the annual values and between different submissions.

Emissions of CO_2 were around 46,6 million tonnes in 2009, which is about 17,7 % lower than in 1990 (Table ES 1). About 92 % of total carbon dioxide emissions comes from the energy sector, including transport, which is the largest source of carbon dioxide in Sweden. Carbon dioxide's share of the total GHG emissions is approximately 78 %.

Emissions of methane (CH_4) arise mainly from agriculture and landfill sites, and in 2009 were approximately 5 million tonnes, expressed in CO_2-equivalents (Table ES 1). Since 1990, emissions have decreased about 25 %, primarily due to measures implemented in the waste sector and agriculture.

In 2009, the total emissions of nitrous oxide (N_2O) were around 7 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 agricultural sector accounts for the bulk of N2O decline.

Total emissions of fluorinated gases (PFCs, HFCs and SF_6) in 2009 were approximately 1 million tonnes expressed in carbon dioxide equivalents (Table ES 1). This corresponds to an increase of about 115 % compared to 1990. The increase is due to the replacement of the ozone-depleting substances by HFCs.

ES.2.2 KP-LULUCF activities

This is the second year in which Sweden reports under the Kyoto Protocol, Article 3.3 and 3.4. For these activities, Sweden has chosen to report the entire period but not on an annual basis.

The activities under Article 3.3, Afforestation/Reforestation (AR), are uncommon in Sweden. Since 2008, the areas of the newly afforested / reforested land have not increased but it remained constant. In 2009, the uptake of all pools was estimated at 0.98 million tonnes CO_2. The proportion of land that is deforested (D) has slightly increased compared to 2008. The total emission in 2009 was estimated at 3.52 million tonnes CO_2.

Sweden has chosen to account the part of Article 3.4 of the Kyoto Protocol that relates to forestry, in which the uptake in 2009 was about 43 million tonnes CO_2. Reporting under Kyoto Protocol Article 3.3 and 3.4 is harmonized with the UNFCCC reporting for forest and land converted to forest land.

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

GREENHOUSE GAS EMISSIONS CO2 eq.(Gg)	CO_2 incl. net CO_2 from LULUCF	CO_2 excl. net CO_2 from LULUCF	CH_4 incl. CH_4 from LULUCF	CH_4 excl. CH_4 from LULUCF	N_2O incl. N_2O from LULUCF	N_2O excl. N_2O from LULUCF	HFCs	PFCs	SF_6	Total (incl. LULUCF)	Total (excl. LULUCF)
1990	11 157	56 646	6 817	6 816	8 416	8 336	4	377	107	26 878	72 286
1991	10 083	57 091	6 803	6 801	8 328	8 267	8	380	109	25 710	72 656
1992	14 213	56 917	6 890	6 888	8 228	8 176	10	252	108	29 702	72 352
1993	17 802	56 609	6 938	6 937	8 328	8 272	30	291	97	33 486	72 235
1994	18 978	59 122	6 862	6 860	8 390	8 333	74	312	100	34 716	74 801
1995	18 509	58 544	6 776	6 774	8 259	8 195	127	343	127	34 140	74 109
1996	20 521	62 044	6 741	6 740	8 386	8 321	204	303	108	36 263	77 720
1997	14 636	57 390	6 690	6 681	8 296	8 231	312	280	153	30 367	73 046
1998	16 040	58 091	6 516	6 515	8 282	8 217	385	272	99	31 595	73 580
1999	15 296	55 180	6 368	6 365	7 847	7 776	489	291	102	30 392	70 203
2000	12 751	53 913	6 186	6 183	7 775	7 701	564	241	94	27 611	68 696
2001	17 030	54 669	6 156	6 153	7 611	7 535	612	236	111	31 757	69 317
2002	16 606	55 714	5 980	5 975	7 528	7 454	665	261	104	31 145	70 174
2003	19 689	56 400	5 844	5 838	7 514	7 432	711	258	69	34 086	70 710
2004	23 809	55 786	5 865	5 860	7 498	7 411	774	254	81	38 280	70 165
2005	21 924	53 187	5 738	5 733	7 362	7 264	804	257	142	36 228	67 387
2006	22 155	52 924	5 654	5 641	7 425	7 319	835	245	111	36 425	67 076
2007	21 963	51 897	5 415	5 413	7 121	7 007	870	248	151	35 769	65 586
2008	19 577	49 876	5 207	5 194	7 194	7 067	912	225	84	33 198	63 358
2009	6 332	46 621	5 085	5 082	7 159	7 031	932	35	82	19 625	59 784

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

GHG SOURCE AND SINK CATEGORIES CO2 equiv.	Energy	Industrial Processes	Solvent and Other Product Use	Agriculture	Land Use, Land-Use Change and Forestry	Waste
1990	53 181	6 318	332	9 237	-45 408	3 217
1991	53 899	6 150	320	9 024	-46 946	3 263
1992	54 036	5 691	326	9 036	-42 650	3 263
1993	53 671	5 824	315	9 271	-38 750	3 154
1994	55 825	6 272	293	9 372	-40 085	3 039
1995	54 972	6 627	309	9 172	-39 969	3 029
1996	58 858	6 417	312	9 129	-41 457	3 004
1997	54 157	6 393	321	9 204	-42 680	2 971
1998	54 734	6 580	318	9 029	-41 985	2 919
1999	51 779	6 597	299	8 729	-39 811	2 799
2000	50 288	6 783	278	8 636	-41 085	2 712
2001	50 989	6 782	269	8 610	-37 560	2 667
2002	51 908	6 924	276	8 544	-39 029	2 522
2003	52 886	6 655	292	8 462	-36 624	2 414
2004	51 889	7 048	311	8 512	-31 885	2 405
2005	49 440	6 988	303	8 390	-31 159	2 266
2006	49 238	6 974	299	8 395	-30 651	2 170
2007	48 043	6 934	286	8 289	-29 817	2 035
2008	46 087	6 837	295	8 292	-30 159	1 846
2009	44 538	5 031	295	8 192	-40 159	1 727

ES 3. Overview of Source and Sink Category Emission Estimates and Trends, including KP-LULUCF

ES.3.1 GHG inventory

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	
	-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 44,5 million tonnes, expressed as carbon dioxide equivalents, in 2009 (Table ES 2), which is equivalent to 74 % of the total emissions. From 1990 to 2009 there was 7 % increase of greenhouse gas emissions from road traffic. However, the increasing trend has been moderated since 2003. In 2009 the greenhouse gases 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, mainly due to a decrease in use of oil for heating in residential and service sector, and that district heating is now increasingly based on biofuels. This means that the energy sector, including transport, has decreased its GHG emissions with about 16 % in 2009 compared to 1990.

For industrial processes, the most dominant greenhouse gas is carbon dioxide contributing 71%, followed by the fluorinated greenhouse gases by 21%, nitrous oxide by about 8% and methane by 0.2%.

Emissions from industrial processes are primarily derived from the production of iron and steel. The total emission in 2009 were approximately 5 million tonnes expressed as carbon dioxide equivalents (Table ES 2), which is approximately 8 % of the total emissions. The total emissions decreased by 1.8 million tonnes of carbon dioxide equivalents or about 26% between 2008 and 2009. The reduction in 2009 was primarily due to a decline mainly in metal production, reflecting the economic downturn that started in 2008 and deepened in 2009.

Since 1990, total emissions in this sector have varied, primarily because production volumes vary with economic cycles. In 2009 emissions were 20 % lower than in 1990.

The use of Solvents and Other products mainly gives rise to emissions of volatile organic substances (VOCs), nitrous oxides and some carbon dioxide. In 2009, emissions of carbon dioxide and nitrous oxide expressed in carbon dioxide equivalents were almost 0.3 million tonnes (Table ES 2), which corresponds to about 0,5 % of the total greenhouse gas emissions. Compared to 1990, emissions have decreased with about 11 %. Almost 21 % of carbon dioxide emissions arise from paint application, even though these emissions have decreased due to a transition to water-based paints.

Agriculture is the largest source of emissions of methane and nitrous oxide. In 2009, total greenhouse gas emissions expressed in carbon dioxide equivalents were 8,2 million tonnes (Table ES 2) in which more than 60% consisted of nitrous oxide and nearly 40 % of methane. The emissions decreased 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.

Estimates of the net removal by sink of the land use, land-use change and forestry, LULUCF in 2009, shows a greater net increase amounting to 40 million tonnes of carbon dioxide equivalents compared with the previous year (Table ES2). The increase in sink size depends both on the methodology used, revision of the arable land acreage, and decreased felling, due to the economic slowdown are probably reasons for this increase. During the inventory year 2009, only 20 % of the surface samples were inventoried to calculate to the sink. This means that the basis for statistical estimates of the size of the sink has a large built-in uncertainty, and estimates for future years can significantly change results. In view of this un-

certainty, there is a tendency that the size of the sink decreased over the period 1990-2009.

Waste sector emissions in 2009 is dominated by methane emissions from landfills by about 79 %, while nitrous oxide emissions from waste water accounts for 9 % and carbon dioxide emissions from the incineration of hazardous waste is 6%. In 2009, the total emissions from the waste sector were about 1,7 million tonnes (Table ES 2) expressed as carbon dioxide equivalents or about 3 % of the total GHG emissions. This is a reduction by 46 % 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.

The total emissions of greenhouse gases in 2009 were 59.8 million tonnes expressed as carbon dioxide equivalents and the emissions that come from sectors outside the trading system were 42.3 million tonnes. This means that emissions in Sweden in 2009 were 17 % below the base year emissions, which indicates that Sweden will comfortably fulfil its commitment.

ES.3.2 KP-LULUCF activities

As the activities under Article 3.3 (afforestation, reforestation and deforestation) are uncommon in Sweden, it is difficult to draw any conclusions on the differences between years. Net uptakes and emissions 2009 were approximately at the same levels as 2008.

Net removals related to Forest management under Article 3.4, increased compared to 2008. This is mainly an effect of reduced fellings.

ES 4. Overview of Emission Estimates and Trends of Indirect GHGs and SO2

Emissions of volatile organic compounds (NMVOC) were 180 ktonnes in 2009 (Table ES 4), a decrease of 49 % compared to 1990. The main contributors to NMVOC emissions are road traffic, wood combustion in the residential sector and solvents- containing 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	2009
NO_X	303	308	294	274	280	267	260	245	234	224	212	202	196	191	182	175	170	164	155	150
CO	939	959	930	886	890	868	840	789	723	699	666	627	611	614	584	582	550	544	533	536
NMVOC	353	307	291	267	259	247	240	229	217	209	200	188	186	188	186	184	182	183	181	180
SO_2	105	101	94	82	80	69	67	60	56	47	42	41	40	41	37	36	36	33	30	30

Emissions of nitrogen oxides (NO_x) were about 150 ktonnes in 2009 (Table ES 4), a reduction of 50 % compared to 1990. Road traffic emissions of NOx have decreased by 62% between 1990 and 2009 and by 5% between 2008 and 2009.The largest sources of emissions of nitrogen oxides are road traffic, mobile machinery,

maritime transport and electricity and heating production. In areas where 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 536 ktonnes in 2009 (Table ES 4), a reduction of about 43 %. About 96 % of emissions come from energy sector of which 40 % comes from transport.

Emissions of sulphur dioxide (SO_2) have decreased from 105 ktonnes in 1990 to about 30 ktonnes in 2009 (Table ES 4), a reduction of about 72 %. 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.

PART 1: ANNUAL INVENTORY SUBMISSION 2011

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 2011. The report contains information on Sweden's inventories for all years from 1990 to 2009 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 Climate change

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 16 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.

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

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

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

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

Compared with carbon dioxide, all other greenhouse gases occur at very low concentrations. Per molecule, however, these substances are much more effective as greenhouse gases than carbon dioxide, which means that they still make a considerable contribution to the greenhouse effect. Furthermore, some of the fluorine

[1] 2002/358/EG

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.

1.1.2 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. 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.

1.1.3 Supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol

Sweden provides supplementary information under Article 7 of the Kyoto Protocol for the Land Use, Land-Use Change and Forestry sector. The inventory for Kyoto protocol activities encompass emissions/ removals originating from the activities Afforestation and Reforestation (AR), Deforestation (D) and Forest management (FM) under article 3.3 and 3.4 under the Kyoto protocol, respectively. FM covers a major part of the Swedish land area whereas ARD are quite uncommon in Sweden.

To a large extent the KP-reporting of FM and AR harmonize with the UNFCCC-reporting of Forest land and land converted to Forest land. Small discrepancies occur regarding the accumulation of reported land areas as described in chapter 11.

In addition to the reporting of carbon pool changes, direct N_2O emissions from N fertilization and emissions from forest fires are reported under FM. Forest fires – both natural and wildfires – are uncommon and, this far, has not been registered on AR-land.

N_2O emissions from disturbance associated with land use conversion from Forest land to Cropland are reported under D.

1.2 Institutional arrangements

1.2.1 Overview of institutional, legal and procedural arrangements for compiling GHG inventory and supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol

The inventory system currently used in Sweden is presented in Figure 1.1. The Swedish Ministry of Environment is the single national entity and 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) conducts the inventory and reporting under a framework contract between the Swedish Environmental Protection Agency and SMED. The contract runs from 2005 and for nine years and thus covers the first commitment period under the Kyoto Protocol. SMED is 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).

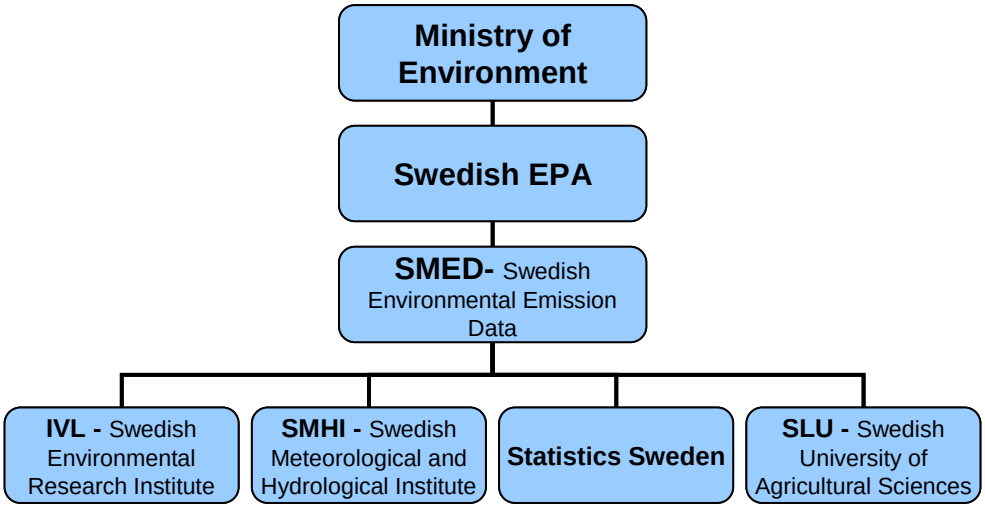

Figure 1.1. The Swedish inventory system.

A national system meeting the requirements laid down in article 5.1 of the Kyoto Protocol has been developed and is confirmed as Ordinance (2005:626) Concerning Climate Reporting. This ordinance provides the basis for the national system and describes the roles and responsibilities of the government agencies in the context of climate reporting. The Swedish National System is further described in Annex 6:1.

1.2.2 Overview of inventory planning

The national system, as described in Annex 6:1, ensures annual preparation and reporting of the national inventory and of supplementary information in a timely manner. Sufficient capacity for timely performance is ensured by the arrangement of responsibilities between government agencies in ordinance 2005:626, and through the framework contract with the SMED consortium of technical experts compiling the inventory.

Planning of the inventory is done on the basis of requirements and guidelines, adapted to national quality objectives. Results and comments from independent review and from national evaluation of the inventory and process of inventory preparation are taken into consideration in the annual activity planning, as well as general good practice on how to prioritise resources in inventory production.

1.2.3 Overview of inventory preparation and management, including for supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol

The Swedish greenhouse gas inventory preparation and management is guided by the National System as described in Annex 6:1 and by the quality system described in Annex 6:2.

The illustration below, also provided in Annex 6:1, shows a process description of the annual Swedish inventory and reporting activity.

SMED					SWEDISH ENVIRONMENTAL PROTECTION AGENCY		MINISTRY OF ENVIRONMENT	UNFCCC SECRETARIAT
Jan-June	**April-Aug**	**Aug-Sept**	**Sept-Oct**	**15 Oct**	**15 Oct - 1 Nov**	**15 Dec**	**15/1 EU, 15/4 UNFCCC**	**May-Sept**
Development projects	Data collection	Calculations	Preparation of the reporting	Report to Swedish EPA	National peer review	Report to Ministry of Environment	Report to EU/UNFCCC	International peer review

The quality system follows the overarching structure of the PDCA-cycle, plan, do check, act. Each step of this cycle, in the context of the quality system as part of the national system, is described further in Annex 6:2.

Planning of the inventory (plan) is done on the basis of requirements and guidelines, adapted to national quality objectives. Preparation of the inventory (do) is done according to detailed work documentation, which fulfils several objectives. This documentation serves the purpose of instructions for inventory compilers to ensure quality and consistency, and also serves as information in the national independent review process. Inventory checking (check) is performed in several steps, and includes tier 1 and ties 2 quality control according to IPCC Good Practice Guidance. Quality assurance comprises national peer review under the responsibility of the Swedish EPA, as well as the international review by independent experts under the UNFCCC. Follow-up and continuous improvement of the inventory (act) is done by taking comments and recommendations from the independent reviews into consideration and by an annual evaluation of the inventory and inventory

preparation process. The results of this follow-up provides the basis for the Swedish EPA´s planning of next year's inventory and reporting.

1.3 Inventory preparation

1.3.1 GHG inventory and KP-LULUCF inventory

The present Swedish greenhouse gas inventory for the period 1990 to 2009 was compiled according to the recommendations for inventories set out in the UNFCCC reporting guidelines according to Decision 18/CP.8, the Common Reporting Format (CRF), Decision 13/CP.9, the new CRF for the Land Use Change and Forestry Sector, the IPCC 1996 Guidelines for National Greenhouse Gas Inventories, which specify the reporting obligations according to Articles 4 and 12 of the UNFCCC (IPCC Guidelines, 1997) as well as the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC GPG, 2000) and the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC GPG-LULUCF, 2003).

During the inventory preparation process, sector experts collect activity data, emission factors and all relevant information needed for finally estimating emissions. The sector experts also have specific responsibilities regarding the choice of methods and data processing Sector experts are also responsible for performing Quality Control (QC) activities that are incorporated in the quality system.

1.3.2 Data collection, processing and storage, including for KP-LULUCF inventory

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.

1.3.2.1 DATA COLLECTION AND PROCESSING

A short description of data collection and processing for each chapter is described below.

1.3.2.1.1 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.

1.3.2.1.2 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.

1.3.2.1.3 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.

1.3.2.1.4 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.

1.3.2.1.5 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.

1.3.2.1.6 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.

1.3.2.1.7 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.

1.3.2.2 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 1990-2009 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.

1.3.3 QA/QC procedures and extensive review of GHG inventory and KP-LULUCF inventory

The KP-reporting of LULUCF uses the same institutional arrangements, national system and corresponding QA/QC procedures as for the UNFCCC reporting.

Emissions reported under Article 3, paragraph 3 and 4 are not overlapping with emissions reported under Annex A of the Kyoto protocol.

1.4 Brief general description of methodologies and data sources used

1.4.1 GHG inventory

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 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.

[2] See Annex 8.1
[3] See Annex 8.3
[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

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 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 in Appendix 3.

1.4.2 KP-LULUCF inventory

The same base methodology, emission factors and data sources is used for the reporting of LULUCF under the KP as for the reporting under UNFCCC.

Data from the Swedish National Forest Inventory (NFI) have been used for developing the land use matrix and is consistent with the data used for developing the land use matrix under the UNFCCC-reporting. The main difference is that activities are reported under the KP while land use categories are reported under the UNFCCC.

The carbon pool changes associated to the activities reported under the Kyoto protocol is estimated in exactly the same way as under the UNFCCC reporting, using the stock change method and area based sampling for most of the carbon pools. However, the living biomass is reported separately for aboveground and belowground biomass, respectively, and the Dead organic matter is reported separately for Litter and Dead wood.

1.5 Brief description of key categories, including for KP-LULUCF key categories

1.5.1 GHG inventory (including and excluding LULUCF)

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 1 and in CRF table 7. Corresponding background tables, according to tables 7.A1 - 7.A3 of the Good Practice Guidance are presented in Appendix 2. The methodology is discussed in detail in Annex 1.

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

1.5.2 Level assessment excluding LULUCF

The level assessment excluding LULUCF for 2009 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 2009. They contribute with 31.6 % and 12.6 %, respectively, of the national total and are the top two on the level assessment list for all years.

Table 1.2. Key categories 2009 in terms of level assessment, excluding LULUCF

IPCC category	GHG	Emissions 2009 Gg CO_2 eq	Contribution to the national total emissions 2009
1A3b. Road Transportation	CO_2	18 899	31.6%
1A1a. Public electricity and Heat production	CO_2	7 551	12.6%
1A2f. Other Manufacturing Industries and Construction	CO_2	4 114	6.9%
4A. Enteric Fermentation	CH_4	2 697	4.5%
4D1. Direct Soil Emissions	N_2O	2 412	4.0%
1A1b. Petroleum Refining	CO_2	2 092	3.5%
1A4c. Agriculture/Forestry/Fisheries	CO_2	1 643	2.7%
1A2d. Pulp, Paper and Print	CO_2	1 369	2.3%
6A. Solid Waste Disposal on Land	CH_4	1 367	2.3%
2C1. Iron and steel production	CO_2	1 334	2.2%
2A1. Cement production	CO_2	1 289	2.2%
1A2a. Iron and Steel	CO_2	1 123	1.9%
1A2c. Chemicals	CO_2	1 062	1.8%
4D3. Indirect Emissions	N_2O	1 055	1.8%
1A4b. Residential	CO_2	1 027	1.7%
1B2. Oil and Natural Gas	CO_2	898	1.5%
2F1. Refrigeration and Air Conditioning Equipment	HFCs	861	1.4%
4D4. Other	N_2O	729	1.2%
1A4a. Commercial/Institutional	CO_2	641	1.1%
1A3a. Civil Aviation	CO_2	532	0.9%
1A3d. Navigation	CO_2	500	0.8%
1A2e. Food Processing, Beverages and Tobacco	CO_2	487	0.8%
4B. Manure Management	CH_4	465	0.8%
4B. Manure Management	N_2O	442	0.7%
1A1a. Public electricity and Heat production	N_2O	425	0.7%
4D2. Pasture, Range and Paddock manure	N_2O	392	0.7%
2A2. Lime production	CO_2	390	0.7%
1A2f. Other Manufacturing Industries and Construction	N_2O	315	0.5%
2B2. Nitric Acid production	N_2O	305	0.5%
1A1c. Manufacture of Solid Fuels and Other Energy Industries	CO_2	254	0.4%
1A5b. Mobile	CO_2	237	0.4%

1.5.3 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 2009, 29 key categories in terms of trend have been identified, excluding LULUCF (Table 1.3). The Energy Sector (CRF 1) contributes with the majority (15 categories) of categories, while Industrial Processes (CRF 2), Agriculture (CRF 4) and Waste (CRF 6) account for 6, 6and 2 categories, respectively.

In 2009, the sources with the most significant increase in trend since 1990 are CO_2 from Road transport (1A3b), followed by CO_2 from Public electricity and Heat production (1A1a), contributing with 21.7 % and 6.4 % 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 2009 contributing 19.5 % and 6.9 % 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 4.8 % contribution.

Table 1.3. Key categories 2009 in terms of trend assessment, excluding LULUCF

IPCC category	GHG	Emissions 1990	Emissions 2009	Contribution to the emission trend 1990-2009
		Gg CO_2 eq	Gg CO_2 eq	
1A3b. Road Transportation	CO_2	17 309	18 899	21.7%
1A4b. Residential	CO_2	6 220	1 027	19.5%
1A4a. Commercial/Institutional	CO_2	2 533	641	6.9%
1A1a. Public electricity and Heat production	CO_2	7 493	7 551	6.4%
6A. Solid Waste Disposal on Land	CH_4	2 874	1 367	4.8%
2F1. Refrigeration and Airconditioning Equipment	HFCs	3	861	4.1%
2C1. Iron and Steel Production	CO_2	2462	1334	3.3%
1B2. Oil and Natural Gas	CO_2	304	898	3.1%
1A1b. Petroleum Refining	CO_2	1 778	2 092	2.9%
1A2f. Other Manufacturing Industries and Construction	CO_2	5 670	4 114	2.7%
1A2d. Pulp, Paper and Print	CO_2	2 186	1 369	2.1%
1A5b. Mobile	CO_2	801	237	2.0%
1A4c. Agriculture/Forestry/Fisheries	CO_2	1536	1643	1.8%
2B2. Nitric Acid Production	N_2O	814	305	1.7%
1A2e. Food Processing, Beverages and Tobacco	CO_2	948	487	1.4%
2C3. Aluminium Production	PFCs	377	33	1.3%
2A1. Cement Production	CO_2	1 272	1 289	1.1%
1A2a. Iron and Steel	CO_2	1 638	1 123	1.1%
4B. Manure Management	CH_4	349	465	0.8%
1A1a. Public electricity and Heat production	N_2O	304	425	0.8%
4A. Enteric Fermentation	CH_4	3 058	2 697	0.8%
4B. Manure Management	N_2O	728	442	0.8%
2C2. Ferroalloys Production	CO_2	243	48	0.7%
2A2. Lime Production	CO_2	295	390	0.7%
4D4. Other	N_2O	719	729	0.6%
1A2c. Chemicals	CO_2	1 128	1 062	0.6%
4D1. Direct Soil Emissions	N_2O	2 783	2 412	0.5%
4D2. Pasture, Range and Paddock Manure	N_2O	379	392	0.4%
6C. Waste Incineration	CO_2	44	108	0.3%

1.5.4 Level and trend assessment including LULUCF

Table 1.4 shows the additional LULUCF-key categories 2009 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), Grassland (5C) and Settlements (5E). One reason for this is that these pools are important (level). Another reason is changes in harvest intensity and this may lead to high fluctuations in stocks between years (trend). Emissions of CH_4 and/or N_2O were never found to be key.

Table 1.4. Additional key categories when including the LULUCF sector 2009 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 2009	Contribution to the level of national total emissions/-removals, including LULUCF 2009	Contribution to the trend of emissions/removals, including LULUCF 1990-2009
		Gg CO_2 eq	Gg CO_2 eq		
5A. Forest land	CO_2	-48077.85	-44490.09	40.5%	27.4%
5E. Settlements	CO_2	1249.80	2766.00	2.5%	5.4%
5B. Cropland	CO_2	2406.90	1945.97	1.8%	0.6%
5C. Grassland	CO_2	-1107.86	-573.17	0.5%	0.7%

1.5.5 KP-LULUCF inventory

The key category assessment for KP-LULUCF is found in section 11.6.1. 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.

Activities Forest management, Afforestation/ Reforestation and Deforestation were considered key-categories (CO_2). Every key-category is estimated using Tier 3.

1.6 Information on QA/QC

In this section roles and responsibilities in relation to quality assurance and quality control (QA/QC) is described as well as the QA/QC process.

1.6.1 QA/QC procedures

1.6.1.1 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. See Annex 6:2.

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

1.6.1.2 DESCRIPTION OF THE QA/QC SYSTEM

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

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

1.6.1.3 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.

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.

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. In order to check activity data and EF, several quality control projects have been carried out over time comparing the inventory data with information from environmental reports and EU ETS data.
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.
2C1	Iron and steel production	Activity data are checked with fuel combustion data in order to avoid double counting of emissions. Activity data is also compared to trade statistics. IEF are compared to IPCC default values.
2C3	PFC emissions from aluminum production	Documented process information obtained directly from the company enable plant-specific data checks.
2F	Consumption of halocarbons and SF_6	Differences between country specific emission factors and default emission factors from IPCC Guidelines are documented.

1.6.2 Verification activities

Key categories should be subject to external peer review according to the Tier 2 of the Good Practice Guidance. The Swedish 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.

1.6.2.1 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.

1.6.3 Treatment of confidentiality issues

In the inventory, several data sources are confidential at micro level (e.g. plant level). This is for example the case for statistical surveys of fuel consumption used in Energy (CRF 1) and data from the Products Register at the Swedish Chemicals Agency used in Solvent and other product use (CRF 3). Results published in the inventory are aggregated, and because of this no confidentiality issues remains in the CRF or in the NIR.

1.7 General uncertainty evaluation

1.7.1 GHG inventory

An uncertainty analysis has been performed according to the Tier 1 method, described in detail in Annex 7 and Good Practice Guidance section 6.3.2. The analysis has been performed both including LULUCF and excluding LULUCF. 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, LULUCF 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 2009 for direct greenhouse gases, e.g. CO_2, CH_4, N_2O and F-gases.

When reporting the results in the NIR,uncertainties are presented on the same aggregation level as the key categories. The purpose is to facilitate combined use of the two analyses, since both aims at showing what parts of the inventory are especially important and/or weak. This is very important information when planning future inventories and, above all, using and evaluating the inventory results.

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

[10] Gustafsson, 2005

In conjunction with the Tier 1 uncertainty calculations of emission levels for 1990 and 2009, uncertainty introduced to the trend 1990-2009 is calculated following the IPCC Tier 1 method.

1.7.1.1 RESULTS

The results of the uncertainty calculations according to the Tier 1 uncertainty approach are presented in Annex 7. The overall uncertainty for 2009 CO_2 equivalent emissions in Sweden is calculated to be ±7.1%, excluding LULUCF. This figure 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 different. The uncertainty including LULUCF is higher (±10.7%), and this is an effect of large and relatively uncertain carbon sinks.

It could be noted that estimated overall uncertainty in submission 2010, excluding LULUCF, was 6.1 % for 2008, which means that the estimated overall uncertainties are higher in this submission. The trend of national total greenhouse gas emissions excluding LULUCF 1990-2009 in Sweden is associated with an uncertainty of 2.4 % (compared to 2.5% in submission 2010). 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 ± 2.4% to the estimated percentage difference between total GHG emissions 1990 and 2009, i.e. there is a 95% probability that the decrease in GHG emissions in Sweden 1990 to 2009 is between 14.9% and 19.7%. Table 1.6 shows the ten sources with the largest uncertainty contributions in the Swedish inventory for 2009, excluding LULUCF.

Table 1.6. The ten sources with the largest uncertainty contributions in the Swedish inventory for 2009, excluding LULUCF.

CRF	IPCC source Category	GHG	Emissions 2008	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in 2009
			Gg CO_2 eq.	%	%	%	%
4.D.1	Direct soil emissions	N2O	2 412	30	140	143.18	5.78
4.D.3	Indirect emissions	N2O	1 055	30	140	143.18	2.53
4.D.4	Other	N2O	729	30	140	143.18	1.75
6.A	Solid waste disposal on land	CH4	1 367	25	50	55.90	1.28
4.A	Enteric fermentation	CH4	2 697	5	25	25.50	1.15
1.AA.3.B	Road transportation	CO2	18 899	2	3	3.32	1.05
4.D.2	Pasture, range and paddock manure	N2O	392	30	140	143.18	0.94
1.AA.1.A	Public electricity and Heat production	CO2	7 551	1	7	7.16	0.90
2.F.1	Refrigeration and air conditioning equipment	HFC	861	10	40	41.23	0.59
4.B	Manure management	CH4	465	20	50	53.85	0.42

1.7.2 KP-LULUCF activities

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 laboratory measurements. We assume that the major source of uncertainty arises from random variation due to sampling. 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 based on expert judgment.

1.8 General assessment of completeness

In the following chapter the completeness of the GHG inventory and the KP-LULUCF inventory is described.

1.8.1 GHG inventory

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.

1.8.1.1 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.

1.8.1.2 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.

1.8.1.3 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.

1.8.1.4 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.

1.8.1.5 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.

1.8.1.6 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.

1.8.2 KP-LULUCF

Sweden has elected the activity Forest management (FM) under Article 3.4 of the Kyoto Protocol (KP). All carbon pools as well as associated mandatory activities (such as fertilization of forest land, biomass burning and conversion to cropland) are reported for activities under article 3.3 and under FM.

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 59.8 million tonnes (excl. LULUCF) in 2009. Aggregated greenhouse gas emissions varied over the period but in all cases were below the 1990 level during the period 1999-2009. Since 2003, emissions have decreased every year compared to the previous year. Emissions decreased by almost 12.5 million tonnes or 17.3% between 1990 and 2009. The uncertainty in the trend is a percentage point range relative to the inventory trend and should be interpreted as ± 2.4%. The trend in emissions from 1990 is a result of decreasing emissions from the residential and service sector, the agriculture sector and the waste sector and since 2007 the emissions from the transport sector have started to decrease. Furthermore the emissions from the industry dereased in 2009, mainly as a consequence of the economic downturn.

During the autumn of 2008, an economic downturn began which was deepened during 2009 and has affected a number of sectors. The recession has meant that many industrial sectors have reduced production considerably, with diminished emissions as a consequence. Transportation has also been affected since the volume of goods transport has lessened. Emissions decreased by 3.6 million tonnes between 2008 and 2009, principally due to reduced emissions from industry.

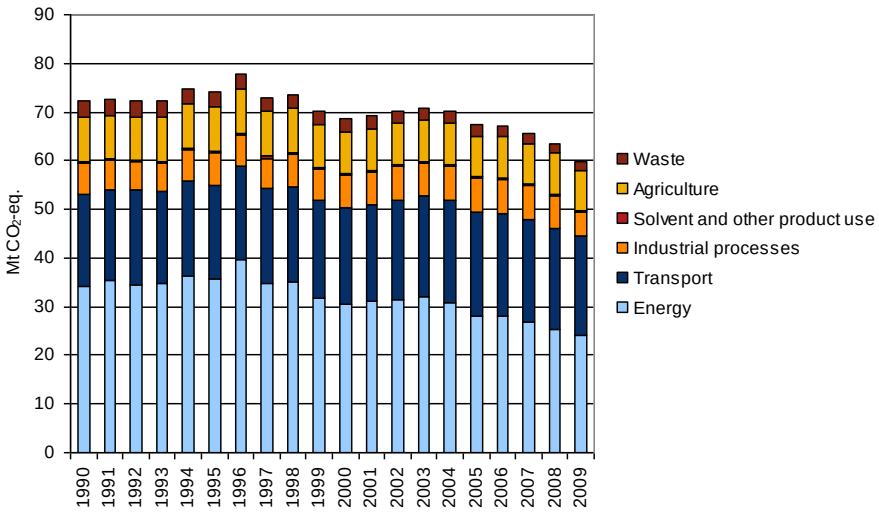

Figure 2.1 Total emissions of all greenhouse gases calculated as CO2 equivalents from the different sectors.

The Land Use, Land-Use Change and Forestry sector (LULUCF) contributed to a yearly net sink in Sweden during the period 1990-2009. The size of the sink varied over the period. However, the size of the net sink and the trend during the period are uncertain due to the methodology used. The net sink in 2009 points to a larger net sink than in 2008 which could be explained by the methodology used and the decrease in felling due to the recession. The net sink in 2009 may however be revised somewhat in the coming years.

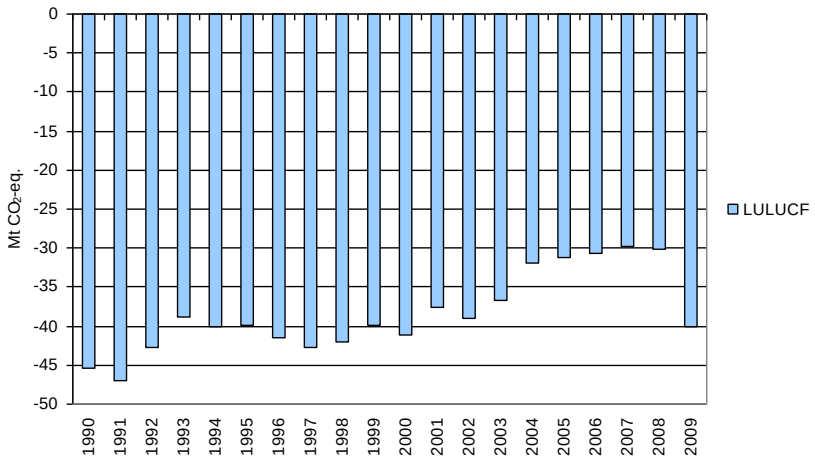

Figure 2.2 Total net removals and emissions from land use, land use change and forestry (LULUCF), calculated as CO2 equivalents.

GDP growth averaged around 2% over the period 1990-2009. The GDP was falling at the start of the 1990s, but has been increasing by an average of around 3% per year since 1994, except 2008 and 2009, when growth fell by 0.5% and 5% respectively. Despite economic growth of around 50% between 1990 and 2007, 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 1990 to 6.4 tonnes per person in 2009.

2.1.1 Sweden's commitment under the Kyoto Protocol and the EU Burden Sharing Decision

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. The assigned amount for Sweden is calculated to 75 million tonnes per year as an average (Assigned Amount Units (AAU)). In addition, Sweden can also credit itself with a carbon sink of maximum 2.13 million tonnes per year (Removal Units (RMU)), according to article 3.3 and 3.4 in the Kyoto Protocol. This means that Sweden's emissions of greenhouse gases will be allowed

to comprise a maximum of 77.13 million tonnes per year on average for 2008-12. Of these emission allowances, an average of approximately 22.3 million tonnes per year has been allocated within the EU emissions trading scheme.

Total greenhouse gas emissions in 2009 were 59.8 million tonnes of carbon dioxide equivalents in Sweden. The allocation for the trading sectors were 22.1 million tonnes in 2009 and the emissions from sectors outside the trading scheme were 42.3 million tonnes carbon dioxide equivalents. This means that the total emissions in Sweden in 2009 were around 16% below the assigned amount, including the net effect of allocation to the EU ETS and the carbon sink. This suggest that Sweden will meet its commitment. The national surplus of Assigned Amount Units and Removal Units was around 12.7 million tonnes in 2009. The corresponding surplus in 2008 was around 13.1 million tonnes. It is not yet decided what to do with the surplus of AAU:s, if it should be cancelled, saved or sold. Note that these figures are uncertain and only preliminary since the final calculations on target fulfilment will be made in 2014.

Mt CO2-eq.	2008	2009
Non EU ETS Emissions	43.3	42.3
EU ETS Verified emissions	20.1	17.5
Allowances EU ETS	20.8	22.1
Total emissions	63.4	59.8
Total emissions incl. net effect of EU ETS	64	64.4
Assigned amount incl LULUCF	77.13	77.13
Emissions incl. effect of EU ETS and LULUCF relative to Assigned Amount	-13.1	-12.7

2.1.2 Sweden's commitment for the non-ETS emissions according to the Effort Sharing Decision

Sweden's commitment for the sectors outside the EU Emissions Trading Scheme according to the EU's Climate and Energy Package is that emissions have to decrease by 17% between 2005 and 2020. The Swedish target according to the 2009 climate policy resolution of the Swedish Parliament is for emissions by non-trading sectors to decrease by 40% or around 20 million tonnes between 1990 and 2020 (of which one third can be reduced by emission reductions in other countries). This is equivalent to a decrease of around 35% between 2005 and 2020. Emissions from the non-trading sectors totalled 46.3 million tonnes in 2005 calculated with the same scope of the trading scheme as in 2008-12 (excluding aviation). Emissions totalled 42.3 million tonnes in 2009, which is a decrease of just over 8% compared with 2005. The economic downturn led to far lower emissions in 2009, but most of the decrease has taken place in those sectors that are included in the EU Emissions Trading Scheme.

Mt CO2-eq.	2005 (scope 2008-12)	2008	2009	2005-2009 (%)
Non EU ETS	46.3	43.3	42.3	-8%
EU ETS	21.1	20.1	17.5	-17%
Total emissions	67.4	63.3	59.8	-11%

2.1.3 Overview of emissions trends per sector

Emissions of greenhouse gases from different sectors of society developed in different directions over the period from 1990 to 2009. The greatest reductions in emissions over the period 1990-2009 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 were, however, reduced or moderated in a number of sectors in 2008-2009 as a consequence of, among other things, the economic downturn that began in the autumn of 2008 and the increased share of renewable fuels and reduced fuel consumption in the transport sector.

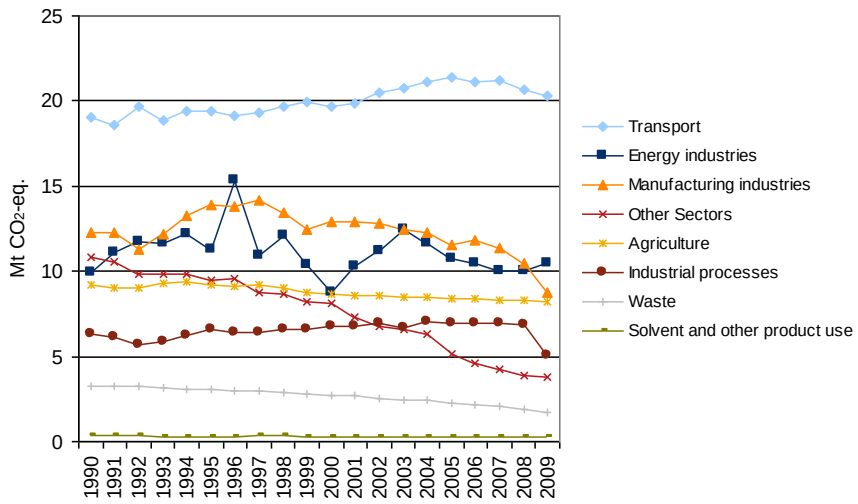

Figure 2.3 Total emissions of all greenhouse gases calculated as CO2-equivalents from the different sectors.

2.2 Description and interpretation of emission trends in relation to gas

In 2009, emissions (excl. LULUCF) of *carbon dioxide* totalled 46.6 million tonnes, which is equivalent to 78% 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 million tonnes, equivalent

to 12%. Only almost 2% or 1 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 1990-2009.

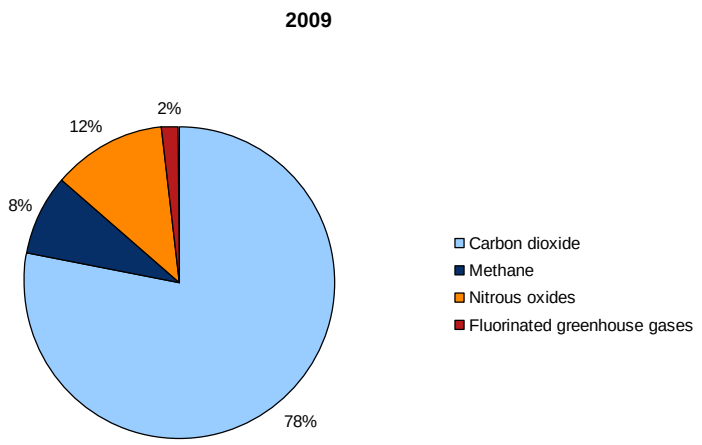

Figure 2.4 Greenhouse gas emissions by gas (2009).

2.2.1 CO_2

In 2009, total *carbon dioxide* emissions in Sweden totalled 46.6 million tonnes, excl. LULUCF. 49% of carbon dioxide emissions came from the energy sector, 43% of carbon dioxide emissions came from the transport sector and the remaining 8% came from industrial processes, solvent and other product use and waste. Emissions were almost 18% lower in 2009 than in 1990, and it is the energy sector that has shown the greatest reduction.

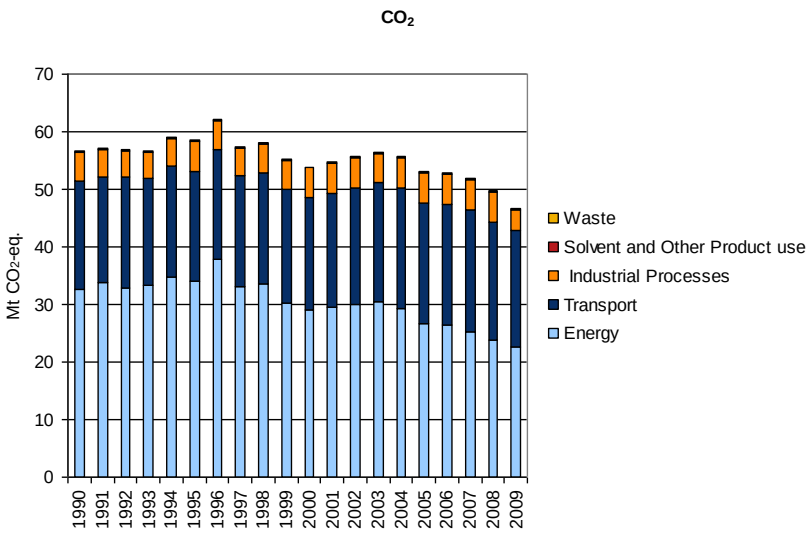

Figure 2.5. Total emissions of CO2 from different sectors.

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 2009, which is equivalent to 5.1 million tonnes calculated as carbon dioxide equivalents or 8% of total greenhouse gas emissions. Emissions have fallen by 25% since 1990, largely due to measures taken in the waste sector.

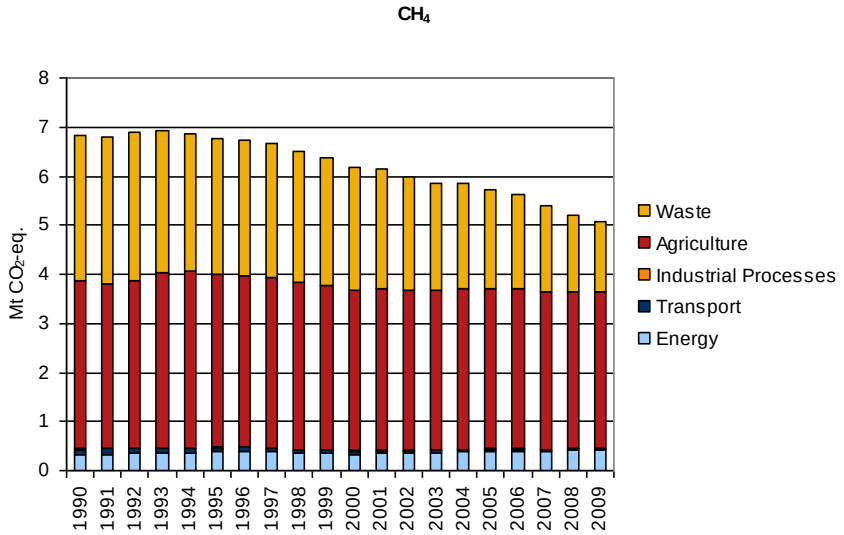

Figure 2.6 Total emissions of CH4 from different sectors, calculated as CO2-equivalents.

2.2.3 N_2O

In 2009, emissions of *nitrous oxide* totalled 23 ktonnes or 7 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 72% of emissions. Compared with 1990, emissions have decreased by 16%, and it is primarily emissions from the agriculture sector that account for the decrease.

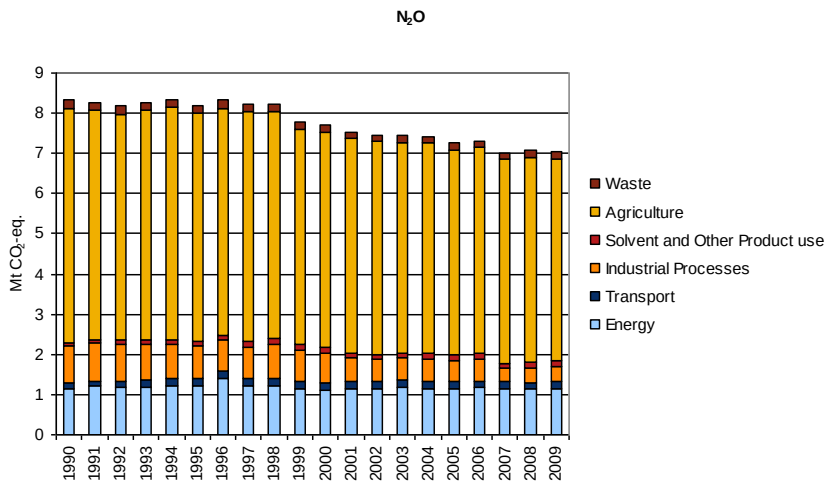

Figure 2.7 Total emissions of N_2O from different sectors calculated as CO_2-equivalents.

Fluorinated greenhouse gases

Emissions of fluorinated greenhouse gases (F-gases) are reported in the industrial processes sector. Total emissions of fluorinated greenhouse gases in 2009 amounted to around 1 million tonnes calculated as carbon dioxide equivalents and account for almost 2% of total emissions. Emissions increased by 115% between 1990 and 2009 but the emissions decreased in 2009 compared to 2008, due to reduced emissions of PFC.

Emissions of HFCs increased in particular, from just under 4 ktonnes of carbon dioxide equivalents in 1990 to 932 ktonnes in 2009. PFC emissions, on the other hand, have decreased. In 1990 emissions of PFCs amounted to 377 ktonnes of carbon dioxide equivalents, and in 2009 they had fallen to around 35 ktonnes. Emissions of SF6 varied between 1990 and 2009. In 1990 they totalled 107 ktonnes and in 2009 they amounted to 82 ktonnes of carbon dioxide equivalents.

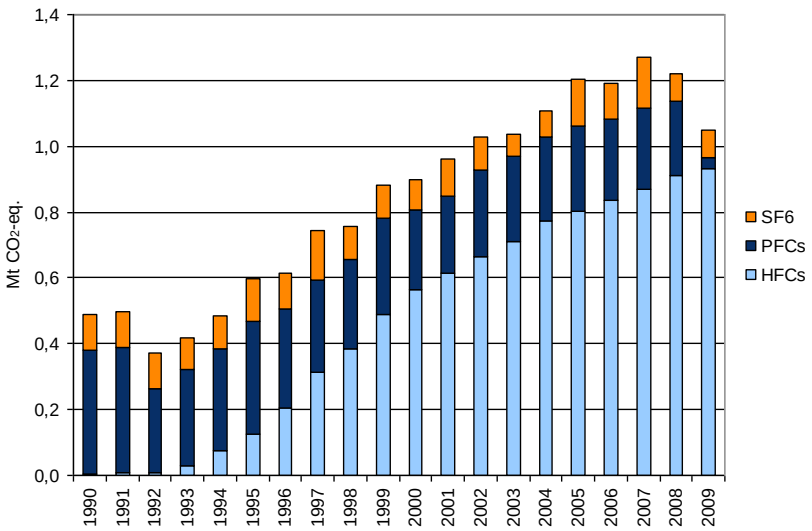

Figure 2.8 Total emissions of SF_6, PFC and HFC, calculated as CO_2-equivalents

2.3 Description and interpretation of emission trends in relation to source

The emissions from the transport and industry sectors accounts for a considerable part of the total emissions in Sweden beside the emissions from energy industries and energy use. In 2009 the emissions from the energy sector, excluding transport, made up 40% of total greenhouse emissions, in which the energy industry accounted for 17%, industrial combustion for 15%, the residential and service sector for 6% and fugitive emissions and other for 2%. Domestic transport accounted for 34% of total greenhouse gas emissions, agriculture for 14%, industrial processes for 8%, the waste sector for 3% and the use for solvents and other products for 0.5%.

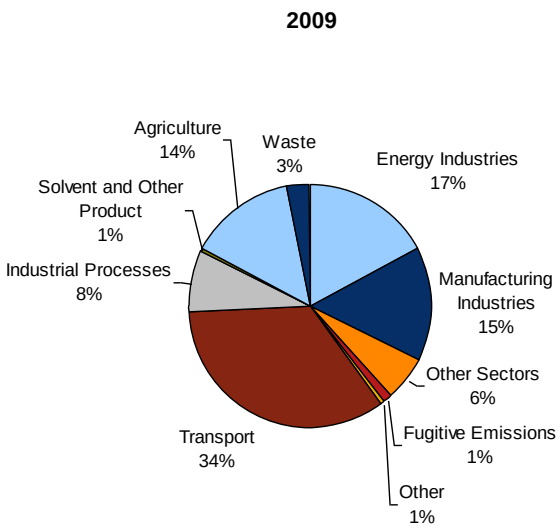

Figure 2.9 Greenhouse gas emissions broken down by sector (2009).

2.3.1 Energy excluding transport

Emissions of greenhouse gases by the energy sector[11] amounted to 24.2 million tonnes of carbon dioxide equivalents in 2009, which is equivalent to 40% 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, the state of the economy and also on instruments that have been changed since 1990. But the trend over the period 1990-2009 was for a slight reduction in emissions. In comparison with 1990, emissions were 29% lower in 2009 and the decrease is principally due to the use of oil for heating in the residential and service sector having declined and district heating being increasingly based on biomass fuels.

Calculated in terms of carbon dioxide equivalents, total emissions from electricity and district heating production amounted to 8.1 million tonnes, from refineries to 2.1 million tonnes and from industrial combustion to 8.7 million tonnes in 2009. The emissions of the residential and service sector of 3.8 million tonnes include emissions from 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 0.9 million tonnes in 2009 and emissions from other were 0.3 million tonnes.

[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

Marginal changes in greenhouse gas emissions can be seen between 2008 and 2009 in the majority of subsectors in the energy sector, with the exception of emissions from electric and district heating, which increased somewhat, and from industrial combustion, which fell sharply. Underlying causes is the recession and increased need for heating due to colder weather than in 2008 in combination with a low production in the nuclear power plants.

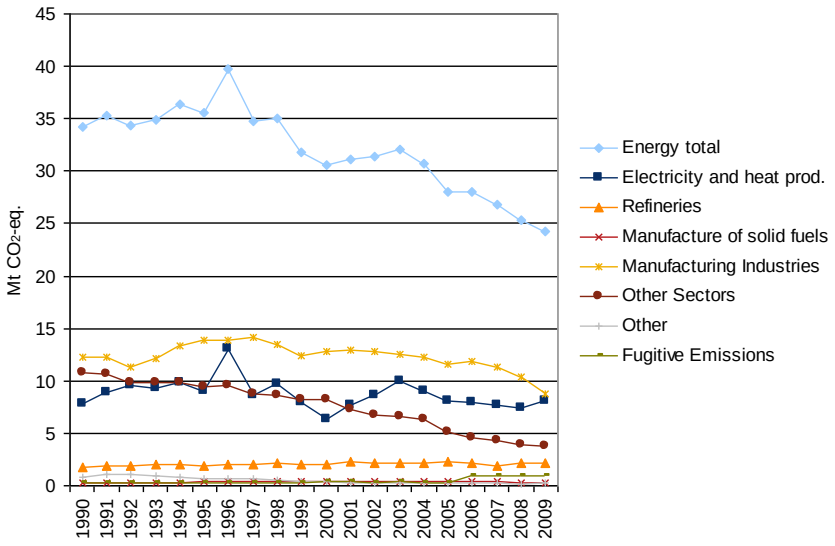

Figure 2.10 Total emissions of all greenhouse gases from the Energy sector, total and per subsector.

2.3.1.1 CARBON DIOXIDE FROM THE ENERGY SECTOR, EXCLUDING TRANSPORT

2.3.1.1.1 Electricity and heat production

Emissions of carbon dioxide from the production of electricity and district heating totalled around 7.5 million tonnes in 2009, which was about the same level as in 1990.

Temperature and precipitation conditions, which vary between years, have an impact on hydropower production and heating needs in individual years and thus lead to a variation in emissions between years. This is 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.

During the period 2000-2010 the variation in emissions is smaller since the Swedish electricity network has been integrated in the Nordic electricity network and the capacity in electricity transfer increased to other countries outside the Nordic countries. Therefore the deficient production of hydropower in 2003 was offset by imports of electricity while shortage of hydropower in 1996, which was another

year of low hydropower production, was partially offset by increased oil condensing production.

Emissions are also affected by the increase in iron and steel production which has taken place since 1990, as residual gases from this industry are used to produce electricity and district heating.

During the period 1990-2009, the use of district heating increased from 41 TWh in 1990 to 59,5 TWh in 2009. On the other hand, emissions have not increased significantly as the expansion has principally taken place through increased use of biomass fuels. Use of biomass fuels, peat and waste in 1990 totalled 10.4 TWh, and it had risen to 42 TWh in 2009 at the same time as the use of oil and coal decreased. Energy and carbon dioxide taxes have, among other things, contributed to this trend.

2009 was notable for both reduced electricity production and reduced use of electricity, but an upturn in combustion in conventional thermal power. Inflow to reservoirs in Sweden was normal. Swedish nuclear reactors had lower production than they have had for several decades due to unforeseen shutdowns in connection with renovation and modernisation. At the same time, electricity use was at its lowest level in the past 20 years, principally due to the downturn in the industrial economy. Some net importing of electricity took place in the end of 2009 (5 TWh). Wind-power production increased sharply, albeit from a low level. The fact that production of biomass fuel-based combined heat and power was higher than in previous years in 2009 is in part due to the electricity certificates system, which improves the profitability of renewable electricity production. 2009 was colder than 2008, leading to a somewhat higher heating need than in 2008. Combustion of natural gas for production of electricity and district heating in 2009 was more than double that in the previous year due to the expansion of combined heat and power plants in Sweden. All together these factors lead to somewhat higher emissions of carbon dioxide from electricity and district heating in 2009 than 2008.

2.3.1.1.2 Refineries

Production of refined products increased in Sweden during the period, leading to an increase in carbon dioxide emissions from the refineries from 1.8 million tonnes in 1990 to 2.1 million tonnes in 2009 or almost 18%. In 2009 the emissions were somewhat reduced compared to 2008 due to the recession. The emissions from refineries are also reported in the fugitive emissions sector and in 2006-2009 the total emissions from refineries were higher than the previous years as a new installation was started. Emissions were higher in 2008 than for 2007, however the increase was mostly due to a substantial plant shutdown in 2007 for purposes of performing maintenance repairs.

2.3.1.1.3 Other Sectors

Emissions of carbon dioxide in 2009 were 3.3 million tonnes in the residential and service sector including combustion in agriculture, forestry and fisheries. This is a decrease of 68% 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 almost 1.7 million tonnes in the year 2009 in consequence of a switch from oil to district heating and in recent years also to heat pumps and pellet-fired boilers. The total use of fossil fuels strongly decreased during the period 1990-2008. However, the difference between 2008 and 2009 was small. In 2008, only 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%. 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. The trend in energy consumption for heating per unit of floor space area in recent years has decreased for houses as well as for commercial premises and apartment blocks. The conversion losses originating from energy use in the sector have also been somewhat reduced. Causes may be energy efficiency improvements and increased use of heat pumps. Another contributing factor to the favourable development has been the warm weather in several years.

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 increasing slightly and totalled 1.6 million tonnes in 2009. Emissions increased by 7% between 1990 and 2009.

2.3.1.1.4 Manufacturing industries

Carbon dioxide emissions from industrial combustion were around 8.2 million tonnes in 2009. Emissions in 2009 were nearly 30% lower than in 1990, but they have varied upwards and downwards over the years, principally due to economic fluctuations and the difference in relative prices between electricity and oil. A small number of energy-intensive industries account for a large proportion of carbon dioxide emissions in the sector. The iron and steel industry and the chemical industry account for equally large emissions in 2009 with 13-14% each. The pulp and paper industry accounts for almost 17%.

A slight decrease in emissions can be seen between 2002 and 2006, principally due to reduced emissions from the pulp and paper industry caused by fuel substitution. The decreases were greater in 2008 and 2009. All branches of industry had lower emissions in 2009 than in the previous year. All industries also had lower emissions than in 1990.

Viewed over a longer period from 1970 on, industry has reduced its use of oil and increased its use of electricity. Between 1990 and 2009 the use of oil decreased by 35%, and from the year with the highest use of oil, 1997, by 48%. Specific oil use (kWh per added value at 2000 prices) and specific electricity use also decreased over the period 1990-2009, by 67% and 51% respectively.

Carbon dioxide emissions from industrial combustion decreased by 17% between 2008 and 2009. Decreases of between 1 and 46% occurred in all industries. Increased use of biofuels in the pulp and paper industry and declining volume of production due to the weakness of the economy are likely reasons for the reduced emissions.

2.3.1.1.5 Fugitive emissions and Other

Emissions from the fugitive emissions sector come for example from refineries. Emissions was 0.9 million tonnes of carbon dioxide in 2009. Emissions from "Other" (principally military emissions) decreased between 1990 and 2009 and totalled 0.25 million tonnes of carbon dioxide in 2009.

2.3.1.2 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. Almost 5% of emissions from the energy sector are emissions of nitrous oxide, and almost 2% are emissions of methane.

Methane emissions from the energy sector excl. transport have increased by 30% between 1990 and 2009. 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. The greatest percentage increase has however happened within the electricity and district heating where emissions sharply increased.

Nitrous oxide emissions were stable between 1990 and 2009.

2.3.2 Transport

Greenhouse gas emissions from domestic transport totalled 20.3 million tonnes of carbon dioxide emissions in 2009, which is 7% higher than the 1990 level, but a decrease in comparison with 2007 and 2008. Greenhouse gas emissions from road traffic were 19 million tonnes, from domestic aviation 0.5 million tonnes, from domestic navigation 0.5 million tonnes, from railways 0.1 million tonnes and from other machinery 0.2 million tonnes.

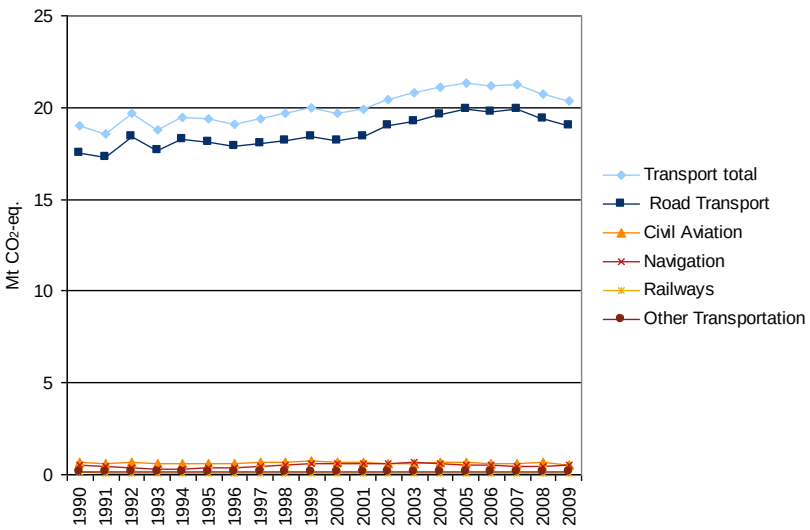

Figure 2.11 Emissions from the transport sector, total and per subsector

2.3.2.1 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 totalled 18.9 million tonnes in 2009, which is 9% higher than 1990 emissions. Emissions increased from 1990 to 2005 before stagnating and then decreasing somewhat in 2008-2009 as a result of an increased share of renewable fuels and reduced fuel consumption.

The increase up to the mid-2000s followed the increase in traffic and transport mileage. It was principally transport mileage with heavy duty vehicles and to some extent with light duty vehicles that increased. There was insignificant improvement in energy efficiency in vehicles during this period. The proportion of diesel-powered light duty vehicles has increased continuously since 1990, and the same change in the market began in the late 1990s for cars, steadily strengthening to the present day. The switch from petrol-powered to diesel-powered cars is leading to greater energy efficiency, which since the mid-2000s has been reinforced by a general improvement in fuel efficiency for new cars which has counteracted the increase in fuel consumption to which the growth in transport has led. The aggregate effect has been sharply increased consumption of diesel fuel and reduced volumes of petrol. The economic downturn which began in 2008 and intensified in 2009 also led to reduced emissions from diesel-powered heavy duty vehicles in 2009 and to somewhat lower overall use of diesel fuel in the road transport sector.

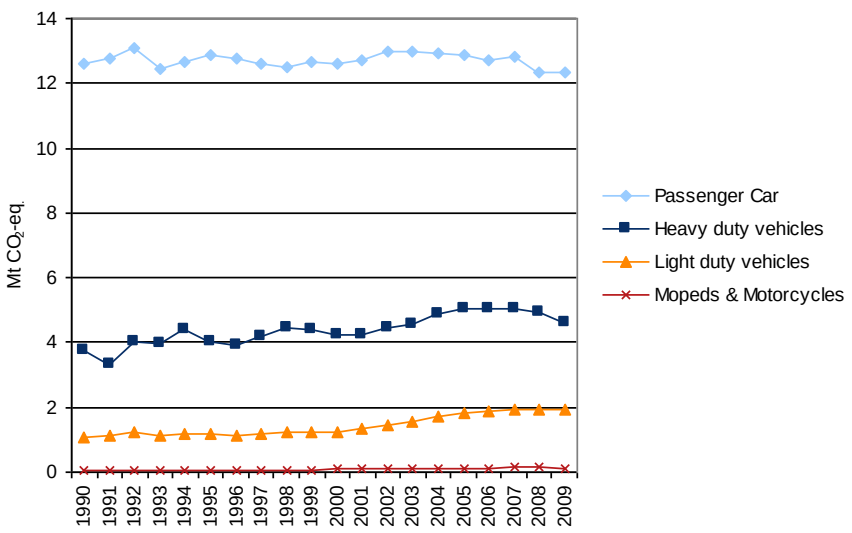

Figure 2.12 Emissions of CO_2 from different vehicle categories. Note that the emissions from different vehicle categories are based on transport mileage and not fuel consumption.

Several points have been significant in limiting emissions from road transport. Among other factors, increased fuel taxes, tax exemption for transport biofuels, carbon dioxide-based vehicle tax and tax relief for green cars, together with rising market price for petrol and diesel, have contributed to more fuel-efficient cars, an increased number of fuel-flexible cars and consequently a switch to renewable

fuels. The use of renewable fuels has been principally boosted by the fact that since 2004 they have been exempt from carbon dioxide tax and energy tax. Large-scale blending of ethanol into petrol began in 2003, with the result that almost all petrol sold in Sweden now contains 5% ethanol. Blending of FAME into diesel also increased in 2009. The use of biofuels for fuel-flexible cars also increased from 2004 to 2008, particularly ethanol (E85), but in 2009 the use of E85 decreased somewhat as a result of high ethanol prices and lower petrol prices.

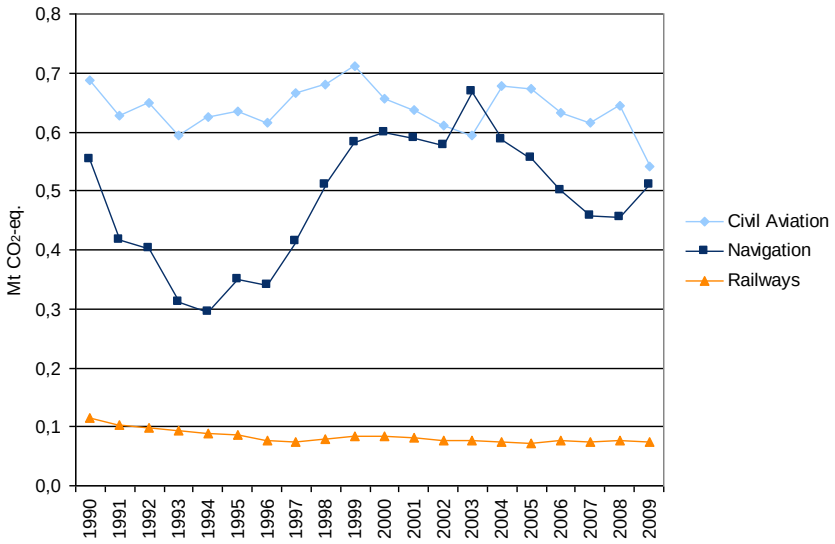

Figure 2.13 Emission from aviation, navigation and railways.

In 2009, emissions of carbon dioxide from domestic aviation were 0.53 million tonnes, which is 21% lower than the level for 1990. However, the emissions varied during the period. The emissions increased sharply in 2004 but then decreased. Domestic aviation has decreased because the share of train and to some extent car journeys has increased. The fact that more people are choosing train or car rather than flying for domestic travel is considered to be due in part to a decline in the availability of short-haul aviation and to new security requirements and routines having reduced the advantages of flying in terms of speed and flexibility.

Carbon dioxide emissions for domestic navigation are estimated at 0.5 million tonnes in 2009, which is around 8% lower than in 1990. Emissions have decreased after a sharp rise between 1994 and 2003.

Railway carbon dioxide emissions from diesel-powered trains account for a marginal share of transport sector emissions and have decreased by around 35 per cent since 1990.

2.3.2.2 METHANE AND NITROUS OXIDE FROM THE TRANSPORT SECTOR

Emissions of methane and nitrous oxide account for a very small share of greenhouse gas emissions by the transport sector. Methane emissions totalled 0.03 million tonnes of carbon dioxide equivalents in 2009 and have fallen by 74% since

1990 as a result of better exhaust emission control. Nitrous oxide emissions totalled 0.16 million tonnes of carbon dioxide equivalents in 2009. Emissions of nitrous oxide increased from 1990 to 2000 in connection with the switch to cars fitted with catalytic converters. Emissions have since decreased with better exhaust treatment technology.

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 5 million tonnes of carbon dioxide equivalents in 2009, which is equivalent to 8% of aggregated emissions. Carbon dioxide emissions are dominant at 71%, followed by fluorinated greenhouse gases at approximately 21%, nitrous oxide at approximately 8% and methane at 0.2%.

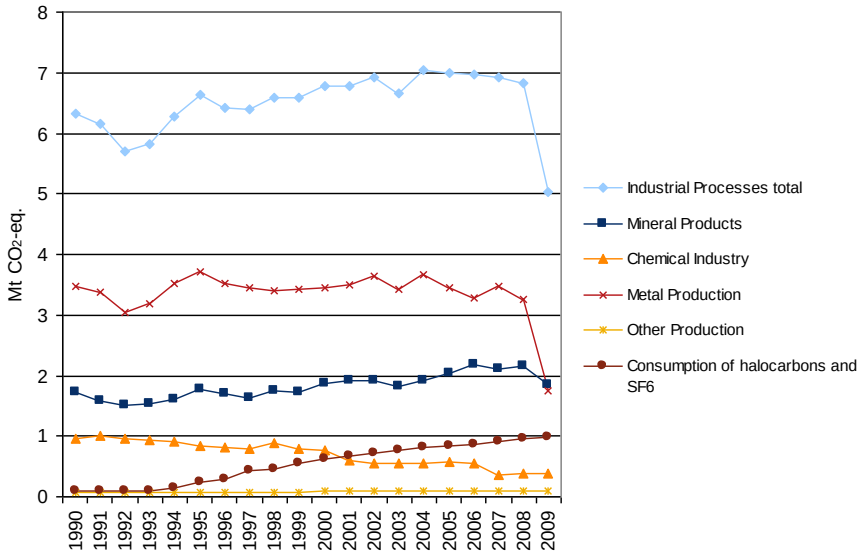

Figure 2.14 Emissions from the Industrial processes sector, total and per subsector.

The 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, for example, while those from the chemical industry have decreased over the same period. In 2009 emissions from industrial processes were much lower than in 2008. Total emissions from industrial processes decreased by 26% between 2008 and 2009, principally due to the decrease in the metal industry, but emissions from the mineral products industry also decreased. The decrease in

emissions in 2009 was principally due to reduced production as a result of the economic downturn which began in 2008 and deepened in 2009.

Carbon dioxide emissions from the mineral industry increased over the period 1990-2008. This was principally due to improving economic conditions in the building sector, both in Sweden and in other countries to which cement is exported. However, emissions decreased in 2009 as a result of a decline in production resulting from the weakness of the economy. 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 26% during the entire period spanning 1990-2008, and the emissions have increased most in recent years. The iron and steel industry was severely affected by the economic downturn in 2008-2009, and emissions in 2009 were 39% lower than in 2008. The emissions from the chemical industry decreased by 61% during the period 1990-2009. Since 2007, 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 nitric acid production.

2.3.3.1 FLUORINATED GREENHOUSE GASES (HFC, PFC, SF_6)

Fluorinated greenhouse gases have a number of uses. Most emissions of fluorinated greenhouse gases in Sweden today are due to leakage from refrigeration and air-conditioning systems and air conditioning in vehicles. Other sources are foam manufacturing, medical inhalers, aluminium production and magnesium foundries. Total fluorinated greenhouse gas emissions in 2009 amounted to around 1 million tonnes calculated as carbon dioxide equivalents and account for almost 2% of total emissions. Emissions of fluorinated gases are showing an increasing trend, however, and increased by 115% between 1990 and 2009, principally due to a sharp increase in HFC emissions. One explanation for the increase is that HFCs in many cases have replaced the ozone-depleting substances CFCs and HCFCs as refrigerants. The ozone-depleting substances decreased sharply between 1990 and 2009 and have now been more or less completely phased out. Another explanation for the increase in HFCs is that the number of refrigeration and air-conditioning systems, air conditioning in vehicles and heat pumps has increased, particularly in the recent years.

Emissions of PFCs come principally from the aluminium industry and have decreased since 1990. SF6 emissions have remained at approximately the same level but have varied somewhat. SF6 emissions were lower in 2008-2009 than previously, due to lower emissions from magnesium foundries. One explanation why these emissions are decreasing is an EU Regulation introduced in 2006. Under this Regulation, certain fluorinated greenhouse gases were banned at various times between 2006 and 2009. Other emissions of fluorinated greenhouse gases have also started to decrease as a result of the EU Regulation.

Emissions of fluorinated greenhouse gases decreased by 14% in 2009 in comparison with 2008, due to reduced emissions of PFCs. PFC emissions come principally from the aluminium industry, and these emissions have decreased in recent years as a result of a investments in a new technology since 2007. Only the new technology was used in 2009, and combined with lower production as a result of the weakness in the economy, this led to a sharp decrease in emissions.

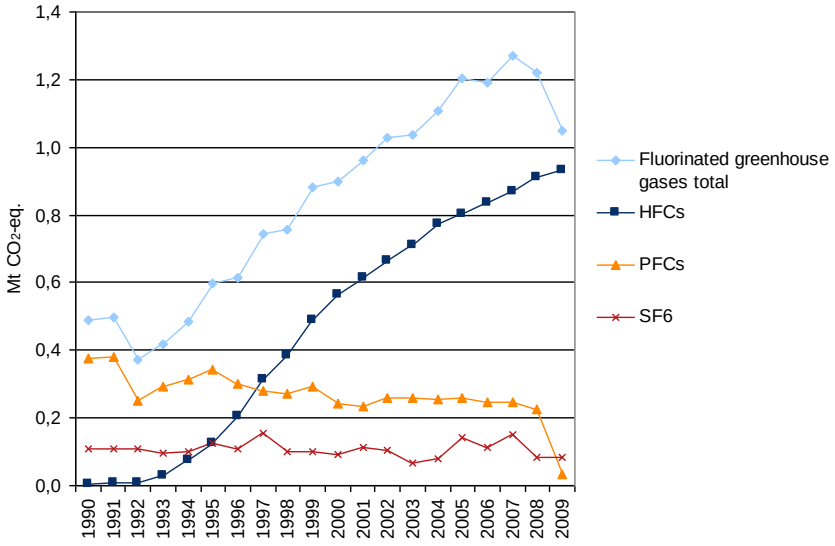

Figure 2.15 Emissions of fluorinated greenhouse gases, total and per gas.

2.3.4 Solvents and other products use

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 2009 totalled 0.3 million tonnes, which is 0.4% of total emissions. In comparison with 1990, emissions have decreased by 11%. Approximately 20% of carbon dioxide emissions come from paints, but these emissions have been reduced by a shift to water-based paints.

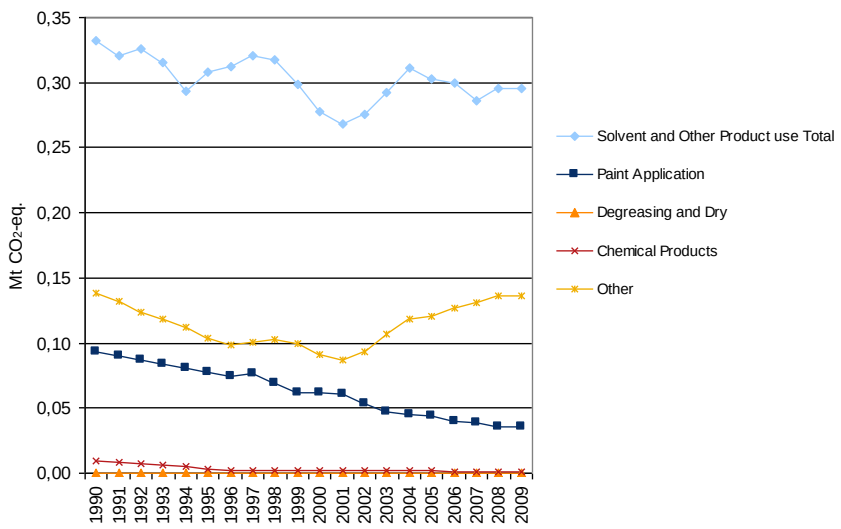

Figure 2.16 Emissions from the use of solvents and other products, total and per subsector.

2.3.5 Agriculture

Agriculture is the largest source of methane and nitrous oxide emissions. Emissions of these greenhouse gases in 2009 amounted to 8.2 million tonnes of carbon dioxide equivalents, of which around 60% was made up of nitrous oxide and almost 40% of methane. Aggregated emissions decreased by 5% over the period 2000-2009, 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. In comparison with 2008, emissions have decreased by 0.1 million tonnes or around 1%.

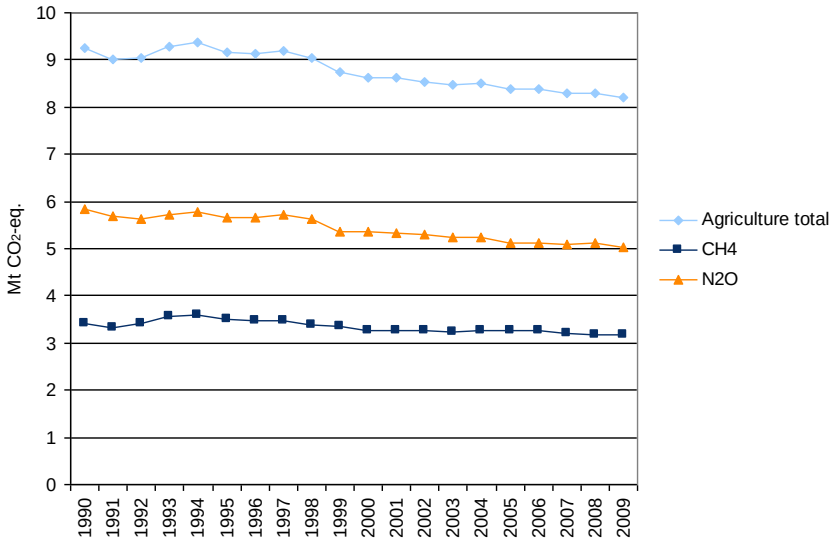

Figure 2.17 Emissions from agriculture, total and per gas.

2.3.5.1 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 and it was mainly the number of dairy cows that decreased from 1990 to 2009. 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.

2.3.5.2 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.

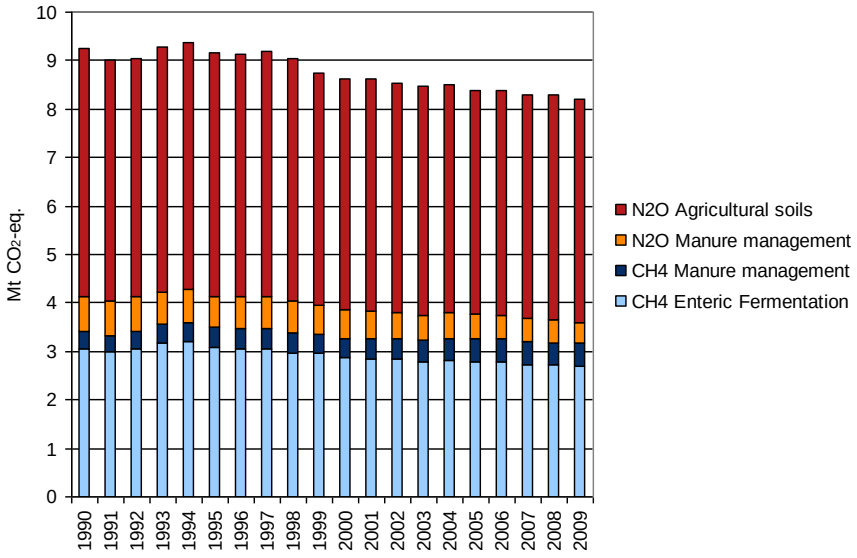

Figure 2.18 Emissions from agriculture, total and per gas and subsector.

2.3.6 Land Use, Land Use Change and Forestry - LULUCF

The Sector Land Use, Land Use Change and Forestry (LULUCF) during the period 1990-2009 contribute to a yearly net sink in Sweden. During the period the sink has varied between 30-47 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 the methodology used and 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, at the same time as felling increases. According to Swedish National Board of Forestry statistics, felling ranged between 64 Mm^3 and 96 Mm^3 over the period 1990-2009, with the exception of 2005 when felling, including wood felled by storms, was estimated at 122 Mm^3. However the uncertainty is greater in data for 2006-09 in the LULUCF sector, since not all sample plots for these years have been inventoried. 2009 points to a greater net sink and one explanation could be decreased felling due to the recession that began in 2008. But only 20% of sample plots have been inventoried, with the result that the size of the sink is very uncertain and may change in the future.

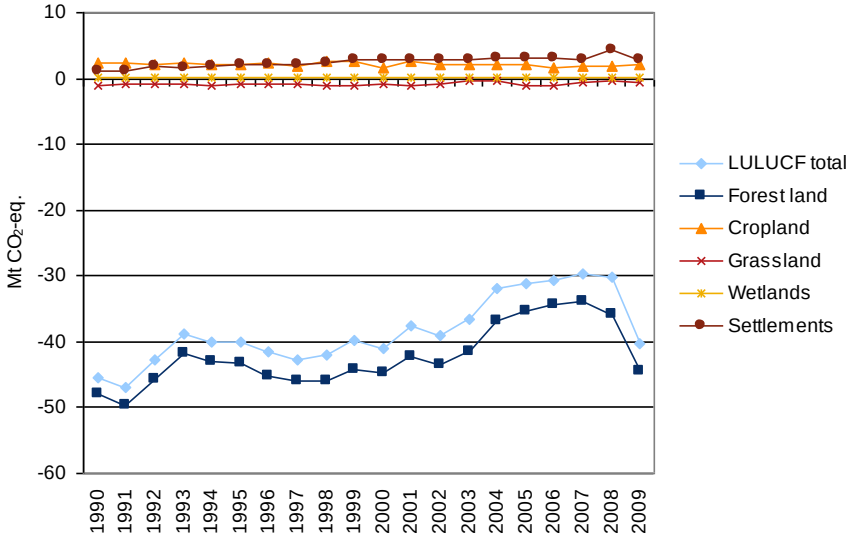

Figure 2.19 Emissions and removals of greenhouse gases from the LULUCF sector

The total size, variation and trend of the net sink are mainly affected by the carbon stock change in the forest. The carbon stock change in living biomass in the forest has the greatest effect. The removal in living biomass in the forest has varied between approximately 25-40 million tones of carbon dioxide during the period 1990-2009. Cropland is responsible for emissions of carbon dioxide when organogenic soils are cultivated. Emissions varied during the period 1990-2009 between around 2-3 million tonnes of carbon dioxide. The subsectors grassland, wetlands and settlements account for very small areas compared to forest land, which leads to higher uncertainty in data. The carbon stock change in grassland and wetlands is small. Emissions from settlements were in the range of 1-4 million tonnes of carbon dioxide during the period spanning 1990-2009.

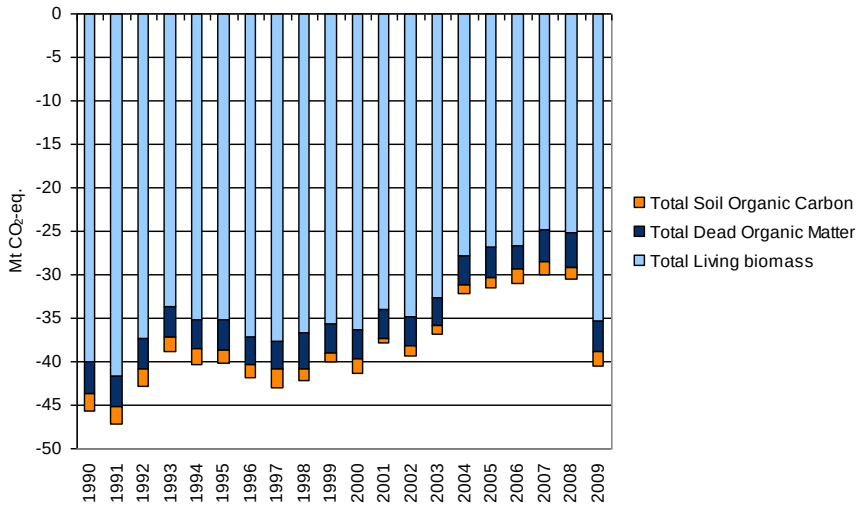

Figure 2.20 Emissions and removals of carbon dioxide from different carbon pools.

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 three carbon pools living biomass, dead organic matter soil organic carbon contribute as an aggregate to a net sink. 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, emissions of CH_4 varied between 0.5-13 ktonnes and emissions of N_2O varied between 50-130 ktonnes per year, calculated as carbon dioxide equivalents.

2.3.7 Waste

Total emissions from the waste sector in 2009 amounted to around 1.7 million tonnes of carbon dioxide equivalents or almost 3% of total greenhouse gas emissions. In comparison with 1990, emissions were 46% lower in 2009. Emissions from the waste sector are dominated by methane emissions from landfills, with 79%, while emissions from wastewater account for 14% and emissions from incineration of hazardous waste for around 7%.

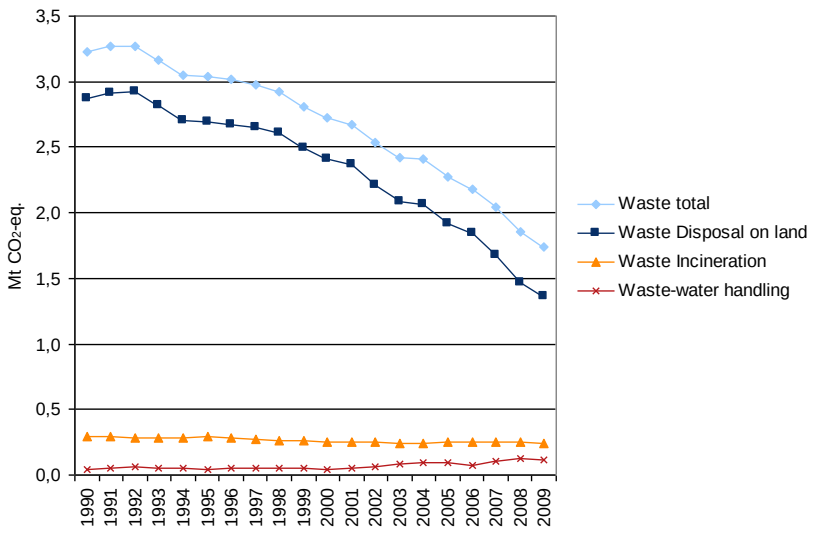

Figure 2.21 Emissions from Waste sector, total and per subsector.

Landfills are the largest source for emissions of methane gas, after livestock farming, as methane is formed when organic waste is placed in 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 in 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. The bans have contributed to a substantial change in waste management in Sweden. 99 per cent of household waste was recycled in 2009. The landfilling of other types of waste has also fallen sharply.

Emissions from wastewater handling were around 0.25 million tonnes of carbon dioxide equivalents in 2009 and accounted for 0.4% of total emissions. Emissions have fallen by 17% since 1990 due to improved sewage treatment.

Emissions from incineration of waste were around 0.1 million tonnes in 2009. 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 9.4 million tonnes of carbon dioxide equivalents in 2009. 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.

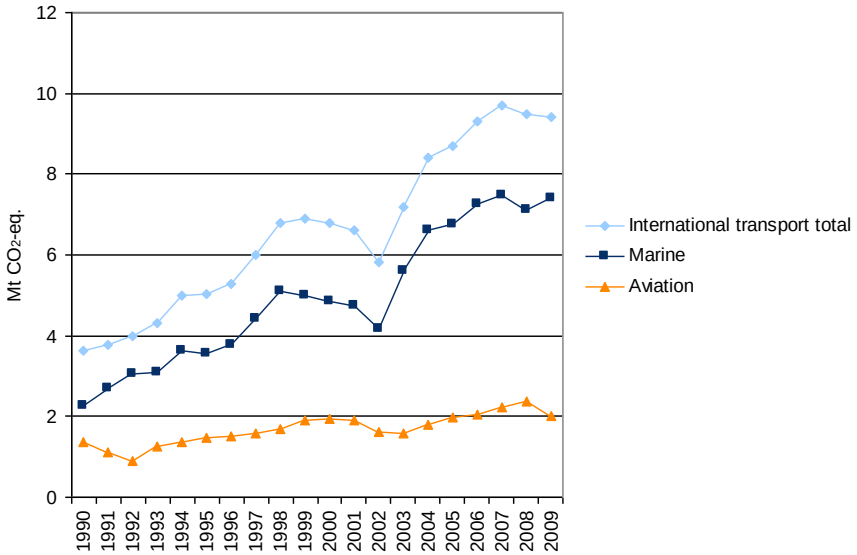

Figure 2.22 Emissions from international bunkers, total and per subsector.

Emissions from international navigation totalled 7.4 million tonnes of carbon dioxide equivalents in 2009. This is an increase of 4% compared with 2008 and an increase of 226% 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.

Greenhouse gas emissions from the international bunkering of aviation was 2 million tonnes of carbon dioxide equivalents in 2009. This is an decrease of 15% compared with 2008 but an increase of 49% since 1990. Emissions from the international bunkering of aviation have varied over time. The long-term trend is increasing although there have been declines in the early 1990s as well as at the beginning of the 2000s and in 2009. The emissions decreased by 0.3 million tonnes between 2008 and 2009. The reduced emissions are among other things due to the economic downturn which has lead to less travelling.

2.4 Description and interpretation of emission trends for indirect greenhouse gases and SO2

2.4.1 NMVOC

Emissions of non-methane volatile organic compounds (NMVOCs) totalled around 180 ktonnes in 2009, and emissions have decreased by 49% 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 48 ktonnes in 2009, a decrease of 22% in comparison with 1990. Most of the decrease occurred in the early 1990s and related to fugitive emissions from oil refineries.

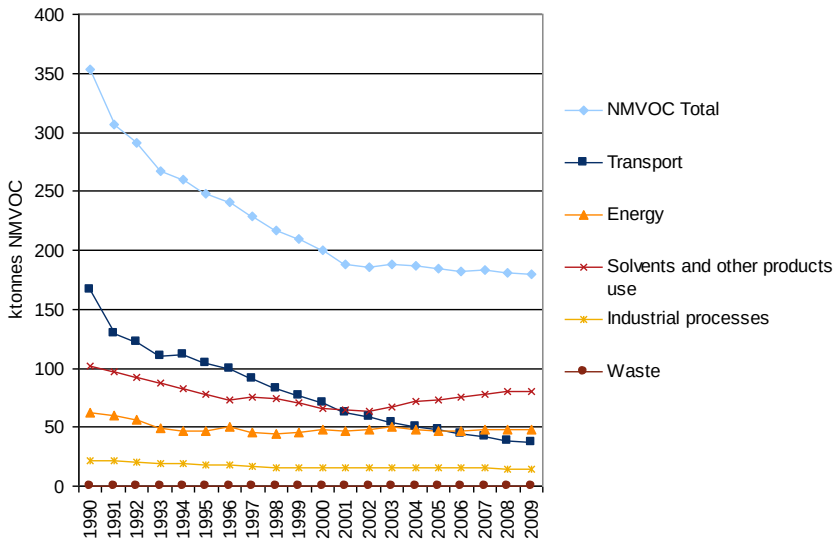

Figure 2.23 Total emissions of NMVOC and emissions from the different sectors.

2.4.2 NO_X

Emissions of nitrogen oxides amounted to around 150 ktonnes in 2009, a decrease of 50% in comparison with 1990. Nitrogen oxides are formed in all combustion in the energy and transport sectors, and the largest emission sources are road traffic, machinery, navigation and production of electricity and heating.

Emissions of nitrogen oxides from the energy sector totalled 59 ktonnes in 2009, a decrease of 38% 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.

25% of emissions in the energy sector in 2009 came from electricity and district heating production. As a result of the NOx charges introduced in the early 1990s and the treatment measures they encouraged, emissions in terms of produced quantity of energy have decreased. Some variation in the absolute quantity of emissions is visible over the years, 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 20% of emissions of nitrogen oxides by the energy sector (excluding transport). These decreased by 42% during the period 1990-2009. Machinery in agriculture and forestry taken together accounts for 18% of the emissions in the energy sector. There has also been a decrease here in recent years.

Traffic is a large source of emissions of nitrogen oxides, and the emissions come largely from road traffic at 66 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 62% between 1990 and 2009 and by 5% between 2008 and 2009.

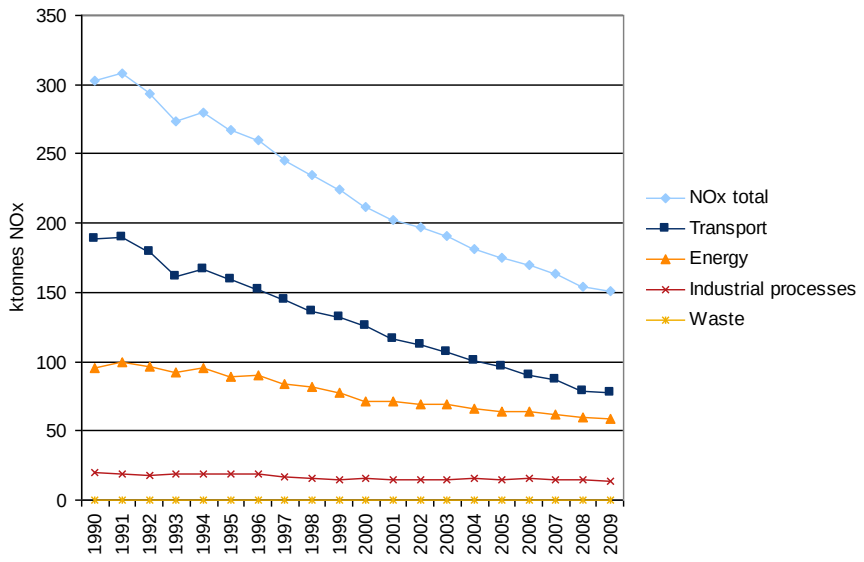

Figure 2.24 Total emissions of NO_X and emissions from the different sectors.

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 536 ktonnes in 2009. 40% of emissions came from the transport sector and 43% from the 'Other Sectors'.

Energy sector emissions of carbon monoxide increased from around 234 ktonnes in 1990 to around 303 tonnes in 2009. Around 75% of emissions from the energy sector came from household energy use.

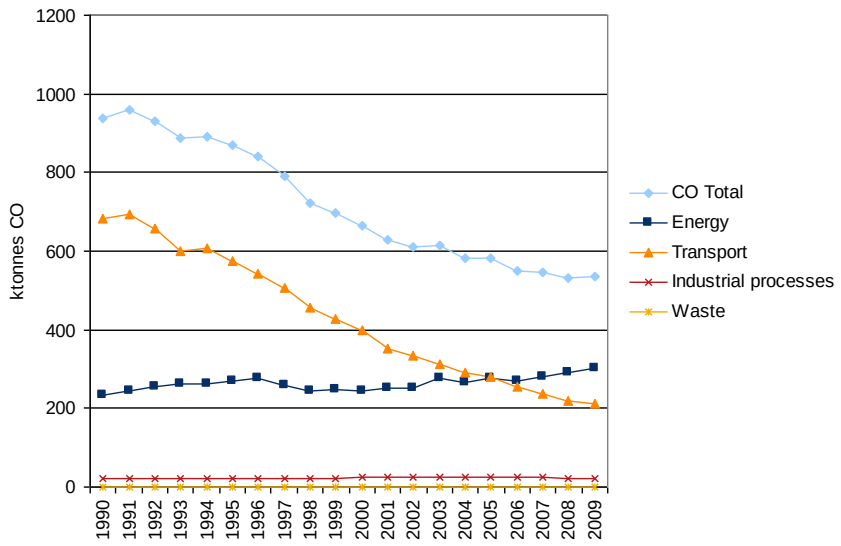

Figure 2.25 Total emissions of CO and emissions from the different sectors.

2.4.4 SO_2

Sulphur dioxide emissions come form the energy, transport and industry sectors and continued to decrease during the 1990s. In 2009, emissions totalled 30 ktonnes, which is a decrease of 72% 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.

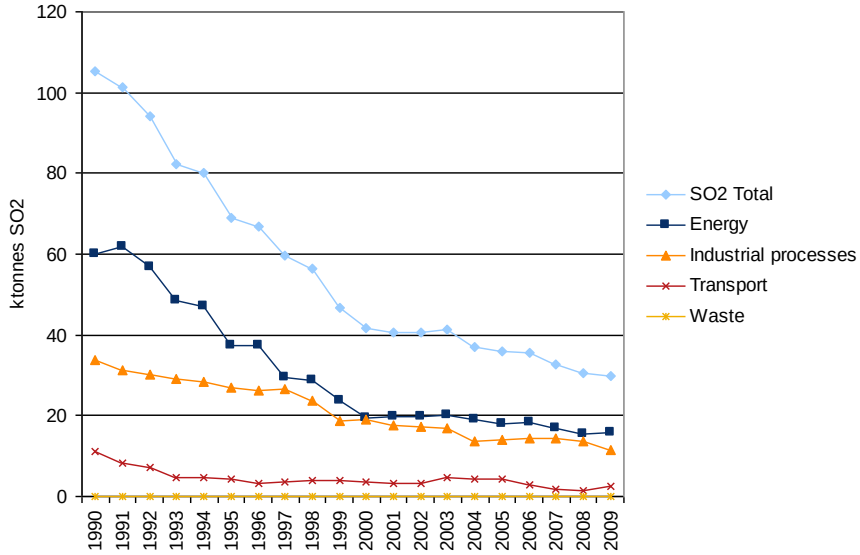

Figure 2.26 Total emissions of SO_2 and emissions from the different sectors.

Energy sector emissions of sulphur dioxide (excl. transport) continued to decrease during the 1990s and in 2009 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. Emissions increased by 4% between 2008 and 2009, as combustion for electricity and district-heating production increased to a greater extent than combustion in industry decreased.

Road traffic emissions of SO2 have fallen by 99% since 1990 as a result of lower sulphur levels in motor fuels, and totalled 0.08 ktonnes in 2009. Sulphur emissions from domestic navigation have decreased by 56% since 1990 and are now 2.2 ktonnes due to a switch to oils with lower sulphur content.

2.4.5 Description and interpretation of emission trends for KP-LULUCF inventory in aggregate and by activity, and by gas

Since the KP-LULUCF has been reported for only two years there is not so much of a trend to describe. However, the reporting under Forest management is strongly linked to the reporting of Forest land remaining forest land under the UNFCCC-reporting so to get a picture of the long term trend it is recommended to read section 2.3.6 which describes the trend in the LULUCF-sector.

3 Energy (CRF sector 1)

3.1 Overview of sector

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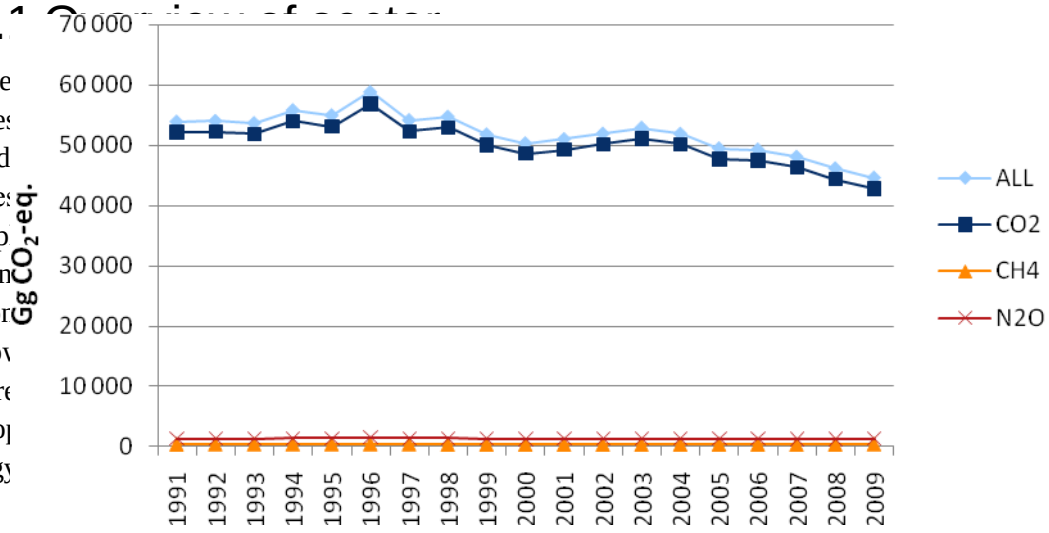

Figure 3.1 that in the energy sector, emissions of CO_2 contribute about 96 % of total greenhouse gas emissions (in CO_2 equivalents) 2009. Emissions of total greenhouse gases from the energy sector have decreased by 16.9 % from 53,181 Gg CO_2 equivalents in 1990 to 44,538 Gg CO_2 equivalents in 2009, mainly due to reduced fossil fuel consumption in the residential sector (CRF 1A4) and the effects of the economic recession 2009 on the manufacturing industries and construction (CRF 1A2) (Figure 3.2).

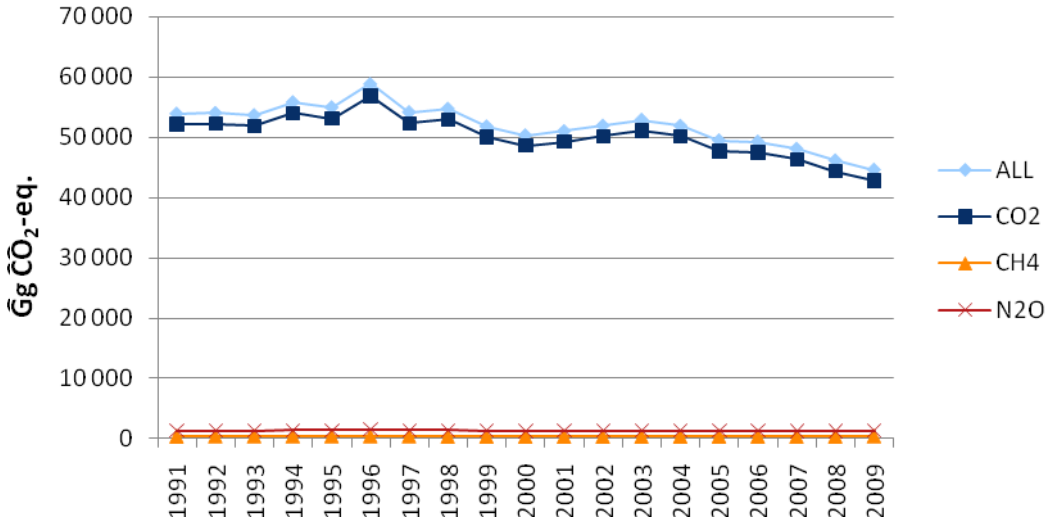

Figure 3.1. Total emissions of all greenhouse gases calculated as CO_2 equivalents from CRF 1 Energy.

[12] Ministry of the Environment, 2001

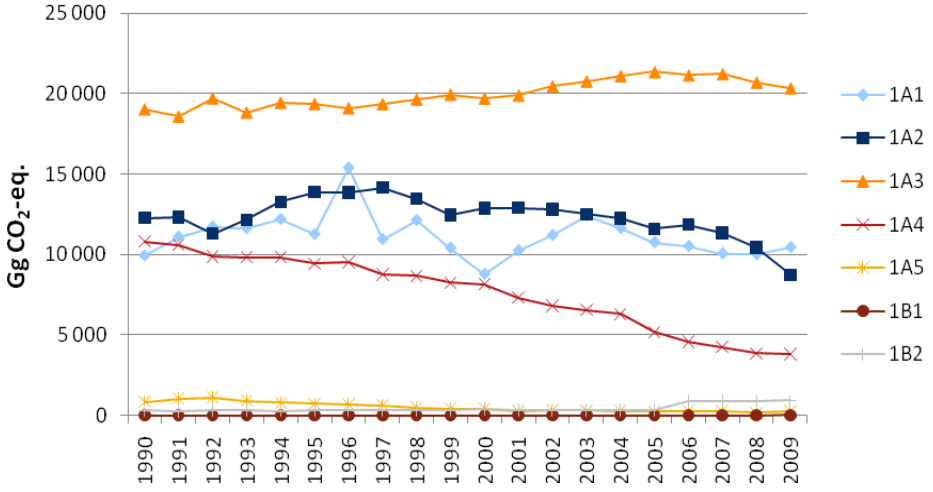

Figure 3.2. Total emissions of all greenhouse gases calculated as CO_2 equivalents from the different sub-sectors within the Energy sector.

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. As mentioned earlier, the emissions from residential heating (CRF 1A4) are decreasing due to reduced consumption of fossil fuels. The dip in emissions from manufacturing industries and construction in 2009 reflects the economic conditions resulting in lower demand of e.g. iron and steel. The recent increase in fugitive emissions from oil and natural gas (CRF 1B2) is caused by hydrogen production facilities put into operation at two of the oil refineries in 2005 and 2006 respectively.

Table 3.1. Recalculations of GHG emissions between submission 2011 and submission 2010 in the energy sector.

Recalculation differences, submission 2011/2010 (Gg CO_2 eq.)									
CRF	1A1	1A2	1A3	1A4	1A5	1B1	1B2	Total CRF 1	% CRF 1
1990		-18	0	0	0		-4	-22	-0.04%
1991		-19	0	0	0		-4	-23	-0.04%
1992		-20	0	0	0		-4	-24	-0.04%
1993		-16	0	0	0		-4	-21	-0.04%
1994		-21	0	0	0		-4	-25	-0.05%
1995		-22	0	0	0		-4	-26	-0.05%
1996		-23	0	0	0		-4	-27	-0.05%
1997		-20	0	0	0		-5	-24	-0.05%
1998		-20	0	0	0		-5	-25	-0.05%
1999		-18	0	0	0		-5	-22	-0.04%
2000		-18	0	0	0		-6	-24	-0.05%
2001		-19	0	0	0		-5	-24	-0.05%
2002		-22	0	0	0		-4	-26	-0.05%
2003		-24	0	0	0		-4	-29	-0.05%
2004		-129	0	0	0		-5	-134	-0.26%
2005		-203	0	-1	0		0	-204	-0.41%
2006		-132	0	-1	0		76	-56	-0.11%
2007	0	-300	0	-257	0		79	-478	-0.98%
2008	0	-253	3	-438	0		91	-597	-1.28%

0 equals value less than 0.5.

3.2 Fuel combustion (CRF 1.A)

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 the formula:

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

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 5.

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

A limited number of industries accounts for the majority of industrial energy use (CRF 1A2), i.e. the pulp and paper industry, iron and steel works 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 2009, fuel consumption in the iron and steel industry fell sharply as a consequence of decreased production. The less dramatic fuel consumption decrease in the chemical industry has the same explanation.

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.[13]

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 68 % in 2008, while the area heated with oil only has decreased from 22 % in 1990 to 2 % in 2008. 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%, and it was the same in 2008. The area heated with oil only in multi-dwellings has decreased from 15 % in 1990 to 1 % in 2008. For one- and two-dwellings, the proportion of the area heated with district heating only increased from 7% to 9% in the period 1990-2007. In 2008, this proportion increased further to 12%.[14]

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

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

3.2.1 Comparison of the sectoral approach with the reference approach

A detailed discussion on the reference approach and its differences compared to the sectoral approach is provided in Annex 4.

Figure 3.3 shows the differences in fuel consumption and CO_2 emissions between the Reference and Sectoral Approach for the whole time series 1990-2009. It is obvious that fuel consumption and CO_2 emissions from the Sectoral Approach exceed the Reference Approach for most years. For a number of years the difference is larger than ± 2%.

[13] Swedish Energy Authority: ES 2009:10 Summary of energy statistics for dwellings and nonresidential premises for 2008

[14] Data for latest year not yet available

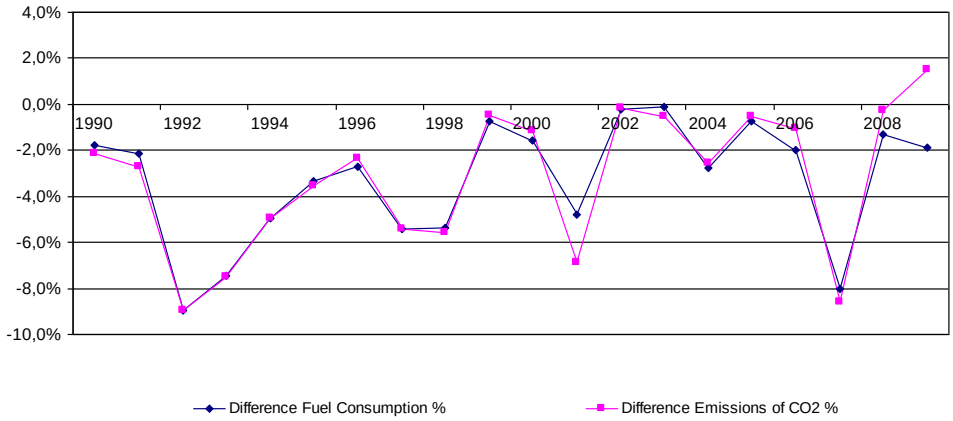

Figure 3.3 Differences between Reference and Sectoral Approach.

The differences for fuel consumption and CO_2 emissions are very closely correlated except for 2009. This indicates that emission factors used in the reference approach are appropriate for the inventory. Differences found are mainly attributed to energy amounts. The divergence in 2009 is related to solid fuels used in iron and steel industry, see below.

Statistical differences in energy balances contribute to a large share of differences especially in the early 1990's.

Large differences for 1997, 1998, 2001 and 2007 are mainly attributed to liquid fuels and most notably crude oil. If resources will become available, this will be reviewed and, if appropriate, revised in submission 2012 if new data will become available.

Emission from the Iron- and steel industry are large and difficult to estimate correctly. This is discussed in detail in section 3 and 4. A special study on the iron and steel industry has been done in 2010, but more work is needed on this issue. The iron and steel industry accounts for a large share of solid fuels used in Sweden, and difficulties in this sector is reflected in the differences between the reference approach and sectoral approach for solid fuels.

3.2.2 International bunker fuels

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.

3.2.2.1 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.

The ERT has noticed that the data reported to the IEA are generally higher than what is reported to the UNFCCC. A study in 2010 showed that the differences between the IEA and the UNFCCC reporting can to some extent be explained by revision policies of the different reporting obligations. Since the UNFCCC has a high demand on consistency of time series, efforts are made to ensure high quality of times series.[15]

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 Annex 2.

Activity data from the SCAA starts from 1994. With regards to bunkering the data has been estimated using 1994 for CO2 emissions. The share of LTO is estimated using an average between 1995-2001.

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. We plan to look further into this issue in upcoming projects[16].

In 2008 the consumption of marine destillate fuels decreased and through an investigation of the reason it became clear that one company through restructuring had not reported what was believed to be full consumption. So the submission 2010 corrected this decrease by using 2007 values. However, new data for 2009 showed the same level of consumption as the year before and the same company still report lower values of residual oil. For submission 2011 this value has not been altered. The reason for not compensating is that through contacts with the specific enterprise it has been verified that it is now purchasing lower amounts than previously.

3.2.2.2 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.

3.2.3 Feedstocks and non-energy use of fuels

Activity data on feedstocks and non-energy use of fuels is collected from the quarterly fuel statistics. As also noted in Annex 2 section 1.1.1, in the survey form for

[15] Hedlund & Lidén 2010
[16] ER 2007:26

the quarterly fuel statistics, respondents are among many other things asked to specify whether fuels are used as raw materials or for energy purposes. This facilitates the use of data for CRF table 1Ad, non-energy use of fuels.

Data on carbon from coke, bound in produced ferroalloys is collected directly from the only ferroalloy producer and is added to the remaining data on carbon from coke. Estimates of carbon stored are derived by multiplying given energy amount with emission factors for CO_2 (as given in Annex 2 section 1.2 and Appendix 3) multiplied by 12/44 (the weight of one atom of carbon is by definition 12/44 the weight of one molecule of CO_2).

CO_2 emissions derived from non-energy use of fuels and reported under CRF 1B and CRF 2 (e.g. flaring of gases and iron and steel process emissions) are added under CRF 1Ad and linked to the CRF 1Ab as carbon stored (see Annex 4).

3.2.4 CO_2 capture from flue gases and subsequent CO_2 storage

So far, storage of CO_2 does not occur in Sweden[17]. There are, however, several research projects going on where CO_2 is captured from flue gases at a pilot scale.[18]

3.2.5 Country-specific issues

No country-specific issues are reported in this submission.

3.2.6 Public electricity and heat production (CRF 1.A.1.a)

3.2.6.1 SOURCE CATEGORY DESCRIPTION

A 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 3.2.

Table 3.2. Summary of source category description, CRF 1A1a.

CRF	Gas	Key Category Assessment 2009			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 pro-

[17] Geological Survey of Sweden, 2010
[18] E-on 2010-11-04, Fortum 2010-11-04

duced 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 2009, 56 % 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 89 PJ (1990) to 189 PJ (2009) but, due to the more frequent use of biomass, greenhouse gas emissions from district heating are at a lower level in 2009 than in 1990. [19]

The number and distribution of Swedish power stations in 2009 are presented in Table 3.3[20]. 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 3.3. Number and distribution of Swedish energy stations in 2009.

Type of plant	Number of plants		Production GWh		Production TJ
Total power stations	2 211		149 651		538 744
Power generation not based on fuels	2 024		71 098		255 953
- Wind		1 138		1 996	7 186
- Water		886		69 102	248 767
Power generation based on fuels	187		78 553		282 791
- Nuclear power		3		63 889	230 000
- Power and heat production		184		14 664	52 790
- Manufacturing industries, ISIC 10-37		45			
- Energy plants, ISIC 40		117			
- Others		22			

3.2.6.2 METHODOLOGICAL ISSUES

The Tier 2 method is used.

The activity data source for emissions in CRF 1A1a is the quarterly fuel statistics, further described in Annex 2.

[19] All numbers are according to data used in the Greenhouse gas inventory this submission.
[20] Data for 2009 currently not available. Statistics Sweden EN11SM 1001.

Emissions from energy plants integrated with the iron and steel industry are allocated to CRF 1A2a. This is discussed in chapter 3.3.4.1 and in detail in chapter 4.4.2.1.2.2.

3.2.6.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The quarterly fuel statistics is a total survey for ISIC 40 and the response rate is almost 100 %. This provides the inventory with data of very good quality, accurate, complete, consistent and with very low uncertainties.

The trend in fuel consumption in this sector varies depending on the production of hydroelectric power and weather variations between years. The greatest changes in fuel consumption are for biomass fuels, where the consumption has increased significantly due to for instance increased district heating. It can also be noted that the use of natural gas in this sector has almost doubled in 2009 compared to the annual consumption 2005-2008. The reason is that the number of gas-fuelled facilities has increased.

The variations in IEFs between years are normally small. The IEFs for solid fuels, however, are considerably more variable than for other fuel types due to the variable supply of energy gases from the iron and steel industry. As blast furnace gas has a much higher CO_2 EF than other solid fuels, the share of blast furnace gas has a very large influence on the aggregate CO_2 IEF for solid fuels. As the production in the iron and steel industry was much lower in 2009 than 2008, the share of blast furnace gas in 1.A.1.a dropped, which explains the drop in CO_2 IEF for solid fuels in 1.A.1.a in 2009.

Emissions of NO_x and SO_2 and in relation to fuel consumption are also slightly variable between years due to variations in fuel mix. In the latest years, especially the SO_2 emissions in relation to fuel consumption have decreased due to a shift from residual fuel oils towards natural gas.

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. Wooden fuels are the most common fuels in this sector, but as CO_2 from biomass is not included in the sectoral total of GHG emissions, CO_2 from combustion of peat, blast furnace gas and “other fuels” accounts for the largest contributions to the aggregate uncertainty of GHG emissions in CRF 1A1a. The activity data uncertainties are relatively low, 2% for peat and blast furnace gas and 10% for “other fuels”. The CO_2 emission factor uncertainties are 20% and 100%, respectively, and thus account for the greater part of the aggregate uncertainties. Activity data uncertainties are assigned by expert judgements made by persons at the energy statistics department of Statistics Sweden. Emission factor uncertainties have been assigned by national experts on emissions from stationary combustion.

3.2.6.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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 all QC procedures listed in GPG section 8.1.7.4 applicable to this sector are used. The activity data has, of course, been subject to QA/QC procedures prior to the publishing of quarterly fuel statistics. In addition, the consumption of every type of fuel in the last year is checked and compared with previous years. If large variations are discovered for certain fuels, the consumption of these fuels is studied on facility level and if necessary, the staff responsible for the quarterly fuel survey is contacted for an explanation. IEFs are calculated per fuel, substance and CRF-code and checked against the emission factors to make sure that no calculation errors have occurred when emissions were computed.

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 companies' legal environmental reports and/or other independent sources. Remarks in recent review reports from the UNFCCC have been carefully read and taken into account whenever time limits allow. The results are verified by calculating CO_2 emissions with the reference approach, and comparing results with the sectoral approach (see Annex 4).

3.2.6.5 SOURCE-SPECIFIC RECALCULATIONS

There were no recalculations in this sector in submission 2011, apart from a very minor correction of the emission factor for CO_2 from diesel oil in 2007-2008 in order to use the same emission factor as for mobile combustion, resulting in 0,0004 Gg lower CO_2 emissions than in submission 2010 for each of these years.

3.2.6.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

There are presently no further improvements planned for this sector.

3.2.7 Petroleum refining (CRF 1.A.1.b)

3.2.7.1 SOURCE CATEGORY DESCRIPTION

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 and consequently reported under CRF 1B2. 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; two facilities have hydrogen production plants and four of the facilities have sulphur recovery plants. The fuel consumption in this sector is mainly based on liquid fuels and the use has increased due to higher demand of refined products.

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 1A1b.

CRF	Gas	Key Category Assessment 2009			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.

3.2.7.2 METHODOLOGICAL ISSUES

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 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[21], data from the EU Emission Trading System (ETS) are used for four refinery plants for 2005 and later years. For the fifth plant data from environmental reports were used. In 2008 and later years, the quality of ETS data is considered to be very high for all five of the refineries, and thus this is the primary data source for the GHG inventory. Environmental reports are used for verification. For refinery gas, plant specific CO_2 emission factors reported to the ETS are used for 2008 and later, since they are considered to be more accurate then the older standard emission factor.

3.2.7.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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. E.g. the slight dip in fuel consumption in 2007 is visible in all available data sources and is thus real and not caused by the shifting of data sources.

[21] Backman & Gustafsson, 2006

The implied emission factor for CO_2 for refinery gas is slightly lower for 2008-2009 when plant specific emission factors are used. However, as the national emission factor used for earlier years is based on information from the refineries, the decreasing IEF is considered to reflect actual technology improvements.

CO_2 from refinery gas is by far the largest source of uncertainty due to the fact that refinery gas accounts for about 90% of the energy from fuel combustion in this sector. The emission factor uncertainty is 5% and the activity data uncertainty is 10%. The assigned uncertainties are based on information directly from the facilities. They are updated regularly but not annually.

3.2.7.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

In general, the same QA/QC procedures are used for CRF 1A1b as for 1A1a described above. For each of the five refineries, ETS data for the latest year are verified against the refineries' legal environmental reports.

3.2.7.5 SOURCE-SPECIFIC RECALCULATIONS

A small amount of domestic heating oil in 2008 was erroneously coded as refinery oil in submission 2010. This has been corrected in submission 2011, resulting in a very minor (0.18 Gg) decrease in CO_2 emissions that year.
The emission factor for SO_2 from refinery oil has been revised from 0.22 to 0.15 kg/GJ for 2005 and later, and the emission factor for NO_x from refinery gas has been revised from 0.038 to 0.030 kg/GJ for 2006 and later. These revisions are the result of a development project in 2008. [22]

The effects of these recalculations on the total emissions of SO_2 and NO_X in CRF 1A1b compared to submission 2010 are shown below:

Table 3.5 Recalculations in CRF 1A1b.

Year	2005	2006	2007	2008
difference SO_2, Gg	-0.185	-0.167	-0.130	-0.122
difference NO_x, Gg	0.000	-0.255	-0.227	-0.272

A very minor correction of the emission factor for CO_2 from diesel oil in 2007-2008 in order to use the same emission factor as for mobile combustion, resulting in around 0,0001 Gg lower CO_2 emissions than in submission 2010 for each of these years.

3.2.7.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

There are presently no further improvements planned for this sector.

[22] Skårman et.al. 2008

3.2.8 Manufacture of solid fuels and other energy industries (CRF 1.A.1.c)

3.2.8.1 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), is presented in Table 3.6.

Table 3.6. Summary of source category description, CRF 1A1c.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1A1c	CO_2	X			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.

3.2.8.2 METHODOLOGICAL ISSUES

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. Activity data is taken from environmental reports and CO_2 emissions are estimated from carbon balances calculated by the facilities' own experts. Emissions of N_2O, CH_4, NMVOC and CO are estimated with the general T2 methodology with national emission factors. Estimates of emissions of SO_2 and NO_X are available from environmental reports on an aggregate level, and these emissions are distributed over the different CRF codes (1A1c, 1A2a, 1B1c and 2C1, SO_2 also 2B5 and 1B1b) according to the activity data distribution. The new methodology is described in detail in the methodological issues section about CRF 2C1.2 (section 4.4.1.2.2.)

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. National emission factors are used.

3.2.8.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The time series is considered to be very consistent as all data on emissions from the coke producing plants has been collected directly from the facilities. The

inter-annual variations in IEFs for solid fuels are caused by variations in the relative amounts of blast furnace gas and coke oven gas, respectively, between years. Solid fuel consumption decreased considerably in 2009 due to lower production of coke caused by lower demand of primary iron and steel. Consumption of liquid fuels has decreased since 2006 and the consumption of biomass is small and fairly constant.

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. CO_2 from blast furnace gas and coke oven gas are the dominating sources of uncertainty.

3.2.8.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The estimation of emissions from coke production is based on carbon balance calculations and the methodology is thoroughly described in chapter 4.

3.2.8.5 SOURCE-SPECIFIC RECALCULATIONS

No recalculations in this sector were carried out in submission 2011.

3.2.8.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Allocation of activities and emissions within the primary iron and steel industry will be further investigated during 2010-2011. This might have implications for CRF 1A1c.

3.2.9 Iron and steel (CRF 1.A.2.a)

3.2.9.1 SOURCE CATEGORY DESCRIPTION

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 2.8 million tonnes of steel in total in 2009, which is 46% less than the production in 2008.[23] The trend of the fuel combustion is increasing slightly since 1990 due to higher production of iron and steel products. In 2009 this trend was broken due to decreasing demand of iron and steel.

A 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.

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

Table 3.7. Summary of source category description, CRF 1A2a.

CRF	Gas	Key Category Assessment 2009			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

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

3.2.9.2 METHODOLOGICAL ISSUES IRON AND STEEL, CRF 1A2A

During 2009, a new methodology was applied for the two largest primary iron and steel works. This is described briefly in section 3.2.8.2 above and in detail in section 4.4.1.2.2.

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 for all facilities apart from the two largest ones mentioned above 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).

3.2.9.2.1 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 4.5 in section 4.4.2.1.2.2). Emissions 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 in accordance with the IPCC Guidelines. The allocation approach used in submission 2011 is the one that was developed during the revision in submission 2010. For comparison, the allocation used in submission 2009 is also provided in the table. There are two main differences between the new allocation and the old one. Firstly, in submission 2009 and earlier, power and heat production was allocated to CRF 1A1a. According to 1996 IPCC Guidelines, this was not correct and hence these emissions are since submission 2010 allocated to CRF 1A2a. Secondly, flaring of blast furnace gas and LD-gas has been reallocated from CRF 1B1c to 2C1.2, resulting in a shift in emissions from CRF 1 to CRF 2.

Table 3.8. Allocation of fuel consumption and CO_2 emissions in 2009 from iron ore based iron and steel industry on different CRF codes.

CRF	CRF sub 2009	Plant station	Fuel consumption 2009 (TJ)	CO_2 emissions 2009 (Gg)
1A1c	1A1c	Coke Oven	3 352	251
1A2a	1A1a, 1A2a	Combustion in Rolling Mills + Power and Heat Production	3 141	482
1A5a	1A5a	Transformations losses of energy in iron and steel industry	31 026	NA
1B1c	1B1c	Flare in Coke Oven (COG)	314	15
2C1.2	1B1c, 2C1.2	Blast Furnace + Steelworks (including Flaring of BFG and LD-gas)	NA	1 073
Total				1 821

Transformation losses of energy in iron ore based iron and steel industry have been estimated and reported under CRF 1A5a for all years. During 2010, efforts have been made to improve the allocation of the energy losses, but further investigations are needed and thus it was not possible to revise the allocation in submission 2011. 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.

3.2.9.2.2 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.

3.2.9.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

For the two largest facilities, the time series is very consistent as all data is based on information from these facilities, and they have checked that the calculated emission and energy data is accurate. For CRF 1A2a in total, the time series is also considered to be consistent, despite the fact that the quarterly fuel survey is used for most years and the yearly industrial energy survey for some years. The quarterly fuel survey data is enumerated to cover the same population as the yearly industrial energy survey. A discussion on the reasons for changing data sources can be found in Annex 2.

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. This also implies that the IEF varies between years, and it is considerably lower in 2009 than recent years because of the drop in blast furnace gas consumption. This ex-

[24] Statistics Sweden EN20SM 1990-2009 row 3.9

plains the fact aggregate CO_2 IEF for CRF 1A2a is considerably lower in 2009 than in earlier years. See also section 4.4.1.2.2.

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. CO_2 from blast furnace gas, coke oven gas and LPG are the largest sources of uncertainty in this sector. For these fuels the activity data uncertainty is 5%. The CO_2 emission factor uncertainty is 20% for blast furnace gas and coke oven gas, and 5% for LPG.

3.2.9.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

In general, the same QA/QC procedures are used for CRF 1A2a as for 1A1a described above. In addition to this, fuel consumption for the year t-2 is verified against the annual industrial energy survey on an aggregate level to check that the enumeration factors for the year t-1 are reasonable. For the two largest facilities, all data is collected directly from the company.

3.2.9.5 SOURCE-SPECIFIC RECALCULATIONS

No recalculations were carried out in this sector in submission 2011 apart from a very minor correction of the emission factor for CO_2 from diesel oil in 2007-2008 in order to use the same emission factor as for mobile combustion, resulting in around 0,00002 Gg lower CO_2 emissions than in submission 2010 for each of these years.

3.2.9.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Transformation losses of energy in the integrated iron and steel industry have been investigated in several studies. As we still haven't found the optimal allocation for these energy losses, the allocation of energy losses currently reported in CRF 1A5a will be investigated further in 2010-2011, and this might have impact on CRF 1A2a.

3.2.10 Non-Ferrous Metals (CRF 1.A.2.b)

3.2.10.1 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), is presented in Table 3.9.

Table 3.9. Summary of source category description, CRF 1A2b.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1A2b	CO_2				T2	CS	Yes
	CH_4				T2	CS	Yes
	N_2O				T2	CS	Yes

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

This source category covers combustion-related emissions from seven aluminium producers (ISIC 27420), six copper producers (ISIC 27440) and five facilities producing various other metals. More detailed descriptions are given in section 4.

Fuel consumption shows a decreasing trend for the period 1990-2002, but from 2003 onwards, the inter-annual variations in fuel consumption for energy production are relatively small and the copper- and aluminium producers account for about 40% each. The most common fuel is LPG followed by natural gas. Smaller amounts of heating oils are also used.

3.2.10.2 METHODOLOGICAL ISSUES

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.

3.2.10.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As for CRF 1A2a, time series consistency despite the changes in activity data source is discussed in Annex 2. In 1999 there is a large jump in the time series due to increased consumed amounts of natural gas. This has been identified as a possible reporting error for one facility, but original raw data from 1999 is no longer available and hence revision is not possible.

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. In 1990, the largest contribution to the aggregate uncertainty arises from CO_2 from “other solid fossil fuels” due to the fact that the emission factor uncertainty for this quite unspecified fuel is as high as 100%. In later years, this fuel is not used in CRF 1A2b, and CO_2 from LPG accounts for most of the uncertainty. The uncertainty is 5%, both in activity data and in the CO_2 emission factor for this fuel. Activity data uncertainties are assigned by expert judgements by staff at the energy statistics department of Statistics Sweden. Emission factor uncertainties have been assigned by national experts on emissions from stationary combustion.

3.2.10.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The same QA/QC procedures are used for CRF 1A2b as for 1A2a described above. In addition to this, a detailed quality study of the non-ferrous metal industry was performed in 2010.[25] This study showed no reasons for revisions in CRF 1A2b.

3.2.10.5 SOURCE-SPECIFIC RECALCULATIONS

No recalculations for this sector in submission 2011.

[25] Danielsson & Nyström, 2010

3.2.10.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

There are presently no further improvements planned for this sector.

3.2.11 Chemicals (CRF 1.A.2.c)

3.2.11.1 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), is presented in Table 3.10.

Table 3.10. Summary of source category description, CRF 1A2c.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1A2c	CO_2	X	X		T2	CS	Yes
	CH_4				T2	CS	Yes
	N_2O				T2	CS	Yes

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

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. The fuel consumption trend is increasing since 1990, especially for liquid fuels, mainly due to increased use within the basic plastic industry. However, since 2003 there is no distinct trend and the fuel consumption in 2009 was about 10% lower than in 2008, which reflects the decreasing demand for this sector in 2009. Throughout the time series, liquid fuels account for about 80% of the energy and gaseous fuels for 10-15%.

3.2.11.2 METHODOLOGICAL ISSUES

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.

Generally, plants classified as ISIC Division 24 according to ISIC Rev.3[26] in the energy statistics are included in this sector, as recommended in IPCC 1996 Revised Guidelines. In submission 2011, it was decided to make an exception from this rule and include one major plastic manufacturing plant that is classified as ISIC 24 some years and ISIC 25 other years in CRF 1A2c all years to improve time series consistency in CRF 1A2c and 1A2f. The reason is that a development project in 2010[27] showed that the production at that particular plant was quite similar dur-

[26] United Nations Statistics Division, 2010
[27] Gustafsson, Nyström & Gerner, 2010

ing the time series and hence the allocation to CRF 1A2f in some years would not be adequate.

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 of the largest facilities, including two plants, ETS data is the activity data source for 2008-2009. In 2005-2007, only parts of these plants were included in ETS and thus ETS data is not a suitable data source for those years. Hence, in 1990-2007, the data source for these two plants was energy statistics verified against the companies' environmental reports and when needed, the environmental reports were used as a complementary data source.

For this facility, plant specific CO_2 emission factors from ETS are used for 2008-2009 for the methane-based gas mixtures. The emission factor is slightly variable and around 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) 2008-2009 than earlier years. We are aware of this inconsistency and the emission factor for earlier years will possibly be revised in submission 2012.

3.2.11.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As for CRF 1A2a and 1A2b, time series consistency despite the changes in activity data source is discussed in Annex 2. There is a known inconsistency in CO_2 EF for methane-like gases as mentioned above, and this causes a drop in IEF for liquid fuels 2008-2009 compared to earlier years. We will try to find a solution to this problem in the next submission.

As noted by the ERT, the implied emission factors for "other fuels" are variable, especially in the early years. This is explained by the fact that municipal waste has occasionally been combusted within the chemical industry, and most years also "other non-specified fuels". As these fuels have very different emission factors for CO_2, the relative amounts of these two fuels cause inter-annual variations in IEFs. The outlier value of 28.4 kg/GJ in 1992 is explained by the fact that a small amount of municipal waste was combusted that year, but no "other non-specified fuels". It should be noted that the group "other fuels" accounts for a relatively low share of the emissions compared to other fuel groups; typically around 5% of the emissions of fossil CO_2 within CRF 1A2c.

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. CO_2 from methane-based gas mixtures accounts for most of the uncertainty. The uncertainty in activity data is 5% and the emission factor uncertainty is assumed to be 10% based on the variation in plant specific values. Activity data uncertainties are assigned by expert judgements by staff at the energy statistics department of Statistics Sweden.

3.2.11.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

In general, the same QA/QC procedures are used for CRF 1A2c as for 1A2a–b described above.

In the development project in 2010[28] mentioned above, the activity data time series 1990-2008 for all fuel types and all facilities within the chemical industry were thoroughly reviewed. Reported emissions and activity data in CRF 1 and 2 were analysed on plant level and verified against environmental reports and when necessary, the plants were contacted for explanations or complementary data. Most of the data reported in submission 2010 was concluded to be correct, but a few revisions had to be made in submission 2011. These are described under source-specific recalculations.

3.2.11.5 SOURCE-SPECIFIC RECALCULATIONS

In the development project mentioned above, it was concluded that the ISIC code was inaccurate for certain plants in 2001-2007, which resulted in reallocation of some emissions from CRF 1A2f to 1A2c. This has, of course, lead to increased fuel combustion and emissions in 1A2c for these years, but for confidentiality reasons, the exact impact of this reallocation cannot be shown.

In addition to the reallocations, a few erroneous activity data records were detected and revised. The errors include double counting, input data errors, and miscoding, e.g. biogenic ethanol that had been coded as natural gas or hydrogen coded as other petroleum fuels.

The project also resulted in revisions of a couple of emission factors. Emission factors for hydrogen, which were previously set to those of "other petroleum fuels" for all substances containing nitrogen, i.e. including N_2O, were corrected and set to zero for all substances except NO_x. The CO_2 emission factor for the methane-based gas mixture mentioned above was set as the same as that for natural gas in submission 2010, and hence varies between years according to variations in the natural gas composition. These variations are not considered to be valid for methane-like gases of other origin, and hence the emission factor was adjusted to 55.0 kg CO_2/GJ based on the carbon content and the NCV of methane.

The revision that had the largest impact on the emissions is the reallocation of some of the natural gas consumption from CRF 1A2c to CRF 1Ad for 2004 and onwards, since it was concluded that the gas is actually used as feedstock and not for energy production. The carbon is stored in products such as hydrocarbons and alcohols, and thus not emitted as CO_2. Again, for confidentiality reasons, the effect of every individual recalculation cannot be shown.

A very minor correction of the emission factor for CO_2 from diesel oil in 2007-2008 in order to use the same emission factor as for mobile combustion, resulted in less than 0,00001 Gg lower CO_2 emissions than in submission 2010 for each of these years.

[28] Gustafsson, Nyström & Gerner, 2010

3.2.11.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Possibly, some emission factors will be investigated more thoroughly, especially the CO_2 emission factor for methane-like gases, and emissions from a few facilities will be reviewed further in detail.

3.2.12 Pulp, Paper and Print (CRF 1.A.2.d)

3.2.12.1 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), is presented in Table 3.11.

Table 3.11. Summary of source category description, CRF 1A2d

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1A2d	CO_2	X	X		T2	CS	Yes
	CH_4				T2	CS	Yes
	N_2O				T2	CS	Yes

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

In 2009 there were 41 paper mill plants, 165 sawmills (production capacity >10 000 m^3/year) and 41 pulp industry plants in Sweden. In total, they were producing 10.9 million tonnes of paper, 16.1 million m^3 of sawn timber and 11.5 million tonnes of pulp. [29] Since 1990, production has had an increasing trend, but not in the latest few years. There is no apparent trend in total fuel consumption since 1990, but in recent years, the share of energy from biomass fuels has increased.

3.2.12.2 METHODOLOGICAL ISSUES

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.

3.2.12.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As for CRF 1A2 in general, time series consistency despite the changes in activity data source is discussed in Annex 2. The fluctuating IEFs for liquid fuels reflect variations in fuel mix. In the 1990s, petroleum coke was used in some facilities, and in the latest years, combustion of heavy heating oils has decreased a bit. Fuels

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

classified as "other fuels" are scarcely occurring in this CRF category, and as in 1A2c, the large variations in IEFs are caused by occasional use of municipal waste.

In recent years, the relative amount of biomass has increased and the relative amounts of liquid fuels, especially residential fuel oil, have decreased. One effect of the increasing share of biomass is that emissions of fossil CO_2 per TJ of total fuel consumption is decreasing. This is the reason behind the fact that fossil CO_2 emissions were lower in 2008 than in 2007, despite the fact that the fuel consumption was higher in 2008 than in 2007.

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. N_2O from wooden fuels and CO_2 from residual fuel oil are the greatest contributors to the aggregate uncertainty in this sector. The activity data uncertainty is 2% for all years for both of these fuels. The N_2O emission factor for wood is 40% and the CO_2 emission factor for residual fuel oil is 1%. Activity data uncertainties are assigned by expert judgements made by persons in the energy statistics department at Statistics Sweden. Emission factor uncertainties have been assigned by national experts on emissions from stationary combustion.

3.2.12.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

In general, the same QA/QC procedures are used for CRF 1A2c as for 1A1a and 1A2a–c described above.

3.2.12.5 SOURCE-SPECIFIC RECALCULATIONS

No recalculations for this sector in submission 2011apart from a very minor correction of the emission factor for CO_2 from diesel oil in 2007-2008 in order to use the same emission factor as for mobile combustion, resulting in around 0,0002 Gg lower CO_2 emissions than in submission 2010 for each of these years.

3.2.12.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Emissions from combustion of sulphur lyes are presently not reported in CRF 1A2d as this activity has been considered as an industrial process. This might, however, be revised in future submissions.

3.2.13 Food Processing, Beverages and Tobacco (CRF 1.A.2.e)

3.2.13.1 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), is presented in Table 3.12.

Table 3.12. Summary of source category description, CRF 1A2e

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1A2e	CO_2	X	X		T2	CS	Yes
	CH_4				T2	CS	Yes
	N_2O				T2	CS	Yes

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

The food and drink industry is the fourth largest branch of industry measured as production value and number of employees. There are about 3200 companies, of which only around 650 have more than 10 employees. [30] The largest number of companies and employees are found in the bakery industry, but the most energy intensive branch is the sugar industry which accounts for about 25% of the fuel consumption in 1A2e. Dairies, breweries, producers of refined vegetable fats and potato products are other industries with significant fuel consumption (around 7-12% each of the fuel consumption in 1A2e). The fuel consumption varies between years. A slight decrease can be observed since 1990. In later years, liquid and gaseous fuels account for about 40-45% each of the total fuel consumption.

3.2.13.2 METHODOLOGICAL ISSUES

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.

3.2.13.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As for CRF 1A2 in general, time series consistency despite the changes in activity data source is discussed in Annex 2. As for other categories in CRF 1A2, the IEFs are slightly variable between years due to variations in fuel mix. The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. In the early 1990's, CO_2 from residual fuel oil was the largest source of uncertainty, followed by CO_2 from natural gas. In recent years, CO_2 from natural gas accounts for most of the uncertainty. For both fuels, the activity data uncertainty is 5%. CO_2 emission factor uncertainty is 1% and 5% for residual fuel oil and natural gas, respectively. Activity data uncertainties are assigned by expert judgements made by persons in the energy statistics department in Statistics Sweden. Emission factor uncertainties have been assigned by national experts on emissions from stationary combustion.

[30] The Swedish Food Federation 2009-09-16

3.2.13.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Generally, the same QA/QC procedures are applied for 1A2e as for other 1A2 categories described above. As a side effect of the quality control of the chemical industry in 2010, the reported consumption of other petroleum fuels in the food and drink industry was investigated, and comparisons with the annual industrial energy survey were made. It turned out that this fuel was miscoded as it was actually landfill gas, i.e. biomass. The large consumption of natural gas in 2008 was checked against the annual industrial energy survey. The enumeration factor for natural gas in 2008 for the food and drink industry in the quarterly fuel survey was found to be erroneous and it was adjusted to the same value as 2007.

3.2.13.5 SOURCE-SPECIFIC RECALCULATIONS

As mentioned above, some consumption of other petroleum fuels was recoded as landfill gas resulting in lower fossil CO_2 emissions in the years 2000-2008. This recalculation had minor effects on the aggregate GHG emissions (around 5 Gg per year 2003-2005 and less than one Gg per year in other years). The correction of the enumeration factor for natural gas in 2007 resulted in -96,6 Gg compared to submission 2010.

3.2.13.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

There are presently no source specific improvements planned for this sector.

3.2.14 Other Industries (CRF 1.A.2.f)

3.2.14.1 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), is presented in Table 3.13.

Table 3.13. Summary of source category description, CRF 1A2f

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
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.

This source category is by nature quite heterogeneous. In terms of stationary fuel combustion and emissions, three branches of industry are dominating; non-metallic mineral production (ISIC 26), manufacturing of wood products (ISIC 20), and mining industry (ISIC 13). In ISIC 20, however, biomass fuels are dominating and hence the emissions of fossil CO_2 from this branch of industry are low. The construction industry also accounts for a significant share of fuel consumption and emissions. The fuel consumption varies between years, but for stationary combus-

tion within 1A2f in total, it has decreased slightly since 1990. Liquid and biomass fuels account for most of the decrease.

3.2.14.2 METHODOLOGICAL ISSUES

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[31]. 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.[32]

Since 2002, for one glassworks plant, it is no longer possible to separate combustion emissions of SO_2 from process emissions. The reason is that the facility has restructured its environmental report, and only reports emissions of SO_2 on an aggregate level. The median value for the share of process related SO_2 emissions to the total SO_2 emissions is 2 % for the years 1990 - 2001. Emission data reported in the plants environmental report are considered to be more accurate than emissions calculated from fuel combustion with standard emission factors. Thus for practical reasons, SO_2 and NO_X emission data available from environmental reports are reported in CRF 2A7. All other energy related emissions for this facility are reported in CRF 1A2F.For 2008 and 2009, activity data for the three plants within the cement production industry is taken from the EU ETS system.

[31] Statistics Sweden, EN20SM 1990-2009. See also Annex 2.
[32] Statistics Sweden, EN20SM 1990-2009. See also Annex 2.

3.2.14.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As for CRF 1A2 in general, time series consistency despite the changes in activity data source is discussed in Annex 2. As for other categories in CRF 1A2, the IEFs are vary slightly between years due to variations in fuel mix. In earlier submissions, the EU Monitoring Mechanism has asked for clarification of the drop in wood consumption in 2000 compared to earlier years. This issue has not been prioritized, but since the annual wood consumption 2001-2009 is considerably lower than in the 1990s, there is no reason to believe that the activity data for 2000 is incorrect.

CO_2 from diesel and heating oils are the largest sources of uncertainty in GHG emissions within CRF 1A2f. The activity data uncertainty for all heating oils within this sector is as high as 20% on an aggregate level, due to the fact that emissions from the construction sector and small industries are estimated with the Tier 1 method. The activity data uncertainty for diesel combusted in off- road vehicles and working machinery is 5%. The CO_2 emission factor uncertainty is 1%, whereas the CO_2 emission factor uncertainty for diesel is as high as 10%. This uncertainty estimate was assigned when the method for emission calculations for off- road vehicles and working machinery was revised in 2008, and it will most likely be updated in submission 2012.

3.2.14.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Generally, the same QA/QC procedures are applied for 1A2f as for other 1A2 categories described above. In some earlier submissions, extensive QA/QC and verification efforts have been made for the other sectors including the construction industry. This is described in section 3.2.21 below.

3.2.14.5 SOURCE-SPECIFIC RECALCULATIONS

Some emissions have been reallocated from CRF 1A2f to 1A2c as described in section 3.2.11. Activity data for the construction sector has been revised for 2007-2008 following revisions of the annual energy balances. A very minor correction of the emission factor for CO_2 from diesel oil in 2007-2008 in order to use the same emission factor as for mobile combustion, resulted in less than 0,05 Gg lower CO_2 emissions than in submission 2010 for each of these years. According to the method applied to off-road vehicles and other machineries, the emission factors change yearly. The full explanation of the procedure is available in Annex 2.

3.2.14.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

For emissions from stationary combustion, no source specific improvements are planned for this sector. In submission 2012, an improved method for estimating emissions from off-road vehicles and working machinery will be applied.

3.2.15 Civil Aviation (CRF 1.A.3.a)

3.2.15.1 SOURCE CATEGORY DESCRIPTION

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.[33] The traffic routed through governmental airports account for about 90 % of the total fuel consumption within the civil aviation sector.

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 3.14.

Table 3.14. Summary of source category description, CRF 1A3a.

CRF	Gas	Key Category Assessment 2009			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

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

3.2.15.2 METHODOLOGICAL ISSUES

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 Transport Agency (SCAA) on fuel use and emissions estimates related to the governmental airports in Sweden.

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. 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 SCAA calculations of emissions. The emissions mostly affected are CO and NOx. In order to avoid underestimation in the greenhouse gas inventory, data for 2007 have been reused to

[33] Swedish Transport Agency.

cover both 2008 and 2009 emissions from private aviation, educational training flights and military aviation. This procedure will need to be revised in up-coming submissions as the fuel consumption is changeable over the years. One result seen is that that a dip between 2007 and 2008 is seen for especially CO. A significant change of domestic LTO in the activity data are seen causing this drop.

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 that the IPCC guidelines follow.[34] For international flights, ICAO standard taxi time has been used for the part of the LTO cycle occurring on international airports.[35]

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

Emissions of CO_2 are based on fuel delivery statistics, national thermal values from Statistics Sweden and emission factors from the Swedish EPA. New emission factors were delivered in time for the submission of 2011, 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.

[34] Gustafsson, 2005.
[35] Näs, 2005.

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 3.4.

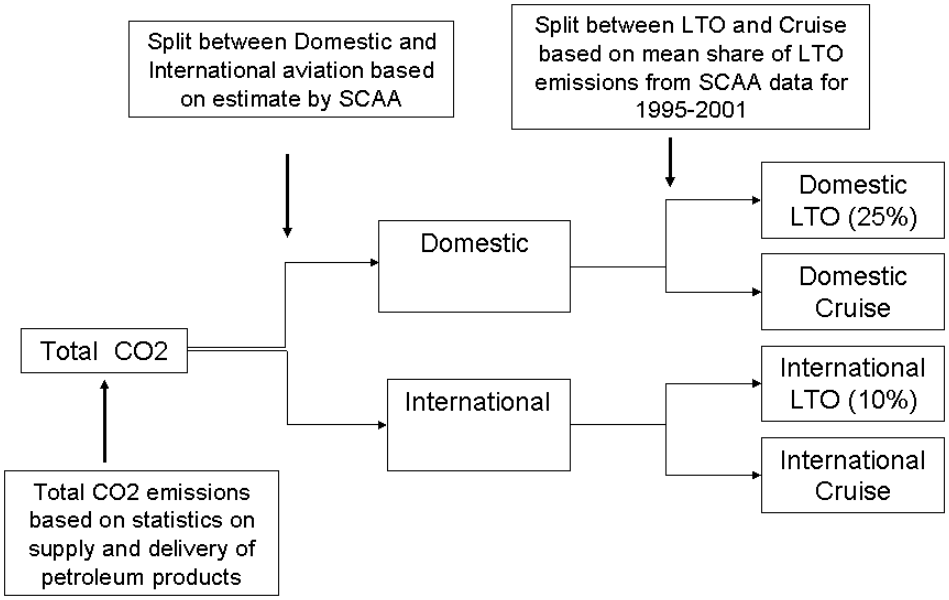

Figure 3.4. Model for estimating Domestic/International LTO/Cruise 1990-1994.

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 and 1998 vary from 29-30%, i.e. they are very stable. 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 %.

3.2.15.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

In order to maintain consistency with the time-series the estimation procedures have been developed as described above. However, due to the level of estimations not based on activity data a certain degree of uncertainty exists.

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7.

3.2.15.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

All Tier 1 general inventory level QC procedures and all QC procedures listed in GPG section 8.1.7.4 applicable to this sector are used. The activity data has, of course, been subject to QA/QC procedures prior to the publishing. In addition, the consumption of every type of fuel in the last year is checked and compared with previous years. If large variations are discovered for certain fuels, responsible staff is contacted for an explanation. IEFs are calculated per fuel, substance and CRF-code and checked against the emission factors to make sure that no calculation errors have occurred when emissions were computed.

3.2.15.5 SOURCE-SPECIFIC RECALCULATIONS

Due to the revision of the regulation non-governmental, some airports were excluded in submission 2010, which meant that emissions of in particular CO and NO_X were underestimated. Upon request from the UNFCCC ERT in 2010 a recalculation and resubmission of 2008 emissions was done in order to reach completeness. The same activity data as for 2007 when the transmitted data from the SCCA included the flights of interest was used an extrapolation of the information. These revised values are kept in submission 2011.

3.2.15.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

The recalculations in resubmission 2010 were a response to the ERT work and the new method needs to be evaluated and further improved in the near future, e.g until submission 2012.

3.2.16 Road transport (CRF 1.A.3.b)

3.2.16.1 SOURCE CATEGORY DESCRIPTION

Road transport includes: Passenger cars, Light duty vehicles, Heavy duty vehicles and Mopeds & Motorcycles.

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 3.15.

Table 3.15. Summary of source category description, CRF 1A3b.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
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

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

3.2.16.2 METHODOLOGICAL ISSUES

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 Transport Agency (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 3. 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[36] 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 3.16.

Table 3.16. Emissions from road transport reported by the SNRA and in the CRF.

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

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

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

Prior to submission 2007, emissions of SO_2 from diesel and gasoline were based on the maximum allowed sulphur content of different environmental classes. Data on maximum allowed sulphur content was provided by SPI. From submission 2007, emissions of SO_2 are based on the actual sulphur content for the different environmental classes of petrol and diesel fuel. The data on actual sulphur content, provided by SNRA, is based on estimates made by VTI[37] 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. Thermal values and emis-

[36] Swedish Road and Transport Research Institute, 2002.
[37] Ibid.

sion 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:

$$A = B - \sum((C-D)/C*E_i)$$

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

3.2.16.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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.

One important basic parameter for the ARTEMIS-model is vehicle-Km, which are calculated through another model. This second model is based on the mileage driven by the vehicle noted at time of MOT (annual testing of the vehicle).

A passenger car that goes through MOT in the beginning of 2009 has driven the most part during 2008. If the development of traffic is without interruption this issue is not a problem for the calculations. However, if a sudden event occurs, such as a drop in the economy as seen recently it will not be shown as clearly in the development of vehicle mileage as in statistics on fuel consumption. One example is for example the calculations of N20 which is actually increasing slightly despite a decreasing fuel consumption overall.
The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7.

3.2.16.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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 all QC procedures listed in GPG section 8.1.7.4 applicable to this sector are used. The activity data has, of course, been subject to QA/QC procedures prior to the publishing of quarterly fuel statistics. In addition to this, the consumption of every type of fuel in the last year

is checked and compared with previous years. If large variations are discovered for certain fuels, responsible staff is contacted for an explanation. IEFs are calculated per fuel, substance and CRF-code and checked against the emission factors to make sure that no calculation errors have occurred when emissions were computed.

3.2.16.5 SOURCE-SPECIFIC RECALCULATIONS

Revision of emissions from off-road vehicles affect the allocation of diesel oil and gasoline to road traffic. Correction of pervious minor erroneous data of e.g. natural gas and biomass.

3.2.16.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No specific improvements are planned.

3.2.17 Railways (CRF 1.A.3.c)

3.2.17.1 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), is presented in Table 3.17.

Table 3.17. Summary of source category description, CRF 1A3c.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1A3c	CO_2				T1	CS	Yes
	CH_4				T1	CR, CS, D, M	Yes
	N_2O				T1	CR, CS, D, M	Yes

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

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

3.2.17.2 METHODOLOGICAL ISSUES

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.

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[38], whereas emission factors used for NO_X and CO estimates are provided by the

[38] www.spi.se August 2005

Swedish Transport Agency. Remaining emissions are calculated based on default emission factors from EMEP/CORINAIR.

3.2.17.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Overall, the emissions for CRF 1.A.3.C is consistent over time and associated with low uncertainties. The estimate of diesel consumption is based on fees paid by the rail operators and is considered to be of very high quality.
The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7.

3.2.17.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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 all QC procedures listed in GPG section 8.1.7.4 applicable to this sector are used. The activity data has, of course, been subject to QA/QC procedures prior to the publishing of quarterly fuel statistics. In addition to this, the consumption of every type of fuel in the last year is checked and compared with previous years. If large variations are discovered for certain fuels, the staff responsible is contacted for an explanation. IEFs are calculated per fuel, substance and CRF-code and checked against the emission factors to make sure that no calculation errors have occurred when emissions were computed.

3.2.17.5 SOURCE-SPECIFIC RECALCULATIONS

Recalculations were done for submission 2011 with regards to 2007 for following emissions: CO_2, N_2O, CO, CH_4, NMVOC and NO_X. The reason for the recalculations are that the Transport Agency delivers updated data.

3.2.17.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

During the calculation process it was discovered that SO_2 for the sector had increased dramatically from 2007 to 2008 (2009 data are estimated based on 2008 values). The changes in SO_2 could not be answered by fuel consumption as the levels have remained constant over time. Unfortunately, the changes could not be verified by the Transport Agency in time for submission 2011 and SO_2 values for 2007 was applied to 2009.

It is expected that the Transport Agency will be able to allocate the reason for the changes until submission 2012.

3.2.18 Navigation (CRF 1.A.3.d)

3.2.18.1 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), is presented in Table 3.18.

Table 3.18. Summary of source category description, CRF 1A3d.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1A3d	CO_2	X			T1	CS	Yes
	CH_4				T1	CR, CS	Yes
	N_2O				T1	CR, CS	Yes

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

The sector covers domestic navigation and leisure boats. Emissions from fuels that are purchased in Sweden but used abroad are reported separately as international bunker emissions.

3.2.18.2 METHODOLOGICAL ISSUES

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.[39] 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 3.19.

Table 3.19. 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[40]. Emissions for 2003 and 2004 have been estimated using emissions factors for 2002 while emissions for 2005 and later years have been calculated using emissions factors provided by the Swedish Maritime Administration (SMA). The emission factors provided by the SMA are based on the mentioned study by SMED.

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

Emissions of NO_X, NMVOC, CH_4, CO and N_2O from leisure boats also depend on the ratio between 2-stroke and 4-stroke engines. The estimated ratios between

[39] Statistics Sweden EN31SM
[40] Cooper and Gustafsson, 2004.

the two are based on a study by Statistics Sweden[41] 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.

3.2.18.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The statistics on fuel purchased and consumed fluctuates yearly. There is no clear indication of why this is the case and that makes the uncertainty higher for CRF 1.A.3.D than for other sectors.

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7.

3.2.18.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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 all QC procedures listed in GPG section 8.1.7.4 applicable to this sector are used. The activity data has, of course, been subject to QA/QC procedures prior to the publishing of statistics on fuel purchased. In addition to this, the consumption of every type of fuel in the last year is checked and compared with previous years. If large variations are discovered for certain fuels, responsible staff is contacted for an explanation. IEFs are calculated per fuel, substance and CRF-code and checked against the emission factors to make sure that no calculation errors have occurred when emissions were computed.

3.2.18.5 SOURCE-SPECIFIC RECALCULATIONS

For submission 2010 new emission factors were provided for CO_2 and the time series 1990-2008 should have been revised. Unfortunately 2008 emission factors for leisure boats remained unchanged. For submission 2011 CO_2 emissions for leisure boats have been revised in accordance with previous instructions. Correction of pervious minor erroneous data also occur.

3.2.18.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No improvements planned for submission 2012. However, the calculation process for navigation includes adjusting for bunkering (CRF 1.C). The statistics covering fuels purchased in Sweden but used abroad has over the years been subject to con-

[41] Statistics Sweden, 2005.

tinued investigation. This is a prioritized area also for development during 2011. Any progress made will be reported in submission 2012.

3.2.19 Other transportation (CRF 1.A.3.e)

3.2.19.1 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), is presented in Table 3.20.

Table 3.20. Summary of source category description, CRF 1A3e.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
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.

Emissions reported under CRF 1A3e refer to emissions from off-road vehicles and other machinery including various mobile vehicles and machinery as for example tractors, dumpers, lawn movers, snowmobiles, cranes, trimmers, forklifts and any other mobile machine that run on liquid fuels.

3.2.19.2 METHODOLOGICAL ISSUES

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. In brief; due to this new methodology the emission factors change yearly.

Emissions from off-road vehicles and other machinery are also reported under CRF 1A2f, 1A4b and 1A4c, in line with IPCC Guidelines, see Table 3.21.

Table 3.21. 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 snowmobiles.
Agriculture	1A4c	Emissions from fuel combustion in agriculture and forestry. Highway agricultural transportation is excluded.
Forestry	1A4c	

3.2.19.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The calculations are based on a model that takes into consideration emission regulations according to EU legislation in g kWh^{-1}, for differences between regulation and value measured at certification, transient use (i.e. difference between static test cycle and real use of the machine), emission deterioration with age, and for differences between certification fuel and Swedish diesel of type “MK1”. The model does not consider market fluctuations. The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7.

3.2.19.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The model is rather new (implemented the first time in submission 2009). During 2010 the model underwent a second verification.

3.2.19.5 SOURCE-SPECIFIC RECALCULATIONS

According to the method applied to CRF 1A3e the emission factors change yearly. The full explanation of the procedure is available in Annex 2.

3.2.19.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Revision of activity data and emission factors for some off-road vehicles are planned to submission 2012.

3.2.20 Commercial/institutional (CRF 1.A.4.a)

3.2.20.1 SOURCE CATEGORY DESCRIPTION

The heated area was just below 135 million m² in 2008. More than one third of this area consists of schools. Since 1990, the total consumption of fuels for heating of premises has decreased significantly due to the increased use of district heating. In the early 1990s, the total annual fuel consumption in this sector was around 35 000 TJ, around year 2000 it had decreased to about 20 000 TJ, and in 2009 it was less than 13 000 TJ. Liquid fuels account for most of the decrease, and in recent years, natural gas is the most common fuel followed by domestic heating oil and wooden

fuels. Over 90% of the area was heated with district heating in 2008. The corresponding share in 1990 was about 55%.

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 3.22.

Table 3.22. Summary of source category description, CRF 1A4a.

CRF	Gas	Key Category Assessment 2009			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

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

3.2.20.2 METHODOLOGICAL ISSUES

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.

3.2.20.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. CO_2 from domestic heating oil is the largest uncertainty source. The activity data and emission factor uncertainties are 20% and 1% respectively. The large activity data uncertainty is due to the use of Tier 1 methodology with data from the annual energy balances.

3.2.20.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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.[42] 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

[42] Gustafsson, et al. 2005.

were identified leading to recalculations of activity data and emissions in CRF 1A4a and 1A4b[43]. 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.

3.2.20.4.1 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[44]. The main problem is still that the timeline for the GHG inventory is too short for using final data for other sectors and construction for the latest year. All available alternatives have specific problems including higher uncertainties etc discussed in the study. The method that was considered to give the best data was using annual 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 the equation below:

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 consumption 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. Further investigations were planned to submission 2011, but this issue was not prioritised.

The large revisions in the annual energy balances lead to large revisions of GHG inventory data as well, and the estimation model yielded poor estimates for 2008 in submission 2010, particularly for heating oils. Unfortunately no other data sources were available in time to improve these estimates.

In submission 2010 it was noted that the consumption of biomass, liquid fuels and gaseous fuels within this sector was higher in 2007 than in 2006 and 2008. In submission 2011, the activity data for 2007 and 2008 were revised as discussed in section 3.21. The fuel consumption in 2007 is still relatively high. The input data to the energy balances for this sector has not been available for analysis. However, the activity data uncertainty is high in this sector and the time series 1990-2009 shows that inter-annual variations in total fuel consumption can be large. Thus the

[43] Paulrud et al. 2005.
[44] Lidén and Gerner, 2008

fuel consumption in 2007 is considered to be high, maybe as a result of the large uncertainty, but not erroneous as no calculation errors have been found.

3.2.20.5 SOURCE-SPECIFIC RECALCULATIONS

As indicated in the previous section, activity data has been revised for all fuels for years 2007 and 2008.

3.2.20.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

There are no specific plans for improvements, although the estimation model for the latest emission year might be reviewed.

3.2.21 Residential (CRF 1.A.4.b)

3.2.21.1 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), is presented in Table 3.23.

Table 3.23. Summary of source category description, CRF 1A4b.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1A4b	CO_2	X	X		T1,T2	CS	Yes
	CH_4				T1,T2	CS	Yes
	N_2O				T1,T2	CS	Yes

Stationary combustion of fuels within the residential sector has decreased by around 50% between 1990 and 2009, mainly due to a continuous increase in district heating use. Most of this change occurred before 2006; however, the use of heating oils is still decreasing while combustion of wood, wood chips and pellets has increased in recent years.

3.2.21.2 METHODOLOGICAL ISSUES

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 source is the annual energy balances. One- and two-dwellings statistics, Holiday cottages statistics and Multi-dwellings

statistics are used as a complementary data source to get more details on biomass combustion. 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 3.21 and use of preliminary data for stationary combustion in other sectors as discussed in section 3.21 also applies to CRF 1A4b.

3.2.21.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. CO_2 from domestic heating oil is the largest uncertainty source. The activity data and emission factor uncertainties are 20% and 1% respectively. The large activity data uncertainty is due to the use of Tier 1 methodology with indata from the annual energy balances.
The time series for 1A4b is considered to be consistent as there haven't been any major changes in methodology or indata to the energy balances that affect this sector. The estimates for the last year, however, are somewhat inconsistent due to the issues described in section 3.21. The CO_2 IEF for liquid fuels shows a decreasing trend because the share of residual fuel oil is decreasing. The CH_4 IEF for biomass is slightly fluctuating between years due to variations in type of biomass and technology as discussed in section 3.2.22.2.

3.2.21.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

See section 3.2.20.4

3.2.21.5 SOURCE-SPECIFIC RECALCULATIONS

Following revisions of the energy balances, the activity data for stationary combustion within 1A4b was revised for all fuels 2007-2008. According to the method applied to off-road vehicles and other machineries, the emission factors change yearly. The full explanation of the procedure is available in Annex 2.

3.2.21.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

The method for estimating emissions from off-road vehicles and working machinery will be improved in submission 2012. For emissions from stationary combustions within the residential sector, there are no specific plans for improvements, although the estimation model for the latest emission year might be reviewed.

3.2.22 Agriculture/forestry/fisheries (CRF 1.A.4.c)

3.2.22.1 SOURCE CATEGORY DESCRIPTION

Fuel combustion in this sector includes stationary combustion for heating purposes and mobile combustion in off-road vehicles and working machinery within agricul-

ture and forestry, and fishing vessels. The structure of the agricultural sector in Sweden is described in chapter 6.

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 3.24.

Table 3.24. Summary of source category description, CRF 1A4c.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1A4c	CO_2	X	X		T1,T2	CS	Yes
	CH_4				T1,T2	CS	Yes
	N_2O				T1,T2	CS	Yes

3.2.22.2 METHODOLOGICAL ISSUES

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 3.2.22.4.1, and use of preliminary data for stationary combustion in other sectors as discussed in section 3.2.22.4 also applies to CRF 1A4c.

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[45] 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[46], 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

[45] Statistics Sweden, 2006 ENFT0601.
[46] Cooper et al., 2005a.

emission abatement technologies used by the fleet (e.g. Selective Catalytic Reduction (SCR) for NO_X reduction) is assumed to be negligible.

3.2.22.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7.

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 they are based on the 1985 survey mentioned above, which was reasonably recent in 1990. The time series for liquid, solid and gaseous fuels are considered to be consistent. Since almost ten years, solid fuels are not used in this sector.

3.2.22.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

See section 3.2.20.4

3.2.22.5 SOURCE-SPECIFIC RECALCULATIONS

The use of coal in this sector in 2005-2008 that was reported in submission 2010 was found to be erroneous and has been revised, i.e. set to zero, in submission 2011. According to Statistics Sweden's energy department, no combustion of coal has occurred in this sector since year 2000. According to the method applied to off-road vehicles and other machineries, the emission factors change yearly. The full explanation of the procedure is available in Annex 2.

3.2.22.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

The method for estimating emissions from off-road vehicles and working machinery will be improved in submission 2012. For emissions from stationary combustions within agriculture, forestry and fisheries, there are no specific plans for improvements, although the estimation model for the latest emission year might be reviewed.

3.2.23 Other stationary (CRF 1.A.5.a)

3.2.23.1 SOURCE CATEGORY DESCRIPTION

CRF 1A5a includes emissions from pressure levelling losses of natural gas and transformation losses of energy in the integrated iron and steel industry. The transformation losses of energy don't cause any emissions, as the carbon is stored in products or in steelwork gases whose emissions when combusted are accounted for in other CRF codes (1A1a, 1A1c, 1A2a, 1B1c and 2C1). The magnitude of these energy losses is roughly the same every year. The pressure levelling losses of natural gas are, however, very variable, and some years zero. This, of course, causes large fluctuations in IEF:s. When there are no pressure levelling losses, all emissions and IEF:s are zero.

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 3.25.

Table 3.25. Summary of source category description, CRF 1A5a.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1A5a	CO_2				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.

3.2.23.2 METHODOLOGICAL ISSUES

Methods used in CRF 1A5a are considered to correspond to the Tier 1 method.

3.2.23.2.1 Transformation losses of energy

Transformation losses of energy in iron ore based iron and steel industry have been estimated and reported under CRF 1A5a for all years. The energy losses have been estimated as the difference between total energy content in inserted coal in coke ovens according to Statistics Sweden[47] 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.

3.2.23.2.2 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.

3.2.23.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As the same methodology and data sources are used for all years, the time series is considered to be consistent. However, as the transformation losses of energy accounts for about 90% of the energy in 1A5 (including 1A5b, mobile) the trends in emissions and energy consumption, respectively, can be contradictory. E.g. in 2009, fuel consumption and emissions from military mobile combustion increased, but the large transformation losses of energy had the effect that for 1A5 in total,

[47] Statistics Sweden EN20SM 1990-2006 row 3.9

emissions increased and energy consumption decreased in 2009 compared to 2008. The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7.

3.2.23.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

By nature, it is difficult to verify data on energy losses. However, the allocation of energy losses within the iron and steel industry has been analyzed in submission 2010 as described earlier in this section.

3.2.23.5 SOURCE-SPECIFIC RECALCULATIONS

No recalculations has been carried out in this sector in submission 2011.

3.2.23.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

The allocation of energy losses within the iron and steel industry might be revised in submission 2012. The ambition is to find a more appropriate allocation of the transformation losses in the integrated iron and steel industry and include only pressure levelling losses of natural gas in CRF 1A5a.

3.2.24 Other mobile (CRF 1.A.5.b)

3.2.24.1 SOURCE CATEGORY DESCRIPTION

CRF 1A5b includes emissions from military transports. Emissions from military transports have decreased over the years 1990-2008 due to a decrease in activity. However in 2009 the Swedish military increased its consumption of bio gas fuels and jet kerosene compared to 2008 (bio gas from 139 m^3 to 2109 m^3 and jet kerosene from 38601 m^3 to 77894 m^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), is presented in Table 3.26.

Table 3.26. Summary of source category description, CRF 1A5b.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1A5b	CO_2	X	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.

3.2.24.2 METHODOLOGICAL ISSUES

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:

Equation 3-1: $A = B - \sum((C-D)/C*E_i)$

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

3.2.24.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7.

3.2.24.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source specific procedures have been made.

3.2.24.5 SOURCE-SPECIFIC RECALCULATIONS

No recalculations have been made in submission 2011.

3.2.24.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No improvements planned for submission 2012.

3.3 Fugitive emissions from solid fuels and oil and natural gas (CRF 1.B)

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.

3.3.1 Fugitive emissions from solid fuels (CRF 1.B.1)

3.3.1.1 SOURCE CATEGORY DESCRIPTION

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. Since 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 section 4.4.1.1.2. 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 of coke oven gas in CRF Table 1B2. The amounts of flared gas vary considerably between years, and in 2009 it was unusually high, resulting in increasing emissions in CRF 1B1. According to environmental reports[48], coke oven gas is flared when the production is temporarily stopped because of urgent needs of reparation of equipment or other maintenance measures.

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 3.27.

Table 3.27. Summary of source category description, CRF 1B1.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1B1	CO_2				T2	CS	Yes
	CH_4				T2	CS	Yes
	N_2O				T2	CS	Yes

CS Country Specific. T2 Tier 2.

3.3.1.2 METHODOLOGICAL ISSUES

The estimation of emissions from flaring of coke oven gas is included in the carbon balance calculations and other plant specific calculations made in cooperation with the two facilities, see section 4.4.

[48] SSAB, 2008 and 2009

3.3.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. The extent of flaring is by nature very variable between years, and the uncertainties in activity data and emission factors are high compared to other activities.

3.3.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The coherence between environmental reports and ETS data is checked when possible, and when differences occur, the facilities are contacted for verification. For a few plants that flare small amounts of gas, activity data as amount of flared gas is shown neither in the environmental reports, nor in the ETS data. Flaring at these plants was investigated in 2005, and the same values are used for later years. Every year, these facilities are asked to verify that the default value is still valid.

3.3.1.5 SOURCE-SPECIFIC RECALCULATIONS

No recalculations in this sector in submission 2011.

3.3.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No improvements are planned for submission 2012.

3.3.2 Oil and natural gas (CRF 1.B.2)

3.3.2.1 SOURCE CATEGORY DESCRIPTION

According to 2006 IPCC Guidelines, emissions from hydrogen production plants should be reported in this sector. Since 2005, one such facility is in operation in Sweden, and another one was taken into operation in 2006. Emissions from these facilities are reported in CRF 1.B.2.A.1 in accordance with 2006 IPCC Guidelines.

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 3.28.

Table 3.28. Summary of source category description, CRF 1B2.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
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

3.3.2.2 METHODOLOGICAL ISSUES

3.3.2.2.1 Hydrogen production plants at refineries, CRF 1B2A1

Both CO_2 and non-CO_2 emissions are estimated using the Tier 2 method. Activity data as consumed amount of fuels (butane gas and naphtha, respectively for the two

plants) 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. National emission factors are used for butane, whereas national emission factors for "other petroleum fuels" are used for naphtha due to lack of specific emission factors for this fuel.

3.3.2.2.2 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 were reported not applicable (NA) in submission 2010 since no default IPCC emission factor for tankers is available. After comments from the UNFCCC Expert Review Team (ERT), fugitive emissions of CO_2 from transport of crude oil are in submission 2011 considered to be not estimated (NE) since there are not enough underlying information to support NA.

3.3.2.2.3 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[49],[50],[51],[52] and Statistics Sweden[53].

[49] Swedish EPA, 1990.
[50] Swedish EPA, 1994a.
[51] Swedish EPA, 1994b.
[52] Swedish EPA. 1995.
[53] Statistics Sweden. 1996 Emissions to air in Sweden of volatile organic compounds (VOC) 1988 and 1994.

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 3.29, 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 3.29, the reported emissions of CH_4 and also activity data can be seen.

Table 3.29. Throughput of crude oil in refineries and estimated fugitive emissions of NMVOC and CH4 (Mg) 1990-2009 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	16 810 000	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	20 305 000	9 661	272
1997	20 130 000	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	19 681 182	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	20 050 576	8 269	258
2007	17 706 518	8 877	233
2008	20 420 061	8 575	263
2009	19 669 472	8 779	253

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[54]. 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.

[54] 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

3.3.2.2.4 Gasoline handling and distribution, CRF 1B2A5

Calculated fugitive emissions of NMVOC from the storage of oil products have been obtained from SPI[55]. The calculations are based on the amount of gasoline handled in the depots. The calculations cover 1990 – 2009 and are based on methods given by Concawe 85/54[56] for the years 1990-2006 and on Concawe 03/07[57] for the years 2007 – 2009. More than 30 depots have been considered during later years. Gas recovery systems and the recovered amount of gas have been considered in the calculations. For five depot areas the reported NMVOC emissions are based on emission measurements in the depot areas and not on calculations based on the amount gasoline handled in the depots. The reporting of measured emissions instead of calculated emissions are based on recommendations from SPI[58]. For some years, for which no data was provided, data were interpolated. Handled amount of gasoline and fugitive emissions of NMVOC from depots for 1990-2009 are presented in Table 3.30.

The calculation of the NMVOC time series for fugitive emissions from gasoline distribution, 1990-2009 (Table 3.30), is based on methods given by Concawe[59], 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[60]. The basic assumptions are presented in Table 3.31.

[55] Per Brännström, 2010, personal communication
[56] Concawe, 1986, Hydrocarbon emissions from gasoline storage and distribution systems, Report No 85/54.
[57] Concawe Report No. 3/07, Air pollutant emission estimation methods for E-PRTR reporting by refineries
[58] Per Brännström, 2010, personal communication
[59] Concawe, 1986, Hydrocarbon emissions from gasoline storage and distribution systems, Report No 85/54.
[60] Andersson, 2000.

Table 3.30. 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	1.91	3.22
1998	5 322 328	1.97	3.19
1999	5 328 572	2.02	3.20
2000	5 290 793	2.07	3.17
2001	5 288 696	2.13	3.17
2002	5 397 682	2.18	3.24
2003	5 393 415	2.23	3.24
2004	5 396 308	2.24	3.24
2005	5 264 990	2.31	3.16
2006	5 233 780	2.39	3.14
2007	5 172 882	2.35	3.10
2008	5 111 132	2.53	3.07
2009	4 917 035	2.41	2.95

Table 3.31. 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 - 2009	
Distribution of gasoline to gas stations	0.16 %	of distributed volume
Spill	0.01 %	of distributed volume
Filling of car tanks	0.18 %	of filled volume
Measures at distribution to gas station	90 %	Efficiency of measures
Measures at filling cars	70 %	Efficiency of measures

The measures at distribution and filling were introduced over a period of time from 1991-1994, to the extent presented in Table 3.32. 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 3.30). The ARTEMIS model is based on a bottom-up approach considered to be Tier 2.

Table 3.32. 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%

3.3.2.2.5 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.

3.3.2.2.6 Venting (CRF 1.B.2.C.1)

In submission 2010, emissions from venting of oil were reported using the Tier 1 approach and default emissions factors from the 2000 Good Practice Guidance. For emissions of CH_4 and CO_2, the maximum values of the default EF are chosen to avoid any risk of underestimating the emissions. In submission 2011, an analysis was carried out which indicated that the emissions from venting are most probably included in other categories of fugitive emissions; mainly in CRF 1.B.2.A.4 but possibly partly in 1.B.2.C.2. Hence, it was concluded that the emissions reported in 1.B.2.C.1. in submission 2010 were double counted, and in submission 2011 emissions from venting of oil are reported as IE (in 1.B.2.A.4 and 1.B.2.C.2.) Venting of natural gas or combined venting of oil and gas are presumed to be not occurring, however, if occurring, they are included in the emission data gathered from environmental reports as described in section 3.3.2.2.3.

3.3.2.2.7 Flaring (CRF 1.B.2.C.2)

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 was 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.

3.3.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. The extent of flaring is by nature very variable between years, and the uncertainties in activity data and emission factors are high compared to other activities.

3.3.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The coherence between environmental reports and ETS data is checked when possible, and when differences occur, the facilities are contacted for verification. For a few plants that flare small amounts of gas, activity data as amount of flared gas is shown neither in the environmental reports, nor in the ETS data. Flaring at these plants was investigated in 2005, and the same values are used for later years. Every year, these facilities are asked to verify that the default value is still valid.

3.3.2.5 SOURCE-SPECIFIC RECALCULATIONS

The naphtha fuelled hydrogen production plant was unknown until this submission, and data for 2006-2008 has been revised/added in submission 2011. The minor emissions in 1.B.2.A.1 in 2005 are also the result of a revision, as it was not known that the butane fuelled hydrogen production plant was taken into operation in small scale already in 2005.

Emissions of CO_2 and CH_4 from venting reported in submission 2010 have been identified as double counted (in CRF 1.B.2.A.4 and 1.B.2.C.2) and thus the notation key “IE” is used in submission 2011.

The throughput of crude oil in refineries has been revised in submission 2011 for the years 1991, 1996, 1997, 2002 and 2006, due to new data published in the environmental report of one of the plants.

NMVOC emissions from refineries for the year 2009 have been revised in submission 2011, since NMVOC emissions from one plant not were reported in submission 2010.

Reported fugitive emissions of NMVOC from the storage of oil products in 1.B.2.A.5 have been revised for the years 1997-2008 in submission 2011. Emissions from the depots where measured emissions are reported have been revised for the years 2004 and 2006 – 2009. Reported emissions for 1997-2002 are interpolated in submission 2011.

Due to minor corrections in handled and distributed gasoline in the ARTEMIS model for the years 2000-2008, the reported volume of handled and distributed gasoline and fugitive emissions of NMVOC from gasoline stations in 1.B.2.A.5 have been revised in submission 2011.

3.3.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Possibilities to separate emissions from venting and report them in CRF 1.B2.C.1. will possibly be investigated during 2011. It is, however, uncertain whether this issue will be prioritized or not.

4 Industrial processes (CRF sector 2)

4.1 Overview of sector

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 decreased 1,287 Gg CO_2 equivalents from 6,318 Gg CO_2 equivalents in 1990 to 5,031 Gg CO_2 equivalents in 2009, a decrease of 20.4% (Figure 4.1). The trend is mainly affected by decreased emissions of CO_2 (-1,338 Gg CO_2 equivalents), N_2O (-509 Gg CO_2 equivalents) and PFCs (-342 Gg) but also increased emissions of HFCs (+928 Gg CO_2 equivalents). In Figure 4.1 it can be seen that in 2009, CO_2 is by far the largest contributor among the greenhouse gases in this sector, accounting for 71.1% of the GHG emissions. Emissions of HFCs are the second largest greenhouse gas in 2009, accounting for 18.5% of the sector emissions.

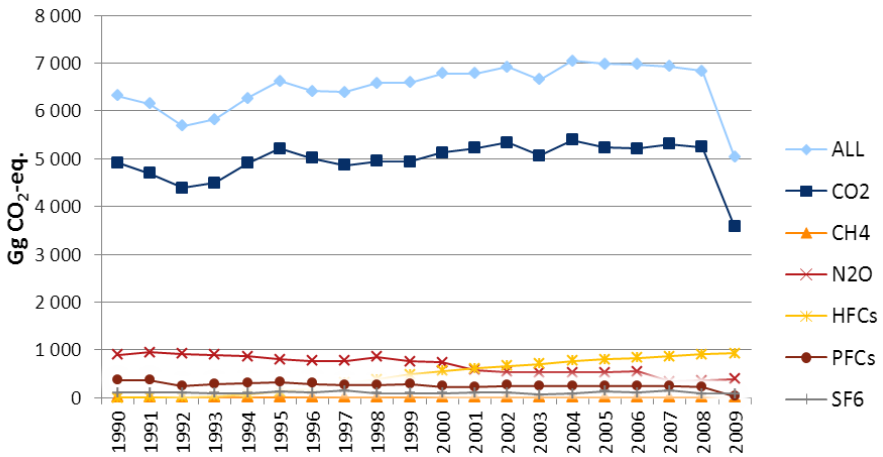

Figure 4.1. Total emissions of all greenhouse gases calculated as CO_2 equivalents from CRF 2 Industrial processes.

Among the industries in this sector, mineral products (CRF 2A) is the largest contributor in 2009 with 1,836 Gg CO_2 equivalents, or 36.5% of the sector emissions. Compared to 1990 there is a slight increase in greenhouse gas emissions from mineral products of about 6.6% (Figure 4.2), mainly due to increased production of lime and clinker.

The second largest contributor of greenhouse gases to this sector 2009 is metal production, accounting for 1,746 Gg CO_2 equivalents or 34.7% (Figure 4.2). In

Figure 4.2 it can be seen that there is a sharp decrease in greenhouse gas emissions from metal production (CRF 2C) from 2008 to 2009 (-1,506 Gg CO_2 equivalents or -46.3%). This is mainly due to the economic recession in 2009 which had a great effect on the production volumes of iron and steel in Sweden and thus the emissions 2009 are significantly reduced. For chemical industry (CRF 2B), greenhouse gas emissions have decreased with 585 Gg CO_2 equivalents since 1990 and amounted to 375 Gg CO_2 equivalents in 2009. The reduction is closely linked to N_2O emissions from nitric acid production.

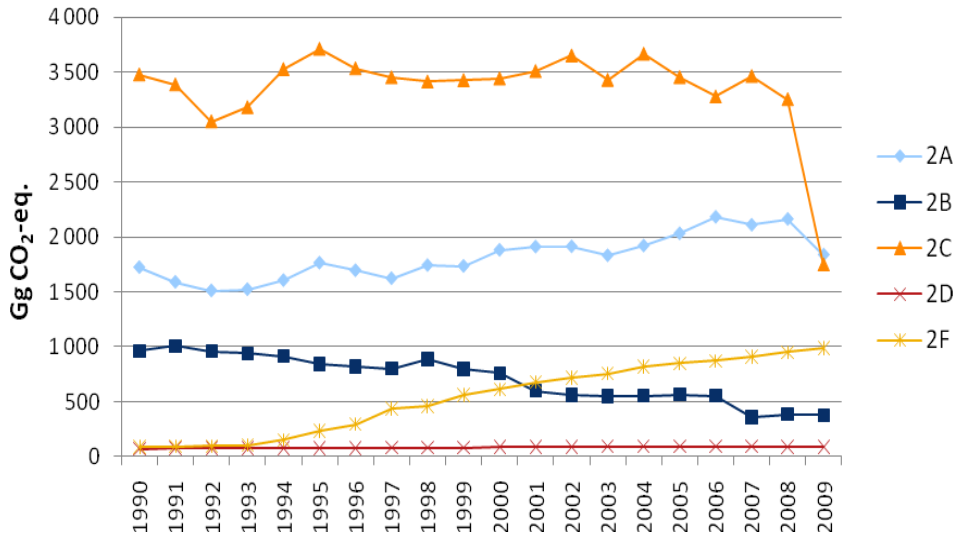

Figure 4.2. Total emissions of all greenhouse gases calculated as CO_2 equivalents from the different Industrial processes sub-sectors.

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, 899 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.

Table 4.1 shows the recalculation differences for the GHG emissions by sub-sector as well as for the total level in the sector reported in submission 2011 compared to data reported in submission 2010. The recalculations differences between the two submissions are mainly due to the fact that CO_2 emissions, for the first time, are included in chemical industry, other (CRF 2B5).

Table 4.1. Recalculations of GHG emissions between submission 2011 and submission 2010 in the industrial processes sector.

Recalculation differences, submission 2011/2010 (Gg CO_2 eq.)						
CRF	2A	2B	2C	2F	Total CRF 2	% CRF 2
1990	0	53	0		53	0.85%
1991	0	55	0		56	0.91%
1992	0	57	0		58	1.02%
1993	0	60	0		60	1.04%
1994	0	56	0		57	0.91%
1995	0	48	0		49	0.74%
1996	0	53	0		54	0.85%
1997	0	41	0		42	0.66%
1998	0	48	0		49	0.74%
1999	0	48	0		49	0.74%
2000	0	48	0		49	0.72%
2001	0	50	0		50	0.75%
2002	0	43	0		44	0.63%
2003	0	46	0		46	0.70%
2004	0	45	0		46	0.65%
2005	0	56	0	0	57	0.82%
2006	0	31	0	0	32	0.46%
2007	0	52	0	0	53	0.77%
2008	0	48	1	-5	44	0.65%

0 equals value less than 0.5.

4.2 Mineral products (CRF 2.A)

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.

4.2.1 Cement production (CRF 2.A.1)

4.2.1.1 SOURCE CATEGORY DESCRIPTION

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. 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 4.2.

Table 4.2. Summary of source category description, CRF 2A1.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2A1	CO_2	X	X		T2	PS	Yes
	CH_4				NA	NA	NA
	N_2O				NA	NA	NA

T2 Tier 2. PS Plant-specific.

4.2.1.2 METHODOLOGICAL ISSUES

All three cement-producing facilities (owned by one company) are covered in the reported estimates and the time series are 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[61]. The protocol has been used for all years except 1991-1994 and 1996, since not enough information was provided from the plants. Instead the cement company has reported production and emissions based on mean values from adjacent years for 1991-1994 and 1996. Data that is reported in the protocol to calculate process emissions is clinker, cement and dust production and the use of limestone and raw meal. The process emissions (Mg CO_2) are then automatically calculated and presented from raw material converted to clinker and from by-pass dust and CKD discarded.

Facts about the GHG protocol

The GHG protocol has been developed to enable companies to uniformly report their emissions of greenhouse gases. Emissions from stationary combustion and from processes are included.

Over 500 experts have developed the protocol and it is used by over 150 companies including industry associations representing pulp and paper, aluminium and cement.

The protocol for CO_2 emissions from the production of cement (WBCSD CSI, version 2.0) can be found on:

http://www.ghgprotocol.org/templates/GHG5/layout.asp?type=p&MenuId=OTAx

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

4.2.1.2.1 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 4.3 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 in line with the conception that dust emission in Sweden are low or non-existent.

The implied emission factor (~0.5425 Gg CO_2/Gg clinker produced) is somewhat higher than the IPCC Guidelines default value (0.5071 Gg CO_2/Gg produced clinker). This is because emissions from the organic carbon content of raw meal and CKD are included in the Swedish estimates whereas these sources are not included in the IPCC Guidelines default value.

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 4.3. 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
2009	2 305	1 289	1 258	5	26	1.004

4.2.1.2.2 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.

4.2.1.2.3 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 2009 have increased compared to the previous year.

4.2.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty for activity data is ± 2% and the uncertainty of the emission factor for CO_2 is ± 5%. The time series are considered accurate, consistent and complete.

4.2.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.2.1.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.2.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.2.2 Lime production (CRF 2.A.2)

4.2.2.1 SOURCE CATEGORY DESCRIPTION

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. 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 4.4.

Table 4.4. Summary of source category description, CRF 2A2.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2A2	CO_2	X	X		D	D	Yes
	CH_4				NA	NA	NA
	N_2O				NA	NA	NA

D Default.

4.2.2.2 METHODOLOGICAL ISSUES

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, 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 activity data are collected from the Swedish Lime Association and The Swedish Lime Industry[62] 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 acquired from the 2006 IPCC Guidelines and the purity of the limestone is thus set to 95% for the production of lime in conventional lime mills and within the pulp and paper industry. The corresponding figure for

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

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 – 2009. 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 was precipitated as $CaCO_3$. For later years this share has increased and in 2009 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 was 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 and 2011 only the part of CaO which is not recovered as $CaCO_3$ is reported as activity data.

In Table 4.5 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.

Table 4.5. 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
2009	55.8	30.3	23.8	94.1%	28.5	1.8	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[63] have been used in submission 2011.

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 – 2009. For the years before 1995, the amounts of make-up lime consumed are estimated using the average ratio between

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

the quantity of make-up lime used and kraft pulp produced for the period 1995 – 2009 and corresponding production data for 1990 – 1994. Earlier information on the need for make-up lime has indicated that it would be less than 20 kg per Mg pulp. 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[64]. The data used in submission 2011 gives an average need (1995 – 2008) of 20 kg make-up lime per Mg kraft pulp (Table 4.6) 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 by using the average ratio between emitted CO_2 and used amounts of make-up lime for the period 1995 –2008. The used amount of Make-up lime was very low in 2009 which led to a reduced amount of emitted CO_2 in 2009 compared to previous years.

Table 4.6. 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	Reported Activity Data (Make-up lime)	IEF (Make-up lime/kraft pulp)	Reported CO2 emissions	IEF (CO2/Make-up lime)
	Gg	Gg	Gg/Gg	Gg	Gg/Gg
1990	5 944	118.7*	0.020**	88.5*	0.7457**
1991	6 129	122.4*	0.020**	91.3*	0.7457**
1992	6 113	122.1*	0.020**	91.0*	0.7457**
1993	6 310	126.0*	0.020**	94.0*	0.7457**
1994	6 270	125.2*	0.020**	93.4*	0.7457**
1995	6 377	119.4	0.019	89.0	0.7458
1996	6 298	125.1	0.020	93.3	0.7458
1997	6 704	131.7	0.020	98.2	0.7458
1998	6 615	141.7	0.021	105.7	0.7458
1999	6 735	152.8	0.023	114.0	0.7458
2000	7 557	138.1	0.018	103.0	0.7457
2001	7 505	123.4	0.016	92.0	0.7456
2002	7 627	139.3	0.018	103.9	0.7457
2003	7 877	143.0	0.018	106.6	0.7456
2004	7 773	142.4	0.018	106.1	0.7455
2005	7 784	172.0	0.022	128.3	0.7456
2006	7 828	156.5	0.020	116.7	0.7455
2007	7 835	188.6	0.024	140.7	0.7457
2008	7 635	164.7	0.022	122.8	0.7458
2009	7 299	116.9	0.016	87.2	0.7458

*estimated

** average ratio for 1995 – 2009

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

4.2.2.2.1.3 Other production of lime

Detailed data on the conventionally produced amounts of lime are obtained from the Swedish Lime Association and The Swedish Lime Industry[65]. The produced amounts of quick lime and dolomitic lime in conventional lime mills was very low in 2009 which led to a reduced amount of emitted CO_2 in 2009 compared to previous years.

Table 4.7. 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
2009	400.6	301.6	0.7528

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 – 2009. The estimations from quick lime production were calculated using emission factors presented in environmental reports by one of the producers[66]. The emission factor provided by the lime producer is substantially higher for 2008 and 2009 than for earlier years. This resulted in an increase

[65] Swedish Lime Association and The Swedish Lime Industry, Svenska Kalkföreningen, personal communication
[66] Nordkalk, http://www.nordkalk.com

of reported SO_2 emissions for 2008 compared to earlier years. However in 2009 the reported SO_2 emissions were again on the same level as before 2008 due to less use of lime.

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 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty for activity data is ± 2% and the uncertainty of the emission factor for CO_2 is ± 5%. The time-series are considered accurate, consistent and complete.

4.2.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The activity data reported in 2A2 have been compared with national statistics from Statistics Sweden in line with the Good Practice Guidance Tier 2[67]. Unfortunately, no national statistics was available for 2009 in time for this submission.

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 economic 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.

Since data collected for the national inventory are consistent and fluctuate less compared to national statistics, data from the Swedish Lime Association and The Swedish Lime Industry[68] has been chosen for the calculations of CO_2 from lime production.

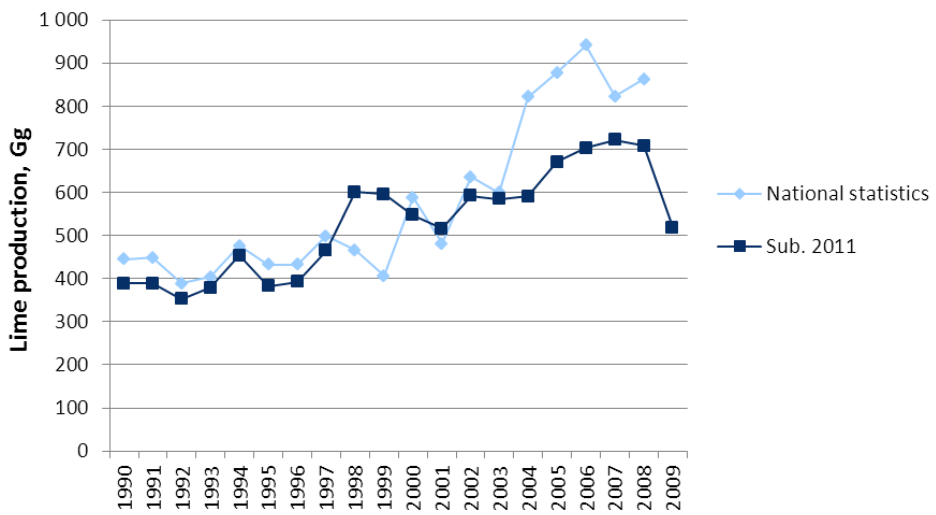

Figure 4.3. National total on produced amount of lime according to data from Statistics Sweden and reported data in CRF 2A2.

[67] Statistics Sweden. Data from the Industrial production database: www.scb.se
[68] Swedish Lime Association and The Swedish Lime Industry, Svenska Kalkföreningen, personal communication

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.

4.2.2.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.2.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.2.3 Limestone and dolomite use (CRF 2.A.3)

4.2.3.1 SOURCE CATEGORY DESCRIPTION

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). 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 4.8.

Table 4.8. Summary of source category description, CRF 2A3.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2A3	CO_2				CS	D	Yes
	CH_4				NA	NA	NA
	N_2O				NA	NA	NA

D Default. CS Country Specific

4.2.3.2 METHODOLOGICAL ISSUES

Activity data and CO_2 emissions from the use of limestone and dolomite 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 are reported in CRF 2A3. The calculations are made by applying the IPCC Guidelines default emission factors for limestone and dolomite[69].

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

Formulas for CO_2 emissions from limestone and dolomite:

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

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

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

According to the IPCC Guidelines, all emissions of CO_2 from the use of limestone should be reported 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 it is not considered to be good practice to spend resources obtaining underlying data to separate these emissions.

Sweden has chosen to not include in 2A3:

- CO_2 emissions from the use of limestone and dolomite in primary and secondary production of steel (2C1.1, 2C1.2),
- CO_2 emissions from the use of limestone and dolomite in other metal production (2C5),
- CO_2 emissions from the use of limestone and dolomite in production of clay based products (2A7) and
- CO_2 emissions from the use of limestone and dolomite in glass production (2A7.1).

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 4.9 the use of limestone and dolomite, and corresponding CO_2 emissions, for glass production (2A7.1), primary (2C1.2) iron and steel production and other metal production (2C5) are presented for 2005-2009. In relation to the amounts reported in 2A3 (Table 4.10), the yearly amounts not included in 2A3 represents around 35% of the total use of limestone and dolomite in Sweden 2005 – 2009.

Table 4.9. Used amounts of limestone and dolomite for production of glass, primary steel production and other metal production, 2005 – 2009.

Year	2A7.1		2A7-clay based products		2C1.1		2C1.2		2C5	
	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	*	*	*	*	84	36.1	5	2.1
2006	73	33.7	*	*	*	*	84	36.1	4	1.8
2007	72	33.6	*	*	*	*	72	30.9	5	2.3
2008	73	33.7	*	*	*	*	89	38.1	4	1.8
2009	55	25.5	*	*	*	*	57	24.5	4	1.7

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

Table 4.10. Used amounts of limestone and dolomite and corresponding CO_2 emissions reported i 2A3.

	Total 2A3 Activity data (limestone and dolomite)	Total 2A3 CO_2	CO_2, Energy producing facilities (flue gas desulphurisation)	CO_2 Other mineral products (glass and mineral wool)	CO_2 Other chemical industry	CO_2 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
2009	223	101.6	11.3	9.6	7.1	72.0

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 lime-

stone and dolomite for raw glass wool production. During 2009 the used amounts of limestone and dolomite was lower compared to previous year.

Data on the use of limestone and dolomite have been acquired from environmental reports, the ETS and through direct contacts with the companies.

4.2.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty for activity data is ± 7% and the uncertainty of the emission factor for CO_2 is ± 5%. 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.

4.2.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.2.3.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.2.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.2.4 Soda ash use (CRF 2.A.4)

4.2.4.1 SOURCE CATEGORY DESCRIPTION

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. 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 2A4.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2A4	CO_2				CS	D	Yes
	CH_4				NA	NA	NA
	N_2O				NA	NA	NA

D Default. CS Country Specific

4.2.4.2 METHODOLOGICAL ISSUES

In 2004 a study was carried out to collect data on soda ash use and calculate CO_2 emissions.[70] 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:

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

- 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 soda ash, and has since 1997 sharply reduced their consumption. In the beginning of the new millennium the soda ash used for manufacturing at this industry is bound in products, and thus no CO_2 is emitted.

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

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

Data on the use of soda ash have been acquired from the ETS and through direct contacts with the reporting companies.
The data used for national GHG estimations from soda ash use is believed to be more consistent and complete, compared with the data from national statistics, since the data for in the inventory is collected from the ETS, from the environmental reports of the facilities or by direct contact with the plants.

4.2.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty for activity data is ± 7% and the uncertainty of the emission factor for CO_2 is ± 5%. 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.

4.2.4.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.2.4.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

[71] The Swedish Chemicals Agency (KemI)

4.2.4.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.2.5 Asphalt roofing (CRF 2.A.5)

4.2.5.1 SOURCE CATEGORY DESCRIPTION

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. 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 4.12.

Table 4.12. Summary of source category description, CRF 2A5.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2A5	CO_2				NA	NA	NA

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

4.2.5.2 METHODOLOGICAL ISSUES

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.[72] These are based on studies performed during the 1970s in the USA and presented by EPA.[73] 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 4.13)[74].

[72] EMEP/CORINAIR Emission Inventory Guidebook: http://reports.eea.eu.int/EMEPCORINAIR4/en
[73] 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.
[74] Danielsson, H. 2004. SMED report: Investigation on the occurrence of emissions from asphalt roofing in Sweden.

Table 4.13. Estimated emissions of NMVOC from manufacturing of asphalt-saturated felt (CRF 2A5) in Sweden 1990 – 2009.

Year	NMVOC emissions from asphalt roofing, 2A5 Mg
1990	77.7
1991	80.2
1992	79.8
1993	89.5
1994	97.4
1995	98.6
1996	92.4
1997	99.6
1998	99.1
1999	98.4
2000	111.1
2001	112.9
2002	109.2
2003	101.1
2004	113.7
2005	139.7
2006	132.7
2007	142.4
2008	138.6
2009	103.1

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.

4.2.5.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The time-series are consistent

4.2.5.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.2.5.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.2.5.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.2.6 Road paving with asphalt (CRF 2.A.6)

4.2.6.1 SOURCE CATEGORY DESCRIPTION

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. 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 4.14.

Table 4.14. Summary of source category description, CRF 2A6.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2A6	CO_2				NA	NA	NA

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

4.2.6.2 METHODOLOGICAL ISSUES

Estimates for the early 1990s are taken from investigations and inventories made in the early 1990s. Data for the years 2002 – 2009 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 4.15). 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 4.15. Emissions of NMVOC 1990–2009 from road paving with asphalt.

Year	NMVOC from road paving with asphalt Mg
1990	6 200
1991	5 900
1992	5 600
1993	5 000
1994	4 400
1995	3 800
1996	3 200
1997	2 600
1998	2 000
1999	1 600
2000	1 170
2001	1 080
2002	845
2003	603
2004	920
2005	1 230
2006	750
2007	935
2008	855
2009	341

4.2.6.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The time-series is consistent.

4.2.6.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.2.6.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.2.6.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.2.7 Other (CRF 2.A.7)

4.2.7.1 SOURCE CATEGORY DESCRIPTION

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“. 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 4.16.

Table 4.16. Summary of source category description, CRF 2A7.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2A7	CO_2				CS	CS, D	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.

4.2.7.1.1 Glass production, CRF 2.A.7.1

In Sweden there is one facility for float glass production, one for container glass and several small facilities for manual glass production. Emissions of CO_2 from the use of limestone and soda ash in glass production are from submission 2010 and onwards 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. 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. All other emissions from the glass production facilities are from combustion for energy purposes, and are allocated to the Energy sector (CRF 1).

4.2.7.1.2 Non-Iron ore mining and dressing, CRF 2.A.7

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 – 2009 is thus reported NE. Estimated emissions from combustion of fuels are included in the Energy sector (CRF 1).

4.2.7.1.3 Glass and mineral wool, CRF 2.A.7

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.

4.2.7.1.4 Battery manufacturing, CRF 2.A.7

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.

4.2.7.1.5 Light expanded clay aggregate (LECA), roofing tile, brick and ceramics production, CRF 2.A.7

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 emissions represent the emissions from totally six facilities the years 1990-2008 and from totally five facilities 2009 since one facility closed down during 2008. One of the facilities is dominating in CO2 emissions. All CO_2 emissions from raw material used are reported in 2A7.

4.2.7.2 METHODOLOGICAL ISSUES

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“.

4.2.7.2.1 Glass production, CRF 2.A.7.1

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.

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.

The process-related SO_2 emissions from container and float glass production are reported for the period 1990 – 2009 in CRF 2A7. The reported NO_X emissions originate from the production of float glass. Data has been provided directly by the companies or collected from their environmental reports.

4.2.7.2.2 Non-Iron ore mining and dressing, 2.A.7

Data on NO_X emissions from use of explosives within the non-iron ore mining industry are reported 2002 – 2009, 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.

4.2.7.2.3 Glass and mineral wool production, 2.A.7

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

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.

4.2.7.2.4 Battery manufacture, 2.A.7

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.

4.2.7.2.5 Light expanded clay aggregate- (LECA), roofing tile, brick and ceramics production, 2.A.7

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. The data in the ETS does not always separate between emissions from limestone/dolomite use and CO_2 emissions from other carbon containing raw material (i.e. from the clay and other carbonates used) 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.

4.2.7.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainties of the direct CO_2 emissions in 2A7 are considered to be ± 7% based on expert judgements.

4.2.7.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.2.7.5 SOURCE-SPECIFIC RECALCULATIONS

One facility for ceramics production was added in submission 2011. CO_2 emissions from this facility for the years 2008 and 2009 are acquired through the ETS. As there is a lack of data before 2008, the reported emission for 2008 is extrapolated for the years 1990-2007. In 2008 the CO_2 emission from the facility added in submission 2011 was 0.01% of the total CO_2 emissions in sector 2A.

In submission 2010 the emission factor for CO_2 from limestone was mixed up with the CO_2 emission factor for barium carbonate for one of the glass producing facilities. This was corrected in submission 2011 and results in a minor change in CO_2 emissions in 2A7 for the years 1990-2004 compared to submission 2010.

4.2.7.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.3 Chemical industry (CRF 2.B)

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

4.3.1 Ammonia production (CRF 2.B.1)

4.3.1.1 SOURCE CATEGORY DESCRIPTION

There is an annual production of about 5 Gg of ammonia in Sweden, according to UN statistics[75]. 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[76]. Emissions from this industry are included in CRF code 2B5. Ammonia production, 2B1, is thus reported as NO in the CRF-tables.

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

4.3.2 Nitric acid production (CRF 2.B.2)

4.3.2.1 SOURCE CATEGORY DESCRIPTION

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. 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 4.17.

Table 4.17. Summary of source category description, CRF 2B2.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2B2	CO_2				NA	NA	NA
	CH_4				NA	NA	NA
	N_2O	X	X		T2	PS	Yes

T2 Tier 2. PS Plant-specific.

4.3.2.2 METHODOLOGICAL ISSUES

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 4.18). The assumed emission factor of 7 kg/Mg for 1991 - 1993 is based on the calculated emission factors for 1990 and 1994 and is in line with the default factors for nitric acid production presented in Table 4.7 in IPCC Good Practice Guidance. The fluctuations in the calculated total EF for N_2O 1994 – 2002 (Table 4.18) are mainly due to fluctuations in one of the facilities. The IEFs are within the IPCC default interval (2-19 kg N_2O/Mg). Activity data and reported emissions have been acquired from reporting in e.g. environmental reports from the facility, but 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 higher 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. During 2009 the production of nitric acid was lower compared to the previous year.

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 confidential.

Table 4.18. 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
2009	243	4.05	0.983

*Emission factors have been assumed

4.3.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty for activity data is ± 2% and the uncertainty of the emissionfactor for N_2O is ± 5%. The time-series is consistent.

4.3.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.3.2.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.3.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.3.3 Carbide production (CRF 2.B.4)

4.3.3.1 SOURCE CATEGORY DESCRIPTION

Silicium carbide production does not occur in Sweden but calcium carbide is produced at one facility. All process-related CO_2 emissions from the industry are included in the code 2B4 2. 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 4.19.

Table 4.19. Summary of source category description, CRF 2B4.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2B4	CO_2				D	PS	Yes

D Default. PS Plant-specific.

4.3.3.2 METHODOLOGICAL ISSUES

To cover all sources of CO_2 from the production of calcium carbide, estimates of emissions from the production of quick lime, from the reduction of quick lime to calcium carbide and CO_2 from use of calcium carbide have been made. In the tables and text below the estimated CO_2 emissions to be reported in CRF 2B4 2 are presented.

4.3.3.2.1 CO_2 emissions from quick lime production

In order to estimate the CO_2 emissions from the first step of the production of calcium carbide, the amount of limestone used for quick lime production is used as activity data together with the default emission factor from Revised 1996 IPCC Guidelines, 0.44 Mg CO_2/Mg limestone used. During the time period 1990 – 2009 the facility some years have produced all quick lime used for the production while in other years large amounts of quick lime has been bought from other producers of quick lime. Thus, the CO_2 emission varies between years as can be seen in Table 4.20.

Table 4.20. Limestone used for quick lime production and associated CO_2 emissions to be reported in CRF 2B4 2, 1990 – 2009.

Year	Limestone used for quick lime production, Gg	CO_2 from quick lime production, Gg
1990	96	42
1991	97	43
1992	74	33
1993	80	35
1994	81	36
1995	79	35
1996	79	35
1997	72	32
1998	74	33
1999	72	32
2000	64	28
2001	64	28
2002	68	30
2003	66	29
2004	65	29
2005	75	33
2006	23	10
2007	69	30
2008	61	27
2009	9	4

4.3.3.2.2 CO_2 emissions from calcium carbide production

Calcium carbide is produced in an electric arc furnace at high temperature, 2000 – 3000 ºC. Quick lime, CaO, is reduced with coke and forms CaC_2. In this process an energy rich gas is produced as a by product. This gas is used as fuel within the facility and to some extent in other nearby plants and thus only a minor part of the gas is flared. To calculate the CO_2 emissions from the reduction of quick lime to calcium carbide, data on produced amounts of calcium carbide, share of gas flared and default emission factor in IPCC Guidelines are used. Since there only is one producer of calcium carbide in Sweden the produced amounts are reported as confidential, C.

Table 4.21. Share of flared carbide oven gas and associated CO_2 emissions to be reported in CRF 2B4 2, 1990 – 2009.

Year	Carbide oven running time / Flaring time, %	CO_2 from the reduction of CaO to CaC_2, Gg
1990	6%	4
1991	10%	6
1992	8%	4
1993	13%	6
1994	11%	5
1995	7%	4
1996	12%	6
1997	13%	7
1998	25%	12
1999	26%	12
2000	14%	6
2001	22%	9
2002	18%	8
2003	17%	7
2004	30%	14
2005	15%	7
2006	13%	6
2007	10%	4
2008	8%	4
2009	10%	3

4.3.3.2.3 CO_2 emissions from use of calcium carbide

In Revised 1996 IPCC Guidelinesit it is stated that to report CO_2 emissions from calcium carbide production, also CO_2 originating from the use of calcium carbide is to be reported. In the Swedish reporting to UNFCCC this part has not earlier been fully covered. The use of calcium carbide within the metallurgical industry is included in 2C while CO_2 from the use of acetylene has not been estimated and reported. To be able to estimate the CO_2 emission from the use of calcium carbide only the amount of calcium carbide for acetylene production and the use within the country has to be taken into account. Information from the calcium carbide producer in Sweden indicates that one third of the calcium carbide is used for acetylene production. Assuming that imported and exported amounts of acetylene have the same utilisation it is possible to reasonably well estimate the CO_2 emissions originating from acetylene use. Yearly statistics on imported and exported amounts from 1998 and onwards are available from Statistics Sweden[77]. Amounts used for acetylene production for earlier years are estimated. The default emission factor presented in the Revised 1996 IPCC Guidelines, 1.1 Mg CO_2/Mg calcium carbide use, has been used for the estimations.

[77] www.scb.se

Table 4.22. Amount of calcium carbide used for acetylene production, and CO_2 emissions from acetylene use reported in CRF 2B4 2, 1990 – 2009.

Year	Amount of calcium carbide for acetylene production, Gg	CO_2 from use of acetylene, Gg
1990	7	8
1991	7	8
1992	6	6
1993	6	6
1994	6	7
1995	6	7
1996	6	7
1997	6	7
1998	6	6
1999	6	7
2000	6	7
2001	6	7
2002	6	7
2003	7	7
2004	7	8
2005	9	10
2006	8	8
2007	8	9
2008	9	9
2009	4	5

4.3.3.2.4 Time series reported in CRF 2B4 2

In Table 4.23, the total CO_2 time series reported in submission 2011 is presented. Since there is only one producer of calcium carbide in Sweden production statistics are reported as confidential, C.

Table 4.23. Time series reported in CRF 2B4 2.

Year	Produced calcium carbide, Gg	CO2 emissions from production and use of calcium carbide, Gg
1990	C	54.5
1991	C	57.7
1992	C	43.2
1993	C	48.5
1994	C	48.2
1995	C	45.8
1996	C	48.3
1997	C	45.8
1998	C	51.6
1999	C	51.2
2000	C	41.4
2001	C	44.7
2002	C	45.4
2003	C	43.9
2004	C	51.5
2005	C	50.2
2006	C	24.7
2007	C	43.8
2008	C	40.5
2009	C	12.0

4.3.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As can be seen in Figure 4.4, CO_2 emissions for 2006 and 2009 reported in submission 2011 are much lower compared to surrounding years. For 2006 a minor part of the quick lime needed for the production of calcium carbide were produced at the facility, the remaining part was bought from external producers. The sharp decrease of the CO_2 emission in 2009 is due to that the lime kiln was only operating during the last quarter of the year. Consequently, most of the quick lime used for calcium carbide production in 2009 was bought from external lime producers.

4.3.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.3.3.5 SOURCE-SPECIFIC RECALCULATIONS

Compared to reported CO_2 emissions in CRF 2B4 2 in submission 2010 the new time series is 6 to 50 % lower depending on year (Figure 4.4). The main reason for this is that in previous submissions, CO_2 from all quick lime used for production of calcium carbide was included in the estimates, whether or not it was produced at the plant or purchased from other producers. The old emission factor also included

CO_2 originating from the fuel used for quick lime production. In Figure 4.4 the CO_2 time series in submission 2010 is compared to the time series in submission 2011.

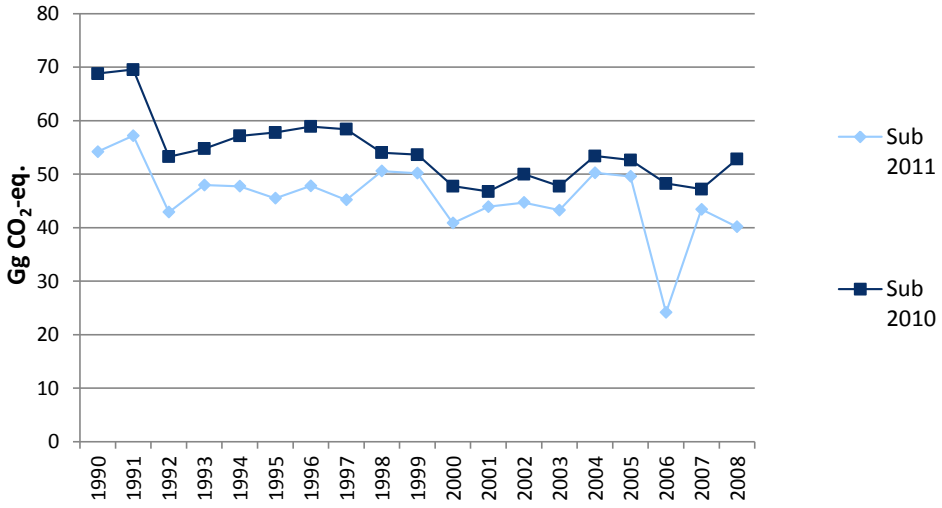

Figure 4.4. Comparison of reported CO_2 emissions in CRF 2B4 2 in submission 2010 and after revision, in submission 2011.

The total reported CO_2 emission in CRF 2B4 2 in submission 2011 is based on:

- produced amounts of quick lime and emission factors from Revised 1996 IPCC Guidelines
- produced amounts of calcium carbide, share of gas flared and the default emission factor according to the Revised 1996 IPCC Guidelines
- amount of calcium carbide used for acetylene production within the country and the default emission factor presented in the Revised 1996 IPCC Guidelines.

Production of calcium carbide is a small source of process-related CO_2 in Sweden. In submission 2010, CO_2 in CRF 2B4 2 contributed by between 0.9% and 1.5% of the total amount reported in sector 2. The time series in submission 2011 does not change the significance of CO_2 from calcium carbide production in Sweden, with CO_2 reported in CRF 2B4 2 in submission 2011 accounting for between 0.5% and 1.2% to the total reported CO_2 in sector 2 in submission 2011.

4.3.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.3.4 Other (CRF 2.B.5)

4.3.4.1 SOURCE CATEGORY DESCRIPTION

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 productions and other non specified chemical production, which are not covered elsewhere. Approximately 70 larger industrial facilities are included in the emission estimates. Emissions of CO_2, CH_4, N_2O, NO_X, CO, NMVOC and SO_2 are reported in this sub-category. It is possible though that some emissions of NMVOC reported in CRF 2B5 should be reported in CRF 3C (e.g. pharmaceutical industries), but as 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.

Emission time-series for GHG are relatively stable. There is a slight drop in emissions of GHG in 2009 compared to 2008 e.g. due to lower production of carbon black. In addition, CH_4-emissions decreased in 1999 due to a much lower production at one facility and N_2O-emissions increased in 1999 due to the fact that one facility within ”Pharmaceutical industry” reported higher emissions that year.

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.

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 4.24.

Table 4.24. Summary of source category description, CRF 2B5.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2B5	CO_2				CS	PS	Yes
	CH_4				CS, D	PS, D	Yes
	N_2O				CS	PS	Yes

D Default. CS Country Specific. PS Plant-specific.

4.3.4.2 METHODOLOGICAL ISSUES

The primary information on emissions of CO_2, 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 the IPCC Guidelines, methods for estimating CH_4 emissions for several chemical products are presented and consequently the CRF Reporter is divided on those products (2B5.1-5). Since several plants in Sweden produce several chemicals products each but report emissions aggregated by plant, it is not possible to report emissions in accordance with the suggested split in the CRF Reporter. In Sweden, since submission 2006 the emissions are thus presented allocated to six separate branch categories: sulphuric acid production, pharmaceutical industry, production of base chemicals for plastic in-

dustry, organic chemical production, inorganic chemical production and other non-specified chemical production.

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

4.3.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Based on expert judgements, the uncertainties of collected emissions of CO_2, CH_4 and N_2O are as follows: ±50%, ±100% and ±125%, respectively.

The time-series for GHG have been reviewed and are considered to be consistent.

4.3.4.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Emissions reported in the plant-specific environmental reports are carefully studied annually to retrieve the most appropriate data for the GHG inventory.

In addition, in 2010, emissions in this sub-category were reviewed as part of a quality control SMED project, financed by the Swedish EPA, aiming at increasing the quality and reducing the uncertainties in the most important air emissions substances from chemicals industries in Sweden[78]. Emissions reported in the environmental reports were compared to plant-specific data in the GHG inventory, significant discrepancies were investigated, and recommendations were provided on feasible improvements for submission 2011 as well as recommendations on further investigations[79].

Overall, the QC-project showed that total reported GHG emissions from the chemical industries in the Swedish inventory are in coherence with the plant emission data.

4.3.4.5 SOURCE-SPECIFIC RECALCULATIONS

Emissions of CO_2, N_2O, NO_X, CO, NMVOC and SO_2 were recalculated in submission 2011. The revision of emissions is the result of the aforementioned quality control project in 2010 on air emissions from chemical industries in Sweden. Some of the main conclusions from the study affecting GHG in this sub-category are: the introduction of previously omitted CO_2 emissions from industrial processes (about 40-60 Gg) and extrapolation of N_2O emissions 1990-2001 for one plant (3.8 Gg) in order to achieve time-series consistency.

4.3.4.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

[78] Swedish EPA . 2010.
[79] Most recommendations on further investigations refer to the energy sector

4.4 Metal production (CRF 2.C)

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

4.4.1 Iron and steel production (CRF 2.C.1)

4.4.1.1 SOURCE CATEGORY DESCRIPTION

In Sweden, there are three primary iron and steel facilities and about ten secondary 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 2C1.3 (reallocated from previous reporting in 2A7). Emissions from a sinter producing facility are also included until 1995, when the production closed down.

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.

The GHG emission trend 1990-2008 is rather stable with some minor inter-annual variations. However, the economic recession in 2009 had a great effect on the production volumes of iron and steel in Sweden and thus the emissions 2009 are significantly reduced.

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 4.25.

Table 4.25. Summary of source category description, CRF 2C1.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2C1	CO_2	X	X		CS, T2	PS	Yes
	CH_4				CS	PS	No, see Annex 5
	N_2O				NA	NA	NA

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

4.4.1.1.1 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 2C1.1. 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. From submission 2010 another two secondary steel industries are included in the reported CO_2 time series. Another four plants with process related NO_X and/or NMVOC emissions are included in this sector. These plants do not produce steel, and hence do not emit CO_2.

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

4.4.1.1.2 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 as part of their 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 thus to be reported as industrial processes from iron and steel production in CRF 2C1, according to the IPCC Guidelines and Good Practice Guidance. The third plant produces iron sponge and iron powder.

4.4.1.1.3 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[80].

4.4.1.1.4 CO2 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.

4.4.1.1.5 CO2 emissions reported in Other, CRF 2C1.5

No emissions of CO_2 reported in this sector.

4.4.1.2 METHODOLOGICAL ISSUES

4.4.1.2.1 Secondary steel production, CRF 2C1.1

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 includes information concerning carbon bound in products, slag, etc, but also other sources for process related CO2 emissions. Prior to submission 2010, these other emissions were not included for all facilities. Estimates of these missing CO2 emissions were performed using ETS data for 2005 – 2008 and production data for years before 2005. All CO2 emissions presented for the facilities in ETS 2005 – 2009 are included in 2C1.1 in submission 2011.

Reported CO2 emissions until year 2008 are for all facilities, except the one which closed down in 2004, based on data in the ETS. Reported CO2 emissions can therefore be classified to follow the Good Practice Guidance method Tier 2 since, according to the ETS guidelines, reported emissions shall be based on all carbon input to and carbon output from the process. For the year 2009 background data needed for estimation of process-related CO2 emissions for one facility, earlier included in the ETS, was collected from the facility's environmental report since this facility was not included in ETS for 2009. For the facility shut down in 2004, plant specific methods were applied.

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.

[80] Wieland, M.S. 2004.

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

4.4.1.2.2.1 Production of iron powder

The emissions of CO_2 are calculated using the Good Practice Guidance method Tier 2. Plant-specific data on emissions from carbon-containing input materials such as coke and anthracite and also specific carbon-contents of output iron and by-products are used for all years. From 2005, ETS data is used and 1990-2004, information has been aquired from the plant. The emissions are verified using national statistics from Statistics Sweden on 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 thus 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).

4.4.1.2.2.2 Production of primary pig iron and steel

As a response to recommendations from UNFCCC expert review teams, since submission 2010, Sweden uses the recommended Tier 2 method according to the IPCC Guidelines, 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.

The carbon contents of external input materials such as coking coal, coke, injection coal, limestone, etc., are balanced against final output materials; coke[81], pig iron[81], 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 4.5 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

[81] If put in stock or sold externally

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.

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 LPG and different oils are used as fuel.

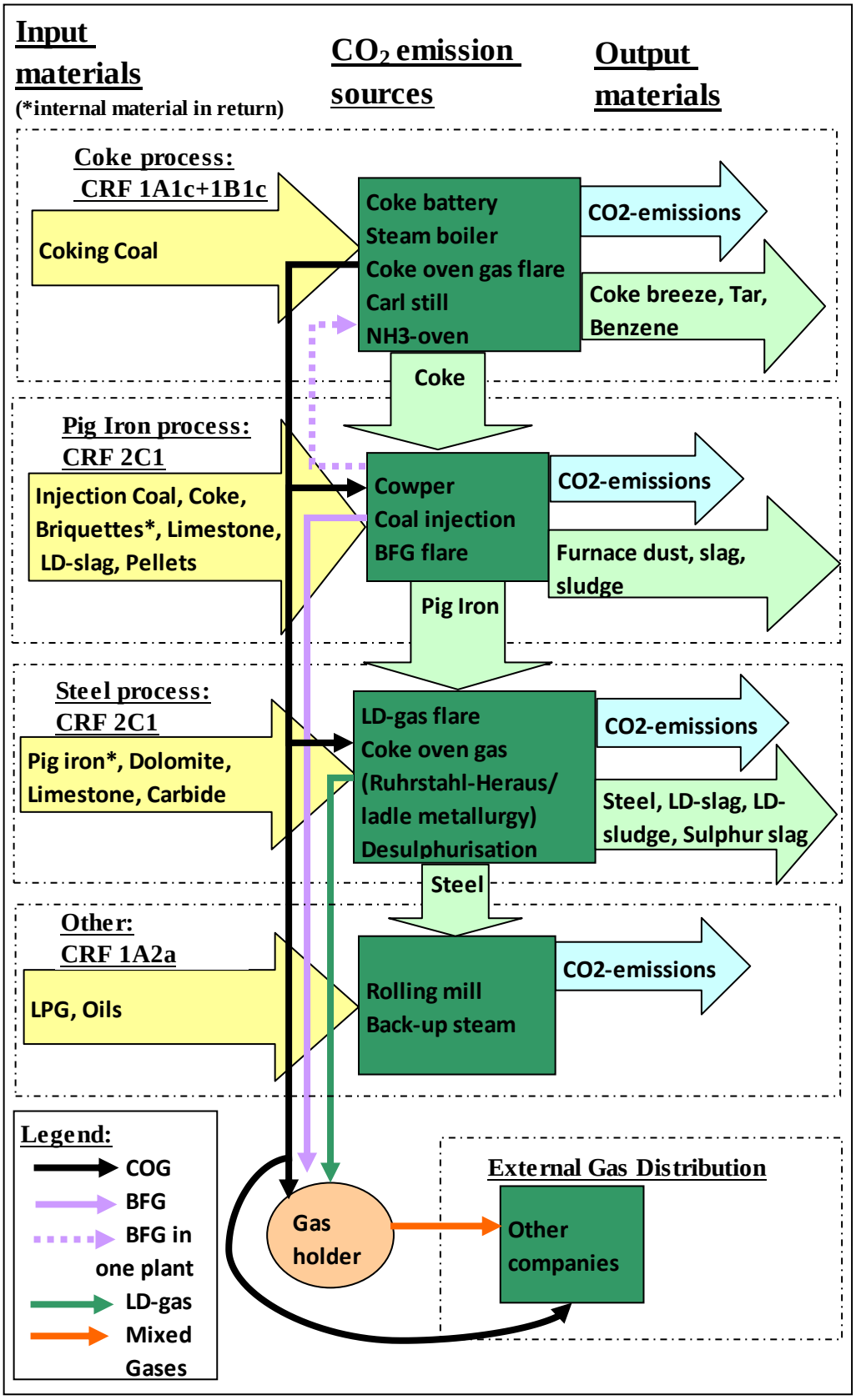

Figure 4.5. Carbon flow chart of integrated primary iron and steel plants in Sweden

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 (mainly in CRF 1A1a electricity and heat production). These amounts of gases and their associated emissions are allocated to the source category where they are consumed and thus not accounted for in the iron and steel production. This is not in accordance with the 1996 Guidelines as they fall under the category "Auto-producers[82]", but in line with the 2006 IPCC Guidelines[83] where allocation of emissions from delivered gases is described. Sweden has chosen to follow the 2006 IPCC Guidelines in this case as they are more in line with the emission reporting for the annual environmental reports and the EU ETS reporting.

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 4.26).

Table 4.26. CO_2 emission allocation 2009 in integrated primary iron and steel production (excluding external gas distribution).

CRF	Plant station	CO_2 emissions 2009 (Gg)
1A1c	Coke Oven	251
1A2a	Combustion in Rolling Mills + Power and Heat Production	482
1B1c	Flare in Coke Oven (COG)	15
2C1.2	Blast Furnace + Steelworks (including Flaring of BFG and LD-gas)	1073
Total		1821

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 annual CO_2 emissions reported by the plants in their environmental reports are equal to those reported to the EU ETS. For 2003 onwards, 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

[82] See IPCC Guidelines: Reporting instructions 1.3
[83] See 2006 IPCC Guidelines: Volume 3: Industrial Processes and Product Use, Box 1.1 (page 1.8)

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 3). 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.

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

Data on production statistics as well as on SO_2 emissions have been supplied by the facilities for the entire time-series. 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. No data concerning the CO emissions is available and the time series is thus reported NE.

4.4.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The largest implication on the national total uncertainties from this category stems from uncertainties in CO_2 emissions in primary iron and steel production (CRF 2C1.2); based on expert judgement by SMED expertise the estimated uncertainty is ±5%. It should be noted however, that total emissions of CO_2 from iron and steel production, including energy related emissions, are likely to deem lower uncertainty estimates.

There is an obvious decrease in CO_2 IEFs since 1990 (Table 4.27) for primary pig iron and steel production, from 0.80 Gg CO_2/kton iron in 1990 to 0.55 Gg CO_2/kton pig iron in 2009. This is due to the undertaking of several energy efficiency measures, e.g. increased temperature in the blast furnaces and increased recycling of energy gases and by-products[84], leading to decoupling between CO_2 emissions and primary pig iron production in Sweden.

The CO_2 IEF is overall significantly lower than the Tier 1 default emission factor (1.35 Gg CO_2/kton pig iron produced) presented in 2006 IPCC Guidelines Ta-

[84] ENET-Steel, 2007.

ble 4.1. This is partly due to that a large share of the energy gases produced at one of the plants is distributed to other companies (as described above) and thus not accounted for in iron and steel production. Adding CO_2 from all the external gas distribution (though some gas is COG) would lead to an IEF in 2008 of 1.21 Gg CO_2/kton pig iron produced and thus considered to be reasonable with regard to the IPCC Guidelines default.

Table 4.27. 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
2009	0.55

4.4.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

All plants in this category report their emissions in environmental reports. For plants included in the EU-ETS the report data is scrutinized and compared to EU-ETS data. EU-ETS data is applied wherever it is judged to be appropriate in line with the Good Practice Guidance. More information on QC activities related to EU-ETS is included in Annex 8.1.

For primary iron and steel production, activity data is compared to production statistics from the Swedish Steel Producers' Association and only minor differences are detected for the time-series.

4.4.1.5 SOURCE-SPECIFIC RECALCULATIONS

Indicated recalculations 1990 - 2005 in CRF Reporter are due to small adjustments on decimals. For 2006-2008, CO_2 from the use of limestone is added for one facility.

4.4.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.4.2 Ferroalloy production (CRF 2.C.2)

4.4.2.1 SOURCE CATEGORY DESCRIPTION

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. The production of iron silicide has decreased sharply since 2005, and since 2008 there is no production at all. Accordingly the SO_2 emissions decreased significantly since 2005 compared to previous years. The economic recession in 2009 had a great effect on the production volumes of ferroalloys in Sweden and thus the emissions 2009 are significantly reduced.

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 4.25.

Table 4.28. Summary of source category description, CRF 2C2.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2C2	CO_2		X		T2	PS	Yes
	CH_4				D	D	Yes
	N_2O				NA	NA	NA

D Default. T2 Tier 2. PS Plant-specific.

4.4.2.2 METHODOLOGICAL ISSUES

CO_2 emissions within the production of ferroalloys are plant specific (in line with Tier 2), and are calculated based on the consumed amount of reducing agents (Tier 1a[85]), 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.

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

- IPCC default factors for coal, coke and electrodes[86].

The used formula 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 4.29, 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 4.30, 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[87])

Data on non-CO_2 emissions has been obtained directly from the company for the whole time series. The reported emissions include NO_X and SO_2 from the process.

Table 4.29. 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
1995	265	274	295
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
2009	48	48	52

Table 4.30. Total amount of carbon bound in produced ferroalloys.

Year	-90	-95	-00	-01	-02	-03	-04	-05	-06	-07	-08	-09
Carbon in ferroalloys, Gg	8.4	8.7	9.5	7.6	7.7	6.7	8.0	8.0	8.3	8.4	7.4	1.8

[86] IPCC. Revised 1996 Guidelines for National Greenhouse Gas Inventories: Reference Manual, Table 2.12.
[87] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Table 4.8

4.4.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties in this category have little impact on the estimated national total emission uncertainty. Emission uncertainties of CO_2 are judged by SMED expertise to be low at ±5% as plant-specific values and Swedish default values give similar results.

Time-series are considered to be consistent.

4.4.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

As presented in Table 4.29 verification of CO_2 emissions reported by the plant is obtained as calculated Swedish default values give similar results.

4.4.2.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.4.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.4.3 Aluminium production (CRF 2.C.3)

4.4.3.1 SOURCE CATEGORY DESCRIPTION

There is one facility that produces primary aluminum in Sweden. The facility consists of two halls. One of the potlines includes 56 closed prebake cells (CWPB), each of 150 kA. The other plant consisted of 262 cells and, until the beginning of 2008, operated three prebake cells and 259 open cells with Söderberg anodes (VSS). The Söderberg anodes were produced in an electrode pulp factory at the facility. By the end of December 2009, 120 of a total of 262 cells had been converted to prebake technology. The remaining 142 cells are undergoing conversion and are projected to be commissioned by the end of 2010. All pot-lines operating the Söderberg technology were shut-down by December 2008.

During 2009 no Söderberg ovens has been in operation. This explains the very large decline in PFC emissions in 2009 (- 85% compared to 2008) (Figure 4.6). Also the reported CO_2 has declined in 2009 relative to previous years. The relatively stable implied emission factor (Table 4.32) provides the explanation that the reduced CO_2 emissions are due to reduced aluminium production in 2008 and 2009.

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 4.31.

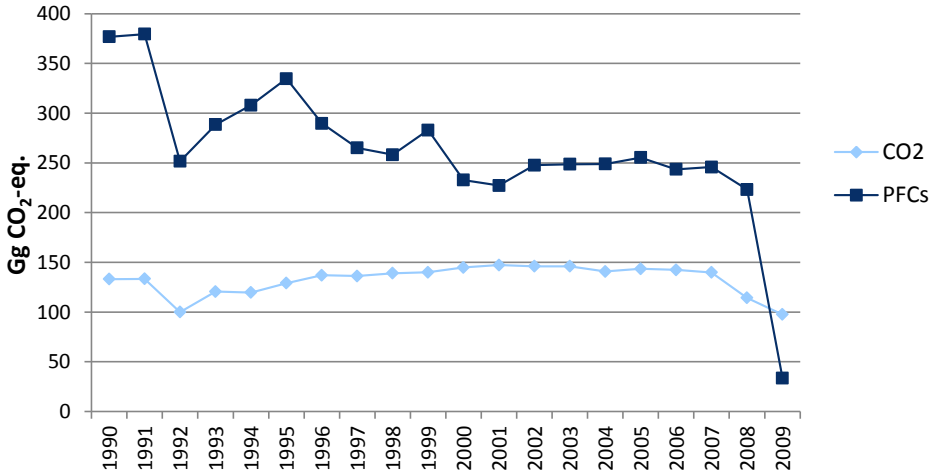

Figure 4.6. Time series for CO_2 and PCF emissions from aluminium production, CRF 2C3.

Table 4.31. Summary of source category description, CRF 2C3.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2C3	CO_2				T2	PS	Yes
	CH_4				NA	NA	No, see Annex 5
	PFCs		X		T2	D	Yes

D Default. T2 Tier 2. PS Plant-specific.

4.4.3.2 METHODOLOGICAL ISSUES

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

Reported emissions of NO_X are calculated from production statistics using emission factors defined by Swedish EPA[88]. NMVOC emissions are calculated from reported emissions of tar, assuming that 70 % of the tar is emitted as NMVOC[88]. CO emissions were for the first time reported in submission 2008 and 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 company as also for the SO_2 emissions during 1990 - 2005. For later years SO_2 emissions data are based on environmental reports published by the company.

Emission data for CO_2 from the production of primary aluminium 2002 - 2009 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 (an-

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

odes) 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 in subsequent 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. 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 prebaked and Söderberg (1.8 and 1.5 Gg CO_2/Gg produced Al) (Table 4.32).

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 4.32. 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
2009	70	98	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 4.33.

Table 4.33. 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	29.6	52.0	1.83	31.74	0.0223	0.0226	0.1737	0.5113
2009	69.7	0.0	0.56	4.36	0.0080	0.0000	0.0625	0.0000

4.4.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As can be seen in Table 4.33 the IEFs show a downward 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 prebake ovens are higher compared to 2007. According to the company the reason for this is due to initial start up problems with the new prebake ovens. The IEF for 2009 indicates less start up problems of new prebake ovens in 2009.

As described earlier (Figure 4.6) is the sharp decline in PFC emissions in 2009 caused by the closure of all Söderberg ovens in 2008.

The reported time series are considered to be consistent.

4.4.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.4.3.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.4.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.4.4 SF_6 used in aluminum and magnesium foundries (CRF 2.C.4)

4.4.4.1 SOURCE CATEGORY DESCRIPTION

In Sweden, four magnesium foundries use SF_6 as a cover gas. No SF_6 is used in aluminum foundries (CRF 2C4.1) as far as known, and thus reported as not occurring (NO). 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 4.25.

Table 4.34. Summary of source category description, CRF 2C4.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2C4	SF_6				D	D	Yes

D Default.

4.4.4.2 METHODOLOGICAL ISSUES

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 2009, as for earlier years, data from the Products register at the Swedish Chemicals Agency was unfortunately not available in sufficient detail to enable crosscheck with data provided by the facilities.

4.4.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Estimated uncertainty in SF_6 emissions is judge by SMED to be ±40%. Time series are considered to be consistent.

4.4.4.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.4.4.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.4.4.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.4.5 Other metal production (CRF 2.C.5)

4.4.5.1 SOURCE CATEGORY DESCRIPTION

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 from one metal recycling company mainly producing lead. 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 4.25.

Table 4.35. Summary of source category description, CRF 2C5.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2C5	CO_2				D	PS	Yes

D Default. CS Country Specific.

4.4.5.2 METHODOLOGICAL ISSUES

Emissions of CO_2 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 smelter are calculated based on the amounts of coke, coal, limestone, plastics and other raw material used in the production. The company directly reports these activity 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 smelter 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. Also CO_2 originating from the limestone used is included. For the years 1990

– 2003 the yearly amounts of limestone used are estimated using activity data for 2004.

The reported emissions of SO_2 originate from the sulphur content in the raw materials used.

4.4.5.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Time-series are considered to be consistent.

4.4.5.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Both plants in this category report their emissions in yearly environmental reports. For the one plant included in the EU-ETS the reported activity data and emissions are analysed and compared to EU-ETS data. Where EU-ETS data is judged to be appropriate and in line with the Good Practice Guidance, it is applied. More information on QC activities related to EU-ETS is included in Annex 8.1.

4.4.5.5 SOURCE-SPECIFIC RECALCULATIONS

In earlier submissions, CO_2 from the use of limestone within one of the plants was not included in reported emissions. Including also this source of CO_2 results in between 0.04% to 0.13% higher emissions in 2C5 in submission 2011 compared to submission 2010.

In submission 2011 also process related SO_2 and NO_X emissions are updated. In earlier submissions these emissions were by mistake not included. The SO_2 time-series in submission 2011 is between 4% and 9% higher compared to submission 2011. Corresponding figures for NO_X are 25% and 66%.

4.4.5.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.5 Other production (CRF 2.D)

Other production covers emissions from the pulp and paper industry (2D1) as well as estimates from the production of food and drink (2D2). Emissions of fossil CO_2 are not estimated for this sector. According to the IPCC Guidelines Reference Manual, emissions of fossil CO_2 from this sector are not likely.

4.5.1 Pulp and paper (CRF 2.D.1)

4.5.1.1 SOURCE CATEGORY DESCRIPTION

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 and during 2009 another two plants closed down their pulp and paper production. 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 - 2009.

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 4.36.

Table 4.36. Summary of source category description, CRF 2D1.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2D1	CO_2				NA	NA	NA
	CH_4				CS	CS	Yes
	N_2O				CS	CS	Yes

CS Country Specific.

4.5.1.2 METHODOLOGICAL ISSUES

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 in CRF 2A2.

4.5.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainty in activity data is ±5% and uncertainty in emission factors (CH_4 and N_2O) are ±20%.

4.5.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.5.1.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.5.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.5.1 Food and drink (CRF 2.D.2)

4.5.1.1 SOURCE CATEGORY DESCRIPTION

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.

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 4.37.

Table 4.37. Summary of source category description, CRF 2D2.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2D2	CO_2				NA	NA	No, see Annex 5
	CH_4				NA	NA	NA
	N_2O				NA	NA	NA

4.5.1.2 METHODOLOGICAL ISSUES

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[89] together with figures on import and export[90]. NMVOC emissions from beer production are based on the Swedish annual total production of beer[91] [92]. 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 4.38 were used. Emissions of CO_2 are not estimated but are believed to be minor or of biogenic origin.

[89] Systembolaget. Försäljningsstatistik. http://www.systembolaget.se/
[90] Statistics Sweden. Data from the Yearbook of Agricultural Statistics 2010 including Food Statistics. http://www.scb.se/
[91] Carlsberg Sweden. http://www.carlsberg.se
[92] Bryggeriföreningen. http://sverigesbryggerier.se

Table 4.38. 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	[93]
Beer	0.35	kg/1000 litres	[93]
Liquors	0.6	kg/1000 litres	EF based on emission and activity data from one producer, 2001
Bread (sponge dough)	8	kg/Mg	[93]
Bread (white)	4.5	kg/Mg	[93]
Bread (whole meal and light rye)	3	kg/Mg	[93]
Bread (dark rye)	0	kg/Mg	[93]
Cakes	0.1	kg/Mg	[93]
Biscuits	0.1	kg/Mg	[93]
Breakfast cereals	0.1	kg/Mg	[93]
Sugar	10	kg/Mg	[93]
Yeast	18	kg/Mg	[94]
Margarine and solid cooking fats	10	kg/Mg	[93]
Coffee roasting	0.55	kg/Mg	[93]
Animal feed	0.1	kg/Mg	[93]

4.5.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The time series is consistent.

4.5.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.5.1.5 SOURCE-SPECIFIC RECALCULATIONS

Activity data, thus affecting reported NMVOC emissions, have been updated for:

- Wine: Import 2007-2008
- Liquors: Import 2008
- Liquors: Export 2008
- Bread (sponge dough): Produced amount 2002-2003, 2008
- Bread (white): Produced amount 2008
- Bread (whole meal and light rye): Produced amount 2008
- Cakes: Produced amounts 2008
- Biscuits: Produced amounts 2008
- Breakfast cereals: Produced amounts 2008
- Sugar: Produced amounts 2008
- Margarine and solid cooking fats: Produced amounts 2008

[93] EMEP/CORINAIR Emission Inventory Guidebook: http://reports.eea.eu.int/EMEPCORINAIR4/en
[94] 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.

- Animal feed: Produced amounts for 2008
- Coffee roasting: Produced amounts 2008
- Yeast: Produced amounts 2008

4.5.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.6 Production of Halocarbons and SF6 (CRF 2.E)

Production of halocarbons and SF_6 does not occur in Sweden.

4.7 Consumption of Halocarbons and SF_6 (CRF 2.F)

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 in 2009. The second largest source is electrical equipment, followed by foam blowing (XPS-foam) and aerosols. All remaining sources are comparatively small emitters of fluorinated greenhouse gases.

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.

An overview of actual reported emissions in CRF 2F are shown in Table 4.39.

Table 4.39. Overview of submitted actual emissions data, Gg CO_2 equivalents.

CRF	Category	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
F1	Refrigeration and air conditioning equipment	2.5	120	427	476	533	586	633	684	733	786	829	863
F2	Foam blowing	NA	NA	111	110	104	97	107	87	74	54	51	40
F3	Fire extinguishers	NA	NA	5.3	5.1	5.6	5.8	6.1	5.7	6.0	5.9	7.6	5.7
F4	Aerosols/Metered dose inhalers	1.3	6.7	22	23	23	24	30	29	24	25	26	25
F5	Solvents	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
F7	Semiconductor manufacture	NA	11.4	8.4	10.5	14.0	10.1	4.2	NO	NO	NO	NO	NO
F8	Electrical equipment	81	95	32	43	26	22	28	28	22	29	28	45
F9	Other	2.5	3.4	7.6	9.8	10	9.3	12	14	12	9.1	7.7	7.7

In estimating the actual emissions, as far as possible, a Tier 2 approach has been used. Based on an earlier inventory model on actual emissions of fluorinated greenhouse gases in Sweden covering the time period 1990-1999[95], in 2005, the

[95] 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.

model was updated and refined e.g. concerning the calculations from the accumulated bank [96]. The model takes into consideration 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. The model is described in more details in Annex 3:1.

Due to a recurring one year lag of updating of the data from the Products Register from the Swedish Chemicals Agency, data on bulk import and export in 2008 are updated. This results in revised data on actual emission estimates from stationary refrigeration and air-conditioning equipment (2.F.1) and from electrical equipment (2.F.8) for 2008 due to the calculation system (as described below).

4.7.1 Refrigeration and air conditioning equipment (2.F.1)

4.7.1.1 SOURCE CATEGORY DESCRIPTION

Emissions of HFCs and PFCs from heat pumps, stationary air-conditioning, mobile air-conditioning, refrigeration and freezing equipment are included in this category. Emissions of SF_6 from refrigeration and air conditioning equipment are not applicable (NA) in Sweden. The most important source of greenhouse gases to the category is emissions of HFC-134a from air- conditioning in cars.

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 4.40.

Table 4.40. Summary of source category description, CRF 2F1.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2F1	HFCs	X	X		CS, T2	CS, D	Yes
	PFCs				CS	CS, D	Yes
	SF_6				NA	NA	NA

D Default. CS Country Specific. T2 Tier 2.

4.7.1.2 METHODOLOGICAL ISSUES

Input data for the calculation of actual emissions consists of information from various sources; the Swedish Chemical Agency, equipment producers and importers. Table 4.41 presents values for chemical charge, lifetime and emission factors for the applications used in the Swedish inventory. They are based on information from the equipment producers and IPCC default values.

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

Table 4.41. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of HFCs or PFCs used in calculations of actual emissions in Sweden. Intervals given indicate changes between 1990 and the last inventory year used in the calculations.

Application	Fluorinated substances	Lifetime**	Amount installed /unit, kg	Emissions at manufacturing	Emissions per year during use	Remained in product at disposal	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%

* Top-down calculations

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

As HFCs from mobile air-conditioning in cars is the most influential sub-source in the category, its underlying factors are compared to IPCC default values and differences are analysed (Table 4.42). The values for car air-conditioner lifetime, charge and annual leakage were chosen based on information in IPCC Guidelines and Good Practice Guidance. The values for EF for production, remaining at decommissioning and share recovered are attained from the Swedish car manufacture Volvo and in cooperation with experts at the Swedish EPA.

Table 4.42. Comparison of IPCC default factors and Swedish factors for MAC in cars.

Parameter	1996 IPCC/ update GPG	Swedish factors	Comment
Lifetime (y)	12/12	11	OK
Charge (kg)	0.8	0.8	OK
Annual leakage (%/år)	10-30/10-20	15-10	OK
EFproduction (%)	4-5/0.5	1	Somewhat high compared to GPG value
Remaining at decommissioning (%)	75/40	90	High; We assume that there is continuous maintenance and refilling of the equipment
Share recovered (%)	0/0	85	OK according to experts at Swedish EPA

The information on refrigerant-related imported amounts of fluorinated gases from the Swedish Chemical Agency's 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 is 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).

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 have been reported as included elsewhere (IE) and the emissions are included in commercial refrigeration in CRF table 2(II) F.

4.7.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The largest contribution to the total national emission uncertainty from this category stem from HFCs from mobile air conditioner and other refrigeration. Based on SMED expert judgement AD and EF uncertainty are ±10% and ±40% for mobile air conditioner, and ±25% and ±50% for other refrigeration.

Data in the category is of varying quality, but generally considered, by expert judgment, to be of medium quality and is usually better for the later years than for the earlier years of the inventory. The time-series are calculated using the same methodology for all years and are thus considered to be consistent.

4.7.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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.

4.7.1.5 SOURCE-SPECIFIC RECALCULATIONS

For emissions of HFCs from heat pumps minor recalculations 2005-2008 are done due to previous data handling error.

4.7.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.7.2 Foam blowing (2.F.2)

4.7.2.1 SOURCE CATEGORY DESCRIPTION

This category consists of HFCs emissions from production and use of XPS foam in Sweden. Emissions of PFCs and SF_6 from foam blowing are reported as not applicable (NA).

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 4.43.

Table 4.43. Summary of source category description, CRF 2F2.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2F2	HFCs				CS	PS	Yes
	PFCs				NA	NA	NA
	SF_6				NA	NA	NA

CS Country Specific. PS Plant-specific.

4.7.2.2 METHODOLOGICAL ISSUES

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 (Table 4.44).

Table 4.44. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of HFCs used in calculations of actual emissions in Sweden.

Application	Fluorinated substances	Lifetime**	Amount installed /unit, kg	Emissions at manufacturing	Emissions per year during use	Remained in product at disposal	Emissions at disposal
Foam blowing (XPS)	HFCs	> 12	*	35%	Declining	$	<76%***

* Top-down calculations

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

*** Based on remaining HFC in products at disposal after 12 years. 2008 is the first year for emissions at disposal in Sweden.

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

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 prod-

ucts. Beside annual losses from products over time, the reported Swedish emissions in the CRF tables contain emissions from manufacturing.

More detailed information on the methodological issues for foam blowing is presented in Annex 3:4.

4.7.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties for the category 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.

The quality of activity data, such as amount of chemical used in applications, is usually better for the later years than for the earlier years of the inventory. The time series are calculated using the same methodology for all years and are thus consistent.

4.7.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.7.2.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.7.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.7.3 Fire extinguishers (2.F.3)

4.7.3.1 SOURCE CATEGORY DESCRIPTION

HFC may be used as extinguishing medium in fixed fire extinguishing systems. In Sweden, emissions of HFCs from fire extinguishers are reported since 1997. Emissions of PFCs and SF_6 for the category are not applicable (NA).

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 4.45.

Table 4.45. Summary of source category description, CRF 2F3.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2F3	HFCs				CS	CS	Yes
	PFCs				NA	NA	NA
	SF_6				NA	NA	NA

CS Country Specific.

4.7.3.2 METHODOLOGICAL ISSUES

All imports of HFCs to be installed in fire extinguishers are registered at the Swedish Chemicals Agency. 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 (Table 4.46).

Table 4.46. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of HFCs used in calculations of actual emissions in Sweden.

Application	Fluorinated substances	Lifetime**	Amount installed /unit, kg	Emissions at manufacturing	Emissions per year during use	Remained in product at disposal	Emissions at disposal
Fire extinguishing	HFCs	30	*	0.5%	2% / 0.1%***	95%	1%

* Top-down calculations

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

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

4.7.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties are mainly associated with the exported amounts, which are relatively large.

The time series are calculated using the same methodology for all years and are thus consistent.

4.7.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.7.3.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.7.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.7.4 Aerosols/metered dose inhalers (2.F.4)

4.7.4.1 SOURCE CATEGORY DESCRIPTION

HFC may be used as propellant gas in aerosols, but also as the actual product e.g. in cleaning sprays. In asthma medication inhalers, HFC-134a (norflurane) is sometimes used as propellant gas. Emissions of PFCs and SF_6 for the category are not applicable (NA).

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 4.47.

Table 4.47. Summary of source category description, CRF 2F4.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2F4	HFCs				CS, T2	D	Yes
	PFCs				NA	NA	NA
	SF_6				NA	NA	NA

D Default. CS Country Specific. T2 Tier 2.

4.7.4.2 METHODOLOGICAL ISSUES

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. Table 4.48 present the assumptions on product lifetime, emissions at manufacturing and disposal as well as remaining HFC in product at disposal.

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.

Table 4.48. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of HFCs used in calculations of actual emissions in Sweden.

Application	Fluorinated substances	Lifetime**	Amount installed /unit, kg	Emissions at manufacturing	Emissions per year during use	Remained in product at disposal	Emissions at disposal
Aerosols/ MDI	HFCs	2	*	NA	50%	50%	100 %

* Top-down calculations

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

4.7.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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.

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. The time series are calculated using the same methodology for all years and are thus consistent.

4.7.4.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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.

4.7.4.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.7.4.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.7.5 Solvents (2.F.5)

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.

4.7.6 Other applications using ODS substitutes (2.F.6)

No other applications are covered in the Swedish inventory.

4.7.7 Semiconductor manufacture (2.F.7)

4.7.7.1 SOURCE CATEGORY DESCRIPTION

HFC, PFC and SF_6 are used in the semiconductor manufacturing process. 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.

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 4.49.

Table 4.49. Summary of source category description, CRF 2F7.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2F7	HFCs				T1	D	Yes
	PFCs				T1	D	Yes
	SF_6				T1	D	Yes

D Default. T1 Tier 1.

4.7.7.2 METHODOLOGICAL ISSUES

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 (top-down calculations) using an average expected lifetime of 1 year.

4.7.7.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Emission estimates are judged to be of good quality. The quality of activity data is usually better for the later years than for the earlier years of the inventory. The time series are calculated using the same methodology for all years and are thus consistent.

4.7.7.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Cross-references with the Products Register at the Swedish Chemicals Agency could not be made for later years, since the level of detail in the Products Register was insufficient.

4.7.7.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.7.7.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.7.8 Electrical equipment (2.F.8)

4.7.8.1 SOURCE CATEGORY DESCRIPTION

In Sweden, emissions of SF_6 from electrical equipment consist of two different parts, emissions from the production of gas-insulated switchgear (GIS), and emissions from SF_6 installed in distribution systems. Emissions of HFCs and PFCs are not applicable (NA) for this category.

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 4.50.

Table 4.50. Summary of source category description, CRF 2F8.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2F8	HFCs				NA	NA	NA
	PFCs				NA	NA	NA
	SF_6				CS, D	CR, PS	Yes

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

4.7.8.2 METHODOLOGICAL ISSUES

The larger part of annual SF_6 emissions in earlier years originated from the manufacture of GIS (Table 4.52), 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 (Table 4.51), as well as the share of products that are exported from the country, which exceeds 90 % of the production.

Table 4.51. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of 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.

Application	Fluorinated substances	Lifetime**	Amount installed /unit, kg	Emissions at manufacturing	Emissions per year during use	Remained in product at disposal	Emissions at disposal
Electrical insulation and GIS manufacture	SF_6	30	*	12→1.5%	0.6→0.5%	#	NA

* Top-down calculations

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

Estimated lifetime at least 30 years, NE.

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[97] (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

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

operating systems results in a calculated annual leakage rate of 0.5 % (Swedenergy and power distribution companies).

Table 4.52. 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	0.87	173.4	1.2
2009	0.90	1.00	200.1	1.9

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 semiconductor 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.

As 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).

4.7.8.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The quality of activity data is usually better for the later years than for the earlier years of the inventory. The time series are calculated using the same methodology for all years and are thus consistent.

4.7.8.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.7.8.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.7.8.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.7.9 Other (2.F.9)

4.7.9.1 SOURCE CATEGORY DESCRIPTION

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 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 4.53.

Table 4.53. Summary of source category description, CRF 2F9.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2F9	HFCs				NA	NA	NA
	PFCs				NA	NA	NA
	SF_6				CS	CS, D, PS	Yes

D Default. CS Country Specific. PS Plant-specific.

4.7.9.2 METHODOLOGICAL ISSUES

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.[98] According to the results from a study performed in early 2004[99] a phasing out of SF_6 and replacement with PFC-218 was started in 2003. The lifetime for shoes is set to 8 years in the national model (Table 4.54).

[98] Weholt, Ø. 1999. Materialstrømsanalyse av SF6. Beregning av potensielt og faktisk utslipp over tid
[99] Kindbom, K. and Skårman, T. 2004. Nya scenarier för fluorerade växthusgaser. U952, Swedish EPA.

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 (Table 4.54). These estimates vary considerably between manufacturers, from 5-50 %. 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.

Table 4.54. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of 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.

Application	Fluorinated substances	Lifetime**	Amount installed /unit, kg	Emissions at manufacturing	Emissions per year during use	Remained in product at disposal	Emissions at disposal
Sound proof windows	SF_6	30	*	5-50%##	1%	#	NA
Jogging shoes	SF_6 PFC-218	8	*	NA	NA	100%	25%

* Top-down calculations

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

Estimated lifetime at least 30 years, NE.

Different emissions at different production units.

4.7.9.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The quality of activity data is usually better for the later years than for the earlier years of the inventory. The time series are calculated using the same methodology for all years and are thus consistent.

4.7.9.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.7.9.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.7.9.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No source-specific improvements are planned.

4.8 Consumption of Halocarbons and SF_6 Potential Emissions (CRF 2.F.P)

4.8.1 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.

Due to the recurring one year lag of updating of the data from the Products Register from the Swedish Chemicals Agency, data on bulk import and export in 2008 are updated. This results in revised data on potential emissions for 2008.

4.9 Other, CRF 2G

Not applicable for Sweden.

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

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 11 % from 332 Gg CO_2 equivalents in 1990 to 295 Gg CO_2 equivalents in 2009 (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.

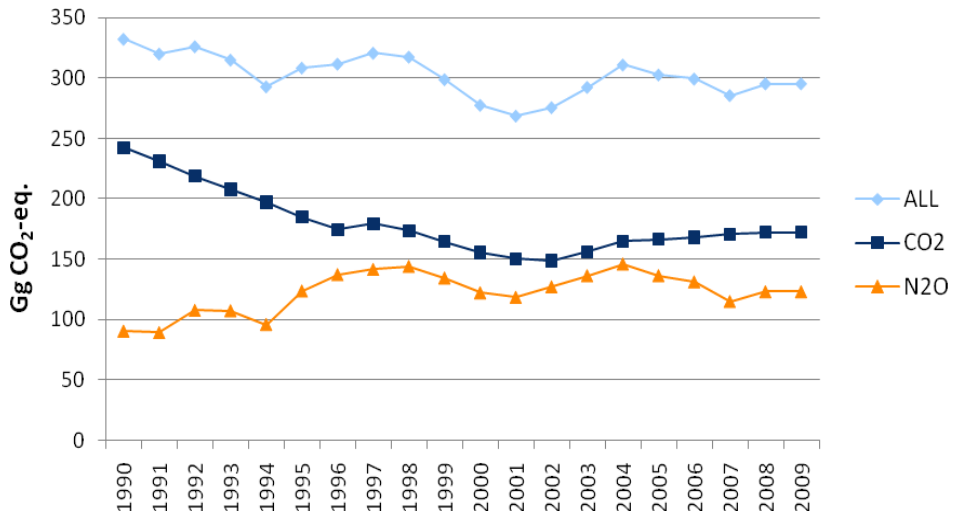

Figure 5.1. Total emissions of all greenhouse gases calculated as CO_2 equivalents from CRF 3 Solvent and Other product use.

CO_2 emissions in CRF 3A (paint application) have decreased by 62 % from 94 Gg CO_2 equivalents in 1990 to 36 Gg CO_2 equivalents in 2009 (Figure 5.2). The largest source of CO_2 emissions from solvents in CRF sector 3 is CRF 3D (other). CO_2 emissions in CRF 3D have decreased by 2 % from 138 Gg CO_2 equivalents in 1990 to 135 Gg CO_2 equivalents in 2009.

CRF 3D (other) also consists of N_2O emissions from CRF 3D4 (other use of N_2O). The use of N_2O has increased with 36 % from 90 Gg CO_2 equivalents in 1990 to 123 Gg CO_2 equivalents in 2009.

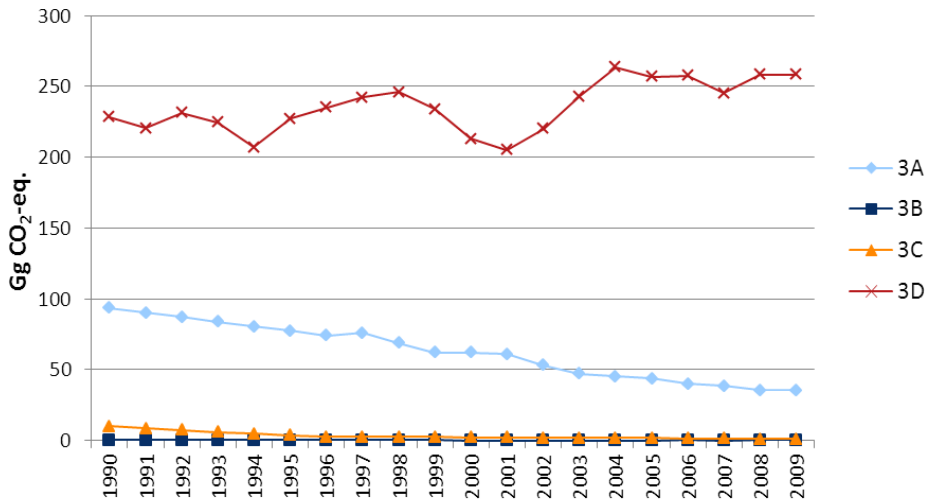

Figure 5.2. Total emissions of all greenhouse gases calculated as CO_2 equivalents from the different Solvent and Other product use sub-sectors. 3A - Paint application. 3B - Degreasing and dry-cleaning. 3C - Chemical products, manufacture and processing. 3D - Other.

Table 5.1 shows the recalculation differences for the GHG emissions by sub-sector as well as for the total level in the sector reported in submission 2011 compared to data reported in submission 2010.

Table 5.1. Recalculations of GHG emissions between submission 2011 and submission 2010 in the Solvent and Other product use sector.

	Recalculation differences, submission 2011/2010 (Gg CO_2 eq.)						
CRF	**3A**	**3B**	**3C**	**3D4**	**3D5**	**Total CRF 3**	**% CRF 3**
2006	-2	0	0	0	4	2	0.72%
2007	-3	0	0	0	5	2	0.59%
2008	-6	0	0	8	10	11	4.03%

0 equals value less than 0.5 Gg.

The model used for estimating the CO_2 and NMVOC emissions reported in sector 3 is described in detail in Annex 3.3.

5.2 Paint application (CRF 3.A)

5.2.1 Source category description

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

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 5.2.

Table 5.2. Summary of source category description, CRF 3A.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
3A	CO_2				CS	CS	Yes

CS Country Specific.

5.2.2 Methodological issues

All activity data from 1995 has been obtained from the Products register at the Swedish Chemicals Agency. Emissions from 1988 are taken from a time series that was compiled in a special study concerning NMVOC emissions, carried out by SMED in 2002[101]. The emissions for 1990-1994 have been interpolated based on the information from the late 1980´s and known data for 1995.

5.2.3 Uncertainties and time-series consistency

The reported time series are considered to be consistent, except for last year (2009) where data for previous year (2008) 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.

5.2.4 Source-specific QA/QC and verification

No source specific QA/QC procedures have been performed.

5.2.5 Source-specific recalculations

Due to the recurring one year lag of updating of the data from the Product Register from the Swedish Chemicals Agency and the use of moving average for compiling the NMVOC and CO_2 time series in subsector 3A, the reported emissions for 2006 - 2008 are updated in submission 2011 (Table 5.1).

5.2.6 Source-specific planned improvements

Category-specific improvements will be decided after the finalization of the submission 2012 as part of the national QA/QC plan.

5.3 Degreasing and Dry cleaning (CRF 3.B)

5.3.1 Source category description

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

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

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 5.2.

Table 5.3. Summary of source category description, CRF 3B.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
3B	CO_2				CS	CS	Yes

CS Country Specific.

5.3.2 Methodological issues

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 contribute 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.

5.3.3 Uncertainties and time-series consistency

The reported time series are considered to be consistent, except for last year (2009) where data for previous year (2008) 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.

5.3.4 Source-specific QA/QC and verification

No source specific QA/QC procedures have been performed.

5.3.5 Source-specific recalculations

Due to the recurring one year lag of updating of the data from the Product Register from the Swedish Chemicals Agency and the use of moving average for compiling the NMVOC and CO_2 time series in subsector 3B, the reported emissions for 2006 - 2008 are updated in submission 2011 (Table 5.1).

5.3.6 Source-specific planned improvements

Category-specific improvements will be decided after the finalization of the submission 2012 as part of the national QA/QC plan.

5.4 Chemical products, Manufacture and Processing (CRF 3.C)

5.4.1 Source category description

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

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 5.2.

Table 5.4. Summary of source category description, CRF 3C.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
3C	CO_2				CS	CS	Yes

CS Country Specific.

5.4.2 Methodological issues

The category 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[101]. Emission data for the rubber industry is known for 1988[101] and data for 1990-1994 have been interpolated based on the information from the late 1980´s and known data for 1995.

5.4.3 Uncertainties and time-series consistency

The reported time series are considered to be consistent, except for last year (2009) where data for previous year (2008) 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.

5.4.4 Source-specific QA/QC and verification

No source specific QA/QC procedures have been performed.

5.4.5 Source-specific recalculations

Due to the recurring one year lag of updating of the data from the Product Register from the Swedish Chemicals Agency and the use of moving average for compiling the NMVOC and CO_2 time series in subsector 3C, the reported emissions for 2006 - 2008 are updated in submission 2011 (Table 5.1).

5.4.6 Source-specific planned improvements

Category-specific improvements will be decided after the finalization of the submission 2012 as part of the national QA/QC plan.

5.5 Other (CRF 3.D)

5.5.1 Source category description

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.

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 5.5.

Table 5.5. Summary of source category description, CRF 3D.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
3D	CO_2				CS	CS	Yes
3D	N_2O				CS	CS	Yes

CS Country Specific.

5.5.2 Methodological issues

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.

There are two companies in Sweden selling N_2O in gas cylinders. Information on sold amounts was obtained from one of the companies (1990 - 1991) and from the Products Register at the Swedish Chemicals Agency (1992 - 2008). 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, 2009, is not

yet official and hence Sweden has chosen to report data from 2008 also for 2009. Data for 2009 will be updated in the next submission.

5.5.3 Uncertainties and time-series consistency

The reported time series are considered to be consistent, except for last year (2009) where data for previous year (2008) 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.

5.5.4 Source-specific QA/QC and verification

No source specific QA/QC procedures have been performed.

5.5.5 Source-specific recalculations

Due to the recurring one year lag of updating of the data from the Product Register from the Swedish Chemicals Agency and the use of moving average for compiling the NMVOC and CO_2 time series in subsector 3D5, the reported emissions for 2006 - 2008 are updated in submission 2011 (Table 5.1). All other adjustments in the 3D5 time series are due to changes of reported decimals.
Recalculations concerning sold amounts and use of N_2O have been performed for 2008, also as for NMVOC and CO_2, due to the recurring one year lag of updating of the data from the Product Register from the Swedish Chemicals Agency

5.5.6 Source-specific planned improvements

Category-specific improvements will be decided after the finalization of the submission 2012 as part of the national QA/QC plan.

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 small holdings 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.[102] 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.[103]

The total greenhouse gas (GHG) emissions from the Swedish agriculture have decreased by 11 % since 1990, from 9.237 Gg CO_2 equivalents to 8.192 Gg CO_2 equivalents (Figure 6.1). In Figure 6.2 it can be seen that the largest emissions in this sector are 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.

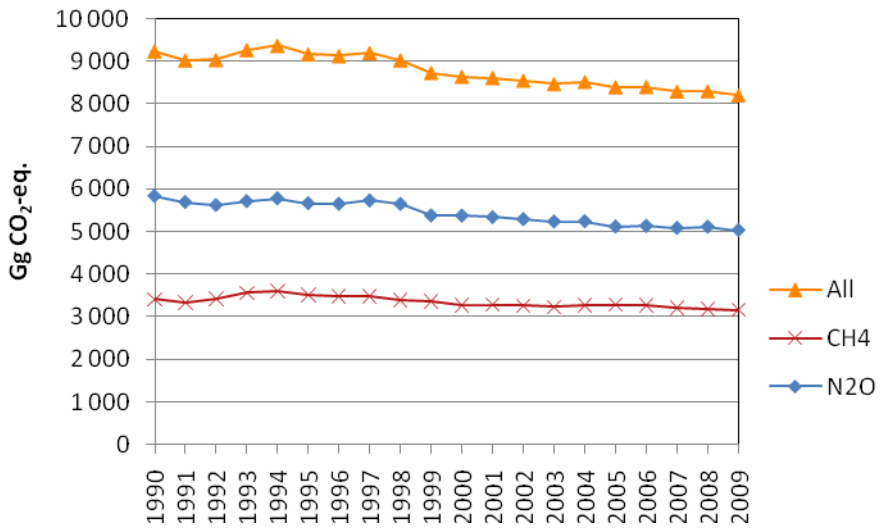

Figure 6.1. Total emissions of all greenhouse gases calculated as CO_2 equivalents from CRF 4 Agriculture.

[102] Ministry of the Environment, 2001.
[103] Swedish Board of Agriculture, www.sjv.se., http://miljomal.nu/

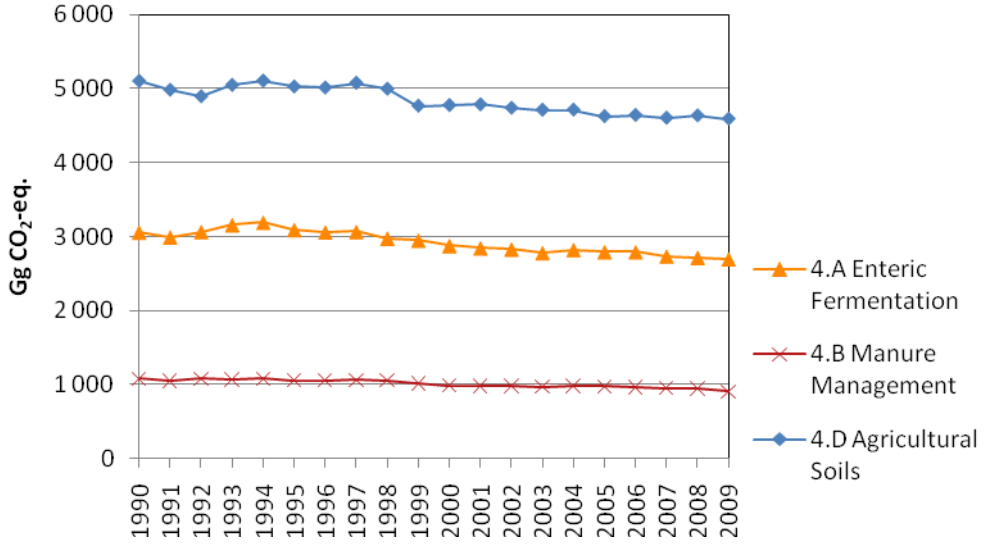

Figure 6.2. Total emissions of all greenhouse gases calculated as CO_2 equivalents from the different agricultural sub-sectors. There are no emissions from 4.C or 4.E-G.

The recalculation differences for the GHG emissions by sub-sector as well as for the total level in the sector reported in submission 2011 compared to data reported in submission 2010 are found in Table 6.1.

Table 6.1. Recalculations of GHG emissions between submission 2010 and submission 2011 in the agricultural sector.

	Recalculation differences, submission 2011/2010 (Gg CO_2 eq.)							
CRF	4A	4B	4D1	4D2	4D3	4D4	Total CRF 4	% CRF 4
1990	0	0	-380	75	1	26	-278	-2.9
1991	0	0	-382	75	0	26	-280	-3.0
1992	0	0	-382	77	-1	26	-280	-3.0
1993	0	0	-381	78	-5	27	-280	-2.9
1994	0	0	-380	79	-7	27	-281	-2.9
1995	0	0	-383	78	-5	27	-283	-3.0
1996	0	0	-385	81	-3	27	-281	-3.0
1997	0	0	-386	80	-3	27	-282	-3.0
1998	0	0	-388	79	-3	27	-285	-3.1
1999	0	0	-391	80	-3	27	-287	-3.2
2000	0	0	-393	79	-1	28	-287	-3.2
2001	0	0	-395	80	-1	28	-288	-3.2
2002	0	0	-395	79	-2	28	-290	-3.3
2003	0	0	-398	80	2	29	-288	-3.3
2004	0	0	-400	81	2	29	-288	-3.3
2005	0	0	-404	82	10	36	-277	-3.2
2006	0	0	-395	83	8	34	-271	-3.1
2007	0	0	-406	80	20	45	-260	-3.0
2008	5	0	-415	81	66	84	-178	-2.1

0 equals value less than 0.5.

Livestock is the main contributor to greenhouse gas emissions from agriculture. In Table 6.2 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.

Table 6.2. 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).

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[104]. 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

[104] Swedish Board of Agriculture, JO 20-series.

estimated to be about 283,000[105]. This larger number has been used for the calculations for all years.
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.

6.2 Enteric Fermentation (CRF 4.A)

6.2.1 Source category description

The animal husbandry sub-sector is an important sector 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 85 % derives from enteric fermentation from cattle. The total numbers of livestock in Sweden in 1990-2009 are presented in Table 6.6 and 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 6.3.

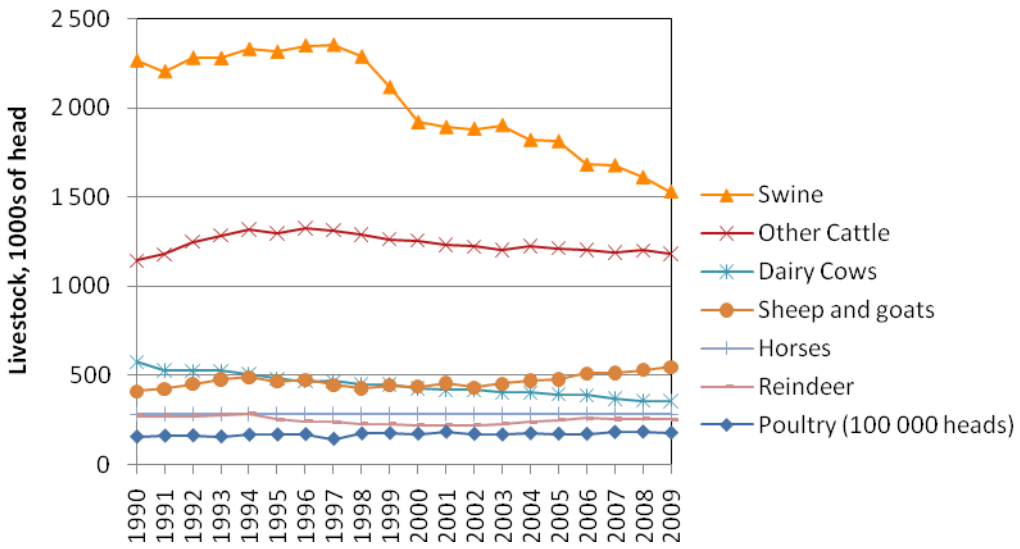

Figure 6.3. Livestock in Sweden 1990-2009, 1000s of head.

Table 6.3. Summary of source category description, CRF 4.A.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
4.A	CH_4	X	X		CS, T1, T2	CS, D	Yes

[105] Statistics Sweden, 2006.

6.2.2 Methodological issues

6.2.2.1 EMISSION FACTORS, METHANE

The livestock population (Table 6.6) in each category is multiplied by an emission factor and the total emission is calculated as:

$$emissions = \sum_i population_i * EF_i$$

Emission factors (EF_i) for the significant cattle subgroups are national. 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.[106] For emissions from swine, sheep, goats and horses the IPCC default values are used. Statistics on livestock categories are presented in Table 6.2. A national methodology based on feed energy requirements expressed as metabolisable energy[107] is used in the Swedish inventory to estimate emission factors for dairy cows, beef cows and other cattle. For dairy cows during the lactation we first calculate the metabolisable energy (MJ/day) from the energy requirements for maintenance and lactation. The metabolisable energy is then used to estimate digestible energy, and from this the emission of methane is calculated using the methane conversion rate.

The calculations for dairy cows were revised some years ago[108]. The emission factors for other cattle groups were also re-evaluated, using the same methodology[108]. 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-dairy 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.

The following is a review of the different stages in the calculation for dairy cows. Metabolisable energy (MJ/day) is calculated using the formula from Spörndly 1999:

Lactation period:

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

Dry period:

Metabolisable energy (MJ/day) =62+13

Metabolisable energy is then converted to digestible energy using the formula[109]:

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

[106] Statistics Finland, 2007
[107] Lindgren, 1980; Murphy, 1992; Bertilsson, 2002.
[108] Bertilsson, 2001.
[109] Lindgren, 1980.

Methane conversion rate of digestible energy is calculated using the formula[110]:

Methane conversion rate (% methane of digestible energy) = 15.7 – 0.030×SK – 1.4×L

Where L is the total feed intake expressed as multiples of maintenance energy. G is the share of coarse feed and Rp is the crude protein content in the food expressed as percentage of total food consumption in dry matter. SK is the digestibility of the feed (% of gross energy). All used constant for the different years are given in Table 6.4. Finally, the actual emission of methane is estimated with the formula:

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

The Swedish method resembles the one used by IPCC. The main difference is that Sweden uses metabolisable energy in the calculations as opposed to gross energy intake. Furthermore, the energy loss caused by methane emissions is calculated as a fraction of digestible energy. This fraction is in turn determined by total feed intake and digestibility of the feed. IPCC instead express energy in methane as a constant fraction of gross energy in feed.

Table 6.4. Constants used for estimating methane from dairy cattle

Year	Dry cows				During lactation			
	L	G	Rp	SK	L	G	Rp	SK
1990	1.2	80.1	14	69	3.0	55	16	69
1991	1.2	80.1	14	69	3.0	55	16	69
1992	1.2	80.1	14	69	3.1	55	16	69
1993	1.2	80.1	14	69	3.1	55	16	69
1994	1.2	80.1	14	69	3.2	55	16	69
1995	1.2	80.1	14	69	3.2	55	16	69
1996	1.2	80.1	14	69	3.3	55	16	69
1997	1.2	80.1	14	69	3.3	55	16	69
1998	1.2	80.1	14	69	3.4	55	16	69
1999	1.2	80.1	14	69	3.4	55	16	69
2000	1.2	80.1	14	69	3.5	55	16	69
2001	1.2	80.1	14	69	3.5	55	16	69
2002	1.2	80.1	14	69	3.5	55	16	69
2003	1.2	80.1	14	69	3.5	55	16	69
2004	1.2	80.1	14	69	3.5	55	16	69
2005	1.2	80.1	14	69	3.5	55	16	69
2006	1.2	80.1	14	69	3.5	55	16	69
2007	1.2	80.1	14	69	3.5	55	16	69
2008	1.2	80.1	14	69	3.5	55	16	69
2009	1.2	80.1	14	69	3.5	55	16	69

For the year 2009 this resulted in an emission of 394 g of methane per day for milk cows during the lactation period. The lactation period is estimated to 305 days per year. For cows during the non-lactation period the value does not change between years and is estimated to 201 g of methane per day. The final emission from milk

[110] Lindgren, 1980.

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 reported 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)

The default values in the IPCC Guidelines are used for the less significant animal groups[111] and for these groups the development of a national emission factor has not been given priority. The emission factors used for dairy cattle and other animal groups are collected in Table 6.7.

Table 6.5. Number of dairy cows and average milk production

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
2009	356 776	285 246	9 486	6 750	8 937

(*) Farm Register, (**) Swedish Dairy Association. (***) Calculated value.

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

Table 6.6. 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	2,4	251	273	283	3,7	1,8	245	5546	1649	10770
2009	357	192	502	488	158	943	426	2,4	254	287	283	3,7	1,8	245	5261	1898	10240

Most data from the Farm register, Swedish Board of Agriculture and Statistics Sweden. (*) Estimated number of horses 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 6.7. 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	1
Dairy cows in 1995, average milk production 7724 kg/yr/head	126.4	1
Dairy cows in 2002, average milk production 8468 kg/yr/head	127.7	1
Dairy cows in 2009, average milk production 8937 kg/yr/head	132,4	1
Beef cows	78	4
Growing animals (12-24 months)	50	4
Calves	50	4
Swine	1.5	2
Sheep	8	2
Goats	5	2
Horses	18	2
Poultry	No fermentation assumed	
Reindeer	19.9	2

(1) The emission factor is related to milk production and calculated from Spörndly, 1999 and Bertilsson, 2001.

(2) IPCC Guidelines. (3) Statistics Finland, 2007, Tier 2. (4) Bertilsson, 2001.

6.2.3 Uncertainties and time-series consistency

Between 1995 and 1996 there was an increase in the 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.

6.2.4 Source-specific QA/QC and verification

The timeseries for the different populations and milk production is checked for consistency.

6.2.5 Source-specific recalculations

The reindeer population has been updated with new data for 2008.

The method for calculating Y_m for dairy cattle (Average CH_4 conversion rate) for the background information in the CRF tables has been changed. This has, however, no effect on the actual emission estimates.

6.2.6 Source-specific planned improvements

Category-specific improvements will be decided after the finalization of the submission 2012 as part of the national QA/QC plan.

6.3 Manure Management (CRF 4.B)

6.3.1 Source category description

Include emission of methane and nitrous oxide from manure management. 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 6.8.

Table 6.8. Summary of source category description, CRF 4.B.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
4.B	CH_4	X	X		T1, T2	CS, D	Yes
	N_2O	X	X		T2	CS	Yes

6.3.2 Methodological issues

Statistics on manure management and the use of manure and fertilisers are collected biannually by Statistics Sweden[112]. Data on stable periods (Table 6.9) and manure management systems (Table 6.10, Table 6.11 & Table 6.12) 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 38 % of its manure was produced in the stable during the grazing period. The Swedish Board of Agriculture publishes data on manure production from cattle and swine as well as on

112 Statistics Sweden, MI 30-series.

nitrogen production from most of the animal subgroups included in the inventory[113]. Data on dairy cows for different levels of milk productivity are presented in Table 6.13. As productivity has increased during the reporting period, the data in Table 6.13 is used for interpolating an accurate mean value for each reporting year in the inventory. The values for manure production and nitrogen production per animal in each of the other animal groups are given in Table 6.14 and Table 6.15, respectively. Due to more intense swine production, the values for sows and pigs for meat production were updated in 2001. All emission factors used in the calculations are presented in Table 6.16.

Table 6.9. 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
2009	(*) 7,1	(*) 5,5	(*) 8,7	(*) 5,8	(*) 8,1	6	0	12

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

[113] Swedish Board of Agriculture, 1993; and Swedish Board of Agriculture, 2001; Swedish Board of Agriculture, 1995; Swedish Board of Agriculture, 2000. The given values are calculated according to the model STANK – the official model for input/output accounting on farm level in Sweden (Linder, 2001).

Table 6.10. Waste management systems, fraction of liquid systems.

Year	Dairy cattle	Other cattle	Pigs for meat pro-duction	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
2009	(*******) 0.58	(*******) 0.18	(*******) 0.94	(*******) 0.61	0	0.25

(*) Statistics Sweden, 1998. (**) Statistics Sweden, 2000b. (***) Statistics Sweden, 2002b. (****) Statistics Sweden, 2004. (*****) Statistics Sweden, 2006. (******) Statistics Sweden 2008, (*******) Statistics Sweden 2010. 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	0,48	0,55
1991	0,52	0,32	0,54	0,45	0,5	0	0,48	0,55
1992	0,52	0,32	0,54	0,45	0,5	0	0,48	0,55
1993	0,46	0,27	0,4	0,31	0,5	0	0,48	0,55
1994	0,46	0,27	0,4	0,31	0,5	0	0,48	0,55
1995	0,44	0,26	0,35	0,26	0,5	0	0,48	0,55
1996	0,44	0,26	0,35	0,26	0,5	0	0,48	0,55
1997	0,41	0,33	0,17	0,65	0,5	0	0,48	0,55
1998	0,41	0,33	0,17	0,65	0,5	0	0,48	0,55
1999	0,35	0,31	0,18	0,67	0,5	0	0,48	0,55
2000	0,35	0,31	0,18	0,67	0,5	0	0,48	0,55
2001	0,31	0,26	0,13	0,58	0,5	0	0,48	0,55
2002	0,31	0,26	0,13	0,58	0,5	0	0,48	0,55
2003	0,27	0,24	0,11	0,51	0,5	0	0,48	0,55
2004	0,27	0,24	0,11	0,51	0,5	0	0,48	0,55
2005	0,23	0,20	0,05	0,44	0,5	0	0,48	0,55
2006	0,23	0,20	0,05	0,44	0,5	0	0,48	0,55
2007	0,20	0,22	0,06	0,41	0,5	0	0,48	0,55
2008	0,20	0,22	0,06	0,41	0,5	0	0,48	0,55
2009	0,16	0,2	0,05	0,32	0,5	0	0,48	0,55

Table 6.12. Waste management systems, fraction of deep litter systems (categorised as "other" in the CRF-tables).

Year	Dairy cattle	Other cattle	Pigs for meat production	Other swine	Sheep, goats, reindeer	Horses	Poultry
1990	0.01	0.08	0.02	0.11	0	0.02	0.2
1991	0.01	0.08	0.02	0.11	0	0.02	0.2
1992	0.01	0.08	0.02	0.11	0	0.02	0.2
1993	0.01	0.08	0.02	0.11	0	0.02	0.2
1994	0.01	0.08	0.02	0.11	0	0.02	0.2
1995	0.01	0.08	0.02	0.11	0	0.02	0.2
1996	0.01	0.08	0.02	0.11	0	0.02	0.2
1997	0.01	0.08	0.02	0.11	0	0.02	0.2
1998	0.01	0.08	0.02	0.11	0	0.02	0.2
1999	0.01	0.09	0.01	0.07	0	0.02	0.2
2000	0.01	0.09	0.01	0.07	0	0.02	0.2
2001	0	0.12	0.01	0.12	0	0.02	0.2
2002	0	0.12	0.01	0.12	0	0.02	0.2
2003	0.01	0.14	0.01	0.11	0	0.02	0.2
2004	0.01	0.14	0.01	0.11	0	0.02	0.2
2005	0.01	0.16	0.01	0.22	0	0.02	0.2
2006	0.01	0.16	0.01	0.22	0	0.02	0.2
2007	0.01	0.17	0	0.12	0	0.02	0.2
2008	0.01	0.17	0	0.12	0	0.02	0.2
2009	0.01	0.16	0.01	0.07	0	0.02	0.2

Table 6.13. 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

Table 6.14. 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 6.15. 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		
Reindeer*	10			

Values are calculated according to the STANK model (Swedish Board of Agriculture)

* Data from Statistics Finland

Table 6.16. Emission factor manure management

Manure management	Emission factor for CH_4	
MFC solid manure(*)	1 % of B_0	1
MFC liquid manure(*)	10 % of B_0	2
MFC deep litter(*)	39 % of B_0	1
Dairy Cattle - volatile solid (VS)	1 937 kg VS/animal/yr	3
Dairy Cattle - B_0(**)	0.24 m^3 CH_4/kg VS	1
Dairy Cattle - Emission per animal	16 kg CH_4/animal/yr	7
Non-Dairy Cattle – volatile solid (VS)	625 kg VS/animal/yr	3
Non-Dairy Cattle – B_0	0.17 m^3 CH_4/kg VS	1
Non-Dairy Cattle – emission/animal (***)	5.6 kg CH_4/animal/yr	4
Swine – volatile solids (VS)	110 kg VS/animal/yr	3
Swine - B_0**	0.45 m^3 CH_4/kg VS	1
Swine – emission per animal (***)	3 kg CH_4/animal/yr	4
Sheep – emission	0.19 kg CH_4/animal/yr	1
Goats – emission	0.12 "	1
Horses – emission	1.40 "	1
Poultry – emission	0.08 "	1
Manure management	**Emission factor for N_2O**	**Note**
Waste Management System	% N_2O-N of N-supply	
Liquid manure	0.1	1
Solid manure	2	1
Deep litter	2	1

(*)MCF = Methane Conversion Factor. (**) B0 = maximum methane producing capacity for manure. (***) Weighted value – more than one animal category. 1) IPCC Guidelines. 2) National, Dustan 2002. 3) National – STANK. 4) Calculated – 2002.

6.3.2.1 4.B(a). 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[114]. 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 system j, where grazing animals are considered as one of the systems, and a climate

[114] According to current estimations, cattle and swine produce about 85-90% of the total methane emissions from manure management.

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 2006 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[115].

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)[116].
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[117] and the interpolated values are used for the intermediate years. Three manure management systems are considered apart from grazing animals: liquid systems (Table 6.10), solid storage (Table 6.11) and deep litter (Table 6.12) (sometimes categorised as "other" in the national inventory). National estimates of stable periods for cattle are collected from the statistical report on use of fertilisers and animal manure in agriculture[118]. This information has been available biannually since 1997. Before 1997, the data are extrapolated to 1990.

6.3.2.2 4.B(b). NITROUS OXIDE

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:

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

where N_T is the number of head of livestock in category T in the country, NEX_T is the annual average excretion of N per head of category T in the country, $GrazPeriod_T$ is the grazing period in days for livestock category T, $MS_{(T,S)}$ is the fraction of

[115] Dustan, 2002.
[116] 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.
[117] Statistics Sweden, MI 30-series.
[118] Statistics Sweden, MI 30-series.

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 (Table 6.13, Table 6.14 and Table 6.15). Stable period and manure management systems are the same as used in the methane calculations (Table 6.9, Table 6.10, Table 6.11 and Table 6.12).

The emission factors are described in Table 6.17. 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 Uncertainties and time-series consistency

Due to more intense swine production, the values for sows and pigs for meat production were updated in 2001.

6.3.4 Source-specific QA/QC and verification

No source specific QA/QC procedures have been performed.

6.3.5 Source-specific recalculations

After recommendations from the ERT the methane conversion factors in CRF table 4.B.(a) are changed from fraction to percent.

An increase in the amount of decimals used in the calculation of manure production from dairy cattle marginally affected the emission estimate from this category.

6.3.6 Source-specific planned improvements

Category-specific improvements will be decided after the finalization of the submission 2011 as part of the national QA/QC plan.

6.4 Agricultural Soils (CRF 4.D)

Emissions of nitrous oxide from agricultural soils are presented under CRF 4.D.1 to CRF 4.D.4. When the subsectors represent relatively different processes they are divided in separate paragraphs and also treated independently in the key categories analyses. Table 6.17 gives an overview of all emission factors used in this sector.

Table 6.17. Emission factor for N_2O from soils

Direct emissions from soils	Emission factor % N_2O-N of N-supply	Note
Mineral fertiliser	0.8	1
Manure	2.5	1
Crop residue	1.25	2
N-fixing Crops	1.25	2
Manure during grazing	2	2
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.

6.4.1 Direct Soil Emissions (CRF 4.D.1)

6.4.1.1 SOURCE CATEGORY DESCRIPTION

The category includes the direct emission of nitrous oxide from soils. In terms of magnitude the most important emissions are from animal manure applied to soils followed by cultivation of histosoils and from the use of synthetic fertilisers, respectively. Also included in this category are emissions from nitrogen fixing crops and crop residues. In this category Sweden also includes emission from sewage sludge used as fertilisers. 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 6.18.

Table 6.18. Summary of source category description for the entire category CRF 4.D.1.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
4.D.1	N_2O	X	X		CS, T1, T1a, T1b, T2	CS, D	Yes

6.4.1.2 METHODOLOGICAL ISSUES

6.4.1.2.1 Emission factors

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[119]. The study includes documented N_2O emission measurements carried out in Sweden and in other countries in northern Europe and in Canada. The results show that there is limited data available. It was for example not possible to develop different emission factors for added nitrogen to mineral or organic soils. Best data availability was found for the use of synthetic fertilisers on mineral soils. Here the emissions of N_2O-N were between 0 and 0.8 % of added nitrogen. However, when the emissions are caused by other processes than newly added fertiliser, a correlation between added nitrogen and emitted nitrogen was not always apparent. For example, the amount of fertiliser used on cereals did not affect the magnitude of emitted N_2O. Thus, a method was suggested where the emissions are divided into two parts, one is dependent on fertiliser use and the other is a constant background emission. When the use of synthetic fertiliser on grass lands increased the emissions with some 0.8 % of added nitrogen an emission factor of 0.8 % was suggested for the use of synthetic fertiliser on all agricultural land. A lower value than the IPCC Good Practice Guidance default value of 1.25 % for mineral fertiliser nitrogen has also been suggested in a synthesis of literature data[120]. The background emission from mineral soils was suggested to be 0.5 kg N_2O-N/ha/year (section 6.4.4). For the use of animal manure the study concluded that there are even less data available and the emissions according to different surveys varied between 0.6 % and 8 % of added nitrogen. Using a regression model an emission factor of 2.5 % was suggested. The study also suggested country specific emission factors for background emission from organic soils and from indirect emissions of N_2O from atmospheric deposition and nitrogen leaching. These emission factors were however not adopted in the inventory as they were considered to be too unreliable. Instead IPCC default factors were used. A summary of all emission factors applied for 4.D is given i Table 6.17.

6.4.1.2.2 Emission of ammonia

The calculations of ammonia emissions from the agricultural sector are mainly built on data collected through Statistics Sweden's field investigation among farmers. The calculation methods have been developed by the Swedish EPA and Statistics Sweden in collaboration with the Swedish Board of Agriculture and the Swedish Institute of Agricultural and Environmental Engineering[121]. The calculations

[119] Klemedtsson, 2001.
[120] Lægreid and Aastveit, 2002.
[121] Swedish Environmental Protection Agency 1997

have been made by Statistics Sweden since 1990 at national and regional levels. Regional results are published from 2005 at the web-site of Statistics Sweden[122]. The results from 1990-1994 are not comparable with these from 1995-2007, due to changed questionnaire in Statistics Sweden's field investigation among farmers and updated methods for calculating the emissions.
In short the calculations are made as follows:

$$A = (V + L + S)$$
$$V = D \times N \times P \times F(v)$$
$$L = D \times N \times P \times (1 - F(v)) \times F(l)$$
$$S = D \times N \times P \times (1 - F(v)) \times (1 - F(l)) \times F(s)$$

A = emission of nitrogen in ammonia
V = emission of nitrogen through stable ventilation (depending on type of handling, type of animal and type of manure)
L = emission of nitrogen during storing (depending on type of manure, storing method and type of animal)
S = emission of nitrogen during spreading (depending on type of manure, time of spreading, method of spreading and time period between spreading and mulching)
D = number of animal[123]
N = production of nitrogen, kg, per type of animal, year and handling[124]
P = stable period[125]
F(v) = emission of nitrogen through stable ventilation, % of total nitrogen content in stable manure[126].
F(l) = emission of nitrogen during storing, % of total nitrogen content in stable manure after ventilation losses[127].
F(s) = emission of nitrogen during spreading, % of ammonium nitrogen content in stable manure after ventilation and storing losses[128].

The calculated data is differentiated by type of animal, type and handling of manure, milk production, time and method of spreading and time period between spreading and mulching. Type of manure, way of storing and time of spreading etc. are estimated from the field investigation among farmers[129]. Ventilation-, storage- and spreading-losses originate from a data calculating program (called STANK) from Swedish Board of Agriculture and from Swedish Institute of Agricultural and Environmental Engineering., Table 6.20 and Table 6.21 give an overview of the emission factors used in the calculations.

[122] Statistics Sweden 2007
[123] Swedish Board of Agriculture 2008 and other sources
[124] Swedish Board of Agriculture 1995; Swedish Board of Agriculture 2000; Swedish Board of Agriculture 2001
[125] Statistics Sweden 2008
[126] Swedish Board of Agriculture 2005
[127] Swedish Institute of Agricultural and Environmental Engineering 2002
[128] Swedish Institute of Agricultural and Environmental Engineering 2002
[129] Statistics Sweden, 2008

Table 6.19. Nitrogen losses caused by ventilation in stables, % of Total-N.

Type of animal	Solid-manure	Deep litter	Liquid manure	Semisolid manure	Urine
Cattle	4	20	4	4	4
Swine	10	25	14	10	10
Laying hens	10	35	10		
Chickens	10	20	10		
Slaughter chickens			10		
Horses	4	15			
Sheep	4	15			

Table 6.20. Nitrogen losses caused by ammonia emission during storage of manure, % of total-N.

	Type of animal					
Type of manure, handling	Cattle	Swine	Laying hens/ chickens	Slaughter chickens	Horses	Sheep
Solid manure	20	20	12		25	25
Semisolid manure	10	10				
Liquid manure, uncovered						
Filled from underneath	6	8	8			
Filled from above	7	9	9			
Liquid manure, covered						
Filled from underneath:						
roof	1	1	1			
floating crust	3	4	4			
other	2	2	2			
Filled from above:						
roof	1	1	1			
floating crust	4	5	5			
other	3	3	3			
Urine, uncovered						
Filled from underneath	37	37				
Filled from above	40	40				
Urine, with cover						
Filled from underneath:						
roof	5	5				
floating crust	17	17				
other	10	10				
Filled from above:						
roof	5	5				
floating crust	20	20				
other	12	12				
Deep litter manure	30	30	20	5		33

Table 6.21. Nitrogen losses caused by ammonia emission during spreading of manure (% of total-N).

Season/ Spreading method	Spreading strategy and tillage timing	Solid manure	Urine	Liquid manure
Early spring/late winter				
Broadcast	Spread on frozen ground	20	40	30
Trailing hoses			30	20
Spring				
Broadcast	Immediately	15	8	10
	Mulching within 4 h	33	14	15
	Mulching within 5-24 h	50	20	20
	Spread on pasture	70	35	40
	Spread on grain		11	20
Trailing hoses	Immediately		7	5
	Mulching within 4 h		14	8
	Mulching within 5-24 h		20	10
	Spread on pasture		25	30
	Spread on grain		10	15
Shallow injection	Spread on pasture		8	15
Early summer, summer				
Broadcast	Spread on pasture	90	60	70
	Spread on grain		10	20
Trailing hoses	Spread on pasture		40	50
	Spread on grain		10	7
Shallow injection	Spread on pasture		15	30
Early autumn				
Broadcast	Immediately	20	15	5
	Mulching within 4 h	35	23	18
	Mulching within 5-24 h	50	30	30
	No mulching	70	45	70
Trailing hoses	Immediately		10	3
	Mulching within 4 h		18	9
	Mulching within 5-24 h		25	15
	No mulching		30	40
Late autumn				
Broadcast	Immediately	10	10	5
	Mulching within 4 h	15	15	8
	Mulching within 5-24 h	20	20	10
	No mulching	30	25	30
Trailing hoses	Immediately		4	3
	Mulching within 4 h		11	4
	Mulching within 5-24 h		18	5
	No mulching		25	15

6.4.1.2.3 4.D.1.1 Nitrous oxide from synthetic fertilisers

Emissions from fertilisers are calculated as:

$$emissions = N_{FERT} \times (1 - Frac_{GASF}) \times EF \times 44/28$$

where N_{FERT} is the total amount of fertiliser nitrogen consumed annually, and $Frac_{GASF}$ is the fraction that volatilises as ammonia. Statistics on sales of fertilisers, recalculated into nitrogen quantities, are published annually by Statistics Sweden[118]. The estimated emissions are based on amount of nitrogen in mineral fertilisers sold in Sweden excluding the nitrogen lost as ammonia (Table 6.22). The proportion of nitrogen lost as ammonia ($Frac_{GASF}$) differs between different types of fertilisers. The values used are from the EMEP/EEA emission inventory guidebook 2009 and calculated using the mean spring temperature of 5.9 degrees centigrade (Table 6.23). In Table 6.22 the sold quantities of ammonia-emitting products are shown, which directly explains variations in the $Frac_{GASF}$ between different years.

Table 6.22. Sold quantity of ammonia emitting fertilisers and nitrogen in sludge used as fertilizers

Year	N in sold fertilisers, tonnes	Ammonium Nitrate, AXAN, N26, N27, N28, tonnes of product	N-solution, tonnes of product	Urea, tonnes of product	NPK, tonnes of N	NP, tonnes of N	NK, tonnes of N	Proportion of emitted fertiliser-N ($Frac_{GASF}$)	Sludge, tonnes of N.
1990	224 500	225 387	10 089	5 932	64 600	11 000	0	0,0084	(**) 1 180
1991	208 600	237 612	6 498	4 683	52 100	11 000	3 700	0,0082	1 180
1992	178 400	179 234	8 837	2 980	45 400	8 500	3 000	0,0083	1 180
1993	207 200	200 004	5 257	3 501	46 100	9 800	3 300	0,0083	1 180
1994	216 400	167 150	7 820	3 061	55 900	12 300	3 000	0,0087	(**) 1 433
1995	198 300	182 486	11 193	1 955	51 050	13 451	2 912	0,0089	(*) 2 304
1996	192 300	158 613	5 949	1 474	48 000	14 000	2 500	0,0078	2 304
1997	204 600	175 558	4 399	1 104	51 500	15 900	2 300	0,0076	2 304
1998	205 600	209 463	2 631	889	53 723	14 286	2 033	0,0076	(*) 2 027
1999	179 200	166 077	3 111	745	50 092	14 619	1 746	0,0079	2 027
2000	189 400	205 869	3 772	655	51 600	11 400	2 200	0,0075	(*) 1 758
2001	196 900	235 495	2 036	553	54 000	11 300	3 000	0,0075	1 171
2002	174 400	189 709	638	446	49 800	9 900	2 000	0,0078	593
2003	180 100	238 828	1 083	382	53 900	10 600	2 200	0,0077	692
2004	176 800	240 553	4 928	475	54 500	11 900	1 800	0,0083	796
2005	161 500	273 036	3 364	519	59 000	8 400	1 600	0,0092	1 053
2006	160 300	267 754	3 164	225	57 800	8 500	1 800	0,0091	1 322
2007	167 100	285 064	0	271	61 100	5 300	2 000	0,0087	1 322
2008	186 500	360 415	13	235	71 029	3 931	1 805	0,0091	2 481
2009	(***)142 400	298 882	67	1 088	43 600	2 000	1 100	0,0094	2 205

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. (***) The decrease in 2009 is due to an overconsumption in 2008 due to a dropped tax on fertilisers

Table 6.23. Fraction of nitrogen for different fertiliser types that is lost as ammonia

Fertiliser	Lost as ammonia (% of N)
Ammonium Nitrate, AXAN, N26, N27, N28	0.9
N-solution	6.3
Urea	12.7
NPK	0.9
NP	1.4
NK	0.9
Sludge	30

6.4.1.2.4 4.D.1.2 Nitrous oxide from animal manure applied to soils

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 6.3.2) and a national estimation of ammonia-N emissions. The formula is:

$$emissions = \sum_T N_T \times Nex_T \times \left(365 - GrazPeriod_T\right)/365 \times \left(1 - Frac_{GASM}\right) \times EF \times 44/28$$

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 emitted as ammonia-N (Table 6.24) is estimated by Statistics Sweden and the Swedish EPA[130]. The estimates are model-based and take into account many factors that influence gas emissions (see 6.4.1.2.2).

Table 6.24. Ammonia-N emissions from manure, fraction.

	1995	1997	1999	2001	2003	2005	2007	2008	2009
Stable manure (FracGASM)	0.33	0.33	0.33	0.33	0,33	0,32	0,33	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	0,08

Statistics Sweden, MI 37-series.

6.4.1.2.5 4.D.1.3 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 regional differences, in combination with the Good Practice Guidance’s default emission factor for direct N_2O emissions. The formula is stated:

[130] Statistics Sweden, MI 37-series.

$$emissions = \sum_{crop,county} Area_{crop,county} \times NfixingAmount_{crop,county} \times EF \times 44/28,$$

The total production of the respective crops is given by multiplying the cultivated area, according to the Farm Register, by standard yield. The reason for using standard yields instead of actual yields in the calculations is that the time series becomes more consistent and not drastically effected by stochastic events like extreme weather conditions. 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[131] (Table 6.29 and Table 6.30).

Areas are given in Table 6.26, Table 6.27 and

Table 6.28. To estimate nitrogen fixation from the atmosphere, a model according to Høgh-Jensen has been used since submission 2006[132]. The model covers fixation from root and stubble as well as transmission to other plants. It has been adapted to account for Swedish conditions[133] 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.

6.4.1.2.6 4.D.1.4 N_2O from crop residue

For the estimation of N_2O from crop residues we also use standard yields instead of actual yields in the calculations. 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 data on crop residues builds on a one-time study from 1997[134] on how straw and tops from different crops are used. The formula used for the calculations is:

$$emission = \sum_{crop} yield_{crop} \times area_{crop} \times Fracresidues_{crop} \times FracN_{crop} (1 - Fracresiduesremoved_{crop}) \times EF \times 44/28,$$

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 field survey[135] from 1997. 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[136]. For other crops, a combination of

131 Statistics Sweden, 2002e.
132 Høgh-Jensen et al. 2004.
133 Frankow-Lindberg, 2005.
134 Statistics Sweden, 1999.
135 Statistics Sweden, 1999.
136 Mattson, 2005.

national factors and IPCC default values was used[137]. All factors used for calculating N input with crop residues are given in Table 6.25. Areas of different crops used in the calculations are stated in Table 6.26, Table 6.27 and

Table 6.28. Standard yield[138] of different crops used in the calculations is presented in Table 6.29 and Table 6.30.

Table 6.25. 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.

[137] Swedish EPA/SMED 2005.
[138] Statistics Sweden, 2002e.

Table 6.26. 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
2009	326 838	48 297	36 633	18 278	351 878	196 038	17 050	53 571

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

Year	Sugar beets	Winter rape	Spring rape	Winter turnip rape	Spring tur-nip 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
2009	39 782	67 841	29 245	282	2 150	19 706	7 252

Table 6.28. Areas of different crops used in the calculations (hectares).

Year	Tempo-rary grass (*)	Tem-porary grass for seed	Green forage	Pasture ground (**)	Peas incl fodder	Peas for conser-vation	Brown beans	Total area arable land	Total area of temporary grass (*****) ha
1990	727 590	10 753	39 698	190 503	32 742	(****) -	(****) -	3 101 869	778 000
1991	696 069	10 418	33 509	239 818	23 327	(****) -	(****) -	3 092 540	740 000
1992	708 384	8 791	2 896	292 825	14 059	(****) -	(****) -	3 084 534	720 000
1993	748 094	7 863	23 137	314 458	8 720	(****) -	(****) -	3 074 808	779 000
1994	757 000	8 241	23 000	314 666	6 598	(****) -	(****) -	3 070 576	788 000
1995	766 776	7 907	23 695	276 927	11 959	8 578	709	3 065 187	798 000
1996	750 085	7 854	22 268	247 369	17 713	8 821	690	3 059 681	780 000
1997	746 832	8 470	24 443	234 677	32 742	9 028	921	3 055 174	780 000
1998	742 068	9 013	21 935	221 418	49 150	8 524	938	3 045 413	773 000
1999	760 227	8 165	21 867	198 091	30 053	8 752	872	3 030 249	790 000
2000	760 227	8 465	21 867	198 091	27 892	8 525	835	3 025 039	791 000
2001	750 200	10 300	26 400	179 400	29 928	8 862	756	3 017 489	787 000(***)
2002	759 419	12 439	32 387	181 604	31 959	8 909	717	3 009 091	804 245
2003	769 200	12 306	31 748	164 100	28 942	9 121	767	3 006 774	813 254
2004	770 412	12 329	35 715	164 359	33 116	9 318	767	2 997 541	818 456
2005	803 920	12 847	39 628	192 670	31 285	8 874	707	2 978 088	856 395
2006	816 400	15 151	42 463	206 270	26 180	8 954	646	3 023 206	874 014
2007	831 390	14 276	46 482	190 400	19 198	8 824	535	2 968 662	892 148
2008	870 740	14 260	44 619	183 380	17 414	7 343	498	2 894 604	929 619
2009	888 800	13 969	54 442	178 210	24 705	8 791	521	3 148 693	957 211

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 6.29. 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
2009	6 210	4 804	5 626	4 266	3 967	3 292	5 044	51 703	3 300	2 184

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

Table 6.30. 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
2009	1 755	1 479	29 470	36 985	4 807	5 000

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

6.4.1.2.7 4.D.1.5 Background emissions of N_2O from cultivation of organic soils

The background emissions from organic soils vary with different crops[139]. They are considered to be higher from ploughed soils than from pasture or temporary grass lands[140] 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[141]. The area of organic soils has only been estimated intermittently. The latest survey in 2009 concluded that approximately 5 % of the total area of arable land consists of organic soils[142]. That fraction has then been used for all years, assuming that the area of organic soils relative the total area of arable land stays constant over time.

6.4.1.2.8 4.D.1.6 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. This emission was included for the first time in the inventory for submission 2006. The activity data used is given in Table 6.22. Out of the total amount of nitrogen emitted, 70 % is assumed to emanate from direct emissions and 30 % from indirect emissions. The emission factor used for the direct emissions is 1.25 % of the nitrogen in the sewage sludge. The corresponding value for the indirect emissions is 1 %. The IPCC Guidelines' default factor for ammonia emissions from fertilisers is used to differentiate between direct and indirect emissions. Statistics on the use of sludge have been collected intermittently by Statistics Sweden and the Swedish EPA from sewage treatment plants (Table 6.22). The emissions are calculated as:

$$emissions = \sum_i F_{Ri} \times N_{SEWAGESLUDGE} \times EF_i \times 44/28,$$

F_{Ri} is the fraction of N emitted as direct/indirect emissions and EF_i is the corresponding emission factor. The direct emissions from sewage sludge have been reported as an optional category in the CRF and the indirect emission is reported under CRF category 4.D.3.1.

6.4.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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 agri-

139 Klemedtsson, 2001.
140 Klemedtsson, 2001.
141 Klemedtsson et al., 1999.
142 Berglund, Berglund & Sohlenius, 2009

culture and Statistics Sweden[143]. 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[143]. The estimated nitrogen content in sold products has for most years been somewhat higher. 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.

Statistics on the use of sewage sludge have been published irregularly and in different reports, but a time series has been created through interpolation/extrapolation and certain assumptions. The quality of data has increased over time and data for the latest years is of satisfactory quality.

6.4.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Category-specific improvements will be decided after the finalization of the submission 2012 as part of the national QA/QC plan.

6.4.1.5 SOURCE-SPECIFIC RECALCULATIONS

Fractions of nitrogen in synthetic fertilisers that is lost as ammonia is updated with new values from the EMEP/EEA emission inventory guidebook 2009 (see 6.4.1.2.3)

To harmonise the activity data between manure and synthetic fertilisers, data for fertiliser in the CRF table 4.D.1.1 is now also given as applied amount instead of gross amount (i.e. amount of N in ammonia is subtracted). Has no effect on the emission estimate.

The area of histosoils is updated with new values from Berglund et al.2009. The time series for area of organic soils is now also estimated as a constant fraction of total agricultural area, as opposed to earlier when the actual area was kept constant. This should more accurately describe the development of area of organic soils which is likely to co vary with to total area of agricultural land in Sweden.

Amount of sewage sludge used as fertiliser is updated with new values for 2008.

6.4.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission 2012 as part of the national QA/QC plan.

143 Statistics Sweden, MI 30-series.

6.4.2 Pasture, Range and Paddock Manure (CRF 4.D.2)

6.4.2.1 SOURCE CATEGORY DESCRIPTION

N_2O emissions from nitrogen excreted during grazing. Calculations are carried out according to the methodology in the IPCC Guidelines. Nitrogen lost as ammonia is considered as well and builds on national estimates of ammonia emissions from grazing manure. 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 6.31.

Table 6.31. Summary of source category description for the entire category CRF 4.D.2.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
4.D.2	N_2O	X	X		CS, T1	CS, D	Yes

6.4.2.2 METHODOLOGICAL ISSUES

For N_2O emissions from N excreted on permanent pastures the default emission factor of 2 % N_2O-N/kg nitrogen excreted is used for all animal groups. This is probably an overestimation of the emission when the nitrogen lost as N_2O is likely to be lower in cold climates as in Sweden. However, very scarce information is available and until better empiric data is available the IPCC default EF will be used. The emissions are calculated as:

$$emissions = \sum_T N_T \times Nex_T \times GrazPeriod_T / 365 \times (1 - Frac_{GASG}) \times EF$$

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 ammonia-N emissions (fraction) and EF is the emission factor. The nitrogen production for the different animal groups is presented in Table 6.13 and Table 6.15.

6.4.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The time-series is consistent.

6.4.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source specific QA/QC procedures have been performed.

6.4.2.5 SOURCE-SPECIFIC RECALCULATIONS

The reindeer population has been updated with new data for 2008.

After recommendation from the ERT the emission factor for nitrous oxide from pasture range and paddock is changed to 2% for all animal groups.

6.4.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission 2012 as part of the national QA/QC plan.

6.4.3 Indirect Emissions (CRF 4.D.3)

6.4.3.1 SOURCE CATEGORY DESCRIPTION

Includes indirect emissions from soils. In generally 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. However, values for losses of nitrogen as ammonia (see 6.4.1.2.2) and nitrogen leakage are national. 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 6.32.

Table 6.32. Summary of source category description for the entire category CRF 4.D.3.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
4.D.3	N_2O	X			CS, T1a	CS, D	Yes

6.4.3.2 METHODOLOGICAL ISSUES

6.4.3.2.1 4.D.3.1 Atmospheric deposition

The formula for estimating the emissions is:

$$emissions = \left(N_{fert} \times Frac_{GASF} + N \times Nex \times Frac_{GASM} + N \times Nex \times Frac_{GASG} \right) \times EF \times 44/28,$$

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.

6.4.3.2.2 4.D.3.2 Nitrogen Leaching and Run-off

The national estimate of nitrogen leaching is estimated by the SLU and calculated from the SOILNDB model[144], which is a part of the SOIL/SOILN model[144]. This simulation model was developed during the 1980s in order to describe nitrogen

[144] Johnsson, 1990; Swedish EPA, 2002.

processes in agricultural soils[145]. Since then the model has been elaborated and tested on data from controlled leaching experiments, and these tests show that the model estimates leaching from soil with good precision[146]. 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:

$$emissions = area \times leachfactor \times EF \times 44/28$$

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 0.3, which is close to the IPCC Guidelines' default value of FracLEACH (0.3).

6.4.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The average nitrogen leaching from agricultural soils, the leach factor, was estimated to 27 kg N/ha in 1994 and used for 1990-1997. The factor was then updated with new data in 1999 to the value 23 kg N/ha[146] which 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 impact on nitrogen leaching into account. Since statistics on the use of fertilisers and manure are produced every other year,[147] the estimates can be updated at most every second year. However, due to economic reasons, the data has been published intermittently.

6.4.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source specific QA/QC procedures have been performed.

6.4.3.5 SOURCE-SPECIFIC RECALCULATIONS

The total area of agricultural land has changed for all years. As a consequence of the method used by SLU for calculating agricultural land the estimates of the five most recent years change for every new submission (see 7.2.2.1). For this submission there has also been a change for earlier years due to an updated method for calculation area of histosols.

[145] Johnsson et al., 1987.
[146] Swedish EPA, 2002b.
[147] Statistics Sweden, NA 30-series; Statistics Sweden, MI 30-series.

6.4.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission 2012 as part of the national QA/QC plan.

6.4.4 Other (CRF 4.D.4)

6.4.4.1 SOURCE CATEGORY DESCRIPTION

Under CRF 4.D.4 Sweden report a background emission from agricultural soils. 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 6.33.

Table 6.33. Summary of source category description for the entire category CRF 4.D.4.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
4.D.4	N_2O	x	x		T1	CS	Yes

6.4.4.2 METHODOLOGICAL ISSUES

Based on a study of national emission factors[148], a background emission from the cultivation of mineral soils have been included with the national emission factor of 0.5 kg N_2O-N ha-1. The total area of mineral soils is calculated as total area of arable land minus the area of organic soils.

6.4.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The estimated emission is strongly dependent on estimated total area of agricultural land. This classification is performed by the Swedish National Forest Inventory (NFI[149]). In total the sample consists of approximately 30 000 sample plots. However, only one fifth are investigated yearly. As a consequence of this the accuracy will increase retroactively until the whole five year cycle is completed. That is, the estimate for the last year will only be based on 6 000 sample plots. Then the accuracy gradually increases until the whole five year cycle is completed. That is, the number of sample plots for two, three, four and five years old data is 12 000, 18 000, 24 000 and 30 000, respectively.

6.4.4.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source specific QA/QC procedures have been performed.

6.4.4.5 SOURCE-SPECIFIC RECALCULATIONS

Values for area of total agricultural land and organic soil are updated.

[148] Klemedtsson, 2001.
[149] Ranneby et al., 1987

6.4.4.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission 2011 as part of the national QA/QC plan.

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

7.1 Overview of LULUCF

Sweden reports carbon stock changes and greenhouse gas emissions from Forest land, Cropland, Grassland and Settlements and associated land-use transfers[150]. 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 2009 the net removal from the LULUCF-sector was estimated to ca 40 M ton CO_2, which should be compared to a net emission from all other sectors of 63M ton CO_2. The net removal increased from 2008 to 2009 by ca 10 M ton CO_2, originating from changes in the net removal in living biomass and in soil organic carbon. The increase in net removal in living biomass was mainly due to a decrease in harvest rates but also sampling randomness may influence on the results. Changes in the soil organic carbon pool was caused by sampling randomness and a new calculation method for mineral soils on Forest land and on recalculations of the Cropland area on organic soils.

The gross removal originating from tree growth in Sweden shows an increasing trend and lies currently around 120 M m3sk (approx. 160 M ton CO_2 per year). The harvest is also increasing but the annual fluctuations are large. In 2009 the gross harvest was approximately 80 M m3sk.

Since Submission 2010 Sweden reports data and supplementary information for the Kyoto Protocol including emission/removals for activities under article 3.3 (Afforestation, Reforestation and Deforestation) and for Forest management under article 3.4. In 2009 afforestation, reforestation and deforestation together constituted a source of 2,5 M ton CO_2 and Forest management represented a removal of 43 M ton CO_2. The supplementary information required for the reporting under the Kyoto Protocol is found in the NIR part II (Chapter 11).

Forest is the major land-use category in Sweden. The total forest area (FAO definition) is about 28.3 million hectares. 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 million hectares[151]. Harvest of trees is more or less restricted to

[150] Sweden uses random sampling methodology to estimate land-use and land-use transfers. The reporting is based on 30 000 permanent sample plots inventoried by the Swedish National Inventory of Forests (RIS). The permanent sample plots have been re-inventoried at intervals of 5-10 years and the land-use of each is described from the year of the first inventory and every year thereafter. The land-use of years between inventories has been interpolated. This means that a full record of plots comprise 30 000 plots whereas the latest reported year is only represented by 6 000 plots. Therefore, estimates of the five most recent years are re-calculated in each submission. Both the current and the re-calculated reporting of these years will be unbiased. However, the accuracy will be better in the latter case.

[151] Swedish University of Agricultural Sciences, 2009

productive forests and the unrestricted productive forest 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 peaking at 2005 (due to wind throws originating from a severe storm), while the growth rate only increased moderately. However, harvest statistics indicate an on average high demand of forest products in recent years with quite large fluctuations between years. It should be noted that from the base year and onwards, the reported growth is larger than the drain – defined as harvest and self mortality. As a consequence of the changes mentioned above, the increase in the stock or the forest carbon sink has declined in Sweden. This trend might change from 2009.

The land use and land-use change matrix (Table 7.1) is based on about 6000 (1990-2009) and 30000 sample plots (1990-2005), respectively[152]. Due to a five-year inventory cycle we can only provide a full record of data 1990-2005. Forest land is the most important land-use category. The gross and net conversions indicate that conversions from Forest land to Settlements are frequent.

Table 7.1a[153] Land Use Categories 1990, 2009 and gross and net land use transfers 1990-2009 (based on about 6000 permanent sample plots inventoried 1983-2009). The carbon stock of Forest land in the mountain area[154] (915 000 ha) is not monitored in the field and changes in the carbon pools for this area are not reported.

Area [1000 ha]	"From" Year 1990	"To" Year 2009 Forest Land	Crop-Land	Grass-Land	Wet-land	Settle-ments	Other Land
Forest land	29141	28633	5	23	123	206	151
Cropland	3301	115	3064	52	2	67	0
Grassland	407	35	66	277	3	16	10
Wetlands	6850	439	0	0	6289	0	121
Settlements	1451	63	13	0	0	1367	8
Other land	4100	103	0	0	67	0	3930
Sum after transfers		29388	3149	352	6485	1655	4220

[152] The reason for reporting two land use matrixes is mainly because it is mandatory to report a land use matrix 1990-2009 and because the accuracy increases when using a full record of sample plots.
[153] Table 7.1a is put together based on a request from the ERT in the centralized review (Subm 2009).
[154] Löfgren, 1998

Table 7.1b Land Use Categories 1990, 2005 and gross and net land use transfers[155] 1990-2005 (based on about 30 000 permanent sample plots inventoried 1983-2005).

Area [1000 ha]	"From" Year 1990	"To" Year 2005 Forest Land	Crop-Land	Grass-Land	Wet-land	Settle-ments	Other Land
Forest land	28251	27984	3	18	59	152	34
Cropland	3100	83	2912	38	3	65	0
Grassland	505	41	44	397	3	13	6
Wetlands	7226	108	0	3	7015	8	92
Settlements	1705	64	19	5	7	1596	14
Other land	4371	20	0	2	29	0	4320
Sum after transfers		28300	2978	463	7116	1834	4467

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.

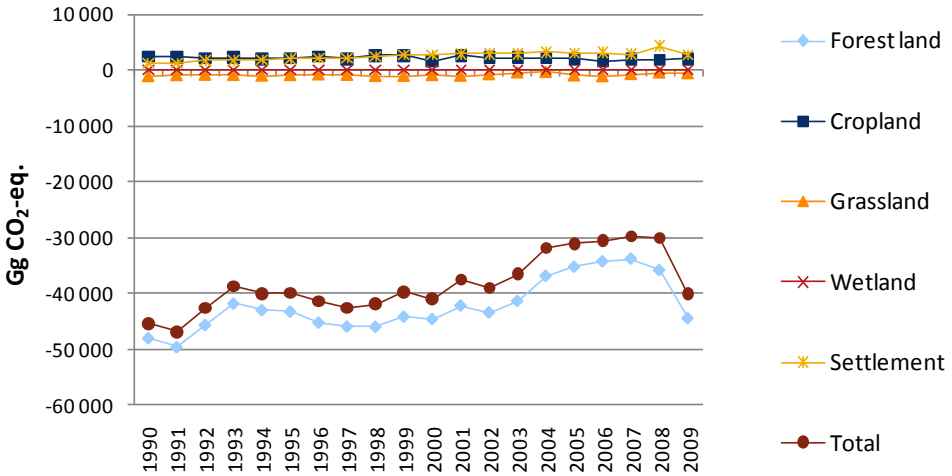

Figure 7.1. Uptake/emissons of GHG in the LULUCF sector from different land-use categories and total net removals

Both the dead organic matter pool and the soil organic carbon pool have been net sinks during the reported period. 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 ca 20 % (approx. 1 M ha) of the Histosols can be assumed to be drained. The Cropland area on Histosols is estimated to approx. 145 kha (2008) and all of that area is drained. The area is decreasing since the total Cropland area (the average trend) in Sweden is decreasing. There has been considerable variation between submissions for specific years in the soil organic carbon. These variations are partly caused by random variation in the sample. Since the

[155] The carbon stock of Forest land in the mountain area (915 000 ha) is not monitored in the field and changes in the carbon pools for this area are not reported.

total pool is huge and the changes in the pool comparatively small the numbers 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. The variation between years within the submission has been reduced after introduction of a new method for extrapolation of data on plot basis. Variation between submissions may still be substantial. We expect that this variation will decrease with time when more plots are re-inventoried.

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 1990-2009. 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.

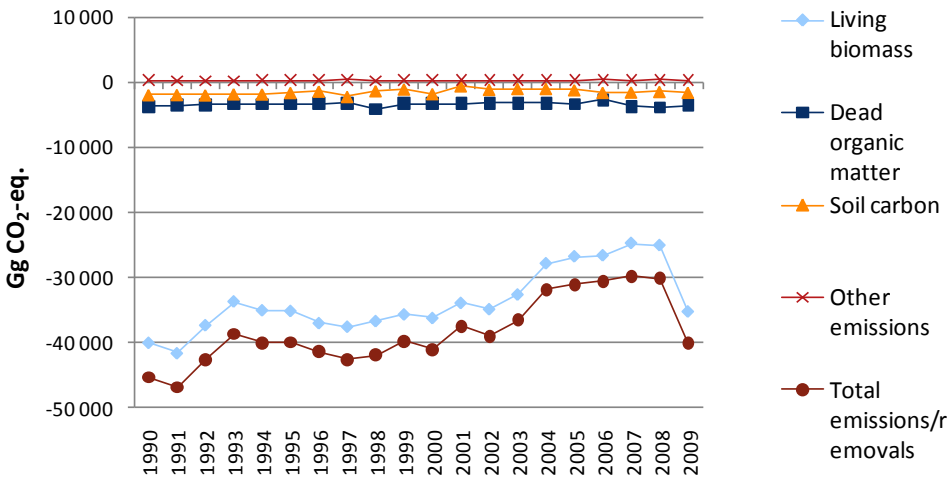

Figure 7.2. Uptake/emissons of GHG in the LULUCF sector from different carbon pools.

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. Due to methodological reasons, the random variation of estimates increses for the most recenet years (e.g. LB for Settlements in 2008).

7.2 a	Carbon pool changes (minus=removal) [M ton CO_2]															
	Forest land				Cropland				Grassland				Wet-land	Settlement		
Year	LB	DOM	SOC Min.	SOC Org.	LB	DOM	SOC Min.	SOC Org.	LB	DOM	SOC Min.	SOC Org.	SOC	LB	DOM	SOC
1990	-39.6	-3.6	-13.9	9.0	0.1	0.0	0.1	2.1	-0.6	-0.4	-0.4	0.3	0.0	0.0	0.3	0.9
1991	-41.1	-3.6	-14.0	9.0	-0.1	0.0	0.2	2.1	-0.4	-0.4	-0.4	0.3	0.0	-0.1	0.4	0.9
1992	-37.1	-3.5	-14.1	9.0	-0.1	0.0	0.1	2.1	-0.3	-0.4	-0.4	0.3	0.0	0.2	0.5	1.1
1993	-33.3	-3.5	-14.1	9.0	-0.1	0.0	0.1	2.1	-0.3	-0.4	-0.4	0.3	0.0	0.0	0.5	1.2
1994	-34.5	-3.6	-14.1	9.0	-0.1	0.0	-0.1	2.0	-0.5	-0.4	-0.4	0.3	0.0	-0.1	0.6	1.4
1995	-34.6	-3.7	-14.1	9.0	-0.2	0.0	0.1	2.0	-0.4	-0.4	-0.4	0.3	0.0	0.0	0.6	1.5
1996	-36.5	-3.6	-14.2	9.1	-0.1	0.0	0.3	2.1	-0.3	-0.4	-0.4	0.3	0.0	-0.1	0.7	1.5
1997	-36.9	-3.5	-14.7	9.1	-0.1	0.0	-0.1	2.0	-0.4	-0.4	-0.4	0.3	0.0	-0.2	0.7	1.6
1998	-36.0	-4.5	-14.6	9.2	-0.1	0.0	0.5	2.1	-0.6	-0.4	-0.3	0.3	0.0	0.0	0.7	1.7
1999	-35.2	-3.7	-14.6	9.2	-0.1	0.0	0.5	2.1	-0.7	-0.4	-0.3	0.3	0.1	0.2	0.8	1.7
2000	-35.5	-3.8	-14.6	9.3	-0.4	0.0	-0.2	2.0	-0.5	-0.3	-0.4	0.3	0.1	0.1	0.8	1.9
2001	-33.1	-3.8	-14.6	9.3	-0.3	0.0	0.7	2.1	-0.6	-0.3	-0.4	0.3	0.1	0.1	0.9	2.0
2002	-34.3	-3.9	-14.6	9.3	-0.2	0.0	0.1	2.0	-0.3	-0.3	-0.4	0.3	0.1	-0.1	0.9	2.1
2003	-32.3	-3.9	-14.7	9.4	-0.2	0.0	0.2	2.0	0.0	-0.3	-0.4	0.3	0.1	-0.2	0.9	2.2
2004	-27.8	-3.9	-14.7	9.4	-0.4	0.0	0.3	2.0	0.1	-0.3	-0.4	0.3	0.0	0.2	0.9	2.1
2005	-26.1	-4.0	-14.7	9.4	-0.3	0.0	0.1	2.0	-0.6	-0.3	-0.4	0.3	0.1	0.1	0.9	2.1
2006	-25.8	-3.3	-14.8	9.4	-0.4	0.0	-0.2	2.0	-0.8	-0.3	-0.3	0.3	0.0	0.2	0.9	2.1
2007	-24.2	-4.3	-14.9	9.4	-0.4	0.0	0.1	2.0	-0.4	-0.3	-0.3	0.3	0.1	0.2	0.8	1.9
2008	-26.0	-4.6	-15.0	9.5	-0.4	0.0	0.1	1.9	-0.1	-0.3	-0.3	0.2	0.1	1.3	0.9	2.1
2009	-34.4	-4.1	-15.5	9.7	-0.5	0.0	0.2	2.1	-0.3	-0.2	-0.3	0.2	0.1	-0.1	1.0	1.9

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	-3,7	-1,9	1.9E-04	7.0E-05	0.17	0.02	5.6E-07	8.2E-05	-45.4
1991	-41,6	-3,6	-1,9	1.1E-04	8.8E-05	0.13	0.02	5.3E-07	7.6E-05	-47.0
1992	-37,4	-3,5	-2,0	7.6E-05	9.2E-05	0.11	0.02	5.3E-07	7.7E-05	-42.7
1993	-33,7	-3,4	-1,8	6.7E-05	1.1E-04	0.13	0.02	5.5E-07	8.0E-05	-38.8
1994	-35,1	-3,4	-1,8	5.9E-05	1.3E-04	0.16	0.02	5.3E-07	7.6E-05	-40.1
1995	-35,2	-3,4	-1,6	6.9E-05	1.4E-04	0.17	0.02	5.3E-07	7.7E-05	-40.0
1996	-37,1	-3,3	-1,4	6.2E-05	1.4E-04	0.19	0.02	5.6E-07	8.2E-05	-41.5
1997	-37,6	-3,2	-2,2	4.9E-05	1.6E-04	0.17	0.10	2.9E-06	4.2E-04	-42.7
1998	-36,7	-4,1	-1,3	5.0E-05	1.6E-04	0.13	0.01	1.5E-07	2.2E-05	-42.0
1999	-35,7	-3,3	-1,0	6.5E-05	1.6E-04	0.16	0.03	9.7E-07	1.4E-04	-39.8
2000	-36,3	-3,3	-1,8	6.4E-05	1.8E-04	0.16	0.03	9.7E-07	1.4E-04	-41.1
2001	-34,0	-3,3	-0,6	5.4E-05	1.9E-04	0.14	0.03	9.9E-07	1.4E-04	-37.6
2002	-34,9	-3,3	-1,1	3.7E-05	2.0E-04	0.13	0.05	1.6E-06	2.3E-04	-39.0
2003	-32,7	-3,2	-1,0	4.4E-05	2.2E-04	0.13	0.07	2.0E-06	2.9E-04	-36.6
2004	-27,9	-3,3	-1,0	5.5E-05	2.2E-04	0.12	0.06	1.8E-06	2.6E-04	-31.9
2005	-26,9	-3,4	-1,2	8.2E-05	2.3E-04	0.12	0.05	1.6E-06	2.4E-04	-31.2
2006	-26,7	-2,7	-1,6	8.8E-05	2.5E-04	0.09	0.13	4.0E-06	5.8E-04	-30.7
2007	-24,8	-3,7	-1,5	1.2E-04	2.4E-04	0.12	0.03	7.9E-07	1.1E-04	-29.8
2008	-25,2	-3,9	-1,4	1.6E-04	2.5E-04	0.10	0.14	4.3E-06	6.3E-04	-30.2
2009	-35,3	-3,6	-1,6	1.5E-04	2.7E-04	0.10	0.03	8.6E-07	1.3E-04	-40.2

7.2 Description of categories 5A, 5B, 5C, 5D, 5E and 5F

7.2.1 Characteristics of categories

A summary of the key categories under the LULUCF-sector is found in Table 7.3. For reporting of all carbon pools and CRF-tables 5A, 5B, 5C and 5E, Sweden uses methodology Tier 3 and country specific emissions factors. Land under 5D (except a small area used for peat extraction) 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 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

7.2.2.1 THE SWEDISH NATIONAL INVENTORY OF FORESTS

The Swedish National Inventory of Forests (RIS[156]) consists of the Swedish National Forest Inventory (NFI[157]) and The Swedish Forest Soil Inventory (MI[158]).

[156] Swedish University of Agricultural Sciences, 2005

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 7.3 and 7.4). 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.

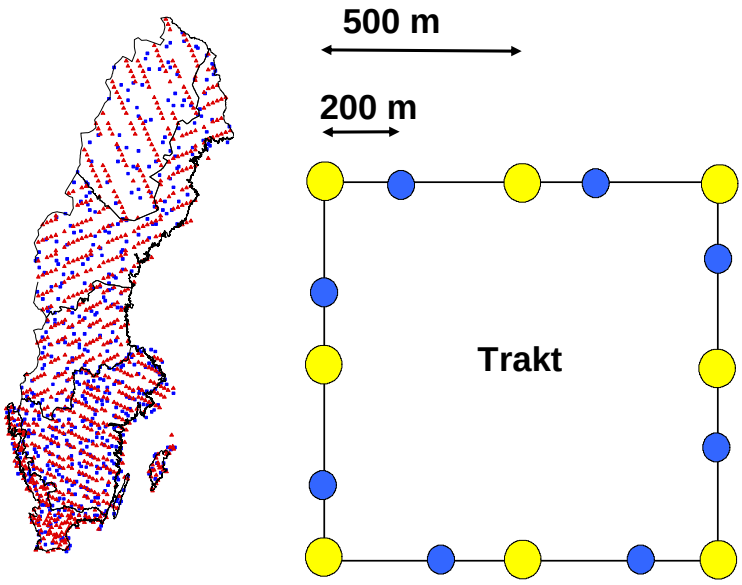

Figure 7.3 Covering whole Sweden, each year a permanent sample grid (red) is re-inventoried and a temporary sample grid (blue) is inventoried. To be able to trace both gross and net land use transfers, only permanent sample plots are used in the reporting. When estimating changes of e.g. C, the accuracy 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).

[157] Ranneby et al., 1987
[158] Swedish University of Agricultural Sciences, http://www-markinventeringen.slu.se/

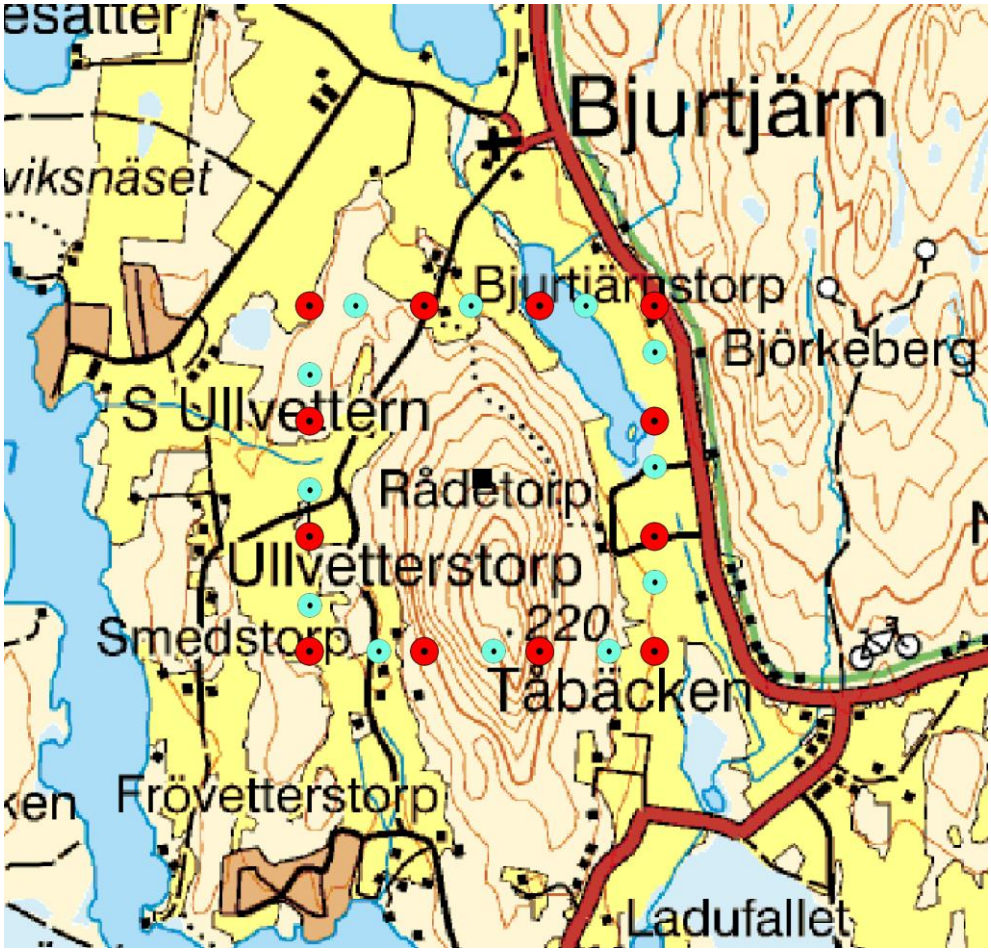

Figure 7.4 The sample plots (red) are covering all relevant land use. On this example map, plots are located on e.g. Forest land, Cropland, Wetlands and some plots are divided into more than one land use category. On the plots, measurements are made to estimate standing biomass of trees. If at the next 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. An additional sample (blue) is used for estimates of harvests.

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[159] and soil samples are taken at fixed depths.

[159] http://biosoil.jrc.it/

7.2.2.2 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[160]. Finally the reported value on national level is estimated as the sum of the county values (For further information, see Annex 3.2).

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.

7.2.2.3 THE LULUCF-REPORTING DATABASE

The reporting database is based on permanent sample plots inventoried by RIS. In total, around 40000 permanent sample plots were laid out during the period 1983-1987 covering the whole country. Thus all land and fresh-water areas are monitored. The permanent sample plots have been re-inventoried at intervals of 5-10 years. The land-use of each plot (or sub-plot for plots divided in two or more land use classes) is described from the year of the first inventory and every year thereafter. The land-use of years between inventories has been interpolated (see Table A.3.2.1 in Annex 3:2).

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 number of sample plots has been reduced by about 25 % to about 30 000.

All data for all plots are assumed to be correct and absolute for the reporting years 1990-2005. Due to the five-year inventory cycle, estimates of the five most recent years in each submission will be re-calculated. 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.

7.2.2.4 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

[160] Thompson, 1992

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 Table 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 7.2.3.1, 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.

7.2.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories

Sweden has defined Forest land according to the Global Forest Resources Assessment (FAO/FRA) 2005[161]. Forest land is land with a tree crown cover (or equivalent stocking level) of more than 10 percent at maturity, 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.

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 2009			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	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

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

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[162]).

7.2.3.1 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 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.

[162] Ranneby et al., 1987

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	

7.2.3.2 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 7.2.3.1) 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.

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

7.2.4.1 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[163]. 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.

7.2.4.2 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 "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 7.4.7).

[163] Swedish University of Agricultural Sciences, 2004

7.2.4.3 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[164]. 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.

7.2.5 Emissions of N2O, CO2 and CH4, CRF 5(I), 5(II), 5(III), 5(IV) and 5(V)

7.2.5.1 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[165]. Since then, the annual fertilized area has decreased to about 20 000 ha in 1997-2004. In 2009, this area had increased to about 55 000 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).

7.2.5.2 N_2O EMISSION FROM DRAINAGE OF SOILS, CRF 5(II)

According to UNFCCC (decision 13/CP.9), reporting emissions of nitrous oxide from drainage (N_2O-direct $N_{drainage}$) is optional. One reason for that is the limited understanding of the processes controlling the emissions. No N_2O emissions from drainage of soils will be reported this year, but some preliminary studies indicate that reliable methods may be available in a few years.

7.2.5.3 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 5 000 ha and the area converted

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

from Grassland to Cropland about 60 000 ha. The area of other land-use conversions to Cropland is negligible.

7.2.5.4 CARBON FROM AGRICULTURAL LIME APPLICATION, CRF 5(IV)

Lime is used for soil improvement in both agriculture and horticulture to mitigate acidification that is caused by the export of biomass, acidifying fertilizers and acid rain. The reported figures are based on quantities sold for agricultural and horticultural purposes plus lime from sugar mills and steel production. The quantities are separated into dolomite ($CaMg(CO_3)_2$) and limestone ($CaCO_3$), where dolomite and Mg-lime are reported as dolomite and all other categories are reported as limestone. All categories are supposed to contain 100 % dolomite/limestone except residual lime from sugar production which is assumed to contain 65 % limestone due to a water content of approximately 35 %. The accuracy of estimates of the sold quantities is assumed to be high and constitutes Official Statistics of Sweden[166]. Separate default IPCC emission factors are used for limestone and dolomite, respectively.

7.2.5.5 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[167] 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. In recent years, an area of approximately 1000-3000 ha is annually burned after clear cutting and 300-2000 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 burned areas is based on estimates of above-ground 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 numbers 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.

[166] Statistics Sweden, 2004
[167] Swedish Rescue Services Agency, 2004

7.3 Methodological issues

7.3.1 CRF-tables 5A, 5B, 5C, 5D, 5E and 5F

7.3.1.1 BASE METHODOLOGY

Sweden reports emission/removals from carbon pools mainly according to the IPCC stock change method (figure 7.5). The stock change method is combined with a sample-based inventory design which makes it possible to estimate errors of the estimates. The Swedish National Inventory of Forests (RIS[168]) has monitored the most relevant carbon pools since 1983. A particular advantage with the Swedish NFI is that it has been undertaken using permanent sample plots, on all land use categories, which makes it possible to monitor both gross and net land-use conversions for the six land-use categories in a consistent and transparent manner (for further details, see Annex 3:2).

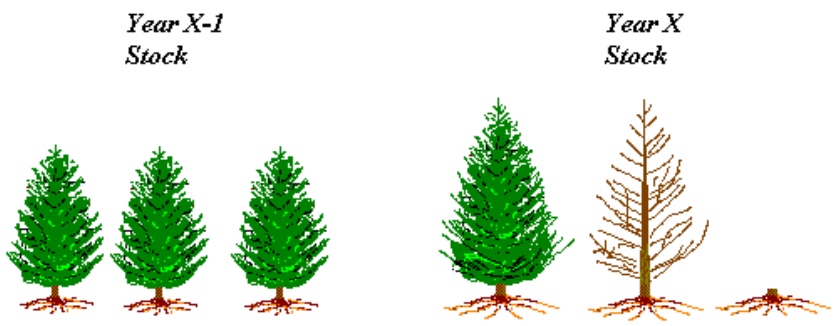

Figure 7.5 For year X, the net emissions/removals are reported as the difference in stock between year X and X-1 (The stock change method)

7.3.1.2 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[169] biomass functions to calliper and sample trees on permanent sample plots of the NFI[170]. The below-ground biomass is estimated by using Peterssons and Ståhl's[171] biomass functions on biomass data from the same trees as for the aboveground biomass. The conversion factor 0.49 is used to convert biomass to carbon[172]. 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

[168] Swedish University of Agricultural Sciences, 2005
[169] Marklund, 1987 and 1988
[170] Ranneby et al., 1987
[171] Petersson and Ståhl, 2006
[172] National Board of Forestry, 2000

1999. Since the estimates are based on representative allometric single tree regression functions or on direct measurements, a low risk of bias is assumed.

7.3.1.3 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 (dead wood, litter and the organic soil horizon) that are estimated slightly differently.

The inventory of dead wood began in 1994 for northern Sweden and from 1995 for the whole country. 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 2011.

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 , see Annex 3:2).

7.3.1.4 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 on 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[173] is used to predict changes in the soil organic carbon stock on mineral soils and an estimation of the subsidence to calculate the change on organic soils.

7.3.1.4.1 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 3:2).

[173] Andrén & Kätterer, 2001

7.3.1.4.2 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 3:2).

7.3.1.4.3 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[174]. 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[175](for further details see Annex 3:2).

7.3.1.4.4 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 were estimated in a national survey[176] Compared to earlier estlmated and reported areas the area is now essentially smaller (for further details see Annex 3:2). 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[177] (for further details see Annex 3:2).

7.3.1.5 METHODOLOGY FOR DEAD ORGANIC MATTER AND SOIL ORGANIC CARBON FOR CONVERSION BETWEEN LAND-USE CLASSES CRF-TABLES 5A.2.1-5, 5B.2.1-5, 5C.2.1-5, 5D.2.1-5, 5E.2.1-5 AND 5F.2.1-5 CROPLAND ON ORGANIC SOILS CRF 5B

The method to estimate the emission/removals in the DOM – and the SOC pools associated with land use changes is a Tier 2 method. In general (except for dead wood and coarse litter) the carbon stock changes associated with conversion of lands is estimated using an emission/removal factor is used in combination with the areal change in land-use for further details see Annex 3:2).

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[174] Andrén & Kätterer, 2001.
[175] Eriksson 1997,1999
[176] Berglund and Berglund, 2009
[177] In previous submissions a small discrepancy in the area of organic soils reported for cropland remaining cropland in the LULUCF sector and the area of cultivated organic soils reported in the agriculture sector was detected (ERT, centralised review Subm 2009). In this submission the consistency has been improved and areas have been estimated as described in the text.

7.3.1.6 CO2 EMISSION FROM MINERALIZATION WHEN EXTRACTING PEAT CRF 5D

The method used to estimate CO_2 emission from peat extraction areas is a Tier 1 approach. A limited area of Wetlands (10000 ha) used for peat extraction is considered managed and reported under Wetlands remaining Wetlands. The reported CO_2 emissions refer to mineralization when extracting peat for fuel and agricultural purposes. The emitted CO_2 [M ton•yr^{1}] is calculated as the product of the extracted area and an emission factor (for further details see Annex 3:2).

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 (for further details see Annex 3:2).

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[178]. 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 3:2).

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[179]) (for further details see Annex 3:2).

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[180] and all liming is assumed to occur on Cropland remaining Cropland. The reported annual carbon emission from

[178] ERT (centralized review submission 2009) recommended Sweden to report emissions from organic and mineral soils separately. The methodology is based on the total retailed amount and there is no appropriate statistics available on where the fertilizer is applied.
[179] Intergovernmental Panel on Climate Change, 2003
[180] Statistics Sweden, 2004

agricultural lime application (C_{lime}; [Gg•yr^{-1}]) is calculated as the product of the applied lime and the emission factors (see Annex 3:2 for further details).

7.3.2.5 EMISSIONS FROM BIOMASS BURNING, CRF 5(V)

A Tier 1 methodology and IPCC default emission factors are used. All land categories are monitored but the reported emission is assumed to occur only on Forest land remaining Forest land and on Grassland remaining Grassland. Calculations are based on the amount of biomass per area, burned area and emission factors (for further details see Annex 3:2).

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[181].

[181] Intergovernmental Panel on Climate Change, 2003

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 36 %. 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	-35276	-	-	30	-	-
Dead organic matter	-3588	-	-	70	-	-
Soil organic carbon	-1559	-		35	-	-
Direct N fertilization, 5 (I)	-	0.147	-	-	50	-
Drainage of soils, 5 (II)	-	NE	-	-	NE	-
Conversion Cropland, 5 (III)	-	0.265	-	-	100	-
Agricultural lime application, 5 (IV)	104	-	-	50	-	-
Biomass burning, 5 (V)	29	0.001	0.125	50	75	75
All	-40290	0.413	0.125	35	86	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 1990-2005 are based on approximately 30000 sample plots and with a corresponding estimated relative standard error of 15% (or 3 M ton CO_2-equivalents). Estimates for reporting years 2006, 2007, 2008 and 2009 are based on approximately 24000, 18000, 12000 and 6000 sample plots, respectively. Consequently, the relative sample error increases from 2006 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 (see Annex 3:2 for further details).

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 7.5. 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 2009. 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 a few ‰ 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.

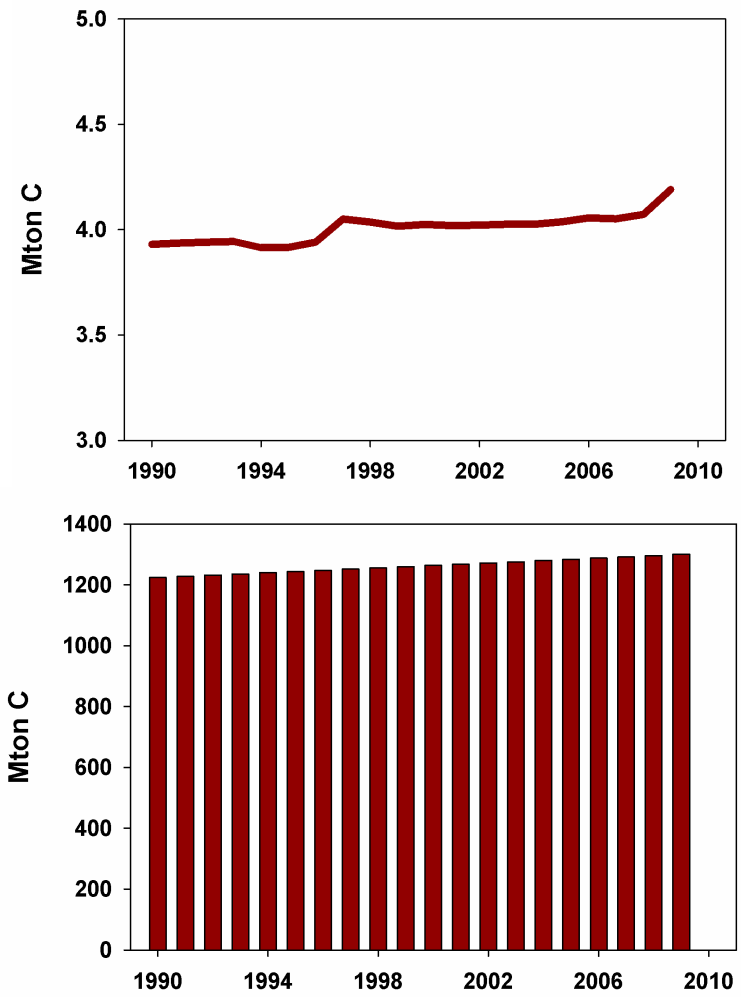

Figure 7.6 The reported change in soil carbon (upper panel) and the stock (lower panel) for Forest remaing Forest in the current submission.

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[182], and ii) the underlying data of the EF does not perfectly match the target population[183,184].

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[185].

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 N2O and CH4 emissions, CRF 5(I), 5(III) and 5(V)

Generally for all N_2O and CH_4 emissions, the error in activity data is small compared to the error due to 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 %

[182] Statistics Sweden, 2002
[183] Kasimir-Klemedtsson et al., 2000
[184] Sund et al., 2000
[185] Intergovernmental Panel on Climate Change, 2003

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. Due to newly published research[186] Sweden has the possibility to report the pool of below-ground dead stump systems in a more accurate way. However it has not yet been possible to fully implement the methods in the annual reporting. The cuttings have gradually increased since 1990[187], 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 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

[186] Petersson and Melin, 2010
[187] National Board of Forestry, 2004

changes with respect to the rate of change between the models and the measurements[188].

7.5 QA/QC

7.5.1 Quality assurance

The quality assurance system of the data collection within RIS used for the UNFCCC and Kyoto reporting has been described by the Swedish University of Agricultural Sciences[189] and a detailed description of routines is under development. These routines were improved during 2006 cooperating with SLU. SLU also works closely with the Swedish EPA to enhance the QA/QC. For this submission, quality assurance has been carried out in an internal review by experts at SLU. A 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 2005-2009 to improve accuracy and each estimate are now based on 6000 more sample plots. The consequence of this re-calculation is an increased 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 effect of this annual recalculation is illustrated in figure 7.7.

The pools dead organic matter and soil organic carbon on mineral soils on Forest land remaining forest land and Grassland-remaining-Grassland have been recalculated for the whole time series from 1990 to 2009 due to introduction of more re-inventoried sample plots and a new approach for interpolation and extrapolation of inventory data. The method is described in Annex 3:2.

188 Ortiz C. et. al. 2009.
189 Karltun, E. et. al.. 2005.

Recalculations of Cropland-remaining-Cropland have also been made in connection to new data on the area of organic soils under cultivation. This resulted in a reduction of the emission from these soils.

Recalculations occur also for non-carbon pools, but these re-calculations are very small and have no practical influence on the accounting. Due to recalculated estimates of areas, emissions from disturbance associated with land use conversion to Cropland (5III) have been updated. Some rounding errors have been corrected (general for both carbon and non-carbon pools).

The recaclulations are summarized in Table 7.6.

Table 7.6. Recalculations of GHG emission/removals between submission 2010 and submission 2011 in the LULUCF-sector.

Recalculation differences, submission 2010-2011 (Gg CO_2 eq.)							
CRF	5A	5B	5C	5D	5E	Total CRF 5	% CRF 5
1990	-12259	-1723	-451	0	66	-14366	46
1991	-11982	-1646	-427	0	65	-13990	42
1992	-10950	-1728	-374	0	62	-12989	44
1993	-10149	-1632	-397	0	54	-12124	46
1994	-14093	-1809	-428	0	54	-16276	68
1995	-14304	-1740	-312	0	63	-16293	69
1996	-10535	-1523	-153	0	63	-12148	41
1997	-6224	-2146	-247	0	63	-8555	25
1998	-3401	-1532	-314	0	65	-5182	14
1999	-2215	-1471	-572	0	82	-4175	12
2000	-2300	-2258	-515	0	113	-4960	14
2001	-2242	-1267	-559	0	113	-3955	12
2002	-2242	-1978	-551	0	110	-4661	14
2003	-2498	-818	-621	0	117	-3821	12
2004	-4515	-828	-766	0	63	-6045	23
2005	-9279	-900	-906	0	224	-10861	54
2006	-11254	-1368	-1036	0	-27	-13685	81
2007	-13331	-1070	-976	0	373	-15004	101
2008	-15069	-1105	-565	0	1254	-15484	106

0 equals value less than 0.5.

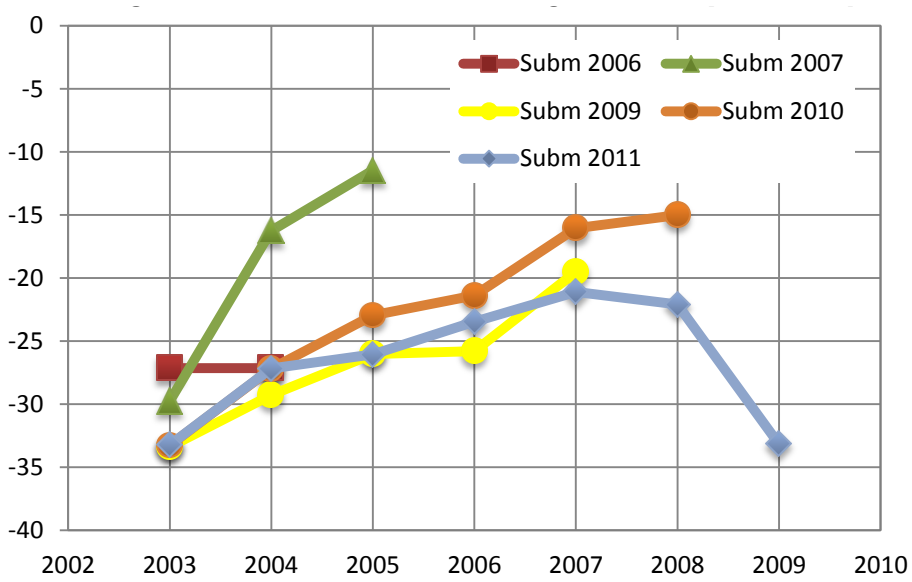

Figure 7.7 Reported living biomass on Forest land remaining forest land (5A1) according to different submissions. The values(the five latest reported years) are continuously re-calculated.

7.7 Coming improvements

7.7.1 New pools and planned improvements

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. In the past, the below-ground dead wood pool has resulted in a net removal of approximately 7 Mton CO_2 per year[190].

Methodologies for reporting small trees (<99 mm stem diameter measured 1.3 m above the ground) will be improved. The reason is to improve models and obtain a better matching of carbon pool changes to correct reporting year. An unpublished pilot study about small trees indicates a re-calculated average net removal of around 3 Mton CO_2 per year (the current reported average net removal is around 7 Mton CO_2 per year).

Methodologies for reporting dead wood will be improved and also here the reason is a better matching of carbon pool changes to correct reporting year.

7.7.2 Informal reporting of HWP

Sweden does not officially report emissions/removals from Harvested Wood Products (HWP). However, to advance the knowledge on the influence of HWP on the reporting and accounting of LULUCF we would like to provide information on

[190] Petersson and Melin, 2010

estimations of 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 where the biomass originates 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[191] (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 approach 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 1990-2009 (Table 7.7). Underlying data have been changed by the FAO since last year and this is the reason for small differences between submission 2010 and 2011 .

Table 7.7 Estimated annual net emissions/removals from Harvested Wood Products using the Production approach. Underlying data are based on figures originating from FAO for years 1961-2009. A Tier 1 methodology is used (IPCC, 2006). The figures are not included in the official reporting.

HWP, PA, [M ton CO_2]									
90	91	92	93	94	95	96	97	98	99
-2,6	-0,5	-0,6	-1,8	-2,0	-2,7	-2,6	-3,1	-2,0	-1,2
00	01	02	03	04	05	06	07	08	09
-2,6	-2,3	-2,5	-2,9	-3,0	-5,1	-4,5	-5,5	-3,4	-1,4

[191] IPCC 2006

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, CRF 6A. Minor categories are the subcategories of wastewater handling, CRF 6B, from where N_2O and CH_4 are reported. Emissions of CO_2, NO_X, SO_2 and NMVOC are reported from waste incineration, CRF 6C. No emissions are reported in CRF 6D.

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 2009 with 6 %.

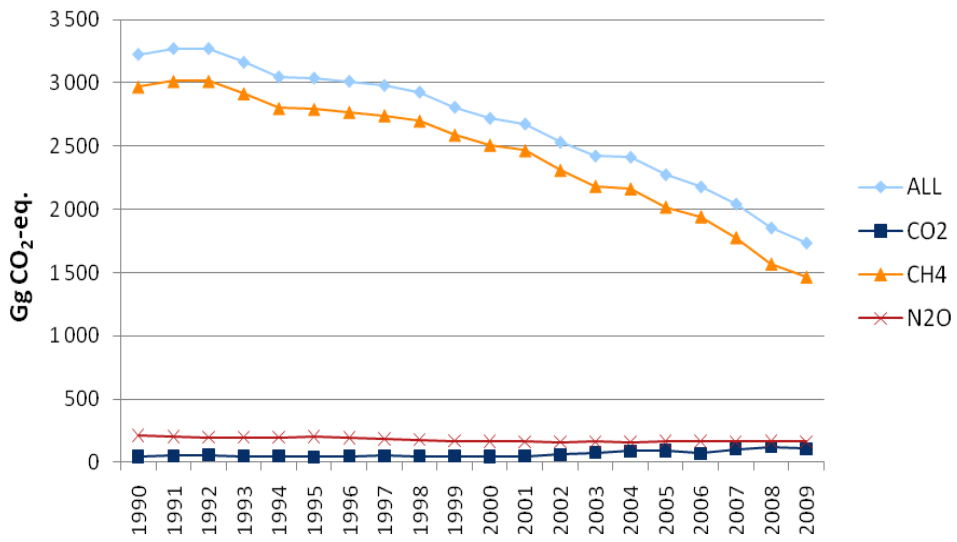

Figure 8.1. Total emissions of all greenhouse gases calculated as CO_2 equivalents from CRF 6 Waste.

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 89 % and 77 % of totally reported greenhouse gases 1990 – 2009.

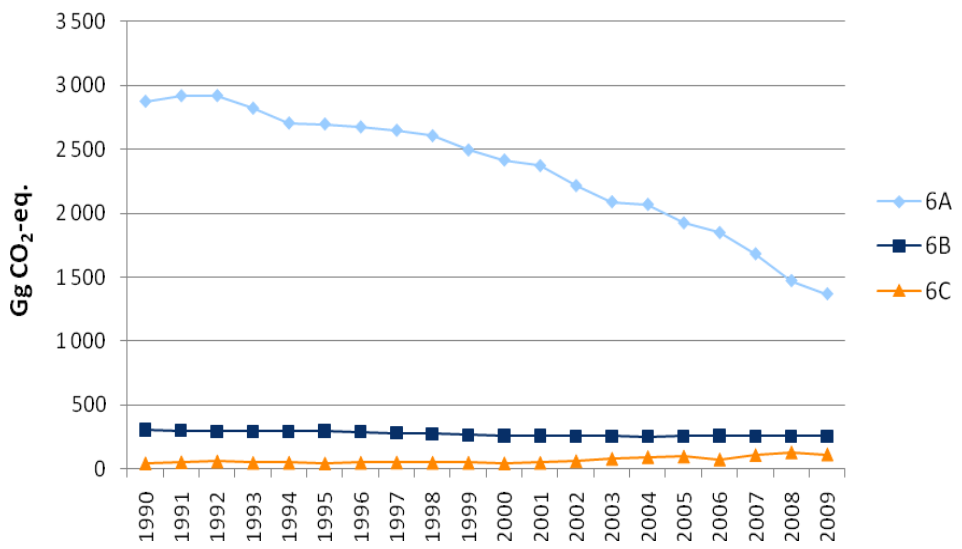

Figure 8.2. Total emissions of all greenhouse gases calculated as CO_2 equivalents from the different Waste sub-sectors.

Table 8.1 shows the recalculation differences for the GHG emissions by sub-sector as well as for the total level in the sector reported in submission 2011 compared to data reported in submission 2010.

Table 8.1. Recalculations of GHG emissions between submission 2011 and submission 2010 in the waste sector.

Recalculation differences, submission 2011/2010 (Gg CO_2 eq.)					
CRF	**6A**	**6B**	**6C**	**Total CRF 6**	**% CRF 6**
1990		95		95	3.0%
1991		95		95	3.0%
1992		95		95	3.0%
1993		95		95	3.1%
1994		95		95	3.2%
1995		95		95	3.2%
1996		96		96	3.3%
1997		96		96	3.3%
1998		97		97	3.4%
1999		97		97	3.6%
2000		98		98	3.7%
2001		99		99	3.8%
2002		99		99	4.1%
2003		99		99	4.3%
2004		100		100	4.3%
2005		100		100	4.6%
2006	2	100		102	4.9%
2007	5	100		106	5.5%
2008	5	13		18	1.0%

8.2 Solid waste disposal on land (CRF 6.A)

Waste management in Sweden has been developed considerably over the past twenty 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 waste treatment methods. There has been a comprehensive extension of the treatment capacity of Swedish incineration plants for household waste (with energy recovery) and development of waste management practices other than solid waste disposal on land (landfilling).

Since Sweden is a country with a developed mining and quarryíng industry, mining waste is by far the most dominating single waste category in generation of waste and landfilling. In 2008, 93.2 % of the landfilled waste (or 59.1 Mt of 63.4 Mt) was mining waste.

In the 1990s, the amount of deposited waste (other than mining waste) decreased significantly. This is especially notable for household waste (in Sweden also referred as "Municipal waste"), which is the largest contributor of greenhouse gases of all waste categories. Only 1.4 % of the generated household waste was deposited in 2009 which can be compared with 43.8 % in 1990. The remaining part of the generated household waste in 2009 was either incinerated (48.4 %), recycled (35.4 %) or treated biologically (13.8 %).

Depositing has become an expensive waste management solution for disposal of waste. Since January 1st 2000, there is taxation on depositing, currently 435 SEK[192] per ton of waste liable to taxation. Another important change is the implementation of the national prohibitions on the landfilling of burnable and organic wastes in the 9-10 §§ of the Landfill Ordinance (2001:512). The landfilling of burnable wastes has been prohibited since 2002, and in 2005 the ban was extended to organic wastes. These prohibitions are regulated in more detail through regulation NFS 2004:4 from the Swedish EPA.

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 decreased 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. The number of active landfills for municipal waste was 85 in 2009.

In 2009, landfill gas was extracted at 57 landfills[193] whereof 36 were active landfills. According to a survey[194], the production of biogas in Sweden in 2008 was totally 1 359 GWh (or 97.5 Gg in methane). 27 % of the produced biogas was produced at landfills. The biogas production on landfills decreased by 19.5 % from 2004 to 2009 since the amounts of deposited organic waste has decreased significantly the past years, due to the implementation of waste treatment policies.

[192] SFS 1999:673
[193] Avfall Sverige / Swedish Waste Management 2010
[194] Swedish Energy Agency, 2010

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 13 % of the biogas produced at landfills was flared in 2009.

Sweden is reporting emissions of methane for CRF 6A1 (managed waste disposal sites). The responsibility for landfills to have a permission or to report the landfill to the authorities, has been regulated in Sweden since 1969.

For CRF 6A2 (unmanaged waste disposal sites), Sweden is reporting NO (not occurring), since there are no known unmanaged disposal sites for organic waste or municipal solid waste in use[195]. Sweden has some problems related to unmanaged waste: *littering.* This occurs in particular around recycling stations. Other kinds of littering of organic waste that are occurring in Sweden are the disposal of smaller amounts of garden waste from households in the nature or that residuals from animals are disposed of where they are hunted. When littering is discovered however, the clean-up is to be performed or paid for by the operator responsible. If the responsible operator can not be found, the relevant municipality has a responsibility to perform the clean-up of the site.

8.2.1 Managed waste disposal on land (CRF 6.A.1)

8.2.1.1 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), is presented in Table 8.2.

Table 8.2. Summary of source category description, CRF 6A1.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
6A1	CO_2				NA	NA	NA
	CH_4	X	X		T2	CS	Yes
	N_2O				NA	NA	NA

CS Country Specific. T2 Tier 2.

8.2.1.2 METHODOLOGICAL ISSUES

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.

[195] Nygren, 2010

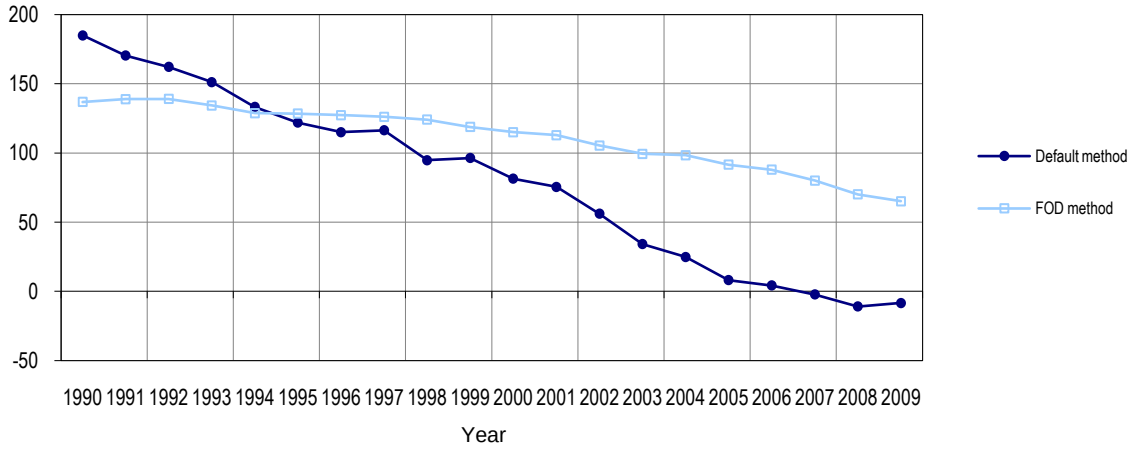

Figure 8.3 Emission of methane from Swedish landfills 1990-2009, estimated by the two IPCC methodologies, (Gg CH_4.)

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 2009 is negative (-8.4 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 8.3, the estimates from the FOD model and the deposited amount of municipal solid waste (MSW) are presented.

Table 8.3 Methane emission from Swedish landfills according to IPCC Default and FOD methods. Deposited MSW*, sludges and total (excl. mining waste), 1990-2005

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 (excl. mining waste)** in 1000 tonnes
1990	185	137	2 323	1 400	5 563
1991	170	139	2 223	1 262	5 161
1992	162	139	2 203	1 174	4 977
1993	151	134	2 199	1 086	4 824
1994	133	129	2 166	860	4 547
1995	122	128	1 974	850	4 330
1996	115	127	1 856	880	4 145
1997	116	126	1 842	975	4 203
1998	95	124	1 678	700	3 868
1999	96	119	1 756	620	3 853
2000	81	115	1 529	587	3 720
2001	76	113	1 488	514	3 488
2002	56	105	1 338	341	3 006
2003	34	99	1 034	223	2 688
2004	25	98	810	113	2 380
2005	8	92	541	58	2 067

* 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.

Table 8.4 Methane emission from Swedish landfills according to IPCC Default and FOD methods, deposited solid waste (containing Degradable Organic Carbon), sludges (containing DOC) and total (incl. mining waste), 2006-2009

Year	Gas emissions Default method Gg CH_4	Gas emissions FOD method Gg CH_4	Deposited solid waste (containing DOC)* in 1000 tonnes	Deposited industrial effluent sludges and common sludge* in 1000 tonnes	Total deposited waste (excl. mining waste)* in 1000 tonnes	Total deposited mining waste* in 1000 tonnes
2006	4	88	1 250	180	4 143	61 820
2007	-2	80	994	144	4 260	60 450
2008	-11	70	739	108	4 376	59 080
2009	-8	65	739	108	4 376	59 080

* Activity data and statistics for 2006 and 2008 are from Swedens reporting to the Commission according to the Waste Statistic Regulation. Activity data for 2007 and 2009 are interpolated/extrapolated values.

8.2.1.2.1 National application to IPCC First Order Decay (FOD)

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[196] 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 2009.

8.2.1.2.1.1 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.[197] The gas potential of the sludge is reduced by 50 % because it is treated.[198] 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.[199] Gas potentials in waste from the food industry are presented in section 8.2.1.

8.2.1.2.1.2 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 2008, about 58 gas plants are in operation, and the amount of re-

[196] Statistics Sweden, 2005
[197] Recounted from RVF, 1996.
[198] Sweco Viak, 2000.
[199] Swedish EPA, 1993.

covered gas is now 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 8.5).

Table 8.5 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 [6]
2008	26 979 [6]
2009	24 240 [6]

1) No gas recovery. 2) 1st plants started. 3) Swedish EPA/RVF. 4) RVF, 1996c. 5) RVF, 1997-2006. 6) Avfall Sverige (Swedish Waste Management), 2007-2010

The table below shows quantities of produced energy from landfill gas and how much that is flared in Sweden. The energy is used for production of electricity and for heating.

Table 8.6 Energy recovery and flaring at landfills in Sweden, MWh[200].

Year	2004	2005	2006	2007	2008	2009
Energy recovery	370 000	340 000	282 200	290 100	310 800	294 240
of which is used for production of electricity	25 000	20 000	20 800	22 600	23 700	17 400
Flaring	50 000	70 000	60 200	52 100	65 100	43 600
Total	**420 000**	**410 000**	**342 400**	**342 200**	**375 900**	**337 840**

[200] Avfall Sverige (Swedish Waste Management)

8.2.1.2.1.3 Other parameters

The Methane Correction Factor for modern Swedish landfills is equal to one unit (Table 8.7). 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 8.7). 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.[201] The choice of the half-life factor has also been motivated by the rather wet climate conditions in Sweden (MAP/PET>1), and that the 2006 IPCC Guidelines recommends the default value of 7 for such climate conditions.

Table 8.7 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.[202] An assumption is therefore made that before 1976, 37 % of all deposited household waste was burned.

8.2.1.2.2 WASTE STATISTICS IN SWEDEN, 1980 - 2005

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.

[201] Börjesson, 2000
[202] Swedish EPA, 1983.

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).

8.2.1.2.3 WASTE STATISTICS IN SWEDEN, 2006 AND ONWARD

The Regulation of the European Parliament and the Council No 2150/2002 of 25 November 2002 on waste statistics (hereafter referred to as “the Waste Statistics Regulation” or “WStatR”) contains rules for the reporting of waste statistics to the EU1. Reporting in accordance with the regulation is to take place every second year. Reporting shall be submitted each time 18 months after the end of the reporting period. The first round of reporting by all member states was completed by 30 June 2006 and concerned waste generation and recovery and disposal of waste during 2004. The treatment of waste is to be reported by treatment method for the different types of waste according to EWC-Stat. The method of treatment relates to various recovery and disposal operations2 (“R and D codes”) are compiled into 5 different groups. Group 4, ”Disposal operations: Land filling, deep injection, surface impoundment, permanent storage and others”, is relevant for “Solid waste disposal on land, CRF 6A”.

The Swedish EPA is responible for the reporting in accordance with the regulation. So far, waste data has been reported for the reference years 2004, 2006 and 2008. No waste statistics on landfilling are compiled for the intermediate years by SEPA.

In 2010, a study[203] was carried out in order to analyze possibilities to use the reported waste data to WStatR for the calculations of CH4 from solid waste landfills. The study recommended implementation of WStatR-data from reference year 2006 and onwards. The advantages of WStatR-data in relation to waste statistics for 1980-2005 are mainly that:

- WStatR-data uses more specific and better developed describtions of waste classifications.
- It is produced regularly (every second year). Therefore it is to a less extent based on extrapolations of old waste data and expert judgements. This means it is more sensitive for rapid changes in amounts of waste and DOC content.
- WStatR-data has per definition 100 % coverage (completeness).

[203] Edborg, Stenmarck, Sundquist & Szudy, 2010

Relevant waste categories (those who is containing Degradable Organic Carbon) were chosen, and the DOC content of the chosen waste categories was investigated by analyzing the statistical source material in cooperation waste experts. Interpolations and extrapolations have been made for the intermediate years.

8.2.1.2.4 WASTE CATEGORIES, 1980-2005

8.2.1.2.4.1 Household waste, sludge and garden waste

Table 8.8 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 8.8 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*

1) Swedish EPA, 1983. 2) Statistics Sweden, 1988; RVF. 3) RVF, 1988. 4) RVF, 1990. 5) Statistics Sweden, 1992. 6-16) RVF, 1996-2006.

* Included in household waste from reference year 2004. ** Estimate

The composition of household waste has been investigated in many studies over the years. Ohlsson[204] 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[205] for 1990 and 1995 are presented in Table 8.3. The composition in the years between the surveys is interpolated. It should be

[204] Ohlsson, 1998 and REFORSK, 1998
[205] Ohlsson, 1998

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.[206] 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 8.9.

Table 8.9. 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 waste treatment plants need permissions in order to deposit organic waste.

The impact of the new legislation on the DOC content of deposited household waste has not been investigated and documented, but the waste composition and DOC content of the of deposited household waste has probably changed since the analysis from 2004. Separation of organic fractions made by the households should lead to a decrease of the DOC content. The organic fractions are treated by composting and anaerobic digestion. Organic fractions (and other fractions) from the mixed waste generated by households and companies are also separated at waste treatment plants before landfilling.

8.2.1.2.4.2 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.[207] 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 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;[208] the waste groups found to generate methane in landfills are presented in Table 8.10. The most important subgroup here is sludge from the pulp industry and the other

[206] RVF, 2005
[207] Profu, 2004.
[208] Swedish EPA, 1993

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 8.10 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 8.11).

Table 8.11 Values of deposited wastewater sludge from the pulp industry, wet weight.

Year	Quantity 1000 tonnes/year
1990	500[1]
1994	250[2]
1995	310[3]
1997	520[4]
1998	210[5]
1999	130[6]
2000	242[7]
2001	184[8]
2002	126[8]
2003	68[8]
2004	10,5[9]
2005	0[9]

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) Swedish Forest Industries Federation.

A study on organic industry-specific waste was published in 1996[209]. In accordance with the report, the deposited waste categories are presented in Table 8.12. The gas potentials were calculated by Sweco Viak.

Table 8.12 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.[210] 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.

[209] Swedish EPA, 1996
[210] Statistics Sweden, 2000

8.2.1.2.4.3 Composition of deposited waste

Table 8.13 illustrates the estimated composition of deposited waste (excl. mining waste) 1990-2005.

Table 8.13 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

8.2.1.2.5 Used statistics on deposited waste, 1952-2009

8.2.1.2.5.1 Used statistics 1952-2005

Table 8.14 - Table 8. shows the activity data 1952-2005 used in the calculations of methane emissions from solid waste disposal on land.

Table 8.14 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

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
1961	290	76%	37%	1049	62	56	260	78
1962	290	76%	37%	1056	62	56	272	80
1963	290	76%	37%	1064	62	56	280	82
1964	290	76%	37%	1072	63	56	301	83
1965	290	76%	37%	1079	63	56	316	85
1966	290	76%	37%	1088	64	56	325	87
1967	290	76%	37%	1096	64	56	330	89
1968	290	76%	37%	1105	65	56	345	90
1969	290	76%	37%	1114	65	56	349	92
1970	290	76%(*)	37%	1122	66	56	364	94
1971	290	76%	37%	1126	66	56	369	96
1972	290	76%	37%	1129	66	56	372	97
1973	290	66%	37%	984	66	56	391	99
1974	290	66%	37%	987	67	56	406	101
1975	290	66%(*)	37%(*)	990	67	56	409	103
1976	290	66%	30%	1109	67	56	452	116
1977	290	66%	22%	1229	67	56	483	131
1978	290	58%	15%	1186	67	56	517	145
1979	290	58%	7%	1292	68	56	593	162
1980			0%	1450(*)	68	56	628	177
1981				1400	68	56	632	179
1982				1300	68	56	627	182
1983				1200	68	56	551	158
1984				1100	68	56	579	161
1985				1040(*)	68	56	595	163
1986				1020(*)	68	56	602	165
1987				1050	69	56	615	168
1988				1080(*)	69	56	624	170
1989				1240	70	56	630	172
1990				1400(*)	70(*)	56	622	175
1991				1390	72	57.1	567	137
1992				1390	75	58.2	554	126
1993				1390	77	59.3	558	115
1994				1380(*)	80(*)	60.3	564	82
1995				1200(*)	60(*)	61.4	571	82
1996				1110(*)	70(*)	62.5	536	78
1997				1150(*)	50(*)	62.5	495	85
1998				1020(*)	45(*)	62.5	477	73
1999				972.5(*)	45(*)	62.5	580	96
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

(*) Taken from statistical sources. Other values are interpolated or extrapolated.

(**) Estimate. (***) Included in household waste from reference year 2004.

Table 8.15 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
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

Year	Deposited sludge from waste water treatment, 1000 tonnes	Deposited sludge from pulp industry, 1000 tonnes
2003	155(*)	68
2004	102(*)	10.5(*)
2005	58(*)	0(*)
2005	58(*)	0(*)

(*) Taken from statistical sources. Other values are interpolated or extrapolated.

8.2.1.2.5.2 Used statistics 2006-2009

Table 8.14 shows waste statistics for 2006-2009 used in the calculations of methane emissions from solid waste disposal on land. It also shows estimated DOC content for each waste category.

Table 8.16 Overview over used statistics* 2006-2009 on deposited waste and interpolated/extrapolated values, 1000 tonnes, and estimated DOC content, percent.

EWC-Stat code	Description of waste categories	2006(*)	2007	2008(*)	2009	DOC content
03.1	Chemical deposits and residues	C	C	176.946	176.946	2
03.2	Industrial effluent sludges: Dry matter	11.914	11.247	10.580	10.580	9
05.	Health care and biological wastes: Hazardous	C	C	0.004	0.004	8
05.	Health care and biological wastes	C	C	0.010	0.010	8
07.2	Paper and cardboard wastes	38.977	20.636	2.296	2.296	36
07.4	Plastic wastes	1.323	0.970	0.617	0.617	0
07.5	Wood wastes	C	C	1.840	1.840	40
07.6	Textile wastes	0.228	0.600	0.972	0.972	24
09A	Animal and vegetal wastes *(excl. 09.11 & 09.3)*	11.548	8.803	6.058	6.058	15
09.11	Animal waste of food preparation and products	0.303	0.323	0.343	0.343	15
09.3	Animal faeces, urine and manure	0.372	0.224	0.075	0.075	9
10.1	Household and similar wastes	203.821	161.904	119.986	119.986	18
10.2	Mixed and undifferentiated materials	482.743	352.592	222.442	222.442	3,1
10.3	Sorting residues	311.483	259.721	507.599	507.599	2,5
11A	Common sludges *(excl. dredging spoils)*: Dry matter	26.383	19.762	13.140	13.140	28
	Total, *wet weight*	**1 430.562**	**1 138.890**	**847.218**	**847.218**	

* Waste statistics for 2006 and 2008 are from Swedens reporting to the Commission in accordance to the Waste Statistic Regulation. Waste statistics for 2007 and 2009 are interpolated/extrapolated values.

C: Confidential

8.2.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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 applying the simple error propagation formula, a total error of estimated methane emissions of about 20 % would be achievable, in the best case, given high quality data.

According to Good Practice Guidance there is some extra uncertainty in the methane generation rate constant [-40 %, 300 %], and in the oxidation factor, if oxidation is assumed. An assessment of the confidence interval for the Swedish methane estimate from landfills would be around 50-60 % for 2005. Swedish waste statistics 2005 on household waste, in particular, are 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 time series in the waste sector are calculated consistently and in line with the Good Practice Guidance. When statistics are not produced annually, interpolation and extrapolation have been necessary tools for imputation.

8.2.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

8.2.1.4.1 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.

8.2.1.4.2 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.

8.2.1.5 SOURCE-SPECIFIC RECALCULATIONS

A new source of waste statistics, Swedens reporting to the Commission in accordance to the Waste Statistic Regulation, is used as activity data has been implemented for 2006-2009. This is described more in chapter;"Methodological issues". The implementation has resulted in minor differences on the quantities of calculated emissions of methane. In submission 2011, the emissions increased by 0.09 - 0.37 percent for 2006-2008, compared to submission 2010.

8.2.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No improvements are planned in this sector for submission 2012.

8.3 Waste water handling (CRF 6.B)

Sweden is reporting data on emissions for Industrial Wastewater, CRF 6B1 and Domestic and Commercial Wastewater, CRF 6B2.

8.3.1 Industrial, domestic and commercial wastewater (CRF 6.B.1 and CRF 6.B.2)

8.3.1.1 SOURCE CATEGORY DESCRIPTION

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.[211] In Sweden, there are approximately 1.3 million people not connected to a municipal treatment.

Considerable quantities of heat and bioenergy are recovered from sewage and wastewater.[212] Anaerobic wastewater treatment and anaerobic digestion of sludge is practised in Sweden and generates methane for production of electricity, heating, vehicle fuel and for local gas distribution networks. Some of the methane is flared.

Emissions (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. Emissions of CH_4 from sludge treatment (Industrial Wastewater, CRF 6B1b, and Domestic and Commercial Wastewater, CRF 6B2b) are reported as "Not estimated" (NE).

[211] Swedish EPA & SMED, 2003
[212] Ministry of the Environment, 2001.

Some improvements has been made for submission 2011: Emissions of CH_4 from wastewater treatment (Industrial Wastewater, CRF 6B1a, and Domestic and Commercial Wastewater, CRF 6B2a) are calculated and reported from submission 2011.

According to a survey[213] by the Swedish Energy Agency on biogas production and utilization, the production of biogas in Sweden in 2008 was 1 359 GWh (or 97.5 Gg in methane) to be compared with 1 239 GWh (or 88.9 Gg in methane) in 2005[214]. In 2008, 44 % of the produced energy from biogas was produced at wastewater treatment plants (anaerobic digestion of sludge). The biogas production at wastewater treatment plants increased by 11.6 % from 2005 to 2008. Approximately 12.7 % of the biogas produced at wastewater treatment plants was flared in 2008.

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 8.15.

Table 8.15. Summary of source category description, CRF 6B.

CRF	Gas	Key Category Assessment 2009			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.

8.3.1.2 METHODOLOGICAL ISSUES

8.3.1.2.1 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:

$$\left(N_{Industry} + N_{WastewaterTreatmentPlants} + PROTEIN * Nr_{People} * 0.16\right) * EF * 44/28$$

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

[213] Swedish Energy Agency, 2010
[214] Swedish Energy Agency, 2007

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.

8.3.1.2.1.1 Wastewater treatment statistics and activity data related to nitrous oxide emissions in Sweden

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.[215]

For industrial wastewater handling, Sweden has better data on emissions in tonnes than in cubic metres. 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 submission 2011, new[216] activity data has been introduced, since data on discharges of nitrogen from chemical industy *(inland)*, iron and steel industry *(inland)*, food manufacturing industry *(inland)*, manufacturing of wood products *(inland and coastal)* and mining and quarrying *(inland = total)* now is compiled and published in the official statistics.

The statistics on discharges of nitrogen exclude municipal wastewater treatment plants designed for fewer than 2,000 person equivalents. These were surveyed in 1999, and were found to represent about 6 % of the total discharged nitrogen, which is compensated for using a “1.1 factor” in the above formula.

The statistics also exclude 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[217] for 1995, 2000 and 2005. The mean of these data is approx. 1 264 000 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 underestima-

[215] Statistics Sweden, MI 22 SM, Swedish EPA and SMED.
[216] MI 22 SM, Swedish EPA and SMED,
[217] Statistics Sweden MI 11 SM 0701, Korrigerad version

tion, 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.

In submission 2011, the national value: 90 g/person/day (or 32.85[218] kg/person/year) has been updated since new[219] data are available. This change was made in order to follows the recommendations from ERT while reviewing submission 2010.

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' were 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.

8.3.1.2.1.2 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, manufacturing of wood products and mining and quarrying industry.

[218] National Food Administration, 2002
[219] National Food Administration / Statistics Sweden, 2007

Table 8.16 Discharges of nitrogen from mining and quarrying and manufacturing industries: Pulp and paper industry (total), Oil refineries (total), Chemical industy (inland and coastal), Iron and steel industry (inland and coastal), Food manufacturing industry (inland and coastal), Manufacturing of wood products (inland and coastal) and Mining and quarrying (total), tonnes.

Year	Pulp and paper (tot.)	Oil ref. (tot.)	Che mical (inl.)	Che mi-cal (coa st.)	Iron and steel (inl.)	Iron and steel (coa st.)	Food (inl.)	Food (coa st.)	Wood prod. (inl.)	Wood prod. (coast.)	Mining (tot.)
1990	5 500	..	..	..	..	..	..	..	..	..	..
1992	3 630	..	..	..	..	..	..	..	..	..	..
1994	3 200	..	..	..	..	..	..	..	..	..	..
1995	3 844	80	..	385	..	70	..	0	..	..	..
1997	3 433	..	..	..	..	..	..	..	..	..	..
1998	3 307	78	..	423	..	230	..	1	..	..	..
1999	3 042	..	..	..	..	..	..	..	..	..	..
2000	3 241	38	..	361	..	114	..	109	..	..	..
2001	3 014	..	..	..	..	..	..	..	..	..	..
2002	3 169	68	..	268	..	72	..	3	..	..	..
2003	3 162	..	..	..	..	..	..	..	..	..	..
2004	3 039	30	..	224	..	54	..	11	2	6	451
2005	3 222	..	..	..	..	..	..	..	..	..	..
2006	3 200	39	..	144	..	74	..	17	2	3	496
2007	2 825	..	..	..	..	..	..	..	..	..	..
2008	2 830	26	256	139	807	68	89	27	2	2	480
2009	2 600	..	..	..	..	..	..	..	..	..	..

Source: NV 4657, NV 4434, NV 4657, NV 4924, NV 4987, NV 5114, Swedish Forest Industries Federation, .MI 22 SM, Swedish EPA and SMED

8.3.1.2.1.3 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.

Table 8.17 Discharges of nitrogen from municipal wastewater treatment plants (from treatment of domestic, commercial and industrial waste water), tonnes.

Year	Municipal wastewater treatment plants
1990	26 200
1992	25 310
1994	..
1995	
1997	..
1998	21 376
1999	..
2000	18 977
2001	..
2002	18 036
2003	..
2004	17 779
2005	..
2006	18 347
2007	..
2008	18 433

Source: MI 22 SM, Swedish EPA and SMED

8.3.1.2.1.4 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, NrPeople is the number of people not connected to municipal wastewater treatment plants, and 0.16 is the fraction of nitrogen in proteins (Table 8.18).

Table 8.18. Protein consumtion in Sweden, g/person/day

Year	Protein consumtion g/person/day
1980	87
1985	86
1990	89
1995	89
2000	97
2003	101
2004	102
2005	102

Source: The Swedish yearbook of agricultural statistics 2007

8.3.1.2.2 Methane (CH_4)

8.3.1.2.2.1 Methane emissions from wastewater treatment

Sweden has previously reported NE (not estimated) for methane emissions from wastewater handling in the CRF tables.

Methane emissions from industries with internal wastewater treatment
Sweden has chosen, based on data availability, a national method for calculating CH_4 emissions from category 6.B.1. Industrial wastewater (wastewater). In Sweden 2008, there was only four (4) facilities using anaerobic wastewater treatment processes. These facilities were in the pulp industry and food industry. The majority of the facilities in Sweden are using aerobic processes, where no CH_4 is supposed to be generated because of the use of aeration in the wastewater treatment process. Data on energy recovery from anaerobic processes are available for 2008: 130 GWh[220] (or 9.3275 Gg CH_4).

According to wastewater treatment expertise[221], the loss of CH_4 in the energy recovery process should be within the range of 2 %-5 %. By using the upper value 5 % to ensure a conservative estimate the emission of CH_4 is calculated to 0.490921 Gg for 1990-2009**.**

Methane emissions from municipal wastewater treatment plants
Sweden divides calculations of the CH_4 emissions from 6.B.2. Domestic and Commercial wastewater treatment into three sections:

* Large wastewater treatment plant (treatment capacity: more than 2 000 pe)
* Small wastewater treatment plants (treatment capacity: 25 -2000 pe)
* Population not connected to wastewater discharge system

In Sweden, all large wastewater treatment plants are using aerobic processes, where no CH_4 is supposed to be generated because of the use of aeration in the wastewater treatment process.

For small wastewater treatment plants the situation is at the moment not well enough investigated, and therefore Sweden is using the IPCC Good Practice Guidance method (Page 5.15 Box 5.1 Check method). Activity data[222] on population connected to small wastewater treatment plants (700 000 people) is derived from background data in a not yet published survey of treatment methods and sewage networks for Swedish municipal waste water treatment plants 2010. By using the formula:

$WM = P \times D \times SBF \times EF \times FTA \times 365 \times 10^{-12}$ *where*

WM = Annual CH4 emission per country, from domestic wastewater (Tg)

[220] Swedish Energy Agency, 2010
[221] Ek, 2010
[222] Brånvall, 2010

P = Population of country or urban population for some developing countries (person)
D = Organic load in biochemical oxygen demand per person (g BOD/person/day), overall default = 60 g BOD/person/day
SBF = Fraction of BOD that readily settles, default = 0.5
EF = Emission factor (g CH4/g BOD), default = 0.6
FTA = Fraction of BOD in sludge that degrades anaerobically, default = 0.8

the CH_4-emissions for small waste water treatment plants for 1990-2009 are calculated to 3.6792 Gg.

Methane emissions from households not connected to municipal wastewater treatment plants

For population not connected to wastewater discharge system, there are no emissions of CH_4 from this section according to wastewater treatment expertise[223]. The reasons are:

1) The sludge in the wastewater is collected in sand filters or infiltration beds, collected and transported to anaerobic digestion plants located at larger wastewater treatment plants.
2) No generation of CH_4 will occur in the remaining wastewater, because the wastewater is too cold and too rich in oxygen. Sweden is a cold country with an average annual temperature of 4.8 (°C) 1991-2005.

8.3.1.2.2.2 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 (NE) because lack of sufficient data on a national level.

There are indications that the leakage is insignificant because of flaring. A study[224] 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.

8.3.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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.

[223] Ek, 2010
[224] Stockholm Vatten, 2004

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 in line with the Good Practice Guidance. When statistics are not produced annually, interpolation and extrapolation have been necessary tools for imputation.

8.3.1.4 SOURCE-SPECIFIC 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.

8.3.1.5 SOURCE-SPECIFIC RECALCULATIONS

For industrial wastewater handling, new activity data has been introduced. The recalculations has led to increasing emissions of N_2O (26.7 % - 52.8 %) from category Industrial wastewater, CRF 6B1a.

For municipal wastewater treatment, new activity data is available for 2008. This has led to increasing emissions of N_2O for 2007 (0.23 %) and 2008 (0.47 %).

The national value: 90 g/person/day (or 32.85 kg/person/year) for protein consumtion has been updated since new data are available. This change was made in order to follows the recommendations from ERT while reviewing submission 2010. The new data (time series) on protein consumtion has led to a slightly higher estimation of N_2O from households not connected to municipal wastewater treatment plants.

Sweden has previously reported NE (not estimated) for methane emissions from wastewater handling in the CRF tables.

- For methane emissions from industries with internal wastewater treatment Sweden has chosen, based on data availability, a national method for calculating CH_4 emissions from category Industrial wastewater, CRF 6B1a. Data on energy recovery from anaerobic processes are available for 2008: 130 GWh[225] (or 9.3275 Gg CH_4). Emissions (estimated loss) of CH_4 in the energy recovery process is calculated to 0.490921 Gg.
- Methane emissions from municipal wastewater treatment plants: For small wastewater treatment plants Sweden is using the IPCC Good Practice Guidance method (Page 5.15 Box 5.1 Check method). The CH_4-emissions for 1990-2009 are calculated to 3.6792 Gg for category Domestic and Commercial Wastewater, CRF 6B2a.

[225] Swedish Energy Agency, 2010

The methane data were reported for the year 2008 in a resubmission of submission 2010. In submission 2011, the same data were reported for the whole time series 1990-2009, and therefore changed from the previously reported notation key "NE" (with the exception of the emission year 2008).

8.3.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No improvements are planned in this sector for submission 2012.

8.4 Waste incineration (CRF 6.C)

8.4.1 Source category description

Emissions from incineration of hazardous waste, and in later years also MSW and industrial waste, from one large plant are reported in CRF 6C. Emissions from other MSW incineration plants combusting waste for energy purposes are included in CRF 1. 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 8.19.

Table 8.19. Summary of source category description, CRF 6C.

CRF	Gas	Key Category Assessment 2009			Method	EF	All sources estimated
		Level	Trend	Qualitative			
6C	CO_2		X		T3	PS	Yes
	CH_4				T2	PS	Yes
	N_2O				T2	PS	Yes

PS Plant Specific. T2 Tier 2. T3 Tier 3.

8.4.2 Methodological issues

For the whole waste category, the methodology and time series consistency are in line with the Good Practice Guidance.

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[226]. 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)[226] 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 - 2009. 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 8.20.

[226] 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 8.20. 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
2009	162	1 107 410	15.00	5.32

* = estimated volume
** = IEF for 2008 used for estimations 1990 - 2007

8.4.3 Uncertainties and time-series consistency

Table 8.21. Uncertainties for activity data, emission factor and emission data in CRF 6C.

GHG	Activity data uncertainty	Emission factor uncertainty	Emission data uncertainty	Reference
	%	%	%	
CO_2	±0	±0	±10	Expert judgement
CH_4	±0	±0	±10	Expert judgement
N_2O	±5	±100	±0	Expert judgement

In Revised 1996 IPCC Guidelines no information concerning uncertanities for CO_2, CH_4 and N_2O can be found. In 2006 IPCC Guidelines is stated that if a default value for emission factor is used the uncertainty has been estimated to be ± 100 percent or more and the uncertainty for plant specific activity data is ± 5%. In this case the activity data referred to is amount of waste incinerated. The Swedish reporting of N_2O is based on an emission factor and measured yearly amounts of flue

gas and the uncertainty for emission factor is set to ± 100% and the uncertainty for activity data is set to 5 % (Table 8.21).

In 2006 IPCC Guidelines it is not easy to find information concerning uncertainties for measured amounts of emitted CO_2 but corresponding information for measured amounts of CH_4 is likely to be in order of ± 10%. Due to lack of other information the emissions data uncertainty for CO_2 and CH_4 are set to ± 10%.

As can be seen in Table 8.20 the implied emission factor (IEF) varies slightly between 2008 and 2009. Reported emissions are based on continuous measurements and the reason for the variation between 2008 and 2009 can be explained by a variation in the composition of the incinerated waste.

8.4.4 Source-specific QA/QC and verification

No source specific procedures have been made.

8.4.5 Source-specific recalculations

No recalculations have been made.

8.4.6 Source-specific planned improvements

No improvements are planned.

9 Other

Not applicable for 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 on-going 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, 2010, together with descriptions on their implications for the emission levels, are given in the sector specific chapters.

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 all GHG in the entire time series 1990-2008. In 2007 and 2008 the recalculations are largely caused by revised activity data in the other sector CRF (1A4a, 1A4b, 1A4c) and parts of Manufacturing Industries and Construction, other (1A2f/Stationary). In addition, due to a development project, emissions from combustion of fuels in Chemical industries CRF (1A2c) have been reallocated to non-energy use of fuels (CRF 1Ad). Finally, some correction of activity data have been made and new emission factors have been applied. Better knowledge of hydrogen production plants has led to revisions of data in Fugitive emissions from Oil (CRF 1B2A1), resulting in larger emissions in this sector compared to submission 2010.

10.2.2 Industrial processes, CRF 2

In Industrial processes, CRF 2, CO_2 emission are reported for the first time in Chemical industry, other (CRF 2B5) leading to slightly increased emissions.

10.2.3 Solvents and other products use, CRF 3

In this sector, the update of the Swedish Chemicals Agency data for 2006-2008 effecting Solvents and other product use (CRF 3A and 3D) results in minor increase of GHG emissions.

10.2.4 Agriculture, CRF 4

The recalculations are made for the whole time series in Agricultural soils (CRF 4d) due to new values on areas on histosols and organic soils in CRF 4D1 and new values on the total area in CRF 4D3 and 4D4, resulting in totally a few per cent lower GHG emissions.

10.2.5 LULUCF, CRF 5

A substantial contribution to the changes in the levels of the reporting of LULUCF is that the method to compile data for Litter and Soil organic carbon on mineral soils (categories Forest land remaining forest land 5A1 and Grassland remaining grassland 5C1) has changed and also that the sample used for these calculations has increased. The reporting of soil organic carbon changes in organic cropland soils has also been improved by using a new assessment of the total area of these lands (category Cropland remaining cropland 5B1). A major part of the large differences in the total removals from 2005 and onwards is the result of the annual update of the reporting data base which results in recalculated data in the carbon pools (mainly Living biomass for all categories) from 2005 to 2008.

10.2.6 Waste, CRF 6

Using a new data source for the activity data has resulted in slightly higher emissions of methane in CRF 6A in 2006-2008. Recalculation for nitrous oxide has also been made in CRF 6B1a due to new activity data on industrial wastewater handling. The emission level increased for the whole time series.

Using new data on protein consumtion, has led to a slightly higher estimation of nitrous oxide from households not connected to municipal wastewater treatment plants.

Methane emissions from industries with internal wastewater treatment in Sweden were estimated for Industrial wastewater, CRF 6B1a, as well as methane emissions from municipal wastewater treatment plants, CRF 6B2a. By introducing these estimates for the years 1990-2007, the whole time series was changed from the previously reported notation key “NE”.

Table 10.1. Recalculations of GHG emissions between submission 2011 and submission 2010 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	-152	-0.2%	-22	0.0%	53	0.9%			-278	-2.9%	-14 366	46%	95	3.0%
1991	-152	-0.2%	-23	0.0%	56	0.9%			-280	-3.0%	-13 990	42%	95	3.0%
1992	-151	-0.2%	-24	0.0%	58	1.0%			-280	-3.0%	-12 989	44%	95	3.0%
1993	-146	-0.2%	-21	0.0%	60	1.0%			-280	-2.9%	-12 124	46%	95	3.1%
1994	-154	-0.2%	-25	0.0%	57	0.9%			-281	-2.9%	-16 276	68%	95	3.2%
1995	-166	-0.2%	-26	0.0%	49	0.7%			-283	-3.0%	-16 293	69%	95	3.2%
1996	-158	-0.2%	-27	0.0%	54	0.8%			-281	-3.0%	-12 148	41%	96	3.3%
1997	-169	-0.2%	-24	0.0%	42	0.7%			-282	-3.0%	-8 555	25%	96	3.3%
1998	-165	-0.2%	-25	0.0%	49	0.7%			-285	-3.1%	-5 182	14%	97	3.4%
1999	-163	-0.2%	-22	0.0%	49	0.7%			-287	-3.2%	-4 175	12%	97	3.6%
2000	-165	-0.2%	-24	0.0%	49	0.7%			-287	-3.2%	-4 960	14%	98	3.7%
2001	-163	-0.2%	-24	0.0%	50	0.7%			-288	-3.2%	-3 955	12%	99	3.8%
2002	-174	-0.2%	-26	-0.1%	44	0.6%	0	0	-290	-3.3%	-4 661	14%	99	4.1%
2003	-171	-0.2%	-29	-0.1%	46	0.7%	0	0	-288	-3.3%	-3 821	12%	99	4.3%
2004	-276	-0.4%	-134	-0.3%	46	0.7%	0	0	-287	-3.3%	-6 045	23%	100	4.3%
2005	-325	-0.5%	-204	-0.4%	57	0.8%			-277	-3.2%	-10 861	54%	100	4.6%
2006	-192	-0.3%	-56	-0.1%	32	0.5%	2	0	-271	-3.1%	-13 685	81%	102	4.9%
2007	-577	-0.9%	-478	-1.0%	53	0.8%	2	0	-260	-3.0%	-15 004	101%	106	5.5%
2008	-701	-1.1%	-597	-1.3%	44	0.6%	11	0	-178	-2.1%	-44 835	-306%	18	1.0%

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 2011 are about 243 Gg CO_2 equivalents higher.

Table 10.2. Difference between Assigned Amount and Base Year emissions submission 2011 by GHG, excluding LULUCF

GHG	Assigned Amount (Gg CO_2 eq.)	Base Year* emissions Submission 2011 (Gg CO_2 eq.)	Difference between Base Year emissions Submission 2011 and Assigned Amount (Gg CO_2 eq.)
CO_2	56 301.08	56 646.32	345.24
CH_4	6 719.22	6 815.61	96.38
N_2O	8 534.73	8 336.33	-198.40
F-gases	596.61	596.65	0.04
Total	72 151.65	72 394.91	243.26

*1995 for F-gases and 1990 for other GHG emissions (excluding LULUCF)

Based on submission 2011, the estimated GHG emissions in Sweden decreased by 17.4% between the base year (72,395 Gg CO_2 equivalents) and 2009 (59,784 Gg CO_2 equivalents). In Table 10.3 it can be seen that in submission 2010 the trend from the base year to 2008 shows a 11.7% decrease. It can also be seen that the recalculation of GHG emissions in submission 2011 increased the downward trend between the base year and 2008 by 550 Gg CO_2 equivalents or 0.78 % compared to submission 2010.

Table 10.3. Impact on emission trends due to recalculations of GHG emissions between submission 2011 and submission 2010 by GHG, excluding LULUCF

Trend Base Year* to 2008						
GHG	Submission 2010		Submission 2011		Difference between submission 2011 and submission 2010	
	Gg CO_2 eq.	%	Gg CO_2 eq.	%	Gg CO_2 eq.	% points
CO_2	-6 190.73	-10.93%	-6 770.13	-11.95%	-579.40	-1.02%
CH_4	-1 556.36	-23.12%	-1 621.84	-23.80%	-65.48	-0.68%
N_2O	-1 369.08	-15.91%	-1 269.14	-15.22%	97.94	0.69%
F-gases	628.58	105.35%	624.00	104.58%	-4.59	-0.77%
Total	-8 487.59	-11.70%	-9 037.11	-12.48%	-549.52	-0.78%

*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 2011 is already compiled in mid-October 2010. The preliminary result of the centralized review in 2010, taking place in September, can thus only be taken into account as minor recalculations and changes in response to the review process. In Table 10.4 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 10.5 describes the ERT recommendations for submission 2009 and earlier not yet implemented in the Swedish inventory and the reasons for that together with possible implementation plans.

Table 10.4. Recalculations and other changes made in response to the UNFCCC review process.

Review[227]	Sector	Paragraph and recommendation in report (shortened)	Actions as a result of ERT recommendations
Submission 2007/2008	General	83. Include information on the commitment period reserve.	Information is included in Annex 6.4.
Submission 2009	General	8. Provide information in CRF table 7 as presented in Annex 1 to the NIR for the purpose of completeness.	Included in submission 2011.
Submission 2009	General	19. Extend the information on its national system to include the specific responsibilities of the organizations participating in SMED and consultants who assist the Swedish EPA in the inventory preparation.	Information on the national system is revised and updated in submission 2011, see Annex 6:1

[227] FCCC/IRR/2006/SWE, FCCC/ARR/2008/SWE and FCCC/ARR/2009/SWE

Submission 2009	General	20. Total emission estimates used for the key category analysis were not the same as those reported in the NIR, CRF tables and the background tables (appendix 20B to the NIR). Perform the key category analysis correctly and report it in the next annual submission.	The key category analysis is subject to QA and QC activities before delivered to the UNFCCC but they were not fully applied in the resubmission of 2009 due to limited time.
Submission 2009	General	21. Extend its overall uncertainty analysis to include the LULUCF sector. Perform uncertainty analysis taking correlations between gases or categories into account in the next annual submission.	Uncertainty estimates for LULUCF are included in submission 2011. IPCC Tier 1 does not allow correction of correlations between activity data when used for estimating several GHG (e.g. CO2, CH4 and N2O based on fuel combustion). The activity data uncertainty is thus applied in several cells in the IPCC Table 6.1 calculations leading to underestimations of total emissions.
Submission 2009	General	28. (a) If recommendations identified during the previous review cannot be implemented, the Party should clearly explain the reasons;	Fullfilled through table 10.5
Submission 2009	General	89. Include correct information on its commitment period reserve in its next annual submission.	Correct information on the commitment period reserve is included in Annex 6:4
Submission 2009	General	90. Report any changes in its national system in accordance with section I.F of the annex to decision 15/CMP.1.	The information on the national system is revised and updated in submission 2011, see Annex 6:1
Submission 2009	General	91. Report in its next annual submission any changes in its national registry in accordance with section I.G of the annex to decision 15/CMP.1.	Appropriate information is provided in submission 2011
Submission 2006	General	12. In the NIR provided more methodological detail so that the relationship between activity data (AD), emission factors (EFs) and equivalent parameters and emission estimates was clear, and if the reasons for apparent outliers or anomalies in implied emission factors (IEFs) had been easier to understand. This would have reduced the number of questions and requests for background material during the review. The ERT recommends that the acces-	Several measures are in place to enable further review of data. E.g. IEFs are compared to IPCC defaults in CRF 2C1.2 and CRF 2F.

		sible style of the NIR be retained, but that more use be made of tabular and graphic material, and annexes to convey the methodological detail.	
submission 2007/2008	General	10. The LULUCF sector requires improved descriptions of country circumstances and the approaches to estimating emissions and removals. One area where transparency could be improved is the use of EU ETS data in the national GHG inventory, in the description of the national system.	The description of the LULUCF sector has continuously been improved since submission 2008 with information concerning the national circumstances. Information on the use of EU ETS data in the Swedish GHG inventory has continuously been improved since submission 2008. See section 3 and 4 and Annex 2 (1.1.10), Annex 6.1 and Annex 8:1. Further information will be added as needed in future submissions.
Submission 2009	General	23. Provide information on QA applied to data from EU ETS.	Information on the use of EU ETS data in the Swedish GHG inventory has continuously been improved since submission 2008. See section 3 and 4 and Annex 2 (1.1.10), Annex 6.1 and Annex 8:1. Further information will be added as needed in future submissions.
Submission 2009	General	24. Improve transparency by providing more precise and detailed explanations of methodologies, AD and EFs used as well as relevant category-specific QA/QC activities in cases Sweden uses AD from different sources for a single category, country-specific EFs, or methods that are not explicitly explained in the Revised 1996 IPCC Guidelines or the IPCC good practice guidance.	More information is included in submission 2011.
Submission 2009	General	28 (d) The implementation of QA/QC procedures needs to be improved to avoid calculation errors and inconsistency between the CRF tables and the NIR;	Sweden's internal handling plan for deliverables between contracting agency SMED and Swedish EPA have been revised in order to enable more time for internal QA/QC routines. Further efforts will be continously made in future submissions in order to improve QA/QC procedures. Improvements will be reported in coming NIRs.

Submission 2009	General	88. In the SIAR enhance the availability of the required public information mentioned above and ensure that rejected transactions are terminated, and should report, in its next annual submission, on these two identified issues.	See complete response in Annex 6.3
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 estimated (NE) in Sweden (see NIR 3.3.2). 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 in CRF 2B5 all years (see NIR 4.3.4)
Submission 2006	Energy	24. Institutionalize system-level checks to minimize the risk of missing plants or data in its future submissions.	The emissions from stationary combustion are calculated with activity data from a sample survey (thoroughly described in Annex 2). SMED internal QC procedures are in place to minimize error in compilation and data handling. The procedures will be continously improved also in future submission.
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 4.4.1)

submission 2006	Energy	34. Improve explanations on fluctuating trend for fugitive emissions of refinery gas in Petroleum refining	Text in NIR section 3.3.2 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 3.2.15
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.
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 requested.
Submission 2009	Energy	32. Report emissions from some categories were reported as “NE”, such as CO2, CH4 and N2O from venting of oil and gas and flaring of gas for all years.	Emissions from venting are considered to be included in other subsectors in 1.B.2 (see section 3.3.2.2). Flaring of natural gas is probably not occurring, but if occurring, it is included in flaring of oil.
Submission 2009	Energy	44. Clearly describe recalculations for off road vehicles and machinery made with the logic for making the revisions in the NIR in its next annual submission.	In submission 2011 there are no recalculations on this category. All recalculations made in other categories are clearly described in the NIR and in the CRF.
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 4.4.1)
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 4.2.1.

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 4.5.1
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 4.2.3
Submission 2009	Industrial processes	46. Correct the discrepancy between figures in CRF and NIR.	Figures are correctly reported in submission 2011 as better SMED internal QC procedures are in place to minimize discrepancy between figures in CRF and NIR.
Submission 2009	Industrial processes	49. Complete the planned revision of methods and explain the new methods for pulp and paper industry in a transparent manner in the next annual submission.	Addressed in submission 2010, see NIR section 4.2.2
Submission 2009	Industrial processes	50. Implement planned improvements in Limestone and dolomite use – CO2 with regards to transparency and allocation of emissions.	Addressed in submission 2010, see NIR section 4.2.3
Submission 2009	Industrial processes	52. Implement planned improvements in Iron and steel production and provide a transparent explanation of the revised estimation methods as well as the reallocation of emissions from the energy sector to this category. Include in the NIR a brief discussion on the results of the carbon balance checks.	Addressed in submission 2010. Emissions have been revised for all years and reported in accordance with IPCC Guidelines (see NIR section 4.4.1).
Submission 2009	Industrial processes	53. Clearly explain this in more detail in the NIR if it continues reporting CO2 from limestone use in iron and steel production.	Addressed in submission 2010, see NIR section 4.4.1
Submission 2009	Industrial processes	55. Calculate and include CO2 emissions from the use of calcium carbide using the default EF presented in the Revised 1996 IPCC Guidelines unless there is evidence showing that the calcium carbide produced is not used in the country.	Addressed in submission 2011, see NIR section 4.3.3
submission 2006	Agriculture	52. Break in time series 1995	Addressed in submission 2010. In the footnote to Table 6.6 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 Background data this is referring to is not used in the actual calculations. 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.	A new paragraph named “Emission of ammonia” was added to NIR in submission 2011 to clarify this issue.
Submission 2007/2008	Agriculture	44. Provide detailed information in its NIR on the assumptions and national conditions supporting the calculation/selection of EFs (e.g. N2O emissions from manure management and from agricultural soils).	The NIR has been updated with additional information about this.
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 was corrected in submission 2010.
Submission 2007/2008	Agriculture	47. Revise this N-excretion rate in accordance with the conditions it is reporting for the number of pigs, that is, number of animals produced (including rotations) or number of average livestock at a given time.	The reference day for the estimation of number of pigs is the first of June. This should approximately be the average number of pigs for an arbitrary time of year.
Submission 2007/2008	Agriculture	48. Encourage Sweden to clarify the decrease in the IEF for solid storage from 0.0197 kg N2O-N/kg N in 1990 to 0.0192 kg N2O-N/kg N in 2006 and indicate which management systems underlie the IEF of 0.02 kg N2O-N/kg N in the category other.	In CRF this value is constantly 0.02 for all reporting years.
submission 2007/2008	Agriculture	51. The ERT recommends that Sweden ensure the consistency of information between CRF tables 4.B(b) and 4.D	In table 4.B(b) the total amount of nitrogen excreted is given. In table 4.D the amount of nitrogen directly lost as ammonia is subtracted from the total amount and the remaining amount is used as activity data for release of nitrous oxide.

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.	A new paragraph named “Emission of ammonia” was added to NIR in submission 2011 to clarify this issue.
Submission 2009	Agriculture	58. Following the recommendations from previous reviews, the ERT recommends that Sweden improve transparency by providing additional information on how the EFs are calculated for tier 2 methods.	Additional information about the country specific EF has been included in the NIR for submission 2010.
Submission 2009	Agriculture	59. Further details on how the EF for dairy cattle is developed.	This has been clarified in submission 2011.
Submission 2009	Agriculture	60. Provide further documentation to explain the trend in emissions for manure management and the changing IEF.	The trend is explained in the beginning of section 6, Agriculture.
Submission 2009	Agriculture	63. Provide further information in the NIR on the appropriateness for Swedish conditions of the factors: country-specific EFs of 0.8 and 2.5 per cent kg N2O-N/kgN for nitrogen from synthetic fertilizer and nitrogen from manure applied to soils, respectively.	This has been clarified in submission 2011.
Submission 2009	Agriculture	64. Further explanation be provided in the NIR of the appropriateness of the use of this country-specific EF (pasture, range and paddock manure is 0.016 kg N2O-N/kg N and unfertilized pastures/grasslands is based on a value in the range of 0.002–0.01 kg N2O–N/kg N).	Sweden has now changed the EF for pasture, range and paddock manure to the IPCC default value of 2%.
Submission 2009	LULUCF	59. Improve its approach for determining land-use change in order to report a consistent time series of annual land-use change matrices, as is suggested in the IPCC good practice guidance for LULUCF.	Sweden has increased the transparency in the description of methods used in the inventory in accordance with IPCCC GPG.
Submission 2009	LULUCF	55. 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.	Sweden has increased the transparency in the description of methods used in the inventory in accordance with IPCCC GPG.
Submission 2007/2008	LULUCF	70. Clarify in the NIR whether annual land-use change data are used to produce the estimates and report a consistent time series of these annual land-use change data in accordance with the IPCC good practice guidance for LULUCF.	Now clearly aaddressed in NIR

Submission 2007/2008	LULUCF	54. The ERT encourages the Party to improve the completeness of its reporting in its future annual submissions by providing estimates and relevant information for categories that are not estimated.	Sweden´s reporting of LULUCF is now complete except for categories that are currently not mandatory to report.
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. Estimators are moved to Annex 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. The full correction is introduced 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	LULUCF	69. Improve consistency in the CRF tables by correcting the errors.	Corrected.
Submission 2006	LULUCF	70. Estimate CO_2 emissions from land converted to wetland.	Addressed in submission 2010. No longer reported unmanaged.
Submission 2006	Waste	75. The ERT recommends that Sweden provide further information on the utilization of gas recovery in its next NIR.	From submission 2008, the use of recovered gas is described in NIR.
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.	From submission 2010, the notation key NE is reported for CH_4 emissions from wastewater treatment (sludge). In submission 2011, by following the recommendations of ERTs Saturday paper, emission estimates has been reported for CH_4 emissions from wastewater treatment (wastewater). This is further described in the NIR section 8.3.1.2.2.1
Submission 2006	Waste	76. Measure CH4 and N2O emissions from hazardous waste incineration periodically on-site.	Addressed in submission 2010, see NIR section 8.4
Submission 2007/2008	Waste	73. CO_2 emissions from solid waste disposal on land could be better reported using the notation key NO.	From submission 2010, the notation key NO is reported for CO_2 emissions.
Submission 2007/2008	Waste	74. CH_4 emissions from wastewater treatment have been reported as NE	In submission 2011, by following the recommendations of ERTs Saturday paper, emission estimates has been reported for CH_4 emissions from wastewater treatment (wastewater). This is further described in the NIR section 8.3.1.2.2.1
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.	From submission 2010, the notation key NE is reported for CH_4 emissions.
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 (See section 8.3.1.2.1 in NIR submission 2011)

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 8.4
Submission 2009	Waste	81. Clarify about unmanaged landfill sites throughout the time series from 1990 to 2007 and provide more information on managed and unmanaged landfill sites in Sweden.	In NIR submission 2011, more information is provided on the matter. This is further described in the NIR section 8.2
Submission 2009	Waste	82. Confirm which Tier is used in CH4 from Solid waste disposal on land and if necessary correct this information.	Tier 3 was changed to Tier 2 in submission 2010.
Submission 2009	Waste	83. Give more and updated information on the amount of landfill gas recovered that was used for energy and was flared.	More information was provided in NIR 2011. This is further described in the NIR section 8.2.1.2.1.2
Submission 2009	Waste	85. Provide some additional information about the lower value in 2006 for CO2 emissions from waste incineration.	Information is provided in section 8.4. Data are direct measurements from the facilitys flue gases and are considered to be correct.

Table 10.5. Recommendations from the UNFCCC review process not yet implemented in the Swedish inventory.

Review[228]	Sector	Paragraph and recommendation in report (shortened)	Rationale for not yet adapting ERT recommendation and possible improvement plan
Submission 2007/2008	Energy	79.The ERT recommends that only one value (e.g. 25 kg CO2/GJ) be used for all years for incinerated municipal waste in order to maintain time-series consistency and consistency with reporting on incineration in category 1.A.	A study performed in 2009 [229]addressed this issue. It was concluded that there is not enough evidence to revise the emission factor for years prior to 2003, and SEPA decided not to revise the emission factor at all. We are aware of this issue and our ambition is to improve this emission factor in future submissions.
Submission 2009	Energy	31, 36, 39. The ERT reiterates the recommendation made by the previous review that Sweden investigates the cause of the difference between the data reported to the IEA and that reported to the UNFCCC.	An study[230] was carried out in 2010. The recommendations from that study have not fully been implemented in the inventory, as described in Annex 4 (Reference approach). Further efforts will hopefully be prioritized in future submissions.
Submission 2009	Energy	32. Report emissions from some categories were reported as “NE”, such as the CH4 and N2O emissions from mobile military use of biomass for the years 1999 to 2001, CO2 from oil transport for all years,	In submission 2011 all categories for which IPCC default methodologies exists are estimated. There are no data available to estimate CH4 and N2O emissions from mobile military use of biomass for the years 1999 to 2001 but emissions are expected to be minor. Sweden lack information on CO_2 emissions from oil transport and there is no IPCC default methodology.
Submission 2009	Energy	35. The ERT reiterates the recommendation made by the previous review that Sweden reconciles the differences between the reference approach and the sectoral approach.	Data and methodology for the reference approach have been studied during 2010. There are, however, still quite large differences between the reference approach and the sectoral approach for some years, and the improvement efforts will continue in future submissions as resources may allow.
Submission 2009	Energy	38. Investigate how distribution of marine distillate fuels and residual fuel oils between domestic and international navigation data corresponds to the definition of international and domestic marine transport in IPCC and explain large inter-annual variations.	We are aware of this issue and consider it to be prioritized. Studies on international marine bunkers will be made when resources are available.

[228] FCCC/IRR/2006/SWE, FCCC/ARR/2008/SWE and FCCC/ARR/2009/SWE
[229] Paulrud, Fridell Stripple, 2009
[230] Hedlund & Lidén, 2010

submission 2007/2008	Industrial processes	41. For CO2 and N2O 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 but addressed in NIR Annex 3.3.
Submission 2009	Industrial processes	48. Continue the discussion with the cement producing company and improve the estimates as appropriate.	This will be addressed in the coming submissions.
Submission 2009	Industrial processes	54. Make efforts to estimate the emissions from foam blowing that are not estimated currently, and include them in the next annual submission.	This will be addressed in the coming submissions.
Submission 2009	Industrial processes	56. Report CH4 and N2O from combustion of cooking liquor in the pulp, paper and print category under the energy sector, in accordance with the Revised 1996 IPCC Guidelines.	This will be addressed in the coming submissions.
Submission 2007/2008	LULUCF	75. The ERT reiterates the recommendation from the previous review that Sweden improve its methodology (to separate emissions from organic and mineral soils (CRF table 5 (III))) in order to be able to report the two soil categories separately in future submissions.	Currently we do not have appropriate information on exactly on which land these changes occur. Therefore the emissions are reported aggregated.
Submission 2007/2008	LULUCF	69. The ERT noted that Sweden may be underestimating the C stock increase in living biomass and recommends that Sweden verify differences in IEF compared to Finland and Norway and make revisions if necessary.	Comparing IEF may not tell the whole story.The annual harvest may differ significantly between years in and between countries. Therefore the difference may not be seen as exceptional.
Submission 2009	LULUCF	57. Report the subcategory mire under grassland, further distinguishing between managed and unmanaged land subcategories.	Grasscovered mires are always saturated with water and therefore reported under Wetlands.
Submission 2006	Waste	77. Account for CO2 emission only from non-biogenic waste incineration sources according to the IPCC Good Practice Guidelines.	This will be addressed in the coming submissions.
Submission 2007/2008	Waste	72. Include information on time series for industrial organic waste in order to provide a more complete picture of municipal solid waste AD.	No data are available, which has been further described in the NIR of submission 2011. See NIR section 8.2.1.2.2.
Submission 2007/2008	Waste	74. Attempt to estimate CH4 emissions from wastewater treatment as part of the general assessment for “NE” categories and to provide the background data on industrial wastewater in CRF table 6.B.	CH4 emissions from wastewaster treatment (wastewater) are estimated in submission 2011. Methods needs to be developed in order to estimate CH_4 emissions from wastewater treatment (sludge). This is further described in the NIR section 8.3.1.2.2.2.

Submission 2007/2008	Waste	78. Include information on biogenic fraction of incinerated municipal waste in its next NIR, and update and validate this value regularly as the biogenic fraction of incinerated municipal solid waste varies over time. It is good practice to assume that the composition of incinerated municipal solid waste is similar to that of generated municipal solid waste (IPCC good practice guidance, page 5.28).	This will be addressed in the coming submissions.

10.5 Major changes in methodological descriptions

Table 10.6. Documentation of major changes in methodological descriptions compared to previous year NIR.

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	DESCRIPTION OF METHODS	RECALCULATIONS	REFERENCE
	Please tick where the latest NIR includes major changes in methodological descriptions compared to the previous year NIR	**Please tick where this is also reflected in recalculations compared to the previous year CRF**	**If ticked please provide some more detailed information for example related to sub-category, gas, reference to pages in the NIR, etc**
Total (Net Emissions)			
1. Energy	X	X	See Source-specific methodologies and recalculations in NIR
A. Fuel Combustion (Sectoral Approach)			
1. Energy Industries	X	X	See NIR 3.2.7-8
2. Manufacturing Industries and Construction	X	X	See NIR 3.2.9, 11 and 14
3. Transport	X	X	See NIR 3.2.15, 17-19
4. Other Sectors	X	X	See NIR 3.2.20-22
5. Other			
B. Fugitive Emissions from Fuels			
1. Solid Fuels	X		See NIR 3.3.1-2
2. Oil and Natural Gas			
2. Industrial Processes			
A. Mineral Products			

B. Chemical Industry	X	X	4.3.3 (2B4), 4.3.4 (2B5)
C. Metal Production			
D. Other Production			
E. Production of Halocarbons and SF6			
F. Consumption of Halocarbons and SF6			
G. Other			
3. Solvent and Other Product Use			
4. Agriculture	X	X	See Source-specific methodologies and recalculations in NIR
A. Enteric Fermentation	X		See NIR 6.2
B. Manure Management		X	See NIR 6.3
C. Rice Cultivation			
D. Agricultural Soils	X	X	See NIR 6.4.1-3
E. Prescribed Burning of Savannas			
F. Field Burning of Agricultural Residues		X	See NIR 6.4.4.5
G. Other			
5. Land Use, Land-Use Change and Forestry		x	Section 7.6 is an overview of all recal-culations in CRF 5
A. Forest Land	X	X	7.3.1.3 and 7.3.1.4;Annex 3.2
B. Cropland	X	X	7.3.1.4; 7.3.1.5; Annex 3.2
C. Grassland	X	X	7.3.1.3 and 7.3.1.4; Annex 3.2
D. Wetlands			
E. Settlements	X	X	7.3.1.5; Annex 3.2
F. Other Land			

G. Other			
6. Waste	X	X	See Source-specific methodologies and recalculations in NIR
A. Solid Waste Disposal on Land	X	X	See NIR 8.2.1
B. Waste-water Handling	X	X	See NIR 8.3.1
C. Waste Incineration			
D. Other			
7. Other (as specified in Summary 1.A)			
Memo Items:			
International Bunkers			
Aviation			
Marine			
Multilateral Operations			
CO2 Emissions from Biomass			

NIR Chapter	**DESCRIPTION**		**REFERENCE**
	Please tick where the latest NIR includes major changes in descriptions compared to the previous year NIR		**If ticked please provide some more detailed information for example reference to pages in the NIR**
Chapter 1.2 Institutional arrangements	X		See NIR 1.2 and NIR Annex 6:1
Chapter 1.6 QA/QC plan	X		See NIR 1.6 and NIR Annex 6:2

PART 2: SUPPLEMENTARY INFORMATION REQUIRED UNDER ARTICLE 7, PARAGRAPH 1

11 KP-LULUCF

11.1 General information

Sweden provides supplementary information under Article 7 of the Kyoto Protocol for the Land Use, Land-Use Change and Forestry sector. This information requested is further specified in Decision 15/CMP.1, 16/CMP.1 and IPCC GPG for LULUCF (IPCC[231]).

Emissions/ removals originating from the activities Afforestation and Reforestation (AR) and Deforestation (D) are quite uncommon in Sweden (Table 11.1 and 11.2). The accumulated AR and D-areas always increase by time when estimates are based on the full set of inventory plots. However, for the most recent years this might not always be the case. This is due to the five-year inventory cycle, where the estimates for the five recent years are based on a decreasing number of plots. The expected values of estimates based on the partly different samples are statistically independent of the used sample size but the sample error decreases by sample size. Each submission, data for the five recent years are re-calculated. IPCC recommends a five-year inventory cycle and to re-calculate data when the intention is to improve the accuracy. Due to this explained sampling randomness from samples based on different number of sample plots, the estimated area under AR decreases between 2008 and 2009. This inconsistency is corrected by reporting a zero change in the accumulated AR-area between years 2008 and 2009 in table NIR2 and KP.A.1.

Sweden has elected the activity Forest management (FM) under Article 3.4 of the Kyoto Protocol (KP). The KP-reporting of FM and AR harmonize (areas) with the UNFCCC-reporting of 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[232] and these juvenile forests are not fertilized. Therefore, direct N_2O emissions from N fertilization and emissions from forest fires are reported only under FM. Forest fires –both natural and wildfires– are uncommon and, this far, has not been registered on AR-land. N_2O emissions from disturbance associated with land use conversion from Forest land to Cropland are reported under D. N_2O emissions from drainage of soils are not reported (voluntary). Most liming is assumed to occur on agricultural land and is not reported under the KP.

[231] Intergovernmental Panel on Climate Change, 2003
[232] 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.

Table 11.1 The accumulated area under activities AR, D and FM and the approximate number of sample plots each estimate is based on. To avoid a decreasing accumulated area, an area of 0.29 kha is reported under AR in CRF-tables for year 2009.

[M ha]	1990	. . .	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
AR	0.02	. . .	0.10	0.11	0.12	0.14	0.15	0.16	0.19	0.21	0.22	0.25	0.29	0.24
D	0.01	. . .	0.11	0.12	0.14	0.15	0.16	0.17	0.18	0.19	0.20	0.20	0.24	0.27
FM	28.2	. . .	28.1	28.1	28.1	28.1	28.1	28.1	28.1	28.1	28.0	28.1	28.4	29.2
Plots	30’	. . .	30’	30’	30’	30’	30’	30’	30’	30’	24’	18’	12’	6’

Table 11.2 Emissions (minus)/ removals (plus), CO_2 [M ton] from reported carbon pools in AR, D and FM for the second year in the commitment period (2009).

[M ton]	Above ground biomass	Below ground biomass	Dead wood	Litter	Soil organic carbon
AR	0.64	0.22	0.02	0.32	-0.22
D	-0.78	-0.26	0.00	-1.23	-1.25
FM	25.1	8.39	2.16	1.44	5.82

The KP-reporting uses the same institutional arrangements, national system and corresponding QA/QC procedures as for the UNFCCC reporting. Emissions reported under Article 3, paragraph 3 and 4 are not overlapping with those emissions reported under KP Annex A. The section below focuses on differences in aggregating underlying data between the UNFCCC- and the KP-reporting.

The same underlying methodology is used for the reporting under the KP of the LULUCF-sector as described for the UNFCCC reporting in NIR chapter 7. The estimates of emissions/ removals and areas are based on permanent 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. Changes in carbon pools on ARD-land are reported for years 2008-2012. Land under FM is accumulated from 1990 and changes in carbon pools are reported on such land 2008-2012.

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

11.1.1 Definitions of forest and any other criteria

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. Both crown cover and height refers to maturity *in situ*, and consequently, Forest land could temporary be unstocked due to human intervention such as final felling.

Normally such land is regenerated within a few years and Forest land is not considered deforestated if not confirmed in field. Assessed land that meets the forest criteria above but where other land-use is predominating is not considered Forest land. For example, agriculture land normally fulfils the forest criteria except for the predominant land use and 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. Tree covered areas less than 0.5 ha does not fulfil the forest criteria and is reported as belonging to the neighbouring land use category – this implies that trees may be reported under any land use category.

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 underlying data are also consistent for the whole reporting period. In fact, the area of Forest land under the UNFCCC reporting should be the same as the areas subject to activities Forest management and Afforestation/ Reforestation under the Kyoto Protocol (this far all land under Afforestation/ Reforestation has secondary classification Forest management and none under Deforestation).

The definition of Forest land 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 randomness of the sample.

Under the Kyoto Protocol it is central to distinguish between definitions of land use categories, activities and spatial assessment units (Figure 11.1). The definition of Forest land has a minimum area but this is not the case for activities. For Sweden the spatial assessment unit is a permanent sample plot (radius 10 m) and since this plot could be delineated into more than one land use category, deforestation close to 0 m^2 could be detected. Area-based sampling is used and a separate sample plot represents an area in the estimation algorithm and all sample plots together represent the total land and fresh water area of Sweden. Sample based National Forest Inventories (NFI) are common but the Swedish NFI is quite unique since the sample frame covers all land-use categories and not only Forest land. This is required when both gross and net land use transfers over time have to be traced.

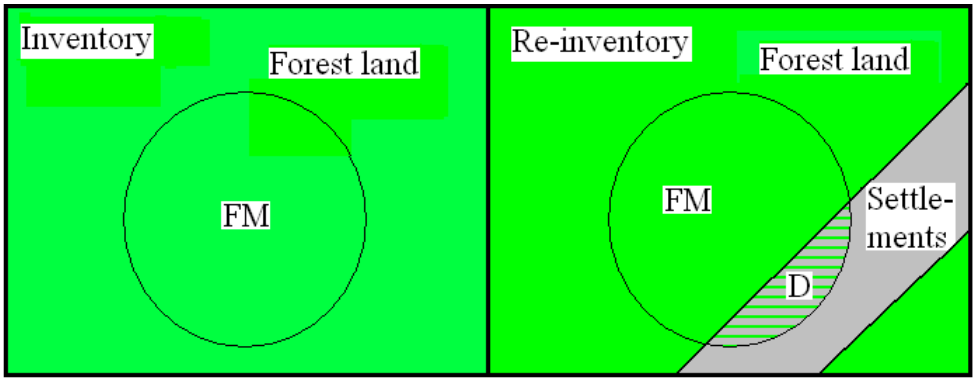

Figure 11.1) Example distinguishing the concepts of land use category, activities under the Kyoto Protocol, and spatial assessment unit in the Swedish sample based inventory: At the first inventory, only the land use category Forest land exist in an area but at the re-inventory part of the Forest land has been deforested to the land use category Settlements. Activities under the Kyoto Protocol are estimated using area based sampling by circular sampling plots (the spatial assessment unit). At the first inventory, the whole plot represents the activity Forest management (FM) but at the re-inventory the plot represent the activities FM and Deforestation (D), respectively. Observe that both land use categories and activities have definitions but Sweden has no minimum area limit set for estimating activities.

11.1.2 Elected activities under Article 3, paragraph 4, of the Kyoto Protocol

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.

11.1.3 Description of how the definitions of each activity under Article 3.3 and each elected activity under Article 3.4 have been implemented and applied consistently over time

Sweden defines Deforestation (D) as land use conversions from Forest land (all managed) to Cropland, Grasslands or Settlements (all land under these three categories are assumed managed). Afforestation/ Reforestation (AR) is defined as land use conversions in the opposite direction (Figure 11.2). Land use categories are strictly defined (see NIR chapter 7) and land use conversions are observed in field using a 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 11.3). If the land use of a sample plot or part of a sample plot is assessed as converted between consecutive inventories the exact year of the conversion is estimated from properties on the sample plot (site, stand and vegetation properties). This method has been used since 2006. For 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 human decision. Normally regeneration is following shortly 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 (1979:429 2 § 1.) as for the UNFCCC reporting. The activity Forest management (FM) is assumed occurring on all land fulfilling the forest definition (see 11.1.1). If

land is subject to AR (or D), this land may have secondary classification FM. Land could only be reported under one activity or none (to avoid double counting).

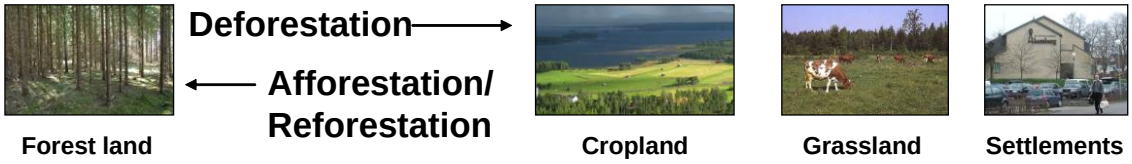

Figure 11.2) D is defined as land use conversions from Forest land (managed) to another managed land use class (all Cropland, Grasslands and Settlements are assumed managed). AR are defined as land use conversions in the opposite direction (C, G or S to F).

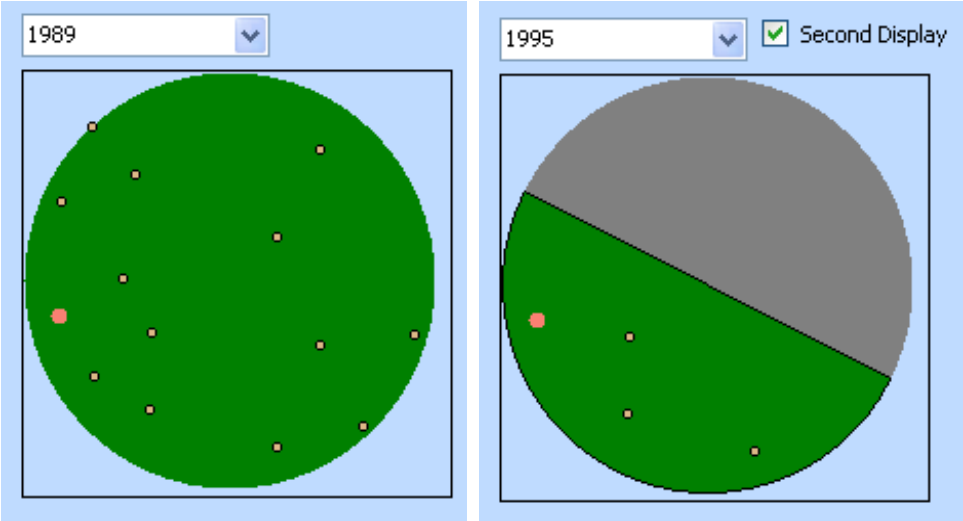

Figure 11.3) The figure shows data for a specific sample plot in the Swedish LULUCF-database. The individual tree biomass on approximately 30 000 permanent sample plots are matched to land use and traced back to before the base year in a consistent way. Applying area based sampling all 30000 permanent sample plots represents the whole land and fresh water area in Sweden and carbon stock changes are estimated using the stock change method on these plots. Part of this specific plot was Deforestated between 1991 and 1992. The positioning of trees is central when matching carbon stock changes in living biomass to activity (about 75% of Deforestated plots are divided into more than one land use category). The position and biomass of the marked tree (right panel) is identified at both inventories and demonstrates the possibility to match individual trees to activities over time.

11.1.4 Descriptions of precedence conditions and/or hierarchy among Article 3.4 activities, and how they have been consistently applied in determining how land was classified.

Precedence conditions are: D, AR and FM since FM is the only activity elected under article 3.4. Land under D could never leave this category and this is also valid for land under AR – except after D (very uncommon and have not yet occurred). 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. Naturally degraded land under FM can leave this category before the 2008, but not during the

commitment period, and is then not reported under the KP (usually reported as Wetlands or Other land under the UNFCCC). At any time deforested land can leave the FM category and is then reported under D. Land under activities is accumulated from end of 1989 and onwards, and changes in carbon pools are reported under such land during the commitment period.

11.2 Land-related information

11.2.1 Spatial assessment unit used for determining the area of the units of land under Article 3.3

The "Spatial assessment unit", which is the same as for the UNFCCC-reporting, is used to determine the area of accounting for ARD. The "Spatial assessment unit" is defined as the minimum area used to detect a land use conversion.

Sweden monitors 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 (Figure 11.1).

11.2.2 Methodology used to develop the land use matrix

Data from the Swedish National Forest Inventory (NFI) have been used for developing the land use matrix. The underlying data are consistent with the data used for developing the land use matrix under the UNFCCC-reporting. The main difference is that activities are reported under the KP while land use categories are reported under the UNFCCC.

The Swedish National Forest Inventory covers all land and fresh water areas before the base year and onwards on sample plots with a fixed position (permanent sample plots). This makes it possible to consistently trace both gross and net land use transfers over time. Each year, a sample plot represent a certain land use category but land use may change for the whole or a part of the sample plot.

11.2.3 Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations

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 11.4). 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 (in a database but confidential due to sampling reasons, but on request in connection with an in country re-

view, the review team has the possibility to visit any plot). A certain year, each sample plot (or a part of a 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 11.3).

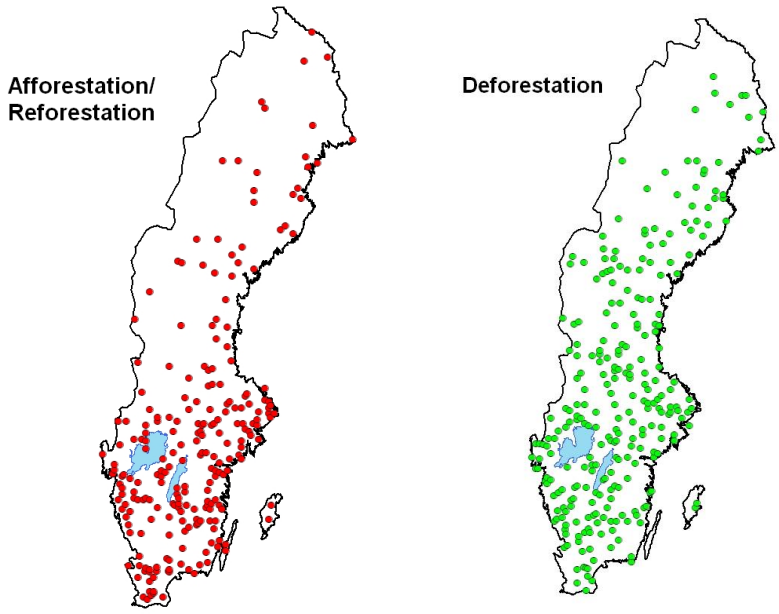

Figure 11.4) The location of sample plots partly or completely reported under ARD in Sweden (1990-2009). Thousands of sample plots within the country border represent FM. Every plot under AR but no under D has secondary classification FM. From sampling reasons, the exact geographical position of each 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 (the whole or a part of the 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.

11.3 Activity-specific information

11.3.1 Methods for carbon stock change and GHG emission and removal estimates

In most cases, methodologies, models and assumptions under the KP-reporting are consistent with the UNFCCC-reporting. This chapter focuses on discrepancies.

11.3.1.1 DESCRIPTION OF THE METHODOLOGIES AND THE UNDERLYING ASSUMPTIONS USED

11.3.1.1.1 Carbon pools

The living biomass pool changes is estimated in exactly the same way as under the UNFCCC reporting using the stock change method and area based sampling (See

7.3.1.2 + NIR Annex 3:2). However, the living biomass is reported separately for aboveground and belowground biomass, respectively.

The dead wood, litter and soil organic pools are calculated using the same methods as for the UNFCCC-reporting (See 7.3.1.3-4 + Annex 3:2)using the area distribution associated with the reported activities under the Kyoto protocol (ARD and FM).

All methods used for FM is Tier 3 whereas methods for Litter, Dead wood and Soil organic carbon for ARD is Tier 2.

11.3.1.1.2 Other emissions

Emissions associated with direct N_2O emissions from N fertilization in forests (TABLE 5(KP-II)1) are estimated in the same way as under the UNFCCC (see 7.2.4.1). The estimates are based on activity data and emission factors with no information of the actual geographical distribution of fertilizer used. The fertilization is strictly regulated by the Forestry act and Sweden assumes that no fertilizer is applied in young forests. Therefore all emissions are assumed to occur under the activity FM and none under AR and the reported figure under "Forest Land remaining Forest Land" (UNFCCC, TABLE 5(I)) should correspond to the reported figure under FM (TABLE 5(KP-II)1)). It should be noted that fertilization is very restricted in Sweden. The annual fertilized area is expected to increase in the coming years but to cover less than 0.5 % of the total area of Forest land.

In line with the UNFCCC-reporting (TABLE 5(II)), N_2O emissions from drainage of soils (TABLE 5(KP-II)2) are not reported. The justification for omitting the emission is found in section 11.3.1.2.

The reporting of N_2O emissions from disturbance associated with land-use conversion to Cropland (TABLE 5(KP-II)3) are only relevant for the activity D and is reported. The reported figure should be similar to the figure reported under "2.1 Forest land converted to Cropland" (UNFCCC, TABLE 5(III) and discrepancies arise only from a different accumulations of land between the two reporting's (see activities).

Liming is restricted to an annual emission of about 0.1 Mton CO_2 that is assumed to occur on Croplands remaining Cropland only and since Sweden has not elected Cropland Management, the notation key "NO" is used in TABLE 5(KP-II)4.

All forest fires (TABLE 5(KP-II)5) are reported under FM and this figure should correspond to the figure reported under Forest land (UNFCCC, TABLE 5(V)). Forest fires may occur in all kinds of forests but no fires have been registered by the National Forest Inventory on land reported under activities AR.

11.3.1.1.3 Activities

Kyoto Protocol activity areas are accumulated from the base year and onwards and, normally, do not leave the class. For the UNFCCC-reporting converted land stays in the conversion class for twenty years and is thereafter reported under the land use category it was converted to. The twenty-year accumulation of land under the UNFCCC-reporting may begin long before the base year and is therefore not suit-

able to, for example, compare D under the Kyoto Protocol with Forest land converted to Cropland, Grassland or Settlements. Using conversions from Forest land as a "proxy" for D has lead to several misunderstandings in the review process of the Swedish reporting.

11.3.1.2 JUSTIFICATION WHEN OMITTING ANY CARBON POOL OR GHG EMISSIONS/REMOVALS FROM ACTIVITIES UNDER ARTICLE 3.3 AND ELECTED ACTIVITIES UNDER ARTICLE 3.4

Sweden accounts for all carbon pools (aboveground biomass, belowground biomass, litter, dead wood and soil organic carbon). This is also valid for all non-carbon pool emissions except nitrous-oxide emissions from drainage of soils under FM (Table 5(KP-II)2). These emissions is optional to report since the available methods to estimate the emissions is not accurate enough (IPCC 2003 GPG, Appendix 3a.2).

11.3.1.3 INFORMATION ON WHETHER OR NOT INDIRECT AND NATURAL GHG EMISSIONS AND REMOVALS HAVE BEEN FACTORED OUT

Sweden argues that the issue of "factoring out" was solved during negotiations with the cap for FM. A footnote of par. 7 of decision 16/CMP1 "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.

11.3.1.4 CHANGES IN DATA AND METHODS SINCE PREVIOUS SUBMISSIONS (RECALCULATIONS)

The uncertainty of estimates increases by decreasing number of sample plots and Table 11.3 illustrate the need of annual recalculations of the most recent years to increase the accuracy. When based on a full set of approximately 30000 sample plots, Table 11.3 indicates that the recalculated area under FM will probably decrease for at least year 2009. Validation by Official Statistics of Sweden indicates that the area under FM and AR should be close to 28.3 M hectares[233]. When based on a full set of sample plots, the accumulated area of D should and AR should normally increase. After next years recalculations we expect an AR area of about 300 kha and an D area of about 240 kha for 2009.

[233] Swedish University of Agricultural Sciences, 2010

Table 11.3 The accumulated area under activities AR, D and FM and the approximate number of sample plots each estimate is based on, presented by submission. Lats three rows express the diference between submissions due to recaclulations.

	[M ha]	1990	. . .	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Submission 2010	AR	0.02	. . .	0.12	0.14	0.15	0.16	0.19	0.21	0.22	0.26	0.35	-
	D	0.01	. . .	0.14	0.15	0.17	0.17	0.18	0.17	0.18	0.18	0.20	-
	FM	28.2	. . .	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’	24’	18’	12’	6’	-
Submission 2011	AR	0.02	. . .	0.12	0.14	0.15	0.16	0.19	0.21	0.22	0.25	0.29	0.24
	D	0.01	. . .	0.14	0.15	0.16	0.17	0.18	0.19	0.20	0.20	0.24	0.27
	FM	28.2	. . .	28.1	28.1	28.1	28.1	28.1	28.1	28.0	28.1	28.4	29.2
	Plots	30’	. . .	30’	30’	30’	30’	30’	30’	24’	18’	12’	6’
Difference between	AR	0.00	. . .	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.06	-
Submission	D	0.00	. . .	0.00	0.00	-0.01	0.00	0.00	0.02	0.02	0.02	0.04	-
2011-2010	FM	0.00	. . .	0.00	0.00	0.00	0.00	0.00	0.20	0.30	0.50	0.80	-

Estimates of carbon stock changes for ARD activities are very uncertain. The major reason for this uncertainty is that ARD activities are very uncommon and due to the sample intensity (Table 11.4. We expect more stable estimates when recalculated estimates are based on the full record of approximately 30 000 sample plots. Estimates for FM are quite uncertain and also here we expect more stable estimates after recalculations. However, the uncertainty will probably not influence on the accounting since the net removal from FM is much larger then the net emission from ARD. Therefore it will probably become possible to offset net emissions from ARD (about 3 M ton CO_2 per year) by the net removal from FM (maybe -30 M ton CO_2 per year) and further claim credits from FM limited by the cap (2.13 M ton CO_2 per year).

Sweden has the possibility to separate D into sub-categories. Year 2009, Sweden identified a small removal of 0.01 Mton CO_2 per year[234] for living biomass on D land (to cropland, mineral soils). Sweden inventory trees also after D and in this case trees have been naturally regenerated on Cropland. This unusual removal is very uncommon (represents only one sample plot) and does not have any influence in practice.

[234]The ERT has in the centralized review (Subm 2009) noted a removal for land reported under D.

Table 11.4 Emissions (minus)/ removals (plus), CO_2 [M ton] from reported carbon pools in AR, D and FM per submission

Activity	Carbon pool	2008 Submission 2010	2008 Submission 2011	2009 Submission 2011	2008 Submission 2011-2010
AR	Above ground biomass	1.10	0.86	0.64	-0.25
	Below ground biomass	0.36	0.28	0.22	-0.08
	Dead wood	0.03	0.02	0.02	-0.01
	Litter	0.39	0.32	0.32	-0.06
	Soil organic carbon	-0.31	-0.22	-0.22	0.09
	Total	1.58	1.27	0.98	-0.31
D	Above ground biomass	-0.47	-1.38	-0.78	-0.91
	Below ground biomass	-0.16	-0.45	-0.26	-0.30
	Dead wood	-0.00	-0.00	-0.00	-0.00
	Litter	-0.92	-1.09	-1.23	-0.17
	Soil organic carbon	-0.84	-1.10	-1.25	-0.26
	Total	-2.38	-4.03	-3.52	-1.65
FM	Above ground biomass	11.6	18.5	25.1	6.90
	Below ground biomass	4.23	6,38	8.39	2.15
	Dead wood	2.23	2.24	2.16	0.01
	Litter	1.24	1.44	1.44	0.20
	Soil organic carbon	-0.68	5.76	5.82	6.43
	Total	18.6	34.3	42.9	15.7

Emissions from KP categories 5(KP-II)1-5(KP-II)5 are very limited in Sweden. Category 5(KP-II)3, N_2O emission from disturbance associated with land-use conversion to Cropland, A.2 Deforestation, has been re-calculated from an emission of 0.04 to 0.03 Gg N_2O per year. The re-calculation is due to recalculated activity data (the conversed area has been recalculated from 9.8 to 7.4 kha).

11.3.1.5 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 due to sampling. 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 by expert judgment.

Table 11.5 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	-

11.3.1.6 INFORMATION ON OTHER METHODOLOGICAL ISSUES

There are currently no methods identified that needs further clarification than those already explained.

11.3.1.7 THE YEAR OF THE ONSET OF AN ACTIVITY, IF AFTER 2008

The onset of activities follows IPCC GPG for LULUCF (IPCC[235]) and no activity has been set on after 2008.

11.4 Article 3.3

11.4.1 Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2012 and are direct human-induced

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 11.2). Land use categories are strictly defined (see NIR chapter 7) and land use conversions are confirmed in field. The estimates are based on area sampling using the approximately 30 000 permanent sample plots inventoried by the NFI. The inventory have been consistent since 1983.

This implies that Sweden uses the broad interpretation of "direct human induced" and an active human removal of trees followed by a land use conversion from Forest land to a managed non-forest land use category is considered direct human induced. This is also valid for the choice to actively abandon managed land

[235] Intergovernmental Panel on Climate Change, 2003

in favor for the management of forests. The management of Forest land on abandoned former managed non-forest land is regulated by the Forestry act (1979:429). The intention of a human induced land use conversion should be permanent. If, for example, a land owner decides to convert former Cropland to Forest land by planting trees, this action is considered AR, but if the land owner in the future decides to cultivate this land back to Cropland, then the land with be reported under D. No such reversed-conversions have been identified (this far).

A field inventory is used to confirm that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2012 and are direct human-induced. 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.

11.4.2 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation

Final felling is a natural step in the rotation cycle of forestry. Also storms may result in large areas of felled trees (wind-throws). If final felling or disturbances as storms have 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. If final felling has occurred on a plot between two consecutive inventories with no sign of D, but D is confirmed at the next re-inventory, then the year of D is “re-calculated” to match the “loss of biomass” to the conversion year.

11.4.3 Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested

About 200 000 ha[236] Forest land is annually losing its forest cover as a natural step in the forest rotation cycle. The position and status of every sample plot that has lost forest cover is known but D is not reported until confirmed. The geographical position and area of all final fellings on Forest land are monitored by change detection using the remote sensing system ENFORMA[237]. Each land owner has to apply to the Forestry Agency before harvest and state if the removal of trees is a natural step in the forest rotation cycle or a permanent D.

[236] Swedish University of Agricultural Sciences, 2010
[237] Olsson et al, 2010

11.5 Article 3.4

11.5.1 Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human induced

The activity FM is assumed to occur on all Forest land and first classification FM is reported under Article 3.4 FM. Land reported 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. Before 2008 (but not during the commitment period), land under FM could leave this category by natural degradation to Wetland or Other land and is then not reported at all. This IPCC-rule has no practical significance for reported removals/ emissions. The area under FM is quite stable and all land use categories, including Forest land, are consistently monitored in field since 1983. 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. Most forest biomass is actively managed for timber and pulp production and remaining forest biomass is managed for nature conservation. The definition used coincides with definition of Forest land according to the Forestry act (1979:429).

11.5.2 Information relating to Cropland Management, Grazing Land Management, and Revegetation, if elected, for the base year

Sweden has not elected these activities.

11.5.3 Information relating to Forest Management

The removal from living biomass (Table 11.6) is important for the total net removal reported under FM. The removal from living biomass is the result from growth and drain and is sensitive to the demand of forest products from the forest industry. Based on harvest applications sent to the Forestry Agency, we expect a reduced removal 2011.

Table 11.6 The removal (plus) from living biomass reported under FM

CO_2 [M ton]	1990	. . .	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
FM	39.6	. . .	35.2	32.8	33.9	31.9	27.3	25.4	25.0	23.3	24.9	33.5

11.6 Other information

11.6.1 Key category analysis for Article 3.3 activities and any elected activities under Article 3.4

A qualitative key category analysis has been made (IPCC GPG for LULUCF (IPCC[238]), p 5.38-5.40). Carbon dioxide emissions/ removals from Activities Forest management, Afforestation/ Reforestation and Deforestation were considered

[238] Intergovernmental Panel on Climate Change, 2003

key-categories (CO_2). Every key-category is estimated using Tier 3. Emissions from non-carbon pools are very restricted under the KP. These are not considered as key categories and reported using Tier 1.

11.7 Information relating to Article 6

Information relating to Article 6 is provided in Annex 6:3.

12 Information on accounting of Kyoto units

12.1 Background information

Information on accounting of Kyoto protocol units and of the national registry is contained in Annex 6.

12.2 Summary of information reported in the SEF tables

A summary of information reported in the SEF tables for calendar year 2010 will be included in Annex 6:5 before submission to UNFCCC in April 2011.

12.3 Discrepancies and notifications

Information on any discrepancies and notifications received for calendar year 2010 will be included in Annex 6:5 before submission to UNFCCC in April 2011.

12.4 Publicly accessible information

Information on publicly accessible information is included in Annex 6:5.

12.5 Calculation of the commitment period reserve (CPR)

The calculation of the commitment period reserve (CPR) is presented in Annex 6:4.

12.6 KP-LULUCF accounting

Sweden reports and accounts for activities under article 3.3 and the activity Forest management under article 3.4 of the Kyoto protocol. Detailed descriptions on definitions of activities and carbon pools as well as methods for the quantification of emissions and removals related to these activities can be found in chapter 11 of the NIR. For 2009 the activities under article 3.3 constituted a net source of 2.5 M ton CO2. Forest management under article 3.4 constituted a removal of 42.8 M ton CO2. After offsetting the article 3.3 source the remaining removal from Forest management constitutes 40,3 M ton CO2. However, final accounting quantity for 2009 is limited by the cap to 2,13 M ton CO2. It may be noted that Sweden has elected commitment period accounting. The referred figures represent only 2009.

13 Information on changes in national system

There has been no significant changes to the national system since last submission. Due to national reorganization of authorities, some involved agencies has reorganized and changed names, but their functions in the national system remain intact. See Annex 6:1.

14 Information on changes in national registry

The changes in the national registry since the last national inventory report are related to upgrading the registry software Greta. The changes are further described in Annex 6:3.

15 Information on minimization of adverse impacts in accordance with Article 3, paragraph 14

This information is provided in Annex 6:9.

16 Other information

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