National Inventory Report Sweden 2019

Greenhouse Gas Emission Inventories 1990-2017

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

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Preface

According to Articles 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC), parties are required to annually submit national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol. This report also constitutes the annual submission under the Kyoto Protocol in accordance with the Doha Amendment to the Kyoto Protocol 1/CMP.8, which established the second commitment period of the Protocol, as well as the complete inventories of anthropogenic emissions by sources and removals by sinks required for the calculation of Sweden's assigned amount for the Kyoto Protocol's second commitment period, in accordance with 2/CMP.8.

The National Inventory Report (NIR) for the year 2019 is prepared in accordance with the Reporting Guidelines agreed by the UNFCCC on its nineteenth session of the Conference of the Parties (COP) in Warsaw 2013 and subsequent decisions. It contains national greenhouse gas inventories for the period 1990 to 2017, and descriptions of methods used to produce the estimates. The methods used to calculate emissions and removals are in accordance with the IPCC 2006 Guidelines for National Greenhouse Gas Inventories, IPCC supplementary guidelines for KP LULUCF, and the IPCC supplementary guidelines for Wetlands (*2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*).

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

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Sammanfattning

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 FN:s klimatpanel (Intergovernmental Panel on Climate Change – IPCC). Två år senare konstaterade panelen att antropogen klimatpåverkan utgör 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 Paris hösten 2015 då världens länder enades om ett globalt klimatavtal. Parisavtalets mål är att hålla ökningen av den globala medeltemperaturen till *väl under* två grader och att *sträva efter* att begränsa temperaturökningen till 1,5 grader. Inom avtalet har alla länder lagt nationellt fastställt bidrag till att nå avtalets mål. Ambitionen i bidragen ska skärpas successivt samt förnyas eller uppdateras vart femte år. Sverige bidrag ingår i EU:s bidrag om att minska utsläppen av växthusgaser inom unionen med 40 procent till 2030 jämfört med 1990. En global översyn för att följa upp framstegen mot avtalets mål kommer att ske vart femte år, med start 2023. Principer för uppföljning och rapportering etablerades även i Paris. Bara knappt ett år efter Paris hade tillräckligt många parter ratificerat Parisavtalet för att det skulle kunna träda i kraft. Regelboken för hur Parisavtalets olika delar ska tillämpas i praktiken, inklusive nya riktlinjer för hur bidragen ska följas upp och parternas rapportering, kommer att beslutas vid COP24 i Polen.

Innan Parisavtalet trädde ikraft var Kyotoprotokollet det viktigaste tillägget till konventionen. Kyotoprotokollet förhandlades fram år 1997 i Kyoto, Japan och trädde i kraft 2005. Kyotoprotokollet innebär bindande åtaganden, för utvecklade länder (Annex I) förutom USA. Skillnaden mellan Parisavtalet och Kyotoprotokollet är därmed att alla parter till Parisavtalet anger ett nationellt fastställt bidrag som definierats av parten själv och som ska uppdateras över tid. Kyotoprotokollets åtaganden gällde bara de rikaste länderna och fastställdes genom förhandlingar.

Kyotoprotokollets åtaganden gäller minskade utsläpp av växthusgaser från dessa parter om minst 5 % under åren 2008-2012 jämfört med basåret 1990. Under första åtagandeperioden under Kyotoprotokollet åtog sig EU att gemensamt minska utsläppen med 8 % i förhållande till 1990 (utom för fluorerade växthusgaser där basåret är 1995). 2012 beslutade parterna under Kyotoprotokollet om en andra åtagandeperiod (2013 till och med 2020) i enlighet med Dohaändringen av Kyototprotokollet 1/CMP.8. Under denna åtagandeperiod har EU tillsammans med Island åtagit sig att minska växthusgasutsläppen till 2020 med 20 % i förhållande till basåret 1990. Sveriges åtagande inom EU är att minska våra nationella utsläpp med 17 % till 2020 jämfört med 2005 inom de sektorer som inte ingår i EU:s system för handel med utsläppsrätter.

Enligt FN:s klimatkonventions fjärde och tolfte artiklar samt den sjunde artikeln under Kyotoprotokollet, måste Annex I-parterna årligen rapportera sina utsläpp från källor och upptag i sänkor för alla växthusgaser som inte omfattas av Montrealprotokollet. Sveriges nationella inventeringsrapport (National Inventory Report – NIR) för år 2019 utgör den årliga rapporteringen enligt både FN:s klimatkonvention och Kyotoprotokollet. Rapporten har förberetts utifrån de riktlinjer som FN:s klimatkonvention antog vid dess nittonde konferens (Conference of the Parties – COP 19) i Warszawa 2013 samt följande beslut tillsammans med motsvarande antagna riktlinjer under Kyotoprotokollet. Rapporten innehåller den nationella växthusgasutsläppsinventeringen för perioden 1990 till 2017 samt beskrivningar av metoderna som använts för att ta fram statistiken. Metoderna som använts följer FN:s klimatpanels riktlinjer för nationell växthusgasinventering från 2006, FN:s klimatpanels tilläggsriktlinjer för markanvändning, förändrad markanvändning och skogsbruk (Land Use, Land Use Change and Forestry – LULUCF) samt tilläggsriktlinjer för våtmarker (se *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*).

Rapporten omfattar utsläpp till luft av de direkta växthusgaserna CO_2, CH_4, N_2O, HFC, PFC, SF_6 och NF_3 samt de indirekta växthusgaserna NO_X, CO, NMVOC och SO_2. Rapporten innehåller information om Sveriges inventering av växthusgaser för alla år från 1990 till 2017, inklusive beskrivningar av metoder, datakällor, osäkerheter, utförd kvalitetssäkring och kvalitetsstyrning (QA/QC) samt en trendanalys.

Vid en intern översyn 2016 upptäcktes att en utökad sekretessklassning var nödvändig jämfört med tidigare rapporteringar för att följa den svenska offentlighets- och sekretesslagen. Detta har påverkat underlagsdata i vissa undersektorer till stationär förbränning (CRF 1) och i industriprocesser och produktanvändning (CRF 2). Dessa har därför blivit klassificerade med sekretesskod (C). Sverige arbetar aktivt för att förbättra transparensen i rapporteringen och strävar efter att minimera sekretessklassningen av information i inventeringen.

Elektroniska utsläppsdata, aktivitetsdata samt emissionsfaktorer bifogas rapporten i det gemensamma rapporteringsformatet (Common Reporting Format – CRF), på FN:s klimatkonventions begäran.

S 2. Översikt av utsläpps- och upptagstrender, inklusive KP-LULUCF, per gas

De totala utsläppen av växthusgaser i Sverige exklusive LULUCF, uttryckt i koldioxidekvivalenter, var 52,7 miljoner ton år 2017 (Tabell S.1 och Tabell S.2). Av dessa var utsläppen som inte omfattas av EU:s system för handel med utsläppsrätter 33,4 miljoner ton, vilket är 62 % av de totala utsläppen. Jämfört med 2016 är det en minskning med ca 0,5 %. Utsläppen har minskat med 26 % mellan 1990 och 2017.

Nettoupptaget för sektorn markanvändning, förändrad markanvändning och skogsbruk (LULUCF) fortsatte att ligga på en hög nivå 2017. Upptaget har ökat med knappt 30 % sedan 1990, främst beroende på att tillväxten i skog och mark är större än avverkningen.

De totala utsläppen av koldioxid (CO_2) 2016 var 27 % lägre än 1990 och 1,2 % lägre än 2016. Koldioxid står för 42 miljoner ton vilket är cirka 80 % av de totala utsläppen av växthusgaser. Energisektorn, inklusive transporter, står för 85 % av de totala koldioxidutsläppen och är därmed den största källan till koldioxidutsläpp i Sverige.

Sedan 1990 har utsläppen av metan (CH_4) minskat med 39 %, vilket främst beror på åtgärder inom avfallssektorn. Även jordbrukssektorn visar minskade utsläpp. Mellan 2016 och 2017 har utsläppen miskat med 0,8 %. Metanutsläppen var 4.5 miljoner ton koldioxidekvivalenter år 2017 vilket motsvarar cirka 9 % av de totala utsläppen av växthusgaser. Metanutsläpp kommer framför allt från jordbruket, avfallsdeponier och från förbränning av fossila bränslen inom energisektorn.

De totala utsläppen av lustgas (N_2O) 2017 var 4,9 miljoner ton koldioxidekvivalenter, vilket är en minskning med cirka 15 % jämfört med 1990 men en ökning med 6,6% jämfört med 2016. År 2017 stod lustgas för cirka 9 % av de totala utsläppen av växthusgaser. Utsläpp av lustgas härrör huvudsakligen från jordbrukssektorn (cirka 78 %).

De totala utsläppen av fluorerade växthusgaser (PFCs, HFCs och SF_6) var 1,2 miljon ton koldioxidekvivalenter år 2017 vilket är 81 % högre jämfört med 1990. Den högre nivån beror främst på att ozonförstörande ämnen ersatts av växthusgaser HFCs. Utsläppen har dock planat ut sedan 2009 till följd av införandet av en ny EU-förordning 2006, och minskat med 1 procent mellan 2016 och 2017. Samtliga rapporterade fluorerade växthusgaser står för 2,3 % av de totala utsläppen av växthusgaser.

Tabell S.1. Utsläpp av växthusgaser per gas (kt CO_2 ekvivalenter)

UTSLÄPP AV VÄXTHUSGASER	1990	1995	2000	2005	2010	2015	2016	2017
CO_2 inkl. LULUCF	21 283	26 307	16 290	20 528	7 159	-4 067	-3 623	-3 332
CO_2 exkl. LULUCF	57 446	59 200	54 678	53 785	52 845	43 057	42 582	42 050
CH_4 inkl. CH_4 från LULUCF	7 893	7 843	7 315	6 636	5 693	5 069	4 992	4 953
CH_4 exkl. CH_4 från LULUCF	7 422	7 371	6 840	6 164	5 243	4 631	4 554	4 518
N_2O inkl. N_2O från LULUCF	7 055	7 209	7 018	6 305	6 096	5 782	5 798	6 090
N_2O exkl. N_2O från LULUCF	5 759	5 913	5 701	4 971	4 807	4 552	4 569	4 870
HFCs	6	136	770	1 110	1 136	1 132	1 149	1 138
PFCs	569	532	376	406	188	35	31	37
SF_6	102	135	119	152	63	53	57	47
NF_3	NO	NO	NO	NO	NO	NO	NO	NO
Ospecificerade HFCs and PFCs	NO	NO	NO	NO	NO	NO	NO	NO
Total (inkl. LULUCF)	**36 908**	**42 163**	**31 888**	**35 137**	**20 336**	**8 005**	**8 405**	**8 933**
Total (exkl. LULUCF)	**71 304**	**73 287**	**68 483**	**66 587**	**64 282**	**53 461**	**52 943**	**52 660**

Tabell S.2. Utsläpp av växthusgaser per sektor (kt CO_2 ekvivalenter)

Källor till utsläpp & sänkor	1990	1995	2000	2005	2010	2015	2016	2017
1. Energy	52 293	53 925	49 128	48 033	47 147	37 888	36 900	36 632
2. Industrial Processes and Product Use	7 611	7 888	8 358	8 828	8 391	7 312	7 854	7 588
3. Agriculture	7 658	7 912	7 774	7 052	6 820	6 860	6 871	7 187
4. LULUCF	-34 396	-31 125	-36 595	-31 451	-43 947	-45 455	-44 538	-43 727
5. Waste	3 742	3 562	3 222	2 673	1 924	1 400	1 318	1 253
6. Other	NO	NO	NO	NO	NO	NO	NO	NO
Total (inklusive LULUCF)	**36 908**	**42 163**	**31 888**	**35 137**	**20 336**	**8 005**	**8 405**	**8 933**

S 3. Översikt av utsläppstrender per sektor

De sektorer som omfattas av inventeringen samt källorna som används för aktivitetsdata och/eller utsläppsdata presenteras i Tabell S.3. Utsläppsstatistiken är hämtad direkt från dessa datakällor eller beräknade baserat på aktivitetsdata. Utsläppen av växthusgaser i Sverige per sektor visas i Tabell S.2.

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 och produktanvändning	Miljörapporter
		Direktkontakt med företag
		EU:s system för handel med utsläppsrätter
		Nationella data från produktregistret på Kemikalieinspektionen
		Nationell statistik, och
		Nationella experter
3	Jordbruk	Officiella statistiska rapporter
		Organisationer och forskare
4	Markanvändning, förändrad markanvändning och skogsbruk	Sveriges lantbruksuniversitet
		Skogsstyrelsen
5	Avfall	Avfall Sverige (fd RVF)
		Skogsindustrierna
		Statistiska centralbyrån
		Naturvårdsverket
		Energimyndigheten/Energigas Sverige
		Miljörapporter

Utsläppen från energisektorn (CRF 1), inklusive transporter, var under 2016 cirka 37 miljoner ton koldioxidekvivalenter 2017, vilket motsvarar 70 % av de totala utsläppen. Trenden för perioden 1990 till 2017 visar på minskade utsläpp om 30 %. Utsläppsminskningen beror huvudsakligen på minskad oljeanvändning för uppvärmning av bostäder och lokaler som ingår i ”Övriga sektorer” (CRF 1A4). ”Övriga sektorer” har minskat utsläppen med 74 % till omkring 2,9 miljoner ton koldioxidekvivalenter 2017. Utsläppen i energisektorn var 0,7 % lägre 2017 jämfört med 2016, beroende på minskade utsläpp från transportsektorn, medan utsläppen från tillverkningsindustrin och bygg samt flyktiga utsläpp ökade.

Energiindustrins (CRF 1A1) totala utsläpp var 9,2 miljoner ton koldioxidekvivalenter 2017, vilket är 8 % lägre med jämfört med 1990. Energiindustrin domineras av el- och fjärrvärmeproduktionen (CRF 1A1a) som stod för 6,8 miljoner ton koldioxidekvivalenter 2017, vilket är 14 % lägre än 1990. Utsläppen från el- och värmeproduktionen varierar mellan åren, framförallt på grund av vädrets (temperatur och nederbörd) påverkan på utsläppen. Utsläppen från el- och fjärrvärmeproduktionen var på samma nivå 2017 än 2016, vilket beror på att utsläppen från de flesta fossila bränslena minskar men samtidigt ökar utsläppen från industrigaser med 18% mellan 2016 och 2017. Utsläpp från förbränning i raffinaderier (CRF 1A1b) och koksverk (CRF 1A1c) var 2,4 miljoner ton koldioxidekvivalenter 2016.

Utsläpp från förbränning inom tillverkningsindustrin och byggsektorn (CRF 1A2) ökade med 1.6 % 2017 jämfört med 2016. Utsläppen har minskat sedan med motsvarande 42 % sedan 1990, men varierar mellan åren med förändrade produktionsvolymer som är kopplade till konjunktursvängningar. Utsläppsminskningen beror till största delen på minskad oljeanvändning, som delvis kan förklaras av en övergång till el och biobränslen.

Utsläppen från transportsektorn (CRF 1A3) står för en tredjedel av de nationella utsläppen av växthusgaser. Utsläppen från transportsektorn var 16,6 miljoner ton koldioxidekvivalenter under 2017, varav ungefär 15,5 miljoner ton från vägtransporter. Utsläppen från transportsektorn minskade med 3 % från 2016 till 2017 och utsläppen var 13 % lägre 2017 jämfört med 1990. Den lägre utsläppsnivån beror på att andelen biobränsle som används inom vägtrafiken har ökat och energieffektivare tekniker. Utsläppsminskningen har dock dämpats av att trafikarbetet har ökat.

Utsläppen av växthusgaser från industriprocesser och produktanvändning (CRF 2) uppgick till 7,6 miljoner ton koldioxidekvivalenter år 2017, vilket motsvarar cirka 14 % av Sveriges totala utsläpp. Inom sektorn är koldioxid den dominerande växthusgasen, följd av fluorerade växthusgaser och lustgas. Utsläppen härrör framför allt från produktion av järn och stål samt från mineralindustrin och är starkt kopplade till produktionsvolym. Utsläppen från sektorn var 3 % lägre 2017 jämfört med 2016. Trenden för perioden 1990-2017 visar på en stabilisering och utsläpp var 2017 0,3 % jämfört med 1990. Utsläppen från produktanvändning var betydligt högre 2017 jämfört med 1990, men visar på en minskande trend sedan 2004.

År 2017 var de totala växthusgasutsläppen från jordbrukssektorn (CRF 3) ca 7,2 miljoner ton CO_2-ekvivalenter vilket motsvarar ca 14 procent av de samlade utsläppen av växthusgaser i Sverige. Av dessa utsläpp var ungefär hälften lustgas

och hälften metan. Utsläppen inom jordbrukssektorn har minskat med knappt 0,5 miljoner ton CO_2-ekvivalenter eller en minskning på 6 % sedan 1990. Minskningen beror på ett antal faktorer som minskning av antal djur (särskilt mjölkkor och svin), minskade volymer stallgödsel, bättre hantering av stallgödsel, lägre användning av kväve-mineralgödsel samt en minskad åkerareal. Mellan 2016 och 2017 ökade utsläppen från sektorn med 4,6 %, vilket främst förklaras med en ökad användning av kväve-mineralgödsel på åkermark och ökat utsläpp från odling av organogena jordar samt ökat utsläpp från nötkreaturens fodersmältning på grund av ett ökat antal djur.

Nettoupptaget för sektorn markanvändning, förändrad markanvändning och skogsbruk (LULUCF - CRF 4) har under 2017 uppskattas till cirka 44 miljoner ton koldioxidekvivalenter. Större delen av nettoupptaget sker i kolpoolerna levande biomassa och mineraljord. Det är framförallt på skogsmark som det stora koldioxidupptaget sker. Skogsmark utgör 63 % av Sveriges landareal. Det totala upptaget för skogsmark ökade från cirka 38 miljoner ton till omkring 44 miljoner ton koldioxidekvivalenter mellan 1990 och 2017.

Utsläppen från avfallssektor (CRF 5) har minskat med ca 67 % jämfört med 1990. Från 2016 till 2017 minskar utsläppen med 4,9 % till följd av fortsatt minskade utsläpp från avfallsdeponier. Utsläppen från avfallssektorn domineras av metangas från avfallsdeponier. Metangasutsläpp står för 76 % av utsläppen, medan lustgasutsläpp från avloppsvattensbehandling samt biologisk behandling av fast avfall står för 19 % och koldioxidutsläpp från förbränning av avfall står för resten. Förbud har införts att deponera avfall och successivt har man övergått till framförallt förbränning av avfall för energiåtervinning. Utsläpp från förbränning av avfall för produktion av el och värme allokeras till energisektorn och inte till avfallssektorn.2017 var de totala utsläppen från avfallssektorn 1,3 miljoner ton koldioxidekvivalenter, vilket motsvarar 2,4 % av de totala växthusgasutsläppen.

S 4. Översikt av utsläppstrender för indirekta växthusgaser och SO_2

De indirekta växthusgaserna NO_X, NMVOCs, CO och SO_2 ingår inte i beräkningen av de totala nationella utsläppen av växthusgaser men redovisas separat. De visas i tabellen S.4.

Tabell S.4. Utsläpp av indirekta växthusgaser och SO_2 (tusentals ton)

Gas	1990	1995	2000	2005	2010	2015	2016	2017
NO_X	282	252	217	185	157	133	129	125
NMVOC	359	269	225	209	181	154	148	147
SO_2	104	69	43	36	29	18	18	18
CO	1 075	932	663	529	455	385	386	385

Utsläppen av kväveoxider (NO_X) var cirka 125 kiloton 2017. The energisektorn står för 79 % av totalen. Industriprocesser och produktanvändningssektorn och jordbrukssektorn star för ca 11 % vardera. NOx-utsläpp har minskat med mer än hälften (56 %) sedan 1990. Mellan 2016 and 2017 minskade utsläppen med 3 %. Detta beror främst på de skärpta utsläppskraven för bilar inom EU. Den ökade användningen av fjärrvärme och införandet av NO_X-avgiftssystemet i början av 1990-talet har också lett till en minskning av utsläppen.

Utsläppen av flyktiga organiska ämnen utom metan (NMVOCs) var 147 kton 2017. Industriprocesser och produktanvändningssektorn (framför allt från lösningsmedel och andra produkter) och energisektorn (framför allt vägtrafik och småskalig vedeldning för uppvärmning av bostäder) är de dominerande källorna till utsläppen, och bidrar med 44 % respektive 35 % av Sveriges total. Jordbrukssektorn bedrog med ca 21 % av utsläppen. NMVOC-utsläpp har minskat kraftigt, med 59 % sedan 1990. De totala utsläppen minskade marginellt jämfört med 2016. Den största reduktionen har skett inom transportsektorn där utsläppen minskade med 92 % sedan 1990 och med 4,5 % jämfört med 2016. NMVOC-utsläpp har även minskat med 63 % från oljeraffinaderier sedan 1990 och med 38 % inom produktanvändningssektorn. Huvudanledningen till den skarpa reduktionen är ökat antal energieffektiva bilar, introduktion av nya avgasreningskrav för fordon samt minskade utsläpp från användning av lösningsmedel.

Utsläppen av kolmonoxid (CO) har minskat med 64 % sedan 1990 och är cirka 385 kton år 2017. Utsläppen har dock varit relativt *konstanta* mellan 2016 och 2017. Ungefär 92 % av kolmonoxidutsläppen härrör från energisektorn, varav 22 % kommer från transporter och 64 % från småskalig uppvärmning av bostäder, lokaler och inom jordbrukssektorn. Utsläppen av kolmonoxid (CO) har minskat kraftigt i Sverige. Detta sedan bilar förseddes med katalysatorer, som omvandlar CO och kolväte till CO_2 och vattenånga.

Utsläppen av svaveldioxid (SO_2) var 18 tusen ton år 1990 och har minskat med 83 % sedan 1990. Utsläppen har också minskat med ca 4 % från 2016 till 2017. Drygt hälften av SO_2-utsläppen (56 %) kommer från industriprocesser och

produktanvändningssektorn, såsom metallproduktion och pappersmassaindustrin. Energisektorn står får 44 % av de totala utsläppen år 2017, framför allt från el- och fjärrvärmeproduktion och tillverkningsindustrier och konstruktionssektorn. Den långsiktiga reduktionen av utsläppen beror främst på en övergång till bränslen med lägre svavelhalt samt skatt på svavel i olja, kol införts 1991.

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. The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 and two years later they concluded that anthropogenic climate change is a global threat, which needs to be addressed through an international agreement. The United Nations started negotiations on a framework convention on climate change (UNFCCC), which came into force in 1994. The long-term goal of the convention is to stabilize the amount of greenhouse gases in the atmosphere at a level where harmful anthropogenic climate changes are prevented.

The most important addition to the convention was negotiated in Paris during the fall of 2015 and resulted in the adoption of a global climate agreement. The Paris agreement aims to hold the increase in the global average temperature to *well below* two degrees over pre-industrial levels and to *pursue efforts* to limit the temperature increase to 1.5 degrees. Within the agreement, all countries have provided nationally determined contributions (NDCs) to achieving the goal of the agreement and that the ambition of the contribution skall be gradually increased as the contributions are renewed or updated every five years. Sweden is part of the EU's contribution of reducing greenhouse gas emissions within the union by 40 percent by 2030 compared to 1990. A global stocktake of the progress towards achieiving the goal of the agreement will also take place every five years starting 2023. Principles for monitoring and reporting of emissions were also established in Paris. A year later, a sufficient amount of parties had ratified the Paris agreement for its entry into force. The rules for the application of the different parts of the Paris Agreement, including new guidelines for tracking progress and reporting by parties, will be adopted at COP24 in Poland.

Before the Paris agreement the most important addition to the convention was negotiated in 1997 in Kyoto, Japan and entered into force in 2005. The Kyoto Protocol provides binding commitments, for developed countries (Annex I) except for the United States. The difference between the Paris Agreement and the Kyoto Protocol is, therefore, that all parties to the Paris agreement provides a nationally determined contribution, which has been defined by the party and that is updated over time. The commitments under the Kyoto Protocol only applied to the richest countries and were determined via negotiations.

The first commitment period of the Kyoto Protocol involves binding obligations for the parties that ratified the protocol (the Annex I parties) to decrease their emissions of greenhouse gases (GHG) with at least 5 % during 2008-2012 compared to the base year 1990. Under the first commitment period of the Kyoto Protocol the European Union, together with Iceland, agreed to reduce their emissions by 8 compared to the base year 1990 (for fluorinated greenhouse gases the base year is 1995). In 2012 the parties under the Kyoto Protocol decided on a second commitment period (2013 to 2020) according to the Doha Amendment to the Kyoto Protocol 1/CMP.8. Under this commitment period the EU has, together

with Iceland, committed to reduce the emissions by 20 % by 2020 compared to the emissions of greenhouse gases in 1990. The Swedish commitment within the EU is to reduce national emissions by 17 % until 2020 compared to 2005 within sectors that are not part of the EU Emissions Trading System.

According to Articles 4 and 12 of the United Nations Framework Convention on Climate Change, parties are required to submit national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol annually. Sweden's National Inventory Report (NIR) for the year 2018, constitutes the annual submission under the Kyoto Protocol in accordance with the Doha Amendment to the Kyoto Protocol (1/CMP.8) which established a second commitment period from 2013 to 2020. During this commitment period, Parties are committed to reduce GHG emissions by at least 18 % below 1990 levels. The report is prepared in accordance with the Reporting Guidelines agreed by the UNFCCC on its nineteenth session of the Conference of the Parties (COP) in Warsaw 2013 and subsequent decisions. It contains national greenhouse gas emission inventories for the period 1990 to 2015, and descriptions of methods used to produce the estimates. The methods used to calculate the emissions and removals are in accordance with the IPCC 2006 Guidelines for National Greenhouse Gas Inventories and IPCC supplementary guidelines for KP Land Use, Land Use Change and Forestry (LULUCF) and also the IPCC supplementary guidelines for Wetlands (*the 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*).

This report covers anthropogenic emissions of direct greenhouse gases CO_2, CH_4, N_2O, HFC, PFC, SF_6, NF_3 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 2016, including descriptions of methods, data sources, uncertainties, the quality assurance and quality control (QA/QC) activities carried out as well as a trend analysis.

An internal review performed during 2016 of the use of confidential data in the inventory showed that additional data should be considered confidential compared to previous submissions in order to comply with the Public Access to Information and Secrecy Act of the Swedish law. This has affected some sub-sectors in stationary combustion (CRF 1) and industrial processes and product use (CRF 2), which have been classified with the notation key Classified (C). Sweden is working continuously with improving the transparency of our reporting and strives to minimize the extent of confidentiality in inventory data.

Electronic data on emissions, activity data and emission factors are provided in the Common Reporting Format (CRF) as requested by the UNFCCC together with this report.

ES 2. Summary of national emissions and removal trends

Total greenhouse gas emissions in Sweden excluding LULUCF, expressed in CO_2-equivalent, were about 52.7 million tonnes in 2017 (Table ES.1). The emissions that are not covered by the EU ETS amounted to 32.4 million tonnes, which is 62 % of total emissions. Total emissions have decreased by approximately 0.5 % compared to 2016 and by about 26% compared to 1990. In 2017, the net uptake within the land use, land-use change and forestry (LULUCF) sector remained at a relatively high level. The net uptake has increased by nearly 30 % since 1990 mainly because growth in forests and land has been greater than harvests. Net removals are influenced by disturbances due to harvests and natural disturbances such as storms.

The national emissions of carbon dioxide (CO_2) were 27% lower in 2017 compared to 1990. CO_2 emissions accounted for approximately 42 Mt in 2017, which is about 80% of the overall GHG emissions in 2016. The energy sector, including transport, accounted for 85 % of the overall carbon dioxide emissions, which makes it the largest source of carbon dioxide in Sweden.

Since 1990, methane emissions (CH_4) have decreased by 39%, mainly due to measures in the waste sector. The agricultural sector also shows reduced emissions. Between 2016 and 2017, emissions have decreased by 0.8%. Methane emissions were 4.5 million tonnes of carbon dioxide equivalents by 2017, which corresponds to approximately 9% of total greenhouse gas emissions. Metan emissions are mainly from agriculture, landfills and fossil fuels burning in the energy sector.

Nitrous oxide emissions (N_2O) were 4.9 million tonnes of carbon dioxide equivalent in 2017, which is a decrease of about 15% compared to 1990 and increased by 6.6% compared to 2016. In 2017, nitrous oxide about 9% of total greenhouse gas emissions. Emissions of nitrous oxide originate mainly from the agricultural sector (approximately 78%).

Emissions of fluorinated greenhouse gases (PFCs, HFCs and SF_6) were 1.2 million tonnes of carbon dioxide equivalents by 2017, which is 81% higher compared to 1990. This is mainly due to the replacement of ozone-depleting substances by greenhouse gases HFCs. However, the trend of emissions of HFCs is showing a stabilisation since 2009 and emissions have dropped by 1 % between 2016 and 2017. All reported fluorinated greenhouse gases account for 2.3% of total greenhouse gas emissions.

Table ES.1. Greenhouse gas emissions by gas (kt CO_2-eq.)

GREENHOUSE GAS EMISSIONS	1990	1995	2000	2005	2010	2015	2016	2017
CO_2 incl. LULUCF	21 283	26 307	16 290	20 528	7 159	-4 067	-3 623	-3 332
CO_2 excl. LULUCF	57 446	59 200	54 678	53 785	52 845	43 057	42 582	42 050
CH_4 incl. CH_4 från LULUCF	7 893	7 843	7 315	6 636	5 693	5 069	4 992	4 953
CH_4 excl. CH_4 från LULUCF	7 422	7 371	6 840	6 164	5 243	4 631	4 554	4 518
N_2O incl. N_2O från LULUCF	7 055	7 209	7 018	6 305	6 096	5 782	5 798	6 090
N_2O excl. N_2O från LULUCF	5 759	5 913	5 701	4 971	4 807	4 552	4 569	4 870
HFCs	6	136	770	1 110	1 136	1 132	1 149	1 138
PFCs	569	532	376	406	188	35	31	37
SF_6	102	135	119	152	63	53	57	47
NF_3	NO	NO	NO	NO	NO	NO	NO	NO
Ospecificerade HFCs and PFCs	NO	NO	NO	NO	NO	NO	NO	NO
Total (incl. LULUCF)	**36 908**	**42 163**	**31 888**	**35 137**	**20 336**	**8 005**	**8 405**	**8 933**
Total (excl. LULUCF)	**71 304**	**73 287**	**68 483**	**66 587**	**64 282**	**53 461**	**52 943**	**52 660**

Table ES.2. Greenhouse gas emissions by sector (kt CO_2-eq.)

GHG SOURCE & SINK CATEGORIES	1990	1995	2000	2005	2010	2015	2016	2017
1. Energy	52 293	53 925	49 128	48 033	47 147	37 888	36 900	36 632
2. Industrial Processes and Product Use	7 611	7 888	8 358	8 828	8 391	7 312	7 854	7 588
3. Agriculture	7 658	7 912	7 774	7 052	6 820	6 860	6 871	7 187
4. LULUCF	-34 396	-31 125	-36 595	-31 451	-43 947	-45 455	-44 538	-43 727
5. Waste	3 742	3 562	3 222	2 673	1 924	1 400	1 318	1 253
6. Other	NO	NO	NO	NO	NO	NO	NO	NO
Total (including LULUCF)	**36 908**	**42 163**	**31 888**	**35 137**	**20 336**	**8 005**	**8 405**	**8 933**

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

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. Greenhouse gas emissions are shown by sector in Table ES.2.

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 and product use	Environmental reports Direct contact with companies CO_2 Data from the European trading scheme (ETS) National data from the Products register at the Swedish Chemicals Agency, National statistics, and National experts
3	Agriculture	Official statistical reports Organisations and researchers
4	Land Use, Land Use Change and Forestry	Swedish University of Agricultural Sciences Swedish Forest Agency
5	Waste	Swedish Association of Waste Management The Swedish Forest Industries Federation Statistics Sweden Swedish Environmental Protection Agency Environmental reports

Emissions from the energy sector (CRF 1), including transport, were approximately 37 million tonnes of CO_2-equivalent in 2017, which corresponds to about 70% of the overall national greenhouse gas emissions. The trend for the period 1990-2017 show a general reduction in emissions of approximately 30%. This decrease is mainly due to a decrease in the use of oil for heating in residential, commercial and institutional buildings, included in "Other Sectors" (CRF 1A4). Emissions in "Other Sectors" have decreased by 74%, to approximately 2.9 million tonnes of CO_2-equivalent in 2017. Emissions decreased by 0.7% between 2016 and 2017 in the energy sector, primarily as a result of decreased emissions from transports while emissions from manufacturing industries and construction as well as fugitive emissions increased.

Greenhouse gas emissions from energy industries (CRF 1A1) were approximately 9.2 million tonnes in 2017, which is 8% lower compared to 1990. The energy industries are dominated by electricity and district heating production (CRF 1A1a) with emissions of 6.8 million tonnes of CO_2-equivalent in 2017, which is 14% lower than in 1990. Emissions from electricity and district heating production fluctuate over the years mainly due to the influence of weather conditions (temperature and precipitation). The emissions from electricity and district heating stays on the same level as in 2016, even though emissions from most fossil fuels categories decreases but at the same time there is an increase in emissions from industrial gases with 18 % between 2016 and 2017. Emissions from Refineries (CRF 1A1b) and Manufacture of solid fuels (CRF 1A1c) amounted to 2.4 million tonnes in 2017.

Emissions from manufacturing industries and construction (CRF 1A2) increased by 2 % in 2017 compared to the previous year. These emissions have decreased by 36% in 2017 compared to 1990, but generally fluctuate with production volumes that are closely related to the economic development. The decrease in emissions is mainly due to decreased use of oil products, which can partly be explained by a shift towards electricity and biofuels.

Emissions from the transport sector corresponds to one third of the national emissions of greenhouse gases. In 2017, emissions were approximately 16.6 million tonnes, of which approximately 15,5 million tonnes were from road transportation. Emissions from the transport sector decreased by 3% from 2016 to 2017 and were 13% lower 2017 compared to 1990. The lower emissions level can be explained by an increased share of renewable fuels and more fuel-efficient vehicles. Nevertheless, the emissions reductions have been dampened by an increased trend in the amount of traffic.

Greenhouse gas emissions from the industrial processes and product use (CRF 2) were 7.6 million tonnes CO_2-equivalent in 2017 (Table ES.2), representing approximately 14 % of the national emissions. Emissions from industrial processes and product use are predominantly carbon dioxide, followed by fluorinated greenhouse gases and nitrous oxide. Metal (iron and steel) and mineral industries (cement) are the major sources of emissions. The emissions from the sector were 3 % lower 2017 compared to 2016. The trend for the period 1990-2017 is stable and emissions were 0.3% lower in 2017 compared to 1990. Emissions from product use were significantly higher in 2017 compared to 1990, but show a stable trend since 2004.

In 2017, the aggregated greenhouse gas emissions from the agriculture sector (CRF 3) were about 7.2 million tonnes CO_2-equivalent, which corresponds to approximately 14 % of the total greenhouse gas emissions in Sweden, of which, about half were nitrous oxide and the second half methane. Emissions from the agriculture sector have decreased by almost 0.5 million tonnes CO_2-equivalents or a decrease by 6 % between 1990 and 2017. The decrease is due to several factors, such as reduction in number of animals (especially dairy cows and swine), reduced volumes of manure, improved manure management practices, lesser use of N-mineral fertilizers as well as reduced are of cropland. Between 2016 and 2017, emissions from the sector increased by 4.6 %, mainly due to increased use of N-mineral fertilizer, elevated emission of N_2O from organic soils and increased emissions from the cattle's digestion due to increased numbers of non-dairy-cows.

In 2017, the net removal in the sector land use, land-use change and forestry (LULUCF) was estimated to circa 44 million tonnes CO_2-equivalent. The majority of the net removals place in living biomass and mineral soils. The largest carbon pool is forest land. Forest land accounts for 63% of Sweden's land area. The net removal in forest land increased from about 38 million tonnes to about 44 million tonnes of carbon dioxide equivalents between 1990 and 2017.

Emissions from the waste sector (CRF 5) have decreased by about 67% compared to 1990. From 2016 to 2017, emissions have been reduced by 4.9 % due to continued reduced emissions from landfills. Emissions from the waste sector are dominated by methane gas from waste landfills. Methane emissions account for 76 % of emissions, while nitrous oxide emissions from wastewater treatment and biological treatment of solid waste account for 19 % and carbon dioxide emissions from waste incineration account for the rest. A ban has been introduced on landfill which has created a shift towards incineration of waste for energy recovery. Emissions from the incineration of waste for electricity and heat production are allocated to the energy sector and not to the waste sector. In 2017, emissions from the waste sector were 1.3 million tonnes of carbon dioxide equivalent, which corresponds to 2.4% of the total greenhouse gas emissions.

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

Indirect greenhouse gases (NO_X, NMVOC, CO and SO_2) are not included in the national total and are reported separately. They are shown in Table ES.4.

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

Gas	1990	1995	2000	2005	2010	2015	2016	2017
NO_X	282	252	217	185	157	133	129	125
NMVOC	359	269	225	209	181	154	148	147
SO_2	104	69	43	36	29	18	18	18
CO	1 075	932	663	529	455	385	386	385

Emissions of nitrogen oxides (NO_X) were about 125 kt in 2017. The energy sector accounts for 79 % of the total. The industrial processes and product use sector and the agriculture sector, mainly from agricultural soils, were responsible for about 11 % each. The total emissions of NO_X have declined by more than a half (56 %) since 1990 and had decreased by about 3 % compared to the previous year. This is mainly due to the tightening of the EU road vehicle emission regulation standards. The increased use of district heating and the "NO_X charge" in the early 1990s have also resulted in a reduction of emissions. A total of 147 kt of non-methane volatile organic compounds (NMVOCs) were emitted in 2017. About a half (44 %) of the emission comes from the industrial processes and product use sector. The energy sector and the agriculture sector contributed with 35 % and 21 %, respectively of the total emission in 2017. Emission of NMVOC has decreased sharply by 59 % since 1990. The emissions in 2017 decreased marginally compared to 2016. The largest reduction has occurred in the transport sector, in which emissions in 2017 decreased by 92 % compared to 1990 and by 4 % compared to 2016. Emissions of NMVOC have also decreased by 63 % from oil refineries and by 38 % from product use since 1990. The main reason behind the reduction of the emission is the introduction of stricter emission standards in the EU regulation for road vehicles and lower emissions from solvents.

Emissions of carbon monoxide (CO) have decreased by 64 % since 1990 and were around 385 kt in 2017. Emissions have been relatively constant between 2016 and 2017. About 92 % of CO emissions came from the energy sector, of which 22 % from the transport sector and 64 % from small-scale combustion in residential heating, premises and in the agricultural sector. Emissions of CO have fallen sharply following that new fuel-driven *vehicles sold* in Sweden have been equipped with *catalytic converters* that convert CO and unburned hydrocarbons to CO_2 and water vapor. Sulphur dioxide emissions (SO_2) were 18 kt in 1990 and have fallen by 83 % since 1990. Emissions have fallen by about 4 % between 2016 and 2017. More than half of SO_2 emissions (56 %) come from the industrial processes and product use sector, such as metal production and the pulp industry. The energy sector is responsible for 44 % of emissions in 2017, mainly from electricity and district heating production and manufacturing industries and construction. The long-term reduction of emissions is mainly due to a transition to lower sulphur fuels, as well as tax on sulphur in oil, coal introduced in 1991.

Summary in Arabic

مقدمة

إن التغيرات المناخية التي نشهدها في عصرنا الحالي يعود سببها إلى زيادة تراكيز غازات الدفيئة (CO_2, CH_4, N_2O, SF_6, PFC, HF) في الغلاف الجوي. لقد كانت هذه الغازات موجودة دائما وبشكل طبيعي في الغلاف الجوي ولكن بتراكيز قليلة. اظهرت البيانات والتحاليل الكيميائية للغلاف الجوي في العقدين الماضيين إزدياداً مضطرداً لتراكيز هذه الغازات مقارنةً عما كانت عليه في العقود الاخيرة. وبالرغم من وجود هذه الغازات دائما وبشكل طبيعي في الغلاف الجوي، فإن تراكيز بعضاً منها آخذة في الارتفاع نتيجة لإزدياد النشاط البشري متمثلاً في حرق المشتقات البترولية للحصول على الطاقة ومن خلال النشاطات الزراعية، والذي بدوره يفاقم من حدة ظاهرة الاحتباس الحراري.

ونتيجةً لذلك، وفي عام 1988 انشيء الفريق الحكومي الدولي المعني بتغير المناخ (IPCC) لمتابعة هذه الظاهرة. وبعد ذلك بعامين خرج الفريق بنتيجة مفادها أن التغيرات المناخية هي من صنع الإنسان وهي تمثل تهديداً عالمياً للبشرية. لقد كانت هناك الحاجة إلى اتفاق دولي للتعامل مع هذه المشكلة. لذا بدأت الأمم المتحدة مفاوضات لإنشاء الاتفاقية الإطارية بشأن تغير المناخ (UNFCCC)، والتي دخلت حيز التنفيذ عام 1994. كان الهدف من هذه الاتفاقية هو تحقيق استقرار، وعلى المدى الطويل، لتراكيز غازات الدفيئة في الغلاف الجوي وعند مستوى يمكن فيها تجنب التغيرات المناخية الضارة والتي تنشأ من صنع الإنسان. في عام 1997 وفي كيوتو، اليابان، تم التفاوض لإضافة أكثر البنود أهمية بالنسبة للاتفاقية وهو بروتوكول كيوتو، والذي يشمل على التزامات ملزمة للبلدان المدرجة في المرفق الأول من الاتفاقية لخفض انبعاثات هذه الدول من الغازات المسببة للاحتباس الحراري (غازات الدفيئة) إلى ما لا يقل عن 5% خلال 2008-2012 مقارنة مع سنة الأساس 1990. أما الفترة الثانية فقد بدأت في 1 يناير 2013 وسوف تنتهي في عام 2020. ويعتبر البند الاضافي لبروتوكول كيوتو للمناخ والذي تم الاتفاق عليه في خريف 2015 في باريس الأهم عندما وافقت دول العالم على اتفاق عالمي جديد بشأن المناخ. وبعد عام بالكاد فقد صادقت العديد من الأطراف على اتفاق باريس الأخير لكي يدخل حيز النفاذ. الفرق بين اتفاق باريس وبروتوكول كيوتو هو أن اتفاق باريس يضمن التزام كافة الأطراف وليس فقط الدول الغنية بهذا الاتفاق.

وفقا للمادتين 4 و 12 من اتفاقية الأمم المتحدة الإطارية بشأن تغير المناخ (UNFCCC)، يطلب من الأطراف أن تقدم سنويا قوائم الجرد الوطنية للانبعاثات البشرية المصدر بحسب مصادرها وعمليات إزاحتها بواسطة المصارف لجميع غازات الدفيئة غير الخاضعة لبروتوكول مونتريال. وينبغي أيضاً تقديم قوائم الجرد بما في ذلك الانبعاثات في نموذج الإبلاغ الموحد (CRF) وتقرير الجرد الوطني (NIR) National Inventory Report.

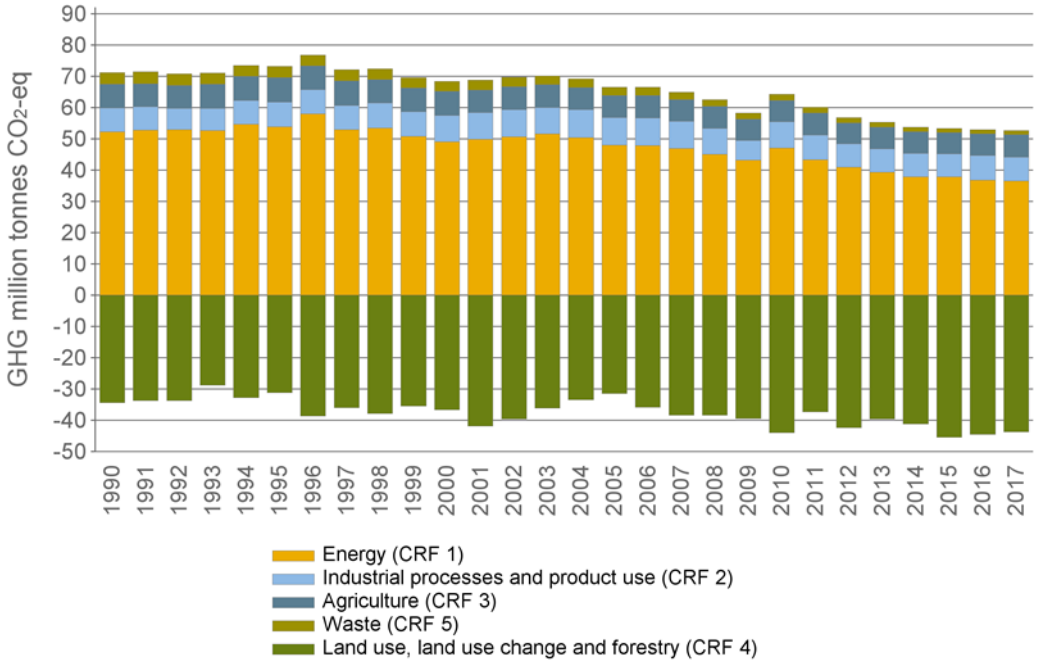
يشكل هذا التقرير (NIR submission 2019) جرداً سنويا لأنبعاثات غازات الدفيئة المباشرة (CO_2, CH_4, N_2O, HFC, PFC, SF_6) وغير المباشرة (SO_2، CO،NO_X، NMVOC) في الغلاف الجوي الناتجة من النشاطات البشرية في السويد لعام 2017 بالإضافة إلى معلومات عن قوائم الجرد لغازات الاحتباس الحراري لجميع السنوات من 1990 إلى 2017، بما في ذلك وصفا للطرق التحليل و معلومات أخرى متعلقة.

نظرة عامة على تقديرات انبعاثات غازات الدفيئة المباشرة واتجاهاتها

قوائم جرد غازات الدفيئة

تقديرات انبعاثات غازات الدفيئة واتجاهاتها ما بين الفترة 1990-2017 ملخصة في الرسم البياني أدناه. بلغ مجموع انبعاثات غازات الدفيئة في السويد لعام 2017 ما يقارب 53 مليون طن مكافيء محسوبة بما يعادلها من ثاني أكسيد الكربون، بإنخفاض بنحو 0.3 طن مقارنةً بعام 2016. وتراجعت الانبعاثات بنسبة حوالي

26% أو ما يزيد على 18 مليون طن بين عامي 1990 و 2017. وفي عام 2017، تم تقدير صافي امتصاص غاز ثاني أكسيد الكربون بواسطة الغابات والاراضي الحرجية بحوالي 44 مليون طن مكافئ ثاني أكسيد الكربون.



مقادير الانبعاثات الصادرة من القطاعات المختلفة في السويد ما بين 1990-2017 مقدرة بمليون طن مكافيء ومحسوبة بما يعادلها من ثاني أكسيد الكربون. يمثل قطاع تغيير إستخدام الأراضي والحراجة (LULUCF) بالمجمل قطاعاً لإمتصاص غاز ثاني أكسيد الكربون.

غاز ثاني أكسيد الكربون (CO_2)

بلغت انبعاثات CO_2 حوالي 42 مليون طن في عام 2017، منخفضاً بما يقارب 27% مقارنةً بعام 1990 .ويستحوذ قطاع الطاقة، بما في ذلك قطاع النقل، على أكثر من 85% من إجمالي الانبعاثات، لذا يعتبر هذا القطاع المصدر ألاكبر لغاز ثاني أكسيد الكربون في السويد. ويمثل هذا الغاز حوالي 80 بالمئه من الانبعاثات الإجمالية لغازات الدفيئة.

غاز الميثان (CH_4)

ينبعث غاز الميثان (CH_4) بشكل أساسي من النشاطات الزراعية ومواقع مكبات النفايات حيث يتكون غاز الميثان خلال عمليات الهضم للحيوانات المجترة وعمليات التخمر لروث هذه الحيوانات في المزارع. أما في قطاع النفايات فيتكون الميثان نتيجة تخمر النفايات العضوية. كان مجمل الإنبعاث في عام 2017 بحوالي 4.5 مليون طن مكافيء محسوبة بما يعادلها من ثاني أكسيد الكربون، منخفضاً حوالي 39% مقارنة مع عام 1990، ويرجع هذا الأنخفاض في المقام الأول إلى التدابير المنفذة في قطاع النفايات والزراعة والتي تحد من تكون الميثان من هذين القطاعين.

غاز أكسيد النيتروز (N_2O)

في عام 2017، بلغت انبعاثات أكسيد النيتروز (N_2O) حوالي 4.9 مليون طن مكافيء محسوبة بما يعادلها من ثاني أكسيد الكربون، منخفضاً بنسبة 15% مقارنة مع عام 1990. ينشأ هذا الغاز أساسا من قطاع

الزراعة وخصوصاً من تخمر روث حيوانات المزارع ومن خلال إنبعاث هذا الغاز من السماد العضوي وغير العضوي المستعمل لتحسين مستوى ألمحاصيل الزراعية. كما يتكون هذا الغاز خلال عمليات إحتراق الوقود المتعلقة في إنتاج الطاقة ومن خلال معالجة مياه الصرف الصحي والعمليات الصناعية. ويمثل القطاع الزراعي الجزء الأكبر من الانخفاض وذلك للتدابير المنفذة في القطاع للحد من إنبعاث هذا الغاز.

غازات الكربون المشبعة بالفلور

بلغ مجموع انبعاثات الغازات المفلورة (مركبات الكربون المشبعة بالفلور، ومركب سادس فلوريد الكبريت، SF_6) في عام 2017 ما يقارب من 1,3 طن مكافيء محسوبة بما يعادلها من ثاني أكسيد الكربون. القطاع الوحيد المسؤول عن هذه الانبعاثات هو قطاع الصناعة حيث تدخل مركبات الكربون المشبعة بالفلور في العديد من الصناعات مثل الاسفنج والمطاط الصناعي.

تقديرات الانبعاثات والإزالة لغازات الدفيئة من القطاعات المختلفة

قطاع الطاقة

تتأثر كميات الانبعاثات الناجمة من قطاع الطاقة بمعدل درجات الحرارة السنوية (شتاء بارد أو معتدل نسبياً) و معدل هطول الأمطار (وهذا يؤثر على معدل إنتاج الطاقة الكهرومائية) وحالة الاقتصاد (معدل الانتاج الصناعي وتأثره بالإنتعاش أو الركود). عموماً فإن اتجاه كميات الانبعاثات من قطاع الطاقه للفترة ما بين 1990-2017 يشير إلى إنخفاضً مستمر. في عام 2017 انخفضت انبعاثات الغازات المسببة للاحتباس الحراري بأكثر من الربع مقارنة بعام 1990 وذلك لانخفاض الانبعاثات الناجمة عن إنتاج الطاقة والنقل. لقد بلغ مجموع انبعاثات غازات الدفيئة من قطاع الطاقة بما في ذلك النقل لعام 2017 حوالي 36,6 مليون طن مكافيء محسوبة بما يعادلها من ثاني أكسيد الكربون. وهذا ما يعادل 70% من إجمالي الانبعاثات. وأصبحت كميات الانبعاثات الصادرة من قطاع المواصلات (حركة المرور على الطرق) عام 2017 تعادل تقريباً مستويات الانبعاثات الصادرة عن هذا القطاع لعام 1990.

انخفضت كميات ثاني أكسيد الكربون من إنتاج الكهرباء وطاقة التدفئة عام 2017 بمقدار 8% مقارنةً مع عام 1990 بالرغم من إزدياد الحاجة للطاقة خلال هذه الفترة ويرجع هذا إلى الاعتماد بشكلٍ أكبر على الطاقة الكهرمائية والطاقة النووية (نظراً لعدم إنتاج أية انبعاثات من هذه المصادر) وهذا أدى بدوره إلى إنخفاض استخدام الوقود الأحفوري.

قطاع الصناعة

يعتبر ثاني أكسيد الكربون أبرز غازات الدفيئة الذي ينبعث من قطاع الصناعة تليه الغازات المفلورة، وأكسيد النيتروز وغاز والميثان بنسبٍ ضئيلة. معظم هذه الانبعاثات من هذا القطاع تصدر أساسا من العمليات الصناعية المتعلقة من إنتاج الحديد والصلب والمعادن في السويد. قدرت الانبعاثات الإجمالية من هذا القطاع في عام 2017 ما يقرب من 7.6 مليون طن مكافيء محسوبة بما يعادلها من ثاني أكسيد الكربون، مما يجعل هذا القطاع يمثل ما يقرب من 14% من اجمالى الانبعاثات الوطنيه. منذ عام 1990 وكميات الانبعاثات من قطاع الصناعة في تذبذب وذلك نتيجة لتذبذب حجم الإنتاج والذي يتأثر بحالة الاقتصاد العالمي لكنها انخفضت بشكل ضئيل منذ عام 1990.

قطاع الزراعة

يشكل قطاع الزراعة أكبر مصدر لانبعاثات غاز الميثان وغاز أكسيد النيتروز. في عام 2017، بلغ مجموع انبعاثات هذا القطاع حوالي 7.2 مليون طن مكافيء محسوبة بما يعادلها من ثاني أكسيد الكربون. ويشكل أكسيد النيتروز وغاز الميثان 52% و 46% على التوالي, بينما تبلغ حصة غاز ثاني اكسيد الكربون حوالي 2% من هذا القطاع. لقد انخفضت الانبعاثات لعام 2017 بنسبة حوالي 6% مقارنة بعام 1990 وذلك يعود

إلى إنخفاض عدد المواشي في السويد وانخفاضإستخدام الأسمدة الصناعية في الزراعة. يتكون غاز الميثان أساساً من خلال عمليات الهضم للحيوانات المجترة وكذلك من خلال عمليات التخمر لروث الماشية. أما انبعاثات أكسيد النيتروز فتنشأ من تبخر هذا الغاز من روث الحيوانات وكذلك نتيجة لإستخدام الأسمدة العضوية والصناعية وزراعة المحاصيل المثبتة للنيتروجين. وتأتي نصف هذه الانبعاثات من الأراضي الزراعية.

قطاع تغيير إستخدام الأراضي والحراجة (LULUCF)

تتميز السويد باحتوائها على مساحات واسعة من الغابات والاحراج. في عام 2017 قدر صافي إزالة ثاني أكسيد الكربون (بواسطة إمتصاص الأشجار لغاز ثاني أكسيد الكربون والتربة) من قطاع تغيير استخدام الأراضي والحراجة (LULUCF) بحوالي 44 مليون طن. وقد انخفض صافي الإزالة عام 2017 بشكل ملحوظ مقارنةً مع 2016.

قطاع النفايات

يهيمن غاز الميثان على الغازات الاخرى التي تصدر عن قطاع النفايات حيث بلغت انبعاثات الميثان في عام 2017 بنحو 76% من إجمالي انبعاثات هذا القطاع. في حين بلغت انبعاثات أكسيد النيتروز من معالجة مياه الصرف الصحي حوالي 19% وانبعاثات ثاني أكسيد الكربون الناتجة عن حرق النفايات نحو 5%. وفي عام 2017 كانت مجموع الانبعاثات من هذا قطاع ما يقرب من 1.3 مليون طن مكافيء محسوبة بما يعادلها من ثاني أكسيد الكربون. وتشكل هذه الكمية حوالي 2% من إجمالي انبعاثات غازات الدفيئة الوطنية. وبالمقارنة مع عام 1990 فقد انخفضت الانبعاثات بنحو 67% وذلك نتيجة لجمع غاز الميثان من مكبات النفايات حيث يتكون هذا الغاز خلال عمليات التخمر للنفايات العضوية. وقد لعبت مجموعة من القوانين المحلية دوراً بارزاً للحد من انبعاثات الميثان من النفايات، كفرض حظراً على التخلص مباشراةً من النفايات العضوية في المكبات. كما أن فرض ضريبة على طمر النفايات كان له دورا رئيسيا في إنخفاض الانبعاثات بشكل كبير انخفضت بنسبة الانبعاثات 5% عام 2017 مقارنةً بالعام 2016.

نظرة عامة على تقديرات انبعاثات غازات الدفيئة الغير المباشرة واتجاهاتها

لإلقاء نظرة على مقاديرانبعاثات غازات الدفيئة الغير المباشرة واتجاهاتها ما بين الفترة 1990-2017 (أنظر إلى Figure 2.44, 2.46, 2.48, 2.50).

أكاسيد النيتروجين (NO_X)

قدرت كميات انبعاثات أكاسيد النيتروجين في السويد عام بحوالي 125 كيلوطن منخفضاً بحوالي النصف مقارنة بعام 1990. كما انخفضت انبعاثات أكاسيد النيتروجين من حركة السير على الطرق بنسبة أكثر من 69% بين عامي 1990 و 2017. تعتبر كلاً من حركة السير على الطرق في المدن والمركبات النقل الكبيرة والنقل البحري وصناعة الكهرباء والتدفئة من أكبر مصادر انبعاثات أكاسيد النيتروجين. ونظراً لمساهمة حركة السير على الطرق الكبير لهذه الانبعاثات فقد أدخلت في أواخر الثمانينات من القرن الماضي الكثير من التعديلات التكنولوجية على المركبات وما رافقها من معايير أكثر صرامة للحد من هذه الانبعاثات حيث أسهمت هذه الاجراءت إلى خفض كبير لمستويات أكاسيد النيتروجين في السويد. وقد أدت زيادة استخدام التدفئة المركزية المعتمدة على الوقود في أوائل تسعينات القرن الماضي إلى سن قانون يعرف "بضريبة iنبعاثات أكاسيد النيتروجين" ونتيجة لهذا فقد إنخفضت انبعاثات أكاسيد النيتروجين من قطاع الطاقة بشكل كبير.

غاز أول أكسيد الكربون (CO)

يتكون غاز أول أكسيد الكربون من خلال عمليات حرق الوقود الاحفوري والعضوي في قطاع الطاقة مثل صناعة الطاقة والتدفئة وكذلك أثناء عملية الإحتراق في محركات المركبات. انخفضت انبعاثات أول أكسيد

الكربون من 1.1 مليون طن في 1990 إلى 0.38 مليون طن في عام 2017 بمقدار 64%. ويصدر عن قطاع الصناعة معظم مجموع إنبعاثات أول أكسيد الكربون، حيث ينتج من قطاع النقل والمواصلات، الذي ينضوي تحت قطاع الطاقة، بما قيمة الخمس من هذه الانبعاثات.

المركبات العضوية المتطايرة (NMVOC)

قدرت كميات انبعاثات المركبات العضوية المتطايرة عام 2017 بحوالي 147 كيلوطن، بانخفاض يزيد عن النصف مقارنة بعام 1990. تعتبر وسائل النقل على الطرق المساهم الرئيسي في انبعاثات المركبات العضوية المتطايرة. كما أن عمليات حرق الحطب للتدفئة المنزلية واستخدام المذيبات في المنتجات الصناعية كالدهانات تؤدي إلى إنبعاث المركبات العضوية المتطايرة وبنسبٍ متفاوتة. وقد أسهمت المعايير البيئية الغير إلزامية المتبعه في تقنيات مواقد الحطب الحديثة إلى خفض هذه الانبعاثات بشكل محسوس.

غاز ثاني أكسيد الكبريت (SO_2)

انخفضت انبعاثات ثاني أكسيد الكبريت من 104 كيلوطن في عام 1990 إلى ما يقرب من 18 كيلوطن في عام 2017 أي إنخفاضاً بنسبة 83% تقريبا. يأتي معظم ثاني أكسيد الكبريت من قطاعات الطاقة والنقل والصناعة. ويرجع الفضل لإنخفاض انبعاثات ثاني أكسيد الكبريت الكبيرة أساسا إلى الإنتقال لإستخدام لأنواع الوقود المنخفض الكبريت بشكلٍ عام كوقود المركبات أو وقود التدفئة. كما أن فرض ضريبة على الوقود الذي يحتوي على نسبٍ عالية من الكبريت عام 1991 ساهم من الحد من هذه الانبعاثات.

Summary in French

Introduction
Les gaz à effet de serre ont toujours été présents dans l'atmosphère, mais la concentration de plusieurs d'entre eux a significativement augmenté en raison de l'activité humaine, ce qui a intensifié l'effet de serre. Dans ce rapport d'inventaire national sont presentées les émissions de gaz à effets de serre directes de CO_2, CH_4, N_2O, HFC, PFC, SF_6 et NF_3 ainsi que les émissions indirectes de NO_x, CO, COVNM et SO_2 pour la Suède sur la période 1990 à 2017. Les méthodes employées, les sources des données, les incertitudes, le contrôle qualité (QA/QC) et l'analyse de tendances sont décrites en accord avec les lignes directrices 2006 du GIEC ainsi que les compléments ultérieurs. Les données électroniques sur les émissions, sur les activités et sur les facteurs d'émission sont fournies dans le format d'inventaire commun (CRF) tel que demandé par la CCNUCC. La Suède suit par ailleurs des règles de confidentlialité qui font que certaines données des catégories CRF1 et CRF2 ont été classées avec la clé de notation Classified (C). La Suède travaille pour limiter l'étendue de la confidentialité de ces données d'inventaire.

L'ensemble des émission directes de gaz à effet de serre en Suède sont à consulter par gaz (tableau ES.1) et par secteur (tableau ES.2).

Résumé des émissions de gaz à effet de serre en Suède, par gas
Les émissions totales de gaz à effet de serre en Suède, hors secteur UTCATF (utilisation des terres, changement d'affectation des terres et foresterie), étaient de 52,7 millions de tonnes en 2017, ce qui est une baisse de 0,5% par rapport à 2016. Les émissions ont diminué de 27% entre 1990 et 2017.

En 2016, l'absorption nette au sein de l'utilisation des terres, changement d'affectation des terres et foresterie UTCATF est resté à un niveau relativement élevé (environ 40 millions de tonnes) et à environ 40% de plus par rapport à son niveau en de 1990 car la croissance forestière a été supérieure à la récolte.

Les émissions de dioxide de carbone (CO_2) étaient de 43 millions de tonnes ce qui représente 80% des émissions de GES en Suède. Par rapport à 1990 ces émissions ont baissées de 26%. Le secteur de l'énergie, y compris le transport, représente près de 86% des émissions totales de dioxyde de carbone.

Les émissions de méthane (CH_4) proviennent principalement de l'agriculture et des sites d'enfouissement, et se chiffraient à environ 4,5 millions de tonnes équivalent CO_2 en 2017, soit 9% du total. Depuis 1990, les émissions ont diminué d'environ 39%, principalement en raison des mesures mises en œuvre dans les secteurs des déchets et de l'agriculture.

En 2017, les émissions globales de protoxyde d'azote (N_2O) étaient d'environ 4,9 millions de tonnes exprimées en équivalent CO_2, soit 9% du total, en baisse d'environ 15% par rapport à 1990. Les émissions d'oxyde d'azote proviennent principalement de l'application d'engrais azotés dans le secteur agricole (environ 78%), mais aussi du domaine de l'énergie, le traitement des eaux usées et les procédés industriels et l'utilisation des produits. Les procédés industriels, l'usage

de produits et le secteur agricole expliquent en grande partie la baisse de ces émissions.

Les émissions totales de gaz fluorés (PFC, HFC et SF6) étaient en 2017 1,2 Mt exprimé en équivalent carbone, soit 2,3% du total. Ces émissions ont augmentées de 81% par rapport à 1990. prinicipalement dû au remplacement des substances destructeurs de la couche d'ozone par les HFC. Cependant, les émissions de HFC se sont stabilisées depuis 2009 à la suite d'unde nouvelle directive européenne introduite en 2006.

Les émissions indirectes de gaz à effet de serre somt estimées à 1 millions de tonnes calculés en équivalent CO_2. Elles sont en baisse de 63% depuis 1990. Les émissions de CO représentent 57% du total.

Résumé des émissions de gaz à effet de serre en Suède, par secteur
Les émissions du secteur de l'énergie (CRF 1), y compris le transport, étaient d'environ 37 Mt ou équivalent CO_2 en 2017, ce qui correspond à environ 70% des émissions nationales totales de gaz à effet de serre. On observe une diminution de 30% sur la période 1990-2017, principalement dûe à une diminution de l'utilisation du pétrole pour le chauffage dans le secteur résidentiel, commercial et institutionnel, inclus dans les « autres secteurs » 1A4. Dans ce secteur, les émissions ont diminuées de 74% pour atteindre environ 2,9 millions de tonnes équivalent CO_2 en 2017. Entre 2016 et 2017, il y a eu une réduction de 0,7% des émissions dans le secteur de l'énergie, principalement en raison d'une réduction des émissions provenant des transports.

Les émissions de gaz à effet de serre du secteur des industries énergétiques (CRF 1A1) étaient d'environ 9,2 millions de tonnes en 2017, soit 8% de moins qu'en 1990. Les industries de l'énergie sont dominées par l'électricité et de chaleur (CRF 1A1A) avec des émissions de 6,8 millions de tonnes équivalent CO_2 en 2017, soit 14% de moins qu'en 1990. Les émissions provenant de l'électricité et la production de chaleur fluctuent au fil des années, principalement en raison de l'influence des conditions météorologiques (température et précipitations), mais ces émissions ont une tendance à la baisse. Les émissions de l'électricité et de la chaleur sont stables 2017. Les émissions provenant des raffineries (CRF 1A1b) et de la fabrication de combustibles solides (CRF 1A1c) s'élevaient à 2,4 Mt en 2017.

Les émissions des industries manufacturières et de la construction (CRF 1A2) (un sous-secteur du secteur de l'énergie) ont augmenté de 2% en 2017 par rapport à l'année précédente. Ces émissions varient en fonction des volumes de production, qui sont eux-mêmes dépendants de la conjoncture économique. Cependant, la tendance générale montre une diminution de 36% par rapport à 1990, principalement du fait d'une diminution de l'utilisation des produits pétroliers, en partie expliquée par un transfert vers l'électricité et les biocarburants.

Les émissions du secteur des transports représentent environ un tiers des émissions nationales de gaz à effet de serre. En 2017, les émissions étaient environ 16,6 millions de tonne, 3% inférieur à celui de 2016 et 13% plus faibles par rapport au niveau de 1990. Une plus forte utilisation des carburants renouvelables et des véhicules économes ont compensé l'augmentation du trafic et contribué à cette tendance à la baisse.

En 2016, les émissions provenant des procédés industriels et de l'utilisation de produits (CRF 2) s'élevaient à 7,6 millions de tonnes équivalent CO_2, ce qui représente environ 14% des émissions nationales. Les émissions de ce secteur sont dominés par du dioxyde de carbone, suivi par les gaz à effet de serre fluorés et de l'oxyde nitreux. Les industries des métaux (fer et acier) et des minéraux (ciment) sont les principales sources d'émissions. Les émissions du secteur CRF 2 ont augmenté de 3% en 2017 par rapport à 2016. La tendance pour la période de 1990 à 2017 montre une stabilisation des émissions. Les émissions provenant de l'utilisation des produits étaient significativement plus élevées en 2017 qu'en 1990, mais montrent une stabilisation depuis 2004.

Le secteur de l'agriculture (CRF 3) est la plus grande source d'émissions d'oxyde nitreux et de méthane. En 2016, le secteur a contribué avec 7,2 millions de tonnes équivalent CO_2 ou 14% du total national. Environ la moitié des émissions provient du N_2O et l'autre moitié du CH_4. Les émissions du secteur ont diminué de 6% par rapport à 1990. En 2017, les émissions globales du secteur agricole a légèrement augmenté de 6%.

En 2016, le stockage de carbone net dû à l'Utilisation des Terres, le Changement d'Affectation des Terres et la Foresterie (UTCATF) a été estimé à environ 44 millions de tonnes équivalent . 63 % de la superficie suédoise est couverte de forêts. La taille et la variabilité des absorptions nettes dans le secteur UTCATF est principalement dû à la variation des stocks de carbone dans les terres forestières, et les changements dans la biomasse vivante constituent la majeure partie de ces changements du fait du changement des stocks de carbone dans sols minéraux. Le stockage net est influencé par les récoltes et les perturbations naturelles telles que les tempêtes. La plus grande source d'émissions provient des terres cultivées des établissements humains.

PART 1: ANNUAL INVENTORY SUBMISSION 2018

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, through the secretariat, shall include emissions and removals in the Common Reporting Format (CRF) and a National Inventory Report (NIR). The submission is prepared in accordance with the reporting guidelines 24/CP.19 under the UNFCCC.

This report is also the official report under the Kyoto Protocol and is prepared in accordance with the KP guidelines decided, 1/CMP.8, 2/CMP.8, 3/CMP.11, 15/CMP.1 and 2/CMP.7.

This report constitutes Sweden's NIR for submission 2019. The report contains information on Sweden's inventories for all years from 1990 to 2017 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, the Swedish national targets and a greenhouse gas (GHG) inventory. 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

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 the concentrations of several of these gases are rising as a result of human activity. This intensifies 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 the change other than as the result of anthropogenic emissions of greenhouse gases (i.e. emissions resulting from human activity).

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 (hydrofluorocarbons). HFCs are used instead of the ozone layer depleting CFCs (freons) in refrigerators and other applications.

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

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

Following the 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. Currently, 197 Parties (including the EU as one party) have ratified the UNFCCC. The long-term goal of the convention 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 to date, the Paris agreement, was negotiated in France in 2015. The agreement sets out a global action plan to put the world on track to avoid dangerous climate change by limiting global warming to well below 2 degrees and to pursue efforts to limit the temperature increase even further to 1.5 degrees. Before the Paris agreement the most important addition to the convention was negotiated in1997 in Kyoto, Japan. The Kyoto Protocol involved binding obligations for the Annex I countries (including all EU Member States and other industrialized countries).

1.1.2 Greenhouse gas inventories

The inventory covers anthropogenic emissions of direct greenhouse gases CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, NF_3 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 the climate in different ways. Indirect greenhouse gas emissions are not included in the total. Ozone (O_3) is also a greenhouse gas, but it is not necessary to report on O_3 separately since it is formed by the chemical reactions of nitrogen oxides, hydrocarbons and/or carbon monoxide. The estimated emissions and removals of greenhouse gases are calculated according to the UNFCCC reporting guidelines (decision 24/CP.19).

The requirements 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 additional rules for how emissions and removals should be estimated, reported and reviewed. Emissions of the direct greenhouse gases CO_2, N_2O, CH_4, HFCs, PFCs, SF_6 and NF_3 are calculated as CO_2-eq. and aggregated to a national total. Emissions of the indirect greenhouse gases NO_X, CO, NMVOC and SO_2 are reported, but not included in the total.

When a method used to estimate emissions or removals is improved, a need to recalculate the whole time series arises in order to maintain consistency. This means that already reported data can be revised in subsequent submissions.

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 according to the requirements under the Kyoto Protocol. The inventory for Kyoto Protocol activities encompasses emissions and 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. Forest Management covers a major part of the Swedish land area whereas Afforestation, Reforestation and Deforestation are quite uncommon relative to the total land area but important when it comes to reported emissions and removals.

Forest Management and Afforestation/Reforestation and Deforestation reporting under the Kyoto Protocol is to a large extent harmonized with the UNFCCC-reporting of Forest land and land converted to and from Forest land. Small

discrepancies occur regarding the accumulation of reported land areas as described in section 10.

In addition to the reporting of carbon pool changes, direct N_2O emissions from N fertilization, non- CO_2 emissions from drained organic soils, emissions from mineralisation and emissions (N_2O and CH_4) from forest fires are reported under relevant activities. Forest fires – both natural and wildfires – are uncommon and, this far, has not been registered on afforestation land.

This report also contains information about international credits under the Kyoto Protocol.

1.1.4 Sweden's commitment under the first commitment period of the Kyoto Protocol and the EU Burden Sharing decision

The Swedish commitment for the first commitment period of the Kyoto Protocol (2008–2012) was the same as the Swedish commitment under the EU burden sharing. The target was 104 % of the base year's emissions as an average for the years 2008–2012, excluding LULUCF. The base year was set to 1990 for all greenhouse gas emissions except fluorinated greenhouse gases for which 1995 was chosen. The emissions of the base year were 72.2 Mt CO_2-eq. when the assigned amount was determined.

Sweden's assigned amount for the first commitment period was set to 75 million units per year (one unit equals one t of CO_2-eq.), as an average for 2008–2012, amounting to 375 million units for the whole period.

1.1.5 Sweden's commitment under the second commitment period of the Kyoto Protocol and the EU Effort Sharing decision

For the second commitment period of the Kyoto Protocol, the EU pledged its 2020 climate and energy package at the eighth Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (CMP.8). In the climate and energy package, the EU commits to decrease greenhouse gas emissions by 20 % by 2020 compared with 1990 year's levels.

The climate and energy package is a combination of the EU ETS – governed by EU Directive 2003/87/EU – and the Effort Sharing decision – governed by EC decision 406/2009/EC. The climate and energy package sets a target for the EU ETS of a reduction of greenhouse gas emissions by 21 % compared with 2005 year's level and under the Effort Sharing decision the reduction for EU jointly is 10 % compared to 2005.

The joint target under the Effort Sharing decision is split among the EU Member States and the Swedish target is a reduction of 17 % compared to 2005. For KP-LULUCF every member state has a commitment. Sweden has chosen to account only for the mandatory activities under article 3.3, Afforestation/Reforestation and Deforestation and article 3.4, Forest Management.

1.1.6 National emission targets

1.1.6.1 THE SWEDISH TARGET FOR 2045

In June 2017, the Riksdag adopted a proposal on a climate policy framework (Govt. Bill 2016/17:146) for Sweden which will give Sweden an ambitious, long-term and stable climate policy. The climate policy framework consists of a climate act, new climate targets and a climate policy council. For more information about the climate policy framework, see Sweden's Seventh National Communication on Climate Change.

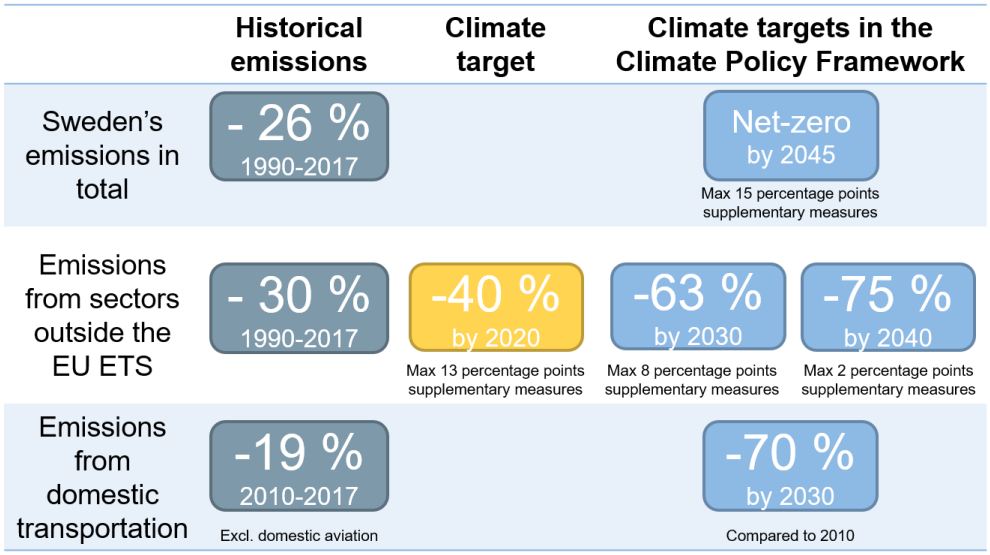


Figure 1.1 – Sweden's national targets

Targets

- By 2045, Sweden is to have no net emissions of greenhouse gases into the atmosphere and should thereafter achieve negative emissions. This means emissions from activities in Swedish territory are to be at least 85 % lower by 2045 compared with 1990.
- Emissions in Sweden outside of the EU ETS should, by 2030, be at least 63 % lower than emissions in 1990, and by 2040 at least 75 % lower. To achieve these targets by 2030 and 2040, no more than 8 and 2 percentage points, respectively, of the emissions reductions may be realised through supplementary measures.
- Emissions from domestic transport are to be reduced by at least 70 %by 2030 compared with 2010. Domestic aviation[1] is not included in the goal since this subsector is included in the EU ETS.

Supplementary measures may count towards achieving these goals. Supplementary measures are such as increased uptake of carbon dioxide in forests and land, climate investments in other countries and negative emissions (for example bio-CCS). International accounting guidelines will be followed in order to account for these measures.

[1] The emissions only includes CO_2.

1.1.6.2 THE SWEDISH TARGET FOR 2020

To provide a clear structure for environmental efforts in Sweden, the Riksdag has adopted 16 environmental quality objectives. One of these, Reduced Climate Impact, forms the basis for climate change action in the country. Current climate policy is also set out in two Government Bills, entitled *An Integrated Climate and Energy Policy*, passed by the Riksdag in June 2009 (Govt. Bills 2008/09:162 and 163). The first of these Bills sets a national milestone target for climate, calling for a 40 % reduction in emissions by 2020 compared with 1990. If the target in 2020 is met, greenhouse gas emissions from the non-ETS sector would be around 20 million tonnes of carbon dioxide equivalent lower than in 1990. This target applies to activities not included in the EU Emissions Trading System and does not include the LULUCF sector.

1.2 Institutional arrangements

Under Article 5 of the Kyoto Protocol each party in Annex 1 has to introduce a national system for estimating anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol by 1 January 2007. The Swedish National system for the GHG inventory was established in 2006 in accordance with 19/CMP.1, 20/CP.7 and decision 280/2004/EC. The national system has to ensure the function of all the institutional, legal and procedural arrangements required to calculate emissions and removals of greenhouse gases. In 2013, EU decision No. 280/2004/EC was replaced by the Monitoring Mechanism Regulation 525/2013/EC. The Monitoring Mechanism Regulation has the same demands for national systems as the Monitoring Mechanism decision.

The Swedish national system came into force on 1 January 2006 and its aim is to ensure that climate reporting to the secretariat of the Convention (UNFCCC) and the European Commission complies with specified requirements. This means, among other things,

- estimating and reporting anthropogenic GHG emissions and removals in accordance with the Kyoto Protocol,
- assisting Sweden in meeting its commitments under the Kyoto Protocol,
- facilitating the review of submitted information,
- ensuring and improving the quality of the Swedish inventory and
- guaranteeing that submitted data is officially approved.

The national system ensures annual preparation and reporting of the national inventory and of supplementary information in a timely manner and that the inventory fulfils all quality criteria, i.e. is transparent, accurate, consistent, comparable and complete.

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

1.2.1 Legal arrangements

The legal basis for Sweden's national system is provided by the Ordinance on Climate Reporting (2014:1434), which describes the roles and responsibilities of the relevant government agencies in this area. The ordinance ensures that sufficient capacity is available for reporting. The previous ordinance concerning climate reporting (2005:626) was updated and expanded to fulfil the reporting requirements under the EU Monitoring Mechanism Regulation 525/2013/EC. It also includes other improvements needed on the national level. The new ordinance came into force in December 2014, superseding the previous ordinance.

Supplemental to the new ordinance, formal agreements between the Swedish Environmental Protection Agency and other national agencies have been signed, listing in detail what is required regarding content and timetable from each responsible agency.

Sweden also has legislation indirectly supporting climate reporting efforts by providing a basis for estimating greenhouse gas emissions and removals.

Environmental reports are submitted under the Environmental Code (SFS 1998:808), and the Official Statistics Act (SFS 2001:99) imposes an obligation for large industries to submit annual data. In addition, government agencies in Sweden must comply by the Information and Secrecy Act (SFS 2009:400).

The General Statistics Act (SFS 2001: 99) and the associated Ordinance (2001:100) Concerning Official Statistics impose an obligation on companies and other organizations to submit annual data. The data then serve as a basis for estimating greenhouse gas emissions and removals in several sectors.

According to Directive 2003/87/EC and national Act (2004:1199) on emission trading, emission data for plants included in the emission trading system should be reported annually. These data are used as a supplementary source within this greenhouse gas inventory.

1.2.2 Institutional arrangements

Preparing the annual inventory and other reports is done in collaboration between the Ministry of the Environment and Energy, the Swedish Environmental Protection Agency and other government agencies and consultants. Sections 13-27 of the Ordinance on Climate Reporting (2014:1434) describe the tasks of the government agencies in the context of the yearly inventory and reporting activity. The illustration in Figure 1.1 and Table 1.2 and the associated text below describe in broad terms which organizations are involved in the work of compiling documentation for the yearly inventory report and for other reporting to the European Commission and the UNFCCC. Depending on the role of the government agencies in climate-reporting activity, this responsibility may range for example from supplying data and producing emission factors/calorific values to carrying out calculations to estimate emissions. Agencies that have a responsibility to participate in the national peer review are indicated by red text in Figure 1.2. Agencies that was added to formally participate from submission 2015 and onwards are indicated *in italics*. In addition to what is described in the Ordinance, the Swedish Environmental Protection Agency (Swedish EPA) engages the SMED consortium as consultants to conduct the greenhouse gas inventory.

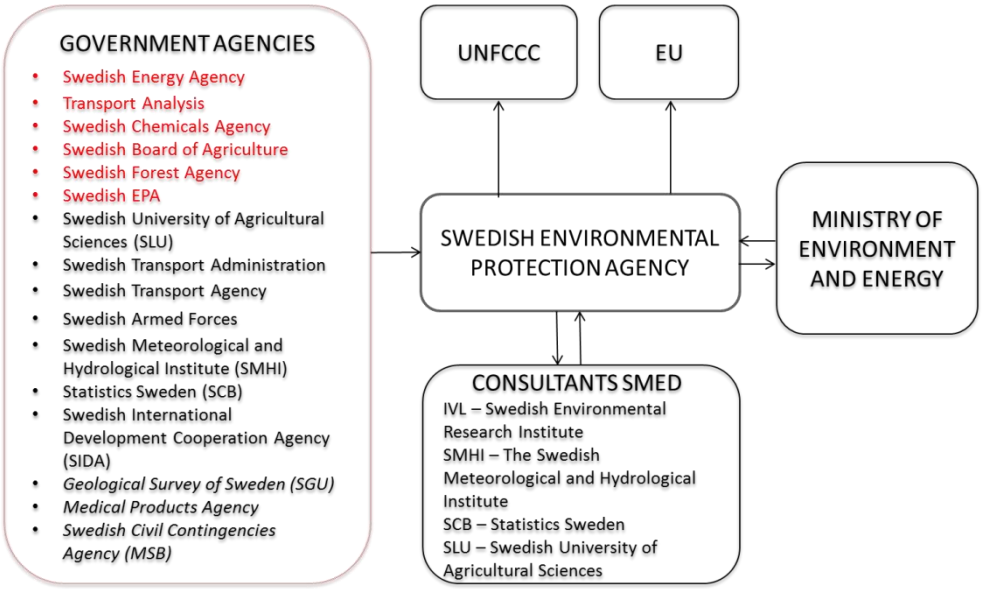


Figure 1.2. The Swedish national system on climate reporting

To be able to report according to decision 24/CP.19 and IPCC methodology guidelines from 2006 and in accordance with 525/2013/EC the national system has been enlarged by three governmental agencies; the Medical Products Agency, the Swedish Civil Contingencies Agency and the Geological Survey of Sweden.

1.2.2.1 SINGLE NATIONAL ENTITY

The Swedish Ministry of the Environment and Energy is the single national entity and has overall responsibility for the inventory.

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1.2.2.2 SWEDISH EPA RESPONSIBILITIES

The Swedish EPA is responsible for co-ordinating the activities for producing the inventory, maintaining the national system and also for the final quality control and quality assurance of the inventory.

The Swedish EPA sends the inventory to Ministry of the Environment and – on behalf of the Ministry of Environment – submits the inventory to the EU and to the UNFCCC. The Swedish EPA is also responsible for making the greenhouse gas inventory available to the public. The National inventory focal point at the Swedish EPA is Ms. Frida Löfström.

1.2.2.3 AGENCIES RESPONSIBILITIES

Agencies responsibilities according to Ordinance on Climate Reporting (2014:1434) are described in Table 1.1 below.

Table 1.1. Agencies responsibilities according to Ordinance on Climate Reporting (2014:1434). Only the Agencies involved in the GHG inventory are included.

Sector	Data and documentation provided by	Peer review conducted by
Energy	Swedish Energy Agency, the Swedish Transport Administration, the Swedish Transport Agency, Transport Analysis, the Swedish Armed Forces.	Swedish Energy Agency (energy sector excluding transports) Transport Analysis (transports)
Industrial Processes and Product Use	Swedish Chemicals Agency, Medical Products Agency.	The Swedish EPA (CO_2, CH_4 and N_2O) Swedish Chemicals Agency
Agriculture	Swedish Board of Agriculture, Statistics Sweden (SCB).	The Swedish Board of Agriculture
Land Use, Land-Use Change And Forestry Sector	Swedish University of Agricultural Sciences (SLU), Statistics Sweden (SCB), the Swedish Forest Agency, the Swedish Meteorological and Hydrological Institute (SMHI), the Swedish Board of Agriculture, Swedish Civil Contingencies Agency (MSB), the Geological Survey of Sweden (SGU).	Swedish Forest Agency The Swedish Board of Agriculture (agriculture related parts)
Waste	The Swedish EPA	The Swedish EPA – another unit, not the one responsible for data.

The Swedish Energy Agency also assists the Swedish EPA by providing information regarding flexible mechanisms and the national register.

1.2.2.4 THE SMED CONSORTIUM

The Swedish EPA engages consultants with documented expert skills to conduct the inventory in the area of climate change. During the spring of 2005, the Swedish EPA completed a negotiated procurement of services under the terms of the Public Procurement Act. After the procurement had been completed, a framework contract was signed with the consortium Swedish Environmental Emissions Data (SMED)[2], consisting of the Swedish Meteorological and Hydrological Institute (SMHI), Statistics Sweden (SCB), the Swedish University of Agricultural Sciences (SLU) and the Swedish Environmental Research Institute (IVL). The contract between the Swedish EPA and SMED did run during nine years and covered the whole first commitment period under the Kyoto Protocol.

During 2014 the contract with the consortium SMED was prolonged for another period (2015 – 2022). The structure of the consortium is a little bit different from the previous period with agency agreements for the national agencies (SMHI, SCB and SLU) and a negotiated procurement of services under the terms of the Public Procurement Act for the Swedish Environmental Research Institute (IVL).

SMED receives data and documentation from responsible authorities as described above (see Table 1.1) and produces the data and documentation in the Swedish

[2] http://www.smed.se/

inventory except for the trend section in the NIR (Swedish EPA) and the supplementary information under KP about the Registry and the KP flexible mechanisms (Swedish Energy Agency).

The regular inventory work is organized as a project involving all SMED organizations. The project is run by a project management team with one person from each organization. Statistics Sweden is main responsible for the energy sector, the agriculture sector and parts of the waste sector, but is also involved in industrial processes since these are closely connected to the energy sector. The Swedish University of Agricultural Sciences is responsible for the LULUCF sector. The Swedish Environmental Research Institute is main responsible for the industrial process and product use sector and also parts of the waste sector and energy sector. The Swedish Meteorological and Hydrological Institute is main responsible for production of gridded emission data. In addition to the ordinary inventory, SMED also conducts development projects necessary for improving the inventory on behalf of the Swedish EPA.

1.3 Inventory planning, preparation and management

The present Swedish greenhouse gas inventory and KP-LULUCF inventory was compiled according to the recommendations for inventories set out in the UNFCCC reporting guidelines according to decision 24/CP.19, decision 6/CMP.9, the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol.

It should be noted that the greenhouse gas inventory is integrated with the inventory of air pollutants for reporting to the UNECE (CLRTAP). This assures effective use of resources and consistency between the reporting to the UNFCCC and to the CLRTAP.

1.3.1 Quality system

The Swedish greenhouse gas inventory is compiled in accordance with the reporting guidelines drawn up by the Intergovernmental Panel on Climate Change (IPCC), KP and the UNFCCC. The national system is designed to ensure the quality of the inventory, i.e. to ensure its transparency, consistency, comparability, completeness and accuracy. The Swedish quality system is based on the structure described in UNFCCC decision 20/CP.7 and applies a PDCA (plan–do–check–act) approach, illustrated in Figure 1.3 below. This is an adopted model for how systematic quality and environmental management activity is to be undertaken according to international standards to ensure that quality is maintained and developed.

The quality system includes several procedures such as training of staff, inventory planning and preparation, QA/QC procedures, publication, data storage, and follow-up and improvements. All QA/QC procedures are documented in a QA/QC plan[3]. The QA/QC plan also includes a scheduled time frame describing the different stages of the inventory from its initial development to final reporting. The quality system ensures that the inventory is systematically planned, prepared and followed up in accordance with specified quality requirements so that the inventory is continuously developed and improved.

[3] Swedish EPA, National Greenhouse Gas and Air Pollutants Inventory System in Sweden

Figure 1.3. Structure of the quality system

The responsibilities of the Swedish EPA and the other government agencies for the quality system are described in paragraph 9 of the Ordinance on Climate Reporting (2014:1434). The Swedish EPA and other government agencies which take part in the climate-reporting work have to ensure that the methodologies applied in the reporting and inventories of emissions and removals attain the quality required for it to be possible for Swedish climate reporting to be done in the correct manner and with correct information. The government agencies have to have internal routines to plan, prepare, check and act/follow up the quality work and consult one another with the aim of developing and maintaining a coordinated quality system.

The responsibility of SMED to maintain and develop an internal quality system is described in the framework contract between the Swedish EPA and the consultants. The SMED quality system is described in a detailed manual[4]. The manual is updated annually and lists all quality control steps that must be undertaken during inventory work (Tier 1 and where appropriate Tier 2). It also includes descriptions of roles and responsibilities, of databases and models, work manuals for each CRF category and documented procedures for uncertainty and key source analyses, as well as procedures for handling and responding to UNFCCC´s review of the Swedish inventory. It also 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. Figure 1.4 below shows a process description of the annual Swedish inventory.

[4] Manual for SMED:s Quality System in the Swedish Air Emission Inventories, available at www.smed.se

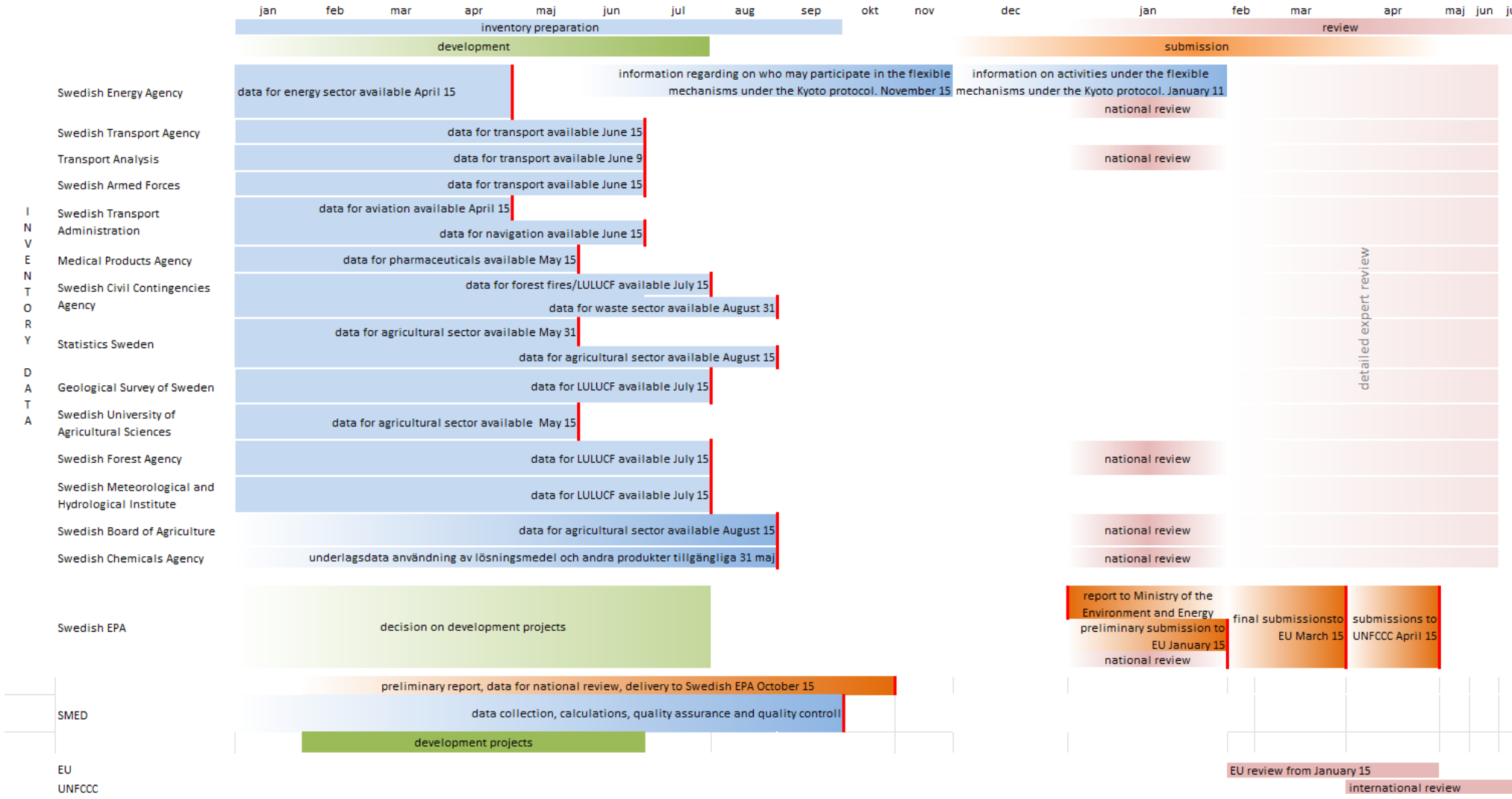


Figure 1.4. Overview of the Swedish GHG inventory planning, preparation and management.

1.3.2 Training, awareness and skills

To meet the quality criteria set out in the UNFCCC and IPCC guidelines, experts from different government agencies are participating in the inventory according to the Ordinance on Climate Reporting (2014:1434). By involving these agencies, it is ensured that the best expertise available in the country is involved. Skills of the part of SMED (consultants) are ensured in accordance with the requirements laid down in the framework contract between the Swedish EPA and the consultants. The levels of consultant's skills are continuously reviewed. There are about 20 active emission inventory experts in SMED involved in the preparation of the 2017 submission. In addition, SMED comprises several national experts and senior researchers involved in specific development projects.

1.3.3 Inventory planning (PLAN)

Planning of the inventory for the submission in year x starts in the fall of year x-2 when the Swedish EPA gets the preliminary budget for year x-1. General priorities for the inventory are decided by the Swedish EPA based on

- recommendations from international review not yet implemented in the inventory
- recommendations from national peer review not yet implemented in the inventory
- key category analysis (focus on major sources/sinks)
- uncertainty analysis (focus on sources/sinks that contributes significantly to the uncertainty of the inventory)
- ideas from SMED and the Swedish EPA on how to improve quality and effectiveness of the inventory
- new international and national requirements, decisions and guidelines

Based on the priorities and on detailed information in the updated list on suggestions for improvements, SMED compiles a gross list of development projects for the coming years. The gross list of development projects is discussed between SMED and the Swedish EPA. During December - February the Swedish EPA decides on whhich projects should be prioritized and performed. The final prioritization is made in December-February.

In January-June (approximately) SMED is working with development projects. Reports on the results and recommendations for implementation in the inventory are delivered to the Swedish EPA who then decides how these new methods/activity data/emission factors should be implemented in the inventory. In order to be able to implement results in the current inventory with sufficient QA/QC, the Swedish EPA has to decide on implementation in June.

From time to time, there is a need to change data provided by responsible authorities as discussed above. When relevant, the Swedish EPA contacts responsible authorities and discusses the needs for updates.

1.3.4 Inventory preparation (DO)

SMED collect data and information for the greenhouse gas emissions calculations from various government agencies, organizations and companies over the period from April to August. The calculations are performed in models, statistics

programs and calculation programs in April to September. Over the period from September to October, the material is put together in a reporting format. A short description of data collection and processing for each sector is provided below. See sections 3-8 for a detailed description. Preparation of the inventory is documented in detailed work documentation, which serves as instructions for inventory compilers to ensure quality and consistency, and also serves as information in the national peer review process.

1.3.4.1 ENERGY- STATIONARY COMBUSTION

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.

1.3.4.2 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.

1.3.4.3 ENERGY – FUGITIVE EMISSIONS

For flaring in refineries, activity data and CO_2 emissions from ETS are used for 2005 and later. In earlier years, data was collected through personal contacts with the facilities. CO_2 emissions from hydrogen production in oil refineries are taken from ETS and reported under CRF 1.B.2.a.1 in line with 2006 IPCC Guidelines. For non-CO_2 emissions, regular emission factors for stationary combustion are used.

Fugitive emissions from refineries and from storage of petroleum products at storage depots are mainly compiled from the facilities' environmental reports. Estimates of fugitive emissions from gasoline stations are calculated from fuel data provided by the National Road Administration.

Transmission and distribution losses of natural gas, natural gas and gasworks gas are estimated using national methods and data from environmental reports and directly from the companies. Emissions from venting and flaring of natural gas are mainly estimated using information from companies.

1.3.4.4 INDUSTRIAL PROCESSES AND PRODUCT USE

Greenhouse gas emissions from industrial processes and product use are based on information from various data sources.

The reported data for industrial processes is mainly based on information from plant-specific environmental reports, and from 2005 onwards, data from the EU ETS. For some minor plants, and when plant-specific environmental reports are not available, a combination of data sources are used to make approximate estimates; production statistics, national statistics and implied emission factors (IEFs) based on similar industries. Default IPCC methods and emission factors are used to some extent where national methods are not available.

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

Emissions of fluorinated greenhouse gases are estimated based on national import and export statistics from the Swedish Chemicals Agency, national vehicle statistics, national emission factors, company-specific information, import of amounts of HFCs in products, and in some cases default IPCC emission factors.

1.3.4.5 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.

1.3.4.6 LAND USE, LAND USE CHANGE AND FORESTRY

Estimates presented in the LULUCF sector are mainly based on data from the SLU and the Swedish EPA. The SLU provides data from the National Forest Inventory, and the Swedish EPA provides data from the Swedish Soil Inventory. The two inventories are integrated and use the same infra-structure for the field sampling. Apart from those two inventories data from the Swedish Forest Agency, the Swedish Meteorological and Hydrological Institute (SMHI), the Swedish Board of Agriculture, Swedish Civil Contingencies Agency (MSB), the Geological Survey of Sweden (SGU) and Statistics Sweden (SCB) is used.

1.3.4.7 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 facility's annual environmental reports.

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

Sweden has incorporated the demands for KP-LULUCF into the Swedish national system. The national system is arranged according to decision 24/CP.19 and 19/CMP.1 (and all related decisions). This means that the same legal arrangements and the same QA/QC is used (but enlarged to deliver according to the demands under the Kyoto Protocol as well as under the convention).

1.3.5.1 QUALITY CONTROL

Quality control is the check that is made during the inventory on different types of data, emission factors and calculations that have been made. The quality control takes place according to general requirements (Tier 1) which apply to all types of data used as support material for the reporting, and specific requirements for quality control (Tier 2) which are applied to certain types of data and/or emission sources. In this inventory, general Tier 1 QC measures, according to Table 6.1 in 2006 IPCC Guidelines, have been carried out as follows:

- Documentation of assumptions and criteria for the selection of various parameters
- Transcription errors in data input and references
- Calculations are made correctly
- Parameters, units and conversion factors are correct
- Integrity of database files
- Consistency in data between source categories
- Correct movement of inventory data between processing steps
- Uncertainties are estimated and calculated correctly
- Time series consistency
- Recalculations, checked and documented
- Completeness check
- Trend and outlier analyses
- Review of internal documentation and archiving

In addition, source specific Tier 2 QC procedures are carried out for several categories (Table 1.2).

In addition to the source specific QC procedures listed in Table 1.2, a cross-sectoral control tool was developed in submission 2018, aiming to allocate CO_2 emissions from industrial plants correctly between CRF 1 and 2 and to ensure that total emissions are accounted for across the entire inventory, by facility. When allocating emissions to respective CRF codes, the IPCC guidelines have been applied as far as possible. All industrial facilities where both energy and process related CO_2 emissions occur have been cross-checked between respective CRF sector.

This includes refineries as well as facilities from the mineral, chemical and metal industry. For each of the relevant facilities, total emissions reported in the energy sector and IPPU are compared to both EU ETS data (if available) and

environmental reporting provided by facilities. Quality control is therefore being conducted on a facility level. In case of discrepancies, they are easily identified and further investigated regarding potential gaps or double-counting. The tool will from now on be used on an annual basis.

All QC measures performed are documented by SMED in QC checklists for each CRF code or group of codes. When the reporting tables and the NIR are completed by SMED, a quality control team (QC-team) performs checks before internal delivery to the SMED quality coordinator. The QC-team consists of one inventory compiler from each of three of the SMED consortium members (IVL, SCB and SLU), and the review is performed so that each member of the team checks parts of the inventory (data and associated documentation) that he/she has not been involved in the preparation of. In addition, the QC-team performs data checks in terms of the functionality of the CRF Reporter (i.e. checks of completeness, time-series consistency and recalculation explanations).

Before delivery of the inventory to the Swedish EPA, the SMED quality coordinator performs the final quality control. The QC-team and SMED quality coordinator checks serve as both quality control and quality assurance in accordance with the 2006 IPCC guidelines.

Table 1.2. Source specific Tier 2 QC procedures carried out in the inventory

CRF		Action
1.A, 1.B 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.
1.B	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.
2.A.1	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.
2.A.2	Lime production, process emissions of CO_2	Emissions are calculated using both the bottom-up (data from EU-ETS) and the top-down method (data from the Swedish Lime Assocication and Statistics Sweden). The results have been compared and differences commented.
2.B.2	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.
2.C.1	Iron and steel production	Activity data are checked with fuel combustion data in order to avoid double counting of emissions or omissions. Activity data is also compared to trade statistics. IEF are compared to IPCC default values.
2.C.3	PFC emissions from aluminium production	Documented process information obtained directly from the company enable plant-specific data checks.
2.F	Product uses as substitutes for ODS	Differences between country specific emission factors and default emission factors from IPCC Guidelines are documented.
5A	Solid waste disposal (CH_4)	Survey data collection methods are reviewed and data is cross-checked with the data for the previous years.
5B	Biological treatment of solid waste (CH_4 and N_2O)	Input parameters are reviewed by waste experts.
5D	Wastewater treatment and discharge (CH_4)	Country-specific value of B0 and the IPCC default value have been compared and differences analysed.
5D	Wastewater treatment and discharge (CH_4)	Agreement between the units used for degradable carbon in waste (TOW) and B0 is confirmed.

1.3.5.2 QUALITY ASSURANCE

The Swedish QA/QC system includes several QA activities outside the SMED QA/QC procedures. At the final stages of completion of the inventory, the Swedish EPA performs a peer review for each sector.

The Swedish QA/QC system also includes national peer reviews by sectorial authorities. The peer review is defined in the Ordinance on Climate Reporting (2014:1434) and is, for all sectors, conducted by a person who has not taken part in the inventory preparation. The Swedish EPA is responsible for coordinating the peer reviews. From the 2016 submission, the national peer review is conducted in two steps:

- *Annual national review*. The aim of the review is to check the robustness of the national system and to guarantee that politically independent emissions and removals data is reported. The review is performed by sectorial authorities prior to submission to meet the demands in 19/CMP.1 annex paragraph 15 (b)

- *In-depth expert peer review*. Each year there will also be an in depth peer review of one sector or part of a sector. The choice of sector depends on the outcome of the results from the EU and UNFCCC reviews and if the national review has identified problems or other needs discovered by SMED inventory experts or Swedish EPA. The aim of the in-depth expert peer review is to improve the inventory data quality. The review is performed by sectorial authorities and other national and international experts in order to meet the demands in 19/CMP.1 annex paragraph 15 (c).

The annual national review is organised as a desk review. Before the desk review the sectorial authorities have received the NIR and the CRF data. After finalizing the review, the reviewers give feedback and inform the Swedish EPA if they find the inventory reliable and independent, if the trends are correct and if the national system is functional. Any recommendations for improvements are recorded in the list of suggested improvements described in section 1.3.5.5.

The in-depth expert peer review includes methodologies, models, activity data and emissions factors. The reviewers also identify areas for improvement, which consolidates the basis for improvements in coming submissions. Results from the national peer review are documented in review reports. Recommendations from the review reports are collected to the list of suggested improvements described in section 1.3.5.5.

Sweden has also initiated expert meetings with Denmark, Finland and Norway, where GHG inventory compilers discuss common problems and needs for e.g. revised methods and further inventory development.

The UNFCCC secretariat administers an international peer review of Swedish reporting after submission. Recommendations from the review reports are collected to the list of suggested improvements described in section 1.3.5.5 (cf chapter 9). The submission will also be reviewed by the EU. Recommendations from this review will be handled in the same way as recommendations from the UNFCCC review and the national peer review.

1.3.5.3 FINALIZATION, PUBLICATION AND SUBMISSION OF THE INVENTORY

The results are published nationally by the Swedish Environmental Protection Agency in late November or early December each year. The Swedish EPA delivers the greenhouse gas inventory to the Ministry of Environment five working days before the preliminary reporting to European Commission (January 15th).
The Swedish EPA, on behalf of the Ministry of Environment, submits the inventory to the European Commission on January 15th and to the UNFCCC on April 15th. Reported data in the submission of year *t* relates to the series of emissions years from 1990 up to and including year *t*-2, in other words emissions which took place during 2011 are reported in early 2013.

1.3.5.4 DATA STORAGE

A system for handling data related to the inventory, entitled Technical Production System (TPS)[5], has been developed and was implemented for the first time in submission 2007. It supports data input from text files and Microsoft Excel sheets. The system is owned and maintained by the Swedish EPA, and allows data to be gathered from SMED. The system is encrypted and approved for handling data considered confidential. For all CRF-categories and sub-categories, time series from 1990 onwards of emission data, activity data, and implied emission factors where relevant, can be presented. The system allows for different types of data exports, e.g. to an xml-file or to MS Excel, that are used to produce national statistics as well as the import formats for CRF Reporter for submission to the EU and UNFCCC. CRF-tables are then generated using the export function in CRF Reporter.

The Swedish EPA is responsible for archiving data and documentation on the calculations of each submission. This is done in the archiving system of the agency following national rules and regulations.

1.3.5.5 FOLLOW-UP AND IMPROVEMENT (ACT)

Each year, all comments received from national and international reviews that are not already addressed and also ideas from SMED and the Swedish EPA are compiled into a list for suggestions on improvements. From this list, development projects are formed each year as describes in section 1.3.3. All suggestions not implemented one year is kept on the list for next year. In Table 1.3 below implemented improvements in this submission due to major development projects are presented. Other corrections, emission estimation improvements and updates of various statistics are described under each source category in section 3-8 below. In addition, improvements related to transparency of the NIR are continuously addressed in response to questions raised by national experts during the national peer review, and in response to previous ERT recommendations.

Each year, the Swedish EPA follows up on delivered data from responsible agencies to ensure correct and appropriate data for next submission.

Development of TPS such as additional functions etc. is organized in a similar way as for the inventory: Ideas are compiled into a list, and from this list issues to be implemented are prioritized.

[5] https://tps.naturvardsverket.se/

Table 1.3. Summary of implemented improvements in this submission due to major development projects

Sector/CRF category	Implemented improvement	Quality criteria (TCCCA)	Need identified by	Reference to NIR section
Energy /1.2.A.C + IPPU/2.B.10	Reallocation of emissions between sectors.	Accuracy	SMED	4.3.10
IPPU 2.F	Adding amounts imported i products 1990-2017. Updated amounts imported in bulk 2014-2017. Changed factors for light duty vehicles. Introduction of HFO-1234yf in MAC. Addition of emissions from MAC in working machinery and off road vehicles	Completeness	ERT/SMED	4.7.1

1.4 Brief general description of methodologies and data sources used

1.4.1 GHG inventory

Emission estimates are mainly based on data from national or official Swedish statistics, e.g. energy statistics, European Union Emission Trading Scheme (EU ETS)[6], environmental reports[7], 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 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines)[8]. In some cases, the methodologies prescribed in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines)[9] and the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (Good Practice Guidance)[10], IPCC´s supplementary guidelines for Wetlands and the Kyoto protocol (WL GL[11] and KP GL[12]) are also used. Some parts of the methodologies are taken directly from the EMEP/EEA air pollutant emission inventory guidebook (formerly called the EMEP CORINAIR emission inventory guidebook).[13]

In Table 1.4, all Tier methods used, which differ from Tier methods recommended in 2006 IPCC Guidelines, 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 2006 IPCC Guidelines, these sectors are not included in Table 1.4. 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.

[6] See Annex 8.1

[7] See Annex 8.3

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

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

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

[11] The WL GL can be found at http://www.ipcc-nggip.iges.or.jp/public/wetlands/index.html

[12] The WL GL can be found at http://www.ipcc-nggip.iges.or.jp/public/kpsg/index.html

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

Table 1.4. Methods used that differ from recommended methods in the 2006 IPCC Guide lines for all sectors

Sector	Used method Tier	2006 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.).

The combined effect of various greenhouse gases has been calculated using global warming potential factors (GWP) according to decision 4/CMP.7 and presented in Annex 8.4. 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 in CO_2-equivalent.

Emission factors and thermal values for the energy sector are provided in Annex 2.

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 used for developing the land use matrix (table NIR-2) comes from the Swedish National Forest Inventory (NFI) and is consistent with the data used for developing the land use matrix under the UNFCCC-reporting. The main difference is that the rules for accumulating areas for KP-activities are slightly different compared to the accumulation of land areas reported under the KP since broader land use categories are reported under the UNFCCC using the 20 year accumulation rule.

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, for the KP-reporting, the living biomass pool is reported separated into above-ground and below-ground biomass, respectively, and the dead organic matter pool is separated into litter and dead wood also for Deforestation and not only for Afforestation/Reforestation and Forest Management.

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

1.5.1 GHG inventory (including and excluding LULUCF)

According to 2006 IPCC Guidelines, key categories in a national inventory 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, the trend, or the uncertainty in emissions and removals". The identification of level and trend key categories is done in two different approaches. The two approaches differ in the sense that approach 2 also includes information of uncertainties. According to the UNFCCC reporting guidelines, Annex I Parties shall identify their key categories for the base year and the latest reported inventory year, using approach 1, level and trend assessment, including and excluding LULUCF. Parties are encouraged to also use approach 2 and to add additional key categories to the result of approach 1. The resulting key categories from the two approaches are presented under each source category description of chapter 3-7, in CRF table 7 and in Table A1.1 – A1.8 in Annex 1. There the methodology is discussed in detail and the corresponding background tables, according to the 2006 IPCC Guidelines, are presented.

Table 1.5. Approach 1 and approach 2 key categories 2016 in terms of level and trend.

IPCC Source Category	GHG	Including LULUCF		Excluding LULUCF	
		App. 1	App. 2	App. 1	App. 2
1 A 1 a Public Electricity and Heat Production: Biomass	N_2O	T		L,T	L,T
1 A 1 a Public Electricity and Heat Production: Gaseous Fuels	CO_2	L,T		L,T	L,T
1 A 1 a Public Electricity and Heat Production: Liquid Fuels	CO_2	L,T		L,T	
1 A 1 a Public Electricity and Heat Production: Other Fuels	CO_2	L,T	L,T	L,T	L,T
1 A 1 a Public Electricity and Heat Production: Peat	CO_2	L,T	L	L,T	L,T
1 A 1 a Public Electricity and Heat Production: Solid Fuels	CO_2	L,T	L,T	L,T	L,T
1 A 1 b Petroleum refining: Gaseous Fuels	CO_2			T	
1 A 1 b Petroleum refining: Liquid Fuels	CO_2	L,T	L,T	L,T	L,T
1 A 1 c Manufacture of Solid fuels and Other Energy Industries: Solid Fuels	CO_2	L,T		L,T	
1 A 2 a Iron and Steel: Gaseous Fuels	CO_2	L,T		L,T	
1 A 2 a Iron and Steel: Liquid Fuels	CO_2	L,T		L	L
1 A 2 a Iron and Steel: Solid Fuels	CO_2	L,T		L,T	
1 A 2 c Chemicals: Gaseous Fuels	CO_2			L	
1 A 2 c Chemicals: Liquid Fuels	CO_2	L,T	L,T	L,T	L,T
1 A 2 c Chemicals: Other Fuels	CO_2		T		L,T
1 A 2 c Chemicals: Solid Fuels	CO_2			T	
1 A 2 d Pulp, Paper and Print: Liquid Fuels	CO_2	L		L,T	T
1 A 2 d Pulp, Paper and Print: Other Fuels	CO_2				L
1 A 2 d Pulp, Paper and Print: Solid Fuels	CO_2			T	
1 A 2 e Food Processing, Beverages and Tobacco: Gaseous Fuels	CO_2	L,T		L	
1 A 2 e Food Processing, Beverages and Tobacco: Liquid Fuels	CO_2			L,T	

IPCC Source Category	GHG	Including LULUCF		Excluding LULUCF	
		App. 1	App. 2	App. 1	App. 2
1 A 2 f Non-metallic minerals: Gaseous Fuels	CO_2	T		L,T	
1 A 2 f Non-metallic minerals: Liquid Fuels	CO_2	L,T		L,T	
1 A 2 f Non-metallic minerals: Other Fuels	CO_2	L,T	L,T	L,T	L,T
1 A 2 f Non-metallic minerals: Solid Fuels	CO_2	L,T		L,T	
1 A 2 g vii Off-road vehicles and other machinery: Liquid Fuels	CO_2	L,T	T	L,T	L,T
1 A 2 g viii Other: Gaseous Fuels	CO_2			L	
1 A 2 g viii Other: Liquid Fuels	CO_2	L,T		L,T	T
1 A 2 g viii Other: Solid Fuels	CO_2	L,T		L,T	
1 A 3 a Domestic Aviation: Jet Kerosene	CO_2	L,T		L,T	L
1 A 3 b i Road Transportation, Cars: Diesel oil	CO_2	L,T	L,T	L,T	L,T
1 A 3 b i Road Transportation, Cars: Diesel oil	N_2O				T
1 A 3 b i Road Transportation, Cars: Gasoline	CH_4			T	T
1 A 3 b i Road Transportation, Cars: Gasoline	CO_2	L,T	L,T	L,T	L,T
1 A 3 b i Road Transportation, Cars: Gasoline	N_2O			T	T
1 A 3 b ii Road Transportation, Light duty trucks: Diesel oil	CO_2	L,T	L,T	L,T	L,T
1 A 3 b ii Road Transportation, Light duty trucks: Gasoline	CO_2	T		L,T	T
1 A 3 b iii Road Transportation, Heavy duty trucks: Biomass	CO_2	L,T		L	L
1 A 3 b iii Road Transportation, Heavy duty trucks: Diesel oil	CO_2	L,T	L,T	L,T	L,T
1 A 3 b iii Road Transportation, Heavy duty trucks: Diesel oil	N_2O			T	L,T
1 A 3 b iv Road Transportation, Motorcycles: Gasoline	CO_2			L,T	
1 A 3 d Domestic Navigation: Gas/Diesel Oil	CO_2	L,T		L	
1 A 3 d Domestic Navigation: Residual Oil	CO_2			T	T
1 A 3 e Other Transportation: Diesel Oil	CO_2	L,T		L	
1 A 4 a Commercial/Institutional: Diesel Oil	CO_2	T		L,T	
1 A 4 a Commercial/Institutional: Gaseous Fuels	CO_2	L,T		L,T	T
1 A 4 a Commercial/Institutional: Gasoline	CO_2	L,T		L,T	
1 A 4 a Commercial/Institutional: Liquid Fuels	CO_2	T	T	L,T	T
1 A 4 b Residential: Biomass	CH_4	L,T	L,T	L	L,T
1 A 4 b Residential: Biomass	N_2O		T		L,T
1 A 4 b Residential: Liquid Fuels	CO_2	L,T	T	L,T	L,T
1 A 4 c Agriculture/Forestry/Fisheries: Biomass	CH_4				T
1 A 4 c Agriculture/Forestry/Fisheries: Liquid Fuels	CO_2	L,T		L,T	L
1 A 4 c Agriculture/Forestry/Fisheries: Solid Fuels	CO_2			T	
1 A 5 b Mobile: Liquid Fuels	CO_2	L		L,T	T
1 B 2 a Oil	CH_4		T		L,T
1 B 2 a Oil	CO_2	L,T		L,T	T
1 B 2 c Venting and flaring	CO_2			L	
2 A 1 Cement Production	CO_2	L,T	T	L,T	L,T
2 A 2 Lime Production	CO_2	L,T		L,T	
2 B 10 Other	CO_2	T		L,T	L,T
2 B 2 Nitric Acid Production	N_2O	T		T	T
2 C 1 Iron and Steel Production	CO_2	L,T	L,T	L,T	L,T
2 C 2 Ferroalloys production	CO_2			L	
2 C 3 Aluminium production	CO_2	L,T		L,T	
2 C 3 Aluminium production	PFCs	T		T	T
2 C 7 Other	CO_2	L,T		L,T	
2 D 1 Lubricant use	CO_2	L,T	L,T	L,T	L,T
2 D 3 Other	CO_2	L,T		L	
2 F 1 Refrigeration and air conditioning	HFCs	L,T	L,T	L,T	L,T

IPCC Source Category	GHG	Including LULUCF		Excluding LULUCF	
		App. 1	App. 2	App. 1	App. 2
2 G 3 N2O from product uses	N_2O			L	
3 A 1 Dairy cattle	CH_4	L,T	L,T	L	L
3 A 1 Non-dairy cattle	CH_4	L,T	L,T	L,T	L,T
3 A 2 Sheep	CH_4	T		L,T	L,T
3 A 4 Horses	CH_4	T	T	L,T	L,T
3 B 1 Dairy cattle	CH_4				L
3 B 1 Dairy cattle	N_2O				L
3 B 1 Non-dairy cattle	CH_4			L,T	T
3 B 1 Non-dairy cattle	N_2O			L	
3 B Indirect N2O emissions	N_2O		L,T		L,T
3 D a 1 Inorganic N fertilizers	N_2O	L,T	L,T	L,T	L,T
3 D a 2 a Animal manure applied to soils	N_2O	L,T	L,T	L,T	L,T
3 D a 2 b Sewage sludge applied to soils	N_2O				T
3 D a 2 c Other organic fertilizers applied to soils	N_2O		T		L,T
3 D a 3 Urine and dung deposited by grazing animals	N_2O	L,T	L,T	L,T	L,T
3 D a 4 Crop residues applied to soils	N_2O	L,T	L,T	L,T	L,T
3 D a 5 Mineralization/immobilization associated with loss/gain of soil organic matter	N_2O		L,T		L,T
3 D a 6 Cultivation of organic soils (i.e. histosols)	N_2O	L,T	L,T	L,T	L,T
3 D b 1 Atmospheric deposition	N_2O		L,T	L	L,T
3 D b 2 Nitrogen leaching and run-off	N_2O	L,T	L,T	L	L,T
3 G Liming	CO_2			L	
4 A 1 Forest land remaining forest land	CO_2	L,T	L,T	-	-
4 A 2 1 Cropland converted to forest land	CO_2	L,T	T	-	-
4 A 2 2 Grassland converted to forest land	CO_2	T		-	-
4 A 2 4 Settlements converted to forest land	CO_2	L,T	L,T	-	-
4 A Drained organic soils	CH_4	L,T	L,T	-	-
4 A Drained organic soils	N_2O	L,T	L,T	-	-
4 B 1 Cropland remaining cropland	CO_2	L,T	L,T	-	-
4 B Drained organic soils	CH_4	L,T	L,T	-	-
4 C 1 Grassland remaining grassland	CO_2	L,T	L,T	-	-
4 C 2 1 Forest land converted to grassland	CO_2	L,T	L,T	-	-
4 D 1 1 Peat extraction remaining peat extraction	CO_2	L,T	L,T	-	-
4 E 1 Settlements remaining settlements	CO_2	T		-	-
4 E 2 1 Forest land converted to settlements	CO_2	L,T	L,T	-	-
4 E 2 2 Cropland converted to settlements	CO_2	L,T	L,T	-	-
4 E 2 2 Cropland converted to settlements	N_2O		L,T	-	-
4 G Total HWP from domestic harvest	CO_2	L,T	L,T	-	-
5 A 1 Managed waste disposal sites	CH_4	L	L	L,T	L,T
5 D 1 Domestic wastewater	N_2O	L,T	L,T	L	L,T

L=Level, T=Trend.

1.5.2 KP-LULUCF inventory

Forest management, Afforestation/Reforestation and Deforestation were considered key-categories for CO_2, Forest management (fertilization and drained organic soils), Afforestation/Reforestation (mineralisation) and Deforestation (mineralisation) were considered key-categories for N_2O and Forest management (drained organic soils) was considered key-category for CH_4. The key-category analysis is based on table 6.1.b.

1.6 Information on QA/QC

See section 0.

1.6.1 QA/QC Procedures

See section 1.3.5.

1.6.2 Verification activities

See section 1.3.5.

1.6.3 Treatment of confidentiality issues

Several data sources that are used for producing emissions estimates for the inventory are confidential at micro level (e.g. company or plant level), . This is the case for:

- statistical surveys on fuel consumption used in the energy and manufacture industries (CRF 1A1, 1A2)
- information collected for the EU Emissions Trading System
- data from the Products Register at the Swedish Chemicals Agency used in Solvent and other product use (CRF 2)
- data on sold medicines from Swedish eHealth Agency.

A thourough confidentiality analysis, using a P%-rule[14], has been conducted for sectors using statistics from statistical surveys on fuel consumption and information collected for the EU Emissions Trading System. Results based on micro-data from Swedish Chemicals Agency and Swedish eHealth Agency are not classified in the CRF-tables since the aggregation level is high enough to protect company data. When the confidentiality analysis showed that a certain category should be classified to protect data of one or more companies, the companies have been asked to give consent to publish the data. If the company declined or a consent could be acquired, the data are considered confidential and marked using notation key 'C'.

Sweden has previously aggregated confidential data, in submission of 2015 and 2016 (e.g. between fuel groups within subcategories). While this method avoided using notation key 'C' in the CRF-tables, the aggregations resulted in inaccurate implied emission factors for those fuel categories. Furthermore, it is difficult to ensure that aggregations are made consistently from submission to submission since different sectors may be considered confidential for different years depending on (i) the quantity of energy use/production levels of specific plants or (ii) if companies have provided consent for publishing statistics for the specific year (consent is normally given for 2-3 years at a time).

An internal review performed during 2016 of the use of confidential data in the inventory showed that additional data should be considered confidential compared to previous submissions in order to comply with the Public Access to Information and Secrecy Act of the Swedish law. This had implications for emissions estimates and activity data based on data from the EU ETS and energy statistics. This has affected some sub-sectors in stationary combustion (CRF 1) and industrial

[14] This implies that it is mathematically impossible to derive a certain company's data within less than P% probability

processes and product use (CRF 2), which have been classified with the notation key Classified (C). Sweden is working continuously with improving the transparency of our reporting and strives to minimize the extent of confidentiality in inventory data.

1.7 General uncertainty evaluation

1.7.1 GHG inventory

An uncertainty analysis has been performed according to the approach 1 method described in volume 1, chapter 3 of the 2006 IPCC guidelines. See Annex 7 for the results and for a description of the method used. The analysis has been performed both including 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 briefly in Annex 7 and in detail in a SMED report[15].

The approach 1 method is based on emission estimates and uncertainty coefficients for activity data and emission factors. The uncertainty coefficients have in many cases been assigned based on expert judgement or on default uncertainty estimates provided in the IPCC 2006 guidelines, if not enough background data was available to make actual statistical uncertainty calculations. Hence, some caution should be taken when interpreting and assessing the uncertainty results.

Uncertainty estimates have been performed for the base year 1990 and 2017 for direct greenhouse gases, e.g. CO_2, CH_4, N_2O and F-gases and are presented as 95 % confidence intervals.

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 important information when planning future inventories and, above all, using and evaluating the inventory results.

Continuous efforts are made to improve the uncertainty estimates, for example by contacting external experts for better information on different sources. During each development project, uncertainties in estimated activity data and emission factors are overhauled and revised when needed.

[15] Gustafsson, 2005

1.7.1.1 RESULTS

The results of the uncertainty calculations according to the approach 1 are presented in Annex 7. The overall uncertainty for 2016 GHG emissions (in CO_2-eq.) in Sweden is calculated to be ±5.1 %, excluding LULUCF (Figure 1.5). A considerable part of the overall uncertainty stems from uncertainty in the agricultural sector (CRF 3). When including LULUCF in national total emissions the uncertainty increases (±89 %), this is due to the combination of large (and increasing) net removals in LULUCF in combination of the prominent decrease in fossil emissions (Figure 1.5). Table 1.6 shows the ten sources with the largest uncertainty contributions in the inventory for 2017, excluding LULUCF.

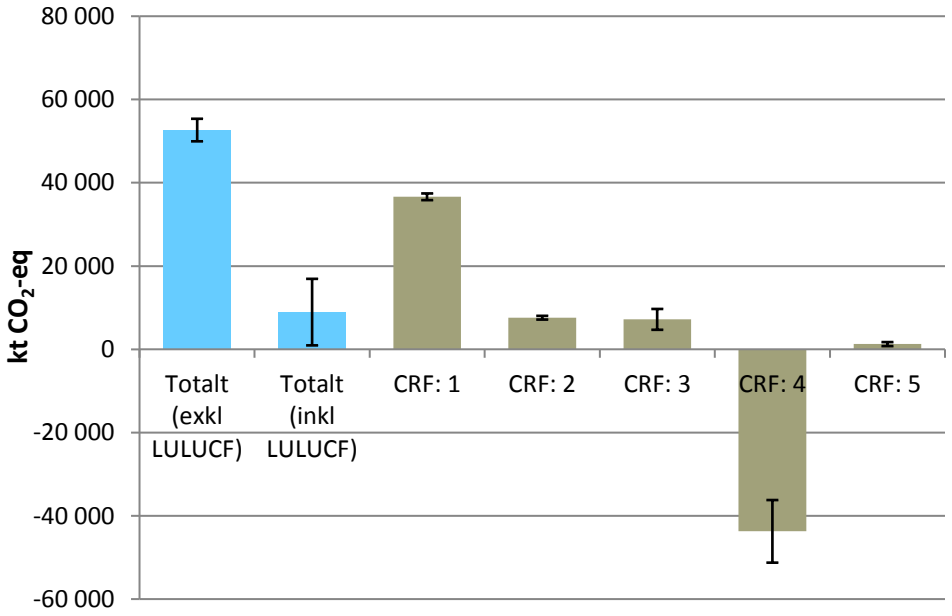


Figure 1.5. Uncertainty estimates, as 95 % confidence intervals, in national total emissions (excluding and including LULUCF) and by sector.

Table 1.6. The ten sources with the largest uncertainty contributions in the Swedish inventory for 2017, excluding LULUCF.

IPCC Source Category	GHG	Year 2017 emissions or removals (kt CO_2-eq.)	Combined uncertainty (%)	Relative contribution to variance in year 2017 (%)
3 D a 1 Inorganic N fertilizers	N_2O	929	203.0	15.5%
3 D a 4 Crop residues applied to soils	N_2O	415	203.0	6.9%
3 D a 6 Cultivation of organic soils (i.e. histosols)	N_2O	832	85.1	5.8%
3 D a 2 a Animal manure applied to soils	N_2O	333	203.0	5.5%
3 D a 5 Mineralization/immobilization associated with loss/gain of soil organic matter	N_2O	258	201.0	4.2%
1 A 1 a Public Electricity and Heat Production: Other Fuels	CH_4	2479	20.0	4.1%
5 A 1 Managed waste disposal sites	CO_2	841	55.9	3.9%
3 D a 3 Urine and dung deposited by grazing animals	N_2O	355	127.5	3.7%
2 F 1 Refrigeration and air conditioning	HFCs	1068	37.0	3.2%
3 D b 1 Atmospheric deposition	CO_2	94	401.5	3.1%

The uncertainty of the trend of national total greenhouse gas emissions excluding LULUCF was ± 2.1 %. The uncertainty in the trend is a percentage point range, relative to the inventory trend and should be interpreted as ± 2.1 % is the estimated percentage point difference compared to the general trend. I.e. there is a 95 % probability that the decrease in GHG emissions in Sweden between 1990 and 2017 is in the interval 23.9 % to 28.1 %.

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 IPCC default and expert judgment.

1.8 General assessment of completeness

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

1.8.1 GHG inventory

The inventory covers all mandatory GHG sources 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.

1.8.2 Energy

All relevant emissions and sources for the energy sector are reported in the inventory.

1.8.3 Industrial Processes and Product Use

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 2006 IPCC Guidelines. However, some exceptions do exist. These are primarily in sub-sectors with a large number of smaller facilities with minor emissions and for which no IPCC default methodology exists. For CH_4 emissions from ethylene production, a default methodology is provided by the 2006 IPCC Guidelines. However, as the company's own estimate is below the result of the default method by about a factor of ten and is below the threshold of 0.05 % of national total emissions (about 30 kt CO_2-eq), Sweden has chosen to report NE for this source, as it is judged to be insignificant in relation to the amount of effort it would require to obtain a complete time series. For CH_4 emissions from direct reduced iron, test calculations have been made with default emission factors applied for the total amount of natural gas used at the facility. The resulting CH_4 amounts are thousand fold below the national totals of 30 kt CO_2 eq, meaning that these emissions can be considered insignificant. CH_4 is therefore reported as NE.

Except for the above mentioned cases, data is complete for all greenhouse gases, possibly with the exception of CH_4 for a few non-mandatory sources, e.g. within the chemical industry.

The estimated emissions from solvent and product use are considered to be complete, as national data from the Products Register is used in the inventory.

1.8.4 Agriculture

All relevant agricultural emissions and sources are reported in the inventory. Reindeer, which are normally not considered as a part of the agricultural sector, are included in the inventory. All sales of fertilizers are included in the inventory, also quantities used in other sectors. N-fixing crops used in temporary grass fields, and sludge used as fertilizer is also included. This means that all anthropogenic inputs to agricultural soils are covered.

1.8.5 Land Use, Land Use Change and Forestry

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

The inventory of the LULUCF-sector is complete in the sense that all carbon pools and other sources, where methods are provided in the 2006 GL, are reported for land use categories that are considered managed.

The reporting of woody biomass stocks refers to above and below ground parts of trees taller than 1.3 m. Other vegetation such as shrubs and herbs are not reported.

1.8.6 Waste

Accidental landfill fires occur in Sweden; however emissions of CO_2, CH_4 and N_2O are reported NE since there is no default method provided by the 2006 IPCC Guidelines that can be applied in this case, and is below the threshold of 0.05 % of national total emissions (about 30 kt CO_2 eq.). Emissions are estimated to be insignificant in relation to the amount of effort it would require to obtain activity and emission data. All other data are complete.

1.8.7 KP-LULUCF

Sweden reports all mandatory activities under Article 3.3 and Article 3.4 of the Kyoto Protocol (KP). All carbon pools (including HWP) as well as associated mandatory emissions (such as fertilization of forest land, non- CO_2 emissions and DOC from drained organic soils, indirect N_2O emissions, N_2O from mineralisation of N and biomass burning) are reported for Afforestation/Reforestation, Deforestation and Forest management.

2 Trends in greenhouse gas emissions

2.1 Total greenhouse gas emissions and removals

In 2017, total greenhouse gas emissions (excluding LULUCF) in Sweden amounted to 52.7 Mt CO_2-eq. (Figure 2.1). The emissions show a decreasing trend although there are some annual fluctuations in a few sectors that affect the total emissions. Total emissions have decreased by 18.6 Mt or 26 % between 1990 and 2017. Between 2016 and 2017, the total greenhouse gas emissions decreased by 0.5 %.

The land use, land-use change and forestry sector (LULUCF, CRF sector 4) has generated annual net removals during the whole inventory period (1990-2017). The removals show substantial annual fluctuations. The net removal level during the last decade is slightly higher compared to the earlier years in the time period starting with 1990.

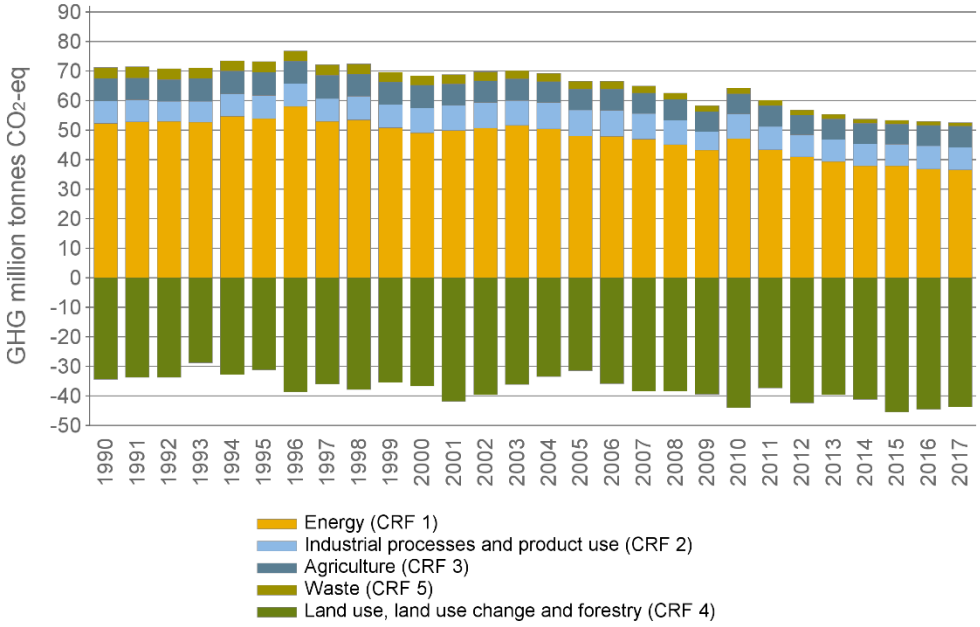


Figure 2.1. Total emissions and removals of greenhouse gases calculated as CO_2-eq. from Land use, land use change and forestry (LULUCF, CRF 4) and the other sectors (CRF 1.2.3 and 5), 1990-2017.

The energy sector contributed the most to the overall decrease in emissions, with 15.7 Mt of greenhouse gases between 1990 and 2017, primarily through reductions of 8.4 Mt in the residential, commercial/institutional and agriculture, forestry and fisheries subsectors (CRF 1.A.4), and of 3.9 Mt in manufacturing industries and construction (CRF 1.A.2). Other sectors also contributed to the overall decreased emissions during the period; waste (CRF 5) by 2.5 Mt, transport (CRF 1.A.3), by another 2.4 Mt, and agriculture (CRF 3) by 0.47 Mt.

2.1.1 Overview of emissions by sector

The energy sector (CRF 1) is comprised by emissions from transport (CRF 1.A.3), 31 % of the total emissions, energy industries (CRF 1.A.1), 17 % of total emissions, and combustion in manufacturing industries and construction (CRF 1.A.2), 13 % of total emissions. Emissions from military activities (CRF 1.A.5) accounted for 0.35 % of total emissions, fugitive emissions (CRF 1.B) for 1.6 % of total emissions, and other activities (CRF 1.A.4) for 5.5 % of total emissions, see Figure 2.2. Agriculture (CRF 3) accounted for 14 % of total greenhouse gas emissions in 2017, industrial processes and product use (CRF 2) accounted for 14 %, and waste (CRF 5) accounted for 2.4 %.

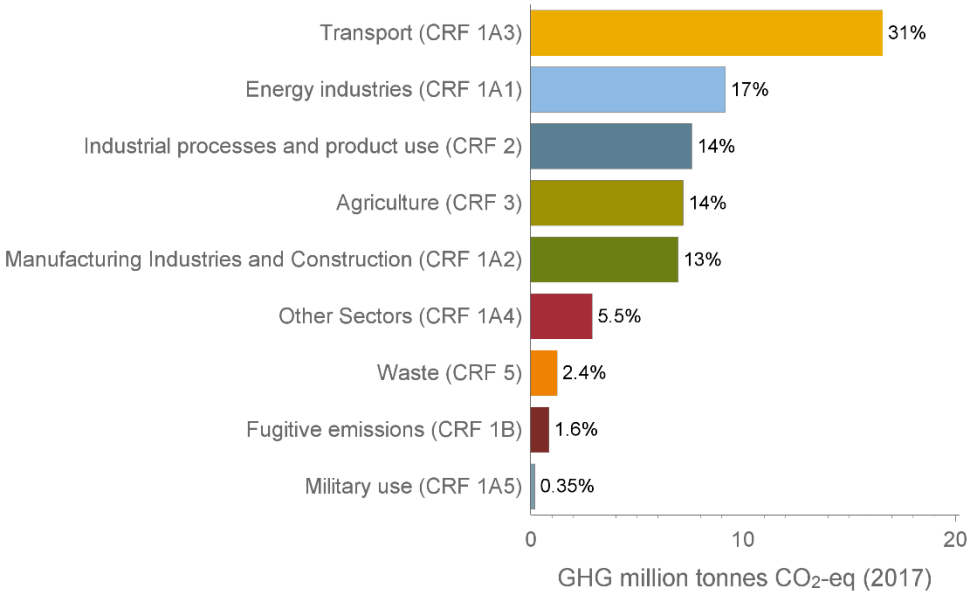


Figure 2.2. Greenhouse gas emissions by sector, 2017.

The historical trends (1990-2017) of the largest categories are shown in Figure 2.3. Emissions from transport are dominated by road transport. The emissions were lower in 2017 than in 1990. The decrease over the years is due to more energy efficient cars and an increased use of biofuels, but the impact of these measures on emissions reductions have been suppressed by an increased trend in the amount of traffic.

Emissions from energy industries primarily come from the production of electricity and heat. The fluctuations in emissions between different years are large, due to the weather conditions' influence on the need for heating. Emissions from manufacturing industries and construction have decreased since the late 90's. They depend on the economic development but there is also a long-term decrease as a result of a switch from oil to biomass, especially in the pulp and paper industry.

Emissions from agriculture have decreased slightly since 1990 due to less livestock and smaller amounts of fertilizers used.

Emissions from IPPU (Industrial Processes and Product Use) consist of emissions from industrial processes as well as emissions from product use, mainly fluorinated

greenhouse gases in, for example, cooling systems. Emissions from IPPU emanate from industrial processes which fluctuate with the level of production. The chemical industry has decreased its emissions due to enhanced production technologies.

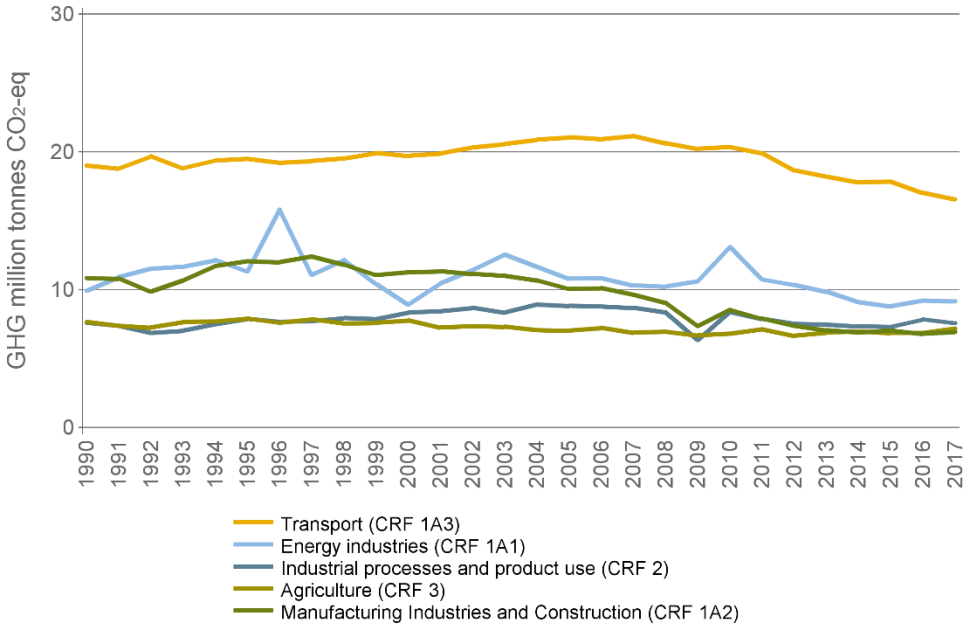


Figure 2.3. Total emissions of all greenhouse gases calculated as CO_2-eq. for agriculture (CRF 3), energy industries (CRF 1A1), Industrial processes and product use (CRF 2), manufacturing industries and construction (CRF 1A2) and transport (1A3), 1990-2017.

2.2 Description and interpretation of emission trends by gas

In 2017, emissions (excl. LULUCF) of carbon dioxide (CO_2) amounted to 42.0 Mt in total, which is equivalent to 80 % of total greenhouse gas emissions, calculated as CO_2-eq, see Figure 2.4. Emissions of methane (CH_4) accounted for 4.5 Mt of CO_2-eq. (about 8.6 % of total emissions), emissions of nitrous oxide (N_2O) 4.9 Mt (9.2 %), fluorinated greenhouse gases 1.3 Mt (2.2 %). The shares of the different greenhouses gases have remained stable over the period 1990 to 2017.

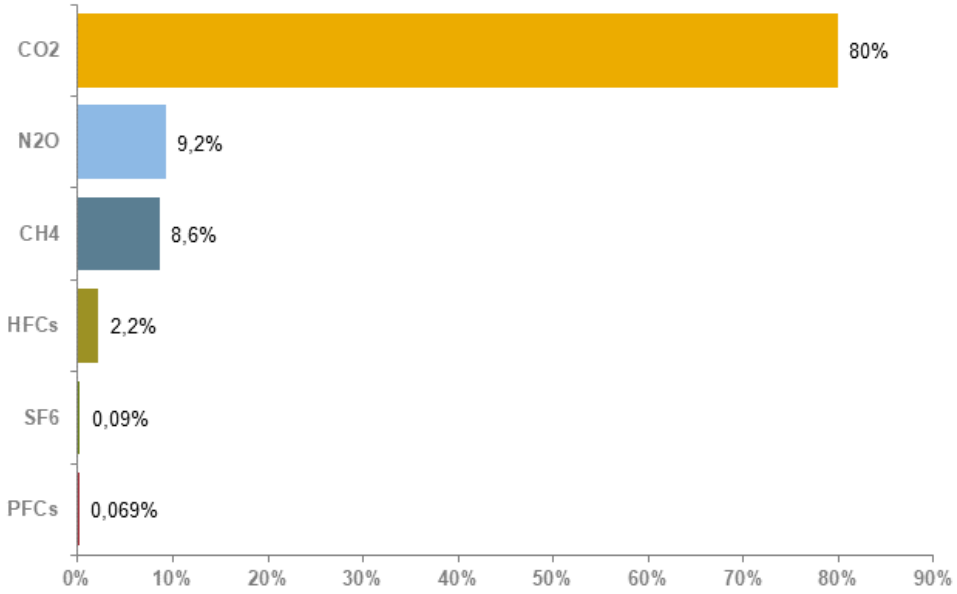


Figure 2.4. Share of greenhouse gases of total emissions in CO_2-eq, in 2017.

2.2.1 Carbon dioxide (CO_2)

In 2016, the carbon dioxide (CO_2) emissions in Sweden amounted to 42.0 Mt in total, excluding LULUCF (Figure 2.5). The main source for emissions of carbon dioxide is the combustion of fossil fuels, which mainly takes place in the energy sector (CRF 1). Another important source is the raw material used in the industry processes. Emissions of carbon dioxide were 27 % lower in 2017 than in 1990.

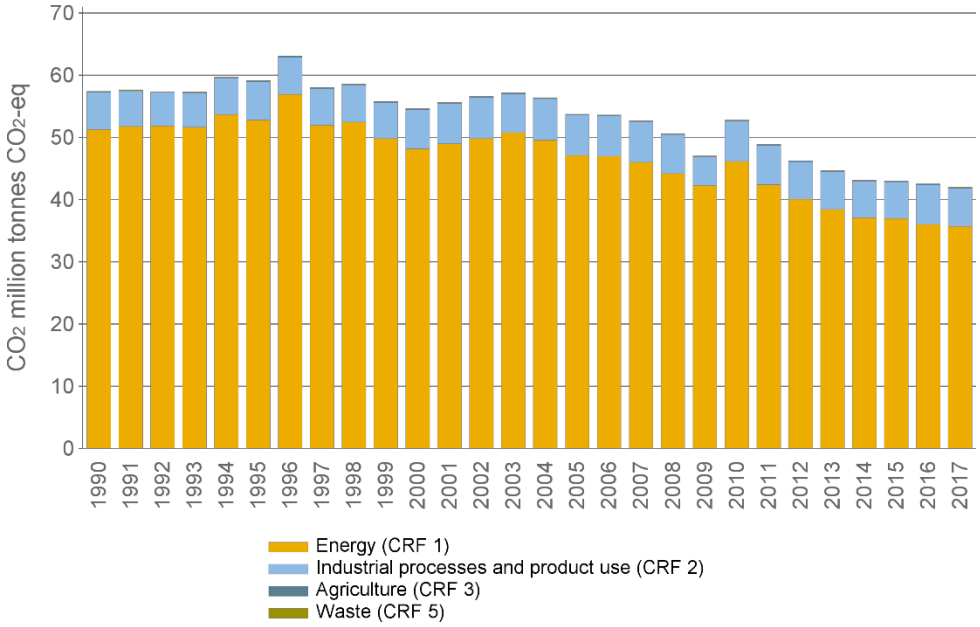


Figure 2.5. Total emissions of carbon dioxide 1990-2017 (excluding LULUCF).

2.2.2 Methane (CH_4)

The total emissions of methane (CH_4), excluding emissions from LULUCF, were 4.5 Mt calculated as CO_2-eq. in 2017, see Figure 2.6. The main sources of methane are agriculture (CRF 3) (73 %), the waste sector (CRF 5) (21 %) and the combustion of fossil fuels in the energy sector (CRF 1) (6 %). Emissions of methane have decreased by 39 % since 1990. The main reason for the decrease is mitigation measures undertaken in the waste sector, for example reduced deposition of organic waste in landfills and collection of landfill gas for combustion. The waste sector decreased its emissions of methane by 72 % between 1990 and 2017, while emissions in the agricultural sector dropped by 7 % during the same period.

2.2.3 Nitrous oxide (N_2O)

In 2016, emissions of nitrous oxide (N_2O) amounted to 4.9 Mt CO_2-eq. (excl. LULUCF), see Figure 2.7. The main source of nitrous oxide emissions is the agriculture sector (CRF 3), which accounted for 78 % of the emissions in 2017. Compared to 1990, the overall emissions of N_2O have decreased by 15 %, or 889 kt of CO_2-eq. The industrial processes and product use sector (CRF 2) accounts for the largest part of the decrease in emissions of nitrous oxide and have dropped by approximately 78 % during the period.

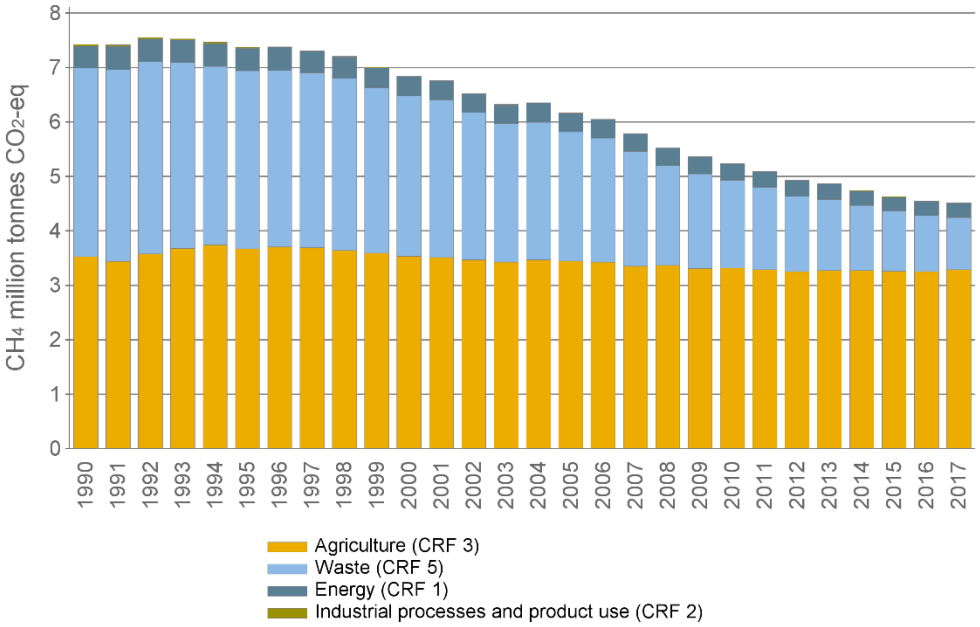


Figure 2.6. Total emissions of methane (CH4) by sectors 1990-2017 (excluding LULUCF).

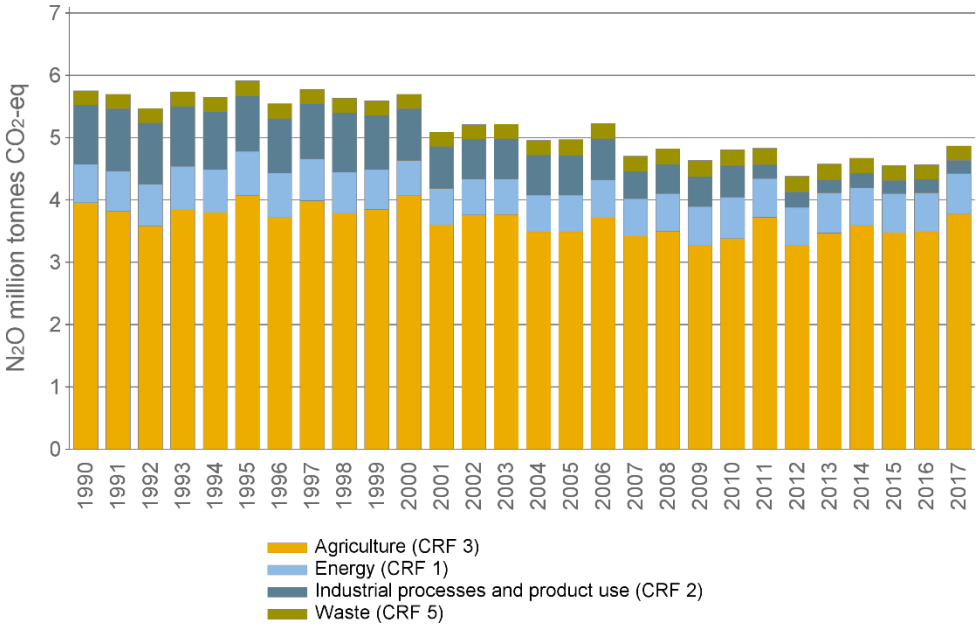


Figure 2.7. Total emissions of nitrous oxide (N2O) by sectors 1990-2017 (excluding LULUCF).

2.2.4 Fluorinated greenhouse gases

The emissions of fluorinated greenhouse gases come mainly from their use in various applications, but also from emissions of perfluorocarbons (PFC) from primary aluminium production processes. Emissions of fluorinated gases are only reported in the industrial processes and product use sector (CRF 2).

Total emissions of fluorinated gases in 2017 amounted to 1.2 Mt CO_2-eq, see Figure 2.8, and accounted for 2,3 % of total greenhouse gas emissions. Emissions have increased by 81 % since 1990. They increased from around 0.7 Mt of CO_2-eq. in 1990 to almost 1.7 Mt in 2007, but have gone down and stabilised to around 1.2 Mt since then. The overall increase is mainly due to increased emissions of HFCs, which accounted for 93 % of the total fluorinated gases in 2017.

The emissions of HFCs increased by 1,1 Mt of CO_2-eq. between 1990 and 2017, mostly as a result of the use of HFCs as refrigerants in refrigerators, freezers and air-conditioning equipment in later years. Since 2009, the trend is showing a stabilisation and emissions have dropped by 1 % between 2016 and 2017.

PFCs emissions, on the other hand, have decreased by 96 % during the period 1990 to 2017. Emissions of SF_6 decreased by 54 % between 1990 and 2017. However, there are inter-annual fluctuations throughout the period.

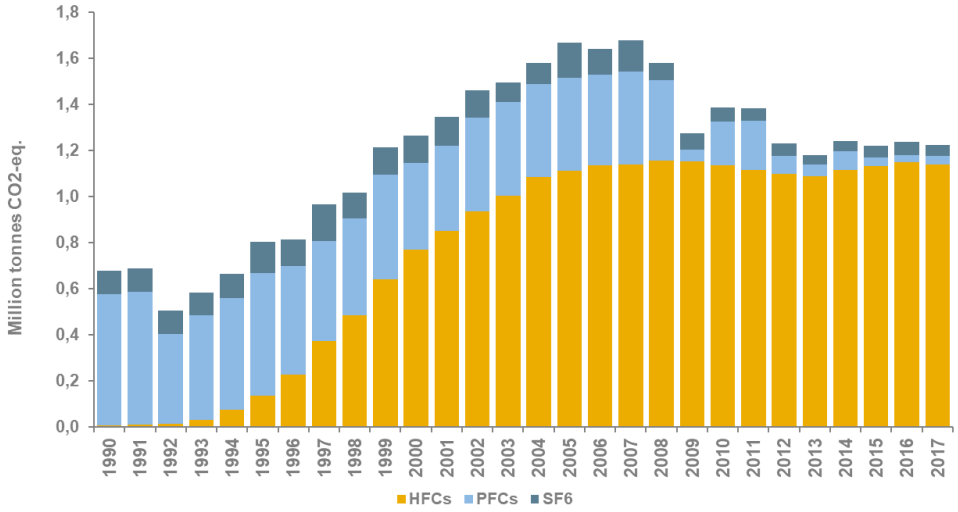


Figure 2.8. Total emissions of HFC, PFCs and SF6, 1990-2017 (excluding LULUCF).

2.3 Emissions by CRF sectors

2.3.1 Energy (CRF sector 1)

The majority of the emissions in the Energy sector arise from transports, electricity and heat production and combustion in manufacturing industries and construction. Since 1990 there has been a decrease in total emissions of one quarter. The main reason is decreased emissions from the residential and commercial/institutional sectors due to the replacement of combustion of fossil fuels for heating with district heating and electricity, including heat pumps. Emissions in the manufacturing industries and construction have decreased by one third compared to 1990 due to a reduction in the use of fossil fuels, mainly as a result of a shift to biofuels and electricity. Moreover, electricity and heat production are increasingly based on renewable energy so although the use of district heating has increased, emissions have decreased. In recent years, the emissions in the transport sector have decreased, mainly due to the use of more energy efficient cars and increased use of biofuel.

Emissions from the energy sector include emissions from the production of electricity and district heating, refineries, manufacture of solid fuels, manufacturing industries, transports, other sectors (including commercial/institutional, residential, agriculture, forestry and fisheries), other (military transports), and fugitive emissions.

The lion's share of emissions come from transports (CRF 1A3), followed by energy industries (CRF 1A1) and combustion in manufacturing industries and construction (CRF 1A2), see Figure 2.9. The production of electricity and heat are important subsectors within the energy industries sector (CRF 1A1), as are heating in the residential and commercial/institutional sectors in "Other sectors" (CRF 1A4).

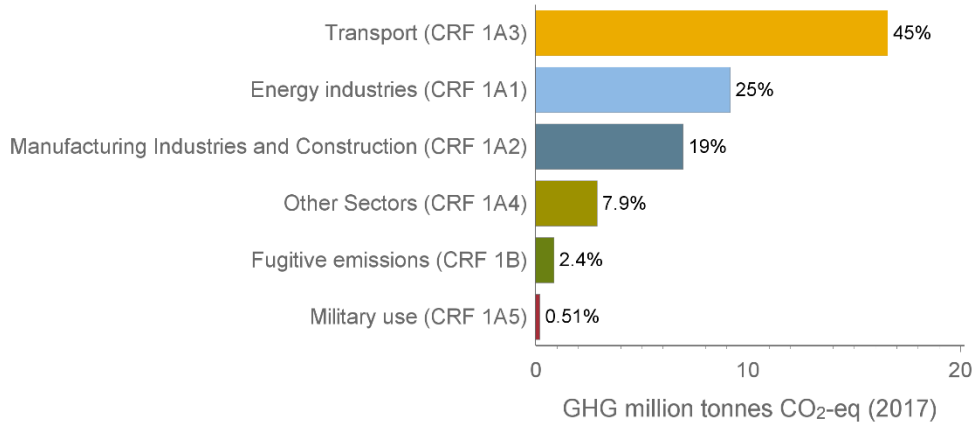


Figure 2.9. Share of emissions within the Energy sector, by subsector in 2017.

Total emissions in the energy sector have decreased over the period 1990-2017, from 52.3 to 36.6 Mt CO_2-eq. This is a decrease of 30 % which mainly depends on a decreased use of fossil fuels in residential and commercial/institutional, included in "Other Sectors" (CRF 1A4), manufacturing industries and construction (CRF 1A2) and in recent years, Transports (1A3). Between 2016 and 2017 there was 1 %

decrease in emissions within the energy sector, mostly because of a decrease of emissions from transports.

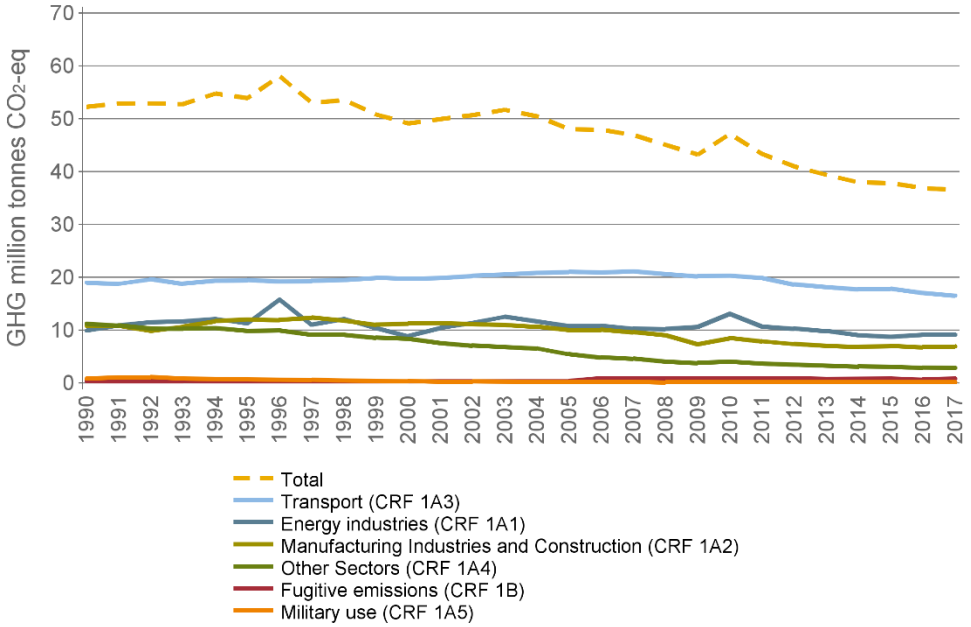


Figure 2.10. Emissions from the Energy sector, total and by subsector, in 2017.

2.3.1.1 ENERGY INDUSTRIES (CRF 1A1)

Energy industries are dominated by the electricity and heat production with by far the largest part of the emissions and also the only subsector where emissions fluctuate over the years. The fluctuations between different years are large, due to the weather conditions' influence on the electricity and heat production (CRF 1A1a). In 2017, there was an increase in emissions from the energy industries by 2 % compared to 2016. Sweden´s electricity and heat production is to a large extent composed by renewable energy and district heating is mainly based on biofuels and waste. Therefore, the emissions are 14 % less than in 1990, even though the supply of district heating has increased with over 40 % in the same period.

Total emissions from energy industries (CRF 1A1) were 9.2 Mt CO_2-eq. in 2017 (Figure 2.11), which is 8 % lower than in 1990. Electricity and heat production (CRF 1A1a) account for the larger part of the emissions with 74 % (6.8 Mt) in 2017. Emissions from Refineries (1A1b) and Manufacture of solid fuels (CRF 1A1c) amounted to 2.4 Mt in 2017.

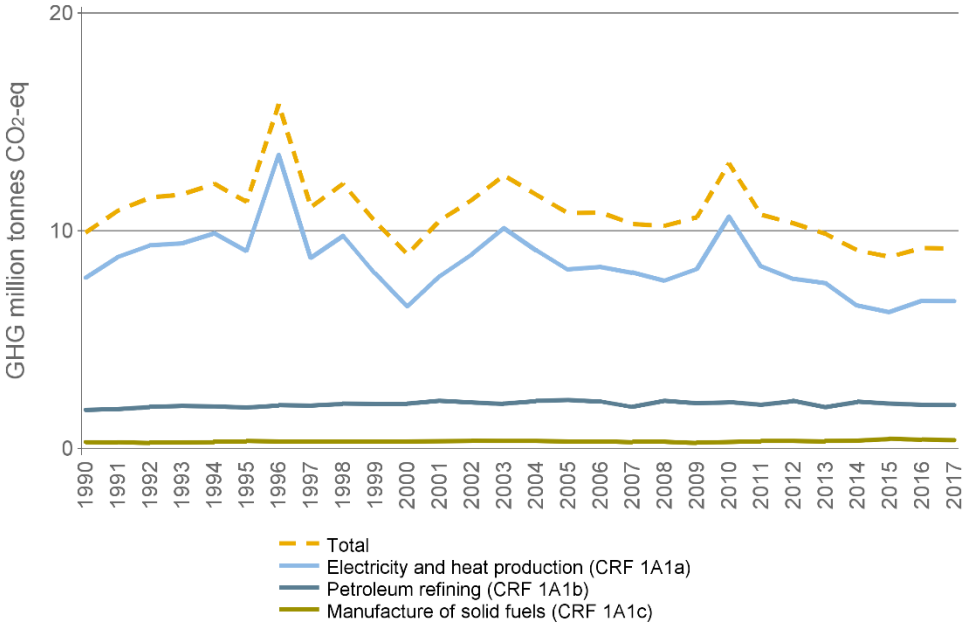


Figure 2.11. Emissions from Energy industries by subsector and total, 2017.

2.3.1.1.1 Electricity and heat production (CRF1A1a)

Emissions from production of electricity and heat production totalled to 6.8 Mt of CO_2-eq. in 2017, which is at the same level as in 2016. The emissions from electricity and heat production vary over time but have been reduced emissions by 14 % between 1990 and 2017. There is no change in emissions in 2017 due to an increase in emissions from industrial gases with 18 % between 2016 and 2017. However, emissions from all other fossile fuels categories decreases in 2017.

The main reason behind the variations between years is the weather conditions' impact on the demand for electricity and heat. Sweden's electricity and heat production are based largely on hydropower, nuclear power and biofuels. Fossil fuels serve as a complement, especially by cold weather. Temperature and precipitation conditions, which vary between years, have an impact on hydropower production and heating needs, which leads 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. Also 2010 was a very cold year, with increased emissions as a result.

In years with low hydropower production, the emissions depend on the kind of electricity production that offsets the hydropower shortage. As an example, the emissions were much lower in 2003 when the deficient production of hydropower primarily was offset by imports of electricity, compared to 1996 when the shortage of hydropower to a larger extent was offset by increased oil-fuelled condensing power production. The increased possibilities to import electricity, primarily from other Nordic countries, make it possible to avoid emissions from fossil-fuelled electricity generation when other power supply is low.

Emissions in this sector are also affected by the iron and steel production as residual gases from the iron and steel industry are used to produce electricity and district heating, and these emissions increased in 2017.

The production of district heating generates the largest greenhouse gas emissions in this sector. Since 1990 the supply of district heating has increased by more than 40%. On the other hand, emissions have decreased as the expansion has principally taken place through increased use of biomass fuels at the same time as the use of coal and oil has decreased.

The influence on fossil carbon dioxide emissions from weather and climatic conditions has been analysed with a normal-year-correction calculation method for the years 1990-2014, which includes emissions from electricity and heat production (1A1a) and the residential and commercial/institutional sectors (1A4a-b). Temperature, precipitation, solar radiation and wind are influencing parameters and for more information about the method used see Annex 8:2. Generally, for all years since 1990 except two (1996 and 2010) the actual emissions were lower than they would have been during a "normal year", see Figure 2.12. The main reason is that years with warm winters have dominated the period.

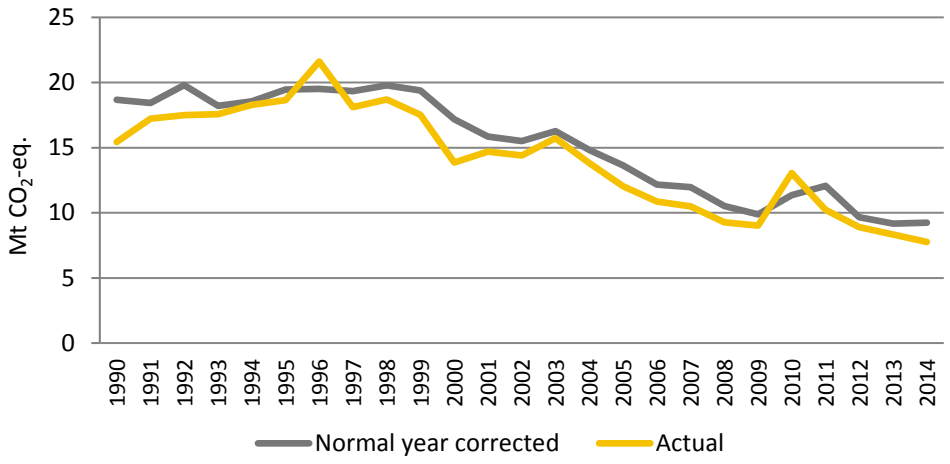


Figure 2.12. Actual and normal-year corrected fossil CO_2-emissions for heating of buildings and electricity generation in Sweden for the years 1990-2014. Included sectors are production of electricity and heat (1A1a) and residential and commercial/institutional. (1A4a-b). Normal-year corrected emissions are only available until year 2014, For the year 2014 preliminary statistics on fossil fuel consumption is used.

2.3.1.1.2 Refineries (CRF 1A1b) and manufacturing of solid fuels (CRF A1c)

2.3.1.2 MANUFACTURING INDUSTRIES AND CONSTRUCTION (CRF 1A2)

The mining, iron and steel as well as pulp and paper industries are examples of historically important industries for Sweden. Emissions from combustion in manufacturing industries and construction were 6.9 Mt CO_2-eq. in 2017 (Figure 2.13). Emissions in 2017 were 36 % lower than in 1990 and 2 % higher compared to 2016. Although increasing slightly up until 1997, the emissions have a steady decreasing trend until 2014. The lower emissions in 2009 and higher emissions in 2010 were due to the financial crisis impact on production levels and their subsequent recovery. The decreasing trend is primarily related to a lower use of oil. Oil has been replaced by electricity or biofuels, partly depending on the difference in relative prices between electricity and oil.

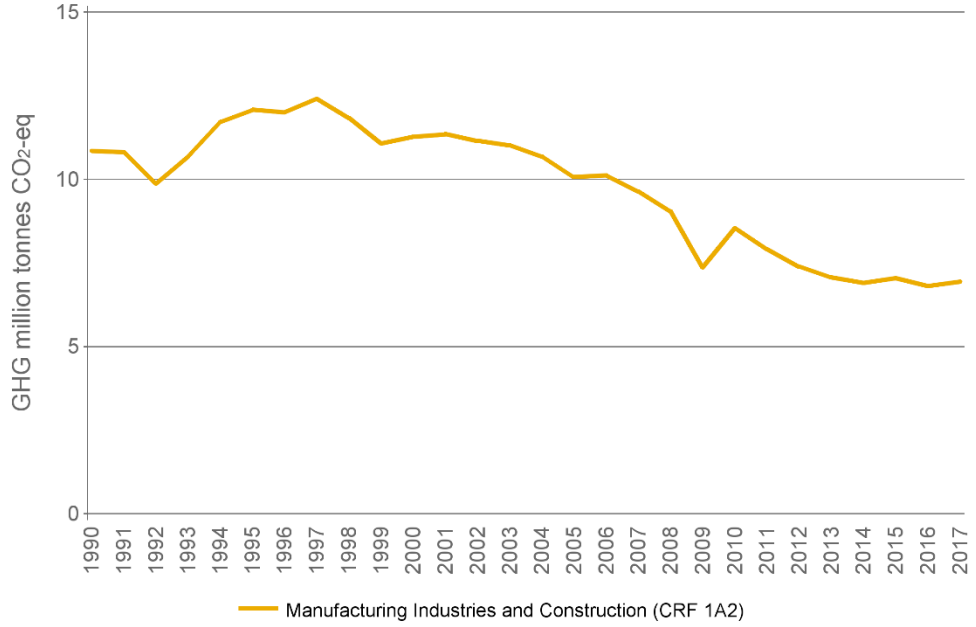


Figure 2.13. Total emissions from manufacturing industries and construction (CRF 1.A.2), 1990-2017.

A small number of energy-intensive industries account for a large share in the sector's greenhouse gas emissions. The iron and steel industry (CRF 1A2a), the non-metallic minerals industry (CRF 1A2f) and the chemical industry (CRF 1A2c) account for 20 %, 18 % and 6.6 % respectively of the emissions in 2017 (Figure 2.14).

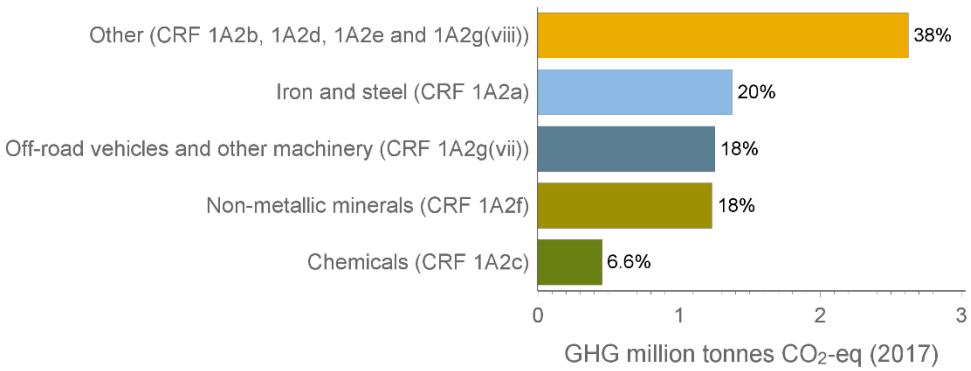


Figure 2.14. Emissions from the Energy sector; Manufacturing industries and construction in year 2017.

Other manufacturing industries, including non-ferrous metals (CRF 1A2b), paper, pulp and print (CRF 1A2d), food processing, beverages and tobacco (CRF 1A2e), and stationary combustion in other industries (CRF 1A2g(viii)), show decreasing emissions between 1997 and 2015 (Figure 2.15).

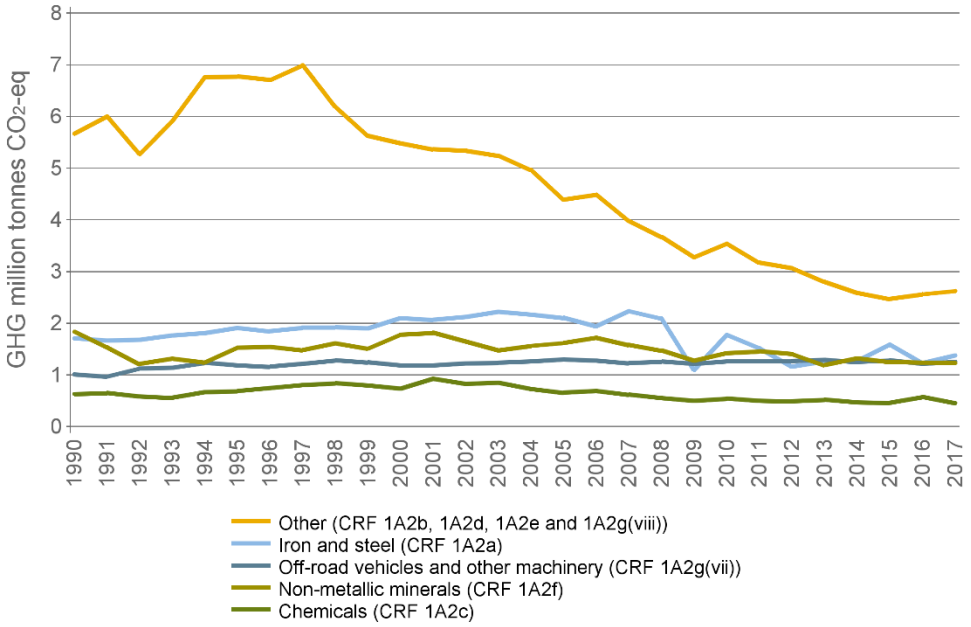


Figure 2.15. Emissions from combustion in manufacturing industries by subsectors, 1990-2017.

The decreasing emissions shown for the iron and steel industry (CRF 1A2a) are strongly linked to production levels in response to market fluctuations. The financial crisis of 2009 had a severe impact on the industry's production level.[16] It should also be noted that the significant amount of emissions from the combustion of energy gases, produced as by-products in iron and steel production processes, that are sold to electricity and heat producers are reported in 1A1a, see further discussion in chapter 3.2.9.

[16] Jernkontoret, 2015

Emissions from chemicals (CRF 1A2c) and non-metallic minerals (CRF 1A2f) have yearly variations in response to market fluctuations but the long-term trends have remained relatively stable since 1990. The emission level of non-metallic minerals is significantly lower in 2017 than in 1990 due to high emissions from use of coal in 1990-1991.

2.3.1.3 FUGITIVE EMISSIONS FROM FUELS (CRF1B)

Fugitive emissions occur for example in processing, storage and use of fuels, flaring of gas, transmission and distribution of gas. Emissions were around 0.86 Mt of CO_2-eq. in 2017, which is an increase of 23 % compared to 2016, see Figure 2.16. The increase of fugitive emissions from oil (CRF 1B2a), observed in the time series from 2006, is related to the establishment of hydrogen production facilities at two oil refineries. In total, the emissions are 126 % higher compared to 1990.

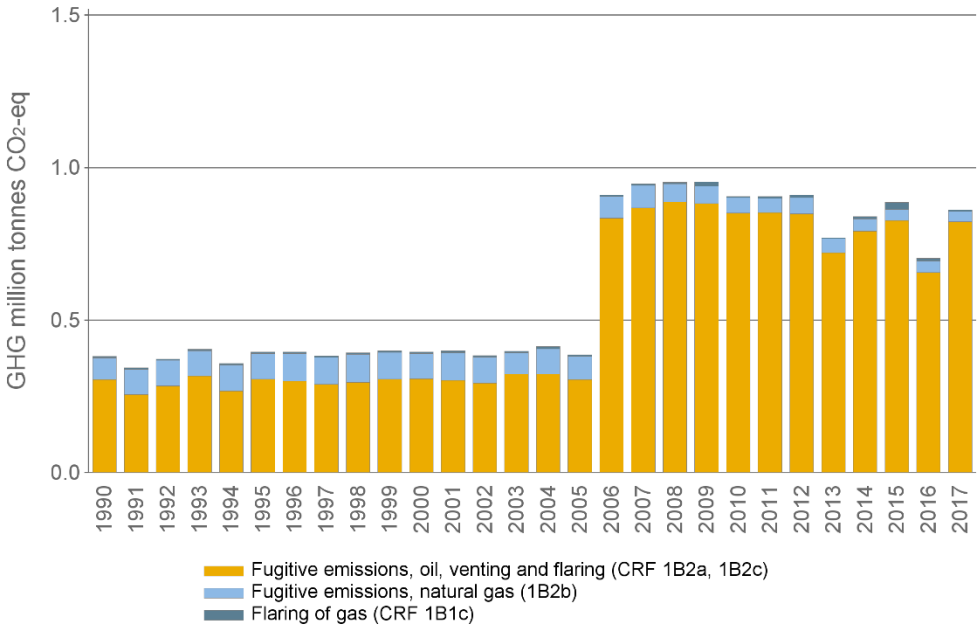


Figure 2.16. Emissions of greenhouse gases from fugitive emissions, total and by major subsectors, 1990-2017.

2.3.1.4 TRANSPORT (CRF 1.A.3)

The majority of the emissions in this subsector come from road traffic; mainly from cars and heavy duty vehicles. The total emissions from transport have decreased since 2010. Emissions from cars have decreased from 2010 to 2016, apart from a slight increase between 2014 and 2015. The decrease in emissions is largely due to increased use of biofuels and increased energy efficiency. The emissions have decreased although traffic in Sweden is increasing. Emissions from heavy duty vehicles follow the fluctuations of economic activity. They increased in general between 1990 and 2011 and subsequently started to decrease, a development that has slowed down in recent years.

Emissions from transport include emissions from domestic aviation (CRF 1A3a), road transport (CRF 1A3b), railways (CRF 1A3c), national navigation (CRF 1A3d) and other working machinery and off-road equipment (CRF 1A3e). The sub-sectors' shares of the total emissions of the sector are shown in Figure 2.17. In 2017, the greenhouse gas emissions from road transport were 15.5 Mt, 0.6 Mt from

domestic aviation, 0.3 Mt from domestic navigation and 0.2 Mt from working machinery. Emissions from railways were less than one tenth Mt in 2017.

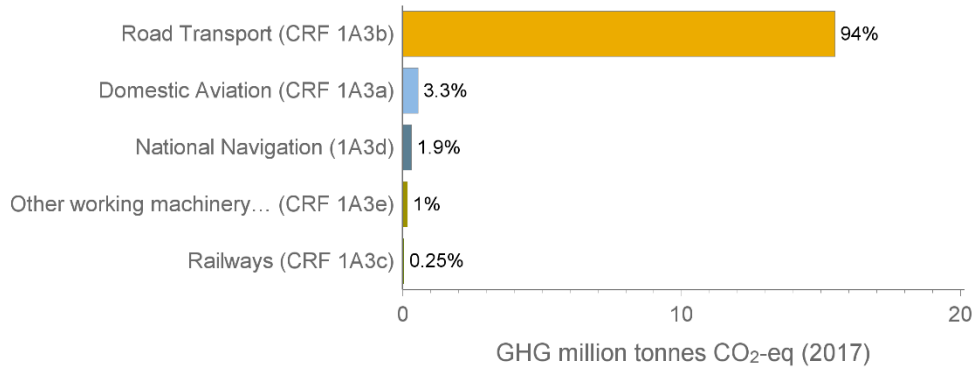


Figure 2.17. Share of emissions from sub sectors in the transport sector 2017.

Carbon dioxide accounts for the largest share of greenhouse gas emissions from the transport sector. Methane emissions were less than one tenth Mt CO_2 eq in 2017 and have fallen 88 % since 1990 as a result of better exhaust emissions control. Nitrous oxide emissions totalled 0.2 Mt of CO_2-eq. in 2017. From 1990 to 1997 there was a general increase in emissions of nitrous oxide due to the increased use of cars fitted with catalytic converters. Emissions decreased during the early 2000s following the introduction of enhanced exhaust treatment technology, but have started to increase again from 2007 and onwards but are still on a lower level than in 1990.

2.3.1.4.1 Road transport

Emissions from road transport includes emissions from passenger cars (CRF 1A3b i), light duty vehicles (CRF 1A3b ii), heavy goods vehicles (1A3b iii), buses (CRF 1A3b iii) and mopeds and motorcycles (CRF 1A3b iv). The emissions in 2017 and the share of the emissions from road traffic are shown in Figure 2.18.

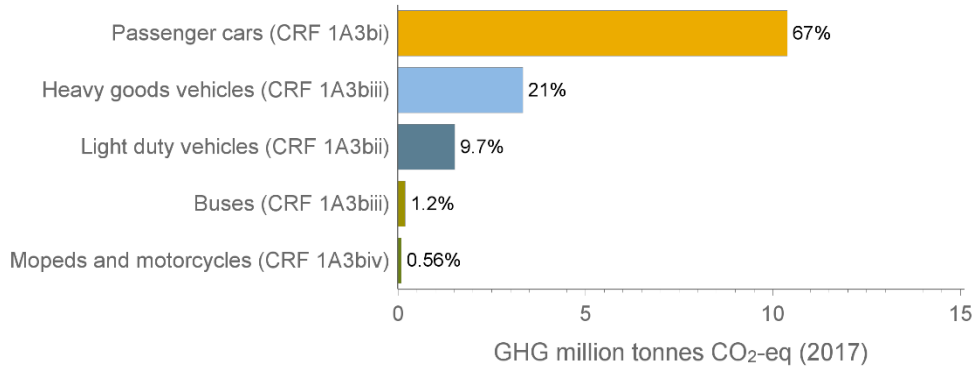


Figure 2.18. Share of emissions from subsectors of road transport in 2017.

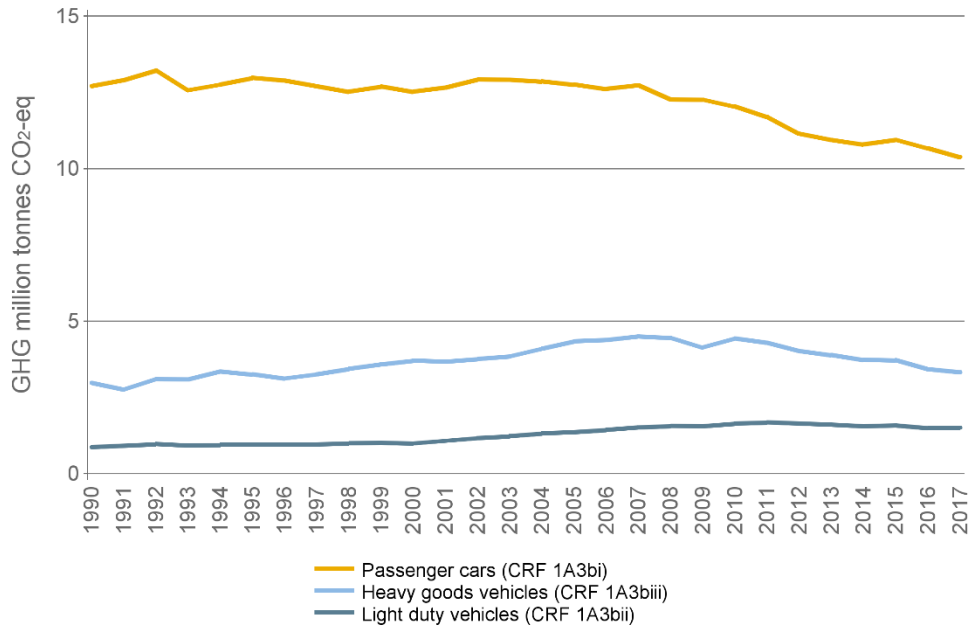


Figure 2.19. Emissions from road traffic by sub-sector, 1990-2017.

Emissions from passenger cars were 10.4 Mt CO_2-eq. in 2017, which is 18 % lower than in 1990. Emissions from passenger cars were on a fairly constant level until 2007 when they started to decrease. Besides a slight increase between 2014 and 2015 the emissions have decreased since 2007. Before 2008 the growth in transport activity was offset by a greater use of renewable fuels, more energy efficient vehicles and reduced fuel consumption which kept the level of emissions constant. The decrease that is seen in emissions after 2007 is much due to increased use of renewable fuels, more energy efficient vehicles and reduced fuel consumption in combination with the economic downturn which started in 2008.

Emissions from heavy duty vehicles were 3.3 Mt CO_2-eq. in 2017. Emissions from heavy-duty vehicles were overall increasing from the early 1990s up until 2008. Since 2010 the emissions are decreasing.

The switch from petrol-powered to diesel-powered cars is leading to a more energy efficient car fleet, which since the mid-2000s has been reinforced by a general improvement in energy efficiency for new cars. The average carbon dioxide emissions per km for new cars decreased since the early 2000th, shown in Figure 2.20, with the largest reduction between 2005 and 2012. Between 2012 and 2013 the energy efficiency rate has stagnated. The stagnation is due to the increased share of four wheel drive vehicles among new cars.[17] There was no change in average carbon dioxide emissions per km for new cars in 2017 compared to 2016.

[17] Swedish Transport Administration, 2015

18 Trafikverket, 2018

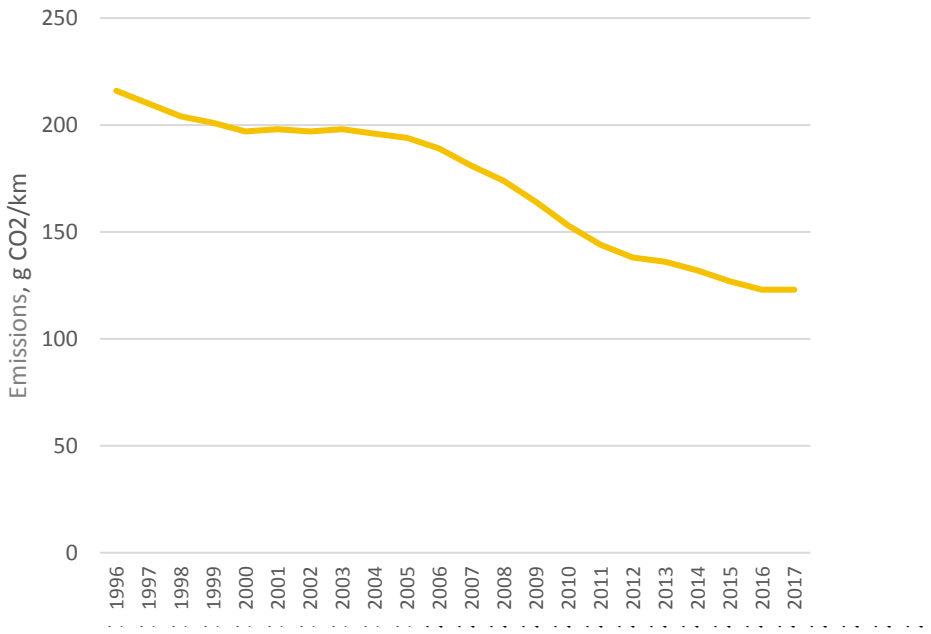


Figure 2.20. Average CO_2 -emissions per km for new cars in Sweden, 1990 – 2017. Source: Trafikverket.

There are several policy measures contributing to the trend for emissions from passenger cars: the EU-requirements limiting the carbon dioxide emissions from new cars, increased fuel taxes, tax exemption for transport biofuels, carbon dioxide-based vehicle tax, tax relief for green cars and green car rebates, together with rising market price for petrol and diesel. They have contributed to more fuel-efficient cars and an increased number of fuel-flexible cars. 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, along with a law from 2006 requiring every major petrol station to provide a renewable fuel. 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 biodiesel, such as FAME and HVO, into diesel has also increased during recent years.

2.3.1.4.2 Domestic aviation, national navigation and railways

In 2017, emissions from domestic aviation totalled 0.6 Mt of CO_2-eq, see Figure 2.22, which is 19 % lower than the level in 1990. However, the emissions varied during the period. The emission levels were unchanged from from 2016 to 2017.

Emissions from national navigation were 0.3 Mt of CO_2-eq. in 2017, see Figure 2.22. This is 47 % lower than in 1990 and 9 % lower than in 2016, but emissions have varied over the period.

Sweden's railways are largely electrified, with only a few smaller lines served by diesel-hauled trains. Emissions from rail transport have been more than halved since 1990 and are now below 50 kt of CO_2-eq. (Figure 2.21).

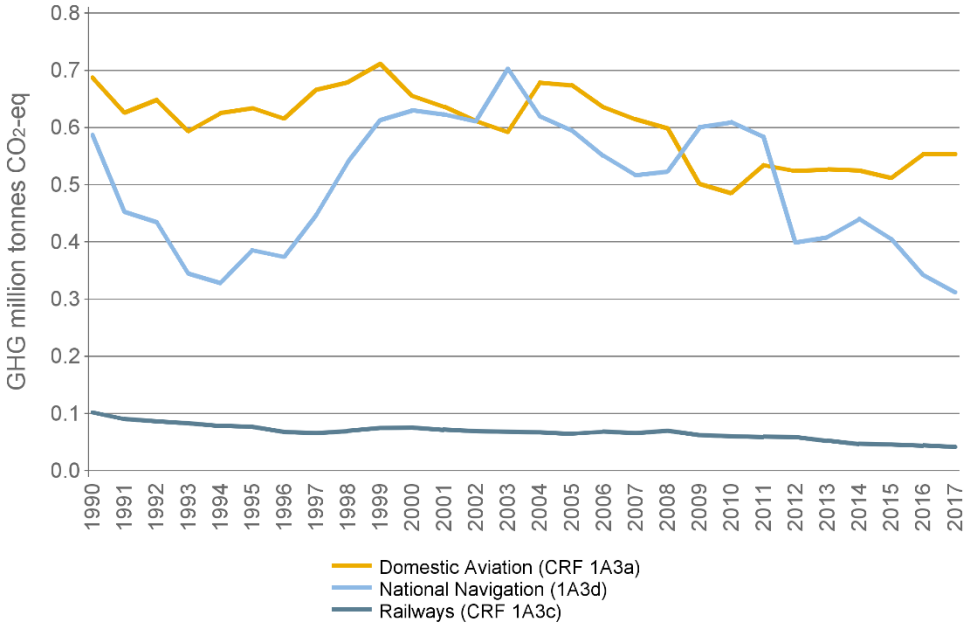


Figure 2.21. Emissions of CO_2 eq. from aviation, navigation and railways, 1990-2017.

2.3.1.5 OTHER SECTORS (CRF1A4)

In other sectors, emissions have decreased by 74 % during 1990-2017 due to a strong decrease in combustion of fossil fuels for heating in the residential and commercial/institutional sectors. Fossil fuels have been replaced by district heating, some biomass, and electricity, including increased usage of heat pumps in recent years. Since emissions from stationary combustion for heating purposes has decreased significantly, the main emissions within the sector now come from working machinery and off road vehicles. There has been a continued decrease in emissions between 2016 and 2017 with 2 %.

Combustion for heat production in the residential (CRF 1A4b), commercial/institutional (CRF 1A4a) and agriculture, forestry and fisheries sectors (CRF 1A4c) are included. Emissions from stationary combustion and working machinery and off road vehicles (mobile combustion) are also included for all subsectors. The highest emissions come from off-road vehicles and other machinery used in agriculture, forestry and fisheries, and stationary combustion in the residential sector, see Figure 2.22.

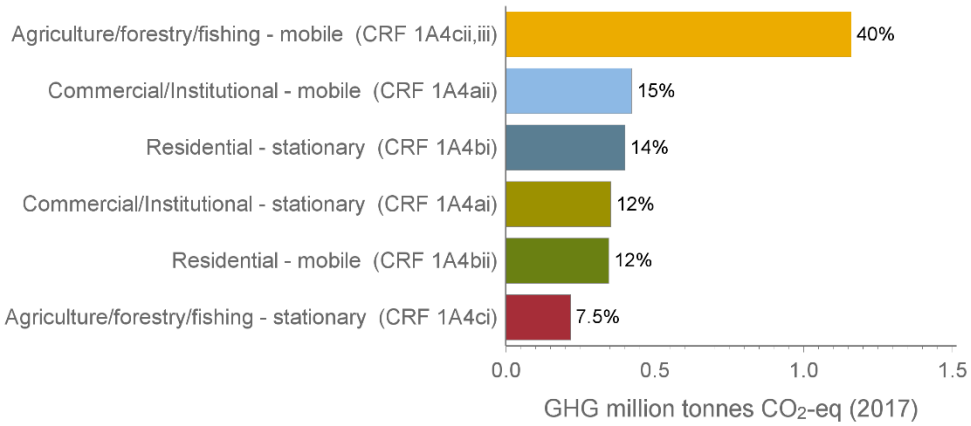


Figure 2.22. Share of emissions within Other sectors by subsector in 2017, with mobile and stationary combustion shown separately for each subsector.

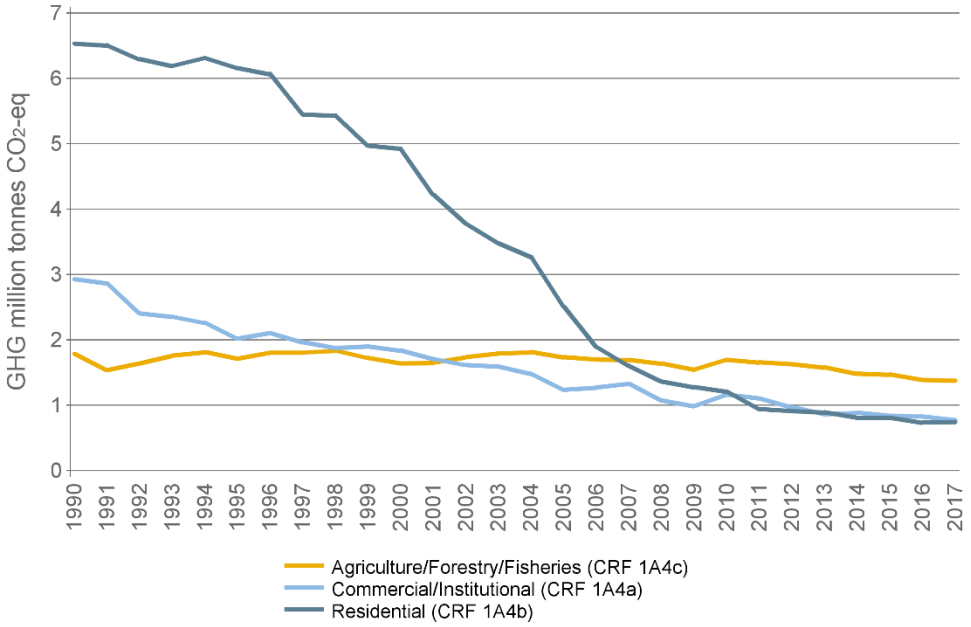


Figure 2.23. Emissions from Other sectors, total and by subsector, 1990-2017.

Emissions in Other sectors were approximately 2.9 Mt of CO_2-eq. in 2017. The reduction is due to a strong decrease in emissions from heating in the commercial/institutional and residential (CRF 1A4a and 1A4b) sectors between 1990 and 2016 (Figure 2.23) of 73 and 85 %, respectively. In comparison with 2015 the total emissions from the residential sector sector continued to decrease with 7 %. Emissions from the commercial/institutional sector, however, were at the same level as in 2015. The emissions from agriculture, forestry and fisheries (CRF 1A4c) were 1.4 Mt CO_2-eq. in 2016, which is 20 % less than in 1990.

Total emissions from off-road vehicles and other machinery within the sector were 2 Mt of -eq, which represents more than two thirds of the emissions from Other

sectors. Distribution between stationary and mobile combustion sources, as well as total emissions, is shown in Figure 2.24 below. Emissions from stationary combustion have decreased by 90 % in total from 1990 to 2017, while emissions from mobile combustion were 1 % lower in 2017 than in 1990 (Figure 2.24).

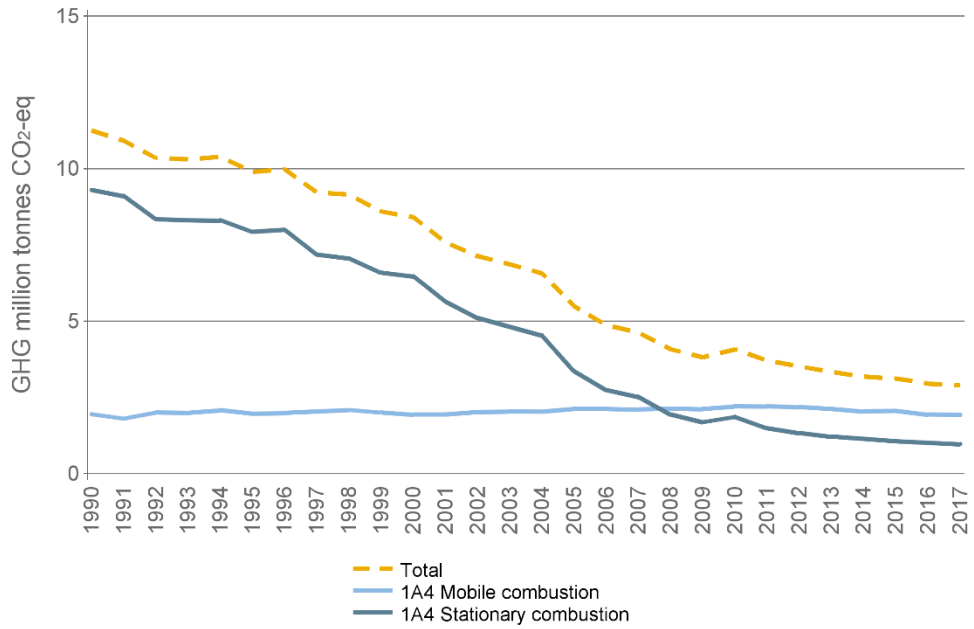


Figure 2.24. Emissions from mobile combustion, stationary combustion and emissions in total, 1990-2017.

Emissions from working machinery and off road vehicles (mobile combustion) have decreased by 1 % in total since 1990. The residential sector (CRF 1A4b) has increased its emissions from mobile combustion by about 20 % since 1990, yet these emissions are relatively low, 0.3 Mt of CO_2-eq. in 2017, see Figure 2.25. Emissions from mobile combustion in agriculture was 4 % lower in 2017 compared to emission levels in 1990. Emissions from mobile combustion in forestry (1A4c) have varied over the years and was around 10 % lower in 2017 compared to 1990, see Figure 2.25. In the commercial/institutional sector (CRF 1A4a) emissions from mobile combustion have varied during the period but were 17 % higher in 2017 compared to 1990. In fisheries (CRF 1A4c) the emissions have been declining during the past decades, following the trend with a shrinking fleet of fishing vessels in Sweden. It should be noted that the emissions from working machinery and off road vehicles are model-based and there is a high uncertainty connected to these emissions. More can be read about the used model in Annex 2.

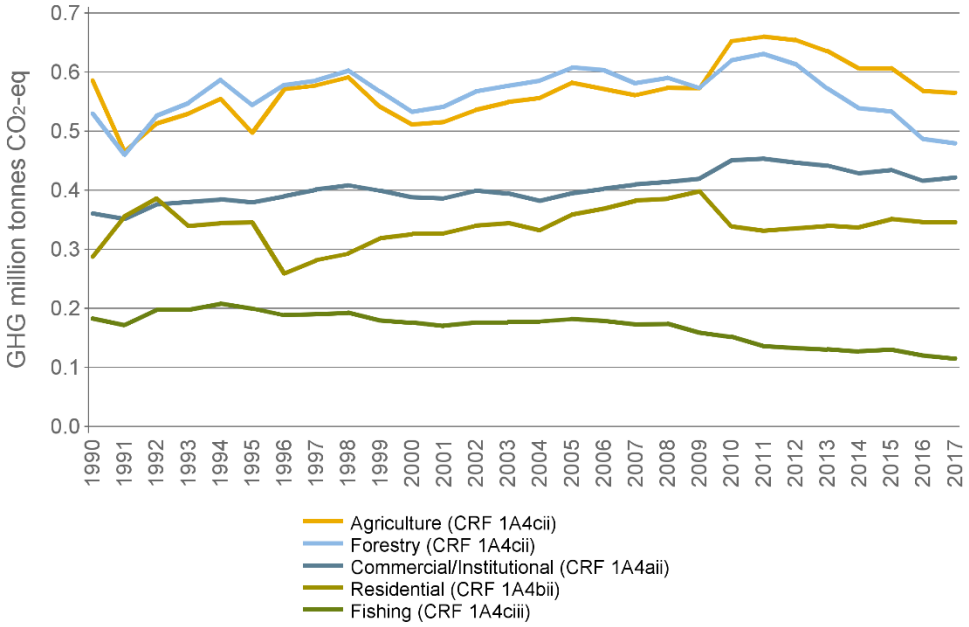


Figure 2.25. Emissions off-road vehicles and other machinery in each subsector, 1990-2017.

In the residential sector (CRF 1A4b), the emissions from stationary combustion have decreased by 94 % since 1990, and in the commercial/institutional sector (CRF 1A4a) emissions from stationary combustion have decreased by 86 %. Emissions from stationary combustion in agriculture, forestry and fisheries (CRF 1A4c) are small and have decreased, with 55 % compared to 1990. Emissions from stationary combustion within each subsector are shown in Figure 2.26.

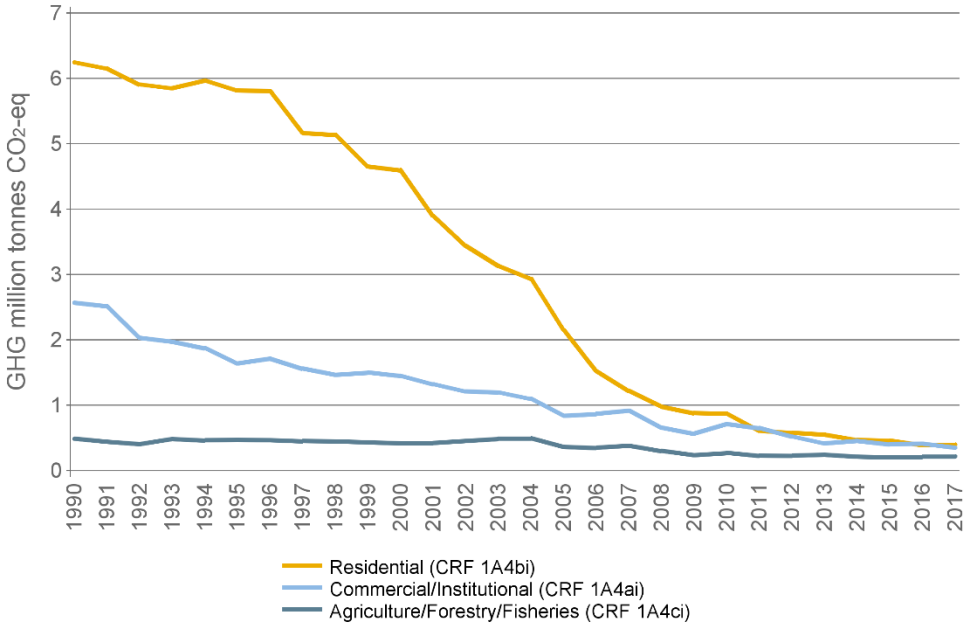


Figure 2.26. Emissions from stationary combustion in each subsector, 1990-2017.

The large reduction in emissions from stationary combustion in the residential and commercial/institutional sector depends on a large decrease in total use of fossil fuels since 1990, see Figure 2.27. There are several reasons for this development: the shift from oil to district heating and electric heating as well as increased usage of heat pumps. The most common source of heating in the residential sector is district heating followed by electric heating and these emissions are included in the electricity and heat production sector (section 2.3.1.1.1). Increased energy efficiency has also contributed to the decrease in emissions.

Another contributing factor to the favourable development has been the generally warm weather since 1990. The outdoor temperature affects the need for heating, which leads to variations in energy usage between years. However, it is mainly usage of district heating and electric heating that increase during cold years in this sector. More information about the weather and normal–year-corrected emissions can be found in section 2.3.1.1.1. and in Annex 8:2.

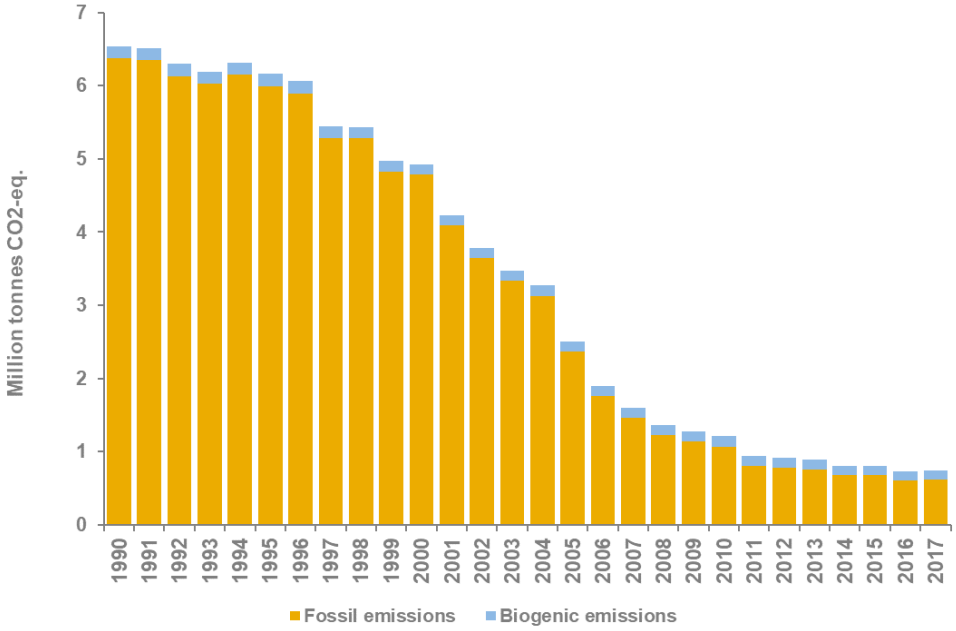


Figure 2.27. Emissions from Residential sector (1A4b) fossil and biogenic, stationary combustion, 1990-2017.

Increased energy efficiency has also contributed to the decrease in emissions. One example of increased energy efficiency is a continued decrease in energy use for heating per unit of floor space area in one and two-dwelling buildings.

2.3.2 Industrial processes and product use (CRF sector 2)

Greenhouse gas emissions within the sector industrial processes and product use (CRF 2) stem from the materials used in industrial processes as well as the use of various products such as fluorinated gases, solvents, lubricants and paraffin waxes. Emissions of greenhouse gases from industrial processes and product use have been decreasing in recent years. Greenhouse gas emissions from industrial processes are mainly affected by production levels in response to market fluctuations. Emissions from product use were significantly higher in 2017 compared to 1990.

Emissions from the industrial processes and products use sector represented 14 % of the total national emissions in 2017. The main sources of emissions in the industrial processes and product use sector is the production of iron and steel (included in metal industry; 2C) and the cement and lime industries (included in mineral industry; 2A), see Figure 2.28. Note that emissions from combustion in manufacturing industries and construction are allocated to CRF 1A2. Also, note that combustion of energy gases produced as by-products in iron and steel production processes that are sold to electricity and heat producers are allocated to CRF 1A1a, see further discussion in chapter 3.2.9.

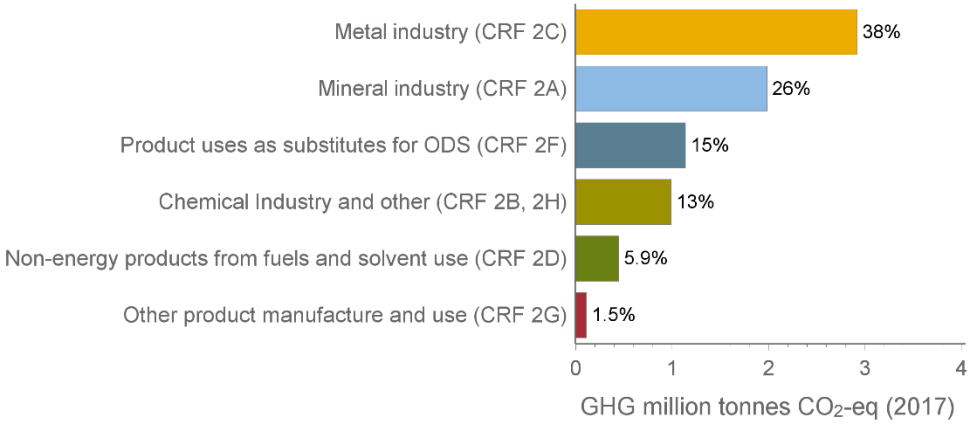


Figure 2.28. Emissions from the industrial processes and product use, 2017.

Greenhouse gas emissions from the industrial processes and product use sector were at the same level in 2017 compared to 1990, see Figure 2.29. After a few years of steady decrease, greenhouse gas emissions in the sector increased with 7 % between 2015 and 2016 and then decreased by 3 % between 2016 and 2017.

Greenhouse gas emissions from industrial processes (CRF 2A, 2B, 2C, 2E, 2H) show an overall decreasing trend since 1995, with the exception of 2009 and some interannual variations, and were 16 % lower in 2017 compared to 1990, see Figure 2.29. Greenhouse gas emissions from product use (CRF 2D, 2F, 2G) showed an increasing trend that has stabilised since 2004, with a small decrease. Nevertheless, greenhouse gas emissions from product use were 200 % higher in 2017 compared to 1990.

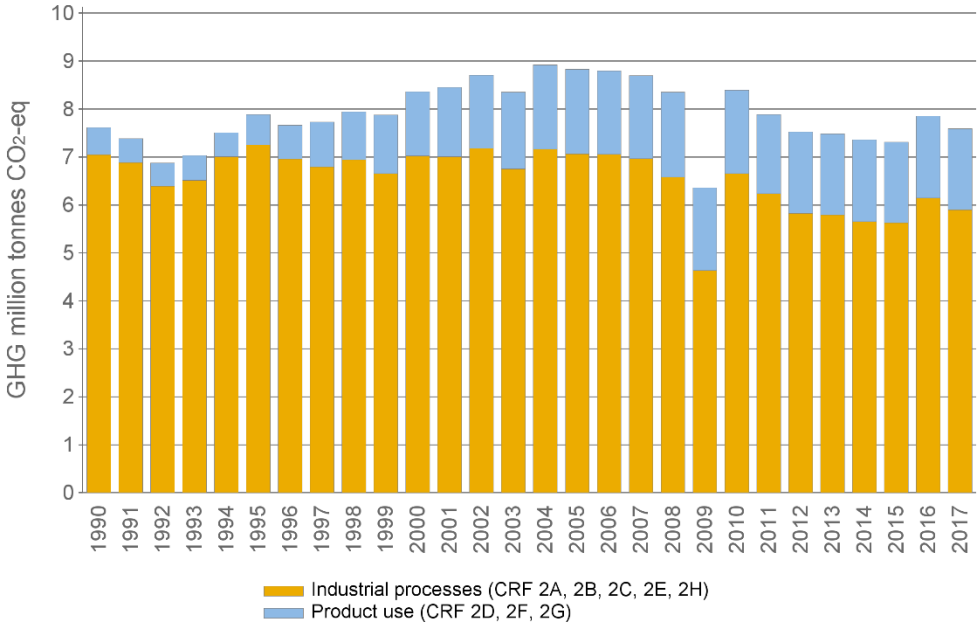


Figure 2.29. Emissions from the industrial processes (CRF 2A, 2B, 2C, 2E, 2H) and product use (CRF 2D,2F,2G), 1990-2017.

2.3.2.1 EMISSIONS PER GAS

Carbon dioxide (CO_2) dominates the emissions of this sector with 5.7 Mt of CO_2-eq. in 2017, representing 81 % of the sector's emissions, see Figure 2.30. CO_2 emissions stem from the use of various materials in industrial processes, the use of solvents, lubricants, paraffin waxes and other types of products.

The sector also emits significant amounts of nitrous oxide (N_2O) and fluorinated gases (HFCs, PFCs and SF_6). N_2O emissions were 0.21 Mt of CO_2-eq. in 2017 and mainly come from the production of nitric acid. In 2017, the N_2O emissions have decreased by 78 % since 1990. of fluorinated gases were 1.2 Mt of CO_2-eq. in 2017 and have increased by 81 % since 1990 (Figure 2.30.

All emissions of fluorinated gases in Sweden are found in the industrial processes and product use sector. Although the fluorinated gases are emitted in relatively small amounts compared to CO_2, they have a much higher GWP (global warming potential) due to their chemical structure and therefore contribute significantly to global warming. The new EU regulation from 2015 on fluorinated greenhouse gases aims to cut the emissions of fluorinated gases in the EU by two thirds by 2030, by ensuring that fluorinated gases are replaced by safer alternatives[18,19]. More information on fluorinated gases and the regulation is provided in section 2.2.4.

[18] EU, 2014

[19] EU, 2012

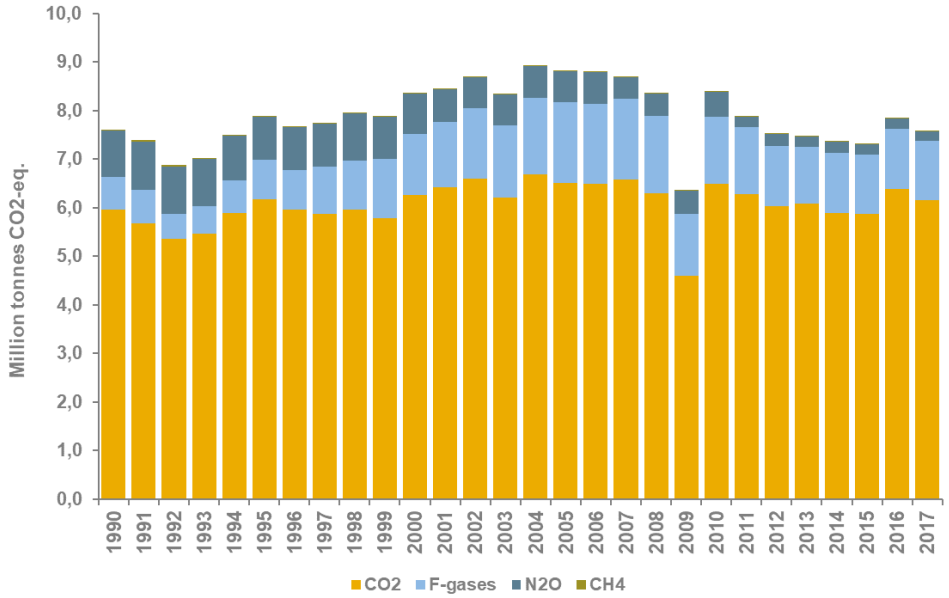


Figure 2.30. Emissions from the industrial processes and product use sector per gas, 1990-2017.

2.3.2.2 INDUSTRIAL PROCESSES (CRF 2A, 2B, 2C, 2E, 2H)

Greenhouse gas emissions from industrial processes have varied since 1990, mainly due to variation in production volumes in response to market fluctuations, see Figure 2.31. The exception is the chemical industries (2B) that reduced their emissions significantly over the period through enhanced emission abatement in their processes. In 2009, the global economic recession caused production to slow down and hence emissions to decrease rapidly, especially in iron and steel (2C). Emissions reverted to previous levels in 2010 and then continued decreasing.

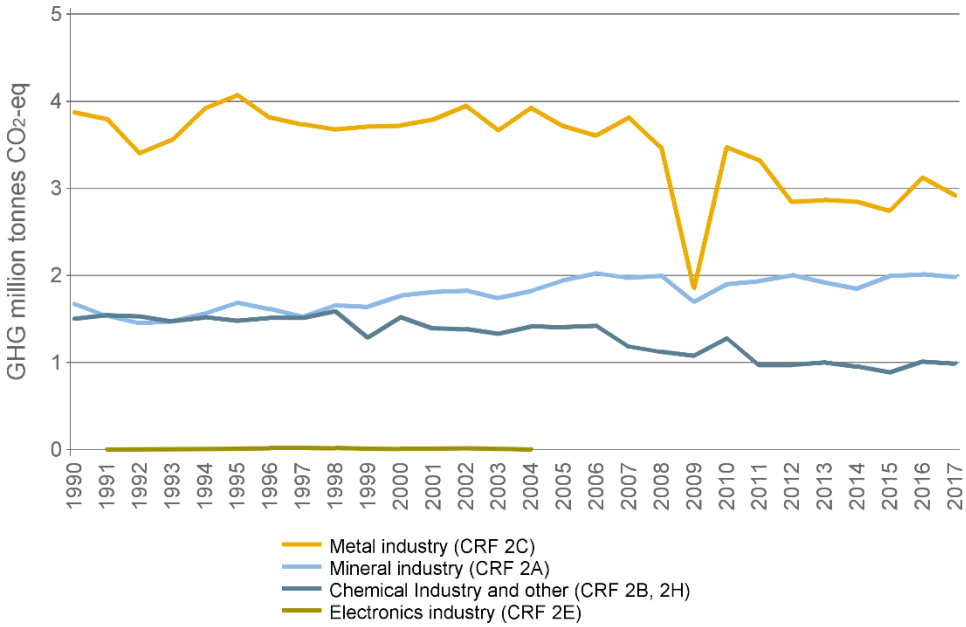


Figure 2.31. Emissions from industrial processes, per subsector, 1990-2017.

The subsector with the largest emissions is the metal industry (2C) with 38 % of the industrial process and product use sector's total emissions in 2017, see Figure 2.31. The emissions were fairly stable until 2008, with the exception of some inter-annual variations. In 2009, emissions decreased rapidly due to reduced production levels in response to the global economic recession. Although production levels – and emission levels – increased again in 2010, the metal industry has not fully reverted to the emission levels prior to the recession (Figure 2.31).

Production of aluminium (CRF 2C3) also causes emissions of perfluorocarbons (PFCs) under conditions where the amount of alumina falls below a critical level in the process (commonly referred to as "anode effects"). These emissions have decreased in recent years, primarily as a result of investments in new technology in primary aluminium production[20] since 2007.

Mineral industry (2A) is the second largest subsector, accounting for 26 % of the sector's total emissions in 2017, see Figure 2.31. Cement production (2A1) accounts for 20 % of the sector's total emissions. The industry also includes production lime (2A2) and glass (2A3). The emissions from the mineral industry show an increasing trend, of 19 %, during the period from 1990 to 2017, mainly due to improving economic conditions in the building sector, both in Sweden and in other countries to which cement is exported. This resulted in an increased production of clinker that is used for the production of cement. Emissions decreased in 2009 as a result of a decline in production in response to the global economic recession. Emissions reverted to previous levels within two years.

Emissions from the chemical industry (2B) show a decreasing trend in emissions from 1990 to 2011 with few minor exceptions. The decrease since 2007 is primarily a result of a new treatment technology for nitric acid production[21]. The new technology has resulted in reduced emissions of nitrous oxide. The technology has been further developed resulting in additional emissions reductions in 2010. Together with other production (2H), that primarily includes process emissions from the pulp and paper industry and mineral wool production, the activities accounted for 2 % of the sector's total emissions in 2017.

The electronics industry (2E) generated insignificant greenhouse gas emissions during the period 1991 to 2004.

[20] Ny Teknik, 2014

[21] Yara, 2007

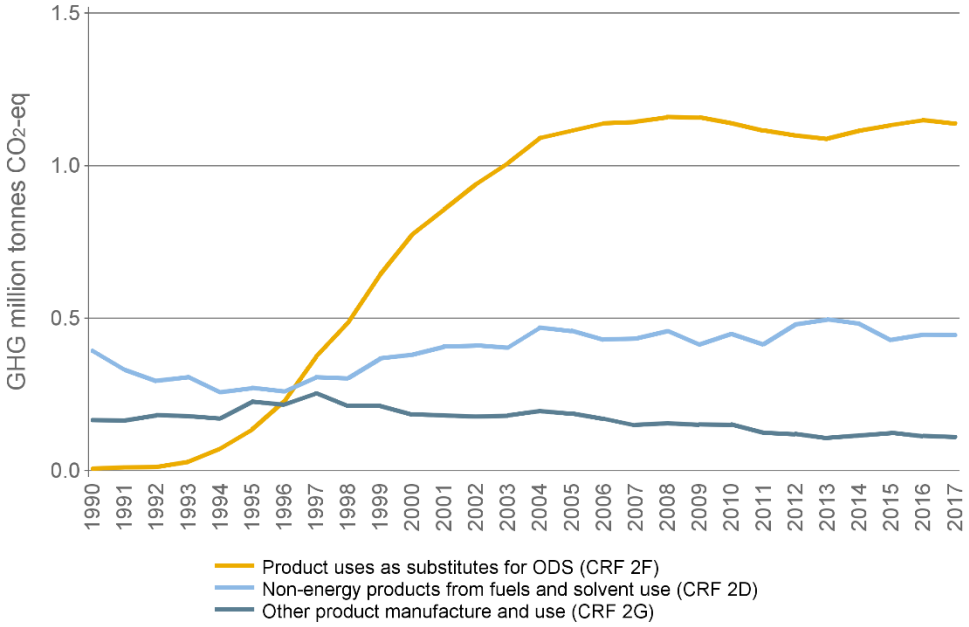


Figure 2.32. Emissions from product use, per subsector, 1990-2017.

2.3.2.3 PRODUCT USE (CRF 2D, 2F, 2G)

Greenhouse gas emissions from product use (CRF 2D, 2F, 2G) represent 3 % of the national total emissions in 2017. The emissions stem from products used as substitutes for ozone depleting substances (2F), non-energy products from fuels and solvent use (2D) and from other product manufacture and use (2G).

The subsector with the largest emissions from product use, as seen in Figure 2.32, is product uses as substitutes for ozone depleting substances (2F). In 2017, the emissions in this subsector accounted for around 1.7 Mt of CO_2-eq, which represents 22 % of the total emissions from industrial processes and product use. The emissions have increased threefold since 1990. The increase between 1990 and 2004 was more than 1 Mt of CO_2-eq. and is primarily due to increases in HFC emissions. HFCs have replaced the use of ozone-depleting substances (CFCs and HCFCs), which have been phased out following the Montreal Protocol, in products like refrigerators, freezers and air-conditioning equipment. At the same time the number of refrigeration and air-conditioning systems, air conditioning in vehicles and heat pumps has increased, particularly in the recent years[22]. Since 2009 the emissions have decreased, which may be a result of the implementation of an EU regulation limiting the use of fluorinated gases.

Greenhouse gas emissions from non-energy products from fuels and solvent use (2D) comprise emissions from a large number of applications of solvents, lubricants, paraffin waxes, etc. as well as urea used in catalysers of for example cars and trucks. More details are given in section 4.5. The emissions of this subsector represented 6 % of the industrial processes and product use sector in 2017, or 0.4 Mt of CO_2-eq. The emissions increased by 13 % during the period 1990 to 2017. The increase is mainly due to increased CO_2 emissions from use of lubricants.

[22] Swedish Chemicals Agency, 2017

The estimated greenhouse gas emissions from other product manufacture and use (2G) consist of fluorinated greenhouse gases from electrical equipment and sound-proof windows as well as N_2O from product use in medical applications. The greenhouse gas emissions in this subsector accounted for around 0.1 Mt of CO_2-eq. in 2017. The trend was increasing until 1995 but has since gradually decreased by 46 %.

2.3.3 Agriculture Sector (CRF 3)

The main sources of greenhouse gas emissions from the agriculture sector are methane from livestock's enteric fermentation and nitrous oxide and methane from agriculture soil and manure management. In addition, there is a small amount of carbon dioxide emission that comes from liming and urea application. In 2017, the aggregated emissions from the sector were about 7.2 Mt CO_2-eq., which equal to about 14 % of the total national *greenhouse gas* emissions *(excluding LULUCF). Emissions from the sector were about 6 % lower compared with 1990 levels. The decrease is due to the decline in numbers of livestock, especially dairy-cows and swine as well as decreased emissions from agriculture soils, particularly from the use of inorganic N-fertilizers. However, emissions in 2017 have increased by 5.5 % compared to the previous year due to a number of factors such as, increased emissions from the use of inorganic N-fertilizers, higher emission of nitrous oxides from organic soils and increased numbers of non-dairy cattle.*

Agricultural activities contribute to emissions of greenhouse gases (CO_2, CH_4 and N_2O) through a variety of processes. The main sources of CH_4 and N_2O emission in Sweden are animal husbandry and crop production in which the later includes for example, emission of N_2O from the use of synthetic fertilizer and manure management. Animal husbandry in Sweden is dominated by beef and dairy cattle, but also has significant swine, sheep and poultry components. Other livestock species farming includes goats, horses, reindeer and fur-bearing animals. Agricultural farming includes predominantly the production of cereals, sugar beet and oilseeds.

In 2017, agriculture soils (3D) and enteric fermentation (3A) were the dominant sources of emissions in the agriculture sector and accounted for 48 % and 42 %, respectively. Manure management (3B) and liming (3G) accounted for about 8 % and 2 % of the sector's emission, respectively. Emission from urea application (3H) is very limited (Figure 2.33).

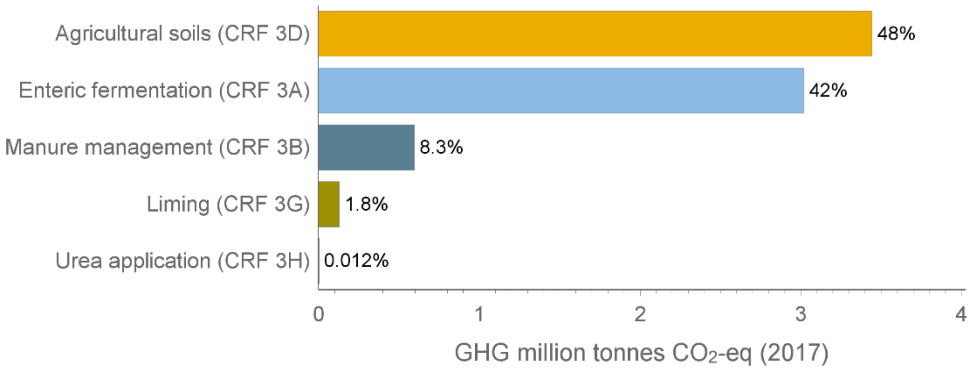


Figure 2.33. Emissions in the Agriculture sector in 2017 (Gg CO_2-eq)

The aggregated emissions from the agriculture sector in 2017 were about 7.2 Mt CO_2-eq. which equal to about 14 % of the total national greenhouse gas emissions (excluding LULUCF). More than a half (52.5 %) of the sector's emission consists of N_2O, 45.7 % CH_4 and about 1.8 % CO_2. Emissions from the sector have decreased by less than 0.5 Mt CO_2-eq., or by 6 % compared to 1990 levels (Figure 2.34).

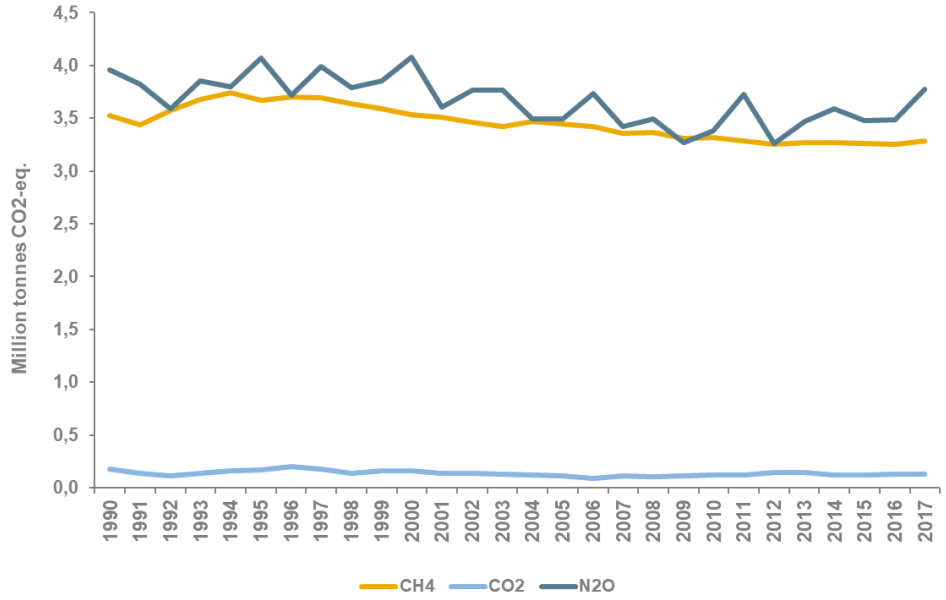


Figure 2.34. Emissions from agriculture sector per gas 1990-2017 (Gg CO_2-eq).

The main drivers behind the long-term decreasing emission trend are: a decline in the numbers of livestock, especially dairy cows and swine, improved manure management practices, decreased use of inorganic N-fertilizers as well as decreased use of other fertilizers such as, liming and urea applied on soils.

Emissions in 2017 have increased by 4.6 % compared to previous year, mainly due to increased emission of N_2O from organic soils (3Da5), increased numbers of non-dairy cows (3A), increased use of inorganic N-fertilizers (3Da1) and increased crop residues applied to soils (3Da4).

2.3.3.1 ENTERIC FERMENTATION (CRF 3A) AND MANURE MANAGEMENT (CRF 3B)

In 2017, the aggregated CH_4 emission from enteric fermentation (3A) were about 3 Mt -CO_2-eq. which equates to about 42 % of the sector's emission, representing the largest single source of CH_4 emission in the inventory. Since 1990, emissions of CH_4 from enteric fermentation have decreased by about 8 %. Between 2016 and 2017, the emissions increased by 1 %, see Figure 2.35.

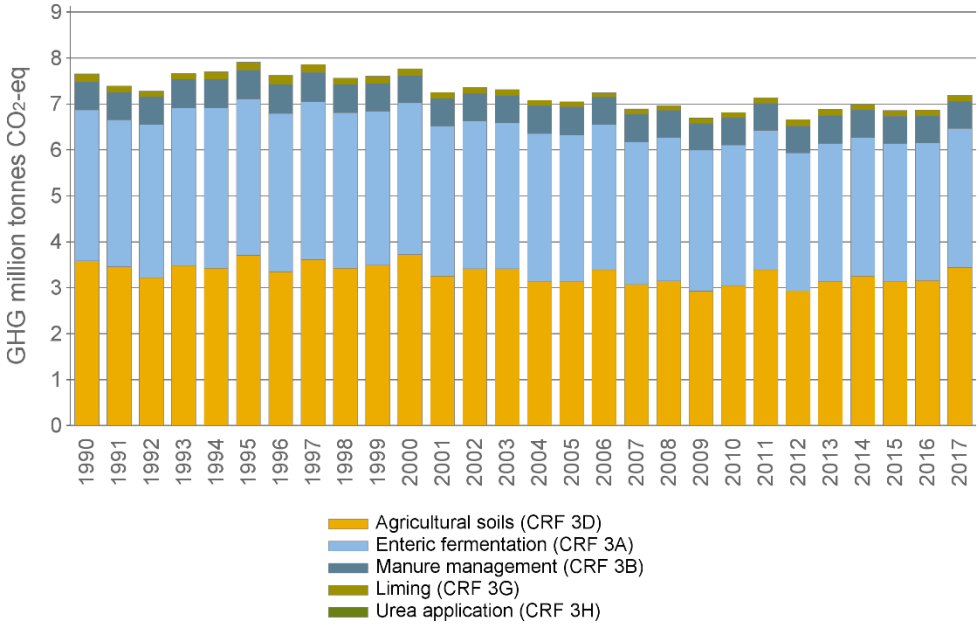


Figure 2.35. Emissions from agriculture subsector 1990-2017 (Gg CO_2-eq).

The key driver for the reduction of CH_4 emission since 1990 is a decline in livestock numbers, mainly dairy cows and swine. The number of dairy-cows, for example, has decreased by about 44 % compared to 1990 (from 576 000 to 322 000 heads between 1990 and 2017). Between 2016 and 2017, the population decreased by about 2.7 % or 8 800 heads. The reduction of the dairy cows numbers has led to a drop of CH_4 emission by about 30 % since 1990. The numbers of swine have also decreased by almost the same magnitude as the dairy cows during this period and the emission of CH_4 has also decreased by 40 % since 1990.

The most important factor affecting the emission from dairy cows is the amount of milk produced in the farm. Higher milk production per dairy-cow gives lower CH_4 emissions per kg milk produced. The milk production per cow has increased by about 46 % between 1990 and 2017 as milk production has become more efficient. The average milk yield per cow in 2017 was 9518 kg yr^{-1} cow^{-1}.
A significant reduction in dairy cattle population (about 8 %) took place in 1990/1991, when a large number of farms abandoned milk production and shifted towards non-dairy cattle. Some of these farms changed to extensive meat production with the aid of government conversion grants, and the number of beef cattle therefore, increased by about 15 % during the first half of the 1990s.

Following Sweden's accession to the EU in 1995, subsidies paid under the EU's Common Agricultural Policy (CAP) stabilised livestock numbers for livestock, for example cattle.

The total number of non-dairy cattle (heifers, bulls and steers) has increased by about 3 % since 1990 (from 1.14 million heads in 1990 to about 1.18 million heads in 2017). The culmination of the number of non-dairy cows in 1996 was followed by a steep decline until 2003, which slowed down until 2016 followed by an increase of 1.8 % until 2017. As a result, CH_4 emissions from non-dairy cattle have increased by about 16 % compared to 1990.

In 2017, the aggregated emissions from manure management (3B) were about 8 % (or 0.6 Mt CO_2-eq.) of the sector's emission. The composition of the emissions was 44 % CH_4 and 56 % N_2O. The total emissions from manure management in 2017 were slightly lower than the levels of 1990, although the numbers of dairy cows and swine have decreased substantially. This can be explained by an increased milk production per cow as cows that produce more milk also produce more manure. In addition, the number of non-dairy cattle has slightly increased. The aggregated emissions in 2017 were very comparable with 2016.

About one-third of the sub-sector's (3B) emission is derived from non-dairy cows, which has increased by 48 % since 1990, due to increased numbers of animals and also as a consequence of intensification of beef-production. Manure emission from diary-cows constituted about 25 % of the sub-sector's emission. However, emissions from diary-cows have decreased by about 27 % since 1990 due to a drop in their numbers and improved manure management practices at the national level.

Nearly one-third (30 %) of the emission of manure management in 2017 was derived from other animal categories (such as poultry, lambs, goats and horses, etc.). Their emissions have increased following their increased population since 1990.

2.3.3.2 AGRICULTURAL SOILS (CRF 3.D)

The sub-sector, agriculture soils (3D) is the largest single source of N_2O emission in the national inventory. The main sources of N_2O emission of this category are the supply and conversion of nitrogen from the use of synthetic fertilizers, cultivation of organic soils from drained histosols, crop residues as well as animal manure applied to soils. Other small sources include, sewage sludge applied to crop fields as fertilizer, emissions from organic soils as a result of mineralization and immobilization associated with loss/gain of soil organic matter, atmospheric deposition as well as conversion of the nitrogen that leaches to lakes and watercourses.

The emission trend of the agriculture soils depends largely on the amount of inorganic nitrogen applied to soils and cultivation of organic soils, but also influenced by other sources such as mineralization and immobilization associated with loss/gain of soil organic matter as well as animal manure applied to soil.

Agriculture soils, as a sub-sector, was responsible for about 48 % (or about 3.4 Mt CO_2-eq.) of the sector's total in 2017 (Figure 2.35). The emissions have decreased by about 4 % since 1990. Between 2016 and 2017, the emissions have increased by

9 %, mainly due to increased use of inorganic N-fertilizers (3Da1), increased emission N_2O from organic soils (3Da5) and increased crop residues applied to soils (3Da4).

Emissions from the use of inorganic N-fertilizers have declined as sales of inorganic N-fertilizers have declined since 1990. For instance, the nitrogen input via application of synthetic fertilizers on agriculture soils declined from 225 kt in 1990 to about 198 kt in 2017, a decrease of about 12 %[23]. In 2017, emissions of N_2O from the use of N-fertilizers increased by about 7 % due to increase sales compared to the previous year. However, sales of mineral fertilizer in Sweden have increased by one-third since 2012 which has led to increased emissions by the same magnitude. Sales of other types of mineral fertilizers, such as phosphorus, potassium, and sulfur fertilizers have also increased during the same period.

2.3.3.3 LIMING (CRF 3.G) AND UREA APPLICATION (CRF 3.H)

In Sweden, liming is mainly applied to acidic soils to improve soil structure and has become popular in recent years. Liming is also applied to counteract phosphorus losses through leaching from clay soils to surface water. Emissions from liming and urea application as well show a long-term downward trend.

The estimated emissions from liming in 2017 were about 127 kt CO_2, compared to 173 kt CO_2 in 1990 (decreased by 27 %). The total emissions of CO_2 accounted for less than 2 % of the sector's emission in 2017 (Figure 2.34).

The amount of urea used in Sweden is smaller than in the rest of Europe. The reason is that urea is a slow release fertilizer, which does not fit well in areas with a short growing season (i.e., *northern latitudes*). In 2017, the estimated CO_2 emissions from urea application (CRF 3.H) were less than 1 kt, compared to 4.3 kt in 1990.

2.3.4 Land Use, Land Use Change and Forestry – LULUCF (CRF sector 4)

This sector consists of source and sink categories linked to land use, land use change and forestry. The total net removal was circa 44 Mt CO_2-eq. in 2017. Forest land covers more than half of the Swedish total land area, and is therefore the dominant category in this sector. The largest net removals occur in forest land and amounted to about 43 Mt CO_2-eq. in 2017, followed by harvested wood products with removals of about 7Mt CO_2-eq. The largest net emissions in this sector occur in settlements, cropland and wetlands. This sector has been a sink the whole period from 1990 until 2017.

Sweden reports carbon stock changes from forest land (CRF 4 A), cropland (CRF 4B), grassland (CRF 4C) and settlements (CRF 4E) and associated land-use transfers and also a small part of wetlands (CRF 4D) where peat extraction occurs. These land use categories are considered managed. This year we also report on other land since the ERT recommended us to do so. We report on land change from managed land to unmanaged land.

[23] Statistics Sweden, 2018

The calculation of net emissions and removals in the LULUCF sector also includes HWP (Harvested Wood Products) (CRF 4G), emissions of nitrous oxide associated with nitrogen fertilization of forest land (4I), nitrous oxide and methane from drained and rewetted organic soils and methane from ditches (4II), carbon dioxide from dissolved organic carbon (DOC), nitrous oxide emissions due to mineralization due to land use conversions and management change (4III), indirect nitrous oxide emissions (4IV) and nitrous oxide, methane emissions from biomass burning (4V).

The most dominant category in this sector is forest land since forest land covers 63 % of the total Swedish land area (Figure 2.36).

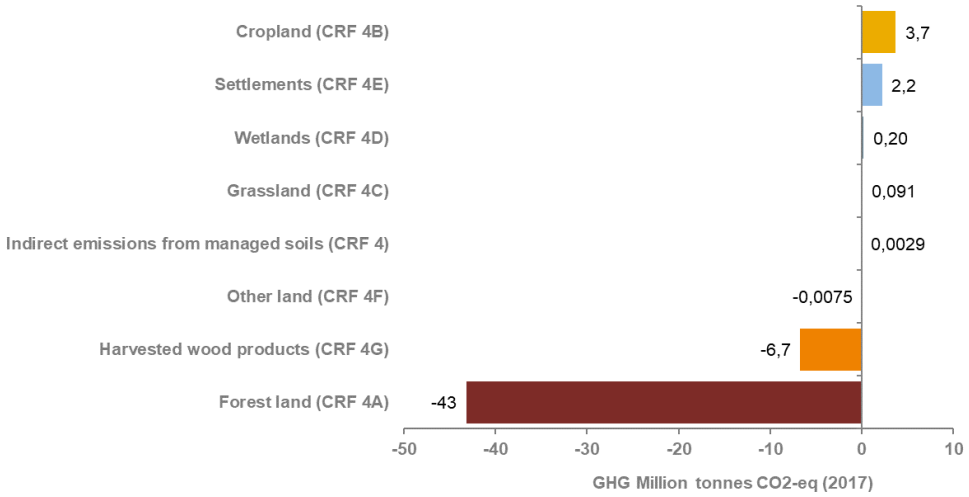


Figure 2.36. Emissions (+) and removals (-) in the LULUCF sector; for the categories, Forest land (CRF4A), Cropland (CRF 4B), Grassland (CRF 4C), Wetland (CRF 4D), Settlements (CRF4F) and HWP (CRF 4G) in 2017.

Net emissions and net removals per category

The LULUCF sector has generated annual net removals in Sweden during the whole period 1990-2017 (Figure 2.37). In 2017 total net removal from the sector was estimated to about 44 Mt CO_2-eq. During the period total net removals have varied between around 34 to 44 Mt of CO_2-eq. Between 2016 and 2017 the total net removals decreased by almost 1 Mt CO_2-eq. The total size and variation of net removals in the LULUCF-sector is mainly affected by the carbon stock change in forest land, and changes in the carbon pool living biomass constitute the major part of these changes in net removals followed by carbon stock changes in mineral soils. Net removals in this sector are heavily influenced by harvests and natural disturbances such as storms on forest land.

Net removals in living biomass in forest land varied between approximately 23 (2005) and 37 (1996 and 2013 - 2017) Mt of CO_2-eq. during the period 1990 until 2017. Between 2016 and 2017 the total net removal on forest land was the same. There are two dips in the trend, in 2005 and 2007, because of two severe storms. According to the Swedish National Board of Forestry, the felling, including wood

felled by storms, was estimated at 122 Mm^3sk in 2005. However, the decrease in the living biomass in 2005, resulted in an increase in the HWP-pool in 2006.

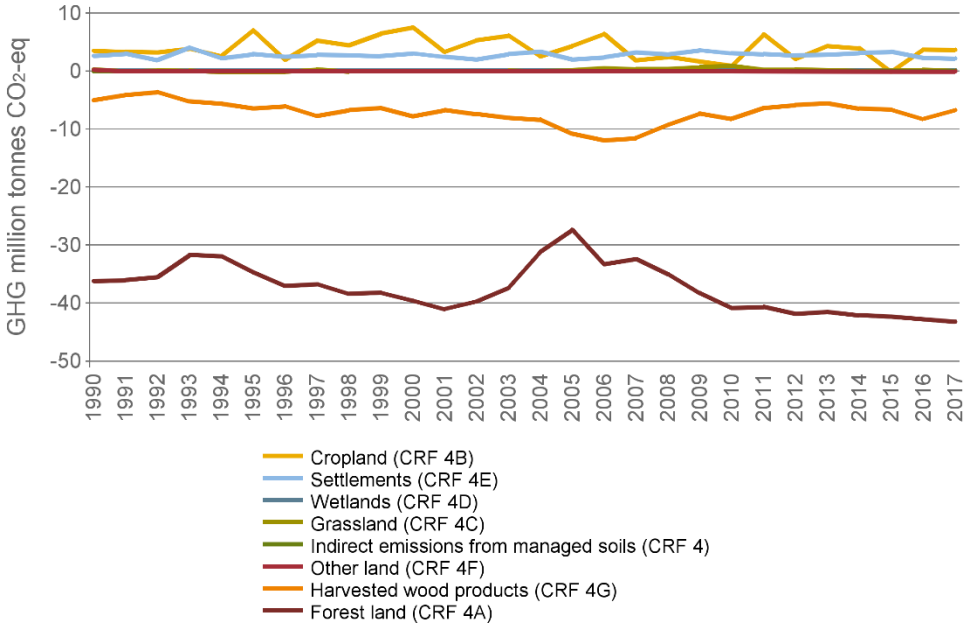


Figure 2.37. Net emissions (+) and removals (-) of greenhouse gases in the LULUCF sector from different land-use categories and total net removals for the LULUCF-sector, 1990-2017.

Although inter-annual fluctuations in harvest rates are quite large, the increase in harvest rates has stagnated in recent years. In 2017 the gross harvest was approximately 90,9 Mm^3sk[24]. Gross removal (growth) in Sweden shows an increasing trend and is currently at around 120 Mm^3sk. Since harvest level is below growth there is a steady carbon stock in living biomass, which has prevailed since the beginning of the 21th century.

The categories grassland and wetlands account for very small areas and small net removals and net emissions compared to forest land. The carbon stock changes in grassland and wetlands were small during the period 1990 to 2017. The net removals in the category grassland have varied during the period and the variation in the net removal is due to the variation in harvest of trees (living biomass) in the grassland category. There is no trend since there has been both net emissions and net removals between 1990 and 2017. The emissions from wetlands are due to drainage of organic soils for peat production. The emissions have increased from nearly 80 kt CO_2-eq in 1990 to around 200 kt CO_2-eq. in 2017.

The largest net emissions in this sector come from cropland and settlements. Net emissions from cropland has been about 4 Mt of CO_2-eq. as a mean value since 1990 until 2017. The inter-annual variation in net emissions in cropland is connected to the variation in mineral soils. The annual variations depend on what are grown and how large areas of crops that are grown between years together with the climatic conditions (air temperature and precipitations). The total net emissions

[24] https://www.skogsstyrelsen.se/statistik/statistik-efter-amne/bruttoavverkning/

in 2017 was the same as 2016.The emissions of carbon dioxide in croplands originate from the cultivation of organic soils. Emissions from drained organic soils are the largest source in in this land use category and in 2017 the net emissions amounted to 3 Mton CO2-eq.

Total net emissions from settlements were as a mean about 3 Mton CO2-eq during the period 1990 until 2017. The highest total netemissions was in 1993 and about 4 Mton CO2-eq. The total net emissions were abolut the same in 2017 as in 2016. Emissions are mainly caused by urbanisation and establishments of power lines and forest roads.

Net emissions and net removals by carbon pool

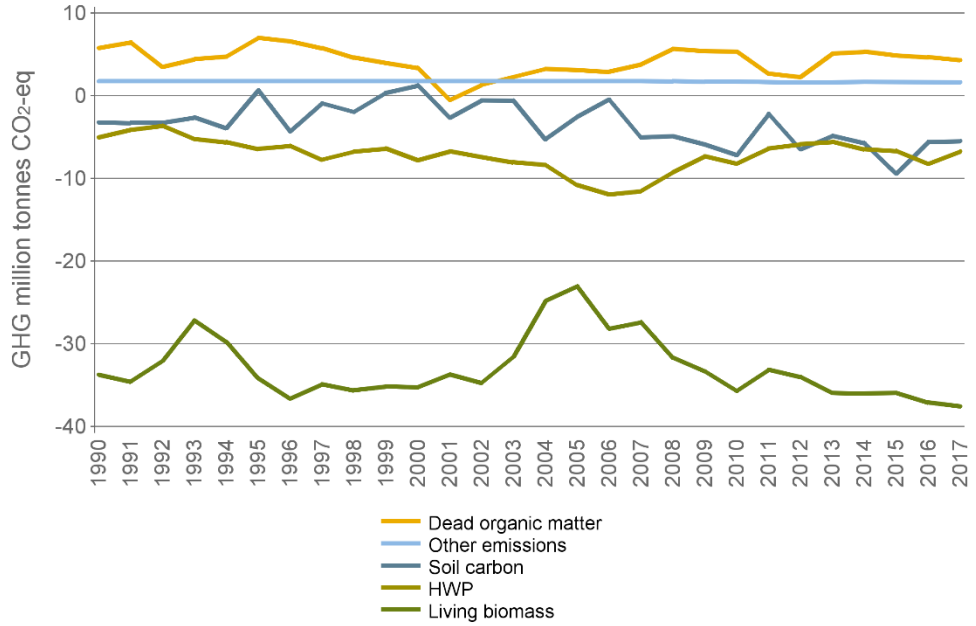


Figure 2.38. Emissions (+) and removals (-) of carbon dioxide from different carbon pools, 1990-2017.

Net removals in the LULUCF-sector are calculated as the total carbon stock change in living biomass, dead organic matter (dead wood and litter including the humus layer of soil), soil organic carbon, harvested wood products (HWP) and other emissions (fertilization N_2O, indirect (N_2O), mineralization (N_2O), biomass burning (N_2O and CH_4) and drainage (N_2O and CH_4) for different land use categories.

Net removals in living biomass are significant, as illustrated by the net removals on primarily forest land. The net removal in the carbon pool living biomassa in 2017 was about 37 MtonCO_2-eq and this is about the same as in 2016. The lowest net removal for living biomass was in 2005 after the storm Gudrun. The HWP pool stock change depends on the estimated difference between the inflow of carbon in terms of new products and the modelled outflow of discarded products. At present, the estimated pool therefore covariates with the Living biomass net removals in the category forest land. The largest net removals in the pool/category HWP, occurred

after the big storm in 2005 resulting in increased felling (salvage logging) the year after the storm. The net removal in the pool HWP was about 7 MtonCO_2-eq in 2017 and this is 1,5 MtonCO_2-eq less than in 2016 this due to the fact that the fellings in 2017 was 2,6% less than in 2016.

The uncertainty of estimates in the LULUCF sector is generally larger than in other CRF sectors in the inventory and the uncertainties are generally larger for the smaller categories (area) in the LULUCF sector than for larger ones.

2.3.5 Waste (CRF sector 5)

Two thirds of the emissions from the waste sector come from solid waste disposal which generates methane. These emissions have decreased by approximately 75 % since 1990 and several policy instruments – both legislative and economic – have had significant impact on this trend. The most important mitigation measures are an expansion of methane recovery from landfills, reduced landfill disposal of organic material, increased levels of recovery of materials and waste incineration with energy recovery.

Emissions from waste (CRF 5) include emissions from solid waste disposal (CRF 5A), wastewater treatment and discharge (CRF 5D), biological treatment of solid waste (CRF 5B) and incineration and open burning of waste (CRF 5C). The shares of the sub sectors of the total emissions of the sector are shown in Figure 2.39. Greenhouse gas emissions from the waste sector amounted to 1.25 Mt CO_2-eq. in 2017, or 2 % of the national total of greenhouse gas emissions. Out of this, 0.8 Mt CO_2-eq. came from solid waste disposal.

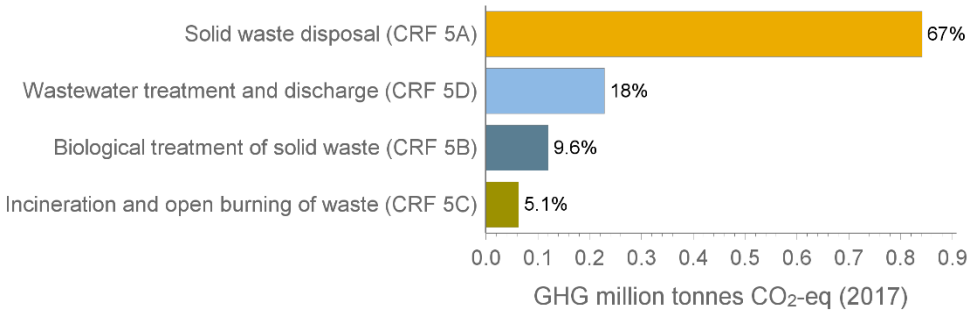


Figure 2.39. Share of emissions from sub sectors in the waste sector 2017.

Emissions in the sector are predominantly methane (CH_4), 76 % in 2017, as seen in Figure 2.40. Emissions of methane from the waste sector have decreased by 72 % in the period 1990 to 2017, due to an increased level of collection and management of methane gas from landfills and reduced amounts of organic material being deposited in landfills.

In 2017, nitrous oxide (N_2O) emissions amounted to 19 % of the emissions. There has 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. The waste sector also emits small amounts of carbon dioxide emissions (CO_2), 4,6 % of the emissions in 2017. These emissions come from the incineration of waste, of which a minor part is reported in the waste sector and the major part is reported in the energy sector.

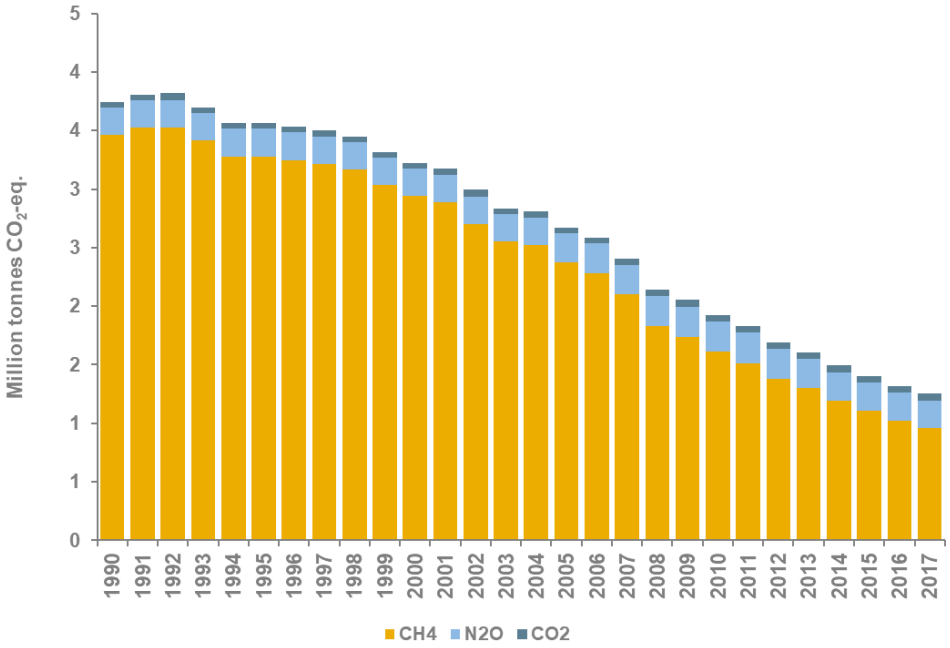


Figure 2.40. Emissions from the waste sector, per gas, 1990-2017.

Emissions from the waste sector have decreased by 67 % since 1990, see Figure 2.41 for a sub sectoral breakdown of emissions over time. The most significant emissions in the waste sector occur as a result of solid waste disposal, however the trend also shows the most significant emission reductions within this subsector – a decrease of 75 % between 1990 and 2017.

While emissions from wastewater treatment and discharge decreased by 13 % from 1990 until 2017, emissions emanating from biological treatment of solid waste and incineration and open burning of waste both show increasing trends from 1990 to 2017, by 866 and 41 % respectively.

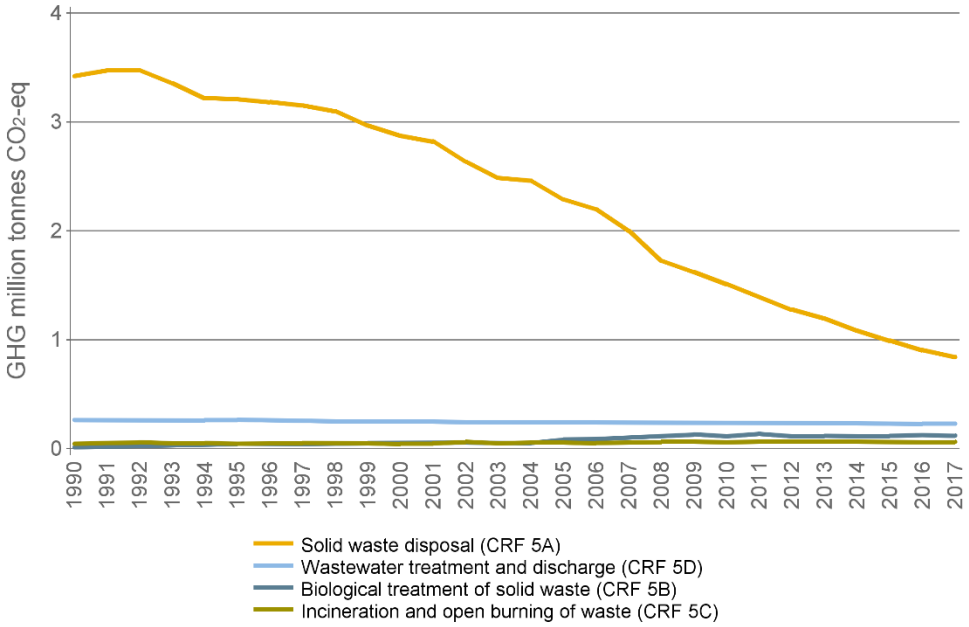


Figure 2.41. Emissions from the waste sector, per subsector, 1990-2017.

2.3.5.1 SOLID WASTE DISPOSAL (CRF 5A)

In 2017, 67 % of the emissions from the waste sector came from solid waste disposal (CRF 5A). Between 2016 and 2017 the emissions decreased by 7 % from this subsector. Solid waste disposal covers managed, unmanaged and uncategorized waste that has been deposited in landfills. Landfills are the second largest source for emissions of methane gas in Sweden, after livestock farming (in agriculture, CRF 3). Methane is formed when organic waste deposited in landfills starts to decay. Increased collection levels and management of methane gas from landfills and reduced amounts of organic material being deposited in landfills have led to steadily declining methane emissions from Swedish landfills since the early 1990s.

Waste management has developed considerably over the past twenty years. Several policy instruments have had a significant impact on this trend. Producer responsibility was introduced for several groups of products in the 1990s and, today, eight groups of products are covered (i.e. batteries, cars, tires, electric and electronic products, packaging, paper, pharmaceuticals and radioactive products)[25]. A tax on depositing waste in landfills was introduced in 2000[26]. Bans on landfill disposal of combustible waste (in 2002) and organic material (in 2005) have also been introduced[27]. These bans contributed to substantial shifts in Swedish waste management. The landfilling of other types of waste has also fallen sharply.

[25] Swedish EPA, 2017

[26] Avfall Sverige, 2017

[27] Swedish EPA, 2012

Finally, the obligation for municipal waste planning that was introduced in 1991[28] may also have contributed to the increased collection of methane from landfills as well as to the reduced deposits of degradable material.

2.3.5.1 WASTEWATER TREATMENT AND DISCHARGE (CRF 5D)

About 18 % of the emissions in the waste sector are emitted from wastewater treatment and discharge. The emissions were approximately 0.2 Mt CO_2-eq. in 2017. Wastewater treatment facilities have been continuously improved since the late 1960s[29]. Emissions from Swedish wastewater treatment and discharge have decreased by approximately 13 % since 1990, which may be explained by the improvement of facilities during the period as well as increased biogas generation from sewage sludge (Figure 2.41).

2.3.5.2 BIOLOGICAL TREATMENT OF SOLID WASTE (CRF 5B)

Biological treatment of solid waste accounted for almost 10 % of the total emissions in the waste sector in 2017 (approximately 0.1 Mt CO_2-eq). Biological treatment of solid waste includes composting (aerobic digestion) and anaerobic digestion of organic waste. While composting generates methane and nitrous oxide, the anaerobic digestion is designed to produce methane for use in other sectors.

The use of methane for combustion is reported in the energy sector, but emissions emanating from the production (e.g. leakages when upgrading biogas) are reported in the waste sector. The emissions from biological treatment of solid waste have shown an increasing trend over the last two decades. In fact, the emissions have increased almost 900 % since 1990, especially in recent years when also production of biogas using anaerobic digestion was scaled up[30]. This may explain the increasing trend together with the fact that composting and digestion overall has become more important treatment methods of municipal waste during the time period (Figure 2.41).

2.3.5.3 INCINERATION AND OPEN BURNING OF WASTE (CRF 5C)

In 2017, 5 % of the total emissions in the waste sector occurred in incineration and open burning of waste. Emissions have shown an increased trend since 1990, and in particular since 2003. The total generation of municipal waste has increased over the period and incineration has become the most important treatment option for municipal waste (Figure 2.41). However, the main incineration of municipal waste uses energy recovery and the emissions are therefore accounted for in the energy sector (CRF 1). Nevertheless, this has led to a higher incineration capacity which together with larger quantities of waste being categorized as hazardous may explain the trend also for incineration and open burning of waste in the waste sector.

2.3.6 International shipping and aviation

International bunkers include refuelling in Sweden by international shipping and aviation. These emissions are reported as memo items and are not included in the total Swedish emissions calculated in relation to the Convention and Kyoto

[28] Swedish EPA, 1991

[29] Swedish EPA, 2009

[30] Swedish Energy Agency, 2015

Protocol commitments. Greenhouse gas emissions from international shipping and aviation, also known as international bunkers, are considerably larger than those from domestic shipping and aviation. In 2017, they amounted to 10.6 Mt of CO_2-eq, which is a increase of 13 % since 2016 (Figure 2.42).

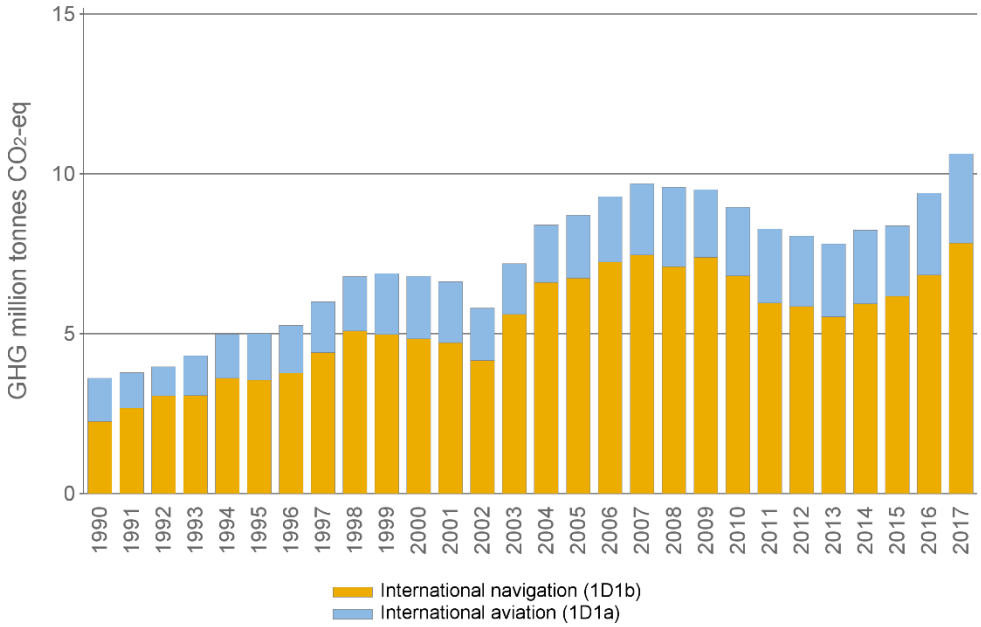


Figure 2.42. Emissions from international bunkers, total and per subsector, 1990-2017.

Emissions from international shipping reached a total of 7.8 Mt of CO_2-eq. in 2017. This is an increase of 15 % compared with 2016 and 246 % higher than in 1990.

Explanations of the increase of emissions from foreign shipping might be:

- That Swedish bunker companies have gained market share in the bunkering market, partly because they were early on offering low-sulfur fuel and partly because a major competing Danish company went bankrupt in 2014.

- The production of residual oil (fuel oil nos. 2-5) has increased due to higher demand for low-sulfur fuel, where residual oil is a by-product from the production of low-sulfur fuel and then the residual fuel are sold as cheaper high-sulfur fuel.

- How much shipping companies choose to bunker in Sweden also has to do with how the fuel price in Sweden is compared to other countries and the shipping routes in general.

Fluctuations in bunker volumes between years are also dependent on fuel prices in Sweden compared with the price in ports in other countries.

Greenhouse gas emissions from international aviation bunkers were 2.8 Mt of CO_2-eq. in 2017. This is an increase of 9 % compared to 2016 and 106 % higher than in 1990. Emissions from international bunkering of aviation have varied over time. The trend points to a rise in these emissions, owing to growth in travel abroad.

2.4 Precursors and indirect emissions

The indirect greenhouse gases in Sweden include nitrogen oxides (NO_X), non-methane volatile organic compounds (NMVOCs), carbon monoxide (CO) and sulfur dioxide (SO_2). The first three gases influence the concentration of ozone in the lower troposphere and hence have influence on the radiative forcing. Sulfur dioxide contributes to aerosol formation in the atmosphere. Sulfate aerosols affect the climate as they reflect sunlight and they also have an indirect effect on climate in that they influence the "seeding" of clouds which have a negative net radiative forcing effect, and therefore tend to cool the surface.

There has been a long-term decrease in the emissions of the indirect greenhouse gases and SO_2 in Sweden as their emissions have declined strongly since 1990.

2.4.1 Non-methane volatile organic compounds (NMVOCs)

A total of 147 kt of non-methane volatile organic compounds (NMVOCs) were emitted in 2017. Less than a half (44 %) of the emissions was derived from the industrial processes and product use sector (CRF 2). In 2017, the energy sector (CRF 1) and the agriculture sector (CRF 3) contributed with 35 % and 21 %, respectively. The remaining emission (0.6 %) came from the waste sector.

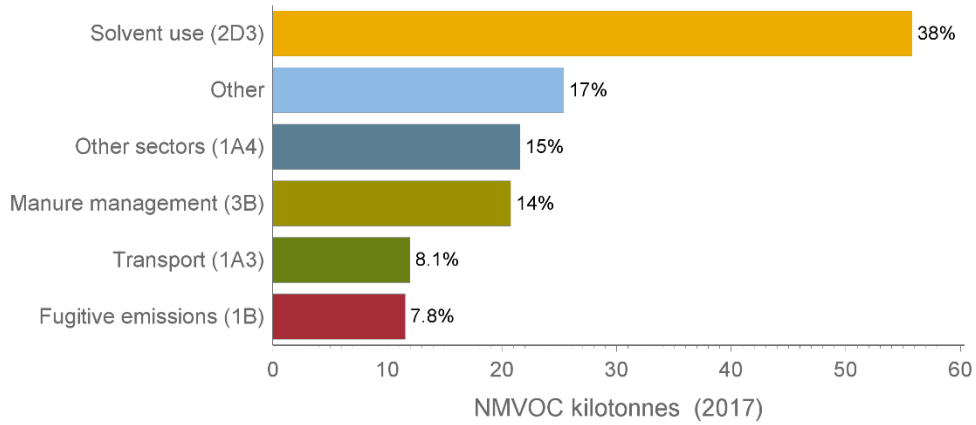


Figure 2.43. Emission sources of NMVOC in 2017 (kt).

In 2017, most of NMVOCs emissions (38 %) are derived from solvent use (2D), while most of the emissions from CRF 1 come from Other sector (1A4) and transport (1A3) as well as fugitive emissions of oil and natural gas (1B) which accounted for 15 %, 8 % and 7.8 %, respectively. Emission from manure management (3B) accounted for 14 % of the national total, see Figure 2.43.

The total emissions of NMVOCs have declined by 59 % since 1990. The emission in 2017 decreased marginally compared to 2016 (see Figure 2.44). The decline is sharp in the energy sector (CRF 1) and clearly visible in the industrial processes and product use sector (CRF 2), amounting to about 76 % and 38 %, respectively. In 2017, emissions of NMVOCs from the energy sector (CRF 1) decreased by 2 % compared to the previous year, while the emissions from (CRF 2) remained almost at the same level.

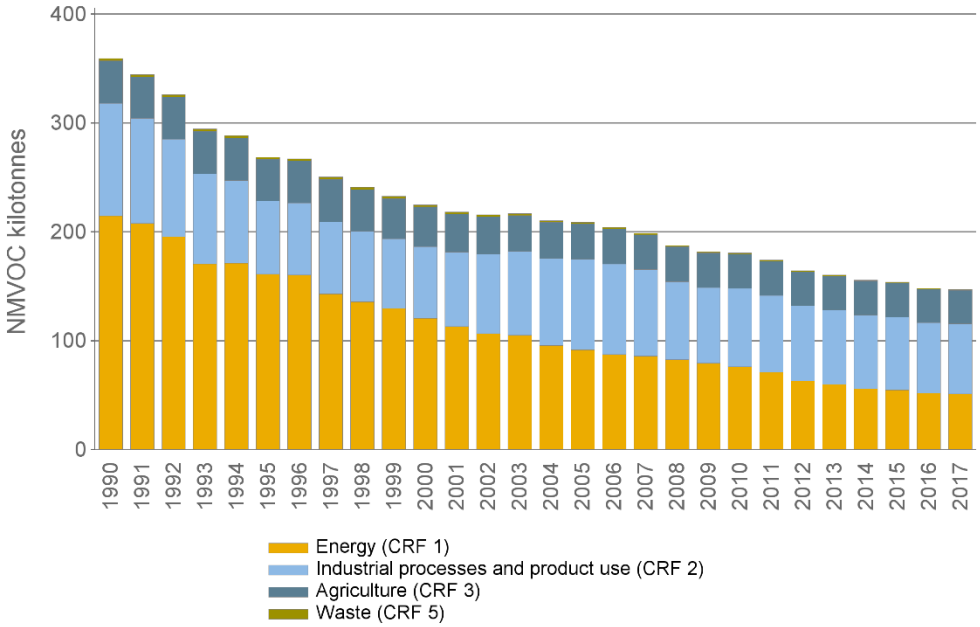


Figure 2.44. Emission trends of NMVOC 1990-2017 in kt.

The largest reduction of NMVOCs since 1990 has occurred in the transport sector, in which emissions in 2017 decreased by 92 % and by 4 % compared to 2016. Emissions have also decreased by 63 % from oil refineries and by 38 % from product use since 1990. The main reasons behind the reduction of the emission is the introduction of stricter emission standards in the EU regulation for road vehicles and lower emissions from solvents. The reduction from fugitive emissions from fuels (1B) is due to technology improvements.

For the industrial processes sector and product use (CRF 2), the decrease of NMVOCs emission is related to national abatement measures, such as the reduction of solvents content in paint. Emissions from the agriculture sector (CRF 3) declined by about 21 % mainly due to decreased population of livestock, especially dairy-cows and swine as well as decreased use of N-fertilizers.

2.4.2 Nitrogen oxides (NO_X)

In 2017, the total emissions of NO_X were about 125 kt. The energy sector (CRF 1) accounted for most of the NO_X emission (79 %). The industrial processes and product use sector (CRF 2) and the agriculture sector (CRF 3) were responsible for about 11 % each. NO_X-emission from the waste sector (CRF 5) is very limited.

In 2017, the transport sector (1A3) and the manufacturing industries and construction (1A2) were responsible for 39 % and 16 %, respectively, while other sector (1A4) and the industrial processes and product use sector (CRF 2) accounted for about 11 % each. The share from the energy industries (1A1) was about 10 % of the national total, see Figure 2.45.

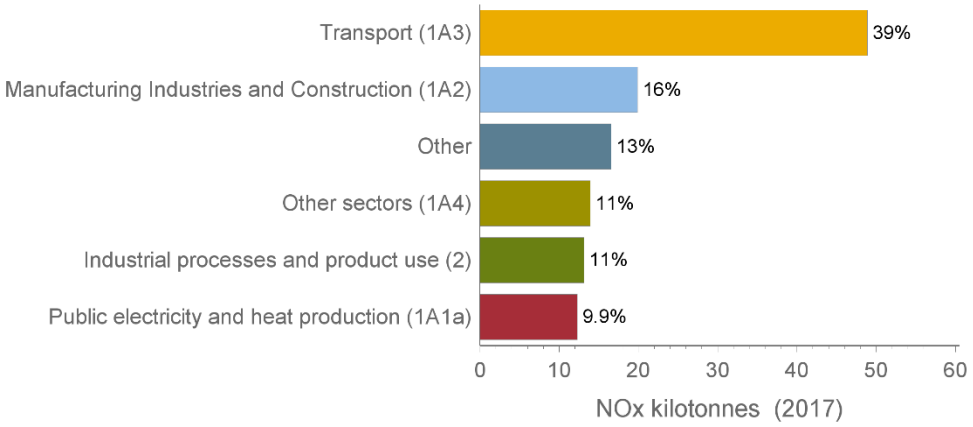


Figure 2.45. Emission sources of NO_X in 2017 (kt).

The pulp and paper industry (2H1) is responsible for about two-thirds of the CRF 2 emissions, while most of the emissions from the agriculture sector (about 11 %) come from agriculture soils (3D).

The total emissions of NO_X have declined by more than a half (56 %) since 1990 and had decreased by about 3 % compared to the previous year, see Figure 2.46. NO_X-emissions from the transport sector (1A3) have declined by more than two-thirds since 1990. Between 2016 and 2017, emissions from the transport sector decreased by about 7 %. In urban areas, road traffic is the most significant contributor to emissions of NO_X, but the introduction of catalytic converters on cars in the late 1980's and the subsequent gradually more stringent emission standards have contributed to the reduction of nitrogen oxide levels in urban areas.

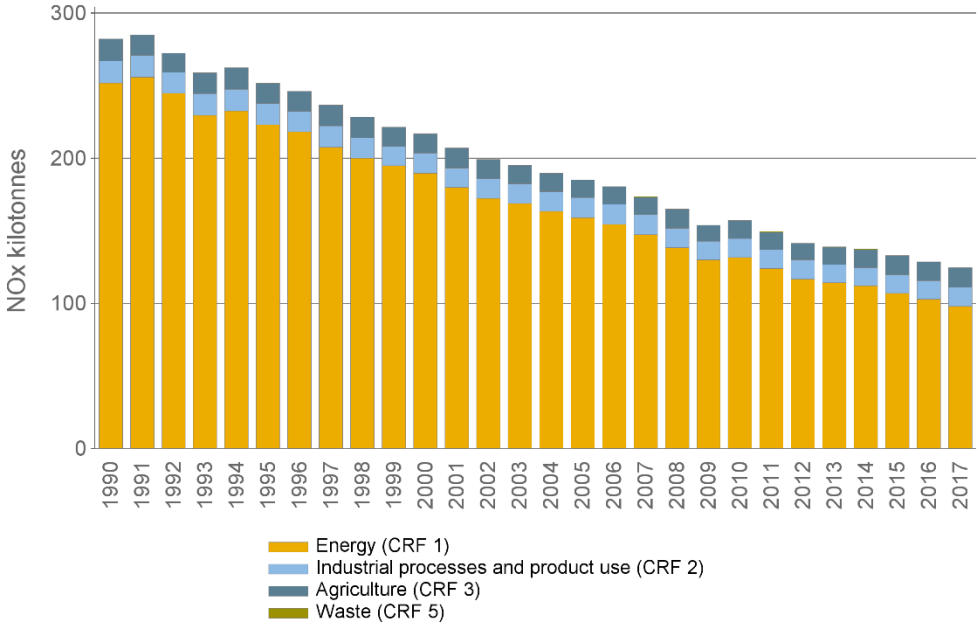


Figure 2.46. Emission trends of NO_X 1990-2017 (kt).

NO_X emissions from energy industries (1A1a), which accounts for about 10 % of the national total, have been reduced by 18 % since 1990. But the annual NO_X emissions from (1A1a) show significant fluctuations between 1990 and 2017.

Weather influences the demand for heating of houses and buildings resulting in emission patterns that mirror the inter-annual variability of weather. The increased use of district heating and the "NO_X charge" of the early 1990s, has also contributed in emission reduction of NO_X.

Emissions of NOx from the industrial processes and product use sector (CRF 2) decreased by 14 % compared to 1990. The reduction comes for mineral, chemical and metal industry. Since 1990, emissions of NO_X from the agriculture sector have declined by 10 %, mainly due to a fall in the use of N-fertilizer. However, the emissions have relatively increased in the last few years as a result of increased use of N-fertilizers.

2.4.3 Carbon monoxide (CO)

The aggregated emissions of carbon monoxide (CO) have decreased by 64 % since 1990 and were around 385 kt in 2017. Emissions have been relatively constant between 2016 and 2017.

In 2017, the energy sector (CRF 1) accounted for most of the CO emission (92 %). The remaining emission come from the industrial processes and product use sector (CRF 2). Emission from the waste sector (CRF 5) is very limited.

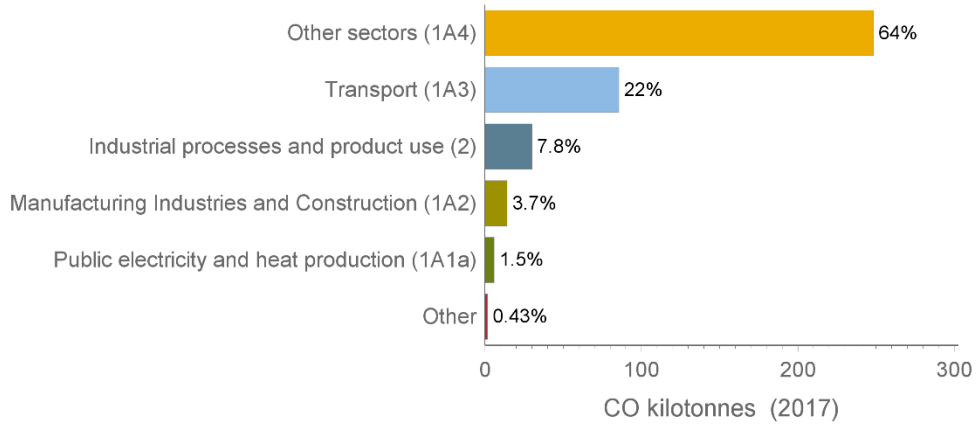


Figure 2.47. Emission sources of CO in 2017 (kt).

The transport (1A3) was responsible for 22 % and other sectors (1A4) accounted for 64 % (mainly from residential heat production (1A4b) and commercial/institutional (1A4a)) of the total emission. Emissions from manufacturing industries and construction (1A2) and the industrial processes and product use sector (CRF 2) accounted for about 4 % and 8 %, respectively of the total, see Figure 2.47.

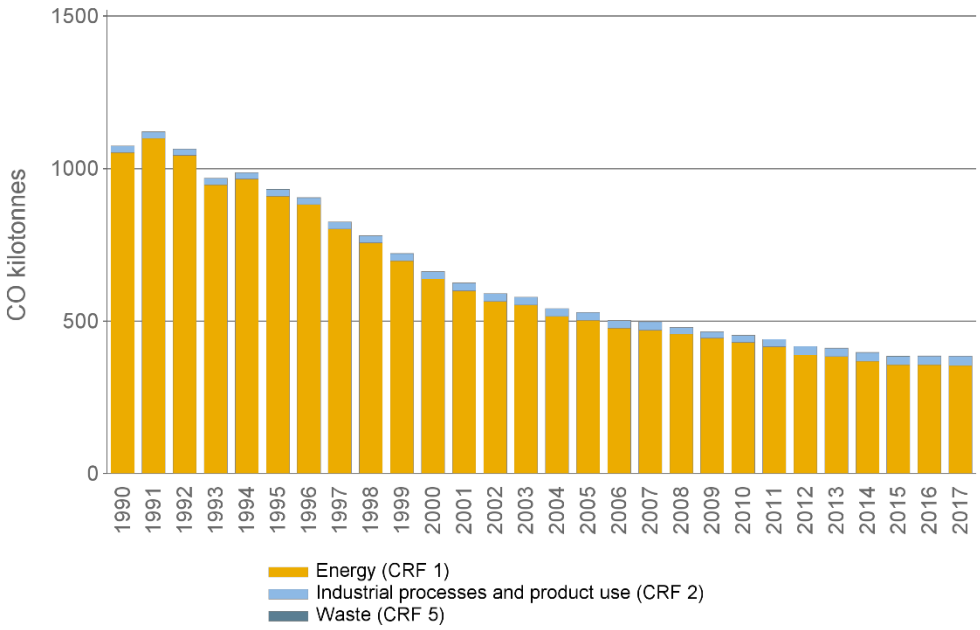


Figure 2.48. Emission trends of CO 1990-2017 (kt).

Carbon monoxide emission shows a declining trend over the period, (see Figure 2.48). Emissions from the entire energy sector have declined by two-third compared to 1990. The transport sector (1A3) is responsible for most of the reduction (89 %) following that new fuel-driven vehicles sold in Sweden have been equipped with catalytic converters that convert CO and unburned hydrocarbons to CO_2 and water vapor.
However, emissions from (CRF 2) have increased by 37 % compared to 1990, mainly from aluminum production (2C3) and pulp and paper industry (2H1).

2.4.4 Sulphur dioxide (SO_2)

Emissions of SO_2 have decreased from about 104 kt in 1990 to about 18 kt in 2017, a reduction of 83 %.

In 2017, about a half (44 %) of the total SO_2 emission comes from the energy sector (CRF 1). The remaining emissions (56 %) derived from the industrial processes and product use sector (CRF 2). SO_2-emission from the waste sector (CRF 5) is very limited.

In 2017, most of the emissions within the energy sector come from combustion of fuels in energy industries (1A1) and manufacturing industries and construction (1A2) which accounted for 15 % and 17 %, respectively. Transport was responsible for about 1 % of the total emission in 2017. The metal industry (2C) and pulp and paper industry (2H) are the main contributors for SO_2 emission and accounted for 28 % and 22 %, respectively of the national total, see Figure 2.49.

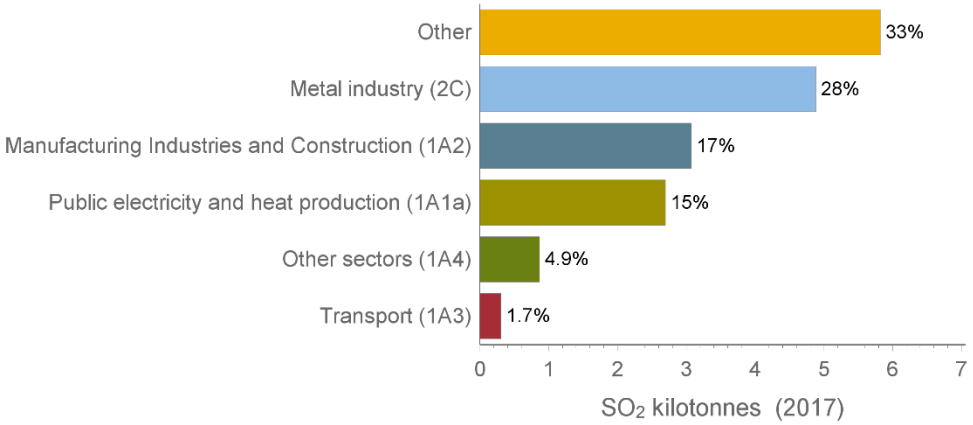


Figure 2.49. Emission sources of SO_2 in 2017 (kt).

Emissions from transport (1A3) in 2017 have declined by 97 % compared to 1990, see Figure 2.50. A similar trend with declining emissions can be seen in other subsectors within the energy sector, such as other (1A4) which declined by 94 %. The emissions have also declined by 71 % from the industrial processes and product use sector. The main reason for the large reduction in SO_2 emission was a transfer from fuels with high sulfur levels to low-sulfur fuels, for both transport (road traffic) and heating. A tax on sulfur, introduced in 1991, has been important in this transition.

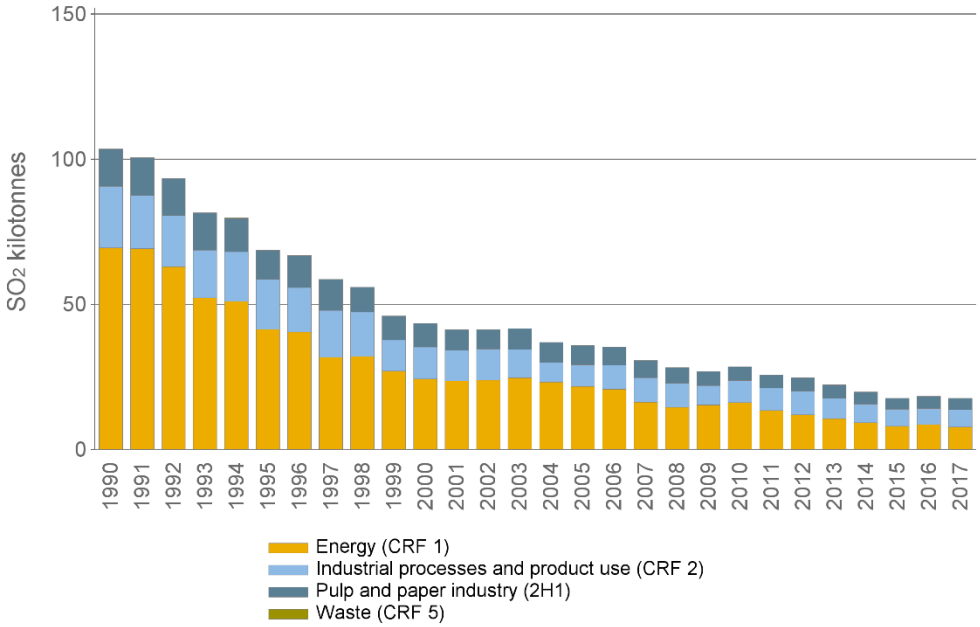


Figure 2.50. Emission trends of SO_2 1990-2017 (kt).

SO_2-emissions have fallen by about 4 % between 2016 and 2017, mainly from the industrial processes and product use sector (CRF 2) and from energy industries (1A1). Domestic navigation contributed with less than 1 % of the total SO_2 emission in 2017. The emissions have decreased by 95 % compared to 1990, due to a switch to oils with lower sulfur content. The emissions from combustion of hazardous waste in the waste sector are insignificant (about 14 ton).

3 Energy (CRF sector 1)

3.1 Overview of sector

The energy sector includes emissions from fuel combustion (CRF 1.A) and fugitive emissions from fuel production and handling (CRF 1.B). Energy consumption per capita is high in Sweden compared to other OECD countries. This is because of the availability of natural resources such as forests and hydropower, which led to the early and rapid expansion of energy-intensive industries. Sweden's geographical location, with low mean annual temperatures also explains the high demand for energy for heating. The energy sector, including transport, has long accounted for the major part of Swedish greenhouse gas emissions and emissions of carbon dioxide dominate overwhelmingly in this sector. However, carbon dioxide emissions per capita from the energy sector are relatively low in Sweden compared with other industrialized nations. This is due to a relatively high use of hydropower and nuclear power and low use of fossil fuels, as well as the use of energy and carbon dioxide taxation for limiting the emissions of carbon dioxide[31].

It can be seen in Figure 3.1 that in the energy sector, emissions of CO_2 contribute about 97 % of total greenhouse gas emissions (in CO_2-eq.) in 2017. Emissions of total greenhouse gases from the energy sector have decreased by 30 % from 52 293 kt CO_2-eq. in 1990 to 36 632 kt CO_2-eq. in 2017, mainly due to reduced fossil fuel consumption in the residential sector (CRF 1.A.4) (Figure 3.2).

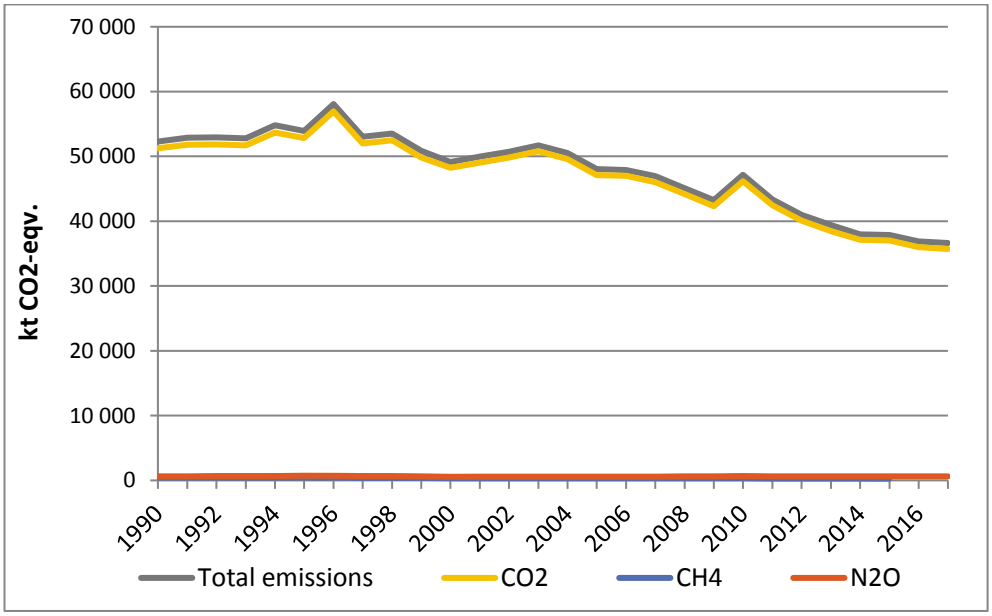


Figure 3.1. Total emissions of all greenhouse gases calculated as Gg CO_2-eq. from CRF 1 Energy.

[31] Ministry of the Environment, 2001

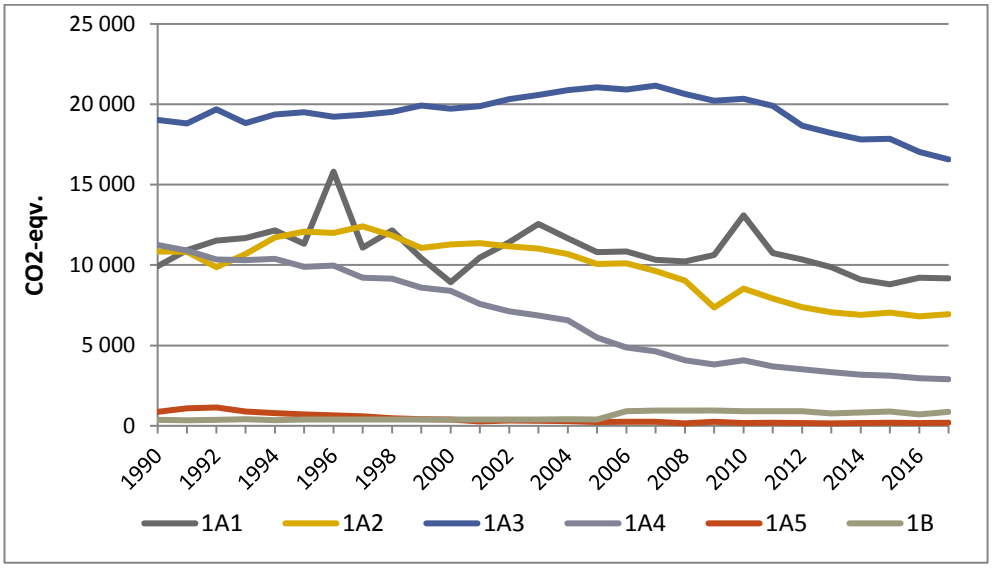


Figure 3.2. Total emissions of all greenhouse gases calculated as CO_2-eq. from the different sub-sectors within the Energy sector. 1A1 Energy industries. 1A2 Manufacturing industries and construction. 1A3 Transport. 1A4 Other sectors. 1A5 Other. 1B Fugitive emissions.

As shown in Figure 3.2, the transport sector (CRF 1.A.3) accounts for the largest part of the GHG emissions from the energy sector. Emissions from public electricity and heat production (CRF 1.A.1) varies mainly because of temperature variations between years. As mentioned earlier, the emissions from residential heating (CRF 1.A.4) are decreasing due to the a shift from usage of heating oils to district heating. In manufacturing industries and construction (CRF 1.A.2), the three largest industries in terms of fuel consumption are the pulp and paper industry, the chemical industry and the iron and steel 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.

The large emissions from CRF 1.A.1 in 1996 and 2010 are mostly due to the cold winters that year and low production of nuclear energy, which meant that the demand of electricity and heat had to be met by combustion based energy. In 2011, conditions were less extreme and emissions especially from electricity and heat production decreased considerably. 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 1.B.2) is caused by hydrogen production facilities put into operation at two of the oil refineries in 2005 and 2006 respectively.

3.2 Fuel combustion (CRF 1.A)

Emissions from fuel combustion, CRF 1.A, are allocated to a number of subsectors.

CRF 1.A.1 **energy industries**, e.g. public electricity and heat production plants, combustion activities within oil refineries, and combustion related to solid fuel production, i.e. coke ovens.

CRF 1.A.2 **manufacturing industries**, combustion-related emissions in manufacturing industries and construction and working machinery within the construction sector allocated to this subsector. Emissions from working machinery within the construction sector are allocated to CRF 1.A.2, but apart from that, CRF 1.A.2 includes only stationary combustion.

CRF 1.A.3, emissions from **domestic transport** include aviation, road traffic, railways and navigation.

CRF 1.A.4, emissions from **other sectors,** include stationary and mobile sources in households, service, agriculture, forestry and fisheries.

CRF 1.A.5, emissions from **other combustion** include domestic military operations.

In addition, emissions from **International aviation and international navigation (international bunkers) and multilateral operations**, CRF 1.D, are not included in the national total.

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:

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

Different tier methods are used for different sub-sectors as discussed in sections below. Activity data sources, thermal values and emission factors are described in detail in Annex 2.

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

3.2.1 Comparison of the sectoral approach with the reference approach

A detailed discussion on the reference approach and the 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 all fossil fuels 1990-2017.

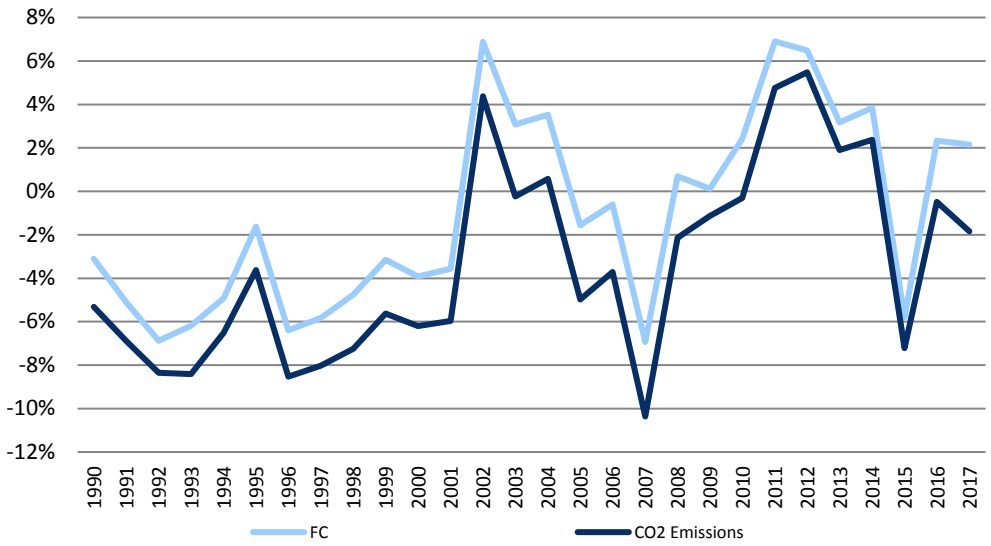


Figure 3.3. Differences between Reference Approach and Sectoral Approach (Reference minus Sectoral expressed as percent of sectoral approach).

Fuel consumption and CO_2 emissions according to the Sectoral Approach are both higher and lower than according to the Reference Approach between 1990 and 2017. For most years the difference is larger than 2 %. In response to recommendations in the in country review of Sweden in 2013, a cooperation between Swedish EPA, Swedish Energy Agency, SMED and Statistics Sweden has been initiated with the aim to find explanations to the differences.

The largest parts of the differences, in absolute numbers, are related to liquid and solid fuels. Consumption of liquid fuels according to sectoral approach is consistent with official energy statistics on fuel consumption, as described in Annex 4. The Swedish Energy agency has initiated efforts to improve the supply statistics, especially for liquid fuels, by way of a large revision of the monthly fuel statistics. Hopefully, this will reduce statistical differences from 2018, submission year 2020.

The differences for solid fuels are very large. One important reason is that the different data sources used for reference and sectoral approaches have very different purposes. In sectoral approach, the main data sources for the iron and steel industry are environmental reports and data reported to EU ETS and are considered as accurate. For the reference approach, monthly fuel statistics, trade and delivery statistics are used. Data on stock change could be part of the problem and will be reviewed with in the cooperation mentioned above.

For solid fuels, the difference in energy and emissions, respectively, is not consistent between years. This is related to solid fuels used in the iron and steel industry. Large amounts of energy are lost in coke ovens and blast furnaces when coking coal is transformed to coke and coke oven gas, and coke is transformed to blast furnace gas. This means that the reported amounts of coke oven gas, blast furnace gas and steel converter gas reported in the sectoral approach contains all the carbon but only parts of the energy reported as coal in the reference approach, which gives a large difference between the reference and sectoral approach for consumption of solid fuels. By using non-energy use data from CRF 2 in the GHG

inventory instead of from the Energy balances in the comparison between SA and RA, as means to explain the large differences, did lead to a decrase in differences, but could however not explain all the discrepancies (See Annex 2 for further details). Further investigations on possible reasons for the differences are needed, with a focus on cooperation between the inventory compilers and the Swedish Energy Agency and the steelworks operators, as there are still reporting consistency deficiencies regarding environmental reports and energy statistics for the iron and steel industry in particular.

For gaseous fuels, the differences are low for most years, except for the period 2004-2008 when the amounts of natural gas used as feedstock are not included in the data used for CRF 1Ad. Further explanations are given in Annex 4.

For other fossil fuels, there are differences due to different classifications of fuels and different assumptions about fossil and biogenic shares of municipal waste.

3.2.2 International bunker fuels

This sector covers emissions from fuel bought in Sweden and used for international navigation and aviation as well as multilateral operations.

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 1.D. This is in accordance with the IPCC Guidelines. However, when the Swedish emissions are evaluated, international bunkers are important, as greenhouse gas (GHG) emissions from international bunkers are almost ten times higher than from domestic navigation and aviation and have increased significantly since 1990. The increase of GHG emissions can be explained by increased travel abroad by flight, an increase in freight transport by shipping and an increased market share for Swedish bunker companies; partly as they were early in offering low-sulfur fuel for navigation and partly because a major competing Danish company went bankrupt in 2014. For more information regarding the increase of GHG as a result of an increase in consumption of bunker fuels, see chapter 2.3.6.

The UNFCCC expert review team (ERT) noticed that data reported to the IEA (International Energy Agency) generally is higher than data 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 timesseries[32].

3.2.2.1 INTERNATIONAL AVIATION, CRF 1.D.1.A

Bunker fuel is defined as fuel used for international aviation purchased in Sweden and used for flights with a destination abroad. This includes emissions from the whole flight cycle, i.e. both the LTO and the Cruise phase.

- LTO (Landing and Take-Off): aircraft emissions that occur *below* an altitude of 3000 feet)
- Cruise: aircraft emissions that occur *above* an altitude of 3000 feet.

[32] Hedlund & Lidén, 2010.

The emissions from both domestic and international aviation, reported to the UNFCCC, are based on data from the monthly survey on supply and delivery of petroleum products from Statistics Sweden (see Annex 2) as well as fuel and emission data reported by the Swedish Transport Agency (STAg). The methodology for calculating national emissions is the same for all years with a few exceptions for the earlier years.

The greenhouse gas (GHG) emissions from international aviation were 2 791 kt of CO_2-eq. in 2017, which is more than double the amount compared with 1990. And it is a 9% increase in the emissions since 2016. Emissions from international aviation have varied over time. The trend indicates a rise in the emissions of GHG, owing to growth in foreign travel.

The Swedish Transport Agency (STAg) have an obligation to report the emissions from aviation in accordance with the Swedish climate regulation. The fuel consumption and emissions published by STAg, are calculated by the Swedish Defence Research Agency (FOI) by using an estimation model and input data provided by STAg regarding:

- Airport of departure and arrival
- Type of aircraft
- Number of flights
- Number of passengers
- International or domestic flight

A database with information regarding 200 different types of aircraft is also used. The emission data regarding different types of aircrafts in the database originates from "ICAO Engine Exhaust Emission Data Bank". All this data is used to calculate emissions and amounts of burnt fuel for total flight time as well as for aircraft movements below 3000 feet at the airports, the so called LTO cycle. The FOI has in a published report described their method for estimating the emission from aviation[33].

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 compared to the International Civil Aviation Organization (ICAO) standards that the IPCC guidelines follow[34]. The traffic from Swedish airports consumes as a result less fuel and gives rise to less emission.

The results from the emission calculations are aggregated into four groups; domestic landing and take-off (LTO), domestic cruise, international LTO and international cruise. The estimated fuel consumption and emissions are then adjusted to correspond to the fuel delivery statistics from the monthly survey on supply and delivery of petroleum products from Statistics Sweden (see Annex 2).

[33] Mårtensson, T. & Hasselrot, A., 2013.

[34] Gustafsson, 2005.

This is in line with the IPCC guidelines and data of good quality exists from 1995 and onwards.

Emissions of CO_2 and SO_2 from 1995 and later, are based on fuel consumption reported by the Swedish Transport Agency (STAg),fuel data from the monthly survey on supply and delivery of petroleum products from Statistics Sweden (see Annex 2), thermal values from 2006 IPCC Guidelines and country specific emission factors. The emissions of HC are estimated by STAg and split into NMVOC and CH_4 based on the ratio according to the EMEP/EEA Air Pollutant Emission Inventory Guidebook 2013. N_2O emissions from LTO are estimated by using the number of LTO cycles reported by FOI together with emission factors from EMEP/EEA Guidebook 2013. N_2O emissions from the Cruise phase are based on delivered amounts of fuel for cruise activities estimated by FOI, together with emission factors according to the EMEP/EEA Guidebook 2013. All emissions estimated by STAg are adjusted to be in line with the national fuel delivery statistics.

Emissions of CO_2 for1990-1994 are based on fuel delivery statistics, thermal values from 2006 IPCC Guidelines, country specific emission factors and an assumed international share of the total air traffic. Emissions of SO_2 are estimated based on the fuel and energy consumption and emissions of CO_2 in 1990-1994. The number of LTO cycles in 1990-1994 was estimated by measuring the mean value for LTO cycles for domestic and international flights in 1995-2000. Emissions of CO for 1990-1994 were calculated by comparing the ratio between CO and CO_2 emissions in 1995. The same ratio was applied for 1990-1994. The calculation of NO_X emissions was made in a similar way as for CO emissions. The emissions of HC in 1990-1994 were estimated by extrapolation.

3.2.2.2 INTERNATIONAL NAVIGATION, CRF 1 D1B

International bunkers from navigation are defined as fuels bought in Sweden, by Swedish or foreign-registered ships, and used for transportation to non-Swedish destinations. The split between international and domestic fuels is based on information from the monthly survey on supply and delivery of petroleum products from Statistics Sweden.

The emission of GHG from international shipping totalled in ~7841 kt of CO_2-eq. in 2017. This corresponds to an increase by 15 % compared to 2016 and the emissions of CO_2-eq have more than tripled since 1990. International freight transport activity has increased, as the volume of goods transported has grown and globalisation of trade and production systems has led to goods being transported over greater distances. Another factor for the increased emissions could be that more shipping companies choose to refuel in Sweden, as Swedish refineries produce low-sulphur marine fuels meeting strict environmental standards. And a major competing Danish company went bankrupt in 2014. Fluctuations in bunker volumes between years are also dependent on fuel prices in Sweden compared with ports in other countries. See chapter 2.3.6. for more information.

In 2011, the fuel consumption by national and international navigation was studied by SMED and the results were presented in the report “Emissions from navigation

and fishing including international bunkers"[35]. Fuel data in the survey "Monthly fuel, gas and inventory statistics" was analysed and found to be of good quality. As a consequence of that the VAT is applied on national fuel consumption, but not on international bunkers, all respondents to the survey are able to separate these fuel amounts accurately. Fuels used for domestic and international navigation have been separated in line IPCC Guidelines.

3.2.2.3 MULTILATERAL OPERATIONS, CRF 1.D.2

Emission from multilateral operations are not included in the national total but instead reported separately as a memo item in CRF 1.D.2, in accordance with 2006 IPCC Guidelines.

The fuel for military operations abroad is according to new information from the National Defence, not bought in Sweden but in the country where the operation takes place. The fuel for aviation is as a result allocated to civil aviation.

3.2.3 Feedstocks and non-energy use of fuels

Activity data on feedstocks and non-energy use of fuels is collected from the environmental reports and the EU ETS statistics. Sweden uses the Swedish Energy Balance non energy use data for CRF table 1.A.d, non-energy use (NEU) of fuels for all fuel groups except for solid fuels, whis is the same as for feedstocks and non-energy uses reported in the IPPPU sector (CRF 2).

Net calorific values and carbon emission factors are the same as in CRF 1.A.b. The parameter "fraction of carbon stored" has been set to 1.00 for all fuels, which is in line with the 2006 IPCC Guidelines. Emissions from use of fuels reported in CRF 1.B or CRF 2 is reported as "CO_2 emissions from the NEU reported in the inventory" in the CRF-tables.

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[36]. There are, however, several research projects going on where CO_2 is captured from flue gases at a pilot scale[37].

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

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

[35] Eklund et al. 2011.

[36] Geological Survey of Sweden, 2010.

[37] E-on 2010-11-04, Fortum 2010-11-04.

significant effect on the use of fuel in electricity production since less electricity can be produced by means of hydropower and more electricity is needed for heating. The largest emissions from electricity production were thus in 1996, due to very dry and cold weather. The winters 2009/2010 and 2010/2011 were unusually cold, which lead to an increase in fuel consumption particularly in 2010. Liquid fuels and natural gas account for most of the increase, although the increase in natural gas use can to a large extent be explained by the fact that new gas fuelled facilities have been taken into operation. The use of solid fuels also increased substantially between 2009 and 2010, but in this case the explanation is the recovery from the dip in production in the iron and steel industry in 2009, which thus affected the amounts of energy gases sold to the public electricity and heat production plants.

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.

From submission 2015, CRF 1.A.1.a is split in three categories according to the IPCC 2006 guidelines: 1.A.1.a.i= Electricity Generation, 1.A.1.a.ii = combined heat and power plants (CHP), and 1.A.1.a.iii = heat plants. The allocation to the three subcategories is based on the classification of the plant according to the Swedish Business Register. For the years before 1999, the classification of the categories CHP and electricity generation is doubtful and not transparently documented. Because of this, emissions from electricity generation are reported as IE, included in CHP, 1990-98. It should be noted that fuel combustion for electricity generation is very minor compared to fuel consumption in CHP plants.

The trend in fuel consumption in this sector varies depending on the production of hydroelectric power and weather variations between years. The largest changes in fuel consumption are for biomass fuels, where the consumption has increased significantly mainly due to increased district heating. It can also be noted that the use of natural gas in this sector increased during 2009 to 2011. The reason is that the number of gas-fuelled facilities increased during this period. Between 2013 and 2014, the consumption of natural gas in this sector decreased, which resulted in a notable decrease in emissions for this sector.

Production of district heating is currently to a large extent based on biomass and waste. There has been a shift from fossil fuels towards biomass since 1990. In 1990, 25 % of fuels used were biomass including biogenic waste, and 6 % was fossil waste. In 2017, 75 % of all fuels used for district heating were biomass (including the biogenic fraction of waste), while waste (fossil fraction) accounted for 11 %[38]. These proportions have been quite similar during the last six years.

[38] All numbers are according to data used in the greenhouse gas inventory this submission. The proportions given are calculated for heat production, and may include plants in both 1.A1.A.ii and 1.A.1.A.iii

Since 1990, there has been a large increase in the use of district heating from 89 PJ (1990) to 185 PJ (51,4 TWh 2016)[39] but, due to the more frequent use of biomass, greenhouse gas emissions from district heating were lower in 2017 than in 1990.

The number and distribution of Swedish power stations in 2016 are presented in Table 3.1[40]. Changes in number of plants and their installed effect have been minor in the production of electricity, but due to growing wind power the number of plants in the electricity sector have increased.

Table 3.1. Number and distribution of Swedish energy stations 2016

Type of plants	Number of plants	Gross Production GWh	Gross Production TJ
Total power stations	4 493	155 986	561 550
Power generation not based on fuels	4 325	77 734	279 842
Wind power	3 334	15 479	55 724
Hydropower	991	62 255	224 118
Power generation based on fuels	168	78 252	281 707
Nuclear power	3	63 101	227 164
Conv. thermal power	165	15 151	54 544

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, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1A1a	CO_2	X (Gaseous fuels, Liquid fuels, Other fuels, Peat, Solid fuels)	X (Liquid fuels, Other fuels, Peat, Solid fuels)		T2	CS	Yes
	CH_4	X (Biomass)	X (Biomass)		T2	CS	Yes
	N_2O	X (Biomass, Other fuels, Solid fuels)	X (Biomass, Other fuels, Peat, Solid fuels)		T2	CS	Yes

CS Country Specific. T2 Tier 2.
* Shows key category (level) per fuel type
** Shows key category (trend) per fuel type

[39] Statistics Sweden/Swedish Energy Agency EN11SM 1701 (Electricity supply, district heating and supply of natural and gasworks gas 2016.). Data for 2017 currently not available.

[40] Data for 2017 currently not available. Statistics Sweden /Swedish Energy Agency EN11SM 1701 (Electricity supply, district heating and supply of natural and gasworks gas 2016).

3.2.6.2 METHODOLOGICAL ISSUES

Plant specific activity data and country- and sector-specific emission factors are used, which is considered to be Tier 2 methodology. The activity data source for emissions in CRF 1.A.1.a is the quarterly fuel statistics, further described in Annex 2. Emission factors, also further described in Annex 2, are generally country specific, but in a few cases plant specific emission factors are used. For energy gases purchased from the iron and steel works and combusted by public electricity and heat production plants, CO_2 emission estimates provided by the iron and steel works are used, which results in aggregate year specific implied emission factors for blast furnace gas, coke oven gas and steel converter gas that are used to calculate CO_2 emissions from the plants using these fuels in CRF 1A1a.

The most important fuels in recent years are wooden fuels followed by solid waste. Greenhouse gas emission factors for wood are national[41]. In submission 2015, solid waste was for the first time split into a biogenic and a fossil fraction, and the emission factors for CO_2 were revised. This is further described in Annex 2. The fractions of the fossil and the biogenic part for the CO_2 emissions of solid waste is estimated by both a national average emission factor and plant specific emission factors for the seven largest plants in Sweden. Since 2015 the seven largest incineration plants report their emissions of CO_2 to the EU Emission Trading System (ETS). This reporting is considered of high quality and therefore the emission factors from this reporting are used for these plants. For the rest of the incineration plants, a national average emission factor is used. In 2019, the fractions of biogenic and fossil waste for the seven largest plants was 60.47 % and 35.46 % respectively. These fractions vary in time and are applied since year 2015. The proportions 64 % biogenic and 36 % fossil is applied for the emission years from 1990 to 2014 for all plants and also since 2015 for plants not included in the ETS[42]. Since the quarterly fuel statistics do not contain information on fossil and biogenic fractions of the waste, these fractions are applied on the fuel consumption for the plants.

Emissions from energy plants integrated with the iron and steel industry are allocated to CRF 1.A.2.a. This is discussed in chapter 3.2.9 and in detail in chapter 4.4.1.

Since submission 2015, emissions from combustion in manufacturing of nuclear fuels are included in CRF 1A1a due to confidentiality reasons. These emissions are however extremely small and thus this reallocation from CRF 1A1c does not affect any trends or conclusions on CRF level. Peat is reported separately, and not included in solid fuels, in order to comply with the new CRF tables.

3.2.6.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The quarterly fuel statistics is a total survey for ISIC (International Standard Industrial Classification of All Economic Activities) 40 and the response rate is almost 100 %. This provides the inventory with data of very good quality.

The variations in IEFs (implied emission factors) between years are normally small. The IEFs for solid fuels, however, are considerably more variable than for

[41] Boström et al, 2004.

[42] Stripple et al, 2014.

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. The production in the iron and steel industry was much lower in 2009 than in other recent years, the share of blast furnace gas in CRF 1.A.1.a dropped, which explains the drop in CO_2 IEF for solid fuels in 1.A.1.a in 2009. In submission 2012, the IEF for N_2O varies significantly. This is mainly because the use of coal, with a relatively high EF compared to e.g. steelwork gases, has decreased during the time series.

The IEFs for the group other fuels also vary between years because the emission factors for the fossil fraction of municipal solid waste are different from the emission factors for other fuels in this group. In recent years, municipal waste accounts for 75-82 % of the consumption of "other fuels". The remaining 18-25 % is in most cases specified as "recycled fuel", but before 2007 there is no such information. As the composition of "recycled fuel" is unknown, there are no specific emission factors for this fuel, so the general emission factors for "other non-specified fuels" are used. The CO_2 emission factor for this fuel is considerably lower than the emission factor for municipal waste. The emission factors are discussed in Annex 2. There is no reliable information about the composition of municipal waste in the 1990's, so the composition calculated by Stripple et al from 2014 is used for all years as described above.

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 emissions from biomass are 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 % for peat and blast furnace gas, and 100 % for "other fuels. Thus EF uncertainties account for the greater part of the aggregate uncertainties. Activity data uncertainties are assigned by expert judgements made by staff at the energy statistics department of Statistics Sweden. Emission factor uncertainties have been assigned by national experts on emissions from stationary combustion.

3.2.6.4 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. 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).

During 2011, there was a study[43] comparing the currently used quarterly fuel statistics with two other data sources, and the conclusion was that the quarterly fuel statistics is of very good quality, and also the only data source that is ready in time for use for the last emission year.

3.2.6.5 SOURCE-SPECIFIC RECALCULATIONS

In submission 2019 emission factor for CO_2 for combustion of waste, peat and landfill gas was revised[44], [45]. An additional plant started to report the biogenic and fossil fuels fraction which is now included in the inventory for the emission factor for waste. Emission factor for CO_2 for peat and landfill gas was updated to newer factors. In addition the emission factor for CO_2 and the NCV for natural gas was revised and harmonised with the energy balance.

The total effect of the recalculations in 1.A.1.a for the two most recent recalculated years was a decrease of the estimated emissions with 4.69 % (3108 kt CO_2-eq) for 2015 and an increase with 3.19 % (279 kt CO_2-eq) for 2016.

3.2.6.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

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 1.B.2. 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 five refineries account for more than

[43] Eklund et al 2011.

[44] Helbig, T. Stripple, H., Hjort, A., Mawdsley, I. 2018. Uppdatering av emissionsfaktorer för CO2 från torv och deponigas. SMED PM 2018-05-20.

[45] Energistyrelsen, 2018-11-26 (https://ens.dk/ansvarsomraader/co2-kvoter/stationaere-produktionsenheder/co2-rapportering-og-returnering)

99 % of the fuel consumption and emissions reported in CRF 1.A.1.b. In addition to the refineries, there are a few small manufacturers of e.g. lubricants which are also classified as ISIC 23200. The emissions from these plants are also reported in CRF 1.A.1b.

The fuel consumption in this sector consists mainly of refinery gas, which is a by-product in the refining process. The use has increased since the 1990's due to higher demand of refined products. The fuel consumption has been quite stable in recent years.

In 2014 the emissions for gaseous fuels increased. This is due to that the combustion of liquified natural gas has been implemented in one of the refineries.

The implied emission factor for CO_2 for refinery gas is slightly lower for 2008 and later years when plant specific emission factors are used. However, since the national emission factor used for earlier years is based on information from the refineries, the decreasing IEF is considered to reflect changes in production conditions which in turn alter the composition of the refinery gas.

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 3.3.

Table 3.3. Source category description, CRF 1.A.1.b, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1A1b	CO_2	X (Liquid fuels)	X (Gaseous fuels, Liquid fuels)		T2	CS	Yes
	CH_4				T2	CS	Yes
	N_2O				T2	CS	Yes

CS Country Specific. T2 Tier 2.
* Shows key category (level) per fuel type
** Shows key category (trend) per fuel type

3.2.7.2 METHODOLOGICAL ISSUES

Refineries are not included in the quarterly fuel statistics. As a result, activity data for the five refineries was 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 was also collected and individual thermal values were calculated for each operator and fuel. For 2000-2004, e.g. before the EU Emission Trading System (ETS) was established, energy statistics was used as the data quality was improved compared to the 1990's and is considered to be sufficient for these years.

Data from ETS are used for four refinery plants for 2005 and later years[46]. For the fifth plant data from environmental reports were used due to lack of transparency in ETS data in the early years. In 2008 and later years, the quality of ETS data is

[46] Backman & Gustafsson, 2006.

considered to be very high for all five of the refineries, and thus this is the primary data source for the GHG inventory. However, most of the refineries report refinery gas and natural gas aggregated in the ETS data, and for these facilities, data from the environmental reports are used to allocate the proper amount of this fuel to gaseous fuels. Environmental reports are used for verification for all five refineries. For refinery gas, plant specific CO_2 emission factors reported to the ETS[47] are used for 2008 and later, since they are considered to be more accurate than the older national emission factor. The CO_2 emission factors for refinery gas are generally quite stable for each of the refineries, but the differences between the refineries are large.

For the smaller plants in ISIC 23200 mentioned above, activity data from the quarterly fuel statistics are used together with national emission factors.

Due to confidentiality reasons emissions of CO are shown as C in CRF-tables for the whole sector for 2017.

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.

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 assigned uncertainties are based on information directly from the facilities. These are updated regularly but not annually. The emission factor uncertainty and the activity data uncertainty is around 10 % for submission 2019. The uncertainty of the activity data is around 1.5 %, but the uncertainty of the NCV is unknown, so the total uncertainty for the activity data was judged to 10 %. Activity data uncertainty for the 1990's is also estimated to 10 %.

3.2.7.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

In general, the same QA/QC procedures are used for CRF 1.A.1.b as for 1.A.1.a described above. For each of the five refineries, ETS data for the latest year are verified against the refineries' legal environmental reports. During the national peer review remarks have been made that gaseous fuels are reported as "NO" for 2003 and questioned if this is the correct notation key. Investigations of activity data files used in earlier submissions show that in 2001 to 2003, sweet gas (a by-product from the cryogen plant) was probably miscoded as natural gas in submission 2005. Data for 2003 has been revised in later submissions, i.e. sweet gas has been re-coded as refinery gas. Environmental reports show that natural gas has been used in CRF 1.A.1.b in 2004 and later, but not in 2003, and hence "NO" is considered to be the correct notation key for 2003. The environmental reports for 2001-2002 are no longer available, and hence there is not enough information to recode the natural gas reported in 2001 and 2002, even though it might be miscoded refinery gas.

[47] Technically, the emission factors are implied emission factors since amounts of fuel, NCV:s and emissions are reported.

Quality control is being conducted annually to improve emission allocation between the energy sector (CRF 1.A) and IPPU (CRF 2) and to establish a procedure for annual cross-sectoral control of reported emissions on a facility level. In case of discrepancies, they are easily identified and further investigated regarding potential gaps or double-counting using a developet quality control tool. This work is ongoing, and feasible reallocations will be done in the submission 2020. For further detailed information see section 1.3.5 concerning QA/QC and Verification in general.

3.2.7.5 SOURCE-SPECIFIC RECALCULATIONS

In submission 2019 several NCV for the refinery gases were revised and reallocation of liquefied natural gas from stationary combustion to IPPU was made.

The total effect of the recalculations in 1.A.1.b for the two most recent recalculated years was a decrease of the estimated emissions with 12.15 % (2030 kt CO_2-eq) for 2015 and an increase with 1.60 % (256 kt CO_2-eq) for 2016.

3.2.7.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

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

3.2.8.1 SOURCE CATEGORY DESCRIPTION

This category includes emissions 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[48]. The trend is related to the amounts of iron and steel produced, and hence there was a dip in 2009. Since 2009, the production and the emissions have increased gradually, and in 2012 the emissions were about the same level as in the early 2000's.

Charcoal production in Sweden and the related emissions from the activity is derived from small companies that are included in the emission estimates from small industries (CRF 1.A.2.g). Since the activity data for this sector is aggregated from the national energy balances, it is thereby not possible for Sweden to separate the emissions that are related to charcoal production from the aggregate. Hence, the fugitive CH_4 emissions from charcoal production are reported in CRF 1.A.2.g. In earlier submissions, the notation key for fugitive CH_4 emissions in 1.A.1.c was mistakenly reported as NO but is now reported as IE.

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.

[48] Fuel combustion in manufacturing of nuclear fuels was included in CRF 1A1c in previous submissions, but for confidentiality reasons the very small emissions from these facilities have been included in CRF 1A1aiii instead.

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

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1A1c	CO_2	X (Solid fuels)	X (Solid fuels)		T2	CS	Yes
	CH_4				T2	CS	Yes
	N_2O				T2	CS	Yes

CS Country Specific. T2 Tier 2.
* Shows key category (level) per fuel type
** Shows key category (trend) per fuel type

3.2.8.2 METHODOLOGICAL ISSUES

Activity data on coke production is taken from environmental reports. CO_2 emissions are estimated based on carbon balances for the two integrated iron and steel production facilities and information on allocation on different categories from the facilities' environmental reports.

Emissions of N_2O, CH_4, NMVOC and CO are estimated with Tier 2 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 (1.A.1.c, 1.A.2.a, 1.B.1.c and 2.C.1, SO_2 also 2.B.5 and 1.B.1.b) according to the activity data distribution. The methodology is described in more detail in the section **Fel! Hittar inte r eferenskälla.** (CRF 2.C.1.2.).

Due to confidentiality reasons emissions of CO are shown as C in CRF-tables for the whole sector for 2017.

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. The composition of each gas is also quite variable, and this is another explanation to the fluctuating IEF's. Solid fuel consumption decreased considerably in 2009 due to lower production of coke caused by lower demand of primary iron and steel. In 2010, the demand increased and thus the fuel consumption increased to about the same level as before 2009.

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

In submission 2019, a revision of the fraction of emissions by fuels type was made. The emissions are based on the reported emissions at total level for the largest iron and steel production plants. The emissions by fuel type is estimated as fractions of total emissions based on modelled results.

3.2.8.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

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

3.2.9.1 SOURCE CATEGORY DESCRIPTION

The iron and steel industry is, together with the pulp and paper industry and the chemical industry, one of the most energy intensive industrial branches in Sweden. In 2009, fuel consumption in the iron and steel industry fell sharply as a consequence of decreased production (2.8 Mt of steel) due to the global recession. In 2017, the production was 4.9 Mt[49], an increase of almost 2 percent compared to 2016. Emissions from iron and steel companies with less than 10 employees are allocated to CRF 1.A.2.g because the model estimate of fuel consumption for these small companies is produced on an aggregate level and not separated by ISIC code.

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 3.5.

Table 3.5. Summary of source category description, CRF 1.A2a, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.2.a	CO_2	X (Gaseous fules, Liquid fuels, Solid fuels)	X (Gaseous fules)		T2,T3	CS, PS	Yes
	CH_4				T2	CS	Yes
	N_2O				T2	CS	Yes

CS Country Specific. PS Plant Specific. T2 Tier 2. T3 Tier 3.
* Shows key category (level) per fuel type
** Shows key category (trend) per fuel type

3.2.9.2 METHODOLOGICAL ISSUES IRON AND STEEL, CRF 1.A.2.A

During 2009, a new methodology was implemented for the two largest primary iron and steel works. This is described in section 3.2.9.2.1.

Activity data for all other facilities 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.

For confidentiality reasons, gaseous fuels are reported together with liquid fuels since submission 2015. Occasionally, small amounts of biomass and peat are used in this CRF category, but the corresponding emissions are reported in CRF 1A2gviii for biomass and in CRF 1A2a solid for peat, also for confidentiality reasons.

[49] The Swedish Steel Producers´ Association, 2018-11-22.

Emissions reported from primary steel works and other iron and steel works are reported in both CRF 1A2a and in CRF 2.C.1 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 2.C.1.1 (secondary steel) and CRF 2.C.1.2 (primary pig iron and steel).

Due to confidentiality reasons activity data and emissions of CO_2-equivalents, CH_4 and N_2O for liquid fuels and biomass are reported as C in CRF-tables 2017.

3.2.9.2.1 Primary iron and steel works

In Sweden, there are two plants for integrated primary iron and steel production 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 Table 3.6). Emissions from fuel combustion (oils, LPG (Liquefied Petroleum Gas) 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. From one of the facilities, large amounts of recovered energy gases are sold to a public heat and power plant, and the emissions from combustion of these gases are hence reported in CRF 1.A.1.a.

Detailed carbon mass balances, simplified energy balances and carbon and energy flowcharts according to EU ETS are compiled for the two integrated plants but are not presented in the NIR due to confidentiality reasons.

The allocation of total CO_2 emissions and energy consumption (TJ) on plant stations and consequently CRF sub-sector is based on measured fuel consumption and associated C emissions.

Table 3.6. Allocation of fuel consumption and CO_2 emissions in 2017 from iron ore based iron and steel industry to different CRF codes.

CRF	Plant station	CO_2 emissions (kt)	Energy consumption (TJ)
1.A.1.a	Power and Heat Production (sold amount of energy gases)	2374	7907
1.A.1.c	Coke Oven	376	4493
1.A.2.a	Combustion in Rolling Mills + Power and Heat Production	599	4023
1.B.1.c	Flare in Coke Oven (COG)	5	115
2.C.1.b	Blast Furnace + Steelworks (including Flaring of BFG and LD-gas)	1607	7687
NA	Products and losses	NA	26918
Total		**4961**	**51143**

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. For these facilities, data on fuel consumption for energy purposes is from the quarterly fuel statistics. National NCVs and emission factors are used.

3.2.9.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

For the two largest facilities, the time series is considered to be very consistent since the time series developed in 2009 was compiled in close cooperation with the facilities. For CRF 1.A.2.a 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 annual industrial energy survey for some years. The quarterly fuel survey data is weighted 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 1.A.2.a 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 explains the fact aggregate CO_2 IEF for solid fuels in CRF 1.A.2.a is considerably lower in 2009 than in earlier and later years. See also section **Fel! Hittar inte r eferenskälla.**. The IEF for coke oven gas and blast furnace gas starts to vary from 2003. The reason for the interannual variability of the IEF for coke oven gas and blast furnace gas are the amounts that vary in time. Between 1990 and 2002 this variability is not seen since the shares of coke oven gas and blast furnace gas were constant due to aggregated activity data. The share of the gases was constant within the same oven. Since 2003 the proportion of gases are enabled due to disaggregated activity data. The reason for the indroduced variability of data from 2003 is due to that the facility started to measure emissions at a finer level than before.

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

3.2.9.4 SOURCE SPECIFIC QA/QC AND VERIFICATION

In general, the same QA/QC procedures are used for CRF 1.A.2.a as for 1.A.1.a 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 weight factors for the year t-1 are reasonable. For the two largest facilities, all data is collected directly from the company.

Quality control is being conducted annually to improve emission allocation between the energy sector (CRF 1.A) and IPPU (CRF 2) and to establish a procedure for annual cross-sectoral control of reported emissions on a facility level. In case of discrepancies, they are easily identified and further investigated regarding potential gaps or double-counting using a developet quality control tool. This work is ongoing, and feasible reallocations will be done in the submission 2020. For further detailed information see section 1.3.5 concerning QA/QC and Verification in general.

3.2.9.5 SOURCE SPECIFIC RECALCULATIONS

In submission 2019, a revision of the fraction of emissions by fuels type was made. The emissions are based on the reported emissions at total level for the largest iron and stell production plants. The emissions by fuel type is estimated as fractions of total emissions based on modelled results.

Emission factor and NCV for CO_2 for natural gas was revised and harmonised with the ones used in the Swedish energy balance[50]. Also emission factors for CO_2 for peat, and landfill gas was revised for all sectors within stationary combustion [51].

The total effect of the recalculations in 1.A.2.a for the two most recent recalculated years was a decrease of the estimated emissions with 0.14 % (8.48 kt CO_2-eq) for 2015 and a decrease with 0.19 % (18.73 kt CO_2-eq) for 2016.

3.2.9.6 SOURCE SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

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

3.2.10.1 SOURCE CATEGORY DESCRIPTION

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 **Fel! Hittar inte referenskälla.**.

As for all subcategories to CRF 1.A.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

[50] Helbig, T. Stripple, H., Hjort, A., Mawdsley, I. 2018. Uppdatering av emissionsfaktorer för CO2 från torv och deponigas. SMED PM 2018-05-20.

[51] Energistyrelsen, 2018-11-26 (https://ens.dk/ansvarsomraader/co2-kvoter/stationaere-produktionsenheder/co2-rapportering-og-returnering)

be used. Emissions from companies with less than 10 employees are allocated to CRF 1.A.2.g.

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. In recent years, the copper producers account for 40-50 % of the fuel consumption in 1A2b and the aluminium producers account for 32-45 %. The most common fuel is LPG (45-61 % in recent years), followed by natural gas and heating oils.

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

Table 3.7. Summary of source category description, CRF 1A2b, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.2.b	CO_2				T2	CS	Yes
	CH_4				T2	CS	Yes
	N_2O				T2	CS	Yes

CS Country Specific. T2 Tier 2.
* Shows key category (level) per fuel type
** Shows key category (trend) per fuel type

3.2.10.2 METHODOLOGICAL ISSUES

Activity data is taken from industrial energy statistics for 1990-1996 and 2000-2002, and from quarterly fuel statistics for 1997-1999 and 2003 and later. For more details on these surveys see Annex 2. National emission factors are used. For more information, see Annex 2.

3.2.10.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As for CRF 1.A.2.a, time series consistency despite the changes in activity data source is discussed in Annex 2.

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 1.A.2.b, 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 1.A.2.b as for 1.A.2.a described above. In addition to this, a detailed quality study of the non-ferrous metal industry was performed in 2010[52].

Quality control is being conducted annually to improve emission allocation between the energy sector (CRF 1.A) and IPPU (CRF 2) and to establish a procedure for annual cross-sectoral control of reported emissions on a facility level. In case of discrepancies, they are easily identified and further investigated regarding potential gaps or double-counting using a developet quality control tool. This work is ongoing, and feasible reallocations will be done in the submission 2020. For further detailed information see section 1.3.5 concerning QA/QC and Verification in general.

3.2.10.5 SOURCE-SPECIFIC RECALCULATIONS

Emission factor and NCV for CO_2 for natural gas was revised and harmonised with the ones used in the Swedish energy balance[53]. Also emission factors for CO_2 for peat, and landfill gas was revised for all sectors within stationary combustion[54].

The total effect of the recalculations in 1.A.2.b for the two most recent recalculated years was a decrease of the estimated emissions with 0.12 % (0.76 kt CO2-eq) for 2015 and a decrease with 0.17 % (1.72 kt CO2-eq) for 2016.

3.2.10.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

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

3.2.11.1 SOURCE CATEGORY DESCRIPTION

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. Throughout the time series, liquid fuels account for about 80 % of the energy and gaseous fuels for 10-15 %.

As in other subcategories of CRF 1A2, emissions from companies with less than 10 employees are allocated to CRF 1.A.2.g.

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

[52] Skårman et.al, 2008.

[53] Energistyrelsen, 2018-11-26 (https://ens.dk/ansvarsomraader/co2-kvoter/stationaere-produktionsenheder/co2-rapportering-og-returnering)

[54] Helbig, T. Stripple, H., Hjort, A., Mawdsley, I. 2018. Uppdatering av emissionsfaktorer för CO2 från torv och deponigas. SMED PM 2018-05-20.

Table 3.8. Summary of source category description, CRF 1A2c, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.2.c	CO_2	X (Liquid fuels)			T2	CS	Yes
	CH_4				T2	CS	Yes
	N_2O				T2	CS	Yes

CS Country Specific. T2 Tier 2.
* Shows key category (level) per fuel type
** Shows key category (trend) per fuel type

3.2.11.2 METHODOLOGICAL ISSUES

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 and later. For more details on these surveys, and explanations of choice of data sources, see Annex 2.
Generally, plants classified as ISIC Division 24 according to ISIC Rev.3[55] in the energy statistics are included in this sector, as recommended in IPCC 2006 Guidelines.

For one of the largest facilities, including two plants, ETS data is the activity data source for 2008 and later. Before 2008, this facility was not fully covered by energy statistics or ETS data, so environmental reports and several energy surveys were used in order to get complete data for this important facility.

One calcium carbide manufacturing facility uses coke both as a fuel and as a reducing agent in the production process. In submission 2013, it was revealed that the reporting of this coke consumption is not properly allocated in the energy statistics, and several years the total amounts reported were obviously too low. For this reason, activity data from environmental reports and in later years from the EU ETS is used for this coke consumption since submission 2013.

According to environmental reports, the "other petroleum fuels" used in this sector is a process by-product consisting mainly of methane. The fuel is produced at one facility and used by several chemical industries in the same municipality. ERT has remarked that this fuel is probably partly originating from natural gas, which is also indicated by the environmental reports. It has, however, not been possible to determine how much of the gas mixture that should be allocated to gaseous fuels, so presently all consumption of this fuel is allocated to liquid fuels. Both natural gas and petroleum products are used as feedstock, and hence the by products as well as the actual desired products are partly of liquid origin and partly of gaseous origin. The major part of the raw material is, however, of liquid origin. This assumption is supported by the comparison between the reference and sectoral approach for gaseous fuels. In later years, apparent consumption of gaseous fuels according to reference approach is in fact lower than in the sectoral approach, which indicates that there are no major underestimations of the consumption of gaseous fuels in the sectoral approach.

[55] United Nations Statistics Division, 2010

In submission 2016, all combustion of petrochemical by-products (i.e. the gas discussed above) is allocated to CRF 1A2c and not to CRF 2. This allocation is the same as in previous submissions, although it might not follow the recommendations in the IPCC 2006 Guidelines.

For the years 2007-2013, plant specific CO_2 emission factors for by product gases from the petrochemical industries are used. The emission factors are based on total emissions for each plant minus process emissions and emissions from combustion of fuels other than by product gases, i.e. they are in fact implied emission factors based on reliable information on total emissions from the environmental reports.

3.2.11.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As for CRF 1A2a and 1A2b, the time series is considered to be consistent despite the changes in activity data sources. This is discussed in Annex 2.

As mentioned above, fuel consumption in 2013 was higher than in 1990. However, since 2003 there is no distinct trend. Except for 2009, when the production and hence also the fuel consumption dipped, the annual fuel consumption 2001-2013 in CRF1A2c is 25-27 PJ.

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 quite 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 1.A.2.c.

The ERT, submission 2012, also noted variable CH_4 IEFs for biomass fuels. This is because the relative amounts of landfill gas, tall oil and other biomass fuels such as wood vary over time, and the fuels have quite different emission factors for CH_4. The exact amounts of the different biomass fuels cannot be shown due to confidentiality reasons.

In 2011, a consistent time series of the CO_2 emission factor for the by-product fuel was developed in cooperation with the facility that produces the fuel and hence it is plant specific. The emission factor used in submission 2011, namely 55 kg CO_2/GJ, was verified by the company for the period 1990-2000. In 1999 to 2001, the process that produces the gas was gradually modified by technological improvements, resulting in an altered composition of the fuel. The proportion of hydrogen increased, which gave a higher calorific value and lower CO_2 emissions. The company also provided a time series of CO_2 emissions covering the period 2001-2010, which was used to calculate the year specific emission factors. These new emission factors were implemented in submission 2012. For non- CO_2 emissions, emission factors for natural gas are used as no specific emission factors are available and both fuels consist mainly of methane.

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 1.5 % (2012) and the emission factor uncertainty is assumed to be 10 % based on the variation in plant specific values. The Activity data uncertainty for this fuel 2012 is as reported to the EU ETS. For the other fuels used and for all fuels for 1990, 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 1.A.2.c as for 1.A.2.a and 1.A.2.b described above. For the largest plants in terms of emissions and fuel consumption, both environmental reports and ETS data are used for verification of the estimates based on energy statistics.

Quality control is being conducted annually to improve emission allocation between the energy sector (CRF 1.A) and IPPU (CRF 2) and to establish a procedure for annual cross-sectoral control of reported emissions on a facility level. In case of discrepancies, they are easily identified and further investigated regarding potential gaps or double-counting using a developet quality control tool. This work is ongoing, and feasible reallocations will be done in the submission 2020. For further detailed information see section 1.3.5 concerning QA/QC and Verification in general.

3.2.11.5 SOURCE-SPECIFIC RECALCULATIONS

Emission factor and NCV for CO_2 for natural gas was revised and harmonised with the ones used in the Swedish energy balance[56]. Also emission factors for CO_2 for peat, and landfill gas was revised for all sectors within stationary combustion[57].

In submission 2019, two facilities were allocated to CRF 2 due to lack of information on the shares of emissions between CRF 1.A and 2 as well as due to energy data for different facilities being inseparable from process emission data, especially for the earlier years of the time series for certain facilities. This work is part of Sweden's annually cross-sectoral control as part of a quality control procedure aiming to allocate CO_2 emissions from industrial plants correctly between CRF 1 and 2 and to ensure that total emissions are reported correctly.

The total effect of the recalculations in 1.A.2.c for the two most recent recalculated years was a decrease of the estimated emissions with 101.89 % (14 465 kt CO_2-eq) for 2015 and a decrease with 107.19 % (16 990 kt CO_2-eq) for 2016.

3.2.11.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

[56] Energistyrelsen, 2018-11-26 (https://ens.dk/ansvarsomraader/co2-kvoter/stationaere-produktionsenheder/co2-rapportering-og-returnering)

[57] Helbig, T. Stripple, H., Hjort, A., Mawdsley, I. 2018. Uppdatering av emissionsfaktorer för CO2 från torv och deponigas. SMED PM 2018-05-20.

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

3.2.12.1 SOURCE CATEGORY DESCRIPTION

In 2017 there were 50 paper mill and pulp industry plants and 120 sawmills (production capacity >10 000 m^3/year) in Sweden. In total, they were producing 10.3 Mt of paper, 18 Mm^3 of sawn timber and 12.2 Mt of pulp[58]. 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, from 68 % of fuel consumption in 2007 to 83 % in 2017. As for CRF 1.A.2 in general, emissions from companies with less than 10 employees are allocated to CRF 1A2g.
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 1A2d, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.2.d	CO_2	X (Liquid fuels)	X (Liquid fuels, Solid Fuels)		T2	CS	Yes
	CH_4				T2	CS	Yes
	N_2O	X (Biomass)	X (Biomass)		T2	CS	Yes

CS Country Specific. T2 Tier 2.
* Shows key category (level) per fuel type
** Shows key category (trend) per fuel type

3.2.12.2 METHODOLOGICAL ISSUES

Emissions from processes in the Pulp, paper and print industry are reported under CRF 2H1 according to IPCC Guidelines (see chapter 4.9). Activity data is collected from industrial energy statistics for 1990-1996 and 2000-2002, and from quarterly fuel statistics for 1997-1999 and 2003 and later. For more details on these surveys see Annex 2. For confidentiality reasons, peat is reported together with other solid fuels. In addition, solid fuels in this category are included in other in the same category (1.A.2.d).

Emissions from combustion of spent cooking liquor are presently not reported in CRF 1A2d as this activity has been considered an industrial process, despite the fact that the process heat is used for heat and electricity production. Emissions of CH_4, N_2O and indirect greenhouse gases from the processes in which the cooking liquor is consumed, are reported in CRF 2. Emissions from combustion of other fuels, such as bark and wood residues as well as fossil fuels, are reported in CRF 1.A.2.d.

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,

[58] The Swedish Forest Industries Federation, 2018-11-27 http://www.skogsindustrierna.se/skogsindustrin/skogsindustrin-i-korthet/fakta--nyckeltal/

and in the latest years, combustion of residual fuel oil has decreased a bit. Fuels 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 residual 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.

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 uncertainty 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 1.A.2.d as for 1.A.1.a and 1.A.2.a – 1.A.2.c described above.

Quality control is being conducted annually to improve emission allocation between the energy sector (CRF 1.A) and IPPU (CRF 2) and to establish a procedure for annual cross-sectoral control of reported emissions on a facility level. In case of discrepancies, they are easily identified and further investigated regarding potential gaps or double-counting using a developet quality control tool. This work is ongoing, and feasible reallocations will be done in the submission 2020. For further detailed information see section 1.3.5 concerning QA/QC and Verification in general.

3.2.12.5 SOURCE-SPECIFIC RECALCULATIONS

Emission factor and NCV for CO_2 for natural gas was revised and harmonised with the ones used in the Swedish energy balance[59]. Also emission factors for CO_2 for peat, and landfill gas was revised for all sectors within stationary combustion[60]. As for CRF 1.A.2.d in particular, emission factors for SO_2 and NOx were adjusted for the year 2016.

The total effect of the recalculations in 1.A.2.d for the two most recent recalculated years was an increase of the estimated emissions with 0.04 % (6.38 kt CO_2-eq) for 2015 and an increase with 0.01 % (2.41 kt CO_2-eq) for 2016.

[59] Energistyrelsen, 2018-11-26 (https://ens.dk/ansvarsomraader/co2-kvoter/stationaere-produktionsenheder/co2-rapportering-og-returnering)

[60] Helbig, T. Stripple, H., Hjort, A., Mawdsley, I. 2018. Uppdatering av emissionsfaktorer för CO2 från torv och deponigas. SMED PM 2018-05-20.

3.2.12.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

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

3.2.13.1 SOURCE CATEGORY DESCRIPTION

The food and drink industry is the fourth largest branch of industry measured as production value and number of employees. There are about 3000 companies, of which only around 650 have more than 10 employees[61]. 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 1.A.2.e. 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 1.A.2.e). The fuel consumption varies between years. A slight decrease can be observed since 1990. In later years, gaseous fuels account for 45-49 % and liquid fuels account for about 27-35 % of the total fuel consumption. As for CRF 1.A.2 in general, emissions from companies with less than 10 employees are allocated to CRF 1.A.2.g.

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 1A2e, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.2.e	CO_2	X (Gaseous fuels)	X (Liquid fuels)		T2	CS	Yes
	CH_4				T2	CS	Yes
	N_2O				T2	CS	Yes

CS Country Specific. T2 Tier 2.
* Shows key category (level) per fuel type
** Shows key category (trend) per fuel type

3.2.13.2 METHODOLOGICAL ISSUES

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

3.2.13.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As for CRF 1.A.2 in general, time series consistency despite the changes in activity data source is discussed in Annex 2. 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

[61] The Swedish Food Federation 2013-10-02

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.

3.2.13.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Generally, the same QA/QC procedures are applied for 1.A.2.e as for other 1.A.2 categories described above.

Quality control is being conducted annually to improve emission allocation between the energy sector (CRF 1.A) and IPPU (CRF 2) and to establish a procedure for annual cross-sectoral control of reported emissions on a facility level. In case of discrepancies, they are easily identified and further investigated regarding potential gaps or double-counting using a developet quality control tool. This work is ongoing, and feasible reallocations will be done in the submission 2020. For further detailed information see section 1.3.5 concerning QA/QC and Verification in general.

3.2.13.5 SOURCE-SPECIFIC RECALCULATIONS

Emission factor and NCV for CO_2 for natural gas was revised and harmonised with the ones used in the Swedish energy balance[62]. Also emission factors for CO_2 for peat, and landfill gas was revised for all sectors within stationary combustion[63].

The total effect of the recalculations in 1.A.2.e for the two most recent recalculated years was a decrease of the estimated emissions with 0.18 % (9.78 kt CO_2-eq) for 2015 and a decrease with 0.30 % (22.59 kt CO_2-eq) for 2016.

3.2.13.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

3.2.14 Non-metallic minerals (CRF 1.A.2.f)

3.2.14.1 SOURCE CATEGORY DESCRIPTION

This source category includes stationary combustion of fuels in non-metallic mineral industries (ISIC 26). Cement production accounts for the major part of the emissions. 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.

[62] Energistyrelsen, 2018-11-26 (https://ens.dk/ansvarsomraader/co2-kvoter/stationaere-produktionsenheder/co2-rapportering-og-returnering)

[63] Helbig, T. Stripple, H., Hjort, A., Mawdsley, I. 2018. Uppdatering av emissionsfaktorer för CO2 från torv och deponigas. SMED PM 2018-05-20.

Table 3.11. Summary of source category description, CRF 1A2f, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.2.f	CO_2	X (Liquid fuels, Other fuels, Solid fuels)	X (Liquid fuels, Other fuels, Solid fuels)		T2	CS	Yes
	CH_4				T2	CS	Yes
	N_2O				T2	CS	Yes

CS Country Specific. T2 Tier 2
* Shows key category (level) per fuel type
** Shows key category (trend) per fuel type

3.2.14.2 METHODOLOGICAL ISSUES

Tier 2 method is used for emissions from stationary combustion for CRF 1.A.2.f, because country-specific emission factors for the source category and fuel for each gas is used.

Activity data is collected from industrial energy statistics for 1990-1996 and 2000-2002, and from quarterly fuel statistics for 1997-1999 and 2003 and later. For 2008 and later, activity data for the three plants within the cement production industry is taken from the EU ETS system, as this data source provides more detailed information on fuel types. The total amount of fuels combusted is consistent with the quarterly fuel statistics.

National emission factors are used. For more details on these surveys and emission factors see Annex 2.

For practical reasons, SO_2 and NO_X emission data available from environmental reports are reported in CRF 2.A.7. All other energy related emissions for this facility are reported in CRF 1.A.2.f.

The increase in NOx emissions in 1.A.2.f. for the entire time series in submission 2018 is the result of a reallocation of emissions from CRF 2.

Due to confidentiality reasons liquid and solid fuels are reported as C for energy consumption and GHG emissions except for CH_4 for solid fuels.

3.2.14.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As for CRF 1.A.2 in general, time series are considered consistent despite the changes in activity data source as discussed in Annex 2. The IEFs are slightly variable between years due to variations in the fuel mix. The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7.

3.2.14.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Generally, the same QA/QC procedures are applied for 1.A.2.f as for other 1.A.2 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 3.2.21.4.1 below.

Quality control is being conducted annually to improve emission allocation between the energy sector (CRF 1.A) and IPPU (CRF 2) and to establish a

procedure for annual cross-sectoral control of reported emissions on a facility level. In case of discrepancies, they are easily identified and further investigated regarding potential gaps or double-counting using a developet quality control tool. This work is ongoing, and feasible reallocations will be done in the submission 2020. For further detailed information see section 1.3.5 concerning QA/QC and Verification in general.

3.2.14.5 SOURCE-SPECIFIC RECALCULATIONS

Emission factor and NCV for CO_2 for natural gas was revised and harmonised with the ones used in the Swedish energy balance[64]. Also emission factors for CO_2 for peat, and landfill gas was revised for all sectors within stationary combustion[65]. As for CRF 1.A.2.f in particular, emission factors for N_2O, CH_4, CO, SO_2, NOx, have been revised regarding residual fuel oil, petroleum coke and coal in order to be in line with the major revision of emission factors within the industry sector that was implemented in submission 2018.

The total effect of the recalculations in 1.A.2.f for the two most recent recalculated years was a decrease of the estimated emissions with 24.67 % (5.67 kt CO_2-eq) for 2015 and a decrease with 12.30 % (23.65 kt CO_2-eq) for 2016.

3.2.14.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

3.2.15 Other Industries (CRF 1.A.2.g)

3.2.15.1 SOURCE CATEGORY DESCRIPTION

This source category is by nature quite heterogeneous. Both stationary and mobile emission sources are included. For 1.A.2.g, Sweden has chosen not to use the drop-down list in the CRF Reporter due to confidentiality reasons.

The stationary sources included are combustion within ISIC 10-37 except from the branches separately reported in 1.A.2.a-1.A.2.f, and stationary combustion within all companies with less than 10 employees regardless of branch, and stationary combustion within the construction sector. The quarterly fuel statistics is a cut-off survey including enterprises with ten or more employees. The estimation of emissions from enterprises with less than ten employees is based on activity data from the annual energy balances, i.e. a model estimate of aggregate fuel consumption in all small enterprises within the entire manufacturing industry. These emissions are reported in 1A2gviii.

The mobile emission source included in this sector is combustion by off-road vehicles and other machinery (working machinery) used in the construction and manufacturing industry. The emissions of greenhouse gases from this sector represent ~ 40 % of all emissions of GHG from working machinery. These emissions are reported in 1A2gvii.

[64] Energistyrelsen, 2018-11-26 (https://ens.dk/ansvarsomraader/co2-kvoter/stationaere-produktionsenheder/co2-rapportering-og-returnering)

[65] Helbig, T. Stripple, H., Hjort, A., Mawdsley, I. 2018. Uppdatering av emissionsfaktorer för CO2 från torv och deponigas. SMED PM 2018-05-20.

In terms of stationary fuel combustion and emissions, two branches of industry are dominating; 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 combustion within 1.A.2.g in total, it has decreased slightly since 1990. Liquid and biomass fuels account for most of the decrease. For mobile combustion, i.e. working machinery, fuel consumption in 2017 was about 70 % higher than in 1990.

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 1A2g, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.2.g Off-road vehicles and other machinery	CO_2	X (Liquid fuels)	X (Liquid fuels)		T2	CS	Yes
	CH_4				T3	CS	Yes
	N_2O				T3	CS	Yes
1.A.2.g Other (1.A.2.g i-vi reported as "C" or "IE" in 1.A.2.g Other)	CO_2	X (Liquid fuels, Solid fuels)	X (Liquid fuels, Solid fuels)		T2	CS	Yes
	CH_4				T2	CS	Yes
	N_2O	X (Biomass)			T2	CS	Yes

CS Country Specific. T2 Tier 2 T3 Tier 3.
* Shows key category (level) per fuel type
** Shows key category (trend) per fuel type

3.2.15.2 METHODOLOGICAL ISSUES

All consumption of motor gasoline and diesel oil in manufacturing industries and construction is allocated to mobile combustion, and all other fuels (heating oils, natural gas etc.) to stationary combustion.

Due to confidentiality reasons, solid and liquid fuels under stationary combustion are reported as C for energy consumption and CO_2-equivalents, CO_2 and N_2O emissions.

3.2.15.2.1 Stationary combustion

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.

Stationary fuel combustion in the construction sector is shown below (Table 3.13).

Table 3.13 Stationary fuel combustion in the construction sector (part of 1A2g), (TJ).

Year	LPG	Domestic heating oil	Residual fuel oil	Natural gas	Biomass
1990	46	5 051	420	39	-
2000	46	4 621	382	40	-
2005	145	1 352	291	-	24
2010	166	1 541	332	-	28
2011	170	1 581	341	-	29
2012	170	1 582	341	-	29
2013	175	1 631	352	-	30
2014	176	1 640	354		30
2015	183	1 705	368	-	31
2016	189	1 757	379		32
2017	198	1 848	399		30

(Preliminary data for 2017)

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, 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 and later. For more details on these surveys see Annex 2.

Emissions from all companies in ISIC 10-37 with less than 10 employees are estimated and reported under CRF 1.A.2.g. Activity data is provided by the Swedish Energy Agency[66]. 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 the Swedish Energy Agency[67]. The methodology used for this sub-category is the same as for stationary combustion in the Other sector, see section 3.2.21.4.1. Activity data is basically from the annual energy balances. Data for the latest emission year is preliminary as the calculations have to be completed before the annual energy balances are published. However, the data in Table 3.13 differ slightly from the official energy balances due to use of slightly different calorific values especially for earlier years.

3.2.15.2.2 Mobile combustion/Working machinery

Emissions from mobile combustion in CRF 1.A.2.g refer to working machinery used in industry, including for example tractors, dumpers, cranes, excavators, generators and wheel loaders. A national model is used to estimate emissions from all working machinery used in Sweden and is considered to correspond to Tier 3 for all emissions, except for CO_2 and SO_2 which are estimated according to Tier 2. The model is further described in Annex 2.[68]

[66] Swedish Energy Agency: Annual Energy balances. See also Annex 2.

[67] Swedish Energy Agency: Annual Energy balances. See also Annex 2.

[68] Annex 2: 1.6 Methodology for off-road vehicles and working machinery

The consumption of gasoline and diesel, estimated by the model for off-road vehicles, is adjusted with regard to low-blended biofuel. The fuel consumption is also modified with a residual of gasoline and diesel. This residual arise as the volume of gasoline and diesel allocated to different sectors through a top-down approach is compared to the total volume of the gasoline and diesel consumed according to a bottom-up estimate. See Annex 2 for more information regarding the allocation of fuels for mobile combustion[69].

Emissions from working machinery are also reported under CRF 1.A.3.eii, 1.A.4.aii, 1.A.4.bii and 1.A.4.cii, in line with IPCC Guidelines, see Table 3.14.

Table 3.14. Distribution of emissions from off-road vehicles and other machinery

Category	CRF	Definition IPCC Guidelines
Industry	1.A.2.g vii	Mobile machineries in industry that run on petroleum fuels, as for example tractors, dumpers, cranes, excavators, generators, wheel loaders, sorting works, pump units etc.
Other	1.A.3.e ii	Combustion emissions from all remaining transport activities including ground activities in airports and harbours, and off-road activities not otherwise reported under 1.A.4.c or 1.A.2.g vii.
Commercial/ Institutional	1.A.4.a.ii	Garden machinery, e.g. lawn mowers and clearing saws, not used by private users, Also tractors not used in industry ore forestry or agriculture.
Residential	1.A.4.b	All emissions from mobile fuel combustion in households, as for example tractors, lawn movers, snow mobiles, forklifts, trimmers, chainsaws and forklifts
Agriculture, Forestry	1.A.4.c	Emissions from mobile fuel combustion in agriculture and forestry, as for example loader-excavator, tractor, harvester, clearing saw etc. Highway agricultural transportation is excluded.

3.2.15.3 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.

As for stationary combustion in 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 1.A.2, the IEFs vary slightly between years due to variations in fuel mix. In earlier submissions, the EC (European Commission) 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.

The emissions of CO_2 from diesel (used by off-road vehicles and working machinery) and heating oils (used for stationary combustion) represent the largest sources of uncertainty in regard to GHG emissions within CRF 1.A.2.g. 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

[69] See Annex 2. chapter “1.4 Allocation of fuels for mobile combustion” for more information.”

for diesel combusted in off-road vehicles and working machinery is 5 % and for gasoline 3 % based on fuel sold.

The consumption of gasoline by off-road vehicles and other machinery drops in 2004, as a result of a large increase in the total consumption of low-blended ethanol, which is allocated to road traffic and working machinery. The amount of low-blended biofuel (Ethanol/FAME) allocated to road traffic is given by the road emission model HBEFA in combination with national fuel statistics. A residual of biofuel arise when the biofuel allocated to road traffic is subtracted from the national deliveries of biofuel. *This residual is distributed to off-road vehicles and other machinery*. The model estimated consumption of gasoline and diesel by working machinery is decreased by the residual of ethanol respectively FAME. In 2004 the consumption of gasoline by working machinery decreased noticeably as a result of an unusual large residual of ethanol allocated to working machinery, due to a large increase in the national deliveries of low-blended ethanol. The same phenomenon took place in 2014, but regarding FAME and diesel; e.g. a noticeable decrease in the consumption of diesel between 2013 and 2014 as a consequence of an increased consumption of low-blended FAME.

3.2.15.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Generally, the same QA/QC procedures are applied for 1.A.2.g as for other 1.A.2 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 3.2.21.4.1 below.

3.2.15.5 SOURCE-SPECIFIC RECALCULATIONS

3.2.15.5.1 Stationary combustion

The emission factor and NCV for CO_2 for natural gas was revised and harmonised with the ones used in the Swedish energy balance[70]. Also emission factors for CO_2 for peat, and landfill gas was revised for all sectors within stationary combustion[71]. Moreover, following revisions of the energy balances, the activity data for stationary combustion within small enterprises reported in 1.A.2.g was revised for all fuels for the years 2013-2016.

The total effect of the recalculations for stationary combustion in 1.A.2.g for the two most recent recalculated years was a decrease of the estimated emissions with 0.01 % (2.82 kt CO_2-eq) for 2015 and a decrease with 0.03 % (8.82 kt CO_2-eq) for 2016.

3.2.15.5.2 Mobile combustion

A redistribution of FAME between road traffic and working machineries in submission 2019 has led to an increased share of fossil fuel for working machinery in CRF 1A2gvii.[72] The model for working machinery has also been updated with

[70] Energistyrelsen, 2018-11-26 (https://ens.dk/ansvarsomraader/co2-kvoter/stationaere-produktionsenheder/co2-rapportering-og-returnering)

[71] Helbig, T. Stripple, H., Hjort, A., Mawdsley, I. 2018. Uppdatering av emissionsfaktorer för CO2 från torv och deponigas. SMED PM 2018-05-20.

[72] Eklund, V. Jonsson, M. Jerksjö, M. 2018.

revised load factors as well as fuel consumption for wheel loaders and an increased number of road rollers for the whole time period.[73] These changes to the model has resulted in an increase in the consumption of diesel. An adjusted and higher number of counterbalanced trucks for the whole period has caused an increased consumption of gasoline as well.

These adjustments are counteracted by a reduced consumption of diesel as a result of revised load factors and fuel consumption for mining trucks.[74]

The end result appears as a minor decrease in the emissions of CO_2 equivalents for later years and a small increase in the earlier years, as the different effects equals each other out.

The total effect of the recalculations of mobile combustion in 1.A.2.g for the two most recent years, was a decrease of the estimated emissions of CO_2 equivalents with 1.3 % (-16.7 kt) and 6.7 % (-87.1 kt) for 2015 and 2016, respectively.

3.2.15.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

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

3.2.16.1 SOURCE CATEGORY DESCRIPTION

Activity data is presently provided for a total of 40 airports with regular and/or charted air traffic in Sweden. The national government administers 13 of these airports, while the remaining 27 are private and/or administered by local governments.[75] The traffic routed through governmental airports account for about 90 % of the total fuel consumption within the civil aviation sector. The emission of greenhouse gases (GHG) from national aviation in 2017 was 553 kt CO_2-eq., which is a neglible decrease since last year, but a decrease by 19 % compared to 1990.

This can be compared to emissions from international aviation which have more than doubled since 1990 and increased by 9 % between 2017 and 2016 to reach 2791 kt CO_2-eq. in 2017.

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.

[73] Eklund, V. Lidén, M. Jerksjö, M. 2017b.

[74] Eklund, V. Lidén, M. Jerksjö, M. 2017b.

[75] Transportstyrelsen, 2013.

Table 3.15. Summary of source category description, CRF 1A3a, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.3.a	CO_2	X (Jet kerosene)			T2	CS	Yes
	CH_4				T3	CS, D	Yes
	N_2O				T3	D	Yes

T1 Tier 1. T3 Tier 3. CS Country Specific. D Default.
* Shows key category (level) per fuel type
** Shows key category (trend) per fuel type

3.2.16.2 METHODOLOGICAL ISSUES

Sweden uses Tier 2 to estimate emissions of CO_2 and SO_2 and Tier 3 to estimate CH_4, N_2O and the indirect greenhouse gases CO, NO_X and NMVOC. Emissions from aviation in agricultural and forestry activities are included in domestic aviation in line with IPCC Guidelines. Emissions from domestic military use of aviation fuels are reported under Other – mobile sources (CRF 1.A.5.b).

The methodology for calculating national emissions is the same for all years with a few exceptions for earlier years. High quality activity data from the Swedish Transport Agency (STAg), former Swedish Civil Aviation Authority (SCAA), is available from 1995.

The Swedish Transport Agency (STAg) is responsible for reporting the GHG emissions from aviation, but the fuel consumption and emissions published by STAg are calculated by the Swedish Defence Research Agency (FOI) by using an estimation model. The STAg provides FOI with statistics regarding:

- Airport of departure and arrival
- Type of aircraft
- Number of flights
- Number of passengers
- International or domestic flight

A database with information regarding 200 different types of aircraft is also used. The emission data regarding different types of aircrafts in the database originates from "ICAO Engine Exhaust Emission Data Bank". All this data is used to calculate emissions and amounts of burnt fuel for the whole flight as well as for aircraft movements below 3000 feet at the airports, the so called LTO cycle (landing and take-off). The FOI has in a published report described their method for estimating the emission from aviation[76].

Due to the fact that the Swedish airports in general are smaller than airports in other countries; taxi times are much shorter for domestic flights and climb-out and take-off times are often shorter as well compared to the International Civil Aviation

[76] Mårtensson, T. & Hasselrot, A., 2013.

Organization (ICAO) standards that the IPCC guidelines follow[77]. The traffic from Swedish airports consumes as a result less fuel and gives rise to less emission.

The emissions reported by STAg are aggregated into four groups; emissions from domestic landing and take-off (LTO), domestic cruise, international LTO and international cruise. The estimated fuel consumption and emissions are then adjusted to be in line with the amounts of aviation fuel in the monthly survey on supply and delivery of petroleum products from Statistics Sweden. This is in line with the IPCC guidelines and data of good quality exists from 1995 and onwards.

Emissions of CO_2 and SO_2 are based on the adjusted fuel consumption, thermal values from 2006 IPCC Guidelines and country specific emission factors.

The estimated emissions of HC are split into NMVOC and CH_4, based on the ratio given in EMEP/EEA guidebook 2013[78]. Emissions of N_2O from LTO are estimated by using the number of LTO cycles reported by STAg and with emission factors in EMEP/EEA guidebook 2013. Emissions of N_2O from cruise are based on the adjusted amount of fuel for cruise activities and emission factors from the EMEP/EEA 2013 Guidebook.

The emissions of NMVOC have decreased noticeably in the last years as the airplane type MD-80/82 has been phased out. This airplane type was a major contributor to the NMVOC emissions.

3.2.16.3 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 fact that some of the estimations are not based on activity data but on other factors as LTO cycles, a certain degree of uncertainty exists. The method for estimating emissions for 1990-1994 is also slightly different, due to lack of activity data.

Emissions of CO_2 and SO_2 for 1990-1994 are based on fuel delivery statistics, thermal values from 2006 IPCC Guidelines and country specific emission factors. The emissions are split into domestic and national aviation based on the mean value for LTO cycles for domestic and international flights in 1995-2000. Emissions of CO for the period 1990-1994 were calculated from the ratio between CO and CO_2 in 1995 (the same ratio was assumed for 1990-1994). The emissions of NO_X in 1990-1994 were estimated in a similar way as for CO, whereas the emissions of NMVOC in 1990-1994 were calculated by extrapolation.

In 2006 the STAg responded to a governmental call to reduce the response burden for statistical respondents. As a result, private aviation as well as educational training flights are no longer covered in STAg's reports on fuel consumption and emissions from aviation as from 2007. However, as the estimated emissions from aviation are adjusted to match the delivered amount of aviation fuels on a national level, the emissions from private aviation as well as from educational training flights will consequently be included.

[77] Gustafsson, 2005.

[78] EMEP/EEA air pollutant emission inventory guidebook 2013.

STAg includes the traffic from a number of non-governmental airports in their estimates from 2005 and from all Swedish airports as from 2006. Since 2010 there is no separate reporting on emissions from governmental and private airports, respectively, only totals are reported.

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. Time series are checked for consistency and recalculations are verified.

3.2.16.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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. 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.

3.2.16.5 SOURCE-SPECIFIC RECALCULATIONS

The fuel for military operations abroad is according to new information from the National Defence, not bought in Sweden but in the country where the operation takes place. The aviation fuel is as a result reallocated to civil aviation, resulting in a slightly increased consumption and emissions for civil aviation.

The total effect of the recalculations in 1.A.3.a for the two most recent recalculated years was an increase of the estimated emissions with 0.1 % (0.76 kt CO_2-eq) and 0.1 % (0.64 kt CO_2-eq) for 2015 and 2016, respectively.

3.2.16.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

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

3.2.17.1 SOURCE CATEGORY DESCRIPTION

Road transport is a significant source of greenhouse gases (GHG) and contributes with 29% of the total emissions of GHG from all sectors (excluding LULUCF) in Sweden. The emissions of GHG from road transportation were about 15,500 kt CO_2-eq. in 2017, which accounts for approximately 77.7 % of the total emissions of GHG from mobile combustion in Sweden. The emissions of GHG from road transportation has decreased by 2.8 % since 2016 and by 11 % since 1990.

Road transport includes five vehicle categories: Passenger cars, Buses, Heavy goods vehicles (HGV), Light commercial vehicles (LCV) and Mopeds & Motorcycles. Gasoline has previously been the most common fuel used for road transportation, but as from 2011 the amount of diesel used by road traffic as well as the emissions of GHG from diesel surpassed gasoline. The increasing consumption of diesel by road traffic is primarily explained by a shift from gasoline cars to diesel cars, but also by an increased consumption of diesel by HGV and LCV. The total consumption of diesel by HGV and LCV correspond to 53 % of the total

consumption of diesel by road traffic in 2017, while passenger cars consume around 46 % of the total diesel for road traffic.

The consumption of diesel by HGV increased by 59 % between 1990 and 2007, from an already high level, and then started to decrease. The consumption of diesel by HGV was 16 % higher in 2017 than in 1990. The consumption of diesel by LCV has increased by 804 % since 1990, levelled out in 2011 and is still on a lower level than both passenger cars and HGV. The consumption of diesel by passenger cars has increased annually since 1995 and increased by 2 % between 2016 and 2017.

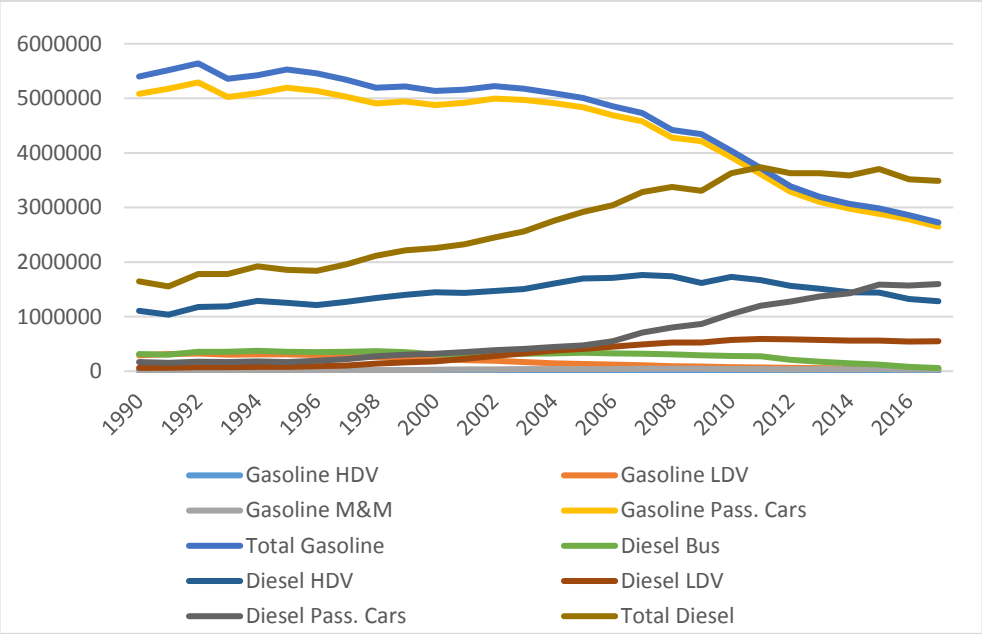


Figure 3.4. Consumption of diesel and gasoline by vehicle type 1990-2017 (m^3).

The total use of liquid biofuels (FAME and ethanol) has increased by more than 850 % since 2003, when large-scale blending of ethanol into petrol began. The increasing production and use of biofuels was initiated by advantageous policy regulations and tax reliefs for biofuels[79]. The amount of biogas used by road traffic has also increased greatly since it was introduced on the market and has doubled every other to every third year between 1998 and 2008.

The main part of ethanol used by road transportation in Sweden is used as a blending component for gasoline. Large-scale blending of ethanol into petrol began in 2003 and the total amount of ethanol used for road traffic nearly tripled between 2003 and 2011. As from 2012, the amount of low-blended ethanol in gasoline started to decline as a result of the shift from gasoline cars to diesel cars. Today, just about all petrol sold in Sweden contains around 5 % ethanol.
Ethanol is also used by ethanol buses and by E85 passenger cars (flexifuel cars). The ethanol used by E85 cars and by buses, increased steadily until 2011 respectively 2012, when the trend turned downward again.

[79] Swedish Energy Agency, 2013.

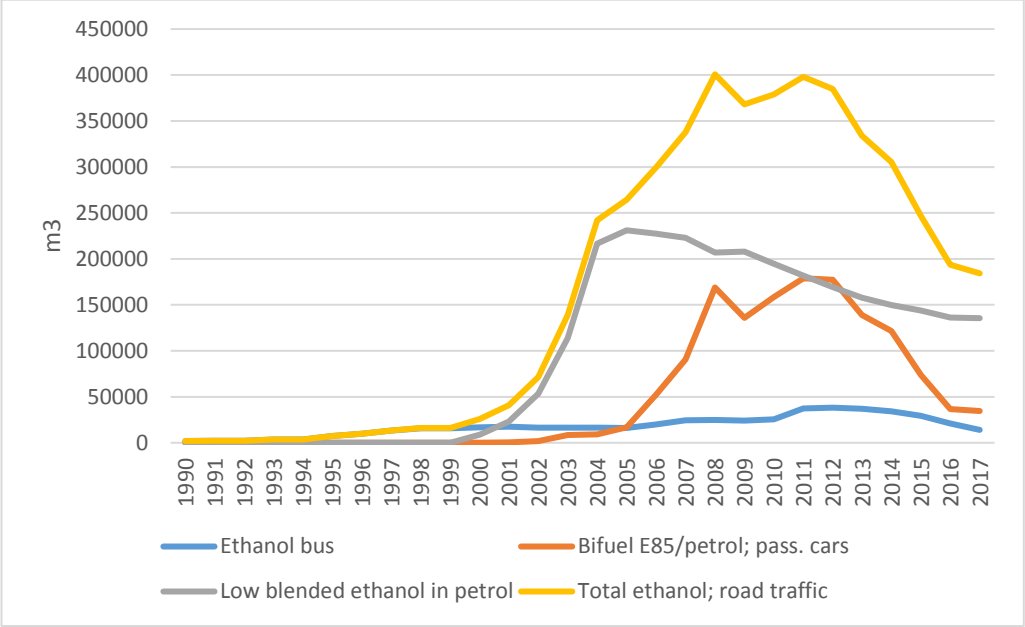


Figure 3.5 Consumption of ethanol by road traffic 1990-2017 (m^3)

Large-scale blending of FAME into diesel began in 2007/2008 and has increased steadily ever since. The total use of FAME by road traffic has increased by 33-49 % each year starting 2011. This is mainly a result of a growing trend for diesel cars and an rising fraction of FAME blended into diesel.

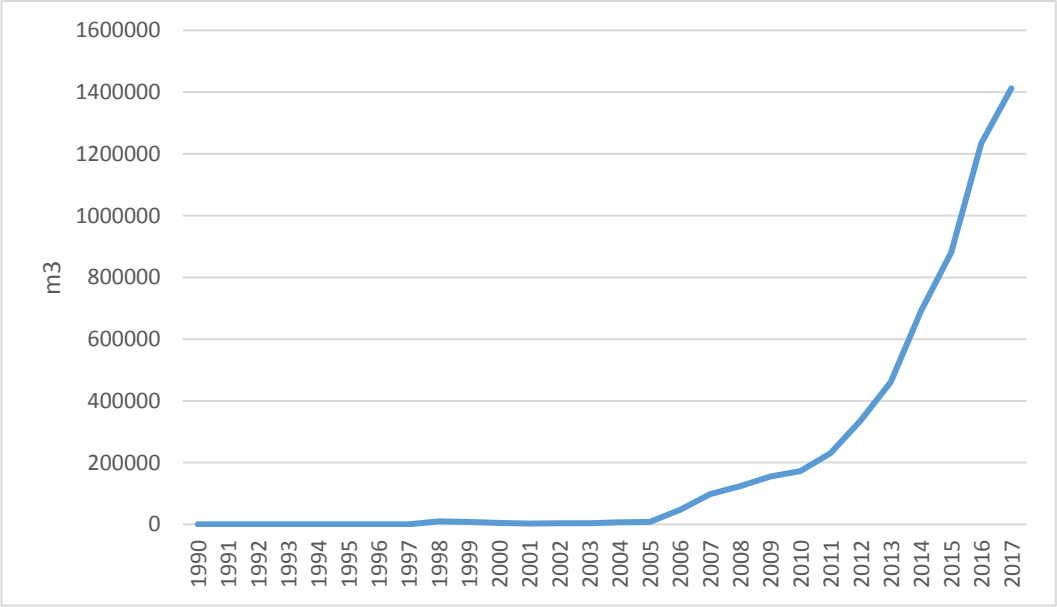


Figure 3.6 Consumption of FAME by road traffic 1990-2017 (m^3).

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 3.16.

Table 3.16. Summary of source category description, CRF 1A3b, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.3.b Cars	CO_2	X (Diesel oil, Gasoline)	X (Diesel oil, Gasoline)		T2	CS	Yes
	CH_4		X (Gasoline)		T2, T3	CS	Yes
	N_2O	X (Diesel oil)	X (Diesel oil, Gasoline)		T2, T3	CS	Yes
1.A.3.b Light duty trucks	CO_2	X (Diesel oil)	X (Diesel oil, Gasoline)		T2	CS	Yes
	CH_4				T2, T3	CS	Yes
	N_2O		X (Diesel oil)		T2, T3	CS	Yes
1.A.3.b Heavy duty trucks and buses	CO_2	X (Diesel oil)	X (Diesel oil)		T2	CS	Yes
	CH_4				T2, T3	CS	Yes
	N_2O	X (Diesel oil)	X (Diesel oil)		T2, T3	CS	Yes
1.A.3.b Motorcycles	CO_2				T2	CS	Yes
	CH_4				T2, T3	CS	Yes
	N_2O				T2, T3	CS	Yes

CS Country Specific, T2 Tier 2, T3 Tier 3.
* Shows key category (level) per fuel type
** Shows key category (trend) per fuel type

3.2.17.2 METHODOLOGICAL ISSUES

The road emission model HBEFA version 3.3 is used by the Swedish Transport Administration (STA) to estimate the fuel consumption and emissions from road traffic. The fuel consumption is adjusted to be in line with national statistics on supply and delivery of petroleum products[80]. The fuel consumption and emissions are allocated by fuel type and five vehicle categories: Passenger cars, Light commercial vehicles (LCV), Heavy goods vehicles (HGV), Buses and Mopeds & Motorcycles. The road traffic emission model HBEFA is updated yearly with new information regarding emission factors, vehicle fleet, composition of the fuel and the current traffic work.

Emissions of CO_2 from combustion of gasoline and diesel are based on country-specific thermal values and emission factors provided by the Swedish Petroleum and Biofuel Institute (SPBI)[81] as shown in Annex 2. 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 is provided by the Swedish Transport Administration (STA) and based on estimates made by the Swedish Road and Transport Research Institute (VTI) for the years 1990-2001 and on fuel analysis from SPBI from 2001 and onwards.

The activity data used to estimate the emissions of CO_2 and SO_2 from natural gas and biofuels are based on national statistics on supply and delivery of natural gas,

[80] Statistic Sweden. Data from Monthly fuel, gas and inventory statistics (www.scb.se). See Annex 2. chapter "1.4 Allocation of fuels for mobile combustion" for more information regarding the allocation of fuels for mobile combustion.

[81] Swedish petroleum and biofuel institute. www.spbi.se

biogas, ethanol and FAME (Fatty Acid Methyl Ester)[82]. Emissions of CO_2 from combustion of ethanol and FAME are based on country-specific thermal values and emission factors[83]. The thermal value and emission factor for CO_2 for natural gas is retrieved from the Danish Energinet for 1990-2017 and from Swedegas as from 2006. Emissions of CO_2 from biogas, ethanol and FAME are reported as biomass and not included in the national totals.

Emissions of CH_4, N_2O, CO, NMVOC and NO_X for most fuel and vehicle types are estimated by the road emission model HBEFA. Emissions of CH_4 and N_2O from low blended ethanol in gasoline and FAME are included in the estimated emissions from gasoline and diesel vehicles in HBEFA. The emissions of N_2O and CH_4 from E85 cars are also estimated by HBEFA, but the model does however not calculate the emissions of N_2O and CH_4 from ethanol buses. These emissions are estimated with default emission factors from 2006 IPCC Guidelines according to Tier 1.

Emissions of N_2O from natural gas and biogas from buses are also missing in HBEFA, but are estimated by using activity data on delivered amounts of natural gas and biogas for road transport and country specific emission factors[84].

Bottom-up estimations of the fuel consumption and CO_2 emissions provided by the Swedish Transport Administration (STA) using the HBEFA model differ from those reported to the UNFCCC (based on fuel delivery). The STA 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. The fuel consumption and the CO_2 emissions of CO_2 reported to UNFCCC, are as a consequence adjusted to be in line with national statistics on supply and delivery of petroleum products.

An overview of the two different objectives is presented in Table 3.17.

Table 3.17. Emissions from road transport reported by the STA 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 1.A.3.b STA	CRF 1.A.3.b	CRF 1.A.3.b * STA to the Swedish border	CRF 1.A.3.b *
Other country	STA	Not reported	STA 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 greenhouse gases from the use of LPG by road traffic are estimated for the first time in submission 2017 and are based on national statistics on supply and delivery of LPG for road traffic. The emissions of CO_2 are estimated using

[82] Monthly surveys from Statistics Sweden: “Deliveries of motor fuel gas” and “Monthly fuel, gas and inventory statistics”

[83] Paulrud, S., Fridell, E., Stripple, H., Gustafsson, T., 2010.

[84] Paulrud, S., Fridell, E., Stripple, H., Gustafsson, T., 2010.

country-specific thermal value and emission factor, while emission factors from IPCC 2006 guidebook are used to estimate the emissions of CH_4 and N_2O. The emissions are minor and only represent 0.02-0.03 % of emissions of CO_2-eq. from road transportation considering the whole time series.

The emissions of methane (CH_4) and nitrous oxides (N_2O) from E85 passenger cars is estimated by HBEFA as from submission 2017. The emissions were earlier estimated by using activity data (fuel consumption) and default emission factors from 2006 IPPC Guidelines (GL). The emissions of CH_4 and N_2O have decreased by 98 % respectively 100 % as an effect of change of method.

Military transport emissions are reported under CRF 1.A.5.b in accordance with the IPCC Guidelines. As Military road transport is included in HBEFA 3.3, the emissions for each vehicle type are reduced by proportional 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.

3.2.17.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Activity data for gasoline, diesel and natural gas is available from 1990, while reliable activity data for biogas exists from 1996, for ethanol from 1998 and for FAME from 1999.

One important basic parameter for the HBEFA model is vehicle-km, which is 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 2015 has driven the most part during 2014. 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, it will not be shown as clearly in the development of vehicle mileage as in statistics on fuel consumption.

The trend in the implied emission factor for CH4 for gaseous fuels (Natural gas & Biogas) shows minor inter-annual fluctuations compared to earlier submissions. The reason is that the country-specific emission factors for CH4 emissions are more harmonized between passenger cars (ca 1 kg/TJ) and buses (ca 20 kg/TJ). This is due to the implementation of CH4 emissions from the HBEFA model in submission 2018. The implied emission factor is an average for both vehicle categories. The consumption of Natural gas and Biogas by buses and passenger cars is shown in Figure 3.7 and Figure 3.8 below.

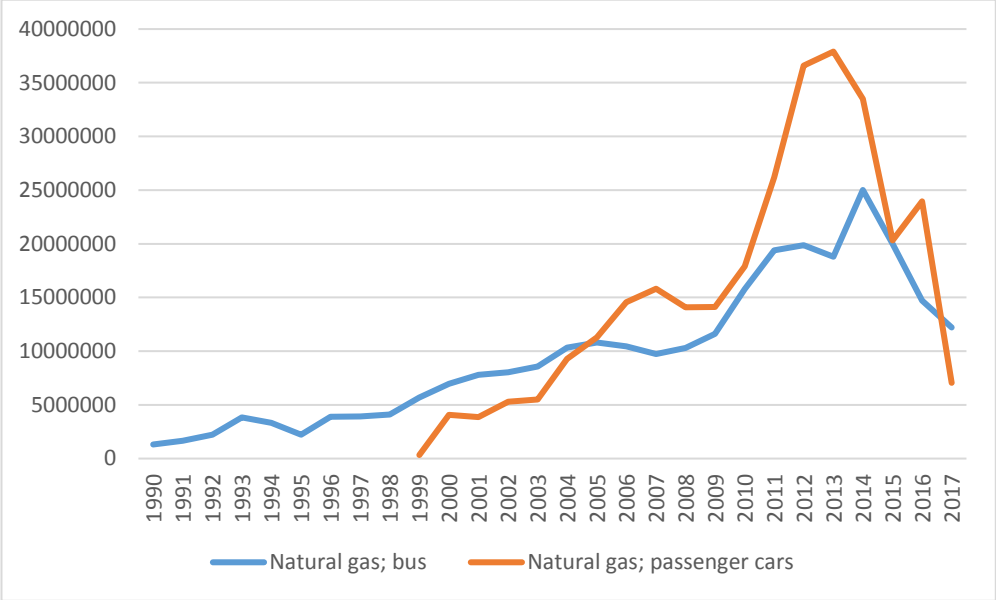


Figure 3.7 Consumption of natural gas by road traffic 1990-2017 (m^3).

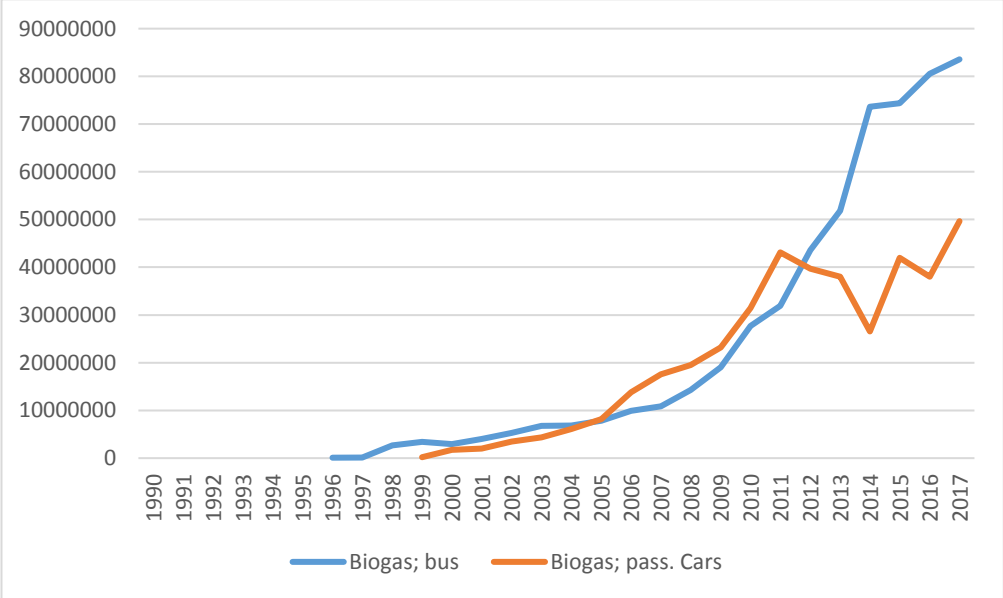


Figure 3.8. Consumption of biogas by road traffic 1990-2017 (m^3).

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

Time series are checked for consistency and recalculations are verified.

3.2.17.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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 been subject to QA/QC procedures. 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.

3.2.17.5 SOURCE-SPECIFIC RECALCULATIONS

The road traffic emission model HBEFA is updated yearly with new information regarding emission factors, vehicle fleet, composition of the fuel and the current traffic work. In submission 2019, a significant revision was done regarding the volumes of natural gas and biogas consumption by road traffic for the year 2014 in particular, in order to be in line with updated data on national deliveries.

The most significant recalculation regarding road traffic in submission 2019 is a redistribution of FAME between road traffic and working machinery from the year 2012[85]. This was done in order to increase the share of biofuels in road traffic since it was considered to be too low. As a first step, a new data source allowed for a more accurate biofuel consumption for buses. The remaining volumes could then be allocated between road traffic and working machinery proportionally, according to diesel consumption. In summary, public transportation was allocated a larger share of biofuels within the road traffic sector and furthermore the road traffic sector as a whole increased its biofuel share in relation to working machinery. Within the road traffic sector, a larger share of biogas was also reallocated from passenger cars to buses while the share of natural gas consumption for buses consequently decreased.

Moreover, in order for the thermal values and CO_2 emission factors for natural gas to better comply with The Swedish Energy Agency (STEM), new data were collected from the Danish Energinet for the whole time series in submission 2019.

Besides the above mentioned, the effect of the HBFEA updates on the emissions from road traffic in submission 2019 is marginal compared to the emissions in submission 2018.

The estimated consumption of gasoline and diesel by HBEFA was modified for all years by a residual of gasoline and diesel. The residual is the difference in the gasoline respectively the diesel consumption when comparing the national statistics on supply and delivery of petroleum products[86] (top-down approach) to the bottom-up estimated fuel consumption. The residual is proportionally redistributed to the following sectors: to 1A3b (road transportation), 1A3d (domestic navigation), 1A2g vii, 1A3e, 1A4b and 1A4c (off-road vehicles and working machinery) and 1A4c (fishing).

The total effect of the recalculations in 1.A.3.b for the two most recent recalculated years was a decrease of the estimated emissions with 0.04 % (-7.0 kt CO_2-eq) in 2015 and an increase of the estimated emissions with 0.1 % (0.64 kt CO_2-eq) in 2016.

3.2.17.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

[85] Eklund, V. Jonsson, M. Jerksjö, M. 2018.

[86] Statistic Sweden. Data from Monthly fuel, gas and inventory statistics (www.scb.se). See Annex 2. chapter “1.4 Allocation of fuels for mobile combustion” for more information regarding the allocation of fuels for mobile combustion.

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

3.2.18.1 SOURCE CATEGORY DESCRIPTION

The majority of all railway traffic in Sweden runs on electricity. Only a small part runs on diesel fuel. Emissions related to the use of electricity for railway should not be included in this sector according to IPCC's guidelines. Production of electricity is accounted for in CRF 1A1A, regardless of where it's consumed.

The consumption of diesel oil for railways has steadily decreased since 1990. As a consequence, the emissions of CO_2-eq. have declined by 59 % from 1990 (102 kt) to 2017 (41 kt).

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 1.A.3.c, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.3.c	CO_2				T2	CS	Yes
	CH_4				T1	D	Yes
	N_2O				T1	D	Yes

CS: Country Specific. D: Default. T1: Tier 1. T2: Tier 2.
* Shows key category (level) per fuel type
** Shows key category (trend) per fuel type

3.2.18.2 METHODOLOGICAL ISSUES

Both Tier 1 and Tier 2 methods are used. Information on emissions from railways is provided by the Swedish Transport Administration (STA). STA estimates the emissions of CO_2, SO_2, NO_X, NMVOC, CH_4, CO, HC and N_2O based on the amount of diesel consumed by the railways[87] and various emission factors.

Country specific emission factors used for calculating CO_2 and SO_2 emissions are supplied by SPBI[88].

Emissions of CH_4 and N_2O are estimated with emission factors from EMEP/EEA Guidebook 2013 for all engines, since these emissions are not regulated by EU directives. The threshold limits for CO and NO_X is used as emission factors for all emissions from engines that comply with the EU emission standards Stage IIIA and Stage IIIB.[89] For engines introduced before the implementation of EU emissions standards, the emission factors from EMEP/EEA guidebook 2013 are used to estimate emissions of CO and NO_X.

[87] The Swedish Energy Agency took over the responsibility for publication of data regarding consumption of fuel by Railways in 2017; previously published by the governmental agency Traffic Analysis.

[88] Swedish Petroleum and Biofuel Institute. www.spbi.se

[89] http://www.dieselnet.com/standards/eu/nonroad.php#rail

The conversion of g/kWh to g/litre is based on the fuel consumption factors in Table 3-5 in the EMEP/EEA Guidebook 2013 and a diesel density of 816 g / litre. The same density is used for all years.

3.2.18.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Overall, the emissions for CRF 1.A.3.c are 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.

3.2.18.4 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 been subject to QA/QC procedures. 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.

3.2.18.5 SOURCE-SPECIFIC RECALCULATIONS

No source specific procedures have been made.

3.2.18.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

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

3.2.19.1 SOURCE CATEGORY DESCRIPTION

The source category covers emissions of greenhouse gases from domestic navigation and leisure boats. Emissions from diesel oil, domestic heating oil and residual fuel oil purchased in Sweden but used abroad are reported separately as international bunker emissions (CRF 1.D). CO_2 emissions from navigation do not show any particular trend, but fluctuates over time. The allocation of emissions from navigation is summarized in Table 3.19.

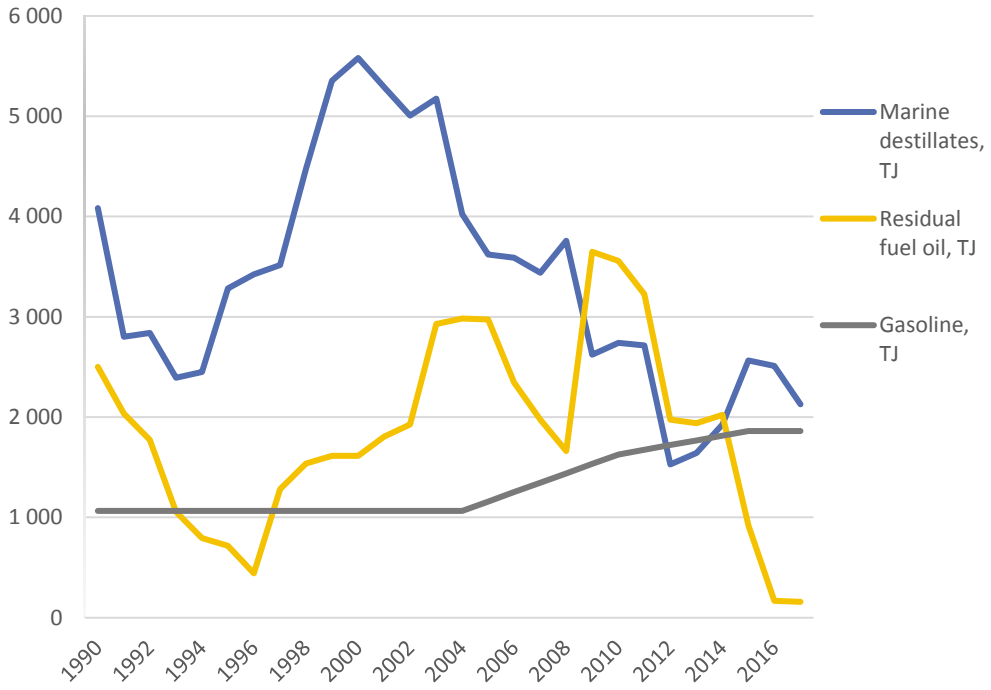
Table 3.19. Reporting of emissions from navigation, according to 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Journey type between two ports	Domestic	International
Departs and arrives in same country	Yes (1A3d)	No,
Departs from one country and arrives in another	No	Yes (1 D)

In 2017, the emissions of greenhouse gases from domestic navigation decreased by 9 % compared to 2016. The emission of greenhouse gases were 312 kt CO_2-eq. in 2017, which is a decline by 47 % since 1990.

This can be compared to emissions of greenhouse gases from international navigation, which have more than tripled since 1990 and increased by nearly 15 % since 2016, to reach 7,841 kt CO_2-eq. in 2017.

In 2012, the consumption of residual fuel decreased noticeably, most likely as a result of stricter rules regarding the sulphur content in marine fuels, which where decided on in 2012 and enforced in January 2015. Since 2012 there has been a continues downward trend for heavy fuel oils.



Figur 3.9. Fuel consumption of residual oil and marine distillate by domestic navigation (including leisure boats) 1990-2017 (TJ)

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 1A3d, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.3.d	CO_2	X (Gas/Diesel oil)	X (Residual Oil)		T2	CS	Yes
	CH_4				T2	CS, D	Yes
	N_2O				T2	CS, D	Yes

T1 Tier 1. T2 Tier 2. CS Country Specific. D Default.
* Shows key category (level) per fuel type
** Shows key category (trend) per fuel type

3.2.19.2 METHODOLOGICAL ISSUES

The emissions from domestic navigation are estimated applying Tier 2. The fuel consumption[90] is based on the monthly survey on supply and delivery of petroleum products[91]. The emissions factor for CO_2 are based on a SMED study conducted in 2004[92] while the emission factors for CH_4, N_2O, CO, NMVOC, NOx and SO_2 was provided by the Swedish Maritime Administration (SMA) for 2005-2015 on a yearly basis and by the Swedish Transport Agency (STA) as from 2016, in accordance with the Swedish climate legislation.

The fuel consumption by leisure boats was reviewed in 2005, 2014 and 2018. The gasoline and diesel consumption by leisure boats in Sweden 1990-2004 is based on a survey regarding leisure boats from 2004 and a study carried out by SMED in 2005[93]. The gasoline consumption by leisure boats was estimated to 32,500 m^3 and the diesel consumption to 12,000 m^3 for 2004[94] as a result of these studies. The same consumption is used for 1990-2004.

In 2010, there was a new leisure boat survey, which is the base for the gasoline and the diesel consumption by leisure boats in 2010-2014. An assessment of the survey was carried out by SMED in 2014[95] and revised in 2018 and resulted in an estimated gasoline and diesel consumption of 49,658 m^3 respectively 15,709 m^3 for 2010.

In 2015 there was a third leisure boat study, which was assessed by SMED in 2018 and resulted in an consumption of gasoline and diesel of 56,793 m^3 gasoline respectively 14,599 m^3 for 2015.[96] The same consumptions is used for the following years. The consumption of gasoline and diesel in 2005-2009 and 2010-2014 was estimated by interpolation.

Emissions of CO_2 and SO_2 from leisure boats are based on the estimated consumption of gasoline and diesel and the same thermal values and emission factors used by road traffic.

Emissions of CH_4 and N_2O from *gasoline leisure boats* are based on the fuel consumption and emission factors from EMEP Corinair, while the emission factors for NO_X, NMVOC and CO were revised in submission 2018 by the Swedish Environmental Research Institute (IVL) for the whole time period.[97]

[90] Except for leisure boats.

[91] Statistic Sweden. Monthly fuel, gas and inventory statistics. See annex 2 for more information regarding different surveys.

[92] Cooper and Gustafsson, 2004.

[93] Gustafsson, 2005.

[94] Statistics Sweden, 2005a.

[95] Eklund V. 2014.

[96] Fridell, E., Mawdsley, I., Wisell T. 2017.

[97] Fridell, E., Mawdsley, I., Wisell T. 2017.

The emissions from gasoline leisure boats also depend on the ratio between 2-stroke and 4-stroke engines and the ratio used is based on a study from 2005[98] and 2017[99]. The studies indicate that the share of 4-stroke engines is increasing over time. Based on information from the periodical publication "Fakta om Båtlivet i Sverige", the ratio has been determined for the years 2003, 2009 and 2015 and the ratio for 1990 has been estimated. For the years in between, the ratio has been interpolated, assuming that the change towards 4 stroke engines is gradual. The ratio for 2016 and 2017 is assumed to be the same as for 2015.

Emissions of CH_4 and N_2O from the consumption of *diesel by leisure boats* are based on the fuel consumption and emission factors provided by the Swedish Maritime Administration up to 2015 and from the Swedish Transport Agency as from 2016. The emissions of NO_X, NMVOC and CO from diesel leisure boats were revised in submission 2018 by the Swedish Environmental Research Institute (IVL) for the whole time period[100].

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.

3.2.19.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The fuel consumption by domestic navigation is based on the amount of fuel purchased and consumed in Sweden (see Annex 2)[101] and shows fluctuations for which it has been difficult to find natural explanations. See Figure 3.10.

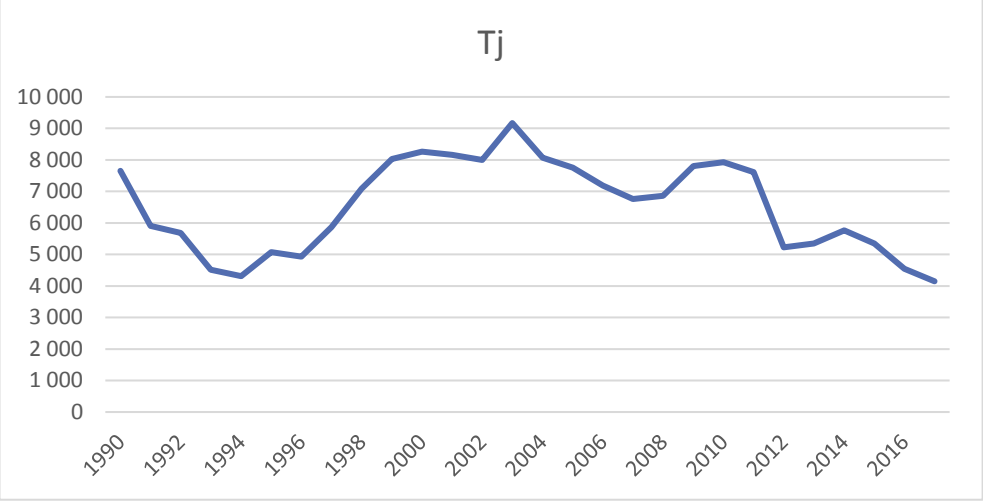


Figure 3.10 Fuel consumption by national navigation (including leisure boats) 1990-2017

[98] Statistics Sweden, 2005a.

[99] Fridell, E., Mawdsley, I., Wisell T. 2017.

[100] Fridell E., Mawdsley I., Wisell T. 2017.

[101] Statistic Sweden. Monthly fuel, gas and inventory statistics. EN31SM.

In 2011, the fuel consumption by national and international navigation was studied and the result was presented in the report "Emissions from navigation and fishing including international bunkers"[102]. Fuel data in the survey "Monthly fuel, gas and inventory statistics" was analysed and in general found to be of good quality.

Fuels used for international navigation and purchased by business corporations are exempt from VAT, as opposed to fuels sold to boats/ships sailing within the Swedish boarders. This serves as the base for splitting liquid fuels between domestic navigation and international navigation. As VAT is applied on national fuel consumption, but not on international bunkers, the respondents to the survey are able to separate fuels used for domestic and international navigation correctly and in line with IPCC Guidelines.

The Swedish Energy Agency (STEM) has for the last 2.5 years worked to improve the survey "Monthly fuel, gas and inventory statistics" [103] which is the source for activity data (fuel consumption), for both domestic and international navigation, in the Swedish inventory. STEM will implement the new version of the survey in January 2018. The results from the new survey will be implemented in submission 2020.

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

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 been subject to QA/QC procedures. 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.

In 2011 an attempt was made to verify the emissions for domestic shipping by comparison with an alternative, independent bottom-up calculation. The bottom-up calculation includes all ship movements in the waters around Sweden. Ship positioning data is gathered using the AIS (Automatic Identification System), which is a complement to radar that provides positions and some static information for almost all ships found in the Baltic and the North Sea. The calculations distinguish domestic shipping from international shipping by tracking each ship from its origin to its destination harbour. A route is classified as domestic if origin and destination is within the same country. Where the ship refuels is not possible to distinguish using this method, which causes a slight difference to the reporting guidelines. However, for the purpose of verification this difference is considered to be of little importance. Emission factors are assigned individually for each ship depending on its technical properties. The power output, fuel consumption and

[102] Eklund et al. 2011.

[103] Monthly fuel, gas and inventory statistics. http://www.scb.se/en/finding-statistics/statistics-by-subject-area/energy/energy-supply-and-use/monthly-fuel-gas-and-inventory-statistics/

emissions are estimated with 5 minute resolution for all ships carrying an AIS transponder. For the years 2009-2011, about 40 000 unique transponder IDs are registered by AIS.

The results from the bottom-up calculation show higher emissions than reported emissions from domestic navigation. This could be related to fishing vessels (reported under CRF 1A4c) and military ships (1A5b). Further studies should also include fishing and military ships to get the whole picture. The data needs to be further analysed.

In 2016-2017 another project was carried out by The Swedish Meteorological and Hydrological Institute regarding AIS data and navigation[104] on behalf of the the Swedish Energy Agency (STEM). This project investigated the possibility to use AIS data as a base, to separate sales statistics into domestic respectively international shipping. To do this, the Shipair model system was used to estimate the fuel consumption by domestic navigation for 2013-2015.

The results showed that the model complies with seasonal variations in sales statistics, with an increase during the warm season as shipping increases in intensity. At the same time, there are major differences between the result in the model and sales statistics. Accumulated throughout the year, the modeled fuel consumption is double as high as the sales statistics for domestic navigation. The STEM will look into the possibility to implement this result in their work to improve the survey "Monthly fuel, gas and inventory statistics".

3.2.19.5 SOURCE-SPECIFIC RECALCULATIONS

The amount of diesel for national navigation was slightly modified for all years with regard to the distribution of the residual of diesel to 1A3b (road transportation), 1A3d (domestic navigation), 1A2g vii, 1A3e, 1A4b and 1A4c (off-road vehicles and working machinery) and 1A4c (fishing). This resulted in slightly decreased emissions of CO_2 equivalents in the beginning of the time series.

The fuel consumption for leisure boats has been adjusted as from 2005. This is due to a revision of the assessed fuel consumption from the leisure boat survey in 2010 and the implementation of the result from a leisure boat survey in 2015. The implictions of these adjustments is an increased gasoline consumption for 2005-2016 while the consumption of diesel has decreased for the same period.

This leads to an slight increase in the emissions of CO2 for some of the years after 2005, while the emissions of CH_4, CO and NMVOC have increased noticeably as from 2005.

The total effect of the recalculations in 1.A.3.d for the two most recent recalculated years was an increase of the estimated emissions with 9.6 % (35.4 kt CO_2-eq) and 10.9 % (33.7 kt CO_2-eq) for 2015 and 2016, respectively.

3.2.19.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

[104] Jakobsson M., Segersson D., Windmark F. 2017.

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

3.2.20.1 SOURCE CATEGORY DESCRIPTION

Emissions reported under CRF 1.A.3.e refer to emissions from combustion of natural gas for pipeline transport (1.A.3.e.i) as well as emissions from off-road vehicles and other machinery (1.A.3.e.ii) including for example lift trucks, tractors and some other mobile machinery. The emissions of greenhouse gases from working machinery in 1A3eii represent only 5 % of all emissions of GHG from working machinery.

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 3.21.

Table 3.21. Summary of source category description, CRF 1A3e, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1.A.3.e	CO_2	X (Diesel oil)			T2	CS	Yes
	CH_4				T1,T2,T3	D,CS	Yes
	N_2O				T1,T2,T3	D,CS	Yes

D Default, T2 Tier 2, T3 Tier 3. CS Country Specific.
* Shows key category (level) per fuel type
** Shows key category (trend) per fuel type

3.2.20.2 METHODOLOGICAL ISSUES

3.2.20.2.1 Pipeline Transport (1.A.3.e.i)

Annual amounts of total natural gas in pipeline transport in Sweden are known for the whole reporting period 1990-2017. Combustion of natural gas for pipeline transport of natural gas in Sweden is only known for 2013 and for the following years, but not for 1990-2012. According to a national expert at Swedegas, the annual amount of natural gas used for pipeline transport is proportional to the total natural gas in the pipelines (about 0.12 % in 2013). Based on data for 2013, annual amounts of natural gas for combustion at pipeline transport were estimated for 1990-2012. The increase in the emissions in 2010 is a result of an icrease in the import of natural gas due to a cold winter.

Annual national calorific values and emission factors are applied to estimate the emissions of CO_2, while tier 1 default emission factors from 2006 IPCC Guidelines are used to estimate the emissions of CH_4 and N_2O. The emissions of CO, NMVOC, NOx and SO_2 are estimated using the same national emission factors as for stationary combustion of natural gas in sector 1A4a.

3.2.20.2.2 Working machinery (1.A.3.e.ii)

A national model is used to estimate emissions from all working machinery used in Sweden and it is considered to correspond to Tier 3 for all emissions, except for

CO_2 and SO_2 which are estimated according to Tier 2. The model is further explained in Annex 2.[105]

The consumption of gasoline and diesel, estimated by the model for off-road vehicles, is adjusted with regard to low-blended biofuel. The fuel consumption is also modified with a residual of gasoline and diesel. This residual arises as the volume of gasoline and diesel allocated to different sectors through a top-down approach is compared to the total volume of the gasoline and diesel consumed according to a bottom-up estimate. See Annex 2 for more information regarding the allocation of fuels for mobile combustion[106].

Emissions from off-road vehicles and other machinery are also reported under CRF 1.A.2.g vii, 1.A.4.A, 1.A.4.b and 1.A.4.c, in line with IPCC Guidelines, see Table 3.22.

Table 3.22. Distribution of emissions from off-road vehicles and other machinery.

Category	CRF	Definition IPCC Guidelines
Industry	1.A.2.g vii	Mobile machineries in industry that run on petroleum fuels, as for example tractors, dumpers, cranes, excavators, generators, wheel loaders, sorting works, pump units etc.
Other	1.A.3.e ii	Combustion emissions from all remaining transport activities including ground activities in airports and harbours, and off-road activities not otherwise reported under 1.A.4.c or 1.A.2.g vii.
Commercial/ Institutional	1.A.4.a.ii	Garden machinery, eg lawn mowers and clearing saws, not used by private users, Also tractors not used in industy ore forestry or agriculture.
Residential	1.A.4.b.ii	All emissions from mobile fuel combustion in households, as for example tractors, lawn movers, snow mobiles, forklifts, trimmers, chainsaws and forklifts
Agriculture, Forestry	1.A.4.c.ii	Emissions from mobile fuel combustion in agriculture and forestry, as for example loader-excavator, tractor, harvester, clearing saw etc. Highway agricultural transportation is excluded.

3.2.20.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The fuel and emission estimates of working machinery are based on a model that takes into consideration emission regulations according to EU legislation in g kWh^{-1}, 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 differences between certification fuel and Swedish diesel of type "MK1". The model does not consider market fluctuations.

The consumption of gasoline by off-road vehicles and other machinery drops in 2004, as a result of a large increase in the total consumption of low-blended ethanol, which is allocated to road traffic and working machinery. The amount of low-blended biofuel (Ethanol/FAME) allocated to road traffic is given by the road emission model HBEFA in combination with national fuel statistics. A residual of biofuel arise when the biofuel allocated to road traffic is subtracted from the national deliveries of biofuel. *This residual is distributed to off-road vehicles and*

[105] Annex 2: 1.6 Methodology for off-road vehicles and working machinery

[106] See Annex 2. chapter "1.4 Allocation of fuels for mobile combustion" for more information."

other machinery. The model estimated consumption of gasoline and diesel by working machinery is decreased by the residual of ethanol respectively FAME. In 2004 the consumption of gasoline by working machinery decreased noticeably as a result of an unusual large residual of ethanol allocated to working machinery, due to a large increase in the national deliveries of low-blended ethanol.

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

3.2.20.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The model was implemented the first time in submission 2009. During 2010 the model underwent a second verification. Activity data and emissions factors were reviewed in 2012 and 2013. Time series are checked for consistency and recalculations are verified every year.

3.2.20.5 SOURCE-SPECIFIC RECALCULATIONS

The emissions of CO, NMVOC, NOx and SO_2 from pipeline transport (CRF 1A3ei) were estimated for the first time in submission 2019.[107] National calorific values and emission factors were used. The emission factors used are the same as for stationary combustion of natural gas in CRF 1A4a.

A redistribution of FAME between road traffic and working machineries in submission 2019 has led to an increased share of fossil fuel for working machinery in CRF 1A3eii.[108] The allocation key in the model for working machinery has also been updated in submission 2019, resulting in a reallocation of the diesel consumption from CRF 1A3eii (Other transportation) to 1A2gvii (Industry) based on a report from 2017.[109]

But as the effects of the updated allocation key were greater, the diesel (fossil) consumption and the emissions of CO_2 equivalents as well as all other emissions have decreased from working machineries for the whole time period.

The total effect of the recalculations in 1.A.3.e for the two most recent years, was a decrease of the estimated emissions of CO_2 equivalents with 16.7 % (-35.8 kt) and 22.5 % (-48.2 kt) for 2015 and 2016, respectively.

3.2.20.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

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

3.2.21.1 SOURCE CATEGORY DESCRIPTION

This category includes stationary combustion for heating of premises used for commercial and institutional activities and emissions from working machinery used in these activities. The emissions of greenhouse gases (GHG) from working

[107] Eklund, V. 2018.

[108] Eklund, V. Jonsson, M. Jerksjö, M. 2018.

[109] Eklund, V. Lidén, M. Jerksjö, M. 2017b.

machinery in 1A4a represent around 12 % of all emissions of GHG from working machinery and has increased by 40% since 1990 and by 3% since last year (2016).

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 35000 TJ, around year 2000 it had decreased to about 20000 TJ, and in 2017 it was around 8000 TJ. Liquid fuels account for most of the decrease. The share of liquid fuels in 1990 was about 95 % and the corresponding share in 2017 was about 25 %.

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 1A4a, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.4.a	CO_2	X (Diesel Oil, Gaseous fuels, Gasoline)	X (Gaseous fuels, Liquid fuels)		T2	CS	Yes
	CH_4				T2, T3	CS	Yes
	N_2O		X (Liquid fules)		T2, T3	CS	Yes

CS Country Specific. T2 Tier 2, T3 Tier 3
* Shows key category (level) per fuel type
** Shows key category (trend) per fuel type

3.2.21.2 METHODOLOGICAL ISSUES

3.2.21.2.1 Stationary combustion

For stationary combustion within CRF 1.A.4.a, all activity data and emission factors are on national level by fuel type and estimated emissions are therefore considered to correspond to Tier 2. The data source for activity data is the annual energy balance, which for this sector is mainly based on premises statistics that is further described in section 3.2.21.4.1 and in Annex 2. Activity data for the latest emission year is preliminary as the annual energy balances are not published at the time when the emission calculations have to be finalized.

3.2.21.2.2 Mobile combustion/Working machinery

Emissions from mobile combustion in CRF 1.A.4.a refer mainly to gardening machines for professional use and tractors that are not used in industry, farming, or forestry. A national model is used to estimate emissions from all working machinery used in Sweden and it is considered to correspond to Tier 3 for all emissions, except for CO_2 and SO_2 which are estimated according to Tier 2. The model is further explained in Annex 2. [110]

[110] Annex 2: 1.6 Methodology for off-road vehicles and working machinery

The consumption of gasoline and diesel, estimated by the model for off-road vehicles, is adjusted with regard to low-blended biofuel. The fuel consumption is also modified with a residual of gasoline and diesel. This residual arise as the volume of gasoline and diesel allocated to different sectors through a top-down approach is compared to the total volume of the gasoline and diesel consumed according to a bottom-up estimate. See Annex 2 for more information regarding the allocation of fuels for mobile combustion[111].

Emissions from working machinery are also reported under CRF 1.A.3.e, 1.A.4.A, 1.A.4.b and 1.A.4.c, in line with IPCC Guidelines, see Table 3.24.

Table 3.24. Distribution of emissions from off-road vehicles and other machinery

Category	CRF	Definition IPCC Guidelines
Industry	1.A.2.g vii	Mobile machineries in industry that run on petroleum fuels, as for example tractors, dumpers, cranes, excavators, generators, wheel loaders, sorting works, pump units etc.
Other	1.A.3.e ii	Combustion emissions from all remaining transport activities including ground activities in airports and harbours, and off-road activities not otherwise reported under 1.A.4.c or 1.A.2.g vii.
Commercial/ Institutional	1.A.4.a.ii	Garden machinery, eg lawn mowers and clearing saws, not used by private users, Also tractors not used in industy ore forestry or agriculture.
Residential	1.A.4.b	All emissions from mobile fuel combustion in households, as for example tractors, lawn movers, snow mobiles, forklifts, trimmers, chainsaws and forklifts
Agriculture, Forestry	1.A.4.c	Emissions from mobile fuel combustion in agriculture and forestry, as for example loader-excavator, tractor, harvester, clearing saw etc. Highway agricultural transportation is excluded.

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 data from the annual energy balances.

The implied emission factor for CO_2 for liquid fuels in CRF 1.A.4.a fluctuates according to the relative proportions of LPG, domestic heating oil and residual fuel oils (the latter not used in the latest years). The IEF is below 70 in the years 2007-2011 due to extensive use of LPG. In 2012, the share of LPG decreased somewhat, resulting in a CO_2 IEF of 71.9 kg/GJ.

The consumption of gasoline by off-road vehicles and other machinery drops in 2004, as a result of a large increase in the total consumption of low-blended ethanol, which is allocated to road traffic and working machinery. The amount of low-blended biofuel (Ethanol/FAME) allocated to road traffic is given by the road emission model HBEFA in combination with national fuel statistics. A residual of biofuel arise when the biofuel allocated to road traffic is subtracted from the

[111] See Annex 2. chapter “1.4 Allocation of fuels for mobile combustion” for more information.”

national deliveries of biofuel. *This residual is distributed to off-road vehicles and other machinery*. The model estimated consumption of gasoline and diesel by working machinery is decreased by the residual of ethanol respectively FAME. In 2004 the consumption of gasoline by working machinery decreased noticeably as a result of an unusual large residual of ethanol allocated to working machinery, due to a large increase in the national deliveries of low-blended ethanol. The same phenomenon took place in 2014, but regarding FAME and diesel; e.g. a noticeable decrease in the consumption of diesel between 2013 and 2014 as a consequence of an increased consumption of low-blended FAME.

3.2.21.4 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. In 2005, a study was performed by SMED, aiming at identifying and analysing the methods and models applied for each sub-sector and determine whether they were in line with the IPCC guideline recommendations[112]. In addition, each fuel was traced back to its original source in order to determine whether it had been correctly allocated on stationary and mobile combustion.

The results from the study show good agreement with IPCC guideline recommendations. All fuels but biomass had little or no changes in methodologies, and where changes occurred, no significant inconsistencies in fuel consumption time series were detected. However, for biomass, several significant inconsistencies were identified leading to recalculations of activity data and emissions in CRF 1.A.4.a and 1.A.4.b[113]. Due to these recalculations there are obvious inconsistencies between the national energy balances and the national emission inventory data for years before 2005. Furthermore, all fuels proved to be correctly allocated on stationary and mobile combustion. All diesel oil and gasoline reported under Other sectors in the energy balances is allocated to mobile combustion, while all the other fuels are related to stationary combustion.

3.2.21.4.1 Activity data for stationary combustion in other sectors

For stationary combustion within the Other sectors the activity data source is the energy balance. The Swedish Energy Agency provides preliminary data for the latest emission year, which are quite coherent with the final data, although minor revisions of data for the most recent years will still be made in subsequent submissions, when final annual energy balances 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 since no suitable alternative or complementary data sources were found.

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

[112] Gustafsson, et al. 2005.

[113] Paulrud et al. 2005.

submission 2011, the activity data for 2007 and 2008 were revised due to revisions in the energy balances (as described above). 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 1990-2010 shows that inter-annual variations in total fuel consumption can be large. Thus the 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.

3.2.21.5 SOURCE-SPECIFIC RECALCULATIONS

3.2.21.5.1 Stationay combustion

Emission factor and NCV for CO_2 for natural gas was revised and harmonised with the ones used in the Swedish energy balance[114]. Also emission factors for CO_2 for peat, and landfill gas was revised for all sectors within stationary combustion[115]. Moreover, following revisions of the energy balances, the activity data for stationary combustion within 1.A.4 was revised for all fuels for the years 2013-2016.

The total effect of the recalculations for stationary combustion in 1.A.4.a for the two most recent recalculated years was an increase of the estimated emissions with 1.20 % (11.93 kt CO_2-eq) for 2015 and a decrease with 1.26 % (1.00 kt CO_2-eq) for 2016.

3.2.21.5.2 Mobile combustion

A redistribution of FAME between road traffic and working machineries in submission 2019 has led to an increased share of fossil fuel for working machinery in CRF 1A4aii.[116] Snow groomers have also been added to the model for working machinery and mainly allocated to CRF 1A4aii. The number of counterbalanced trucks have also been adjusted and increased in the model. [117]

The revision of input data to the model has resulted in an increased consumption of diesel and increased emissions of CO_2 equivalents for the whole time period. The emissions of N_2O and NOx have also increased noticeably during 1990-2017.

The total effect of the recalculations for mobile combustion in 1.A.4.a for the two most recent years, was an increase of the estimated emissions of CO_2 equivalents with 16.5 % (61.6 kt) and 13.6 % (49.9 kt) for 2015 and 2016, respectively.

3.2.21.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

[114] Energistyrelsen, 2018-11-26 (https://ens.dk/ansvarsomraader/co2-kvoter/stationaere-produktionsenheder/co2-rapportering-og-returnering)

[115] Helbig, T. Stripple, H., Hjort, A., Mawdsley, I. 2018. Uppdatering av emissionsfaktorer för CO2 från torv och deponigas. SMED PM 2018-05-20.

[116] Eklund, V. Jonsson, M. Jerksjö, M. 2018.

[117] Eklund, V. Lidén, M. Jerksjö, M. 2017b.

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

3.2.22.1 SOURCE CATEGORY DESCRIPTION

In this category both stationary and mobile combustion occur. Stationary combustion of fuels within residential decreased by 61 % between 1990 and 2017, mainly due to a continuous increase in district heating use[118]. In recent years, the use of heat pumps has also increased significantly[119]. 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. In 2009-2010, fuel consumption increased due to the cold winters these years, especially in 2010. Despite this, the consumption of heating oil continued to decrease while consumption of wooden fuels and natural gas increased quite considerably. Emissions of CO_2, CH_4 and N_2O from the use of charcoal are included in this source category.

Mobile combustion in 1.A.4.b refer to gardening machines used in households e.g. lawn mowers, hedged cutters, clearing saws and more. Also snow mobiles and four wheelers not used for professional purposes are allocated to 1.A.4.b. The emissions of greenhouse gases (GHG) from working machinery in 1.A.4.b represent around 9% of all emissions of GHG from working machinery and has increased by 29% since 1990 but are stable compared to 2016.
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 1A4b, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.4.b	CO_2	X (Liquid fuels)	X (Liquid fuels)		T2	CS	Yes
	CH_4	X (Biomass)			T2,T3	CS	Yes
	N_2O	X (Biomass)	X (Biomass, Liquid fuels)		T2,T3	CS	Yes

CS Country Specific. T2 Tier 2, T3 Tier 3.

* Shows key category (level) per fuel type

** Shows key category (trend) per fuel type

[118] Swedish Energy Agency 2014a

[119] Swedish Energy Agency 2014b

METHODOLOGICAL ISSUES

3.2.22.1.1 Stationary combustion

For stationary combustion, all activity data is on national level by fuel type and estimated emissions are therefore considered to correspond to Tier 2.

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. As from submission 2019, biomass activity data and emission factors for boilers and stoves are separated into traditional and modern technology for the whole time series.[120] Estimation models and allocation methods for fuel in the Other sectors, and use of preliminary data for stationary combustion in other sectors as discussed in section 3.2.21.4.1, also applies to CRF 1.A.4.b.

Emissions arising from the use of charcoal are estimated using national statistics and default 2006 IPCC guidelines EFs.

3.2.22.1.2 Mobile combustion/Working machinery

A national model is used to estimate emissions from all working machinery used in Sweden and it is considered to correspond to Tier 3 for all emissions, except for CO_2 and SO_2 which are estimated according to Tier 2. The model is further explained in Annex 2. [121]

The consumption of gasoline and diesel, estimated by the model for off-road vehicles, is adjusted with regard to low-blended biofuel. The fuel consumption is also modified with a residual of gasoline and diesel. This residual arise as the volume of gasoline and diesel allocated to different sectors through a top-down approach is compared to the total volume of the gasoline and diesel consumed according to a bottom-up estimate. See Annex 2 for more information regarding the allocation of fuels for mobile combustion[122].

Emissions from off-road vehicles and other machinery are also reported under CRF 1.A.2.g vii, 1.A.3.e, 1.A.4.A and 1.A.4.c in line with IPCC Guidelines, see Table 3.26.

[120] Helbig, T., Gustafsson, T., Kindbom, K. Jonsson, M. 2018. Uppdatering av nationella emissionsfaktorer för övrig sektor (CRF/NFR 1A4). SMED rapport no 13 2018.

[121] Annex 2: 1.6 Methodology for off-road vehicles and working machinery

[122] See Annex 2. chapter “1.4 Allocation of fuels for mobile combustion” for more information.”

Table 3.26. Distribution of emissions from off-road vehicles and other machinery

Category	CRF	Definition IPCC Guidelines
Industry	1.A.2.g vii	Mobile machineries in industry that run on petroleum fuels, as for example tractors, dumpers, cranes, excavators, generators, wheel loaders, sorting works, pump units etc.
Other	1.A.3.e ii	Combustion emissions from all remaining transport activities including ground activities in airports and harbours, and off-road activities not otherwise reported under 1.A.4.c or 1.A.2.g vii.
Commercial/ Institutional	1.A.4.a.ii	Garden machinery, eg lawn mowers and clearing saws, not used by private users, Also tractors not used in industy ore forestry or agriculture.
Residential	1.A.4.b	All emissions from mobile fuel combustion in households, as for example tractors, lawn movers, snow mobiles, forklifts, trimmers, chainsaws and forklifts
Agriculture, Forestry	1.A.4.c	Emissions from mobile fuel combustion in agriculture and forestry, as for example loader-excavator, tractor, harvester, clearing saw etc. Highway agricultural transportation is excluded.

3.2.22.2 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 input data from the annual energy balances.
The time series for 1.A.4.b is considered to be consistent as there haven't been any major changes in methodology or input data to the energy balances that affect this category. The estimates for the last year, however, are somewhat inconsistent due to the issues described in section 3.2.21.4.1. 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.

In 2004 the consumption of gasoline by working machinery drops as a result of a large increase in the total consumption of low-blended ethanol, which is allocated to road traffic and off-road vehicles and working machinery. The amount of low-blended gasoline allocated to road traffic is given by the road emission model HBEFA in combination with national fuel statistics. The rest of the ethanol is allocated to working machinery. The consumption of gasoline drops noticeably when the gasoline consumption by working machinery is decreased by a larger amount of low-blended ethanol in 2004.

3.2.22.3 SOURCE-SPECIFIC QA/QC AND VERIFICATION

See section 3.2.21.4

3.2.22.4 SOURCE-SPECIFIC RECALCULATIONS

3.2.22.4.1 Stationary combustion

Emission factor and NCV for CO_2 for natural gas was revised and harmonised with the ones used in the Swedish energy balance[123]. Also emission factors for CO_2 for peat, and landfill gas was revised for all sectors within stationary combustion[124]. Moreover, following revisions of the energy balances, the activity data for stationary combustion within 1.A.4 was revised for all fuels for the years 2013-2016.
The total effect of the recalculations for stationary combustion in 1.A.4.b for the two most recent recalculated years was a decrease of the estimated emissions with 184.58 % (75.84 kt CO_2-eq) for 2015 and a decrease with 75.69 % (187.93 kt CO_2-eq) for 2016.

In submission 2019, activity data and emission factors for CH_4, CO and NMVOC from biomass combustion within 1.A.4.b was separated into modern and traditional technology for the whole time series in order to capture the phasing out of old technology. [125]The revision is described more in detail in Annex 2.

3.2.22.4.2 Mobile combustion

The number of snowmobiles and 4-wheelers have been updated in the model for working machinery as well as the distribution of engine types (2-stroke / 4-stroke) for the same machines in submission 2019.[126] These adjustments have resulted in increased emissions of GHG for 1990-1993 and decreased emissions of GHG for 1994-2016 from combustion of gasoline.

A redistribution of FAME between road traffic and working machineries in submission 2019 has led to a minor increase in the share of fossil fuel and emissions of CO_2 equivalents for working machinery in CRF 1A4bii.[127]

The total effect of the recalculations of mobile combustion in 1.A.4.b for the two most recent years, was a decrease of the estimated emissions of CO_2 equivalents by 16.0 % (-67.1 kt) in 2015 and by 17.1 % (-71.2 kt) in 2016.

3.2.22.5 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

[123] Energistyrelsen, 2018-11-26 (https://ens.dk/ansvarsomraader/co2-kvoter/stationaere-produktionsenheder/co2-rapportering-og-returnering)

[124] Helbig, T. Stripple, H., Hjort, A., Mawdsley, I. 2018. Uppdatering av emissionsfaktorer för CO2 från torv och deponigas. SMED PM 2018-05-20.

[125] Helbig, T., Gustavsson, T., Kindbom, K. Jonsson, M. 2018. Uppdatering av nationella emissionsfaktorer för övrig sektor (CRF/NFR 1A4). SMED rapport no 13 2018.

[126] Eklund, V. Lidén, M. Jerksjö, M. 2017b.

[127] Eklund, V. Jonsson, M. Jerksjö, M. 2018.

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

3.2.23.1 SOURCE CATEGORY DESCRIPTION

This category includes emissions from stationary combustion for heating purposes and mobile combustion in working machinery within agriculture and forestry, and fishing vessels. The emissions of greenhouse gases (GHG) from working machinery in 1.A.4.c represent around 33 % of all emissions of GHG from working machinery and has increased by 23% since 1990 and by 2% since last year (2016). 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 3.27.

Table 3.27. Summary of source category description, CRF 1A4c, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.4.c	CO_2	X (Liquid fuels)	X (Liquid fuels, Solid fuels)		T2	CS	Yes
	CH_4		X (Biomass)		T2,T3	CS	Yes
	N_2O		X (Biomass)		T2,T3	CS	Yes

CS Country Specific. T2 Tier 2, T3 Tier 3.
* Shows key category (level) per fuel type
** Shows key category (trend) per fuel type

3.2.23.2 METHODOLOGICAL ISSUES

3.2.23.2.1 Stationary combustion

For stationary combustion, all activity data and emission factors are on national level by fuel type and estimated emissions are therefore considered to correspond to Tier 2 for agriculture and forestry (stationary combustion is not occurring for fisheries). Activity data is taken from the annual energy balances, which for this sector are 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 3.2.21, and use of preliminary data for stationary combustion in other sectors as discussed in section 3.2.21.4.1 also applies to CRF 1.A.4.c.

3.2.23.2.2 Mobile combustion

The estimated fuel consumption for fisheries is based on a survey on energy consumption within the fishing industry by Statistics Sweden[128] together with data on the Swedish fishing fleets' total installed effect in kW from the Swedish Agency for Marine and Water Management (SwAM). The estimate on fuel consumption provided by Statistics Sweden refer to 2005, and for the previous and following

[128] Statistics Sweden, 2006 ENFT0601.

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[129], 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. However, from 2007 and onwards the emission factors for SO_2 from fisheries are assumed to be the same as for domestic navigation, which are updated every year.
Emissions from fisheries are derived under the assumption that the fishing fleet operates using medium speed diesel engines running on marine distillate fuel. The emission abatement technologies used by the fleet (e.g. Selective Catalytic Reduction (SCR) for NO_X reduction) is assumed to be negligible.

Mobile combustion in CRF 1.A.4.c refers also, beside the fishing industry, to working machinery used in agriculture and forestry. A national model is used to estimate emissions from all working machinery used in Sweden and it is considered to correspond to Tier 3 for all emissions, except for CO_2 and SO_2 which are estimated according to Tier 2. The model is further explained in Annex 2. [130]

The consumption of gasoline and diesel, estimated by the model for off-road vehicles, is adjusted with regard to low-blended biofuel. The fuel consumption is also modified with a residual of gasoline and diesel. This residual arises as the volume of gasoline and diesel allocated to different sectors through a top-down approach is compared to the total volume of the gasoline and diesel consumed according to a bottom-up estimate. See Annex 2 for more information regarding the allocation of fuels for mobile combustion[131].

Emissions from off-road vehicles and other machinery are also reported under CRF 1.A.2.g vii, 1.A.3.e ii, 1.A.4.a.ii and 1.A.4.b in line with IPCC Guidelines, see Table 3.28.

[129] Cooper et al., 2005a.

[130] Annex 2: 1.6 Methodology for off-road vehicles and working machinery

[131] See Annex 2. chapter “1.4 Allocation of fuels for mobile combustion” for more information.”

Table 3.28. Distribution of emissions from off-road vehicles and other machinery

Category	CRF	Definition IPCC Guidelines
Industry	1.A.2.g vii	Mobile machineries in industry that run on petroleum fuels, as for example tractors, dumpers, cranes, excavators, generators, wheel loaders, sorting works, pump units etc.
Other	1.A.3.e ii	Combustion emissions from all remaining transport activities including ground activities in airports and harbours, and off-road activities not otherwise reported under 1.A.4.c or 1.A.2.g vii.
Commercial/ Institutional	1.A.4.a.ii	Garden machinery, eg lawn mowers and clearing saws, not used by private users. Also tractors not used in industry, forestry or agriculture.
Residential	1.A.4.b	All emissions from mobile fuel combustion in households, as for example tractors, lawn movers, snow mobiles, forklifts, trimmers, chainsaws and forklifts
Agriculture, Forestry	1.A.4.c	Emissions from mobile fuel combustion in agriculture and forestry, as for example loader-excavator, tractor, harvester, clearing saw etc. Highway agricultural transportation is excluded.

3.2.23.3 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. Solid fuels have not been used in this sector since 2000.

The consumption of gasoline by off-road vehicles and other machinery drops in 2004, as a result of a large increase in the total consumption of low-blended ethanol, which is allocated to road traffic and working machinery. The amount of low-blended biofuel (Ethanol/FAME) allocated to road traffic is given by the road emission model HBEFA in combination with national fuel statistics. A residual of biofuel arise when the biofuel allocated to road traffic is subtracted from the national deliveries of biofuel. *This residual is distributed to off-road vehicles and other machinery*. The model estimated consumption of gasoline and diesel by working machinery is decreased by the residual of ethanol respectively FAME. In 2004 the consumption of gasoline by working machinery decreased noticeably as a result of an unusual large residual of ethanol allocated to working machinery, due to a large increase in the national deliveries of low-blended ethanol. The same phenomenon took place in 2014, but regarding FAME and diesel; e.g. a noticeable decrease in the consumption of diesel between 2013 and 2014 as a consequence of an increased consumption of low-blended FAME.

3.2.23.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

3.2.23.5 SOURCE-SPECIFIC RECALCULATIONS

Emission factor and NCV for CO_2 for natural gas was revised and harmonised with the ones used in the Swedish energy balance[132]. Also emission factors for CO_2 for peat, and landfill gas was revised for all sectors within stationary combustion[133]. Moreover, following revisions of the energy balances, the activity data for stationary combustion within 1.A.4 was revised for all fuels for the years 2013-2016.
The total effect of the recalculations for stationary combustion in 1.A.4.b for the two most recent recalculated years was a decrease of the estimated emissions with 36.47 % (1637.99 kt CO_2-eq) for 2015 and a decrease with 0.002 % (0.09 kt CO_2-eq) for 2016.

The number of snowmobiles and 4-wheelers have been updated in the model for working machinery as well as the distribution of engine types (2-stroke / 4-stroke) for the same machines.[134] This results in decreased emissions as from 1994, from combustion of gasoline in the agriculture sector. The decrease in emissions from gasoline is also effected by the reallocation of counterbalanced trucks from agriculture (1A4cii) to industry (1A2gvii).

A redistribution of FAME between road traffic and working machineries in 2009-2016 has resulted in an increased share of fossil diesel and increased emissions of CO_2 equivalents especially in 2012-2015.[135]

The total effect of the recalculations for mobile combustion in 1.A.4.c for the two most recent recalculated years was an increase of the estimated emissions with 2.5 % (31.1 kt CO_2-eq) in 2015 and a decrease of the estimated emissions with 3.3 % (-48.2 kt CO_2-eq) in 2016.

3.2.23.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan. Activity data for stationary combustion 2005-2012 will be reviewed and possibly revised in submission 2016 due to recent revisions of the annual energy balances.

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

No emissions are reported in this sector.

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

3.2.25.1 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.

[132] Energistyrelsen, 2018-11-26 (https://ens.dk/ansvarsomraader/co2-kvoter/stationaere-produktionsenheder/co2-rapportering-og-returnering)

[133] Helbig, T. Stripple, H., Hjort, A., Mawdsley, I. 2018. Uppdatering av emissionsfaktorer för CO2 från torv och deponigas. SMED PM 2018-05-20.

[134] Eklund, V. Lidén, M. Jerksjö, M. 2017b.

[135] Eklund, V. Jonsson, M. Jerksjö, M. 2018.

The consumption of jet kerosene is the largest contributor to GHG from military activities (1.A.5.b) in Sweden. The emissions of GHG from 1.A.5.b increased sharply 1990-1993, but have had a decreasing trend for the rest of the time series. The decrease slowed down in the last years, but has increased by 15 % since 2014. The emissions of GHG from military activities were 191 kt in 2015, which is a decrease by 78 % since 1990.

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 3.29.

Table 3.29. Summary of source category description, CRF 1A5b, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.5.b	CO_2	X (Liquid fuels)	X (Liquid fuels)		T2	CS	Yes
	CH_4				T2, T3	CS	No, see Annex 5
	N_2O		X (Liquid fuels)		T2, T3	CS	No, see Annex 5

CS Country Specific. T1 Tier 1.
* Shows key category (level) per fuel type
** Shows key category (trend) per fuel type

3.2.25.2 METHODOLOGICAL ISSUES

Emissions from military transport are based on data on fuel consumption[136] including all military activities and country specific emission factors and are considered to correspond to Tier 2 and Tier 3. 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 1999-2001. But as nothing has been done for the other years, this biodiesel is considered fossil in the inventory.

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 HBEFA model (road transport). These estimates are considered to 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 1.D.2.

Military road transport is included in the road traffic emissions estimated by the HBEFA model. To subtract and separate emissions from military transport from emissions from civil road transport, emissions according to the HBEFA model for

[136] Activity data on fuel consumption is supplied by the Armed Forces.

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:

$$A = B - \sum \left[\frac{(C - D)}{(C \times E_i)} \right]$$

Where,
A = Military transport emissions
B = Total HBEFA emissions
C = Total fuel consumption National Statistics
D = Military fuel consumption Swedish Armed Forces
Ei = HBEFA emissions per vehicle type

Emissions of CH_4 and N_2O from the use of ethanol by military road transportation, is based on military consumption of ethanol for road traffic and default emission factors from 2006 IPCC guidelines. These estimates are considered to be Tier 1.

3.2.25.3 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.

3.2.25.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source specific procedures have been made.

3.2.25.5 SOURCE-SPECIFIC RECALCULATIONS

A special estimation for the use of FAME was conducted by the military for the years 1999-2001. But as nothing has been done for the other years, this biodiesel was converted to fossil diesel in submission 2019, which led to an minor increase in the emissions of the emissions of CO_2 equivalents.

3.2.25.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

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 stem from flaring of fuels at refinery plants, hydrogen production, transport of crude oil, transmission losses of gasworks gas, storage and handling of oil in refineries, depots and gasoline distribution, as well as losses, venting and flaring in the national natural gas and biogas transmission network (including storage).

Table 3.30 gives and overview of data sources used to calculate fugitive emissions of greenhouse gases reported in CRF 1.B.

Table 3.30. Data sources used to calculate fugitive emissions of direct and indirect greenhouse gases reported in CRF 1.B.

CRF	GHG	Activity data	Emission factors	Emissions
1.B.1.b: Coke production	SO_2	—	—	Environmental reports
	NO_x, NMVOC	Amounts of produced coke in environmental reports	Default EFin EMEP /EEA Guidebook 2016	—
1.B.1.c: COG flaring	CO_2, CH_4, N_2O, NMVOC, CO, SO_2, NO_x	Amounts of flarted COG in environmental reports	National emission factor for stationary combuston of COG	Calculated
1.B.2.A.1: Hydrogen production	CO_2	—	—	EU ETS
	CH_4, N_2O, NMVOC, CO, SO_2, NO_x	Not reported (different types of activity data at different facilities) but available in EU ETS	National emission factors for stationary combustion of nafta, butane and methane-rich gas	Calculated
1.B.2.A.3: Oil transport	CH_4	Import/export of crude oil	Default EF in revised 1996 IPCC guidelines	Calculated
1.B.2.A.4: Oil refining	CH_4, NMVOC	—	—	Adjusted total *diffuse emissions* in environmental reports
	SO_2	—	—	Emissions from sulphur recovery units in environmental reports
	CO_2	—	—	EU ETS

CRF	GHG	Activity data	Emission factors	Emissions
	CH_4, N_2O NMVOC, SO_2	Amounts of burned make-up coke in EU ETS	National emission factor for stationary *combustion of petroleum coke*	Calculated
1.B.2.A.5: Gasoline storage	NMVOC	—	—	Environmental reports
1.B.2.B.4*: Gas transmission	CO_2, NMVOC	Amount of facilities in the Swedish network for gas storage and transmission	CO_2 och NMVOC content in leaked natural gas	Calculated
	CH_4		CH_4 leakage rates	Calculated
1.B.2.B.5*: Gas distribution	CO_2, CH_4, NMVOC	Length of distribution networks	CO_2, CH_4 och NMVOC content in leaked natural gas	Calculated
1.B.2.C.1.2*: Gas venting	CO_2, CH_4, NMVOC	Amounts of natural gas vented	CO_2, CH_4 och NMVOC content in vented natural gas	Calculated
1.B.2.C.2.1: Flaring at refineries	CO_2	—	—	EU ETS
	CH_4, N_2O, NMVOC, CO, SO_2, NO_x	Amounts of flared gases in EU ETS	National emission factor for stationary *combustion of refinery gas*	Calculated
1.B.2.C.2.2*: Flaring in the natural gas network	CO_2, CH_4, N_2O, NMVOC, CO, SO_2, NO_x	Amounts of natural gas flared	National emission factor for stationary *combustion of natural gas*	Calculated

* Activity data and leakage factors for gas networks are obtained via personal communication with Swedish gas companies.

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

3.3.1.1 SOURCE CATEGORY DESCRIPTION

There are no coal mines in Sweden and hence no fugitive emissions from coal mines occur (hence reported as NO).

Fugitive emissions from solid fuels instead include emissions from quenching and extinction at coke ovens (reported in CRF 1.B.1.b), and flaring of coke oven gas from the coke ovens (reported in CRF 1.B.1.c). CRF 1.B.1 is in fact not designed to include flaring, but since CRF 1.B.2 only refers to liquid and gaseous fuels, it is not possible to report flaring of coke oven gas in CRF Table 1.B.2. Flaring of blast furnace gas in the blast furnace and steel converter are reported in CRF 2.C.1 in accordance with the 2006 IPCC Guidelines.

Reported activity data is amounts of produced coke in CRF 1.B.1.b (Mton) and amounts of flared coke oven gas (COG) (Mton) in CRF 1.B.1.c.

The amounts of flared COG vary considerably between years, and during some years (2009, 2015) they were unusually high, resulting in increasing emissions in

CRF 1.B.1. According to environmental reports[137], COG 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 3.31.

Table 3.31. Summary of source category description, CRF 1B1, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.B.1	CO_2				T2	CS	Yes
	CH_4				T2	CS	Yes
	N_2O				T2	CS	Yes

CS Country Specific. PS Plant Specific. T2 Tier 2. T3 Tier 3
* Shows key category (level) per fuel type
** Shows key category (trend) per fuel type

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. Data on SO_2 emissions from quenching and extinction at coke ovens are obtained directly from the operators of the two facilities; NO_x and NMVOC emissions from the same processes are calculated with default emission factors specified in the EMEP / EEA Guidebook.

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 uncertainty for the activity data (amount of flared coke oven gas) has been estimated to ± 50 %. The extent of flaring is by nature very variable between years, and the uncertainty in activity data is high compared to other activities. The emission factor uncertainty has been estimated to ±5 % for CO_2 and ±20 % for CH_4 and N_2O.

3.3.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

3.3.1.5 SOURCE-SPECIFIC RECALCULATIONS

No recalculations have been made in submission 2019.

3.3.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

[137] SSAB, 2008, 2009, 2015

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

3.3.2.1 SOURCE CATEGORY DESCRIPTION

In the Swedish inventory, fugitive emissions from a number of different activities related to production and handling of liquid fuels and natural gas are reported in this sector. These activities include hydrogen production at oil refineries (1.B.2.A.1), crude oil transport (1.B.2.A.3), activities in refineries such as catalytic, desulphurisation and storage and handling of oil (1.B.2.A.4), gasoline handling and distribution (1.B.2.A.5), natural gas and biogas transmission (1.B.2.B.4), distribution of natural gas, biogas and gasworks gas (1.B.2.B.5), venting of natural gas (1.B.2.C.1.2), and flaring of natural gas and oil (1.B.2.C.2).

In 1990-2005 the emissions of CO_2 in 1B2 were relatively constant – ~ 300 kt/year. Due to the start of production of hydrogen at refineries in 2006 the emissions of CO_2 more than doubled (>800 kt/year) from 2006 and onwards.

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 3.32.

Table 3.32. Summary of source category description, CRF 1.B.2, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.B.2.a	CO_2	X (Oil)	X (Oil)		T3	PS	No, see Annex 5
	CH_4				T1, T2	D, CS, PS	Yes
	N_2O				T2	CS	Yes
1.B.2.b	CO_2				T2, T3	CS, PS	Yes
	CH_4	X			T2, T3	CS, PS	Yes
1.B.2.c	CO_2	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. D Default
* Shows key category (level) per fuel type
** Shows key category (trend) per fuel type

3.3.2.2 METHODOLOGICAL ISSUES

3.3.2.2.1 Hydrogen production plants at refineries (CRF 1.B.2.A.1)

Since 2005, one hydrogen production facility at a refinery 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 line with the IPCC 2006 Guidelines (Volume 2, Chapter 4, Section 4.2.2). Hydrogen production in Sweden also occurs at several facilities within the chemical industry – emissions from that production are reported in CRF 2.B.

CO_2 emissions are estimated using the IPCC Tier 3 method, and non- CO_2 emissions – using Tier 2 method. CO_2 emissions are taken from the company's report to the EU ETS system.

Activity data is reported as NE because one of the plants has changed reporting method so that activity data no longer represents amounts of feedstock - a mixture of butane, off-gas from one of the refinery units, and LNG (from 2014). Instead, to calculate CO_2 emissions reported to EU ETS, the facility from now one will use amounts of so called 'PSA (pressure swing adsorption) gas' - energy-poor off-gas from the hydrogen production unit [138]. PSA gas is a good proxy for activity data for this particular plant with a complicated feedstock structure; however, it is not a feedstock and thus cannot be summed up with feedstock data (naphta for 2006 – 2011 and LNG from 2011 onwards) from the other plant. Activity data for both facilities can be provided to reviewers upon request.

Non- CO_2 emissions are calculated with plant-specific activity data and national emission factors. Due to lack of specific emission factors, "other petroleum fuels" emission factor was used for naphta, and emission factor for methane-rich gas was used for PSA gas. During 2018, a project was initiated with the purpose to improve reporting in the sector CRF 1.B.2, in particular by investigating whether alternative emission factors can be used instead of currently used national emission factors for stationary combustion. The project work is focused on both collecting relevant information at Swedish facilites by personal contacts, and studying available information about reporting of hydrogen production in other countries. The results are supposed to be implemented in submission 2020.

3.3.2.2.2 Transport (CRF 1.B.2.A.3)

Crude oil is transported to and from Sweden by tankers. In response to recommendations from the UNFCCC expert review teams in submission 2010, Sweden estimates emissions of CH_4 from transport of crude oil using the default IPCC method. National statistics available from Statistics Sweden on imported and exported amounts of crude oil is used as activity data. The activity data is corresponding to the data in the Reference Approach. Since no reliable country-specific measurements are carried out and no default IPCC emission factor for tanker ships is available in the 2006 IPCC Guidelines, the default emission factor for Western Europe from the Revised 1996 IPCC Guidelines (745 kg CH_4/PJ) is applied. Fugitive emissions of CO_2 from transport of crude oil are not estimated (NE) as no country-specific measurements have been carried out and no default IPCC emission factor for tanker ships is available.

3.3.2.2.3 Refining/Storage (CRF 1.B.2.A.4)

CO_2 emissions are estimated using the IPCC Tier 3 method, and non- CO_2 emissions – using 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 combustion of cracker coke (CO_2, CH_4, N_2O, NMVOC, SO_2), desulphurisation (SO_2), and from the storage and handling of oil (NMVOC, CH_4). Reported activity data is amounts of crude oil processed at the refineries (Mt).

Fugitive emissions of CH_4 from refineries include emissions from the process area as well as emissions from the refinery harbours when loading tankers. The estimate of fugitive CH_4 emissions are for two refineries based on reported data in the facilities' environmental reports. For the remaining three refineries the fugitive CH_4

[138] Ortiz, C., et al.. Överlappande mellan CRF 1 och 2, SMED memorandum, 2017

emissions are estimated as 5 % of the total fugitive VOC emission. This estimate has been provided by one refinery that refines about 50 % of the crude oil in Sweden. Since no information from the two remaining refineries was obtained the same perccentage has been used to estimate the fugitive CH_4 emissions also from these plants. The reported emissions of CH_4 are very uncertain due to limited measurements – however, using a value of 0.2-3%, assumed by default emission factors for oil refining in IPCC 2006 Guidelines, seem to result in underestimation of CH_4 emissions. 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 3.33, reported emissions of CH_4 and activity data can be seen. Due to data confidentiality, data for 2015-2017 cannot be displayed.

The trend of hydrocarbon emission does not follow the fluctuations of the crude oil throughput very well. This is most likely due to the uncertainties in the method used by the refineries to estimate the emissions.

Table 3.33. Throughput of crude oil in refineries and estimated fugitive emissions of CH_4 (t) reported in CRF 1.B.2.A.4. Due to data confidentiality, data for 2015-2017 cannot be displayed.

Year	Throughput of crude oil (t)	Total emissions of CH_4 (t)
1990	17 330 000	460
1995	19 430 000	400
2000	20 253 120	577
2005	19 919 968	399
2010	20 278 888	469
2011	19 034 115	431
2012	21 021 566	436
2013	17 021 700	383
2014	19 320 478	398

Since submission 2009, emissions from combustion of cracker coke in refineries, earlier reported in CRF 1.A.1.B, were allocated to CRF 1.B.2.A.4 to be in line with the IPCC guidelines (hence the combustion is not carried out for energy purposes). This was based on a study performed by SMED[139]. 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. Combustion of cracker coke occurs at three facilities. Activity data as amount of cracker coke and CO_2 emissions are taken from the company's report to the EU ETS system. Non- CO_2 emissions (CH_4, N_2O, and NMVOC) are calculated with these plant specific activity data and national emission factors.

[139] 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 1.B.2.A.5)

Calculated fugitive emissions of NMVOC from the storage of oil products have been obtained from the environmental reports of the oil depots. The calculations are based on the amount of product handled in the depots. The calculations are based on methods given by Concawe 85/54[140] for the years 1990-2006 and on Concawe 03/07[141] for 2007 and onwards.

The calculation of fugitive NMVOC emissions from gasoline distribution, 1990-2017, is based on methods given by Concawe[142], 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[143].

3.3.2.2.5 Natural gas transmission (CRF 1.B.2.B.4)

In 2013, a national method for estimating the Swedish emissions of natural gas was developed and described in Jerksjö et al. [144]. Emission estimates are based on information provided by Swedegas, the operator of the transmission pipeline and storage of natural gas in Sweden. Emission data includes transmission and storage of gas and was for the first time adopted in submission 2014.

The Swedish network for gas storage and transmission includes several different types of facilities: metering and regulation stations (M/R stations), compressor stations, ramification stations, valve stations, pig launcher & receiver stations, and a storage facility. According to Swedegas[145], many of the facilities are combined, e.g. valves located close to M/R stations. To enable biogas transmission in the network, two compressor stations were put into operation in 2014 – one combined with M/R station and one stand-alone facility.

In 2016, the method for estimating the emissions from the gas transmission network was revised since new measurements of methane emissions became available[146]. Methane leakage rates per hour have been measured at all major types of facilities. Estimated emission factors (see table 3.34 below) have been applied to the number of facilities of each type. Emissions earlier reported as gas leakage have been re-allocated to the sector *CRF 1.B.2.C.1.2 Natural gas venting* since these emissions are controlled and associated with regular network maintenance work rather than with uncontrolled gas leakage.

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

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

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

[143] Andersson, 2000.

[144] Jerksjö, M., Gerner, A., Wängberg, I. 2013. Development of method for estimating emissions of methane, NMVOC and carbon dioxide from natural gas, biogas and town networks in Sweden. SMED Report No: 121, 2013.

[145] Bjur & Lindsjö, 2016

[146] Jerksjö, M., Salberg, H. 2016. Mätningar av metanläckage längs svenska naturgasnätets stamledning, IVL report C202 (in cooperation with Fluxsense)

Table 3.34 Method for estimation of gas leakage from the national gas transmission network

Facility type	CH_4 EF g/hour	Number of facilities in 2017	Comment
M/R station	91	42	Number of facilities is known for the whole time series
Storage	200	1	In operation since 2006
M/R + compressor station	222	1	In operation since 2014
Compressor station	100	1	In operation since 2014
Valve station	30	26	For the years 1990-2014, the number of facilities is assumed to be in direct proportion to the network's length (320 km in 1990, 620 km in 2017)
Pig launcher & receiver station	300	9	
Ramification station	30	39	

Parameters used to calculate emissions of carbon dioxide and NMVOC via composition of natural gas are shown in Table 3.35. Information on gas composition was obtained from Swedegas and constitutes average values from the period 2006 to 2012.

Table 3.35. Composition and physical properties of natural gas

Property	Unit	Value
Methane content in natural gas	% by weight	78.6
Carbon dioxide content in natural gas	% by weight	1.80
NMVOC content in natural gas	% by weight	19.0
Density of natural gas	kg/Nm^3	0.817
Density of methane	kg/Nm^3	0.716

As explained above, emissions of CO_2 and CH_4 are based on the amount of the different facility types within the national gas transmission network. Swedegas has been contacted in submission 2019 and confirmed that the amount of facility types has not changed since 2014. Hence emissions of CO_2, CH_4 and NMVOC are constant for 2014-2017.

Methane leakage during gas transmission based on the recent measurements is comparable to the emissions calculated via the IPCC default emission factor, as shown in table 3.36 below.

Table 3.36. Estimated fugitive methane emissions from gas transmission (storage excluded)

Year	Swedegas	IPCC (2006)[1]	IPCC (2006)[2]
	kt	(kt)	(kt)
2006	0.070	0.061	0.442
2007	0.072	0.063	0.461
2008	0.074	0.058	0.422
2009	0.074	0.077	0.557
2010	0.074	0.103	0.749
2011	0.074	0.082	0.595
2012	0.074	0.071	0.514
2013	0.074	0.068	0.494
2014	0.075	0.056	0.405
2015	0.077	0.051	0.369
2016	0.077	0.057	0.417
2017	0.077	0.047	0.342

[0.1]Lower value = 6.6×10^{-5} kt per year and 10^6 Nm^3 marketable gas
[1]Upper value = 4.8×10^{-4} kt per year and 10^6 Nm^3 marketable gas

3.3.2.2.6 Natural gas distribution (CRF 1.B.2.B.5)

There are three types of gas networks for distribution of gas in Sweden.

1. The gas network for distribution of natural gas
2. Local biogas distribution network
3. Gasworks gas distribution network.

The gas network for distribution of natural gas is connected to the national transmission pipeline via M/R stations as mentioned above and had a total length of 2620 km in year 2012. This network delivers natural gas to the end users, which are industries or municipalities which in turn use the gas for energy production, to feed their town gas networks, etc. There are about 40 small local distribution networks for biogas in Sweden[147]. The total length was 146 km in 2012. The biogas is of similar quality as natural gas and is distributed in similar distribution pipes as natural gas.

Most of the gasworks gas networks use natural gas and their distribution system has been modernised and considered to be of the same standard as the distribution system for natural gas. However, the gasworks gas networks in Stockholm and Gothenburg (the two largest cities in Sweden) are different. These networks consist to a large part of old pipes with considerable high leaking rate. Between 1990 and 2011, a facility in Stockholm produced gasworks gas from cracking light petroleum. In 2011, they started to use a mixture of natural gas and air. The city of Gothenburg produced gasworks gas of a similar quality as that in Stockholm during the period 1990 – 1993. In 1993, the city of Gothenburg shifted to a mixture of natural gas and air and since the beginning of 2011, only pure natural gas is distributed in Gothenburg. Activity data in terms of leakage of gasworks gas has

[147] Jerksjö, M., Gerner, A., Wängberg, I. 2013. Development of method for estimating emissions of methane, NMVOC and carbon dioxide from natural gas, biogas and town networks in Sweden. SMED Report No: 121, 2013.

been obtained from the gasworks gas distributor in Stockholm for the years 2002-2012. For earlier years, only production data is available, and the average relation of leakage to production has been used to estimate leakage for the years 1990-2001. The emissions of CH_4 and CO_2 have been calculated with data on chemical composition of gas from cracking and natural gas/air mixture. The methodology is described in Jerksjö et al[148].

Since no measurement on fugitive methane emissions from distribution of gas has been made in Sweden, emission factors found in the literature were compared and examined. Information on the Swedish gas network was collected by contacting the operators. Based on this information an emission factor obtained from a Dutch investigation (Wikkerlink 2006[149]) was chosen. The emission factor is the result of an evaluation of data from measurements of gas leaks at several places in the Netherlands and is equal to 120 Nm^3 methane per km distribution line. According to net operators of new or renewed Swedish networks for natural gas, the networks in Sweden are of similar standard and design as those in the Netherlands. The Dutch emission factor is considered to be valid for pipes made from PVC and polyethylene, etc., and can be used as an average value covering different pressure regimes. The emission factor from the Dutch study was adopted for estimating the methane emissions from Swedish gas networks 1. (Natural gas) and 2. (Biogas) and also gas networks in cities with new or renewed distribution systems. The fugitive emissions from distribution of gasworks gas in Stockholm and Gothenburg has been estimated based on statistics on production of gasworks gas and natural gas mixed with air and leakage rate obtained from Stockholm Gas[150].

Data on gas mixtures, sources of activity data and emission factors used for emission calculations in CRF 1.B.2.B.5 for each gas distribution network are summarized in Table 3.37.

[148] Jerksjö, M., Gerner, A., Wängberg, I. 2013. Development of method for estimating emissions of methane, NMVOC and carbon dioxide from natural gas, biogas and town networks in Sweden. SMED Report No: 121, 2013.

[149] Wikkerlink. 2006.

[150] Jerksjö, M., Gerner, A., Wängberg, I. 2013. Development of method for estimating emissions of methane, NMVOC and carbon dioxide from natural gas, biogas and town networks in Sweden. SMED Report No: 121, 2013.

Table 3.37. Summary of method for calculating emissions from Swedish gas distribution networks

Gas distribution networks	Natural gas*	Local biogas	Gasworks gas – Stockholm
Gas mixture used	Natural gas	Biogas of similar quality as natural gas	Mixture of natural gas and air. Until 2011 – gasworks gas and mixture of natural gas and air
Source of activity data	Gas distribution companies	Grönmij. 2009	Stockholm gas environmental reports
Type of activity data	km length	km length	Nm^3 gas leakage
Emission factor for CH_4	120 Nm^3/ km (Wikkerlink, 2006[151])		No emission factors are used. Emissions are calculated based on the content of CH_4, CO_2 and NMVOC in the gas mixtures considered.
Emission factor for CO_2	No emission factors are used. Emissions are calculated based on estimated methane emissions and the content of CO_2 and NMVOC in the natural gas.		
Emission factor for NMVOC			

* Including a number of city gas distribution networks, for instance Gothenburg gas distribution network since 2011.

Parameters used to calculate the content of methane, carbon dioxide and NMVOC in gasworks gas and natural gas air mixture are shown in Table 3.38 and Table 3.39, respectively. Information on gas composition was obtained from Stockholm Gas and Swedegas.

Table 3.38. Composition and physical properties of gasworks gas

Property	Unit	Value
H_2 content	% by volume	54
CH_4 content	% by volume	30.0
CO_2 content	% by volume	11.5
NMVOC content	% by volume	2.0
Air content	% by volume	2.5
Amount of CH_4 per Nm^3 gas	kg/Nm^3	0.21
Amount of CO_2 per Nm^3 gas	kg/Nm^3	0.23
Amount of NMVOC per Nm^3 gas	kg/Nm^3	0.04

[151] Wikkerlink. 2006.

Table 3.39. Composition and physical properties of natural gas air mixture

Property	Unit	Value
Density of natural gas air mixture	kg/Nm^3	1.054
CH_4 content	% by weight	30.4
CO_2 content	% by weight	0.7
NMVOC content	% by weight	7.4
Air content	% by weight	61.5
Amount of CH_4 per Nm^3 gas	kg/Nm^3	0.32
Amount of CO_2 per Nm^3 gas	kg/Nm^3	0.0075
Amount of NMVOC per Nm^3 gas	kg/Nm^3	0.08

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

In submission 2011, an analysis was carried out with the aim to investigate if vented emissions from refineries already were included in reported emissions in other CRF categories. The conclusion from this study was that the emissions from venting at refineries most probably are 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 and later, emissions in CRF 1.B.2.C.1.1 and 1.B.2.C.1.3 are reported as IE (in 1.B.2.A.4 and 1.B.2.C.2.). The fugitive CH_4 emissions from oil refineries reported in CRF 1.B.2.A.4 are based on measurements of total hydrocarbon emissions from the refinery areas. These emissions include leakages but also emissions from venting activities. It is therefore not possible to report fugitive emissions and emissions from venting separately. However, the hydrocarbon emissions from venting activities at refineries are assumed to be very small, since during normal operation conditions the vented gases enters the gas flare systems.

Venting of natural gas from transmission pipelines and the storage facility, reported under CRF 1.B.2.C.1.2, occurs as a part of maintenance. Swedegas reports estimates of the annual amounts of vented gas. Venting at M/R stations during ordinary maintenance procedures results in ~ 0.3 to 0.5 t methane emissions per year. In addition, similar amounts of gas are vented as a part of a network inspection conducted by Swedegas usually once in eight years[152] but sometimes more often. Such an inspection requires so called piggning – emptying M/R stations, which means release of certain amounts of natural gas. A larger part of the released gas is flared but some is vented. For the years 2014-2017, estimated amounts of gas vented during the inspections have been obtained from the operator. For the years 2006, 1998 and 1990 estimates were made based on the relation of the amount of vented gas to the number of M/R stations in 2014-2015. Total amounts of vented gas from M/R stations are shown in figure 3.11.

[152] Hellström 2013-2015

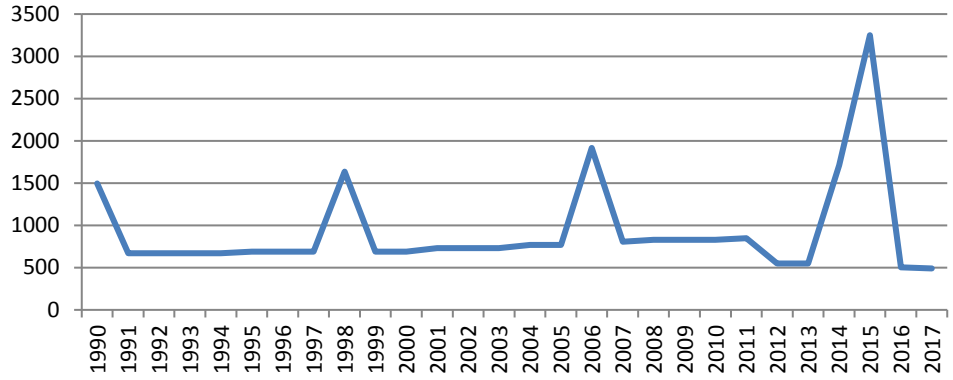

Figure 3.11. Gas venting at M/R stations, Nm^3 natural gas

The reported emissions from the gas storage facility, dominated by venting, are shown in Table 3.40 in comparison with the corresponding values obtained using the 2006 IPCC Guidelines. For the years 2006, 2007 and 2012 the emissions are at the same level as the estimations according to 2006 IPCC Guidelines. For other years, except for 2013, Swedegas has reported emissions that are 2 to 7 times lower than using the 2006 IPCC Guidelines estimate. The large emission of natural gas from the gas storage in 2013 was due to a compressor failure[153]. The emissions reported from the operator seem reasonable in comparison to other estimates that can be made using emission factors found in the literature and it was concluded that it constituted the best estimate available at the moment[154].

Table 3.40. Estimated total methane emissions from gas storage

Year	Swedegas			
	Fugitives, (kt)	Venting, (kt)	Total emissions, (kt)	IPCC (2006)[1], (kt)
2006	0.002	0.028	0.030	0.023
2007	0.002	0.032	0.034	0.024
2008	0.002	0.007	0.009	0.022
2009	0.002	0.002	0.004	0.029
2010	0.002	0.002	0.004	0.039
2011	0.002	0.002	0.004	0.031
2012	0.002	0.021	0.023	0.027
2013	0.002	0.068	0.070	0.026
2014	0.002	0.001	0.002	0.021
2015	0.002	0.002	0.004	0.019
2016	0.002	0.001	0.003	0.022
2017	0.002	0.001	0.003	0.018

[1] 2.5×10^{-5} kt per year and 10^6 Nm^3 marketable gas

3.3.2.2.8 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 refineries. Reported activity data is amounts of flared gases in TJ. 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. For 1990-2007, quarterly fuel

[153] Hellström 2013-2015

[154] Jerksjö, M., Gerner, A., Wängberg, I. 2013. Development of method for estimating emissions of methane, NMVOC and carbon dioxide from natural gas, biogas and town networks in Sweden. SMED Report No: 121, 2013.

statistics is used as main data source. From 2008, data has been collected directly from the plant operators, and from environmental reports. 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. During 2018, a project was initiated with the purpose to improve reporting in the sector CRF 1.B.2, in particular by investigating whether alternative emission factors can be used instead of currently used national emission factors for stationary combustion. The project work is focused on both collecting relevant information at Swedish facilites by personal contacts, and studying available information about reporting of flaring in other countries. The results are supposed to be implemented in submission 2020.

In submission 2010 EU ETS data was analysed carefully. It was concluded that the notation key for flaring of natural gas (NE in earlier submissions) could be changed, since no such flaring of pure natural gas could be found in the EU ETS data, and all plants that might be flaring are included in the EU ETS. However, certain amounts of natural gas can be used as feedstock in the refinery processes together with liquid fuels. Hence, it cannot be ruled out that the flared gases, which are mostly refinery gas and petrochemical by-products gases, might also contain some natural gas. 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.

Emissions from flaring of natural gas in connection with gas transmission pipeline maintenance (piggning) are reported for the first time in Submission 2016 under CRF 1.B.2.C.2.2. For the years 2014-2016, estimated amounts of flared gas have been obtained from the operator. For the years 2006, 1998 and 1990 estimates were made based on relation of the amount of flared gas to the number of M/R stations in 2014. The same emission factors and calorific values as for natural gas combustion in industries were used. Occurring greenhouse gas emissions are around 0.001-0.012 kt CO_2-eq. per year and increase between 1990 and 2014 together with the number of M/R stations.

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.

1.B.2.A.1: According to data reported to the EU ETS, both hydrogen production plants use the level 2 method to measure activity data, which means that the activity data uncertainty is ± 2.5 % or less. The emission factor uncertainties have not been available for the GHG inventory staff, and hence the same emission factor uncertainties as for the corresponding fuels in stationary combustion, i.e. ± 5 % for CO_2 are used. For the CH_4 emission factor, general uncertainty from 2006 IPCC Guidelines for oil refining activities (±100 %) was used instead, following the precautionary principle. For N_2O emission factor, the uncertainty is set to ±25 % in accordance with GPG 2000.

1.B.2.A.3, 1.B.2.A.4: The uncertainty for the activity data have been estimated to ± 7.5 %. The emission uncertainty for fugitive emissions of CH_4 has been estimated to ±400 %. The reason for the high emission factor uncertainty is not the use of inaccurate method but the large uncertainties for the measurements with high inter-

annual variation. Uncertainties for emission factors for cracker coke combustion processes are estimated to ±20 % for CH_4, ±5 % for CO_2 and ±25 % for N_2O.

1.B.2.A.5: Based on expert judgements, the uncertainties of collected emissions of NMVOC are ±75 %.

1.B.2.B.4: Emissions have been revised in submission 2017 due to new measurement results available. The associated emission uncertainty is ±50 % according to expert estimates.

1.B.2.B.5: Fugitive emissions from the distributing network in Stockholm constitute 80 – 90 % of the total emissions from gas distribution in Sweden. The emission data from the Stockholm distribution network is based on measurements provided by the operator and the associated uncertainty is estimated to ± 50 %. The total uncertainty concerning distribution of gas in Sweden is largely influenced by the contribution from the gas network in Stockholm, and is thus likewise estimated to ± 50 %.

1.B.2.C.1.2, 1.B.2.C.2.2: Estimates of emissions from natural gas venting are provided by the operator. The associated uncertainty is ± 50 % according to expert estimates. For gas flaring, the total emission uncertainties are affected by uncertainties in the emission factors, which are the same as for industrial combustion of natural gas – 10 % for CO_2, 30 % for CH_4 and N_2O.

1.B.2.C.2.1: The activity data uncertainties for different fuels and plants are as reported to EU ETS and are in the range ±7.5-17.5 %. For the total uncertainty from all fuels we use ±17.5 %. The emission factor uncertainties have not been available for the GHG inventory staff, and hence the same emission factor uncertainty as for the corresponding fuels in stationary combustion is used for CO_2, i.e. ± 5 %. For N_2O, the uncertainty in emission factor is estimated to ±80%. For CH_4 emission factor, general uncertainty from 2006 IPCC Guidelines for oil refining activities (±100 %) was used instead, following the precautionary principle.

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. These facilities are regularly asked to verify that the default value is still valid.

Emissions from oil refineries are included in the cross-sectoral control tool that was developed in 2017. The tool is described in detail in section 1.3.5.

3.3.2.5 SOURCE-SPECIFIC RECALCULATIONS

1.B.2.A.1: National emission factors used for hydrogen production have been corrected resulting in small decrease of NOx emissions for 2011-2016.

1.B.2.A.3: As data is obtained with a one-year-delay, emissions have been updated for 2016, resulting in an decrease for emissions CH_4 by about 0.013 kt.

1.B.2.A.4: National emission factors for CH_4 and N_2O from stationary combustion used for calculation of emissions from burning make-up coke have been corrected. The resulting changes in emissions are in the range of 0.45-0.65 kt CO_2 equivalents.

1.B.2.A.5: Emissions of NMVOC in 2016 have been recalculated due to an error in the calculations. NMVOC emissions decrease by about 7 % or 0.3 kt.

1.B.2.B.4, 1.B.2.C.1.2: Emissions of CO_2 in 2016 have been recalculated due the fact that biogas has been mixed into the supplied natural gas from 2016 on. CO_2 emissions arising from biogas are biogenic and therefore excluded from reported CO_2 emissions. Emissions of CO_2 decrease by 3.6% or about 0.002 t.

1.B.2.B.5: No recalculations have been made in submission 2019.

1.B.2.C.2.1: Emissions from flaring occuring at other sites than refinery plants have been allocated to the relevant sectors in accordance with the 2006 IPCC Guidelines. In particular, flaring at one of the large chemical facilities is now reported in CRF 2.B, and flaring and one pulp industrial plant had already been reported in CRF 2.H. and thus removed from CRF 1.B.2.C.2.1. Besides, national emission factors for stationary combustion have been corrected, and emission factors for early years have been chosen to be used for flaring since no abatement is assumed. The resulting decrease in greenhouse gas emissions vary from 6 to 73 kt CO_2 equivalents, mostly due to re-allocation of emissions to other sectors.

1.B.2.C.2.2: Emissions of CO_2 in 2016 have been recalculated due the fact that biogas has been mixed into the supplied natural gas from 2016 on. CO_2 emissions arising from biogas are biogenic and therefore excluded from reported CO_2 emissions. Emissions of CO_2 decrease by 3.6% or 0.03 t CO2.

3.3.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.Industrial processes and product use (CRF sector 2)

4 Industrial processes and product use (CRF sector 2)

4.1 Overview of sector

The most important industries within the Swedish industrial sector has historically been basic materials industries such as mining, iron and steel industry and pulp and paper industry. Other important industries when considering emissions of greenhouse gases from industrial processes include the cement industry, primary aluminium production, consumption of fluorinated greenhouse gases and some processes within the chemical industry.

Greenhouse gas emissions from the industrial processes sector have decreased by 22 kt CO_2 eq. since 1990, from 7,611 kt CO_2 eq. in 1990 to 7,588 kt CO_2 eq. in 2017, which is a decrease of 0.3 % (Figure 4.1). Emissions of N_2O, PFCs, CH_4 and PFCs have decreased since 1990 by 745 kt CO_2 eq., 532 kt CO_2 eq., 17 kt CO_2 eq. and 55 kt CO_2 eq., respectively. Compared to 1990, only HFCs and CO_2 have increased in 2017 (1,132 kt CO_2 eq. and 195 kt CO_2 eq. respectively). Figure 4.1 shows that CO_2 is by far the largest contributor among the greenhouse gases in this sector in 2017, accounting for 81 % of emissions. Emissions of HFCs are the second largest among the greenhouse gases in 2017, accounting for 15 % of sector emissions.

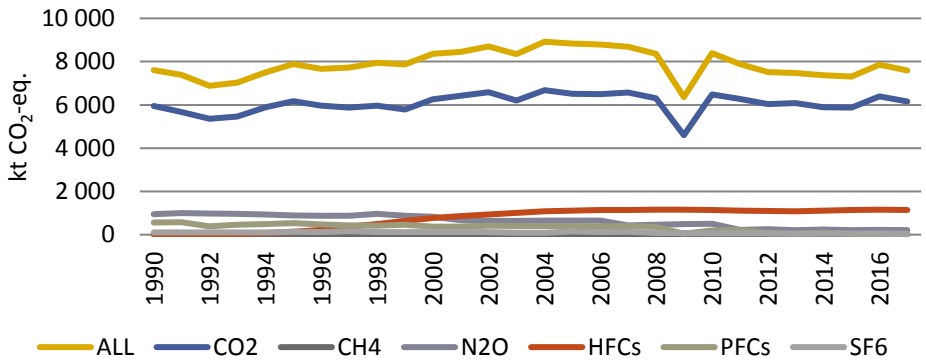

Figure 4.1. Total emissions of all greenhouse gases calculated as CO_2 eq. from CRF 2 industrial processes.

Among the industries within this sector, the metal industry (CRF 2.C) is the largest contributor to greenhouse gas emissions in 2017, accounting for 2,920 kt CO_2 eq. or 38 % (Figure 4.2). Emissions in CRF 2.C in 2017 have decreased by 25 % (951 kt CO_2 eq.) since 1990. Figure 4.2 shows that there was a sharp decrease in greenhouse gas emissions from the metal industry (CRF 2.C) in 2009. This was mainly due to the economic recession in 2009 which largely affected the production volumes of iron and steel in Sweden and thus the emissions are significantly reduced in 2009.

The second largest contributor of greenhouse gas emissions in this sector is the mineral industry (CRF 2.A) with 1,984 kt CO_2 eq., or 26 % of the sector emissions

in 2017. Compared to 1990 there is an increase in greenhouse gas emissions from the mineral industry of about 19 % (312 kt CO_2 eq.) (Figure 4.2), mainly due to increased production of lime and clinker. Greenhouse gas emissions from the chemical industry (CRF 2.B) have decreased since 1990. The reduction is closely linked to N_2O emissions from nitric acid production.

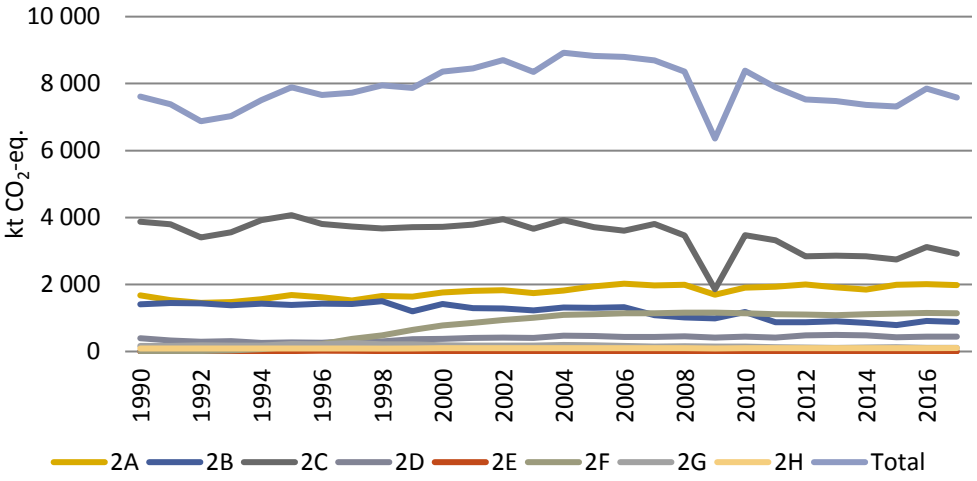

Figure 4.2. Total emissions of all greenhouse gases calculated as CO_2 eq. from the different Industrial processes sub-sectors. 2A Mineral products. 2B Chemical industry, 2C Metal industry. 2D Non-energy products from fuels and solvent use. 2E Electronics industry, 2F Product uses as substitutes for ODS, 2G Other product manufacture and use, 2H Other.

Estimated emissions of fluorinated greenhouse gases consist of emissions from the use of these in various applications, as well as PFC emissions from the primary aluminium production process. Emissions of greenhouse gases from product uses as substitutes for ozone-depleting substances (CRF 2.F) have increased substantially, by 1,132 kt CO_2 eq., since 1990 (Figure 4.2). The use of HFCs as refrigerants in refrigerators, freezers and air-conditioning equipment has contributed to the larger share in later years.

Emissions of greenhouse gases from non-energy products from fuels and solvent use (CRF 2.D) accounted for 445 kt CO_2 eq. in 2017, which is an increase of about 13 % since 1990.

Estimated greenhouse gas emissions from other product manufacture and use (CRF 2.G) consist of fluorinated greenhouse gases from electrical equipment (2.G.1) and sound-proof windows (2.G.2), and N_2O from product use (2.G.3). In 2017, these emissions accounted for 111 kt CO_2 eq., which is a decrease of about 33 % since 1990.

Process emissions from production of pulp and paper and mineral wool, reported in other production (CRF 2.H) have increased since 1990 but remain one of the sectors that contribute the least to greenhouse gas emissions in the IPPU sector.

The electronics industry (CRF 2.E) in Sweden does not generate greenhouse gas emissions, thus it is reported as not occurring (NO).

4.2 Mineral industry (CRF 2.A)

Reported emissions include estimates for cement production (2.A.1), lime production (2.A.2), glass production (2.A.3) and other process uses of carbonates including ceramics, other uses of soda ash and other uses of limestone, dolomite and sodium bicarbonate (2.A.4).

4.2.1 Cement production (CRF 2.A.1)

4.2.1.1 SOURCE CATEGORY DESCRIPTION

Cement production occurs at three facilities in Sweden (owned by one company), with one being dominant. Annual production of cement in Sweden is about 2,000-3,000 kt. Emissions from cement production stem both from combustion of fuels and from raw materials used in the processes. Emissions arising from fuel combustion are reported in the energy sector (CRF 1.A.2.g) with exception of SO_2 which is reported in 2.A.1.

For process-related emissions, facility data are obtained from environmental reports, EU ETS (European Union Emission Trading Scheme) and by direct contacts with the facilities. Process related CO_2 emissions from cement production arise as a by-product during the production of clinker as limestone is heated to produce lime. CO_2 emissions related to limestone used for flue gas cleaning are also reported in CRF 2.A.1 according to the 2006 IPCC Guidelines, but accounts only for about 0.2 % of total CO_2 emissions from the cement industry. Process related CH_4 and N_2O emissions from cement production are assumed to be negligible according to the 2006 IPCC Guidelines and thus 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 4.1. An overview of the rationale for data sources used for key categories in the industrial processes sector is presented in Annex 3.5.

Table 4.1. Summary of source category description, CRF 2.A.1, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.A.1	CO_2	X	X		T3	PS	Yes
	CH_4	NA	NA		NA	NA	NA
	N_2O	NA	NA		NA	NA	NA

PS Plant-specific. T3 Tier 3.

4.2.1.2 METHODOLOGICAL ISSUES

CO_2 emissions from the Swedish cement industry are estimated on a plant-specific basis. Estimates include emissions from by-pass dust and cement kiln dust (CKD), as well as emissions from organic carbon contained in the raw material.

For 1990-2004, information from the company on CO_2 emissions is based on clinker production and default EF from the GHG protocol, CKD correction factor and organic carbon contained in the raw material:

> CO_2 = Production of cement clinker (kt) * 0.525 (kt CO_2/ kt clinker, i.e. default value in the GHG-protocol) * CKD correction factor+ CO_2 from organic carbon content of raw meal

The emission estimates were made on initiative by the WRI (World Resources Institute) 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[155]. The protocol tool calculates CO_2 emissions from raw material converted to clinker, by-pass dust and CKD discarded, and has been used for all years except 1991-1994 and 1996, for which insufficient information was provided from the plants. Instead the cement company has reported production and CO_2 emissions 1991-1994 and 1996 based on mean values from adjacent years.

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

As of 2005, the company reports plant-specific data on CO_2 emissions to the EU ETS and from this year onwards, CO_2 estimates as well as produced amount clinker are calculated according to the national guidelines (NFS 2007:5[156]) for reporting to the EU ETS [157]. For calculation of produced amount clinker, following formula is used:

> Produced amount clinker = (delivered amount cement + stock change of cement) * ratio of clinker/cement – imported clinker + delivered clinker + stock change of clinker

Within the ratio of clinker/cement, cement deliveries, stock change, input materials to the cement, bypass dust and cement kiln dust are accounted for.

A CO_2 emission factor is calculated on a plant-specific basis according to the national guidelines by using the stoichiometric relationship of CaO and MgO in the product (0.785 for CO_2/CaO and 1.092 for CO_2/MgO). Also CO_2 emissions from organic carbon contained in the raw material are included in the CO_2 emissions reported to the EU ETS.

Table 4.2 shows information on clinker production and total CO_2 emissions from clinker production for certain years. For the years prior to 2005 the table shows the

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

[156] NFS 2007:5 Naturvårdsverkets föreskrifter och allmänna råd om utsläppsrätter för koldioxid. Available in Swedish: http://www.naturvardsverket.se/Documents/foreskrifter/nfs2007/nfs_2007_05.pdf

[157] Lyberg, A., Cementa, Personal communication, September 2011

calculated emissions from CKD and the resulting CKD correction factor as well as CO_2 emissions from organic carbon content of raw meal.

Table 4.2. Amount of produced clinker and associated CO_2 from specific sources.

Year	Clinker Production	Total CO_2 emissions	CO_2 from Clinker *	CO_2 from CKD	CKD correction factor	CO_2 from organic carbon content of raw meal	CO_2 from limestone used in flue gas cleaning
	(kt)	(kt)	(kt)	(kt)		(kt)	(kt)
1990	2 348	1 272	1 233	13	1.010	27	-
1995	2 405	1 296	1 263	6	1.005	27	-
2000	2 389	1 288	1 254	6	1.005	27	-
2005	2 457	1 315	1 313	IE	NA	IE	2
2010	2 454	1 324	1 322	IE	NA	IE	1
2015	2 826	1 537	1 524	IE	NA	IE	4
2016	2 847	1 554	1 534	IE	NA	IE	4
2017	2 768	1 484	1 467	IE	NA	IE	4

* From 2005 incl. CKD and organic carbon content
IE - Included elsewhere. NA – Not applicable.

Total emissions of NO_x by facility are found in the environmental reports or have been obtained directly from the company. Emissions originate mainly from fuel combustion and less from industrial processes. Hence IE is reported for NO_x in CRF 2.A.1 and emissions are reported in CRF 1.A.2.f.

SO_2 emissions from cement production are fully allocated to CRF 2.A.1 and have been obtained directly from the company or from the environmental reports. Reported emissions are decreasing over time since 1990.

4.2.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Activity data and CO_2 emissions are reported to the EU ETS and have thus been verified by an accredited verification body. The uncertainty for activity data is judged to be ± 2 % and the uncertainty of the emission factor for CO_2 is judged to be ± 5 %.

All three cement producing facilities in Sweden are covered in the reported estimates and the time-series are considered complete, accurate and more or less consistent. As described above, for 1990-2004, constant CO_2 EF (0.525 kt CO_2/kt clinker produced) is used together with CKD correction factor and CO_2 emissions from organic carbon of raw meal. Since 2005, CO_2 emissions are retrieved from EU ETS, which are based on the content of CaO and MgO in clinker. This means that different methods are used over time, however there is no indication that either methods lead to over- or underestimations of CO_2 emissions.

4.2.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The implied emission factor for total CO_2 emissions from 2005 and onwards (average 0.539 kt CO_2/kt clinker produced) is somewhat higher than the 2006 IPCC Guidelines Tier 1 default value (0.52 kt CO_2/kt produced clinker) and among the highest of the reported IEF:s found in inventory reports under the UNFCCC.

The main reason for the higher implied emission factor is that the MgO content in clinker is accounted for in the reported emissions for Sweden. In addition, in line with the 2006 IPCC Guidelines, CO_2 emissions from limestone used for flue gas cleaning are included in CRF 2.A.1, which results in a further increase of the implied emission factor.

Figure 4.3 illustrates the CO_2 IEF from clinker production, excluding emissions from the use of limestone in flue gas cleaning. There are larger variations after the introduction of EU ETS data as data source. The reason for the varying CO_2 IEF is varying content of CaO and MgO in clinker; a higher concentration of these compounds in the produced clinker implies that a larger amount of CO_2 has been released per unit produced clinker. Table 4.3 lists the content of CaO and MgO for the years 2008-2016 for the largest facility (accounting for an average of 74 % produced clinker in the years 2008-2016). The correlation between CaO and MgO content and CO_2 IEF for the largest plant is illustrated in Figure 4.4. In Figure 4.4, CaO and MgO content is shown as a sum, however MgO in clinker has given rise to a slightly larger amount of CO_2 per unit than CaO, explaining the small differences of IEF and CaO and MgO content in the figure. In 2017 the facility used some alternative raw materials for clinker production (slag), which can probably explain weaker correlation between CO_2 IEF and CaO and MgO content in the clinker. This issue will be followed up and, if necessary, investigated in more detail in submission 2020.

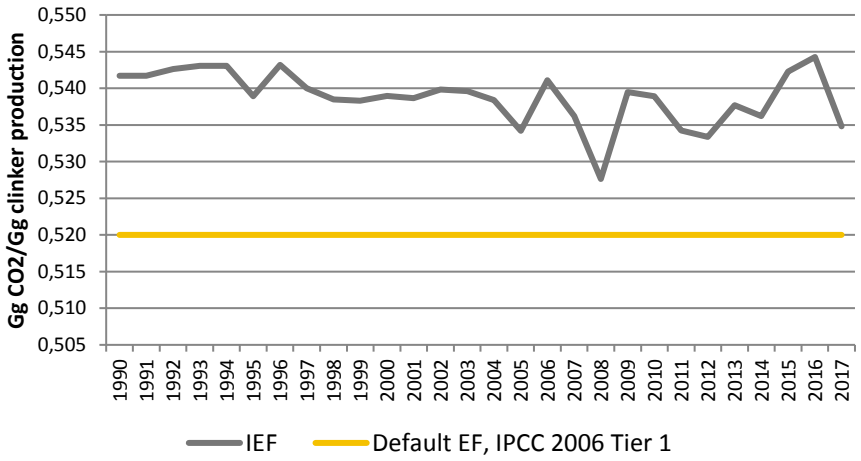

Figure 4.3. CO_2 IEF for total emissions from clinker production 1990-2017, excluding emissions from flue gas cleaning.

Table 4.3. CaO and MgO content in clinker produced in the years 2008-2017 in the largest facility (accounting for an average of 74 % produced clinker in the years 2008-2017).

Year	CaO content %	MgO content %
2008	63.91	2.74
2009	65.73	2.83
2010	65.43	2.92
2011	65.05	2.58
2012	64.92	2.49
2013	64.76	2.96
2014	64.96	2.87
2015	64.94	2.96
2016	65.27	3.07
2017	65.24	3.13

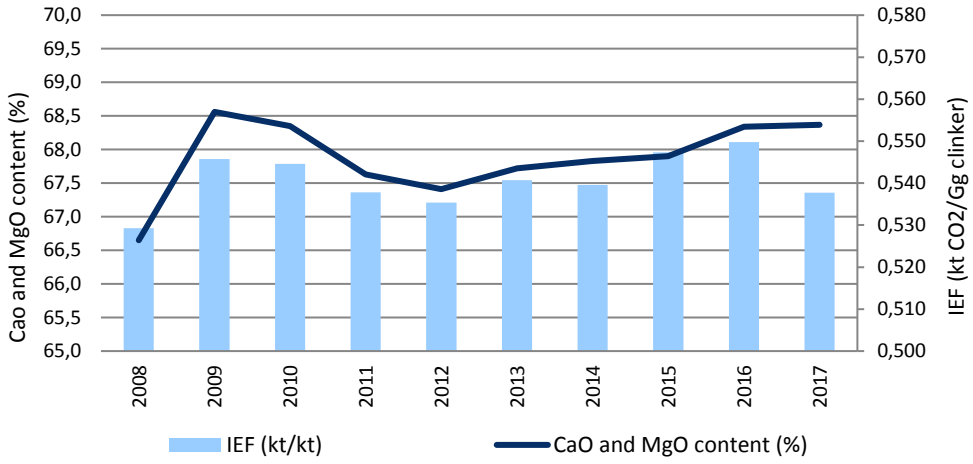

Figure 4.4. CO_2 IEF is compared to CaO and MgO content for respective year, indicating a strong correlation. Data is taken from the largest facility for the period 2008-2017 and exclude emissions from flue gas cleaning.

In response to previous UNFCCC review recommendations, discussions with the cement producers have led to the conclusion that CO_2 emissions from dust and from carbon content in the raw material are included in the estimations for the whole time series (see methodological issues above). In Table 4.2 above, information on clinker production, emissions from production, the calculated emissions from CKD before 2005 and the corresponding CKD correction factors are presented. Compared to the 2006 IPCC default value (1.02) the presented CKD correction factor is generally lower which is in line with the conception that dust emission in Sweden is low or nearly non-existent.

4.2.1.5 SOURCE-SPECIFIC RECALCULATIONS

One of the facilities reports CO_2 emissions from CKD separately to EU ETS. This was not taken into account earlier. In Submission 2019, these emissions were added to the total reported emissions from clinker production, which resulted in the annual emisison increase by ~9 kt (1% of the total CO_2 reported in CRF 2A1) in 2013-2016.

4.2.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.2.2 Lime production (CRF 2.A.2)

4.2.2.1 SOURCE CATEGORY DESCRIPTION

In Sweden, quicklime, hydraulic lime and dolomitic lime is produced at a number of facilities, owned by a few companies. 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. The production of lime has increased since 1990 (about 440 kt) and peaked in 2005 (about 730 kt). In 2009 there was a large decrease in lime production due to the economic recession.

CO_2 is emitted during lime production through calcination of the calcium carbonate ($CaCO_3$) in limestone, or through the decomposition of dolomite ($CaCO_3 \cdot MgCO_3$). Emissions are reported for lime produced in lime production plants, the use of make-up limestone in pulp and paper plants, and lime production within the carbide and sugar industry that occurs as part of the process. Out of these sources, emissions from lime production plants are by far the most important.

Process related CH_4 and N_2O are not emitted during lime production and thus reported as not applicable (NA). Lime contains sulphur which is released as SO_2 during the production process.

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 2.A.2, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.A.2	CO_2	X	X		T3	D	Yes
	CH_4	NA	NA		NA	NA	NA
	N_2O	NA	NA		NA	NA	NA

D Default. T3 Tier 3.

4.2.2.2 METHODOLOGICAL ISSUES

4.2.2.2.1 CO_2 (kt)

As of submission 2016, activity data and emissions for 2005 onwards (2009 onwards for sugar production) are based on EU ETS data. For 1990 to 2004 (or 2008), statistics are mainly received from the Swedish Lime Association, which is a trade organisation that collects data on lime from various industries. In Mawdsley 2015[158], it was concluded that EU ETS data and data from the Swedish Lime Association were comparable, however EU ETS data is received in time for the UNFCCC reporting, as opposed to data from the Swedish Lime Association. Thus, for later years (since 2005 or 2009), CO_2 emissions from lime production are based on the individual companies' data reported to the EU ETS. Reported emissions are used directly, and activity data is calculated using emission factors and purities according to the 2006 IPCC Guidelines.

Sugar industry

For 2009 onwards, EU ETS data is used for emission estimates from the sugar industry. For determining activity data and emissions of CO_2 within the sugar industry prior to 2009, the amounts of limestone for the production of quicklime are used. The quantities are obtained directly from the sugar producing company from 1999. 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 % $CaCO_3$.

In the production of sugar, lime is used for purification of the juice. Lime is added to raw juice and 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 in the agricultural sector. According to information from the company, around 88 % of the lime used was precipitated as $CaCO_3$ for the years before 2005. For later years this share has increased and is as an average 91%. No dolomitic lime is used.

Pulp and paper industry

From 2005 onwards, CO_2 emission data is retrieved from the EU ETS for individual pulp and paper plants. Lime kiln sludge that is put in storage and reburnt in the lime kiln is excluded from the estimations, as resulting CO_2 emissions stem from biogenic carbon from other parts of the production process.

Prior to 2005, data on make-up lime is obtained from the Swedish Lime Association and the Swedish Lime Industry. In response to previous review recommendations, detailed data on 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 trade organisation from 1995 onwards[159].

[158] Mawdsley, I. 2015. Change of activity data for lime production

[159] Swedish Lime Association and The Swedish Lime Industry, personal communication

Based on the 2006 IPCC Guidelines, the purity of the limestone is set to 95 %. The corresponding figure for dolomite is 100 %. For the years before 1995, limestone quantities used as make-up lime are estimated using the average ratio between limestone used as make-up lime and produced Kraft pulp for the period 1995 – 2009 and corresponding production data for 1990 – 1994. This gives an average (1995 – 2008) of 2.1 kg limestone per Mg Kraft pulp (Table 4.6) and is used for estimations of limestone use for the years before 1995. Similarly, CO_2 emissions are estimated for 1990 – 1994 by using the average ratio between emitted CO_2 and used amounts of limestone for the period 1995 –2008. Less than 1 % of total make-up lime within the pulp and paper industry is dolomitic lime.

Calcium carbide industry

In order to estimate CO_2 emissions from production of quicklime at Sweden's only calcium carbide production plant, emission data is collected from the EU ETS from 2005 onwards. For 1990-2004, the amount of limestone used for quicklime production is used as activity data together with the default emission factor from 2006 IPCC Guidelines; 0.44 Mg CO_2/Mg limestone used.

Lime production plants

For all other production of quicklime, hydraulic lime and dolomitic lime, which occurs at lime production plants, EU ETS emission data for the individual lime plants are used from 2005 onwards, and emission factors and purities according to the 2006 IPCC Guidelines are used to calculate activity data.

Detailed data from 1990 to 2004 are obtained from the Swedish Lime Association. To avoid double counting of emissions, activity data for produced quicklime, hydraulic lime and dolomitic lime in the sugar industry and the pulp and paper industry has been deducted. Based on 2006 IPCC Guidelines, the purity of the limestone is set to 95 % for the production of lime in conventional lime mills. The corresponding figure for dolomite is 100 %. Between 2 % and 8 % of the total production of lime in conventional lime mills is dolomitic lime. Production data and reported CO_2 emissions for lime plants are shown in Figure 4.5 together with the implied emission factor. From 2005 onwards however, activity data is calculated based on CO_2 emissions from the EU ETS, and thus the emission factor is constant.

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

Year	Reported Activity Data (quick lime and dolomitic lime, excluding lime in sugar, pulp and carbide industry)	Reported CO2 emissions (excluding emissions in sugar, pulp and carbide industry)	IEF (CO2/quicklime + dolomitic lime)
	(kt)	(kt)	(kt/kt)
1990	367	277	0.7555
1995	350	264	0.7550
2000	513	387	0.7544
2005	665	496	0.7458
2006	625	466	0.7458
2007	659	491	0.7458
2008	638	476	0.7458
2009	468	349	0.7458
2010	620	463	0.7458
2011	619	462	0.7458
2012	579	432	0.7458
2013	594	443	0.7458
2014	507	378	0.7458
2015	516	385	0.7458
2016	529	395	0.7458
2017	578	431	0.7458

4.2.2.2.2 SO_2 (kt)

Emissions of SO_2 from 1990 have been estimated for production of quicklime. The estimations from quicklime production were calculated using emission factors presented in environmental reports by one of the producers[160]. The emission factor provided by the lime producer is substantially higher for 2008 than for earlier years. This resulted in an increase 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. For 2009-2017 the emission factor for 2008 has been used for the estimation of emissions of SO_2 due to lack of more recent information in the environmental reports.

Emissions of SO_2 from quicklime production intended for the pulp and paper industry are not included in the estimates reported in CRF 2.A.2 as they are included in CRF 2.H.1.

4.2.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties are estimated based on the 2006 IPCC Guidelines and is estimated to ± 5 % for activity data and ± 2 % for CO_2 emission factors. Although different sources of activity data are used over the time series, the time series is considered consistent based on comparisons of different data sources (see section 4.2.2.4).

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

4.2.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Activity data reported in CRF 2.A.2 has been compared with national statistics from Statistics Sweden[161] and from the Swedish Lime Industry[162], in line with the IPPC Guidelines 2006. The comparison (Figure 4.5) shows that national statistics from Statistics Sweden are more irregular but for early years the coherence is good. The differences are especially high in 1998, 1999 and from 2004 and onwards. Comparison between reported activity data and activity data from the Swedish Lime Industry shows good compliance and only has small differences for a few years.

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. This leads to larger fluctuations and higher uncertainties in the national statistics from Statistics Sweden compared to data from the Swedish Lime Association and the Swedish Lime Industry.

In a study conducted in 2013[163], Gustafsson and Gerner concluded that national statistics from Statistics Sweden would likely result in overestimated emissions, as imported quantities are likely included in the data.

In 2015 a review of CRF 2A2 was made, where different data sources were compared and where it was determined that the best available data source for this source code is the EU ETS. The main reason beeing that data from the Swedish Lime Association often arrive too late for the ordinary reporting timeline.

As recommended by the ERT, other possible sources on national production of limestone have been explored. As part of the QA / QC procedures, a comparison is made annually between activity data from the different data sources (EU-ETS, Statistics Sweden, the Swedish Lime Association).

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

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

[163] Gustafsson, T., Gerner A. 2013. Verification of activity data for lime production.

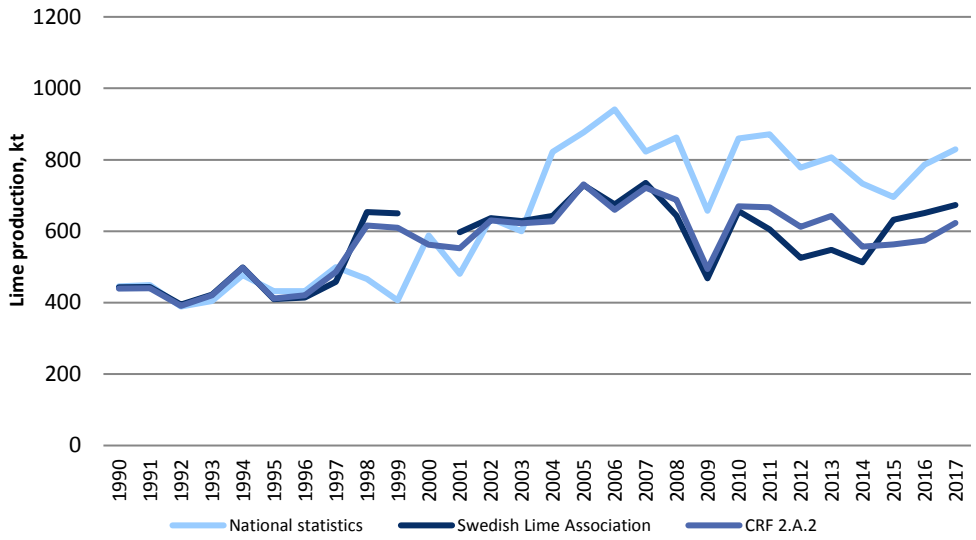

Figure 4.5. National total on produced amount of lime according to data from Statistics Sweden, the Swedish Lime Assocication and reported data in CRF 2.A.2

4.2.2.5 SOURCE-SPECIFIC RECALCULATIONS

Activity data and emissions from one pulp and paper plant have been added to the inventory between 1990 and 2008. The plant represents about 0.01% or lower of the total CO_2 emissions reported in CRF 2.A.2.

4.2.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.2.3 Glass production (CRF 2.A.3)

4.2.3.1 SOURCE CATEGORY DESCRIPTION

In Sweden there is one facility for container glass production and several small facilities for manual glass production. The only float glass producer ceased production in 2013. CRF 2.A.3 also includes glass wool production, which occurs at one facility.

From the float glass production, the total emissions of SO_2 and NO_X from the glass furnace are allocated to 2.A.3 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).

Emissions of CO_2 from the use of limestone and soda ash in glass and glass wool production are reported under glass production. The CO_2 emissions in 2009 are lower than in adjacent years due to the fact that the demand for glass was low in 2009. In addition, less amount of glass was manufactured from raw material that year - instead recycled glass was used to a larger extent. In 2013, one plant producing glass according to the float glass method was shut down and only very

small emissions are reported for 2013 from this facility. Therefore, total CO_2 emissions from CRF 2.A.3 decreased with 65 % in 2013 compared to 2012 and, since NO_X emissions are only reported from this facility, the corresponding decrease in NO_X emission is 96 %. No NO_X emissions from CRF 2.A.3 occur after 2014.

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 4.6.

Table 4.6. Summary of source category description, CRF 2.A.3, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.A.3	CO_2				T3	CS, D	NO, see Annex 5
	CH_4	NA	NA		NA	NA	NA
	N_2O	NA	NA		NA	NA	NA

D Default. CS Country Specific. T3 Tier 3.

4.2.3.2 METHODOLOGICAL ISSUES

Emissions of CO_2 from the use of limestone and from the use of soda ash in glass production are reported in CRF 2.A.3 together with CO_2 emissions from other carbon containing raw material. Of the reported total CO_2 emissions in 2.A.3, approximately 41 % is caused by the use of soda ash and 58 % 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 kt 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 perccentage 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 kt, annually.

The process-related SO_2 emissions from container and float glass production are reported for the period 1990 – 2017 in CRF 2.A.3. 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.

CO_2 emissions from the one glass wool producer in Sweden derive from the use of glass wool waste (glass wool production). Glass wool consists almost entirely of glass. A large proportion of the batch mixture, the so-called melt, consists of recovered glass material, e.g. recycled household glass and excess glass from the fiberization process. Also glass wool waste can be recycled and used in the production of glass wool by a method called the "Oxymelt" process. In this process the organic compounds (binders) are incinerated and the mineral part ("oxymelt

glass") of the glass wool waste can be recovered and used as a resource for the production of new glass wool. The incineration of the organic binders gives rise to emissions of CO_2. In the EU ETS, CO_2 emissions from the oxymelt process are reported since 2005 for the glass wool producer. Activity data, emission factor and CO_2 emissions data from the "oxymelt glass" process, based on information from EU ETS, is included for the years 2005-2017. The same information for 1991-2004 has been obtained from the company. In 1990 no oxymelt glass was used. The emission factor used is 0.13 kt CO_2 kt^{-1} oxymelt glass.

NMVOC emissions from glass wool production are estimated from data received from the company directly or as reported in environmental reports together with earlier total estimates. Emitted NMVOCs consist of formaldehyde and phenol.

4.2.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainties of the direct CO_2 emissions in 2.A.3 are considered to be ± 7 % based on expert judgements. The expert judgements of the uncertainties of CO_2 in 2.A.3 were made without any knowledge of the missing oxymelt process that now is included. The estimated uncertainties are still considered to be valid.

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

A technical correction in calculations was made for 2005-2012, resulting in insignificant (0.0003% of total reported in CRF 2A3) CO_2 emission changes.

4.2.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.2.4 Other process uses of carbonates (CRF 2.A.4)

4.2.4.1 SOURCE CATEGORY DESCRIPTION

In CRF 2.A.4, Sweden reports emissions from Ceramics (CRF 2.A.4.a), Other uses of soda ash (CRF 2.A.4.b) and Other (CRF 2.A.4.d). Non-metallurgical magnesium production does not occur 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 4.7.

Table 4.7. Summary of source category description, CRF 2.A.4, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.A.4	CO_2				T3	D	Yes
	CH_4	NA	NA		NA	NA	NA
	N_2O	NA	NA		NA	NA	NA

D Default. T3 Tier 3.

4.2.4.1.1 Ceramics (CRF 2.A.4.a)

Sweden reports 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 1.A.2.f, 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 six facilities in total during the years 1990-2008 and from five facilities in total from 2009 and onwards since one facility closed down in 2008. One of the facilities is dominating the total CO_2 emissions. All CO_2 emissions from raw material used are reported in 2.A.4.a. In the past three years, production volumes have declined significantly.

4.2.4.1.2 Other uses of soda ash (CRF 2.A.4.b)

Due to difficulties in allocating emissions to their respective CRF code, all emissions from soda ash use is reported in CRF 2.A.4.b Other uses of soda ash. 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 (2.A.3).

4.2.4.1.3 Other (CRF 2.A.4.d)

Other process uses of carbonates which occur in Sweden and do not fit into any other category, are the use of limestone, dolomite and sodium bicarbonate for flue gas cleaning purposes in energy industries, whereby CO_2 is emitted. Sodium bicarbonate used within one pulp and paper industry is also reported in 2.A.4.d. Process-related CH_4 and N_2O are not emitted during the use of these carbonates and thus reported as not applicable (NA).

4.2.4.2 METHODOLOGICAL ISSUES

Specified sub-categories under this heading are “Ceramics”, “Other uses of soda ash”, and ”Other“.

4.2.4.2.1 Ceramics (CRF 2.A.4.a)

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. In line with the 2006 IPCC Guidelines, CO_2 emissions from limestone and dolomite as well as other carbon containing raw materials are reported in 2.A.4.a. As there is a lack of data before 2005, the reported emissions for 2005 are linearly interpolated for 1990-2004.

As activity data reported in 2.A.4.a 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 carbon 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. During 2008-2017, clay contributed to between 65-75 % of all process-related CO_2

emissions from LECA production, compared to 47-58 % contribution during 1990-2003. The facility producing LECA corresponds to around 70 % of yearly reported CO_2 emissions in 2.A.4.a.

4.2.4.2.2 Other uses of soda ash (CRF 2.A.4.b)

CO_2 emissions from soda ash use are estimated according to 2006 IPCC Guidelines Tier 3. In 2004 a study was carried out to collect data on soda ash use and calculate CO_2 emissions.[164] Activity data consists of soda ash use from ten plants within several areas:

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

Emissions have decreased by over 90 % since 1990. The reason behind this effect is the large changes in the use of soda ash at two chemical plants. One plant, spending considerable amounts of soda ash during the early 1990s, has since 1997 sharply reduced its consumption. Since the beginning of the new millennium the soda ash is bound in products, and thus no CO_2 is emitted from this plant. The other plant has reduced its soda ash consumption with about 90 % since 1990. One of the facilities closed detergent production in 2016 which resulted in significant decrease in amounts of soda ash used and related CO_2 emissions in 2017.

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[165] and the dominant snuff manufacturer. The emissions are calculated by applying the emission factor for soda ash and assuming a calcination fraction of 1:

$$\mathrm{CO_2(kt)} = \frac{44.0098}{105.9884} \times \text{soda ash (kt)}$$

Data on the use of soda ash have been acquired from environmental reports 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 the inventory is collected from the environmental reports of the facilities or by direct contact with the plants.

4.2.4.2.3 Other- Limestone and Dolomite use (CRF 2.A.4.d)

Process-related CO_2 emissions from the use of limestone and dolomite in the production of cement (2.A.1), lime (2.A.2), glass and glass wool (2.A.3), ceramics (2.A.4.a), carbide (2.B.5), chemicals (2.B.10), iron and steel (2.C.1.a, 2.C.1.b and 2.C.1.c), iron pellets (2.C.1.e), other metals (2.C.7) and mineral wool (2.H.3) are reported in corresponding CRF source categories in accordance with the 2006 IPCC Guidelines. CO_2 emissions from the use of limestone, dolomite and sodium bicarbonate in flue gas desulphurisation at energy plants (also one pulp-and-paper plant) are reported in 2.A.4.d.

[164] Nyström, A-K. 2004. CO2 from the use of soda ash. SMED report 61 2004.

[165] The Swedish Chemicals Agency (KemI), www.kemi.se

Data on the use of limestone and dolomite in this source category has been acquired from environmental reports, the ETS and through direct contacts with the companies. Activity data for sodium bicarbonate has been collected from the ETS for the years 2005 onwards. For the period 1990-2004 activity data has been estimated based on the average emissions for the period 2005-2008; equivalent to about 0.54 kt a year. The calculations are made by applying the emission factor for respective carbonate according to 2006 IPCC Guidelines Tier 3[166].
Formulas for CO_2 emissions from limestone, dolomite and sodium bicarbonate:

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

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

$$CO_2\ (Gg) = \frac{44.0098}{84.007} \times f\ \times sodium\ bicarbonate\ (Gg)$$

where *f* is the purity of the carbonates, set to 97 % for limestone and 100 % for dolomite and sodium bicarbonate.

4.2.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

In CRF 2.A.4.b (soda ash) and CRF 2.A.4.d (other use), the uncertainty of activity data is ±5 % and ±4 %, respectively, and the uncertainty of the emission factor for CO_2 is ±5 %. In CRF 2.A.4.a (ceramics) the emission uncertainty is ±7%. The time series is consistent and complete.

4.2.4.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Data from Statistics Sweden on import and export of carbonates has been compared to production data provided by the Geological Survey of Sweden (SGU) and known use included in the national inventory. When calculating carbonate use based on clinker production ib CRF 2.A.1 the comparison shows a good coverage of carbonate use included in the inventory. The margin of error is however bigger than the amount reported in CRF 2.A.4. which makes this comparison difficult and less reliable.

4.2.4.5 SOURCE-SPECIFIC RECALCULATIONS

4.2.4.5.1 Ceramics (CRF 2.A.4.a)

No source-specific recalculations were performed in Submission 2019.

4.2.4.5.2 Soda ash use (CRF 2.A.4.b)

Small correction for one facility has been made resulting in 0.0002 kt (0.03% of the total reported in CRF 2.A.4.a) CO_2 increase in 2016.

[166] IPCC. 2006 Guidelines for National Greenhouse Gas Inventories: Volume 3 section 2.5.

4.2.4.5.3 Other limestone and dolomite use (CRF 2.A.4.d)

Emissions for one plants have been corrected for 2016. CO_2 emissions reported in CRF 2.A.4.d in 2016 decrease therefore by 0.09 kt (1% of the total reported in CRF 2.A.4.d).

Emissions from soda ash use at a pulp and paper producing facility have been reallocated to CRF 2H1, in accordance with the 2006 IPCC Guidelines. The resulting CO_2 emission reduction for years 1990-2012 is up to 0.55 kt (2-4% of the total reported in CRF 2.A.4.d).

4.2.4.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.3 Chemical industry (CRF 2.B)

Sources covered in the reporting are nitric acid production (2.B.2), carbide production (2.B.5) and other (2.B.10), which include a large variety of processes in the chemical industry. Included in 2.B.10 are also various processes which produce petrochemical products, which according to the 2006 IPCC Guidelines should be reported in 2.B.8, however, due to difficulties in separating these products they are allocated to CRF 2.B.10. No production of ammonia (2.B.1), adipic acid (2.B.3), caprolactam, glyoxal and glyoxylic acid (2.B.4), titanium dioxide (2.B.6), soda ash (2.B.7) or fluorochemicals (2.B.9) 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 kt of ammonia in Sweden, according to United Nation statistics[167]. 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[168]. Emissions from this industry are included in CRF 2B5. Ammonia production, 2.B.1, is thus reported as NO.

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 facilities was shut down at 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 4.8. An overview of the rationale for the data sources used for key categories in the industrial processes sector is presented in Annex 3.5.

Table 4.8. Summary of source category description, CRF 2.B.2, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources Estimated
		Level	Trend	Qualitative			
2.B.2	CO_2	NA	NA		NA	NA	NA
	CH_4	NA	NA		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 produced amount of nitric acid, have 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 is not available for all facilities for 1991-1993 and since

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

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

two plants have 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 4.9). The assumed emission factor of 7 kg/Mg for 1991 - 1993 is based on 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. From 2007 N_2O and NO_x emissions are continuously measured in one of the two production lines. From 2011 the emissions are continuously measured in both production lines.

Documentation has been received from the facility concerning production data, production capacity and abatement measures, used emission factors and the method used for estimating emissions as well as uncertainty in emission estimates and measurements. N_2O measurements are carried out using an EN-14181 certified continuous measuring system.

The facility has in 2012 completed a joint implementation project for catalytic reduction of nitrous oxide emissions from the nitric acid production. The project activity involved installation of a new N_2O abatement technology. The new abatement is a combination of precious metal primary catalyst and secondary catalysts which are installed inside all of the Ammonia Oxidation Reactors, underneath the precious metal primary catalyst gauzes. The N_2O emissions are monitored using an automated system based on EU standards.[169], [170]

Table 4.9. Activity data, emission factors and emissions of N_2O for nitric acid production.

Year	Production of nitric acid, (kt)	Calculated IEF, kg/t	Emissions of N_2O, (kt)
1990	374	7.02	2.63
1995	417	5.48	2.29
2000	430	4.80	2.06
2005	264	5.37	1.42
2010	257	3.92	1.01
2011	263	0.50	0.13
2012	265	0.82	0.22
2013	251	0.64	0.16
2014	262	0.67	0.17
2015	239	0.51	0.12
2016	248	0.70	0.17
2017	267	0.52	0.14

4.3.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty for activity data is ± 2 % and the uncertainty of the N_2O emissions, or emission factors for early years, is ± 5 %. The time-series is consistent. The fluctuations in the calculated total EF for N_2O 1994 – 2000 (Table 4.11) 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.

[169] Joint Implementation Supervisory Committee, 2011. YARA Köping S2 N2O abatement project in Sweden.pdf

[170] Joint Implementation Supervisory Committee, 2011. YARA Köping S3 N2O abatement project in Sweden.pdf

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. For the years 1991-1993 the applied emission factor from 1990 have been used together with activity data 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 were reduced compared to previous years. The used abatement system is described in the BREF document for large volume inorganic chemicals[171]. During 2009 the production of nitric acid was lower compared to previous years and also lower compared to later years. The higher N_2O implied emission factor in 2009 is due to that the N_2O reduction catalysts were not used during 2009. This was because 2009 was set as base year in a joint implementation project with the aim to reduce N_2O emissions. For some months in 2010 N_2O-reducing catalysts were used again, now in both production units at the facility. In one of the production units the catalyst was used from March and in the other unit from December. The fact that the catalysts were not used during all months of the year is the reason for the higher implied emission factor in 2010 compared to 2007 and 2008. From 2011 and onwards the catalysts in both production units were used the whole year with a significant decrease of N_2O emissions compared to earlier years. The time series 2011 – 2017 shows that the N_2O emissions tend to vary as much as ± 25% from one year to another. In 2017, the emissions were lower than in 2016 but higher than the emissions in 2015. Hence, no trend can be discerned. Uncertainty estimates are based on information from the company, which is considered to be the best available information.

4.3.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The company is contacted for verification of production capacity and to collect data on purification technology and its effectiveness.

The methodology for estimating N_2O emissions from nitric acid production has been discussed during a joint Nordic workshop in May 2015. A comparison of implied emission factors in Sweden, Finland and Norway (Figure 4.6), based on open UNFCCC data[172], shows similar trend in the three countries – a decrease by 85-90 % compared to the 1990-level. The drop in N_2O implied emission factor in Finland during 2010 is explained by the implementation of N_2O abatement technology (similar as installed in Sweden) at one of the Finnish largest plants. In all the three countries, nitric acid plants are currently equipped with automatic systems based on EU standards to continuously measure N_2O emissions, according to national experts.[173,174]

[171] European Commission, 2007

[172] GHG data from UNFCCC http://unfccc.int/ghg_data/ghg_data_unfccc/items/4146.php , 2015

[173] Kolshus, H. Norwegian Environmental Agency. Personal communication. 2015

[174] Forsell, P. Statistics Finland. Personal communication. 2015

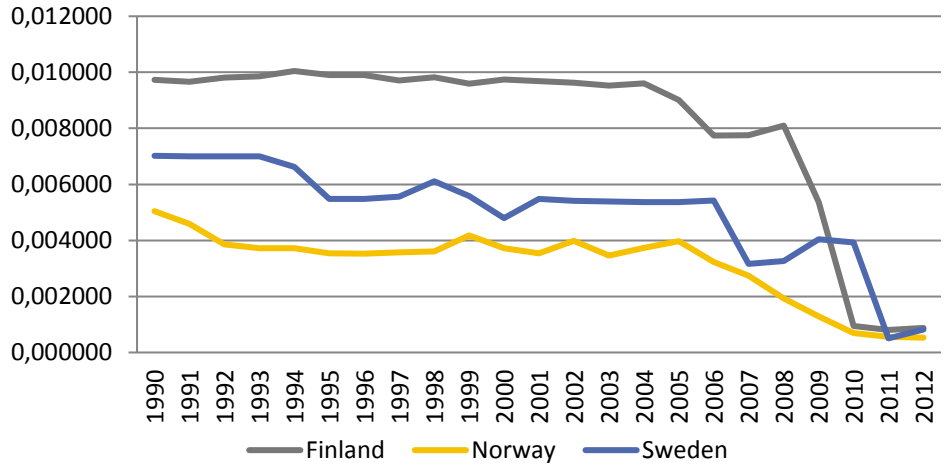

Figure 4.6. Implied N_2O emission factors for CRF 2.B.2 Nitric acid production in three Nordic countries, kt N_2O/Gg nitric acid

4.3.2.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations were performed in submission 2019.

4.3.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.3.3 Adipic acid production (CRF 2.B.3)

4.3.3.1 SOURCE CATEGORY DESCRIPTION

No production of adipic acid occurs in Sweden, and thus NO is reported for CRF 2.B.3.

4.3.4 Caprolactam, glyoxal and glyoxylic acid production (CRF 2.B.4)

4.3.4.1 SOURCE CATEGORY DESCRIPTION

No production of caprolactam, glyoxal or glyoxylic acid occurs in Sweden, and thus NO is reported for CRF 2.B.4.

4.3.5 Carbide production (CRF 2.B.5)

4.3.5.1 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 carbide plant with the exception of emissions from quicklime production are included in 2.B.5.b. Emissions from quicklime production is included in CRF 2.A.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 4.10.

Table 4.10. Summary of source category description, CRF 2.B.5, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.B.5	CO_2				T1	PS	Yes

D Default. PS Plant-specific.

4.3.5.2 METHODOLOGICAL ISSUES

To cover all sources of CO_2 from the production of calcium carbide, estimates of emissions from reduction of quicklime to calcium carbide and emissions from the use of calcium carbide have been made. However, CO_2 emissions from production of quicklime at the carbide plant are reported in CRF 2.A.2 in accordance with the 2006 IPCC Guidelines. In the tables and text below the estimated CO_2 emissions to be reported in CRF 2.B.5.b are presented. Emissions from flaring are allocated to 2B5 together with all other emissions from carbide production.

4.3.5.2.1 CO_2 emissions from calcium carbide production

Calcium carbide is produced in an electric arc furnace at high temperature, 2000 – 3000 ºC. Quicklime, 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 quicklime to calcium carbide, data on produced amounts of calcium carbide, share of gas flared and default emission factor from the 2006 IPCC Guidelines are used. Share of gas flared does not depend on carbide production numbers – thus, CO_2 emissions from carbide production correlate with share of gas flared rather than with carbide production, and IEF based on produced amounts are not relevant.

Table 4.11. Share of flared carbide oven gas and associated CO_2 emissions to be reported in CRF 2.B.5.b.

Year	Flaring time/carbide oven running time, %	CO_2 from the reduction of CaO to CaC_2, (kt)
1990	6 %	3.8
1995	7 %	3.8
2000	14 %	6.0
2005	15 %	6.7
2010	9 %	3.3
2011	11 %	4.2
2012	23 %	8.6
2013	9 %	3.8
2014	10 %	4.0
2015	11 %	4.3
2016	3 %	1.1
2017	4 %	1.4

4.3.5.2.2 CO_2 emissions from use of calcium carbide

In the Revised 2006 IPCC Guidelines it is stated that in addition to reporting CO_2 emissions from calcium carbide production, also CO_2 originating from the use of

calcium carbide has to be reported. To be able to estimate CO_2 emission from use of calcium carbide only the amount of calcium carbide for acetylene production and the use within the country should 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. Annual statistics on imported and exported amounts from 1998 and onwards are available from Statistics Sweden[175]. Amounts used for acetylene production for earlier years are estimated. The default emission factor presented in the 2006 IPCC Guidelines, 1.1 t CO_2/Mg calcium carbide use, has been used for the estimations.

Table 4.12. Used amounts of acetylene and associated CO_2 emissions reported in CRF 2.B.5.b.

Year	Amount of calcium carbide for acetylene production, (kt)	CO_2 from use of calcium carbide for acetylene production, (kt)
1990	7	8
1995	6	7
2000	6	7
2005	9	10
2006	8	8
2007	8	9
2008	9	9
2009	4	5
2010	5	6
2011	5	6
2012	4	4
2013	7	8
2014	6	7
2015	6	6
2016	7	8
2017	6	6

4.3.5.2.3 Time series reported in CRF 2.B.5. b

In Table 4.15, total CO_2 emissions for some years between 1990 and 2017 are presented. The total reported CO_2 emissions in CRF 2.B.5.b are based on:

- produced amounts of calcium carbide, share of gas flared and the default emission factor according to the 2006 IPCC Guidelines
- amount of calcium carbide used for acetylene production within the country and the default emission factor presented in 2006 IPCC Guidelines.

Amounts of produced carbide and used carbide are attributable to different processes with different emission factors, meaning that summarizing them in a one

[175] www.scb.se

set of activity data would not be relevant. Besides, as mentioned above, share of flared gas (actual activity data used for calculation of emissions from the carbide production process) does not correlate with prodution numbers. Activity data for CRF 2.B.5.b is therefore reported as not applicable, NA.

Table 4.13. Time series reported in CRF 2.B.5 b. Activity data is reported as not applicable, NA, in CRF tables.

Year	Activity data as produced calcium carbide, (kt)	CO_2 emissions from production and use of calcium carbide, (kt)
1990	55	11.9
1995	46	10.6
2000	38	12.6
2005	42	16.6
2006	39	14.1
2007	38	13.2
2008	42	13.2
2009	24	7.56
2010	35	9.31
2011	33	10.1
2012	35	13.0
2013	38	11.3
2014	38	10.8
2015	34	10.7
2016	36	9.2
2017	34	7.6

CO_2 emissions from production of quicklime at the carbide production facility are in accordance with the 2006 IPCC Guidelines reported in 2.A.2.

4.3.5.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As can be seen in Table 4.13, CO_2 emissions in 2009 are low compared to adjacent years. This is because the amount of produced carbide that year was lower.

Based on expert judgements, the uncertainty of collected emissions of CO_2 is ±5 %.

4.3.5.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source specific procedures have been made in submission 2019.

4.3.5.5 SOURCE-SPECIFIC RECALCULATIONS

No recalculations have been made in submission 2019.

4.3.5.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.3.6 Titanium dioxide production (CRF 2.B.6)

4.3.6.1 SOURCE CATEGORY DESCRIPTION

No production of titanium dioxide occurs in Sweden, and thus NO is reported for CRF 2.B.6.

4.3.7 Soda ash production (CRF 2.B.7)

4.3.7.1 SOURCE CATEGORY DESCRIPTION

In 2004 a study was carried out to collect data on soda ash use and calculate CO_2 emission[176]. From this study it became clear that no production of soda ash occur in Sweden, and is hence reported as NO in the CRF.

4.3.8 Petrochemical and carbon black production (CRF 2.B.8)

4.3.8.1 SOURCE CATEGORY DESCRIPTION

Petrochemicals and carbon black are produced in Sweden. However, emissions from these sources are reported in CRF 2.B.10 Other, since it is difficult to separate these emissions from emissions from other sources within the chemical industry. Moreover, part of the emissions originating from internal make-up fuels is reported in the CRF 1A since these emissions are very difficult to separate from other emissions from fuel use, which are to be reported in the energy sector. Thus, IE is reported for CRF 2.B.8.

4.3.9 Fluorochemical production (CRF 2.B.9)

4.3.9.1 SOURCE CATEGORY DESCRIPTION

No production of fluorochemicals occurs in Sweden, and thus NO is reported for CRF 2.B.9.

4.3.10 Other (CRF 2.B.10)

4.3.10.1 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. Production of petrochemical products (ethylene, ethylene dichloride and vinyl chloride monomer and ethylene oxide) as well as carbon black, which are described in IPCC 2006 Guidelines under CRF 2.B.8, are included in 2.B.10 due to difficulties in separating these emissions. 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 2.B.10 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 2.B.10.

[176] Nyström, A-K. 2004. CO_2 from the use of soda ash. SMED report 61 2004.

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, 2004 and in 2014 due to the fact that one facility within ”Pharmaceutical industry” reported higher emissions these years.

The SO_2 emissions reported in 2.B.10 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. CO emissions raise in 2014 is due to rather high CO emission from one facility within organic chemical 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 4.14.

Table 4.14. Summary of source category description, CRF 2B10, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.B.10	CO_2	X	X		T3	PS	Yes
	CH_4				T1, T3	PS, D	No, see Annex 5
	N_2O		X		T3	PS	No, see Annex 5

D Default. CS Country Specific. PS Plant-specific. T1 Tier 1. T3 Tier 3.

4.3.10.2 METHODOLOGICAL ISSUES

A total of approximately 70 facilities are included in the Swedish chemical industry. In the 2006 IPCC Guidelines, methods for estimating CH_4 emissions for several chemical products are presented and consequently the CRF Reporter is divided on those products. 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 industry, organic chemical production, inorganic chemical production and other non-specified chemical production.

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. For facilities reporting to the EU ETS, CO_2 emissions from the EU Register are compared to those provided in the environmental reports. Process-related CO_2 emissions in the chemical industries origin mainly from hydrogen production and combustion of internal gases. CO_2 emissions from the use of limestone and soda ash in the process

are included for one plant as well. Limestone and soda ash activity data are collected from the plant's environmental reports and the 2006 IPCC Guidelines emission factors are used together with an assumed limestone purity of 97%.

The 2006 IPCC Guidelines include instructions to allocate emissions from fuels produced within the facility (internal make-up gases) in the corresponding IPCC source category. Sweden has followed the recommendations as far as possible; however, exceptions have been made for some chemical industries, due to the fact that CO_2 emissions in these industries are very difficult to separate from other emissions from fuel use, which are to be reported in the energy sector. In those cases IE has been reported in 2.B.10. For some facilites, there is a certain share of emissions (derived mainly from environmental reports) allocated to 2.B.10 while the remaining emissions are reported in the energy sector. Irrespective of the chosen method, comparisons have been made by applying a cross-sectoral control tool to ensure that all emissions are covered in either sector and that no double-reporting occurs. The tools and procedures used for this comparison and verification are described in more details in the sections 1.3.5.1 and 4.3.10.4.

The 2006 IPCC Guidelines include methods on reporting of methane emissions from production of ethylene oxide. Such production does occur in Sweden (one company). The company's own emission estimate is around 4 tons/year, based on measurements, however a complete time series is not available. Applying the default emission factor, given in the 2006 IPCC Guidelines, results in emissions of about ten times the amount estimated by the company, due to the fact that the plant uses catalytic oxidation, reducing methane emissions by about 90 % according to measurements. Thus, the default method is believed not to be representative and methane emissions from this company is reported NE, since they are less than 0.05 % of the national emissions, and the effort to collect sufficient data is disproportionate to the significance of the emissions.

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 (0.06 kg CH_4/ton production). These emissions are included under 2.B.10 (Other inorganic chemical production) together with the process-related CO_2 emissions, and IE is reported for CRF 2.B.8. Energy-related CO_2 emissions from this facility are reported in the CRF 1.A.

Amounts of product in the chemical industry are attributable to different processes with different emission factors, meaning that summarizing them in a one set of activity data would not be relevant. Activity data for CRF 2.B.10.a is therefore reported as not applicable, NA.

4.3.10.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Based on expert judgements, the uncertainties of collected emissions of CO_2 from inorganic and organic chemical products are ±50 % and ±5 % for CO_2 from base chemicals for plastic industry. The uncertainty of collected emissions of CH_4 is estimated to be ±100 % for all chemical industries reported in CRF 2.B.10.a. Collected emissions of N_2O are associated with an uncertainty of ±125 % according to experts with the exception of N_2O emissions from other organic chemical products where the uncertainty is estimated to be ±80 %.

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

4.3.10.4 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.

Verification of sector emissions and allocation between CRF 1 and CRF 2

Emissions in this sub-category were reviewed as part of a quality control SMED project, financed by the Swedish EPA, during 2010. The project aimed at increasing the quality and reducing the uncertainties in the most important air emissions substances from chemicals industries in Sweden[177]. 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[178]. 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.

Before submission 2018, a development project[179] was carried out with the specific purpose to improve emission allocation between the energy sector and IPPU and to establish a procedure for annual cross-sectoral control of reported emissions. Within this project, a new quality control tool has been developed to ensure that comparisons of emissions in the energy sector and in CRF 2.B.10.a are done on a more regular basis, for the same range of facilities, and using a unified procedure. In the tool, for each of the relevant facilities, emissions reported in the energy sector (CRF 1A) are summed up with the emissions reported in the CRF 2.B.10, and the sum is compared to both EU ETS data (if available) and environmental reporting provided by facilities. Quality control is therefore being conducted on a facility level. In case of discrepancies, they are easily identified and further investigated regarding potential gaps or double-counting.

In 2017 and 2018, allocation issues between mainly the energy sector and IPPU have been further investigated for the chemical industry[180], and in submission 2019 certain changes to the allocation between the sectors have been implemented (se section on source-specific recalculations). An allocation strategy for the chemical sector has been developed which aims at achieving a correct allocation between the sectors according to the 2006 IPPC Guidelines where possible, however making sure that total reported emissions are in accordance with plant-specific data as the main priority.

A comparison between CO_2 emissions reported in environmental reports or to the EU ETS and emissions reported in submission 2019 shows that inventory data

[177] Gustafsson, T., Nyström, A-K., Gerner, A. Riktad kvalitetskontrollstudie av utsläpp från kemiindustrin i Sveriges internationella rapportering. SMED report 2010.

[178] Most recommendations on further investigations refer to the energy sector

[179] Ortiz, C., Jonsson, M., Yaramenka, K., Helbig, T., Danielsson, H. Överlappande mellan CRF 1 och 2, SMED memorandum, 2017

[180] Mawdsley, I., Ortiz, C. Allocation of emissions from the chemical sector between CRF/NFR 1 and CRF/NFR 2, SMED memorandum, 2018

exceeds these two sources for the years 2013-2016 (Table 4.15). The comparison was only made for these years since EU ETS data covers less chemical plants for earlier years. The reason for the inventory estimate being larger is that all plants and sources are not included in the EU ETS or do not report emissions in environmental reports.

Table 4.15. Comparison between CO_2 emissions from environmental reports/EU ETS and reported inventory data, submission 2019.

Source	2013	2014	2015	2016
Environmental reports / EU ETS, kt	1202	1158	1115	1211
Inventory, kt	1364	1259	1203	1423
Difference, kt	162	101	88	212
Inventory data compared to plant data	113 %	109 %	108 %	118 %

Verification of activity data and emissions for some chemical products

Some of the main chemical production processes included in the emission inventory were compared with national production data from Statistics Sweden in order to ensure that all production of these chemical products are accounted for. The results showed that all production of ethylene, VCM, ethylene oxide and carbon black are accounted for in the emission inventory. In addition, comparing implied emission factors calculated from emissions and activity data showed good agreement with emission factors from 2006 IPCC Guidelines.[181]

4.3.10.5 SOURCE-SPECIFIC RECALCULATIONS

A number of recalculations have been performed, mainly due to reallocations of emissions from CRF 1.A.2.c and CRF 1.B.2.C.2.1 to CRF 2.B.10.a for several plants including a larger cracker plant. Reallocations have been performed based on a project carried out in 2017/2018[182] and results from applying the cross-sectoral control tool described in section 1.3.5. Thus, all emissons from the cracker plant are now reported in CRF 2.B.10.a. For four plants, all CO_2 emissions are reported in CRF 1.A.2.C despite some of the emissions being process related and therefore to be reported in CRF 2.B.10.a. This is due to energy data being inseparable when calculating emissions in CRF 1.A.2.C for these plants. For two other plants, the remaining difference between total reported CO_2 emissions by the plants and the total CO_2 emissions in the inventory are reported in 2.B.10.a to ensure that total emissions from the plants are included in the inventory.
The combination of these measures affects significantly emissions of CO_2 and NO_X as well as emissions of CH_4, N_2O, CO, NMVOC and SO_2 to a lesser extent throughout the entire time series. Other recalculations have been performed due to minor corrections of emissions of CO from one plant as well as correcting NMVOC emissions from two plants.

The following table summarizes exemplary all changes in emissions for 2016 due to recalculations and their effect on total emissions reported in CRF 2.

[181] Mawdsley, I., Ortiz, C. Allocation of emissions from the chemical sector between CRF/NFR 1 and CRF/NFR 2, SMED memorandum, 2018

[182] Mawdsley, I., Ortiz, C. Allocation of emissions from the chemical sector between CRF/NFR 1 and CRF/NFR 2, SMED memorandum, 2018

Table 4.16. Summary of performed recalculations in CRF 2.B.10.a and their effects on CRF 2 total emissions for year 2016.

Gas	Value in sub-mission 2018 [kt]	Value in sub-mission 2019 [kt]	Change between submissions [kt]	Change in relation to CRF 2 total (%)
CO_2	138	844	+706	+12.4
NO_X	0.23	0.68	+0.45	+3.7
CH_4	0.03	0.03	+0.0002	+0.07
N_2O	0.02	0.02	+ <0.001	+0.008
CO	0.13	0.12	-0.01	-0.04
NMVOC	2.03	2.00	-0.03	-0.04
SO_2	0.56	0.57	0.004	+0.04

Activity data is reported as NA instead of NE for all plants from submission 2019 onwards since it is not comparable among the different industries and therefore not possible to sum up.

4.3.10.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.4 Metal industry (CRF 2.C)

The sub-categories which are covered in the estimates include iron and steel production (2.C.1), ferroalloy production (2.C.2), aluminium production (2.C.3), SF_6 used in magnesium foundries (2.C.4) and other (2.C.7). Other (2.C.7) consists of estimates from one large non-ferrous smelter plant and one metal recycling plant. Other (2.7.C) also include emissions from lead production (2.C.5), zinc production (2.C.6), and emissions from copper production and nickel production since these emissions cannot be separated.

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

4.4.1.1 SOURCE CATEGORY DESCRIPTION

In Sweden, there are two primary iron and steel facilities equipped with blast furnaces, producing iron and steel products from virgin materials, and about ten secondary steel plants equipped with electric arc furnaces, producing iron and steel products from scrap and direct reduced iron. One of the facilities is using a shaft furnace process to produce stainless steel from recovered flue gas dust and other waste products. 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 refinement processes. From submission 2009 and onwards, emissions from two major iron ore mines and three facilities producing pellets in Sweden are reported in 2.C.1.e. Emissions from one sinter producing facility are reported in 2.C.1.d 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 2.C.1. As the plants also generate emissions from fuel combustion (CRF 1.A.1.c and CRF 1.A.2.a) and fugitive emissions (CRF 1.B.1.c), the text in this section is closely connected to the text in the corresponding section in the energy chapter. Emissions of N_2O do occur to a small extent according to the 2006 IPCC Guidelines[183], however no default method is available and since Sweden has not developed a country-specific method for estimating N_2O emissions, they are reported NE.

In the Swedish inventory, emissions from primary iron and steel production and secondary steel production are reported separately and fed into CRF Reporter under 2.C.1.b Pig iron and 2.C.1.a Steel, respectively. This enables process emissions from the two integrated iron and steel production plants in Sweden to be reported together (2.C.1.b Pig iron), and thus not introducing further sources of uncertainty due to additional data handling. One facility is producing direct reduced iron and its emissions are reported in 2.C.1.c Direct reduced iron.

Production increased in the 1990s and remained at a stable high level until 2008, which is also reflected in the reported emissions. 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. In later years emissions are back at about the same level as prior to 2009.

[183] IPCC 2006 Guidelines. http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf

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. An overview of the rationale for data sources used for key categories in the industrial processes sector is presented in Annex 3.5.

Table 4.17. Summary of source category description, CRF 2.C.1, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.C.1	CO_2	X	X		T2, T3	PS	Yes
	CH_4				T2	CS	No, see Annex 5
	N_2O	NA	NA		NA, NE	NA, NE	No, see Annex 5

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

4.4.1.1.1 Secondary steel production (CRF 2.C.1.a)

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 2.C.1.a. Reported CO_2 emissions also include emissions from the use of limestone and dolomite in secondary steel industry.

The reported CO_2 emissions in CRF 2.C.1.a included data from eleven plants in 1990-2003 and ten plants from 2004. Also another five plants with process related NO_X, SO_2 and/or NMVOC emissions are included in this sector. These plants do not produce steel, and hence do not emit CO_2.

4.4.1.1.2 Primary iron and steel production (CRF 2.C.1.b)

There are two plants in Sweden that 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 ensure oxidation and to act as reducing agents. The associated emissions are thus to be reported as industrial processes from iron and steel production in CRF 2.C.1, according to the IPCC Guidelines.

During 2015, blast furnace at one of the facilities was closed for renovation. The blast furnace was stopped for several month, and after it was in operation again, pig iron production required substantially lower input of injection coal and coke than usually, according to the facility. This is why in 2015, CO_2 emissions were relatively low and did not follow the trend for pig iron production.

4.4.1.1.3 Direct reduced iron (CRF 2.C.1.c)

There is one plant in Sweden which produces iron sponge and iron powder using direct reduction of iron ore pellets.

4.4.1.1.4 Sinter (CRF 2.C.1.d)

During 1990-1995 a sinter plant was in operation at one of the integrated primary iron and steel plants. Operation of sinter plants produces CO_2 emissions from oxidation of the coke breeze and other inputs. When carbon-containing materials are heated in the furnace for sinter production or iron production, volatiles, including CH_4, are emitted[130]. SO_2 from the sulphur content in the ore is also considered to be emitted from the facility.

4.4.1.1.5 Pellet (CRF 2.C.1.e)

CO_2 emissions arise mainly from the use of limestone and dolomite, and to a smaller extent from bentonite and organic binder. SO_2 emissions, which stem from the sulphur content in the ore and NO_X emitted as a result of the use of explosives, are also reported from pellets production. The use of mining explosives also causes emissions of carbon monoxide, CO[184], which however are not reported. Estimated emissions from combustion of fuels are included in the Energy sector (CRF 1). In 2014 the SO_2 emissions were lower than previous years due to implementation of stage one of a new abatement technology at one facility. Stage two was completed by the end of 2015. The new abatement technology have led to a reduction of the SO_2 emissions by more than 95%.

4.4.1.1.6 CO_2 emissions reported in Other (CRF 2.C.1.f)

No emissions of CO_2 reported in this source category.

4.4.1.2 METHODOLOGICAL ISSUES

4.4.1.2.1 Secondary steel production (CRF 2.C.1.a)

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 CO_2 emissions. Prior to submission 2010, these other emissions were not included for all facilities. Estimates of these missing CO_2 emissions were performed using ETS data for 2005 – 2008 and production data for years prior to 2005. All CO_2 emissions presented for the facilities in ETS 2005 – 2017 are included in 2.C.1.a.

Reported CO_2 emissions until year 2008 are for all facilities, except the one which closed down in 2004, based on data in the ETS. Reported CO_2 emissions can therefore be classified to follow the 2006 IPCC Guidelines Tier 2, since according to the Guidelines reported emissions shall be based on all carbon input to and carbon output from the process. From 2009 to 2012 background data needed for estimation of process-related CO_2 emissions for one facility is collected from the facility's environmental report, since all data needed could not be retrieved from ETS for these years.

For non- CO_2 emissions, the companies' environmental reports are the main information source. NO_X, NMVOC and SO_2 emissions emitted from electric arc furnaces are reported in 2.C.1.a. NO_X emissions may also arise from pickling and NMVOC emissions from rolling mills. These sources are also included in the estimates.

4.4.1.2.2 Primary iron and steel production (CRF 2.C.1.b)

Sweden uses the recommended Tier 3 method according to the 2006 IPCC Guidelines and the calculations of CO_2 emissions are based on carbon mass-

[184] Wieland, M.S. 2004.

balances in order to reduce the risk of double counting or omitting CO_2 emissions. Calculations of CO_2 emissions and simplified mass-balances are made by facilities as a part of their reporting to ETS. Emissions are also specified in the facilities' environmental reports that are used as a primary information source for estimation of emissions from CRF 2.C.1.b and other CRF sub-sectors relevant for primary iron and steel production. Total CO_2 emissions as specified in the facilities' environmental reports are further verified by more detailed mass-balances developed by emission inventory experts and based on ETS reporting complemeted with data from faciltities' environmental reports. While environmental reports are used to distribute total reported CO_2 emissions by relevant CRF codes, reporting to ETS provide data on carbon contents in all in-coming materials and products. The total CO_2 emissions in both sources are exactly the same.

Production processes and plant stations – an overview

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

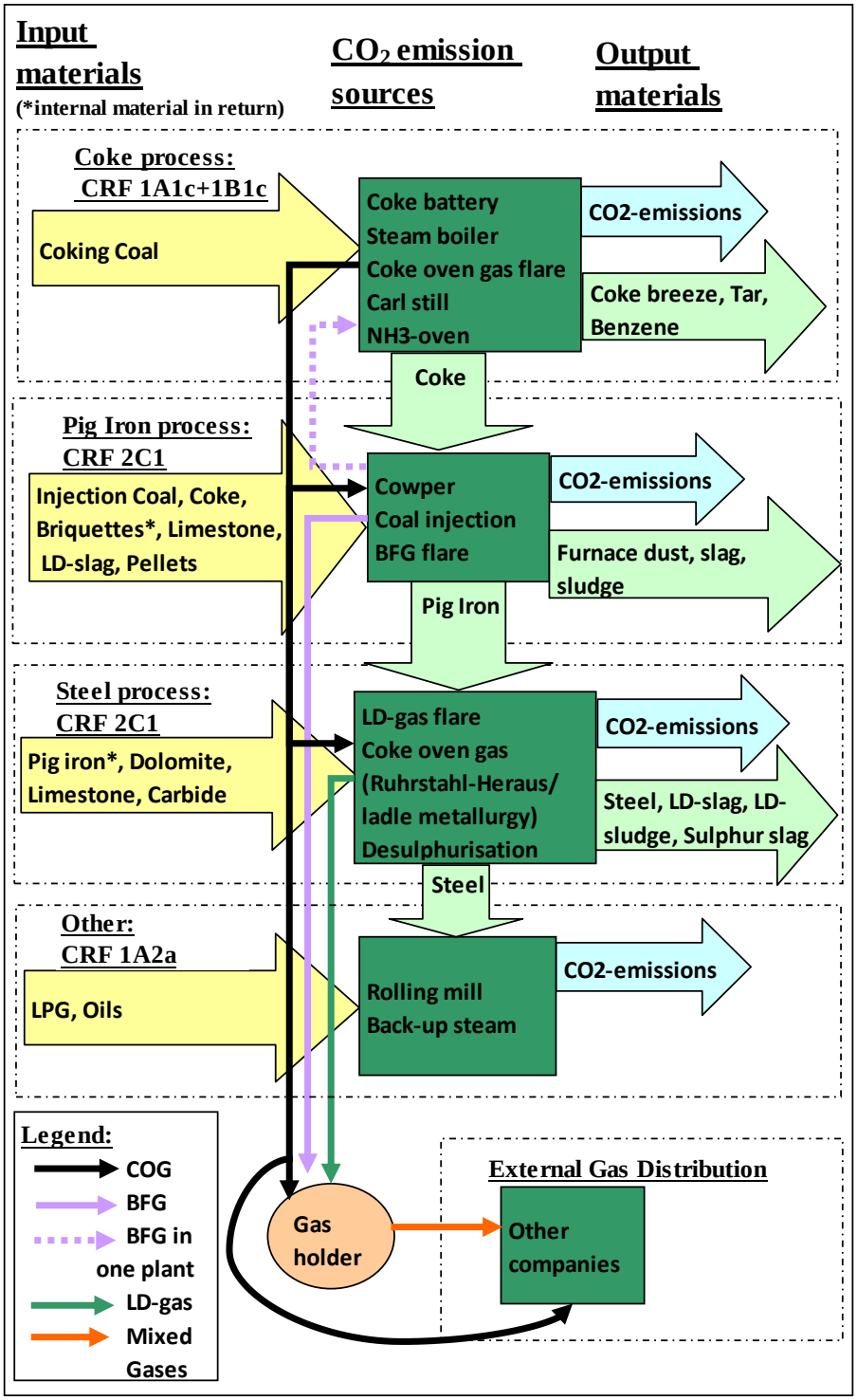

Figure 4.7. Carbon flow chart of integrated primary iron and steel plants in Sweden

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

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.

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 1.A.1.a 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 in accordance with the 2006 IPCC Guidelines[185] where allocation of emissions from delivered gases is described.

Distribution of total CO_2 emissions for national reporting

During the whole process from raw material to final product, emissions of CO_2 are released. The **allocation of total CO_2 emissions and energy consumption (TJ)** on plant stations and consequently CRF sub-sectors is based on measured fuel consumption and associated CO_2 emissions (see Tables 4.18 and 4.19 and the describing text below). Note that energy consumption (TJ) cannot be reported in CRF-reporter for 2.C.1.b.

Table 4.18. Allocation of CO_2 emissions in integrated primary iron and steel production

Year	CO_2 emissions, kt					
	1.A.1.a	1.A.1.c	1.A.2.a	1.B.1.c	2.C.1.b	Total
1990	4 418	300	876	5	2 094	**7 694**
1995	4 800	341	993	6	2 383	**8 524**
2000	5 384	335	1 101	6	2 270	**9 096**
2005	8 668	344	1 160	5	2 206	**12 384**
2010	6 937	313	950	5	2 317	**10 523**
2017	2 374	376	599	5	1 607	**4 961**

[185] See 2006 IPCC Guidelines: Volume 3: Industrial Processes and Product Use, Box 1.1 (page 1.8)

Table 4.19. Allocation of energy consumption in integrated primary iron and steel production

Year	Consumed energy, TJ						
	1.A.1.a	1.A.1.c	1.A.2.a	1.B.1.c	2.C.1.b	Products and losses	Total
1990	5 278	4 433	3969	116	15 584	29 921	**59 300**
1995	5 683	5 048	4 498	132	15 522	29 801	**60 684**
2000	7 990	4 647	4 977	120	15 620	29 991	**63 345**
2005	8 879	4 834	5 280	115	17 586	33 765	**70 459**
2010	7 384	4 069	4 331	109	17 151	32 929	**65 972**
2017	7 907	4 493	4 023	115	7 687	26 918	**51 143**

Main data sources used for allocation of emissions and energy flows in **2003-2017** are environmental reports and personal communication. Amounts of derived solid fuels (COG, BFG, LD-gas) – combusted/ flared at different plant stations as well as sold outside – are available in the environmental reports. CO_2 emissions by station are obtained directly from one of the plants, and for the other plant all emissions are derived from environmental reports. Emissions from coke oven at this plant cover both COG combustion in coke ovens (CRF 1.A.1.c) and flaring (CRF 1.B.1.c) – emissions from flaring are calculated with national CO_2 emission factors, and the remaining emissions are allocated to CRF 1.A.1.c. Emissions from sold energy gases CRF 1.A.1.a) are calculated based on amounts specified in environmental reports, and national emission factors.

For **1990-2002**, CO_2 emissions for one of the plants were obtained directly from the plant. 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 1.A.1.c, 1.A.2.a, 1.B.1.c and 2.C.1.b) in 1990-2002 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 2006 IPCC Guidelines 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 2.C.1.b is produced amount of primary pig iron. Amounts of pig iron produced 1990-2002 were obtained directly from both plants.

Energy allocated to **products and losses** (primary and secondary products, distribution losses and transformation losses) is estimated as total energy in input materials and stock change subtracted by the measured energy in fuels used, and consequently emissions are not applicable. Data on main input materials and their calorific values are summarized based on environmental reporting and personal communication with the facilities[186]. Examples of material inputs for certain years, as well as their calorific values, are given in Tables 4.20 and 4.21, respectively.

[186] Gustafsson et al. 2011

Table 4.20 Material input in the Swedish iron and steel production processes, ton

Plant	Year	Coking coal	External coke	Injection coal	External scrap metals	Source
1	1990	937 000	60 000	100 000	175 000	Personal communication
1	1995	920 000	70 400	102 000	141 400	Personal communication
1	2000	920 700	56 300	146 700	63 900	Personal communication
1	2005	946 100	39 300	314 000	113 200	Environmental report
1	2010	895 800	117 900	286 500	114 700	Environmental report
2	2005	623 972	136 901	170 217	94 289	Environmental report
2	2010	583 274	127 310	94 754	16 476	Environmental report

Table 4.21 Calorific values by input material in the Swedish iron and steel production processes, GJ/ton

Plant	Coking coal	External coke	Injection coal	External scrap metals	Source
1	31.31	29.66	31.31	7.35	Personal communication
2	27.5	31	31	7.35	Environmental report

Verification with data reported to ETS: CO_2 emissions and detailed carbon mass-balances

Detailed mass-balances, simplified energy balances and carbon and energy flow charts according to EU ETS have been compiled for the two plants included in the reporting for several recent years. Due to data confidentiality, they cannot be displayed here but can be provided for reviewers upon request.

The carbon contents of external input materials such as coking coal, coke, injection coal, limestone, etc., are balanced against final output materials; coke and pig iron[187], steel, tar, sludge, slag, etc. The remaining carbon contents are accounted for as CO_2 emissions:

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

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*).

The mass balances indicate that among all input materials coking coal makes the largest cocntribution to the carbon inputs. Carbon content of the coking coal was summarized and the relevant time-series for both facilities were compiled within a delopment project during fall 2018[188]. Due to data confidentiality, these time series cannot be displayed here but can be provided for reviewers upon request.

[187] If put in stock or sold externally

[188] Yaramenka, K, Jönsson, M, 2018, Förbättringar av inventeringar av utsläpp från SSAB, SMED PM

It is important to note that carbon mass balances are not used directly in the calculations of CO_2 emissions from integrated iron and steel facilities but mainly as a verification tool, for the following purposes:

- To assure that data on CO_2 emissions and energy flows at the facilities, available in their environmental reports, are consistent with the EU ETS reporting;
- To estimate non-emissive energy use (losses and product-bound materials);
- To verify energy use and emissions in the CRF 1.A.1.a attributable to combustion of solid fuels sold by the integrated iron and steel facility to the power sector.

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 1.A.1.c, 1.A.2.a, 1.B.1.c and 2.C.1.b) are taken from the environmental reports.

Emissions of **CH_4, 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 Annex 2). 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 2.C.1.b. Emissions of NO_X and SO_2 are based on detailed plant information from the environmental reports.

4.4.1.2.3 Direct reduced iron (CRF 2.C.1.c)

Emissions of CO_2 are calculated using the 2006 IPCC Guidelines Tier 3 method. 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 for 1990-2004 information has been acquired 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 2.C.1.c. The remaining amounts of natural gas used by the facility are considered to be energy-related and the corresponding emissions are reported in the Energy sector (CRF 1.A.2.a). Limestone used in the production is included in the emissions from the production of iron powder in CRF 2.C.1.c. Reported activity data is produced amount of direct-reduced iron (iron sponge).

For CH_4 emissions from direct reduced iron, test calculations have been made with default emission factors applied for the total amount of natural gas used at the facility. The resulting CH_4 amounts are thousand fold below the national totals of 30 kt CO_2 eq, meaning that these emissions can be considered insignificant. CH_4 is therefore reported as NE.

4.4.1.2.4 Sinter (CRF 2.C.1.d)

During 1990-1995 a sinter plant was in operation at one of the integrated primary iron and steel plants. No plant-specific or national emission factors are available. Thus, in accordance with the 2006 IPCC Guidelines, emissions are estimated using production data and default emissions factors (0.2 t CO_2/t sinter produced and 0.7 kg CH_4/ t sinter produced). Production data has been collected from "Statistics of the Swedish Mining Industry"[189] produced by the Geological Survey of Sweden (SGU).

4.4.1.2.5 Pellet (CRF 2.C.1.e)

Production data (iron pellets) are collected from the facilities yearly environmental reports from 2006 onwards. For earlier years national production statistics from Statistics Sweden are used. SO_2 emissions have been supplied by the facilities for the entire time series. Amounts of bentonite and organic binder used for the production of iron ore pellets and the corresponding CO_2 emissions are for later years collected from the EU ETS. For earlier years the amounts of bentonite and organic binder were provided by the company and EFs for bentonite and organic binder from the EU ETS were used for the calculations. Also information on limestone and dolomite used in the pellets production is collected from the EU ETS. In the EU ETS information of the amounts of carbon bound in products are available. For earlier years the average of these figures are used to estimate how much of the carbon that is not emitted but bound in product. The 2006 IPCC Guidelines emission factor for limestone and dolomite use is used to calculate CO_2 emissions and a purity of 97 % and 100 % are used for respective carbonate. 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

During the preparation of submission 2013 for reporting to UNFCCC a significant increase in the CO_2 implied emission factor (IEF) for year 2011 for the two primary pig iron production plants was noticed. This was due to the fact that the reported CO_2 emissions were overestimated for one of the plants. During 2011, one of the two blast furnaces at the plant was out of operation from July until December, and consequently the production of pig iron decreased compared to the previous year. At the same time the production rate at the coke plant was kept under normal conditions. This resulted in an increased intermediate stock of coke at the plant. After consulting the operator it was concluded that the operator did not take into account any intermediate stock change of produced coke in the carbon mass balance used when calculating the CO_2 emissions, i.e. large amounts of carbon assumed to be released into the atmosphere was actually stored in the coke stocks. This led to an overestimation of CO_2 emissions not in line with the IPCC methodologies prescribed by the UNFCCC for annual greenhouse gas emission inventory reporting. The operator explained that the same method has been used for all years since emission year 2005, i.e. the first year for reporting to EU ETS. The exclusion of the change in storage of coke in the carbon mass balance is more pronounced for years when for example the operation of the blast furnaces has been restricted (e.g. 2011). During 2012 the operator applied to the county administrative board to change their monitoring methodology for CO_2 according to ETS, i.e. including any intermediate stock change of produced coke in the carbon

[189] Geological Survey of Sweden. http://www.sgu.se.

mass balance. However, the method change did not apply until emission year 2012. During 2013 the Swedish EPA initiated a project in order to achieve an accurate time series for CO_2 emissions from the plant for the submission 2014 reporting to the UNFCCC. Direct contact was taken with the operator of the plant of concern. For the purpose of UNFCCC reporting, the operator has revised its data by year excluding the annual amounts of produced coke stored at the facility from its carbon mass balance.[190]

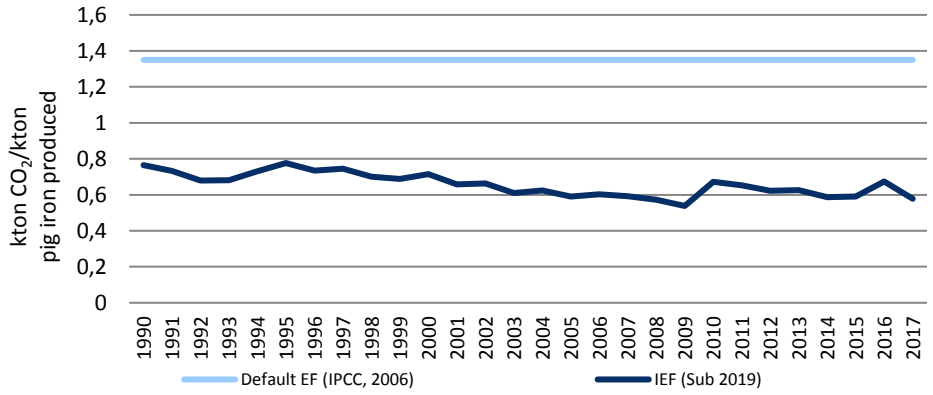

Figure 4.8 Default 2006 IPCC CO_2 EF for pig iron production and the CO_2 IEF for primary pig iron production in Sweden for submission 2019.

Figure 4.8 shows the default 2006 IPCC CO_2 EF for pig iron production and the CO_2 IEF for primary pig iron production in Sweden for submission 2019. It is obvious that the Swedish CO_2 IEF (0.54-0.78 kt CO_2/t pig iron) is significantly lower than the default IPCC value (1.35 kt CO_2/t pig iron). The main reason for the large difference is due to the allocation model used in the Swedish inventory, where large amounts of derived gases (and associated CO_2 emissions) produced in the processes (blast furnace and LD-steel converters) are used in the coke plant and for power and heat production purposes.

As the different process gases are allocated to different source categories according to a system, the implied emission factor for CRF 2.C.1.b can show an annual variation as a result of this allocation, which is not in correlation with the total emissions from the industry. However, several energy efficiency measures have been undertaken, e.g. increased temperature in the blast furnaces and increased recycling of energy gases and by-products[191], leading to a decrease in CO_2 IEFs since 1990 for primary pig iron and steel production, from 0.77 kt CO_2/kt iron in 1990 to 0.54 kt CO_2/kt pig iron in 2009 (see Figure 4.8).

In 2010, reparation work was performed at the LD gas holder at one of the plants, and during 2011 the LD gas holder was out of operation during a large part of the year because of problems with leakage after repairing the unit in 2010. During 2010-2012 there were disruptions or constraints in the production at the blast furnaces at the second plant and the start-ups of the blast furnaces after disruptions

[190] Skårman, T. and Gustafsson, T. 2013. Revision of estimated greenhouse gas emissions for integrated iron and steel production. SMED Report No 126 2013.

[191] ENET-Steel, 2007.

require extra fuel. Still in 2014, only one out of two blast furnaces was in use, due to the overall weak economy. These activities or events may have contributed to the higher CO_2 IEF for 2010-2016.

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 2.C.1.b); based on 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.

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 reported 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 2006 IPCC Guidelines. Detailed carbon mass balances according to the EU ETS are compiled for both integrated iron and steel plants included in the reporting. This information is used for verification but for 2015-2017 cannot be displayed due to data confidentiality. More information on QC activities related to EU ETS is included in Annex 8.1.

Emissions from this source are included in the cross-sectoral control tool that was developed in 2017, described in detail in section 1.3.5.

Due to the fact that one of the operators of the integrated iron and steel plants did not take into account any intermediate stock change of produced coke in the carbon mass balance used when calculating the CO_2 emissions (see section 4.4.1.3), there will be discrepancies in the annual CO_2 emissions used in the reporting to the UNFCCC and the plant-specific data already reported to the EU ETS for 2005-2012. It should be noted that 2011 is the year with the largest discrepancy in reported CO_2 emissions between the two sources.

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

For the company producing iron sponge by direct reduction of iron, the CO_2 IEF seems to have increased during the time period 1990-2014 (see Figure 4.10). However, this is due to the fact that the production of iron powder has increased with about 140 % over the time period whereas the production of iron sponge has been relatively stable. The reduction of iron to iron sponge gives rise to most of the process-related CO_2, although some CO_2 is released by the production of iron powder. Almost all of the produced iron sponge is further processed to iron powder. Iron powder is however also produced from other raw materials, such as scrap materials, adding to the CO_2 emissions. This production has increased substantially over the time series; in 1990 approximately 80 % of the iron powder produced at the plant originated from the plant's production of iron sponge, and in 2014 that figure has decreased to around 30 %, indicating that other materials now stand for the majority of the iron powder production. This is the reason why the implied emission factor for CO_2 seems to be increasing when using sponge

production as activity data. However, if calculated from total iron powder production it is decreasing.

As the main part of process-related CO_2 emissions stem from iron sponge production, this has been chosen as reported activity data. Figure 4.9 illustrates the different IEFs as well as the trend of the production ratio of iron sponge to iron powder production. Due to data confidentiality, data for 2015-2017 cannot be displayed.

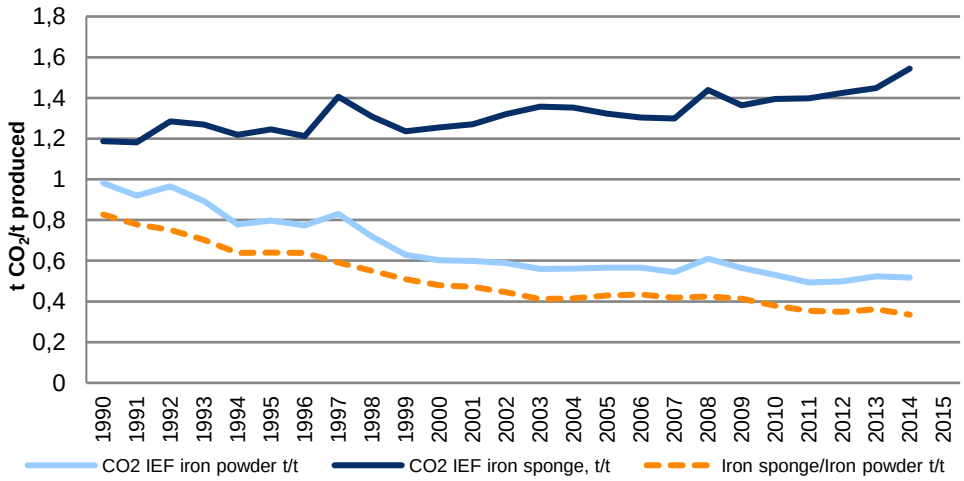

Figure 4.9. CO_2 implied emission factors in relation to iron sponge production and total iron powder production, as well as the production ratio of iron sponge to iron powder.

4.4.1.5 SOURCE-SPECIFIC RECALCULATIONS

2.C.1.a: Small corrections have been made for the years 2015 and 2016 in submission 2019. The resulting changes in the emissions of SO_X are 0.0005 kton for 2015 and 0.0004 kton for 2016.
2.C.1.b: No recalculations have been made in submission 2019.
2.C.1.c: No recalculations have been made in submission 2019.
2.C.1.d: No recalculations have been made in submission 2019.
2.C.1.e: Activity data have been updated and are now mainly from the facilities annual environmental reports. This leads to minor changes in reported SO_2 emissions from one of the plants from 2009 to 2016. To submission 2019 the timeseries for CO_2 is updated. The amounts of carbon that is not emitted but bound in product is now not included in reported emissions. This results in decreased CO_2 yearly emissions between 7 kton and 29 kton.

4.4.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.4.2 Ferroalloy production (CRF 2.C.2)

4.4.2.1 SOURCE CATEGORY DESCRIPTION

Due to data confidentiality, data for 2015-2017 cannot be displayed for this category. 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 2.C.1. The production of ferrosilicon has decreased sharply since 2005, and between 2008 and 2011 and again in 2014, there was no production at all. As CH_4 emissions within CRF 2.C.2 stem only from ferrosilicon production, this led to zero emissions of CH_4 during these years. In addition, production of ferrosilicon leads to larger emissions of SO_2 compared to production of ferrochromium, which is why the reduced or non-existent ferrosilicon production since 2005 resulted in a distinct decrease in SO_2 emissions. The economic recession in 2009 had a great effect on production volumes of ferroalloys in Sweden and thus the emissions 2009 are significantly reduced compared to adjacent years.

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 4.22.

Table 4.22. Summary of source category description, CRF 2.C.2, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.C.2	CO_2				T3	PS	Yes
	CH_4	NA	NA		NA	NA	NA
	N_2O	NA	NA		NA	NA	NA

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

4.4.2.2 METHODOLOGICAL ISSUES

The estimation of CO_2 emissions due to the production of ferroalloys are plant specific (in line with Tier 2). CO_2 emissions reported by the plant are calculated based on consumed amounts of reducing agents (Tier 1a[192]), i.e. electrodes and coke (and in 2003 coal), together with their specific carbon contents, and the amount of carbon bound in produced ferroalloys. The general carbon balance is:

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

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

- Emission factors and thermal values used for stationary combustion for coke and coal and information from the company that the electrodes contain 90 % carbon.
- IPCC default factors for coal, coke and electrodes[193].

The following formula is used:

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

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

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

where 44/12 is the molecular weight ratio of CO_2 and carbon. As can be seen in Table 4.20, there are differences in the plant specific data, 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 coke may vary from one year to another.

Since 2013 the CO_2 emission is entirely calculated based on plant-specific data on raw material consumption and its carbon content as well as the carbon content of products produced and the carbon content in slag and dust as reported to EU ETS.

The following formula is used:

$$[(AD_{coke} \times CC_{coke} + AD_{coal} \times CC_{coal} + AD_{graphite\ electrodes} \times CC_{graphite\ electrodes} + AD_{chrome\ ore} \times CC_{chrome\ ore} + AD_{added\ material} \times CC_{added\ material}) - (AD_{slag} \times CC_{slag} + AD_{produced\ metal} \times CC_{produced\ metal} + AD_{dust} \times CC_{dust})] \times 44/12.$$

Where AD and CC denotes the Activity Data of each component and its Carbon Content, respectively. The ratio 44/12 is the molecular weight of carbon dioxide divided by the atomic weight of carbon.

Total amounts of carbon in the produced ferroalloys is presented in Table 4.21, and is calculated based on the carbon content in coke, coal, electrodes and dust. The amount of carbon in the produced ferroalloys varies between 0.1 % and 7 %. This carbon is stored in the product and reported under CRF 1.AD.10 (Non-energy use of fuels and feedstocks) - coke and coal.

As activity data, the carbon content of coke, electrodes and slag binder is used. The reason for this is that the company produces both ferrochrome and ferrosilicon, which bind carbon to different extents. The relative production of each product varies greatly between years (Table 4.23), affecting CO_2 emissions to a large extent. To report total production volumes as activity data would therefore not give any good indication on the relation between production and CO_2 emissions.

CH_4 emissions from production of ferrosilicon alloys are reported from submission 2010 and calculated based on ferrosillicon alloy production (Tier 2[194]). 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.

[194] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Table 4.8

Table 4.23. 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. Due to data confidentiality, data for 2015-2017 cannot be displayed.

Year	Plant specific data, (kt CO_2)	Swedish values, (kt CO_2)	IPCC default values, (kt CO_2)
1990	243	244	263
1995	265	274	295
2000	240	266	287
2005	225	215	231
2010	107	96	104
2011	117	122	132
2012	101	100	108
2013	88	75	81
2014	110	100	109

Table 4.24. Total amount of carbon bound in produced ferroalloys and production data. Due to data confidentiality, data for 2015 - 2017 cannot be displayed.

Year	Carbon in ferroalloys, (kt)	Ferrosilicon, (kt)	High Carbon Ferrochrome, (kt)	Charge chrome, (kt)
1990	8.4	20.6	NE	NE
1995	8.7	23.4	NE	NE
2000	9.5	20.2	34.2	98.7
2005	8.0	10.5	41.5	78.4
2010	4.0	0	1.6	59.5
2011	4.7	0	80.1	0
2012	2.2	9.8	39.0	0
2013	2.7	0.9	49.0	0
2014	4.1	0	66.0	0

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.

The time-series are considered to be consistent.

4.4.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

As presented in Table 4.20 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 were performed in ferroalloy production during submission 2019.

4.4.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.4.3 Aluminium production (CRF 2.C.3)

4.4.3.1 SOURCE CATEGORY DESCRIPTION

There is one facility that produces primary aluminium in Sweden. The facility consists of two plants. One of the potlines (plant 1) includes 56 closed Prebake cells (CWPB), each of 150 kA. The other plant (plant 2) consisted of 262 cells and, until the beginning of 2008, operated three closed Prebake cells and 259 open cells with Söderberg anodes (VSS). The Söderberg anodes were produced in an electrode pulp factory at the facility. In 2012, 56 closed Prebake cells in plant 1 and 242 closed Prebake cells were in operation. From 2008, when all Söderberg cells were shut down, these pot-lines have gradually been replaced by closed Prebake cells. During the conversion from Söderberg technology to Prebake technology there were start-up problems that caused increased emissions of PFC, especially in 2010 and 2011.

The time series of emissions compiled for primary aluminium production include emissions of CO_2, PFCs, NO_X, CO, NMVOC and SO_2. Use of SF_6 as a cover gas is not occurring in Swedish aluminium foundries, thus reported as 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. An overview of the rationale for data sources used for key categories in the industrial processes sector is presented in Annex 3.5.

Table 4.25. Summary of source category description, CRF 2.C.3, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.C.3	CO_2	X			T2	PS	Yes
	CH_4	NA	NA		NA	NA	NA
	PFCs	X	X		T2	D	Yes

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

4.4.3.2 METHODOLOGICAL ISSUES

Reported production statistics and emissions data are based on information in the environmental reports or received directly from the company.

Emission data for CO_2 from the production of primary aluminium 2001 - 2017 are derived through measurements and reported directly by the plants, whereas the emissions for 1990-2000 are calculated based on the mass of coal elements (anodes) such as electrodes, coke etc. and the amount of carbon that is bound in soot and rest anodes. The formula used for CO_2 (t) for 1990-2000 is:

$$\text{Mass anodes (100\% C)} \times \frac{44}{12} \times (1 - 0.259^{*})$$

* Average mass CO_2 bound in soot and rest anodes 2001-2008

The value for carbon bound in soot and rest anodes (0.259) is based on average of reported values for 2001-2008. For subsequent years the amounts bound in soot and rest anodes vary between 0.181 and 0.297. The low IEF for 1992 might be

explained by the use of a too high perccentage of carbon bound in soot and rest anodes. Apart from 1992, the variation in IEF between years is relatively small.

For the years from 2001 and onwards the emissions reported by the plant have been verified by collecting data on the amount of coal elements used and by calculating the emissions based on the equation above. Both methods show similar results.

The carbon bound in soot and in rest anodes is not emitted to the atmosphere as CO_2, and it is therefore excluded in the reported CO_2 emissions in 2.C.3. Therefore, the IEF values in the Swedish inventory are lower than the IPCC Guidelines Tier 1 default emission factors for Prebake and Söderberg technologies (1.6 and 1.7 kt CO_2/kt produced Al) (Table 4.26).

Table 4.26. Implied emission factor for CO_2 for the production of aluminium.

Year	Aluminium production (kt)	Emissions of CO_2 (kt)	IEF kt CO_2/kt Al
1990	96	133	1.4
1995	94	129	1.4
2000	101	145	1.4
2005	103	144	1.4
2010	96	135	1.4
2011	113	159	1.4
2012	131	200	1.5
2013	131	198	1.5
2014	114	173	1.5
2015	119	180	1.5
2016	124	190	1.5
2017	126	206	1.6

The two different processes for aluminium production, Prebake (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.

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 Prebake and Söderberg technologies. The reported emissions and calculated Implied Emission Factors are presented in Table 4.27.

Table 4.27. Activity data, emissions of C_2F_8, CF_4 and calculated IEF for aluminium production

					Calculated IEF			
Year	Al production, CWPB, kt	Al production, VSS, kt	Total emissions, C_2F_6 t	Total emissions, CF_4 t	CWPB kg C_2F_6/t	VSS kg C_2F_6/t	CWPB kg CF_4/t	VSS kg CF_4/t
1990	23.4	72.9	4.27	69.92	0.0426	0.0449	0.3518	0.8463
1995	22.8	71.2	3.56	64.65	0.0102	0.0467	0.0845	0.8808
2000	23.0	78.1	2.46	45.08	0.0057	0.0299	0.0470	0.5635
2005	23.6	78.9	2.67	49.84	0.0021	0.0332	0.0175	0.6262
2010	96.1	-	2.52	20.80	0.0262	-	0.2164	-
2011	113.3	-	2.90	24.00	0.0256	-	0.2118	-
2012	130.8	-	1.05	8.68	0.0080	-	0.0663	-
2013	131.0	-	0.68	5.62	0.0052	-	0.0429	-
2014	113.7	-	1.10	9.12	0.0097	-	0.0803	-
2015	119.4	-	0.47	3.86	0.0039	-	0.0323	-
2016	124.1	-	0.42	3.43	0.0033	-	0.0277	-
2017	125.8	-	0.49	4.07	0.0039	-	0.0323	-

Reported emissions of NO_X are calculated from production statistics using emission factors defined by Swedish EPA[195]. NMVOC emissions are calculated from reported emissions of tar, assuming that 70 % of the tar is emitted as NMVOC[196]**Fel! Bokmärket är inte definierat.**. Closing down the Söderberg o vens also eliminated the need for anode production in late 2008.

The shutdown of the anode production ended the tar emissions which meant that also the NMVOC emissions fell sharply. From 2009 and onwards, emissions of NMVOC are reported NE since no emission factor is specified in the EMEP/EEA Guidebook.
CO emissions were for the first time reported in submission 2008 and are for 2002 - 2017 as reported in the company's environmental reports. For the period 1990 to 2001, the CO emissions are calculated based on production statistics and emission factors provided by the company. The same method is used for SO_2 emissions during 1990 to 2005. For later years SO_2 emissions data are based on environmental reports published by the company.

The elevated SO_2 emission in 2012 is primarily due to high sulphur content in delivered anodes. The desulfurization of flue gases in the flue gas treatment facilities was not sufficiently efficient. In 2014 the SO_2 emissions were lower than previous year due to improved abatement technology. The improved abatement technology is also shown in low SO_2 emissions in 2015 - 2017. Also the CO emissions were higher for 2012 compared to previous years. The reason for this is, according to the company, that a new calculation method has been used from 2012 onwards.

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

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

4.4.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty for activity data is estimated to ± 2 %. The uncertainty for CO_2 emission factor is estimated to ± 5 %. Uncertainty for SO_2, NO_X and NMVOC are ± 30%, ± 50%, ± 75%, respectively.

As can be seen in Table 4.22 the IEFs show a downward trend from 1990 to 2007, especially so for CF_4. This reflects the company's on-going work aiming to reduce the time and frequency of the anode minutes. Between 2008 and 2011 the Söderberg pot-lines have gradually been replaced by closed Prebake cells.

By the end of December 2009, 120 of a total of 262 cells in plant 2 had been converted to the Prebake technology and in the beginning of December 2010 242 Prebake cells in plant 2 were in operation. At the end of December 2010 a power outage lead to major disturbances in plant 2 leading to both increased emissions and major production problems. On January 7 2011, 120 Prebake cells were shut down as a direct result of the power outage. At the end of June 2011 all Prebake cells in plant 2 were restarted and in operation.

The shutdown of Söderberg ovens explains the very large decline in PFC emissions in 2009 (-89 % compared to 2008) (Figure 4.10). Also the reported CO_2 has declined in 2009 relative to previous years. The cold winter in 2010 resulted in high power input to the anodes, thus leading to high emissions of PFCs. There were also problems with power outages which affected the production and led to increased number of AE minutes. During the start-up period in 2011, emissions to air increased but later in 2011 the emissions decreased to expected levels. During the first few months in 2012 there was however problems with disturbances in the oxide distribution, leading to elevated emissions of PFCs. In all, the PFC emissions in 2012 were considerably lower in comparison to 2010 and 2011. In 2013 the PFC emissions continued to decrease due to the fact that the production process was stable with less anode effects in min/oven day. In 2014 the PFC emissions were higher than 2013 year due to a transformer failure that caused disturbances in the production. In August 2015 a new transformer was installed and operating which led to lower emissions of PFCs in 2015 - 2017.

The reported time series are considered to be consistent.

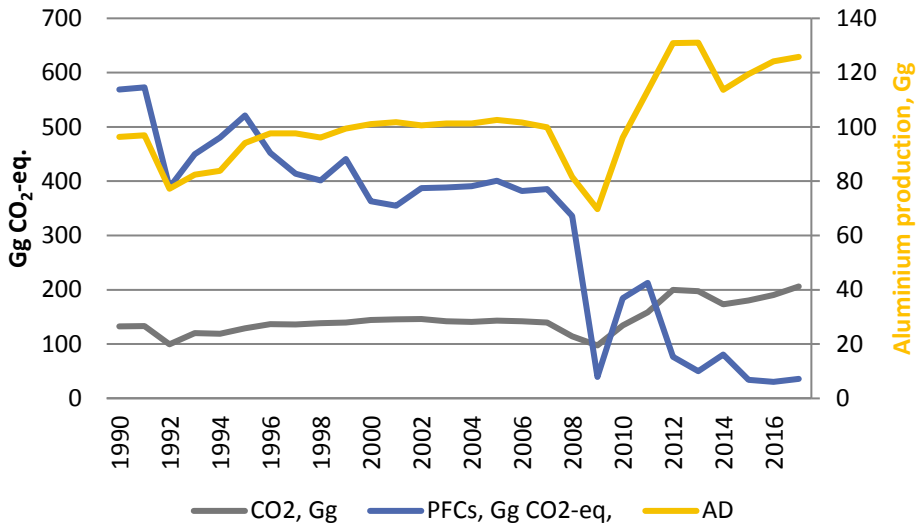

Figure 4.10. Time series for CO_2 and PCF emissions and produced amounts of primary aluminium in CRF 2.C.3.

4.4.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The implied emission factors for CO_2 and PFCs are analysed annually. Explanations for unexpected variation between years are obtained by direct contact with the company or from information in their legal environmental reports.

4.4.3.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations were performed in aluminum production during submission 2019.

4.4.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.4.4 Magnesium production (CRF 2.C.4)

4.4.4.1 SOURCE CATEGORY DESCRIPTION

There are no production of magnesium i Sweden, thus emissions of CO_2, NO_X, CO, NMVOC and SO_2 are reported as NO (Not ocurring) in the CRF tables. However thera are four magnesium foundries in Sweden, using SF_6 as a cover gas. For 2012 and 2013 one of the foundries also used HFC-134a. 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 4.28.

Table 4.28. Summary of source category description, CRF 2.C.4, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.C.4	SF_6	X	X		Tier 2	D	Yes
2.C.4	HFC-134a				Tier 2	D	Yes

D Default.

4.4.4.2 METHODOLOGICAL ISSUES

The total amount of SF_6 and HFC-134a used annually in the magnesium foundries (CRF 2.C.4) is reported as emissions, according to the 2006 IPCC Guidelines. Data is obtained from companies using SF_6 and HFC-134a as a cover gas.

4.4.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

In submissions prior to Submission 2014 the total uncertainty in CRF 2.C.4 were ± 40 %. After comments from Expert Review Team during an In Country Review in September 2013, the uncertainty estimate has been revised. For the three sites where the data is obtained directly from the companies an uncertainty of 5 % is applied, according to data in the 2006 IPCC Guidelines. For the "unknown" plant a much higher uncertainty (~ ± 200 %) is applied. The total uncertainty has thus been estimated for CRF 2.C.4 to ± 20 %. Time series are considered to be consistent. In 2012, the largest magnesium foundry reduced its use of SF_6, by replacing parts of this gas with HFC-134a, which has resulted in significantly lower emissions in 2012 compared to previous years. After 2013, the company has not used HFC-134a.

4.4.4.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

In response to questions raised during the 2011 submission UNFCCC review, data for 2009 has been checked with information from the Swedish Chemicals Agency's Products Register and the data was found to be consistent.

During the review of the 2017 submission, the Expert Review Team recommended Sweden to report both amounts of magnesium casted and emissions of SF_6 in CRF 2.C.4. Despite efforts, Sweden has not been able to find national data on amount of magnesium casted. Sweden will therefore continue to report "NE" for amounts of magnesium casted.

In Figure 4.11, below, implied emission factors for the largets of the magnesium foundries are presented, from 2009 to 2017.

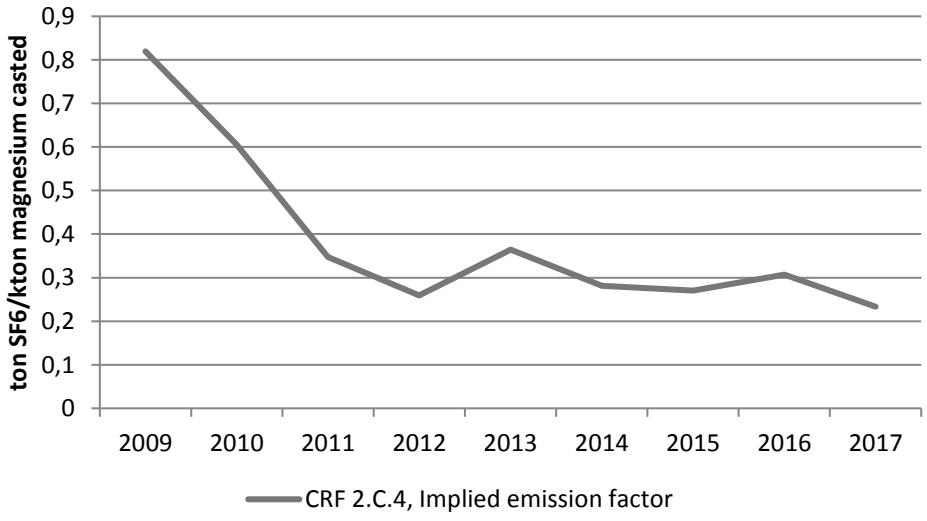

Figure 4.11. Implied emission factors for the largets Swedish magnesium foundry, 2009 – 2017.

4.4.4.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations were performed in submission 2019.

4.4.4.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.4.5 Lead production (CRF 2.C.5)

4.4.5.1 SOURCE CATEGORY DESCRIPTION

Lead production does occur in Sweden. However, since Swedish non-ferrous metal smelters produce several metals in the same process, emissions cannot be separated and are all included in CRF 2.C.7.c Other metal production. Thus IE is reported in CRF 2.C.5.

4.4.6 Zinc production (CRF 2.C.6)

4.4.6.1 SOURCE CATEGORY DESCRIPTION

Zinc production does occur in Sweden. However, as Swedish non-ferrous metal smelters produce several metals in the same process, emissions cannot be separated and are all included in CRF 2.C.7.c Other metal production. Thus IE is reported in CRF 2.C.6.

4.4.7 Other metal production (CRF 2.C.7)

4.4.7.1 SOURCE CATEGORY DESCRIPTION

Due to data confidentiality, data for 2015 -2017 cannot be displayed for this category.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 4.29.

Table 4.29. Summary of source category description, CRF 2.C.7, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.C.7	CO_2	X			T3	PS	Yes
	CH_4	NA	NA		NA	NA	No, see Annex 5

D Default. PS Plant-Specific.

4.4.7.2 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 plant-specific data on raw material consumption and respective CO_2 emission factors as reported to EU ETS (available for 2013 and onwards). Data on raw material consumption for 1990-2012 has been obtained directly from the facility and from its environmental reports. In cases where exact numbers on material use are unavailable, approximation, interpolation, and relations to production volumes have been

applied (Yaramenka & Mawdsley[197]). In particular, the following assumptions have been made:

- The amount of electronic scrap increases linearly during 1990-2005 whereas the amount of metal ashes at the same time decreases linearly;
- The amount of metal dust for 1990-1992 is the same as for the year 1993;
- The amount of lead cable correlates with lead production;
- The amount of electrode mass correlates with copper production.

It is assumed that all emission factors are constant over the period 1990-2013 and are the same as reported to EU ETS for 2013, see table 4.30.

Table 4.30. Emission factors applied for estimating CO_2 emissions from the non-ferrous metals smelter plant in 1990-2013.

Raw material	Emission factor, Gg CO_2 / Gg material
Lead cable	0.18
Limestone	0.44
Coke	2.89
Metal ashes	0.14
Concentrate	0.01
Electronic scrap	0.90
Electrode mass	3.00
Less valuable electronic scrap	2.24
Metal dust from steel	0.03
Coal	2.85

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 from EU ETS. 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.

The reported activity data comprises amounts of copper, lead and zinc produced at the two above mentioned facilities. As shown in Figure 4.12 below, metal production does not show the same trend as CO_2 emissions. It does, however, correlate with the total raw material consumption at the smelter that dominates production (material consumption at the recycling plant is not available for the entire time series and has not been included in this comparison). The main reason

[197] Yaramenka, K., Mawdsley, I. 2015

for the different CO_2 emission trends is variations in the combination of raw materials at the smelting facility. Ratio of materials with high and low carbon content is a crucial factor determining implied emission factors for non-ferrous metal production.

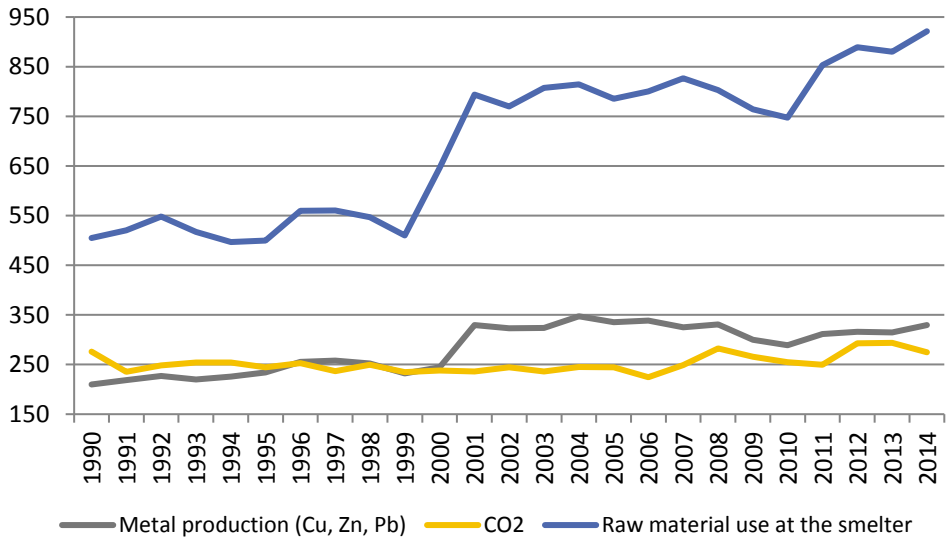

Figure 4.12. CO_2 emissions and activity data trends in CRF 2.C.7.c, kt. [Due to confidentiality reasons, data for 2015 - 2017 cannot be displayed]

Shares of specific raw materials in the total material consumption at the smelting facility are presented in Figure 4.13. The dominating - by mass - raw material is metal concentrate, but materials with high carbon content affect the CO_2 emission trend much more. Figure 4.14 illustrates changes in the total consumption of five such materials – coal, coke, electrode mass, metal ashes and electronic scrap (including less valuable scrap) – and related changes in CO_2 emissions at the facility. A much stronger correlation between the emissions and raw material consumption is seen here than in Figure 4.12; this is because materials with low emission factors are excluded.

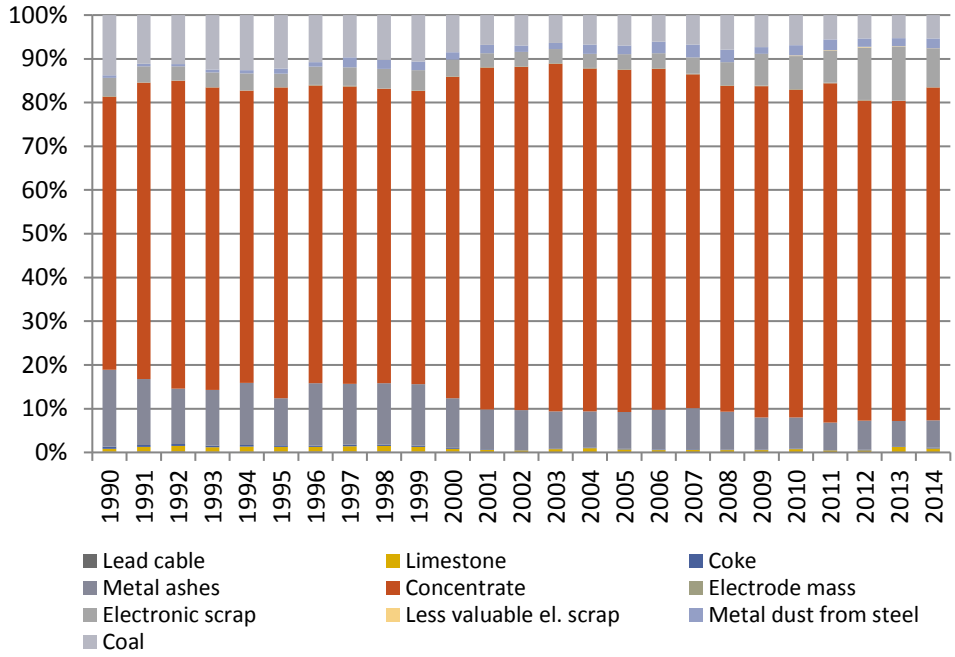

Figure 4.13. Raw materials used in the metal production at the smelting facility, shares in the total input. Due to confidentiality reasons, data for 2015 - 2017 cannot be displayed]

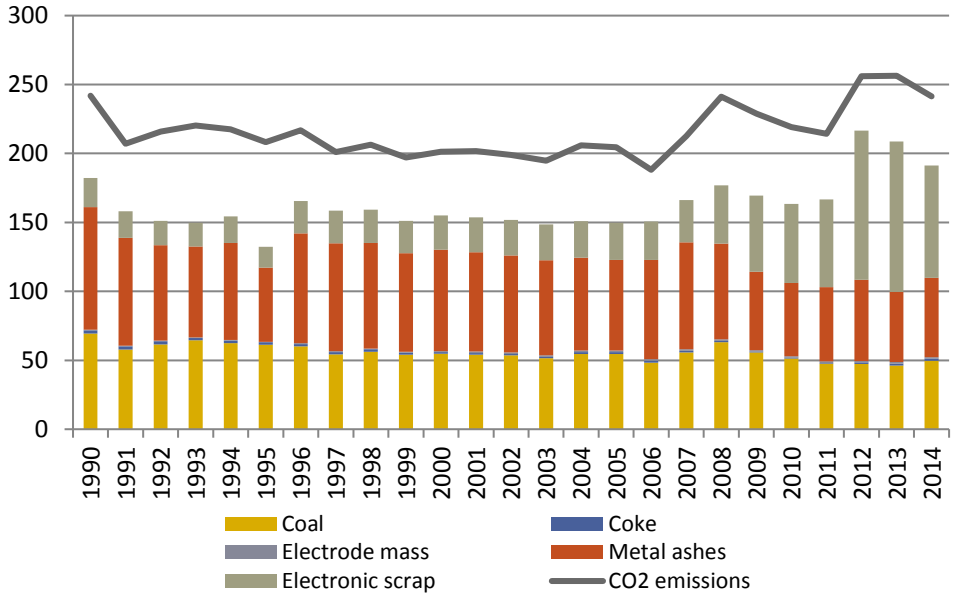

Figure 4.14. Consumption of raw materials with high carbon content and CO_2 emissions at the smelter, Gg. [Due to confidentiality reasons, data for 2015 - 2017 cannot be displayed]

The share of coal in the total raw material consumption at the smelter is estimated as 10-14 % during 1990-1998 and only 7 % in 2001. A substantial increase in the produced copper from 133 kt in 2000 to 216 kt in 2001 is not followed by a similar increase in CO_2 emissions, because it has been reached due to higher consumption of copper concentrate with a low emission factor, while the use of other materials, in particular coal, has not increased. Similar relations between emissions and metal

production, characterized by rather low implied emission factor, continues until 2008 (see figure 4.12 above), when higher amounts of electronic scrap and much more modest increase in copper production cause a notable raise in CO_2 emissions. In 2012 the company has installed a new E-kaldo oven for smelting electronic scrap. This resulted in further increase in CO_2 emissions during 2012-2013 compared to previous years. In 2014 the amount of processed electronic scrap was rather low, which is seen in the emission decrease.

4.4.7.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty for activity data is estimated to ± 4 %. The uncertainty for CO_2 emission factor is estimated to ± 5 %. Time-series are considered to be consistent.

4.4.7.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

CO_2 emissions from the smelter have previously been calculated based on the amounts of coke, coal, limestone, plastics and other raw material used in the production, reported by the company together with carbon content in slag products. The emissions from coal and coke were calculated based on national thermal values (TV) and emission factors (EF). The IPCC default value was used for CO_2 emissions from limestone. In connection with the company's first reporting to EU ETS it was discovered that this method results in substantial underestimation of CO_2 emissions – about 100 kt in 2013. The reasons for the discrepancies have been investigated, and a new method has been applied in Submission 2016. The new method is described in detail in Yaramenka & Mawdsley[198]. The differentiation of raw materials is much wider in Submission 2016 than previously – category "plastic and other raw materials" is substituted with sub-categories "lead cable", "metal ashes", "concentrate", "electrode mass", "electronic scrap", "less valuable electronic scrap" and "metal dust from steel production", each with its own emission factor.

Both plants in this category report their emissions in yearly environmental reports. The reported activity data and emissions are analysed and compared to EU ETS data. More information on QC activities related to EU ETS is included in Annex 8.1.

In addition, emissions from the large smelter and the metal recycling plant are included in the cross-sectoral control tool as part of a QC procedure that was developed in 2017 and is further described in section 1.3.5.1. This tool was used again in submission 2019 and suggests that summed emissions reported in CRF 1 and CRF 2 match total emissions reported in the respective environmental reports or to the EU ETS in a sufficient manner.

4.4.7.5 SOURCE-SPECIFIC RECALCULATIONS

A minor correction for SO_2 emissions in 2016 has been implemented, affecting total SO_2 emissions in CRF 2 by decreasing less than 0.01%.

4.4.7.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

[198] Yaramenka, K., Mawdsley, I. 2015

4.5 Non-energy products from fuels and solvent use (CRF 2.D)

4.5.1 Lubricant use (CRF 2.D.1)

4.5.1.1 SOURCE CATEGORY DESCRIPTION

In CRF 2.D.1 CO_2 emissions from lubricants during use are reported.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any significant sources are not estimated (NE), is presented in Table 4.31.

Table 4.31. Summary of source category description, CRF 2.D.1, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.D.1	CO_2	X	X		T1	D	Yes

D Default. T1 Tier 1.

4.5.1.2 METHODOLOGICAL ISSUES

Amounts of lubricants per year are obtained from the Swedish Energy Agency and Statistics Sweden. Due to the delay of the data delivered by the Swedish Energy Agency, data for the latest reporting year is set equal to the previous year. Since, no obvious trend can be discerned and that no data is available for the current year this is considered to be the best available method. Data for 2017 is thus preliminary and will be updated in submission 2020. Some lubricants have a vapour pressure of 0.01 kPa or more at 293.15 K, meaning that CO_2 emissions from these lubricants are included in CRF 2.D.3_Other_Solvent_use. Therefore, these CO_2 emissions are subtracted from the amounts reported in CRF 2.D.1_Lubricants.

Emissions of CO_2 from oxidation of lubricants during use is calculated according to the following formula:

$$Emissions = \left[\frac{(SM_{TJ} \times CC_{SM} \times ODU_{SM} \times \frac{44}{12})}{1000}\right] - CO_{2_{2D3}}$$

Emissions = CO_2 emissions from oxidation of lubricants.
SM_{TJ} = Lubricants, TJ
CC_{SM} = Carbon content in lubricants, t C/TJ
ODU_{SM} = ODU factor (proportion oxidized during use) for lubricants, %
44/12 = mass ratio CO_2/C
/1000 = conversion from t to kt
CO_{22D3} = CO_2 emissions included in CRF 2.D.3_Other_Solvent_use

Factors used for CO_2 estimates are presented in Table 4.32.

Table 4.32. Parameters used when calculating emission from oxidation of lubricants

Parameter	Factor	Unit	References
CC_{SM}	20	Ton C/TJ	IPCC 2006
ODU_{SM}	20	%	IPCC 2006

The time series for CO_2 emissions and used amounts of lubricants in CRF 2.D.1 is presented in Figure 4.15.

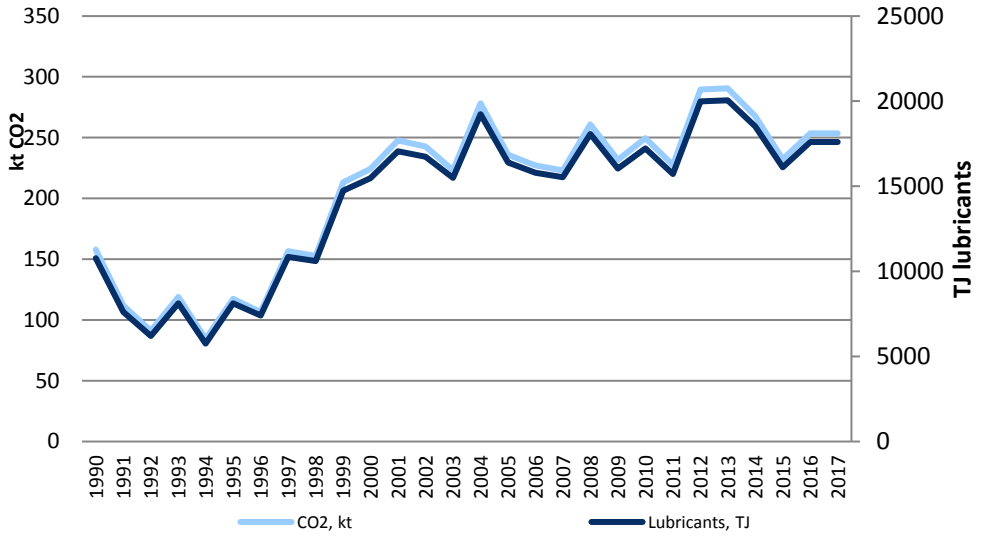

Figure 4.15. Time series for CO_2 (kt) and used amounts of lubricants (TJ) in CRF 2.D.1

4.5.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The applied methodology has been the same during all the years and is therefore considered to be consistent. The activity data is based on information from the Swedish Energy Agency (2005 – 2015) and from Statistics Sweden (1990 – 2004). Data for 2017 is preliminary and will be updated in submission 2020.

Uncertainties for CRF 2.D.1_Lubricants is in accordance with 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The total uncertainty of the EF used is set to ± 50 %, and the uncertainty of activity data is set to ± 5 %.

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

As data from the Swedish Energy Agency was not available in time in submission 2019, input data for 2017 was estimated based on data for 2016 from the Swedish Chemicals Agency. In Submissions 2019, activity data for 2016 has been retrieved from the Swedish Energy Agency and were updated accordingly in the

calculations. Thus the amount of lubricants consumed in 2016 increased by 1494 TJ, resulting in an increase of CO_2 emissions of about 21 kt.

A small amount of CO_2 emissions from the use of lubricants included in 2.D.3-Other solvents use are excluded from 2.D.1. Since CO_2 emissions in 2.D.3 – Other solvents are are calculated over a running average of three years, also emisions from 2014 and 2015 are recalculated in submission 2019. The recalculations for 2014 and 2015 led to a decrease of CO_2 emissions of 0.4 respectively 0.8 kt.

4.5.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.5.2 Paraffin wax use (CRF 2.D.2)

4.5.2.1 SOURCE CATEGORY DESCRIPTION

Paraffin waxes are produced from crude oil and used in a number of different applications such as candles, corrugated boxes, paper coating and many others. Incineration of such products results in emissions of fossil CO_2. In CRF 2.D.2, CO_2 emissions from the use (incineration) of paraffin candles are reported, while emissions from incineration of e.g. corrugated boxes and coated paper are to be reported in the energy sector (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), is presented in Table 4.33.

Table 4.33. Summary of source category description, CRF 2.D.2, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.D.2	CO_2				T1	D	Yes

D Default. T1 Tier 1.

4.5.2.2 METHODOLOGICAL ISSUES

Quantities of imported and exported candles (stearin and paraffin candles, tapers) are taken from Statistic Sweden's statistical database. Import and export data for the years 1990-2001 are considered to be uncertain, thus for these years the values for 2002 are applied. For the assumption of the fraction of paraffin candles of the total imported and exported candles, information from Norway's reporting to UNFCCC has been used (66 %), since domestic data is missing.

Amounts of imported paraffin waxes are obtained from the Product Register at the Swedish Chemicals Agency (KemI). Information on the amount of carbon in these paraffin waxes has been received from KemI. Data for 1990 - 1994 is missing in the Product Register, and for these years the value for 1995 is applied. Based on this data, CO_2 emissions are calculated using emission factors and other information presented in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. As there is a one-year lag in the data delivered by KemI, the carbon content for the latest reporting year is set equal to the previous year. This value is updated in the following submission.
The CO_2 emission estimates are performed in two ways depending on the data source:

1. Imported and exported amounts of candles
2. Imported amounts of paraffin waxes

$$Emission = \left[\frac{(TL_t \times PF_{\%} \times VV_{Wax} \times CC_L \times \frac{44}{12})}{1000}\right] \quad (1)$$

$$Emission = \left[\frac{(TP_{Wax} \times ODU_{Wax} \times \frac{44}{12})}{1000}\right] \quad (2)$$

Emission = CO_2 emissions from incineration of paraffin candles, kt
TL_t = total import of candles – total export of candles, t
$PF_{\%}$ = Proportion of paraffin candles, %
VV_{Wax} = Heating value for paraffin wax, TJ/t
CC_L = carbon content in paraffin candles, t C/TJ
TP_{Wax} = carbon content in paraffin wax, t
ODU_{Wax} = ODU factor for paraffin (proportion oxidized during use = share of paraffin wax used for paraffin candle production), %
44/12 = mass ratio CO_2/C
/1000 = conversion from t to kt

Factors used for the CO_2 estimates are presented in Table 4.34.

Table 4.34. Parameters used when calculating emission

Parameter	Factor	Unit	References
$PF_{\%}$	66	%	National Inventory Report, Norway[199]
VV_{Wax}	0.0402	TJ/t	Statistics Sweden
CC_L	20	Ton C/TJ	IPCC 2006
ODU_{Wax}	20	%	IPCC 2006

The time series for CO_2 emissions in CRF 2.D.2 is presented in Figure 4.16. The IEF is the same for the whole time series, 0.073 kt/Tj.

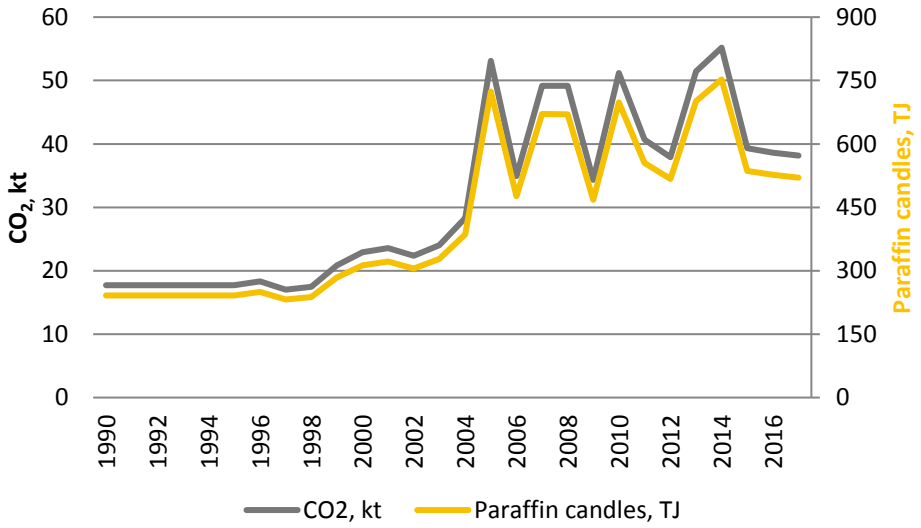

Figure 4.16. Time series for CO_2 (kt) and used amounts of paraffin candles (TJ) in CRF 2.D.2.

4.5.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The applied methodology is the same for all years and is therefore considered to be consistent. The amount of paraffin waxes for 2017 is preliminary and will be updated in submission 2020.

Uncertainties for CRF 2.D.2_Paraffin wax use is, as far as possible, in accordance with information in Chapter 3 of the 2006 IPCC Guidelines. Most of the CO_2 emissions reported in CRF 2.D.2_Paraffin wax use derives from the data on imported and exported amounts of candles. These statistics are judged to be of high quality with relatively low uncertainty. The share of reported CO_2 based on the carbon content of imported paraffin constitutes only 5-10 % of the total CO_2. The high uncertainty for ODU factor according to the 2006 IPCC Guidelines for

199 http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8108.php

National Greenhouse Gas Inventories should thus not be of great importance for the overall uncertainty.

The total uncertainty of the EF used is set to ± 50 %, and the uncertainty of activity data is set to ± 10 %.

4.5.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.5.2.5 SOURCE-SPECIFIC RECALCULATIONS

Activity data for 2015 have been updated, resulting in a increase of about 6 TJ and about 0,440 kt of CO_2 emissions. Also activity data for 2016 have been updated, resulting in a decrease of about 3.5 TJ and about 0.259 kton of CO_2 emissions.

4.5.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.5.3 Other (CRF 2.D.3)

4.5.3.1 SOURCE CATEGORY DESCRIPTION

In this source category, emissions from asphalt roofing, road paving with asphalt and urea used as a catalyst are included. Also emissions from solvent use in chemical products, coating applications, degreasing, domestic solvents, dry cleaning, leather industry, printing, textile finishing, wood preservation and other uses are 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 4.35.

Table 4.35. Summary of source category description, CRF 2.D.3, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.D.3	CO_2				T1* T3**	D* CS**	Yes

D Default. CS Country Specific. T1 Tier 1. T3 Tier 3.

* Urea used as a catalyst

** Solvent and product use

4.5.3.1.1 Asphalt roofing

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. Since Submission 2016 CO emissions have been estimated and reported. Emissions from asphalt roofing are reported in 2D3 Road paving with asphalt together with emissions from road paving with asphalt due to confidentially reasons.

4.5.3.1.2 Road paving with asphalt

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 varied within the interval 17- 50 % during 2002-2014. In this inventory, only NMVOC emitted in the process of paving the roads is included. Emissions from road paving with asphalt are reported together with emissions from asphalt roofing due to confidentially reasons.

4.5.3.1.3 Urea used as a catalyst

Urea is used as a reducing agent in some types of NO_X reducing catalysts. These kind of catalysts are used in the transport sector, e.g. in trucks, passenger cars and ships, but also in stationary combustion plants. The increased use later years are mainly a consequence of increased use in heavy duty road vehicles since catalysts have been more or less necessary to comply with the latest emission standards (Euro V and later). When reacting with the nitrogen oxides and oxygen at the catalyst surface the carbon from the urea molecule will result in CO_2 emissions.

4.5.3.1.4 Solvent use

Use of solvents and products containing solvents results in emissions of non-methane volatile organic compounds (NMVOC), which is regarded as an indirect greenhouse gas since it over a period of time will oxidise to CO_2 after being emitted to the atmosphere. The model used for estimating the CO_2 and NMVOC emissions reported in the various solvent use categories is described in more detail in Annex 3.3 and fully described in Skårman et al., 2016[200].

Emission estimates reported for solvent use in CRF 2.D.3 include emissions from the source groups “Domestic solvent use” (all domestic use except use of coatings), “Coating applications” (industrial coating, domestic coating, non-industrial coating), “Degreasing” (use of degreasing in industry), “Dry cleaning” (non-domestic dry cleaning), “Chemical product use” (vehicle industry, rubber industry, paint industry, textile industry, leather industry), “Printing” (printing industry) and “Other solvent and product use” (all other use of solvents).

Emissions of CO_2 from solvents and products containing solvents have decreased by 47 % from 213 kt CO_2 in 1990 to 112 kt CO_2 in 2017 (see Figure 4.17).This can largely be explained by the reduced use of solvents in coating application due to a shift to water-based paints.

[200] Skårman et al., 2016. Swedish method for estimating emissions from Solvent Use. Further development of the calculation model. SMED report 192.

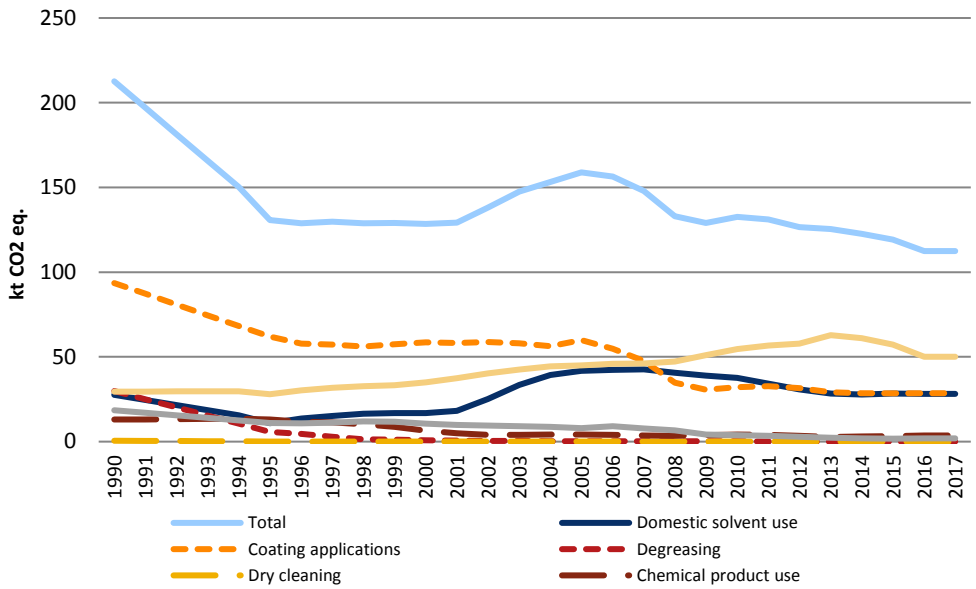

Figure 4.17. Total CO_2 emissions from the different solvent and other product use sub-categories.

CO_2 emissions from coating applications have decreased by almost 70 % from 94 kt CO_2 in 1990 to 29 kt CO_2 in 2017. The largest source of CO_2 from solvents reported in CRF 2.D.3 is, in later years, "Other product and solvent use". In this sub-sector an increase of emitted CO_2 from 1990 (30 kt CO_2) to 2017 (50 kt CO2) can be observed.

4.5.3.2 METHODOLOGICAL ISSUES

4.5.3.2.1 Asphalt roofing

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.[201] These are based on studies performed during the 1970s in the USA and presented by EPA.[202] 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 for estimating the NMVOC emissions from the Swedish production of asphalt-saturated felt.

The NMVOC emissions from the production of asphalt-saturated felt originate from the felt saturation and coating processes. In submission 2018 new information and measurements from both companies were presented leading to new calculations of NMVOC emissions for the whole time series. The new information

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

[202] 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.

also showed that no NVMOC emissions came from leakage from the asphalt storage tanks. The NMVOC emissions, 1990-2008, for one company are calculated by an emission factor based on measurements in 2009. The NMVOC emissions for 2009-2017 are based on measurements. For the other company the NMVOC emissions, 1990-2015 and 2017, are calculated by an emission factor based on the measurements in 2016. However, emissions from asphalt roofing are reported in 2D3 Road paving with asphalt due to confidentially reasons.

4.5.3.2.2 Road paving with asphalt

Estimates for the early 1990s are taken from investigations and inventories made in the early 1990's. Data for the years 2002 – 2013 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 1990's were interpolated. 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. Due to the lack of producers' data emissions for 2014 - 2017 are estimated based on the implied emission factor – NMVOC emissions per ton asphalt – calculated with asphalt statistics[203] and emissions in 2013. Since data regarding the total amount of road paving mixtures delivered in Sweden is only available with a lag of one year, production data and emissions for 2016 are updated. As for 2017, activity data has been set equal to 2016 and will be updated in Submission 2020.

4.5.3.2.3 Urea used as a catalyst

There is no production of urea in Sweden, meaning that all used urea is imported. For estimation of CO_2 emissions from urea used in catalysts the net imports is used as activity data. Data is taken from the Product Register at the Swedish Chemical Agency, where 100 % pure urea for use in catalysts is specified as a category. The emissions are calculated with equation 3.2.2 presented in section 3.2.1.1 of the mobile combustion chapter in the Energy sector in 2006 IPCC Guidelines, based on the assumption of purity of 100%. No data is available prior 1995 and therefore the CO_2 emissions for 1990-1994 is estimated from the average CO_2 emission from 1995-1999. Due to the fact that activity data for the last year is not provided in sufficient time, activity data and CO_2 emission for 2017 is estimated with data from 2016. CO_2 from the urea use is calculated in accordance with 2006 IPCC Guidelines. See Table 4.36 for activity data and calculated emissions.

[203] EAPA, Asphalt in figures http://www.eapa.org/promo.php?c=174 , 2016

Table 4.36. Activity data and emissions of CO_2 from urea used in NO_X reducing catalysts

Year	Net imports of urea, kt	CO_2 emissions, kt
1990	6.5	4.7
1995	7.1	5.2
2000	6.3	4.6
2005	14.3	10.5
2010	20.6	15.1
2011	20.5	15.1
2012	34.4	25.2
2013	38.3	28.1
2014	49.7	36.5
2015	51.6	37.9
2016	55.3	40.6
2017	55.3	40.6

4.5.3.2.4 Solvent use

Activity data regarding all solvent use sub-categories for year 1995 and onwards has been obtained from the Product register at the Swedish Chemicals Agency.

The Products Register does not provide reliable data for the period 1990-1994 for most industry categories. Data from reported time series compiled in a dedicated study on NMVOC emissions carried out by SMED in 2002 (Kindbom et. al, 2004) has been used for the estimations of emissions for 1990 for most sources. Exceptions are the emissions for 1990 for "Degresing", "Vehicle industry" and "Other solvent and product use". The 1990 emissions for "Degreasing" have been calculated with activity data from the GAINS-model and emission factors from EMEP/EEA. The 1990 emissions for the "Vehicle industry" are based on the information that the number of produced vehicles was around 22 % lower in 1990 than in 1995, and this information has been used to calculate the NMVOC and CO_2 emissions for 1990. The 1990 emissions for "Other product and solvent use" are based on the correlation between GDP (gross domestic product) (Ekonomifakta, 2016) and emissions from 1995 to 2013. From known GDP for 1990 and the mathematical function for the correlation between emissions and GDP, emissions of NMVOC and CO_2 have been calculated.

The emissions for 1991-1994 have been interpolated based on the available information for1990 and the known data for 1995.

Emission factors given in the literature, for example the EMEP/EEA guidebook (EEA, 2016), EU legislations, and other countries IIR´s, have been compiled and included in the model. The used emission factors are presented in Annex 3.3. The model has been developed in order to make it possible to test different datasets of emission factors. Two emission factors have been developed for each activity; one for solvents used as raw material and one for the remaining quantities. The emission factors for raw material have been set very low, since most of the solvents will end up in the product and will not be emitted during production.
A new emission factor for products used diluted in water has been introduced in the new model. The new emission factor is set to 0.275 and it has been calculated

based on available information given in the EMEP/EEA guidebook (Domestic solvent use). In the previous estimates these products were not treated separately and consequently the emission factor of 0.95 was used also for water diluted products.

The country specific emission factors have been developed in order to adjust to the old time series 1990-2001, developed by SMED in 2002 (Kindbom et. al., 2004). However, for some activities errors have been identified in previously reported data for 1990, and consequently those emissions have been corrected. Furthermore, application techniques, available information in the environmental reports for specific industries, as well as other pathways of release (e.g. water), have been considered when developing the country specific emission factors.

Domestic solvent use
Domestic solvent use is a moderate source of CO_2 and NMVOC but increases over time. This increase, starting in 2002, is due to an increased use of the product groups washer fluid, degreasing agents, and ignition fluids. However, a decrease in emissions from the use of ignition fluids can be seen for later years.
Two different emission factors are used for domestic solvent use which are used for the whole time series:

- Diluted 0.275 (product groups that are used diluted in water)
- Not diluted 0.95 (product groups that are not used diluted in water)

The separation between diluted and not diluted products is a new approach compared to the old calculation model.

Coating applications
Coating applications is a moderate source of CO_2 and NMVOC and has decreased over time. Coating in industry is the dominating source, followed by domestic coating, and that non-industry coating is of less importance. Emissions of NMVOC and CO_2 from coating application have decreased for the whole time series from 1990. The decrease is both due to reduced use of paints containing solvents and more efficient abatement technologies as indicated in available environmental reports.

Degreasing
Degreasing within the industry is a minor source of CO_2 and NMVOC and has decreased over time. The estimates are based on abatement efficiency factors given in EMEP/EEA guidebook and the distribution between different abatement technologies has been based on information available in the GAINS-model (scenario: EGEO_Baseline_CLE) for 1995, 2000, 2005 and 2010. Emissions of both NMVOC and CO_2 have decreased from 1990, mainly due to a decreased use of degreasing products, but also a shift in technology, i.e. lower emission factors for the later years.

Dry cleaning
Dry cleaning is a minor source of CO_2 and NMVOC. The time series for emissions of NMVOC and CO_2 from dry cleaning has decreased from 1990 mainly due to less use of dilution and thinner products.

Chemical product use
Chemical product use is a minor source of CO_2 and NMVOC. The vehicle industry is the predominant source of emissions for chemical product use. The emissions are decreasing over time. The decrease during the 90's is both due to reduced solvent content in used products, as well as more efficient abatement technologies according to information available in environmental reports for the rubber and vehicle industry. The sources in Chemical product use are:

- Vehicle industry
- Rubber industry
- Paint industry
- Textile and leather industry

Printing industry
Printing industry is a minor source of CO_2 and NMVOC. A steady decrease in the emissions of NMVOC and CO_2 from 1990 depends on a reduced use of solvent products within the industry as well as a technology shift.

Other solvent and product use
Other solvent and product use is a major source of CO_2 and NMVOC and has increased over time. The increased emissions for the activity are mainly due to a greater use of the product groups preservatives, refrigerants, metal mordants/etchants and coolant agents. These products account for about 70 % of the increase.

4.5.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

4.5.3.3.1 Asphalt roofing and Road paving with asphalt
The time series are considered to be consistent.

4.5.3.3.2 Urea used as a catalyst
No activity data as net imports of urea used in catalysts is available until 1995. From 1996 and onwards the reported time series are considered to be consistent. Activity data and CO_2 emission for 2017 are estimated to be same as 2016 due to that activity data from the product register not is reported in sufficient time to be able to perform the calculations and report in a timely manner.

The total uncertainty of the EF used is set to ± 5 %, and the uncertainty of activity data is set to ± 40 %.

4.5.3.3.3 Solvent use
Reported time series are considered to be consistent, except for the last year (2017) where data for previous year (2016) has been reported. This practice has been questioned by the ERT several times. The reason for Sweden to report activity data and emissions from solvent use with a delay of one year is due to the fact that activity data from the Product Register is not provided in sufficient time data to be able to perform the calculations and report in a timely manner. Also, as emissions are calculated over a running average of three years, the two years prior to the one added to the time series are affected and will be recalculated every submission.

The uncertainty for emissions of NMVOC and CO_2 for 1990 - 1994 is ± 25 %.

For activity data (1995 and onwards) the uncertainty is ± 15 %. The uncertainties have been discussed and assigned in co-operation with the Swedish Chemicals Agency. Uncertainty estimates for the emission factors were estimated by expert judgement. Information available in environmental reports, in the GAINS model and in the EMEP/EEA guidebook has been taken into account when developing the emission factors. The uncertainty for emissions factors is judged to be ± 15 %.

The combined uncertainty is calculated according to equation 3.1 in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 1 General Guidance and Reporting, chapter 3 (IPPC, 2006) (see below).

$$U_{total} = \sqrt{U_{AD}^2 + U_{EF}^2}$$

Where U = uncertainty, AD = activity data and EF = emission factor. U_{total} represents the combined uncertainty.

4.5.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

4.5.3.4.1 Urea used as a catalyst

Activity data from the Product Register as net imports of urea used in catalyst has been compared with estimated national sales of urea solutions during 2010-2013 done by one of Sweden's importers of urea solutions for catalysts. The sources agree well 2010 and 2011 but in 2012 the Product Register data is significant higher. Since data from the importer were estimates and not official data we have chosen to go with the official data from the Product Register.

CO_2 emissions from urea use in road vehicles have beside the already described method also been calculated using the default method from IPCC 2006 Guidelines, as a quality check. The IPCC 2006 method only includes urea used in road vehicles and not in ships or stationary combustion plants. The importer estimates that of total used urea in 2010 (as pure urea and not urea water based solution) 25 % were used in ships, 35 % in road vehicles and 40 % in stationary combustion plants. The estimated urea use from road vehicles according to Guidelines is about 45 % of Sweden's estimates of total used urea in 2010.

Since 2010 the share of urea used in road vehicles has increased due to more road vehicles using urea based catalysts.

4.5.3.5 SOURCE-SPECIFIC RECALCULATIONS

4.5.3.5.1 Asphalt roofing

Reported emissions for NMVOC from asphalt roofing for 2016 was corrected in submission 2019. However these emissions are reported in 2D3 Road paving with asphalt due to confidentially reasons.

4.5.3.5.2 Road paving with asphalt

Due to the recurring one year lag of updating of the data the reported emissions from road paving with asphalt for 2016 were updated in submission 2019. However the reported data for 2016 was the same as estimated in sumission 2018

which led to no recalculation of NMVOC emissions in submission 2019 for road paving with asphalt.

4.5.3.5.3 Urea used as a catalyst

Due to the recurring one year lag of updating of the data from the Product Register from the Swedish Chemicals Agency the reported emissions for 2016 were updated in submission 2019. The update resulted in a CO_2 emission increase by 2.7 kt.

4.5.3.5.4 Solvent use

As mentioned above, emissions are calculated over a running average of three years. Hence the two years prior to the one added to the time series are affected and will be recalculated every submission. In submission 2019, data for 2016 has been obtained and the years 2014-2016 have been updated accordingly. Table 4.37 shows the differences in emissions for NMVOC and CO_2 for the years 2014-2016 between submission 2018 and submission 2019.

Table 4.37. Comparison of CO_2 and NMVOC emission data from submission 2018 and submission 2019 from solvent use.

Year	CO_2 (kt)		NMVOC (kt)	
	Sub18	Sub19	Sub18	Sub19
2014	129	123	60	58
2015	133	119	61	57
2016	133	112	61	56

4.5.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.6 Electronics industry (CRF 2.E)

4.6.1 Integrated circuit or semiconductor (CRF 2.E.1)

4.6.1.1 SOURCE CATEGORY DESCRIPTION

HFC, PFC and SF_6 are used in the semiconductor manufacturing process. Semiconductor manufacture has in earlier 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 4.38.

Table 4.38. Summary of source category description, CRF 2.E.1, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.E.1	HFCs	NA	NA		T1*	D*	Yes
	PFCs	NA	NA		T1*	D*	Yes
	SF_6	NA	NA		T1*	D*	Yes

D Default. T1 Tier 1.
* From 2005 NO

4.6.1.2 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 2006 IPCC Guidelines Tier 1 method using an average expected lifetime of one year.

4.6.1.3 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.

4.6.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Cross-references with the Products Register at the Swedish Chemicals Agency could not be made for the reported time series, since the level of detail in the Products Register was insufficient.

4.6.1.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.6.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.6.2 TFT Flat panel display (CRF 2.E.2)

4.6.2.1 SOURCE CATEGORY DESCRIPTION

No production of TFT flat panel displays is currently known to occur in Sweden, thus NO is reported for CRF 2.E.2.

4.6.3 Photovoltaics (CRF 2.E.3)

4.6.3.1 SOURCE CATEGORY DESCRIPTION

No production of photovoltaics occurs in Sweden, thus NO is reported for CRF 2.E.3.

4.6.4 Heat transfer liquid (CRF 2.E.4)

4.6.4.1 SOURCE CATEGORY DESCRIPTION

There are no electronic industries using FCs in Sweden, thus NO is reported for CRF 2.E.4

4.6.5 Other (CRF 2.E.5)

4.6.5.1 SOURCE CATEGORY DESCRIPTION

NO is reported for CRF 2.E.5.

4.7 Product uses as substitutes for ODS (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. The increase in emissions up to 2009 is mainly due to increased accumulated bulk of HFC in such equipment.

Between 2009 and 2013, the annual addition of HFC (as CO_2 eq) installed in equipment are more or less equal to the amounts of HFC in equipment being disposed. This leads to a more or less stable amount of HFC installed in applications. Due to falling initial leakage factors in CRF 2.F.1.e, falling annual leakage factors in CRF 2.F.1.d, CRF 2.F.1.e and 2.F.1.f (heat pumps) and falling leakage factors at decommissioning in 2.F.2, HFC emissions decreased from 2009 up to 2013. For 2014, 2015 and 2016, the addition of HFC installed in equipment exceeds the amounts in disposed equipment. This is reflected by increasing emissions in CRF 2.F.1 for 2014-2017 compared to 2013.

The largest source in 2017 is refrigeration and airconditioning (2.F.1) and the second largest is aerosols (2.F.4), followed by foam blowing (2.F.2, XPS-foam). The remaining source, fire protection (2.F.3), is a comparatively small emitter of fluorinated greenhouse gases.

All sub-categories are covered in the estimates except solvents (2.F.5). According to the information available, solvents containing HFCs or PFCs are not used in Sweden. An overview of reported emissions in CRF 2.F are shown in Table 4.39.

Table 4.39. Overview of submitted emission data in CRF 2.F, kt CO_2 eq.

Year	2.F.1 Refrigeration and air-conditioning	2.F.2 Foam blowing agents	2.F.3 Fire protection	2.F.4 Aerosols	2.F.5 Solvents	2.F.6 Other use of ODS substitutes
1990	5.1	NO	NO	1.4	NO	NO
1995	128	NO	NO	7.3	NO	NO
2000	626	118	6.0	24	NO	NO
2005	987	90	6.6	32	NO	NO
2010	1072	31	5.6	30	NO	NO
2011	1048	34	2.3	31	NO	NO
2012	1034	33	2.1	30	NO	NO
2013	1021	35	1.3	32	NO	NO
2014	1046	33	1.1	34	NO	NO
2015	1066	32	0.8	35	NO	NO
2016	1083	31	0.8	35	NO	NO
2017	1069	30	3.3	37	NO	NO

In estimating the emissions in all subcategories, as far as possible, a national model has been used, corresponding to the IPCC Tier 2 approach. The basis for the emission estimates are the annual bulk import and export statistics of fluorinated greenhouse gases recorded in the Swedish Chemicals Agency's Products Register. However, the register does not cover all chemicals already included in products imported to or exported from Sweden (e.g. air-air heat pumps, metered dose

inhalers, refrigerates trucks and lorries, passanger cars, light and heavy duty vehicles and busses). In order to make a complete reporting of fluorinated greenhouse gas emissions and, as far as possible, to facilitate allocation of emissions onto the IPCC source categories, additional information from various trade associations and companies are collected annually. The Swedish model, a combination of top-down and bottom-up, is schematically illustrated in Figure 4.18 below.

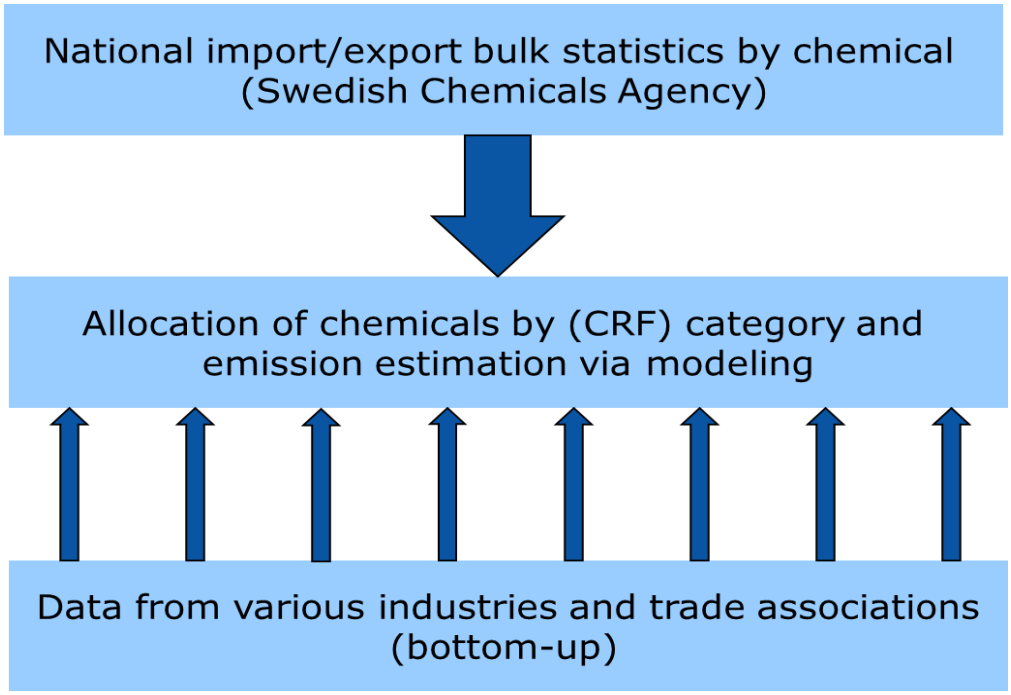

Figure 4.18. Schematic illustration of the Swedish national model used for estimation of emissions of fluorinated greenhouse gases

Based on an earlier inventory model on emissions of fluorinated greenhouse gases in Sweden covering the time period 1990-1999[204], the model was updated and refined e.g. concerning the calculations from the accumulated bank in 2005 [205]. 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, emissions from operating systems and emissions from disposal. In 2011, a SMED study[206] was carried out to analyse the model's flexibility to adapt to the newly introduced international and national legislations on fluorinated greenhouse gases. In addition, the study aimed at updating model factors using available information, but also to analyse the accuracy of the estimates of e.g. emissions from disposal. The study resulted in several recalculations for the 2012 submission, but also suggestions on future improvements. In response to questions raised by the expert review team

[204] 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.

[205] Kindbom, K. 2005. Revision of Methodology and Estimated Emissions of Fluorinated greenhouse Gases in Sweden. Report Series SMED Nr 16 2005, www.smed.se

[206] Gustafsson, T. 2011. Fluorinated Greenhouse Gases in Sweden. Review of Methodology and Estimated Emissions Reported to the UNFCCC and the EU monitoring Mechanism. SMED report 2011.

(ERT) in 2017 several changes in 2.F.1 were performed in Submission 2018. New data on amounts imported in products were added to the model. After the completion of Submission 2018 it was found that the statistics on imported light and heavy duty vehicles, passenger cars, buses and refrigerates trucks and lorries did not cover vehicles imported and sold by Swedish general agents or dealers. Therefore, in the work with Submission 2019, these amounts have also been included in the model. The addition of F-gases affects CRF codes 2.F.1.a, 2.F.1.c and 2.F.1.f.

Emissions from commercial and industrial refrigeration and stationary air-conditioning were in prior to Submission 2018 reported together in 2.F.1.a (commercial refrigeration). Starting with Submission 2018 these emissions are allocated to commercial refigeration (2.F.1.a), industrial refrigeration (2.F.1.c) and stationary air-conditioning (2.F.1.f). Leakage rates and lifetimes have been changed from national factors to default factors from 2006 IPCC Guidelines for 2.F.1.a, 2.F.1.c and 2.F.1.f. Calculations of emissions from heat pumps, reported in 2.F.1.c, are however calculated using national emission factors. The model is described in more details in Annex 3:1.

Starting with Submission 2015 the reporting is in accordance with the 2006 IPCC Guidelines. This means, for example, that the reporting include the new F-gases HFC-152, HFC-161, HFC-236cb, HCF-236ea, HFC-245fa, HFC-365mfc, $C_{10}F_{18}$, c-C_3F_6 and NF_3. Of the new gases only HFC-245fa is used in small amounts in Sweden. Consumption data is classified as confidential and the amounts have been summed up with another gas with a comparable GWP. Small amounts of HFC-143a with CAS number 460-73-1 and small but confidential amounts of HFC-134 are for the first time included in Submission 2015. As for HFC-245fa, HFC-134 is summed up with another gas with comparable GWP.

From Submission 2017 onwards, amounts of gases recovered at decommissioning are reported in the CRF tables for CRF 2.F. Recovered amounts are calculated as amount in products at decommissioning minus emissions from disposal.

In Submission 2019 data on bulk import and export from the Products Register from the Swedish Chemicals Agency are updated for 2014, 2015 and 2016. For HFC-125, HFC-134a and HFC-143a preliminary data for 2017 is used. For other F-gases, data for 2016 is used for 2017 due to a recurring one year lag from data from the Products Register.

4.7.1 Refrigeration and air conditioning (CRF 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 occurring (NO) in Sweden. The most important source of greenhouse gases to the category is emissions of HFC-134a from air- conditioning in mobile air conditioning (CRF 2.F.1.e), representing between 27 and 42% of the total emissions in 2.F.1 from 2006 onwards (in submission 2019 also emissions from working machinery and off road vehicles are included). Almost as important is emissions of HFCs from commercial refrigeration (CRF 2.F.1.a), representing between 22 and 30% for the same period. It can been seen in Table 4.36 that

emissions of HFCs and PFCs from 2.F.1 has increased from 5 kt CO_2 eq. 1990 to 1069 kt CO_2 eq. 2017. The use of HFCs as refrigerants in refrigerators, freezers, heat pumps and air-conditioning equipment in vehicles (MAC) is the main reason for the large increase in emissions. As a result of the introduction of HFO-1234yf as a substitute for HFC-134a in passenger cars, a decrease in emissions can be seen from mobile air conditioning from 2012 onwards (CRF 2.F.1.e). But because of the increased total amounts of HFCs imported i bulk between 2014 and 2017, emissions in CRF 2.F.1 for these years are higher compared to 2013.

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 2.F.1, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.F.1	HFCs	X	X		T2	CS	Yes
	PFCs		X		T2	CS	Yes
	SF_6	NA	NA		NO	NO	NO

CS Country Specific. T2a Tier 2a.

4.7.1.2 METHODOLOGICAL ISSUES

Input data for the calculation of emissions consists of information from various sources; the Swedish Chemicals Agency, equipment producers and importers. Table 4.41 summarizes the 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, from IPCC default values and, for working machinery and off road vehicles, from the national model used to estimate other emissions than HFCs (number of working machinery/off road vehicles and lifetime)[207] and from the Finnish inventory[208].
Intervals given indicate changes between 1990 and the last inventory year used in the calculations.

[207] Described in Annex 2

[208] Tommi Forsberg, SYKE, Finland, personal communication 2018-08-29

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 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	Initial emissions, %	Lifetime emissions, %	Remained in product at disposal, %	Emissions at disposal, %
Stand-alone commercial applications (2.F.1.a)	HFCs	10	*	0.5	1	90	5
Medium and large commercial applications (2.F.1.a)	HFCs, PFC-218	7	*	0.5	10	90	5
Domestic refrigeration (2.F.1.b)	HFCs	20	0.1	2	1	90	5
Industrial refrigeration (2.F.1.c)	HFCs	15	*	0.5	7	90	5
Transport refrigeration (2.F.1.d)	HFCs	10	10 - 6	4.5	30 - 7	90	15
Mobile air-conditioning, heavy duty vehicles (2.F.1.e)	HFCs	6	1.2	1 – 0.5	15 - 10	90	15
Mobile air-conditioning, light duty vehicles (2.F.1.e)	HFCs	11	0.8 - 0.7	1 – 0.5	15 - 5	90	15
Mobile air-conditioning, passenger cars (2.F.1.e)	HFCs	11	0.8 - 0.7	1 – 0.5	15 - 5	90	15
Mobile air-conditioning, buses (2.F.1.e)	HFCs	12	7	1 – 0.5	10	90	15
Mobile air-conditioning, working machinery/off road vehicles - tractors (2.F.1.e)	HFCs	7	1	5	30	90	15
Mobile air-conditioning, working machinery/off road vehicles - other (2.F.1.e)	HFCs	8-20***	1.5	5	30	90	15
Heat pumps (2.F.1.f)	HFCs	20-15	5 - 1	1	10 - 1	90	5
Other stationary AC (2.F.1.f)	HFCs	10	*	1	1	90	5

* Top-down calculations
** Lifetime means the average expected lifetime of a product, not the designed technical lifetime from its first commissioning.
*** Depending of type of machinery

The information on refrigerant-related imported amounts of fluorinated gases from the Swedish Chemicals 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-sources Commercial applications (2.F.1.a), Industrial refrigeration (2.F.1.c) and Stationary AC (2.F.1.f). The chemicals concerned are HFC-23, HFC-32, HFC-125, HFC-134, HFC-134a, HFC-

143a, HFC-152a, HFC-245fa and PFC-218 (C_3F_8). Information from the Swedish Refrigeration & Heat Pump Association givs that all air to air heat pumps, that 5% of all new installed liquid water and about 30% of all air water heat pumps are imported pre-filled with refrigerants. The amounts of F-gases in imported heat pumps are thus not included in the bulk import statistics from the Swedish Chemicals Agency.

In submissions prior to 2018 emissions from commercial, industrial and stationary applications were reported together in commercial refrigeration, 2.F.1.a. As there currently are no national statistics that can be used for allocation between 2.F.1.a, 2.F.1.c and 2.F.1.f, an alternative reallocation model has been used. This model is based on information from Germany's reporting of installed amounts of F-gases in 2.F.1.a, 2.F.1.c and 2.F.1.f from Submission 2016. The gases reported by Germany in these codes are also included in the Swedish reporting for 2.F.1.a, 2.F.1.c and 2.F.1.f. Most of the gases show similar trends in quantities used in Germany as used in Sweden in the period 1990 - 2014. Exception is HFC-143a where there is an increase in use in Sweden while it is decreasing in Germany.

According to Germany's NIR, the calculations for these three CRF codes are based mostly on models. The input for 2.F.1.a is the sales area of supermarkets or the number of stores (for low cost markets) and the quantity and type of refrigeration and freezing systems used per m^2 and per store (emission factor). The emission factor for 2.F.1.a is based on information from literature or by so-called "expert judgment". For 2.F.1.c, inputs to the calculations are the amount of food and beverages produced and estimation from the literature of the cooling effect required for the production of these foods and beverages. The calculations of emissions in 2.F.1.f are based on data on the number of produced and the number of installed heat pumps and emission factors.

The distribution of the F gases between 2.F.1.a, 2.F.1.c and 2.F.1.f has been developed for the period 1990 - 2014 and applied to corresponding amounts in the Swedish model. For 2015 – 2017 the same distibution as for 2014 has been used. As before, it is the amount of HFCs and PFCs not allocated to other codes within 2.F that are allocated to 2.F.1.a, 2.F.1.c and 2.F.1.f.

In the UNFCCC review in September 2017, the ERT pointed out that the Swedish national leakage factors appear to be too low for emissions from installed volumes. The ERT also pointed out that the leakage factors for emissions from manufacturing were in many cases considerably higher in the Swedish F-gas model compared to other countries and to IPCC default factors. Therefore, it was important to, if possible, find new leakage factors relevant to Sweden. As mentioned earlier, there are currently no national statistics that can be used to find new national emission factors in CRF 2.F.1.a, 2.F.1.c and 2.F.1.f. Therefore, IPCC default factors (lowest value in range) have been used in the Swedish F-gas model for Submission 2018 and Submission 2019, both for emissions from manufacturing and for emissions from installed amounts for 2.F.1.a, 2.F.1.c and 2 .F.1.f. Calculations of emissions from heat pumps, reported in 2.F.1.c, are however calculated using national emission factors. In 2006 IPCC Guidelines emission factors given for Stand-alone Commercial Applications and for Medium & Large Commercial Refrigeration differ significantly. In order to be able to allocate quantities of F-gases within 2.F.1.a to these two types of applications, statistics

from Finland has been used (data for 2000-2015). For 1990 - 1999, the distribution for 2000 has been applied and for 2016-2017, the distribution for 2015.

As the assumed lifetime of the applications has a significant impact on emissions from installed volumes and also on emissions from decommissioning, the IPCC default values (lowest value in range) have been used for lifetime in 2.F.1.a, 2.F.1.c and 2.F.1.f (but national lifetimes for heat pumps).

All factors used for emission estimates in 2.F.1a, 2.F.1.b, 2.F.1.c, 2.F.1.d and 2.F.1.f are in detail presented in Table 4.42, Table 4.43, Table 4.44, Table 4.45, Table 4.46 and Table 4.47 below.

Table 4.42 Emission factors used (1990 – 2017) for emission estimates for Stand-alone Commercial Applications (2.F.1.a).

Year	Lifetime, years	EF Initial Emission, %	EF Operation Emission %/year	Emissions at disposal, %	Initial Charge Remaining, %
1990-2017	10	0.5	1	5	90

Table 4.43 Emission factors used (1990 – 2017) for emission estimates for Medium & Large Commercial Refrigeration (2.F.1.a).

Year	Lifetime, years	EF Initial Emission, %	EF Operation Emission %/year	Emissions at disposal, %	Initial Charge Remaining, %
1990-2017	7	0.5	10	5	90

Table 4.41 Emission factors used (1990 – 2017) for emission estimates for Domestic refrigeration (2.F.1.b).

Year	Lifetime, years	Charge, kg	EF Initial Emission, %	EF Operation Emission %/year	Emissions at disposal, %	Initial Charge Remaining, %
1990-2017	20	0.1	2	1	5	90

Table 4.44 Emission factors used (1990 – 2017) for emission estimates for Industrial refrigeration (2.F.1.c).

Year	Lifetime, years	EF Initial Emission, %	EF Operation Emission %/year	Emissions at disposal, %	Initial Charge Remaining, %
1990-2017	15	0.5	7	5	90

Table 4.45 Emission factors used (1990 – 2017) for emission estimates for Transport refrigeration (2.F.1.d).

Year	Lifetime, years	Charge, kg	EF Initial Emission, %	EF Operation Emission %/year	Emissions at disposal, %	Initial Charge Remaining, %
1990	10	10	4.5	30	15	90
1991	10	9.5	4.5	30	15	90
1992	10	9	4.5	25	15	90
1993	10	8.5	4.5	20	15	90
1994	10	8	4.5	20	15	90
1995	10	8	4.5	15	15	90
1996	10	7.5	4.5	14	15	90
1997	10	7	4.5	13	15	90
1998	10	6.5	4.5	11.5	15	90
1999	10	6	4.5	10	15	90
2000	10	6	4.5	10	15	90
2001	10	6	4.5	10	15	90
2002	10	6	4.5	9	15	90
2003	10	6	4.5	9	15	90
2004	10	6	4.5	8	15	90
2005-2017	10	6	4.5	7	15	90

Table 4.46 Emission factors used (1990 – 2017) for emission estimates for heat pumps (2.F.1.f).

Year	Lifetime, years	Charge, kg	EF Initial Emission, %	EF Operation Emission %/year	Emissions at disposal, %	Initial Charge Remaining, %
1990	20	5	1	10	5	90
1991	20	5	1	9	5	90
1992	20	4.5	1	8	5	90
1993	20	4.5	1	7	5	90
1994	20	4	1	6	5	90
1995	20	4	1	5	5	90
1996	20	4	1	4	5	90
1997	20	3	1	3	5	90
1998	20	3	1	2	5	90
1999	20	2	1	1	5	90
2000	20	1	1	1	5	90
2001	20	1	1	1	5	90
2002	20	1	1	1	5	90
2003	20	1	1	1	5	90
2004-2017	15	1	1	1	5	90

Table 4.47 Emission factors used (1990 – 2017) for emission estimates for other stationary air-conditioning (2.F.1.f).

Year	Lifetime, years	EF Initial Emission, %	EF Operation Emission %/year	Emissions at disposal, %	Initial Charge Remaining, %
1990-2017	10	0.2	1	5	90

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 conditioning, commercial and industrial refrigeration and from stationary air-conditioning. Based on SMED expert judgement AD and EF uncertainty are ±10% and ±40% for mobile air conditioning (2.F.1.e) and ±25% and ±50% for domestic (2.F.1.b) and transport refigeration (2.F.1.d). Uncertainty for AD and EF for 2.F.1.a, 2.F.1.c and 2.F.1.f reported together, based on earlier SMED expert judgement, were set to ±25 % and 50%, respectively. This corresponds to an AD uncertainty of ±40% and an EF uncertainty of ±80% for each of the codes 2.F.1.a, 2.F.1.c and 2.F.1.f.

The uncertainty of emission factors in 2.F.1 has been compared with emission factor uncertainties for other countries. The comparison shows that the Swedish emission factor uncertainties for CRF 2.F.1.a, 2.F.1.c and 2.F.1.f are slightly higher compared to comparable countries such as the Netherlands and Austria (EF uncertainty ±50%, Submission 2016).

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

When data from equipment producers has been used it has been compared against IPCC default data and been judged as reasonable. Estimates have been checked with the trade association "Svenska Kyl & Värmepumpföreningen" (SKVP)[209], with experts at the Swedish EPA[210] and with the Swedish Car Recyclers Association[211]. 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.

In the SMED study[212], based on contacts with the Swedish road vehicles manufacturers, several factors were modified for MAC in road vehicles for 2010 onwards to be more in line with the present status of the Swedish road vehicle fleet. The emission factors used for emission estimates for MAC in road vehicles are presented in Table 4.48.

[209] Per Jonasson, Managing Director, Swedish Refrigeration & Heat Pump Association. Personal communication

[210] Swedish EPA . Ujfalusi, Bernekorn , and Björsell. Personal communication.

[211] Michael Abraham, Managing Director, Swedish Car Recyclers Association. Personal communication

[212] Gustafsson, T. 2011. Fluorinated Greenhouse Gases in Sweden. Review of Methodology and Estimated Emissions Reported to the UNFCCC and the EU monitoring Mechanism. SMED report 2011.

Table 4.48. Emission factors used (1990 – 2017) for emission estimates for MAC in heavy and light duty vehicles, passenger cars and buses.

	Mobile air-conditioning, heavy duty vehicles						Mobile air-conditioning, light duty vehicles						Mobile air-conditioning, cars						Mobile air-conditioning, buses					
Year	Lifetime, year	Charge, kg	EF Initial Emission, %	EF Operation Emission, %/year	Emissions at disposal, %	Initial Charge Remaining, %	Lifetime, year	Charge, kg	EF Initial Emission, %	EF Operation Emission, %/year	Emissions at disposal, %	Initial Charge Remaining, %	Lifetime, year	Charge, kg	EF Initial Emission, %	EF Operation Emission, %/year	Emissions at disposal, %	Initial Charge Remaining, %	Lifetime, year	Charge, kg	EF Initial Emission, %	EF Operation Emission, %/year	Emissions at disposal, %	Initial Charge Remaining, %
1990	6	1	1	15	15	90	11	1	1	15	15	90	11	1	1	15	15	90	12	7	1	10	15	90
1991 – 1999, same as 1990																								
2000	6	1	1	12	15	90	11	1	1	12	15	90	11	1	1	12	15	90	12	7	1	10	15	90
2001	6	1	1	10	15	90	11	1	1	10	15	90	11	1	1	10	15	90	12	7	1	10	15	90
2002 – 2009, same as 2001																								
2010	6	1	0.5	10	15	90	11	1	0.5	7.5	15	90	11	1	0.5	7.5	15	90	12	7	0.5	10	15	90
2011-2017	6	1	0.5	10	15	90	11	1	0.5	5	15	90	11	1	0.5	5	15	90	12	7	0.5	10	15	90

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 4.49). The emission factors for lifetime, charge, annual leakage, production, remaining at decommissioning and share recovered for car air conditioning are attained from the Swedish car manufacture Volvo, in cooperation with experts at the Swedish EPA and from the Swedish Car Recyclers Association.

Table 4.49. Comparison of IPCC default factors and Swedish factors for MAC in cars

Parameter	2006 IPCC	Swedish factors	Comment
Lifetime (y)	9 - 16	11	OK
Charge (kg)	0.5 - 1.5	0.8 - 0.7	OK
EF Operation Emission (%/year)	10 - 20	15 - 5	OK
EF Initial Emission (%)	0.2 - 0.5	1 - 0.5	OK
Initial Charge Remaining (%)	0 - 50	90	High; We assume that there is continuous maintenance and refilling of the equipment
Recovery Efficiency (%)	0 - 50	85	OK according to experts at Swedish EPA and the Swedish Car Recyclers Association

During the review of the 2015 and 2016 annual submissions the ERT requested documentation supporting the Swedish country specific emission factors used for estimates of emissions from disposal in CRF 2.F.1. The documents "Letter to Swe Environmental Protection Agency regarding leakage at decommissioning_Swedish Refrigeration & Heat Pump Association.pdf" and "Swedish Car Recyclers Association.pdf" (Annex 3:6) supports the use of the existing national factors in the Swedish GHG inventory, in line with the requirements of the 2006 IPCC Guidelines. The national factors are based on information from the Swedish Refrigerants Code of Best Practices ("Svensk Kylnorm") and national expert judgments from the relevant business associations (the Swedish Refrigeration & Heat Pump Association and the Swedish Car Recyclers Association). The documents are signed by the Managing Director of the Swedish Refrigeration & Heat Pump Association and the Managing Director of the Swedish Car Recyclers Association.

4.7.1.5 SOURCE-SPECIFIC RECALCULATIONS

General: Due to a recurring one year lag in the updating of the data from the Products Register from the Swedish Chemicals Agency, data on bulk import and export in 2016 were updated.

Beside this update many changes of emission estimates have been done for submission 2019. This includes:

- adding of amounts imported in products 1990-2017 (Table 4.50) (affecting reported emissions in 2.F.1.a, 2.F.1.c and 2.F.1.f)
- change of factors used for emission estimates for light duty vehicles, 1993-2016. Earlier, factors for heavy duty vehicles were used, now the same factors as for passenger cars are used. Leads to decreased yearly emissions for light and heavy duty vehicles between less than 1 kton to 17 kton CO_2 eq (for 2016).
- minor corection in emission estimates for MAC in buses 1990-1995 (< 0.001 kton CO_2 eq).
- correction of numer of built passenger cars with HFC-134a 2010-2016 and introduction of HFO-1234yf from 2012. This leads to decreased emissions of less than 1 kton CO_2 eq for 2010 and 2011 and between 2 and 18 kton CO_2 eq for 2012 and 2016, respectively.
- introduction of emission estimates for MAC in working machinery and off road vehicles 2000-2017. This leads to increased emissions of between 2 kton CO_2 eq in 2000 and up to around 12 kton CO_2 eq in later years.

Table 4.50. Comparison of amounts imported in products in CRF 2.F.1 in submission 2018 and 2019, kton CO_2 eq.

Year	Submission 2018	Submission 2019
1990	<1	1
1991	<1	1
1992	<1	1
1993	<1	4
1994	4	27
1995	6	37
1996	8	49
1997	13	76
1998	16	90
1999	38	189
2000	61	193
2001	46	154
2002	43	168
2003	53	200
2004	59	250
2005	49	271
2006	40	309
2007	39	229
2008	29	196
2009	20	164
2010	22	198
2011	24	215
2012	24	188
2013	24	170
2014	22	175
2015	19	177
2016	18	179

Comparison of reported emissions in CRF 2.F.1 in submission 2018 and 2019 is presented in Table 4.51.

Table 4.51. Comparison of reported emissions in CRF 2.F.1 in submission 2018 and 2019, kton CO_2 eq.

Year	Submission 2018	Submission 2019
1990	4	5
1991	7	8
1992	9	10
1993	27	27
1994	68	69
1995	123	128
1996	199	207
1997	271	285
1998	360	380
1999	477	510
2000	578	626
2001	653	710
2002	734	797
2003	800	876
2004	850	940
2005	883	987
2006	910	1032
2007	929	1055
2008	942	1073
2009	949	1085
2010	926	1072
2011	893	1048
2012	874	1034
2013	861	1021
2014	844	1046
2015	832	1066
2016	818	1083

4.7.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.7.2 Foam blowing agents (CRF 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 occurring (NO). Emissions of HFCs peaked in year 2000 and have since then decreased due to reduced leakage during manufacturing, according to data from the manufacturer.

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 4.52.

Table 4.52. Summary of source category description, CRF 2.F.2, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.F.2	HFCs		X		T2a	PS	Yes
	PFCs	NA	NA		NO	NO	NO
	SF_6	NA	NA		NO	NO	NO

PS Plant Specific. T2a Tier 2a.

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 4.53). According to the information provided by the manufacturing company the HFC-134a remains in products for a very long time, while all HFC-152a is emitted during the first 10 years. Since 2008 no HFC-134a is used during manufacturing of XPS foam in Sweden. Thus, the reported emissions of HFC-134a from 2008 represent only emissions from stocks and disposal.

Table 4.53. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of HFCs used in calculations of emissions in Sweden. Intervals given indicate changes between 1996 and the last inventory year used in the calculations.

Application	Foam blowing (XPS)
Fluorinated substances	HFCs
Lifetime**	> 12
Amount installed /unit, kg	*
Emissions at manufacturing, %	46 - 35
Emissions per year during use	Declining
Remained in product at disposal	$
Emissions at disposal, %	<76***

* Top-down calculations
** Lifetime means the average expected lifetime of a product, not the designed technical lifetime from its first commissioning.
*** 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 basis for the calculation is the amount of HFC-134a and HFC-152a that is introduced into products used in Sweden, and subsequently leaked from the products. Beside annual losses from products over time, the reported Swedish emissions in the CRF tables contain emissions from manufacturing.

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

4.7.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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. Data from the manufacturers is considered to be complete and cover all sources of HFC emissions in Sweden. 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

The current calculation method provided by the company, used for reporting of emissions, has been compared to the Tier 2a method given in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

The leakage factors (year 1 to 15) in the national method are in Table 4.54 compared to the default factors from 2006 IPCC Guidelines.

Table 4.54. Leakage factor used for the first 15 years in the national method compared to 2006 IPCC Guidelines Table 7.6.

	National method		2006 IPCC Guidelines, Table 7.6	
Year	Leakage factor HFC-134a	Leakage factor HFC-152a	Leakage factor HFC-134a	Leakage factor HFC-152a
1	9.5 %	66 %	25 %	50 %
2	3.9 %	20 %	0.56 %	13 %
3	3.0 %	8.3 %	0.56 %	9.4 %
4	2.5 %	3.5 %	0.55 %	7.0 %
5	2.2 %	1.5 %	0.55 %	5.3 %
6	2.0 %	0.62 %	0.55 %	4.0 %
7	1.9 %	0.26 %	0.54 %	3.0 %
8	1.7 %	0.11 %	0.54 %	2.2 %
9	1.6 %	0.050 %	0.53 %	1.7 %
10	1.5 %	0.020 %	0.53 %	1.3 %
11	1.5 %	0 %	0.53 %	0.94 %
12	1.4 %	0 %	0.52 %	0.70 %
13	1.3 %	0 %	0.52 %	0.53 %
14	1.3 %	0 %	0.51 %	0.40 %
15	1.2 %	0 %	0.51 %	0.30 %

The calculated emissions according to the national method and to the method described in 2006 IPCC Guidelines are presented in Table 4.55. The product life time of XPS-foam is very long, several decades, and the total amounts of emitted chemical are in the long run comparable.

Table 4.55. Emissions of HFC-134a and HFC-152a from stock from the national method compared to calculated emissions using leakage factors in 2006 IPCC Guidelines

Year	Emissions of HFC-134a and HFC-152a according to the national method (kt CO2 eq.)	Emissions of HFC-134a and HFC-152a according to 2006 IPCC Guidelines (kt CO2 eq.)
1996	12	12
1997	81	88
1998	88	98
1999	106	118
2000	118	124
2001	116	120
2002	110	113
2003	101	101
2004	111	109
2005	90	86
2006	75	67
2007	53	42
2008	48	36
2009	38	28
2010	31	23
2011	34	26
2012	33	24
2013	35	27
2014	33	26
2015	32	25
2016	31	25
2017	30	24
SUM 1996 - 2017	1406	1340

4.7.2.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations were performed in submission 2019.

4.7.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.7.3 Fire protection (CRF 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 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 4.56.

Table 4.56. Summary of source category description, CRF 2.F.3, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.F.3	HFCs				T1a	CS	Yes
	PFCs	NA	NA		NO	NO	NO
	SF_6	NA	NA		NO	NO	NO

CS Country Specific. T1a Tier 1a

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 4.57). From 2017 only HFC-227ea is imported for installation in equipment. Thus, the reported emissions of HFC-125 and HFC-134a from 2017 represent only emissions from stocks and disposal.

For 2017 one of the companies reported unusual high emissions of HFC-227ea from stock (1.8 kton CO_2 eq).

Table 4.57. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of HFCs used in calculations of emissions in Sweden

Application	Fire extinguishing
Fluorinated substances	HFCs
Lifetime*	10
Amount installed /unit, kg	**
Emissions at manufacturing, %	0.5
Emissions per year during use, %	2 / 0.1***
Remained in product at disposal, %	95
Emissions at disposal, %	5

* Lifetime means the average expected lifetime of a product, not the designed technical lifetime from its first commissioning.
** Top-down calculations
*** 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

HFC's in fire protection equipment have been used in Sweden since 1997. In submissions prior to submission 2015 a "Lifetime" factor of 30 years was used. After contact with the industry it became evident that this factor was too high[213]. The information from the industry revealed that there are regulated controls of the cylinders in fire protection systems in Sweden. The cylinders have to be controlled by an accredited personnel every 10th year. Because of this new information, the factor for "Lifetime" has been changed from 30 to 10 years. The industry also suggested a change of the "Emissions at disposal" factor from 1 % to 5 %.

4.7.3.5 SOURCE-SPECIFIC RECALCULATIONS

Minor correction of installed amounts of HFC-125 and HFC-134a 2015 and 2016 lead to decreased emissions of less than 0.06 kton CO_2 eq.

4.7.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.7.4 Aerosols (CRF 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) and HFC-227ea (apaflurane) are sometimes used as propellant gases. Emissions of PFCs and SF_6 for the category are 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 4.58.

Table 4.58. Summary of source category description, CRF 2.F.4, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.F.4	HFCs	X	X		T2a	D	Yes
	PFCs	NA	NA		NO	NO	NO
	SF_6	NA	NA		NO	NO	NO

D Default. T2a Tier 2a.

[213] Danielsson, H., Mawdsley, I and Gustafsson, T. 2014. Fluorinated greenhouse gases – is there a risk of underestimation of reported Swedish emissions from disposal of products and equipment? SMED report.

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 4.59 presents the assumptions on product lifetime, emissions at manufacturing and disposal as well as remaining HFC in product at disposal. Due to technical issues in CRF reporter, yearly emissions from disposal are reported together with emissions from the use of aerosols.

For metered dose inhalers, statistics on the numbers of sold inhalers was, for the years 1990 until 2008, received from the Swedish retailer for medical products, Apoteket. From 2009 - 2013 the corresponding information has been received from the company Pharmacy Service AB and from 2014 onwards, the data are received from Swedish eHealth Agency. Information concerning the content of HFC in the inhalers is provided by the Swedish Medical Products Agency.

Table 4.59. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of HFCs used in calculations of emissions in Sweden

Application	Aerosols/ MDI
Fluorinated substances	HFCs
Lifetime*	2
Amount installed /unit, kg	**
Emissions at manufacturing, %	NA
Emissions per year during use, %	50
Remained in product at disposal, %	50
Emissions at disposal, %	100

* Lifetime means the average expected lifetime of a product, not the designed technical lifetime from its first commissioning.
** Top-down calculations

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 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

Corrections of AD for metered dose inhalers 2013-2016 have led to increased emissions between 0.8 and 1.6 CO_2 eq yearly.

4.7.4.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.7.5 Solvents (CRF 2.F.5)

Efforts have been made to find national information concerning this sub-category. For instance potential users of solvents containing HFCs or PFCs were contacted. No information indicating that these kinds of solvents are used in Sweden was found. Emissions from solvents are consequently reported as NO, not occurring.

4.7.6 Other applications (CRF 2.F.6)

No other applications are covered in the Swedish inventory.

4.8 Other product manufacture and use (CRF 2.G)

4.8.1 Electrical equipment (CRF 2.G.1)

4.8.1.1 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 occurring (NO) for this category.

The use of SF_6 for insulation purposes in operating power systems started to occur in Sweden in the middle of the 1970s[214]. The end-of-life factor of 35 years indicates that SF_6 containing equipment now is beginning to be replaced. Therefore the Swedish reporting of SF_6 from Electrical Equipment (2.G.1) also include emissions from disposal.

Swedenergy has estimated the SF_6 content in the operating Swedish power system from 1975 until 1990. Based on this information, estimates of SF_6 emissions from disposal are made[215].

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 4.60.

Table 4.60. Summary of source category description, CRF 2.G.1, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.G.1	HFCs	NA	NA		NO	NO	NO
	PFCs	NA	NA		NO	NO	NO
	SF_6	X	X		T2	CS	Yes
					T3	PS	

CS Country Specific. PS Plant-specific. T2 Tier 2. T3 Tier 3

* Distribution

** Production

In submission 2017, amounts of gases recovered at decommissioning are reported for the first time in the CRF tables for CRF 2.G. Recovered amounts are calculated as amount in products at decommissioning minus emissions from disposal.

4.8.1.2 METHODOLOGICAL ISSUES

The larger part of annual SF_6 emissions in earlier years originated from the manufacture of GIS (Table 4.50), 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

[214] Matz Tapper, Swedenergy. Personal communication.

[215] Danielsson, H., Mawdsley, I and Gustafsson, T. 2014. Fluorinated greenhouse gases – is there a risk of underestimation of reported Swedish emissions from disposal of products and equipment? SMED report.

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 4.61), as well as the share of products that are exported from the country, which often exceeds 90 % of the production.

Table 4.61. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of SF_6, used in calculations of emissions in Sweden.

Application	Electrical insulation and GIS manufacture
Fluorinated substances	SF_6
Lifetime**	35
Amount installed /unit, kg	*
Emissions at manufacturing, %	12 – 0.5
Emissions per year during use, %	0.6 - 0.5
Remained in product at disposal, %	98 %
Emissions at disposal, %	2 %

* Top-down calculations
** Lifetime means the average expected lifetime of a product, not the designed technical lifetime from its first commissioning.

In Table 4.62 intervals given indicate changes between 1990 and the last inventory year used in the calculations. Emissions from installed amounts of SF_6 for insulation purposes in operating systems have previously contributed less to the annual emissions. In 2001-2002, a questionnaire was sent out to power companies from the trade association Swedenergy[216] (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 t SF_6 and an annual leakage rate of 0.6 % (equals the amount replaced from the questionnaire) and these were used as input data in the inventory. For later years, data on replaced amounts of SF_6 in operating systems results in a calculated annual leakage rate of 0.5 % (Swedenergy and power distribution companies).

[216] Swedenergy. Matz Tapper. Personal communication.

Table 4.62. Calculated emissions and accumulated stock of SF_6 for electrical equipment

Year	Accumulated stock, t	Annual losses $SF_{6,t}$	Emissions from GIS manufacture $SF_{6,t}$	Emissions from disposal $SF_{6,t}$	Total emissions $SF_{6,t}$
1990	60	0.36	3.0	NO	3.4
1995	70	0.42	3.5	NO	3.9
2000	101	0.61	0.68	NO	1.3
2010	184	0.92	0.30	0.086	1.3
2011	199	0.99	0.21	0.086	1.3
2012	206	1.0	0.10	0.086	1.2
2013	225	1.1	0.10	0.086	1.3
2014	227	1.1	0.06	0.086	1.3
2015	229	1.1	0.30	0.086	1.5
2016	236	1.2	0.34	0.086	1.6
2017	248	1.2	0.13	0.086	1.5

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 (between 10 and 35 %). Sources of SF_6 emissions that are covered in the calculations are the use in semi-conductor manufacture, in production of sound-proof windows, in magnesium foundries, in the production of gas-insulated switchgear and as insulation in electrical equipment. Information from the Products Register did not indicate that any areas of use have not been covered and are missing from the calculations.

For all sources, except as insulation in electrical equipment, the levels of annual SF_6 consumption is comparatively easy to estimate with some confidence since there are few end-users. It was thus concluded that the amounts of SF_6 not already accounted for elsewhere, most reasonably should be allocated to the electrical equipment source. However, even though information concerning SF_6 in electrical equipment is more difficult to judge concerning completeness, indications from end-users are that the difference between imported amounts according to the Products Register and those already accounted for in the calculations seem too large to annually be consumed for electrical insulation. One explanation to the difference could be that there is an underreporting of exported SF_6 from the Products Register, where no export at all of SF_6 is registered.

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).

4.8.1.3 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.

4.8.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.8.1.5 SOURCE-SPECIFIC RECALCULATIONS

Due to the recurring one year lag in the updating of the data from the Products Register from the Swedish Chemicals Agency, data on bulk import and export in 2016 were updated. Also, due to new information from the GIS manufacturer, activity data for 2016 is updated. These updates results in reduced emissions of 1.6 kton CO_2 eq in 2016.

4.8.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.8.2 SF_6 and PFCs from other product use (CRF 2.G.2)

4.8.2.1 SOURCE CATEGORY DESCRIPTION

The estimated emissions from the use of SF_6 and PFC-218 in jogging shoes and SF_6 in sound-proof windows are reported in CRF 2.G.2. No production of SF_6 or PFC containing shoes has ever occurred in Sweden; hence reported emissions only represent emissions from disposal. Since 2008 SF_6 has not been used in production of sound-proof windows.
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 4.63.

Table 4.63. Summary of source category description, CRF 2.G.2, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.G.2	HFCs	NA	NA		NO	NO	NO
	PFCs				T1*	D*	Yes
	SF_6				T1*	D*	Yes
					T2**	PS**	
					T2***	CS***	

D Default. CS Country Specific. PS Plant specific. T1 Tier 1. T2 Tier 2.
* Jogging shoes
** Sound-proof windows, manufacturing
*** Sound-proof windows, stock

4.8.2.2 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.[217] According to the results from a study performed in early 2004[218] a phasing out of SF_6 and replacement with PFC-218 was started in 2003. The lifetime for shoes is, in accordance with 2006 IPCC Guidelines, set to 3 years in the national model (Table 4.58).

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

[218] 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 4.58). 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 2006 IPCC Guidelines.

In Table 4.64, intervals given indicate changes between 1990 and the last inventory year used in the calculations. With an assumed lifetime of 30 years for barrier gas windows, emissions of SF_6 from disposal will be needed to estimate within a few years.

Table 4.64. 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 emissions in Sweden.

Application	Sound proof windows	Jogging shoes
Fluorinated substances	SF_6	SF_6, PFC-218
Lifetime*	30	3
Amount installed / unit, kg	**	**
Emissions at manufacturing, %	5-50##	NO
Emissions per year during usage, %	1	NO
Remained in product at disposal, %	100	100
Emissions at disposal, %	NO	100

* Lifetime means the average expected lifetime of a product, not the designed technical lifetime from its first commissioning.
** Top-down calculations
Different emissions at different production units.

4.8.2.3 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.

4.8.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.8.2.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.8.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.8.3 N_2O from product use (CRF 2.G.3)

4.8.3.1 SOURCE CATEGORY DESCRIPTION

In CRF 2.G.3 sold amounts and use of N_2O are reported. Due to confidentiality, data for 2.G.3.a – Use of N_2O for Medical Applications and 2.G.3.b – N_2O from Propellant for Pressure and Aerosol Products cannot be reported separately. All emissions are therefore reported in 2.G.3.b. N_2O for use in fire extinguishers is not occurring in Sweden and thus reported as 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), are presented in Table 4.65.

Table 4.65 Summary of source category description, CRF 2.G.3, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.G.3	N_2O	X			T1	CS	Yes

CS Country Specific. T1 Tier 1

4.8.3.2 METHODOLOGICAL ISSUES

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 - 2016). The time series of use of N_2O in Sweden are reported in N_2O from product uses - 2.G.3.b Other (since data for use of N_2O for Anaesthesia and use of N_2O in Aerosol cans cannot be reported separately due to confidentiality). Activity data for year 2017 is not yet official and hence Sweden has chosen to report data from 2016 also for 2017. Data for 2017 will be updated in the next submission.

4.8.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Reported time series are considered to be consistent, except for last year (2017) where data for previous year (2016) has been reported. This practice has been questioned by the ERT several times. The reason for Sweden to report activity data and emissions in CRF 2.G.3 with a delay of one year is due to the fact that activity data from the Product Register is not provided in sufficient time to be able to perform the calculations and report in a timely manner.

4.8.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.8.3.5 SOURCE-SPECIFIC RECALCULATIONS

Due to the recurring one year lag of updating the data from the Product Register from the Swedish Chemicals Agency, the reported emissions of N_2O in CRF 2.G.3 for 2016 is updated in submission 2019 (-0.04 kton N_2O).

4.8.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.8.4 Tobacco smoking and use of fireworks (CRF 2.G.4)

4.8.4.1 SOURCE CATEGORY DESCRIPTION

CRF 2.G.4 includes emissions from tobacco smoking and use of fireworks.

4.8.4.2 METHODOLOGICAL ISSUES

Emissions of NO_X, SO_2, NMVOC and CO from tobacco smoking and use of fireworks are included in CRF 2.G.4. Emissions from tobacco smoking are based on activity data from official statistics on sold amounts of tobacco for the entire time series. Activity data include only "legal" purchases of tobacco products in Sweden; products that are purchased through tax-free and cross-border trading are not included. For fireworks, activity data is made up of imported and exported amounts of fireworks. No significant production of fireworks occurs in Sweden. Emission factors from EMEP/EEA Guidebook 2016 are used for the calculations.

4.8.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The time series is consistent as the same method is used throughout.

4.8.4.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.8.4.5 SOURCE-SPECIFIC RECALCULATIONS

Minor recalculations of emissions of NO_X, SO_2 and CO from use of fireworks have been performed in submission 2019 due to updated activity data.

4.8.4.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.9 Other product manufacture and use (CRF 2.H)

Other production covers emissions from the pulp and paper industry (2.H.1), the food and beverages industry (2.H.2) and other (2.H.3). CRF 2.H.3 includes battery production, mineral wool production and quarrying and mining of minerals other than coal. For CRF 2.H.2 fossil CO_2 is reported as not estimated (NE). According to the IPCC Guidelines Reference Manual, emissions of fossil CO_2 from the sector are not likely but in submission 2019 minor CO_2 emissions from the use of soda ash and limestone for flue gas cleaning in CRF 2.H.1 are included for the first time.

4.9.1 Pulp and paper (CRF 2.H.1)

4.9.1.1 SOURCE CATEGORY DESCRIPTION

The pulp and paper industry in Sweden is an important source of industrial process emissions. Emissions from 44 individual pulp and paper facilities are included in the inventory. Of those, six facilities only have energy related emissions which are reported in CRF 1.A.2.D. Of the facilites included with process related reported in CRF 2.H.1 one shut down in 2004, two in 2008 and one in 2012. For 2017 emissions from 34 individual pulp and paper facilities are included in reported emissions in CRF 2.H.1. The Kraft process (sulphate) dominates in Sweden but there are also emissions from sulphite facilities and facilities that are mainly CTMP (Chemo Thermo Mechanical Pulp) or TMP (Thermo Mechanical Pulp) facilities reported in CRF 2.H.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 4.66.

Table 4.66. Summary of source category description, CRF 2.H.1, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.H.1	CO_2	NA	NA		NA	NA	NA
	CH_4				CS	CS	Yes
	N_2O	X	X		CS	CS	Yes

CS Country Specific.

4.9.1.2 METHODOLOGICAL ISSUES

Reported emissions from the pulp and paper industry are primarily based on information on 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 terpenes.

The Swedish definition of process emissions includes the combustion of spent cooking liquor (black liquor) which gives rise to emissions of N_2O and CH_4. The black liquor contains organic compounds and chemicals and is combusted to recover Na and S, but also to utilise the energy in the black liquor. The recovered Na and S (as Na_2CO_3 and Na_2S) are recycled and used in the process again.

The estimated CO_2 process emissions that arise as a result of the use of limestone as make-up lime are allocated in CRF 2.A.2. Minor emissions of fossil CO_2 from use of soda ash and from use of lime stone for flue gas cleaning are in submission 2019 for the first time reported in CRF 2.H.1.'

Activity data is presented in figure 4.19 below. The various kinds of pulp produced in Sweden are categorized into sulphate, suphite and mechanical pulp with production of sulphate pulp dominating throughout the years.

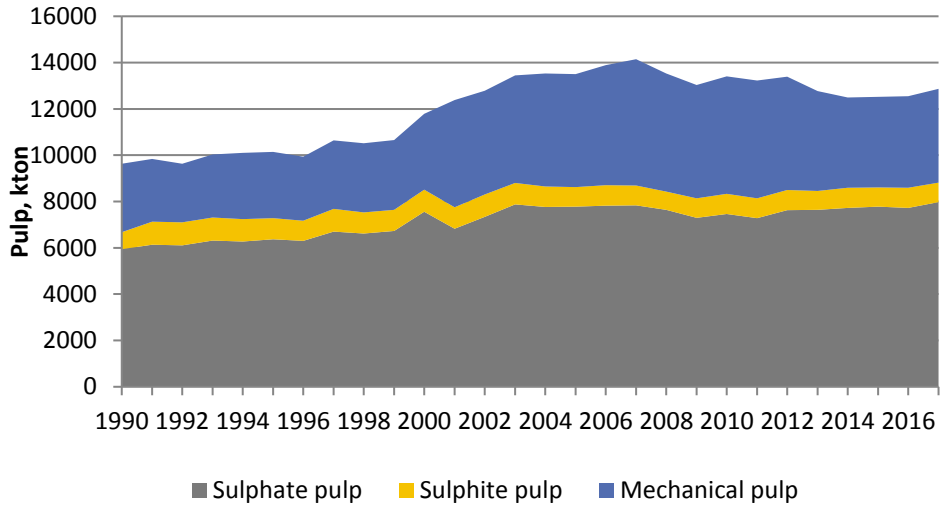

Figure 4.19. Production of pulp in Sweden 1990-2017

4.9.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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

4.9.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.9.1.5 SOURCE-SPECIFIC RECALCULATIONS

Minor emissions of fossil CO2 from use of soda ash and from use of lime stone for flue gas cleaning are in submission 2019 for the first time reported in CRF 2.H.1. Updates of reported emissions of NOX have been made for four facilities in 2015 and 18 facilities in 2016. Also minor updates of reported SO2 have been made, for four facilities in 2015 and 19 facilities in 2016. Update of activity data for one facility resulted in minor update of reported emissions of NMVOC in 2016. Emissions of NOX decreased with less than 1 ton in 2015 and increased with 0.013 kton in 2016. Emissions of SO2 decreased with around 0.4 kton in 2015 and increased with 0.1 kton in 2016. NMVOC increased with around 0.003 kton in 2016.

4.9.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.9.2 Food and drink (CRF 2.H.2)

4.9.2.1 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. Greenhouse gas emissions have not been estimated due to the lack of available methodology and data. Emissions of greenhouse gases are however considered to be insignificant.

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 4.67.

Table 4.67. Summary of source category description, CRF 2.H.2, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.H.2	CO_2	NA	NA		NA	NA	No, see Annex 5
	CH_4	NA	NA		NA	NA	NA
	N_2O	NA	NA		NA	NA	NA

4.9.2.2 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[219] together with figures on import and export[220]. NMVOC emissions from beer production are based on the Swedish annual total production of beer[221]. 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 4.68 were used. Emission factors from EMEP/EEA that was used in 2.H.2 can be found at: https://www.eea.europa.eu/publications/emep-eea-guidebook-2016/part-b-sectoral-guidance-chapters/2-industrial-processes/2-h-other-industry-production/2-h-2-food-and.
Emissions of CO_2 are not estimated but are believed to be minor or of biogenic origin.

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

[220] Statistics Sweden. http://www.scb.se/

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

Table 4.68. NMVOC emission factors for the reported production activities in CRF 2.H.2 - Food and drink

Production activity	Emission factor	Unit	Reference EF (see footnotes)
Liquors	0.6	kg/1000 litres	222
Wine	0.08	kg/1000 litres	EMEP/EEA Guidebook 2016
Beer	0.035	kg/1000 litres	EMEP/EEA Guidebook 2016
Bread (sponge dough)	0.45	kg/Mg	EMEP/EEA Guidebook 2016
Bread (white)	0.45	kg/Mg	EMEP/EEA Guidebook 2016
Bread (whole meal and light rye)	0.45	kg/Mg	EMEP/EEA Guidebook 2016
Bread (dark rye)	0.45	kg/Mg	EMEP/EEA Guidebook 2016
Cakes	0.1	kg/Mg	EMEP/EEA Guidebook 2016
Biscuits	0.1	kg/Mg	EMEP/EEA Guidebook 2016
Breakfast cereals	0.1	kg/Mg	EMEP/EEA Guidebook 2016
Sugar	1	kg/Mg	EMEP/EEA Guidebook 2016
Yeast	1.8	kg/Mg	EMEP/EEA Guidebook 2016
Margarine and solid cooking fats	1	kg/Mg	EMEP/EEA Guidebook 2016
Coffee roasting	0.055	kg/Mg	EMEP/EEA Guidebook 2016
Animal feed	0.1	kg/Mg	EMEP/EEA Guidebook 2016

4.9.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The time series is consistent. The uncertainties are calculated according to Guidebook 2016. The uncertainty for NMVOC is ± 200 %, and the uncertainty of activity data is set to ± 20 %.

4.9.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.9.2.5 SOURCE-SPECIFIC RECALCULATIONS

New emission factors from EMEP/EEA Emission Inventory Guidebook 2016 have been implemented for all different components except spirits. This has led to an update for the whole time series. Since the EF in EMEP/EEA Guidebook 2016 includes abatement of 90 % the emissions have decreased significantly. Also activity data, thus affecting reported NMVOC emissions, have been updated, due to new information for statistics available at Statistics Sweden's website, for 1996-2016. The recalculations resulted in decreased NMVOC emissions of between -4.1 to -2.2 kt.

4.9.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.9.3 Other (CRF 2.H.3)

4.9.3.1 SOURCE CATEGORY DESCRIPTION

In CRF 2.H.3, NMVOC emissions from battery production, CO_2 and NMVOC emissions from mineral wool production and NO_X emissions from Quarrying and mining of minerals other than coal are reported.

[222] Based on information from one producer, 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), is presented in Table 4.69.

Table 4.69. Summary of source category description, CRF 2.H.3, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.H.3	CO_2				PS	D	No, see Annex 5
	CH_4	NA	NA	NA	NA	NA	NA
	N_2O	NA	NA	NA	NA	NA	NA

D Default. PS Plant-Specific.

4.9.3.1.1 Quarrying and mining of minerals other than coal, CRF 2.H.3.a

The only emissions reported for the non-iron ore mining and dressing are, in this submission, NO_X released from use of explosives. Estimated emissions from combustion of fuels are included in the Energy sector (CRF 1).

4.9.3.1.2 Mineral wool, CRF 2.H.3.b

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

4.9.3.1.3 Battery manufacturing, CRF 2.H.3.c

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

4.9.3.2 METHODOLOGICAL ISSUES

4.9.3.2.1 Quarrying and mining of minerals other than coal, 2.H.3.a

Data on NO_X emissions from use of explosives within the non-iron ore mining industry are reported 2002 – 2017, 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.

4.9.3.2.2 Mineral wool production, 2.H.3.b

CO_2 emissions from mineral wool producers in Sweden derive mainly from the use of limestone and dolomite in the process. Blast furnace slag was used in the process between (1990-1995 and 1998-1999), causing a smaller amount of CO_2 emissions. Activity data on limestone and dolomite are obtained from the EU ETS and the 2006 IPCC emission factor for respective carbonate is used. Limestone is assumed to have a purity of 97 % and dolomite a purity of 100 %. Data on slag consumption has been obtained from the mineral wool producers. The emission factor is 0.04 kt CO_2 /kt 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

Within mineral wool production, limestone and dolomite used also cause process emissions of CO_2 which are estimated based on activity data for each type of carbonate and corresponding emission factor:

> Emissions of CO_2 (Mg) from use of limestone and dolomite = Limestone (Mg) * 0.97*44.0098/100.0892 + Dolomite (Mg) * 88.02/184.4

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.

4.9.3.2.3 Battery manufacture, 2.H.3.c

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.

4.9.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty of direct CO_2 emissions is set to ± 6 % and the time series is consistent.

4.9.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.9.3.5 SOURCE-SPECIFIC RECALCULATIONS

Quarrying and mining of minerals other than coal, 2.H.3.a: NOx emissions for 2012-2016 from one mine was added in submission 2019.
Mineral wool 2.H.3.b: No source-specific recalculations were performed during submission 2019.
Battery manufacture 2.H.3.c: No source-specific recalculations were performed during submission 2019.

4.9.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

5 Agriculture (CRF sector 3)

5.1 Overview of sector

In the agricultural sector emissions of nitrous oxide (N_2O), methane (CH_4) and carbon dioxide (CO_2) are reported. Carbon dioxide from working vehicles and other energy use is reported in the energy sector and carbon dioxide from agricultural soils (excluding liming) is reported in the LULUCF sector. Sweden's inventory includes emissions from enteric fermentation, manure management, agricultural soils, liming and urea application. Rice cultivation, burning of savannahs, burning of agricultural residues and emissions from other carbon-containing fertilisers do not occur in Sweden. The agriculture in Sweden 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 the remaining holdings are growing larger. Livestock farmers predominately engage in milk production and the main crops grown in Sweden are grain and fodder crops.[223] The decrease of agricultural land area has continued since Sweden joined the European Union in 1995 but the acreages of land for hay and silage have had an increasing trend. Organic farming has increased from 6 % of the arable land area in 1996 to 19 % in 2017.[224]

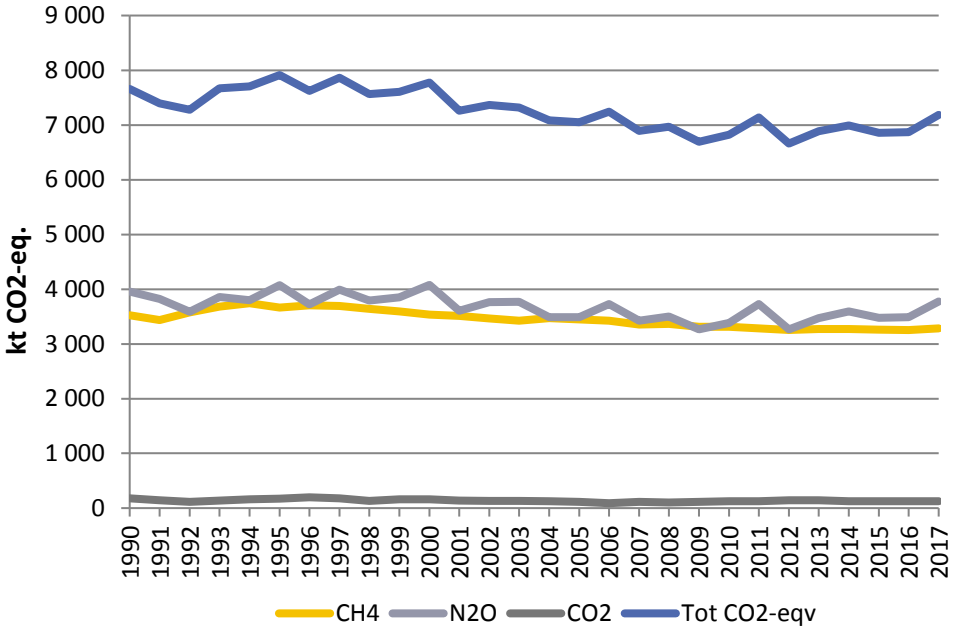

Figure 5.1. Total emissions of all greenhouse gases calculated as CO_2-eq. from CRF 3, agriculture.

[223] Ministry of the Environment, 2001.

[224] Swedish Board of Agriculture, www.jordbruksverket.se

Total greenhouse gas (GHG) emissions from the agricultural sector have decreased by 6.2 % since 1990, from 7 658 kt CO_2-eq. to 7 187 kt CO_2-eq. (figure 5.1). The most significant sub-sectors in Sweden are enteric fermentation (3.A) and agricultural soils (3.D), see figure 5.2.

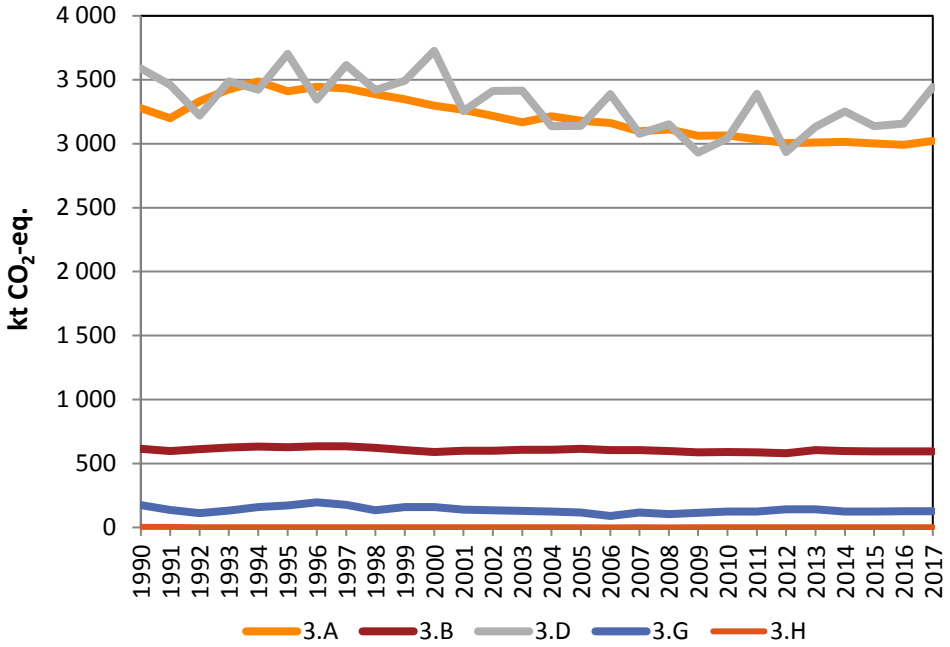

Figure 5.2. Total emissions of all greenhouse gases calculated as CO_2-eq. from the different agricultural sub-sectors. There are no emissions from 3.C, 3.E-F and 3.I-J.

Emissions from livestock are the main source of greenhouse gas from agriculture. In table 5.1 all the livestock subgroups used in the calculations are presented. The Farm Register is the main source for agricultural statistics in Sweden. This register is administered by the Swedish Board of Agriculture together with Statistics Sweden and provides annual information on the total number of animals of different categories on Swedish farms[225]. The information on livestock refers to the situation prevailing in June of that year and is considered 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 younger than 6 months and the rest are assumed older than 6 months. Concerning horses, the Farm Register underestimate the number of horses because only horses on farms are included (i.e. not horses for private leisure activities). However, three separate surveys[226] estimate the total number of horses in Sweden in 2004, 2010, and 2016. These estimates are used in the inventory. The number of slaughter chickens (i.e. average number of chickens kept during the year) is estimated from the number of slaughtered chickens by taking into account the timespan between production cycles.

[225] Swedish Board of Agriculture, JO 20-series.

[226] Swedish Board of Agriculture, JO 24-series.

Table 5.1. Livestock subgroups used in the calculations

Categories according to IPCC Guidelines	Sub-categories Enteric Fermentation	Sub-categories Manure management	Sub-categories Grazing animals
Dairy Cattle (**)	Dairy cows	Dairy cows	Dairy cows
Non-Dairy Cattle (**)	Suckler cows	Suckler cows	Suckler cows
	Heifers	Heifers	Heifers
	Bulls and steers	Bulls and steers	Bulls and steers
	Calves	Calves < 6 months Calves > 6 months	Calves
Swine (**)	Swine	Sows	NO
		Boars	
		Pigs for meat production	
		Piglets	
Sheep (**)	Sheep	Sheep	Sheep
Goats (**)	Goats	Goats	Goats
Horses (***)	Horses	Horses	Horses
Poultry	NE	Laying hens (**)	NO
		Chickens (**)	
		Slaughter Chickens (****)	
		Turkeys (**)	
Fur-bearing animals	NE	Minks (**)	NO
		Foxes (**)	
Other (*****)	Reindeer	NO	Reindeer

(*) The age distribution of calves is accomplished by using standard values. (**) The Farm Register. (***) Statistics Sweden. (****) Swedish board of agriculture. (*****) Sametinget (The Sami Parliament of Sweden).

5.2 Enteric Fermentation (CRF 3.A)

5.2.1 Source category description

Enteric fermentation from cattle is the major source of methane emissions in CRF 3.A. The total number of livestock in Sweden in 1990-2017 is presented in table 5.5. 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 5.2.

Table 5.2. Summary of source category description, CRF 3.A, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qual.			
3.A.1 Dairy cattle	CH_4	X	X		CS	CS	Yes
3.A.1 Non-dairy cattle	CH_4	X	X		CS	CS	Yes
3.A.2 Sheep	CH_4	X	X		T1	D	Yes
3.A.3 Swine	CH_4	X			T1	D	Yes
3.A.4 Goats	CH_4				T1	D	Yes
3.A.4 Horses	CH_4	X	X		T1	D	Yes
3.A.4 Poultry	CH_4				T1	D	Yes
3.A.4 Reindeer	CH_4	X	X		T1	CS	Yes

CS - Country Specific. T1 - tier 1. T2 - tier 2. D - Default.

5.2.2 Methodological issues

5.2.2.1 EMISSION FACTORS, METHANE

The livestock population (table 5.5 and table 5.6) for each category is multiplied by an emission factor and the total emission is calculated as:

$$emissions = \sum_i population_i \times EF_i$$

All emission factors (EF_i) for cattle are national. The IPCC guidelines recommends that the methane conversion rate should be zero for calves feeding only milk. Personal communication with Swedish experts resulted in that this period is assumed two months for calves of dairy breed and three months for other breeds. When no default emission factor exists for reindeer, the emission factor is estimated based on the live weight ratio between deer and reindeer according to the suggested formula in the guidebook. To estimate the average weight of reindeer in Sweden we have used statistics from the Sami parliament of Sweden (Sametinget) on slaughter weight and on the distribution of different types (i.e. cows, calves, bulls and oxen) of reindeer in the heard. With the assumption (also from the Sami parliament) that the slaughter weight represents half the live weight, the average reindeer weight was estimated to 64 kg. To estimate the emissions from swine, sheep, goats and horses the IPCC default values are used.

The country specific emissions factors for cattle are developed at the department of animal nutrition and management at the Swedish university of agricultural sciences

(SLU) [227]. The methods and the activity data used are to a large extent developed within the NorFor[228] organization. The NorFor organization is formed by experts in animal nutrition and information technology from the Nordic countries. One of their main activities is to develop and maintain a feed evaluation system called the NorFor Model. The system is currently in use in Denmark, Sweden, Norway and Iceland on approximately 9,000 dairy farms with some 1,000,000 head of cattle. A distinction between this system and the previous feed evaluation systems is that NorFor is based on net energy (NE) instead of metabolisable energy (ME). Data on how animals actually are fed on farms are not available to the same extent today as 10 years ago. Today most farmers produce the forage for cattle feeding themselves but concentrates are often bought from feed companies. To estimate actual feed, standard diets have been used when available in the web-based advisory package AgriWise[229] together with other surveys concerning feeding of cattle. The equations used by the NorFor to estimate methane emissions are based on Nordic feed trials carried out during the recent years on research stations in all participating countries.

5.2.2.1.1 Dairy cattle

One of the variables needed for the dairy cattle calculations is milk yield per cow. This is estimated from total milk delivered to Swedish dairies[230], complementing with the on farm consumption (including milk that does not meet the dairies quality demands) which is estimated to 5.6% of amount delivered. The live weight of dairy cows is assumed to be 650 kg. This is based on experiences from SLU's research herds as well as for research herds where both Holstein and red cows have this weight. The different equations used for the development of the emission factor are:

$$ECM = MilkYield \times ((383 \times Fat + 242 \times Protein + 783.2) / 3140)$$

ECM is the amount of energy corrected milk, MilkYield = total milk delivered to Swedish dairies, Fat = fat content of the milk, Protein = protein content of the milk.

$$ECM/day = ECM \times 1.056 / Population / 365$$

Amount of milk produced per cow and day, including on farm consumption.

$$ME = (0.507 \times 650^{0.75}) + ECM/day \times 5 + (1/12 \times (8.5+13+19.5)$$

ME = metabolisable energy required per day including maintenance, lactation and pregnancy. 0.507 = maintenance energy (MJ/kg live weight), 650 = average weight (kg), 5 = energy requirements to produce one kg of ECM (MJ). The energy additional requirement for pregnancy in estimated to be 8.5, 13 and 19.5 MJ per day in months 7, 8 and 9, respectively.

$$ME\_Corr = 1.11 \times ME - 13.6$$

Metabolisable energy corrected for actual feeding levels.

$$ME\_Feed = FracCO_{nc} \times Conc + (1- FracCO_{nc}) \times Silage$$

[227] Bertilsson, 2016.

[228] http://www.norfor.info

[229] http://www.agriwise.org

[230] Data from The Federation of Swedish Farmers (www.lrf.se)

Metabolisable energy content in the feed (MJ/kg). $FracCO_{nc}$ = fraction of concentrates in the feed, Conc = energy content in concentrates (13.4 MJ/kg DM), Silage = energy content in silage (increases from 9.5 to 10.1 MJ/kg DM between 1990 and today).

$$FA = FracCO_{nc} \times Conc\_F + (1- FracCO_{nc}) \times Silage\_F$$

Fatty acids content in the feed. Conc_F = fat content in concentrates (43 g/kg DM), Silage_F = fat content in silage (12 g/kg DM).

$$DMI = ME\_Corr / ME\_Feed$$

DMI is the total dry matter intake per animal and day (kg DM/animal/day).

$$CH_4\_MJ = 1.39 \times DMI - 0.091 \times FA$$

CH_4_MJ is the total energy content in the methane emitted (MJ/cow/day). The equation is based on Nordic feed trials carried out during the last few years on research stations within NorFor. This equation was found to be the one that most accurately predicted the emissions for dairy cows[231].

$$EF\_Dairy = (CH_4\_MJ / 55.65) \times 365$$

And finally, EF_Dairy is the total methane emissions from enteric fermentation (kg/animal/year) where 55.65 MJ/kg CH_4 is the energy content of methane (see table 5.6).

5.2.2.1.2 Suckler cows

The same equations as for the dairy cattle are used for suckler cows, but with some modification of activity data. (i) The average amount of milk produced is estimated to 5.5 kg ECM per animal and day. Milk yields are assumed to be 14, 12, 12, 10, 10, 8 kg ECM/cow/day during lactation months 1 to 6, respectively. (ii) The live weight is estimated to be 750 kg. (iii) The additional energy requirement for pregnancy in estimated to be 10, 16 and 29 MJ per day in months 7, 8 and 9, respectively. (iv) $FracCO_{nc}$ is zero, i.e. only silage feeding is assumed.

5.2.2.1.3 Heifers and bulls

The estimation of the emission factors for heifers and bulls differ slightly from the method used for dairy cattle and suckler cows. Especially a reduced amount of activity data are needed for the calculations. In table 5.3 the activity data used are presented, and in table 5.4 the intermediate calculation steps to estimate the different emission factors are given.

[231] Nielsen et al. 2013

Table 5.3. Activity data used to estimate the emissions factors for enteric fermentation.

	Heifers			Bulls and steers		
	<1 year	1-2 years	>2 years	<1 year	1-2 years	>2 years
Live weight	200	385	580	250	500	625
Energy requirements (MJ)	45.5	70.5	93.5	71	106.5	107.5
Metabolisable energy in feed (MJ/kg DM)	11.5	10.1	10.1	12.3	11.7	10.4
$FracCO_{nc}$	0.50	0.15	0.15	0.7	0.5	0.1
Gross energy in feed (MJ/kg DM)	19.2	19.8	19.8	18.9	19.2	19.8

Table 5.4. Intermediate steps to calculate the emissions factors for enteric fermentation.

	Heifers			Bulls and steers		
	<1 year	1-2 years	>2 years	<1 year	1-2 years	>2 years
DMI (kg DM/head/day)	4.0	7.0	9.3	5.5	8.7	9.8
Gross energy intake (MJ/head/day)	76.3	138.1	183.2	103.8	166.7	194.6
CH_4 MJ (fraction of GE)	0.048	0.064	0.064	0.039	0.048	0.067
EF (kg CH_4/head/year)	**24**	**58**	**77**	**27**	**53**	**85**

The first step in table 5.4 is to estimate the dry matter intakes (DMI). This is done by dividing the energy requirements with the metabolisable energy in feed. Then the gross energy intake per animal and day is calculated by multiplying the DMI by the gross energy content in the feed. In the subsequent step the percentage of the gross energy that is lost as CH_4 is estimated from the equation,

$$CH_4 \text{ MJ (fraction of GE)} = -0.046 \times ConcP + 0.071379$$

Where ConcP is the fraction of concentrates in the feed. This equation is used in the NorFor and is based on Danish trials[232]. Then the average annual energy lost as CH_4 is calculated by multiplying this fraction with the gross energy intake. Finally, the emissions factors are estimated by dividing the result with the energy content of methane (55.65 MJ/kg CH_4) and multiplying it with 365 the get the annual emissions.

The total emissions are then estimated by multiplying the calculated emissions factors with the number of livestock in the different categories in the official statistics (i.e. heifers, bulls and steers and calves) (see table 5.7).

[232] Nielsen 2013

Table 5.5. Population size of different animal groups (1000s heads). See table 5.6 for dairy cattle.

	Non-Dairy Cattle				Swine				Sheep	
Year	Suckler cows	Heifers	Bulls and steers	Calves	Sow	Pig for meat production	Piglet	Boar	Sheep	Lamb
1990	75	337	206	524	221	1 276	758	8.6	162	244
1995	157	370	226	542	237	1 300	768	7.6	195	266
2000	167	365	224	500	202	1 146	566	4.2	198	234
2005	177	327	200	508	185	1 085	538	2.7	222	249
2010	197	322	191	479	154	937	427	2.3	273	292
2015	184	311	178	467	140	830	384	1.5	289	306
2016	194	305	184	475	139	835	378	1.5	281	297
2017	208	307	193	472	140	836	385	1.6	301	305

Table 5.5 (continued).

	Horses	Goats		Other		Poultry			
Year	Horse	Goat	Kid	Reindeer	Fur-bearing animals	Laying hen	Turkey	Chicken	Slaughter Chicken
1990	316	2.8	2.8	271	297	6 400	122	2 200	4 476
1995	316	2.8	2.8	253	254	6 100	122	1 800	7 055
2000	316	2.8	2.8	221	276	5 700	122	1 700	7 896
2005	323	3.7	3.7	261	290	5 100	122	1 700	8 453
2010	363	5.2	5.2	250	180	6 061	130	1 647	9 159
2015	363	6.8	6.8	250	210	7 571	156	1 842	11 044
2016	356	7.1	7.1	248	200	8 174	130	1 575	11 659
2017	356	7.7	7.7	254	200	7 294	131	1 994	11 723

Table 5.6. Activity data used for estimating the emissions from enteric fermentation for dairy cattle.

Year	Dairy cows (number of heads)	Total milk delivered* (kt)	Average fat content (%)	Average protein content (%)	Yield per cow, kg ECM/yr	CH_4 EF for Dairy Cattle
1990	576 409	3 432	4.31	3.36	6 503	112.2
1995	482 118	3 243	4.33	3.34	7 352	121.9
2000	427 621	3 297	4.18	3.28	8 240	130.6
2005	393 263	3 163	4.25	3.38	8 734	135.2
2010	348 095	2 862	4.23	3.41	8 928	135.7
2015	339 823	2 933	4.25	3.42	9 401	140.0
2016	330 833	2 862	4.24	3.45	9 433	140.3
2017	322 010	2 817	4.21	3.47	9 518	141.3

* Including on farm consumption.

Table 5.7. Methane from animals, used emission factors

Livestock subgroups	kg CH_4/head/year	Method
Dairy cows	See table 5.6	1
Suckler cows	92	1
Heifers	63.7	1
Bulls and steers	57.8	1
Calves	25.5	1
Swine	1.5	2
Sheep	8	2
Goats	5	2
Horses	18	2
Poultry	No fermentation assumed	
Reindeer	12.5	3

(1) Bertilsson, 2016. (2) IPCC 2006 Guidelines. (3) Estimated from the value for deer.

5.2.3 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. Since no estimate on the number of horses exists before 2004, the value for 2004 is used for all preceding years.

5.2.4 Source-specific QA/QC and verification

The time series for the different populations and milk production is checked for consistency. Annual increase or decrease is verified for the whole time series for all sub sources to decide that all annual changes are reasonable. We compare the times series for the emission with the time series for the activity data to confirm that are in agreement. We regularly conduct crosschecks of country-specific factors against the IPCC defaults. We annually utilize experts from the Swedish board of agriculture to conduct expert peer review of the methods used and we have regular meetings with authorities that provide activity data to the inventory to ensure that the quality of the data are of satisfactory quality and that they in turn use appropriate QC methods.

5.2.5 Source-specific recalculations

- The complete time series for number of goats have been revised, due to updated data from the Swedish Board of Agriculture.
- There was a minor recalculation for 2016 because of revised data from the Swedish Dairy Association on total milk delivered in 2016.
- The Sami parliament of Sweden updated the time series for number of reindeer.

The total effect of the recalculations in 3.A for the two most recent recalculated years was an increase of the estimated emissions with 0.03 % (1.01 kt CO_2-eq) and 0.05 % (1.37 kt CO_2-eq) for 2015 and 2016, respectively.

5.2.6 Source-specific planned improvements

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

5.3 Manure Management (CRF 3.B)

5.3.1 Source category description

This category includes emissions of methane and nitrous oxide from manure management. It also includes indirect emission of N_2O through volatilisation of nitrogen during storage. 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), are presented in table 5.8.

Table 5.8. Summary of source category description, CRF 3.B, according to approach 1

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
3.B.1 Dairy cattle	CH_4	X			T2	CS, D	Yes
	N_2O	X	X		T2	D	Yes
3.B.1 Non-dairy cattle	CH_4	X	X		T2	CS, D	Yes
	N_2O	X	X		T2	D	Yes
3.B.2 Sheep	CH_4				T1	D	Yes
	N_2O				T2	D	Yes
3.B.3 Swine	CH_4	X			T2	CS, D	Yes
	N_2O	X			T2	D	Yes
3.B.4 Goats	CH_4				T1	D	Yes
	N_2O				T2	D	Yes
3.B.4 Horses	CH_4				T1	D	Yes
	N_2O				T2	D	Yes
3.B.4 Poultry	CH_4				T1	D	Yes
	N_2O	X	X		T2	D	Yes
3.B.4 Reindeer	CH_4				T1	D	Yes
	N_2O				T2	D	Yes
3.B.4 Fur-bearing animals	CH_4				T1	D	Yes
	N_2O				T2	D	Yes
3.B.5 Indirect	N_2O	X			T2	CS	Yes

CS - Country Specific. T1 - tier 1. T2 - tier 2. D - Default.

5.3.2 Methodological issues

Statistics on manure management and the use of manure and fertilisers in agriculture have since 1988 been collected every second or third year by Statistics Sweden[233]. Data on stable periods (table 5.9) and the manure management systems, liquid (table 5.10), solid (table 5.11) and deep litter (table 5.12) originate from this survey. Deep litter is categorised as "other" in the CRF-tables. Data on manure treated in anaerobic digesters (table 5.13) are derived from the report series "Production and use of biogas and digestate", produced by the Swedish Energy Agency[234]. This report series is produced since 2005. Between 1997 (when the first pilot plants started to produce small amounts of biogas) and 2005, we assume a

[233] Statistics Sweden, MI 30-series.

[234] Swedish Energy Agency. Produktion och användning av biogas och rötrester.

linear increase in amount of manure used as substrate. Data on composting (table 5.13) originate from the report "Horse keeping in Sweden 2016"[235]. Only horse manure is systematically composted in significant amounts in Sweden. National estimates of stable periods has been available since 1997. Before this, the data are extrapolated to 1990. Since dairy cows often are stabled at night and spend time in the stables during milking, the data on stable periods for this animal category is combined with the assumption that 38 % of its manure is excreted in the stable during the grazing period. Data on manure and nitrogen excretion are compiled by the Swedish board of agriculture and based on nutrient balance calculations. The underlying data are based on a variety of sources. The data for the most significant animal groups (i.e. cattle and swine) are from public reports produced by the Swedish Board of Agriculture. Some of the data for the less significant animal groups are based on expert opinions. See "Compilation of data on manure and nitrogen excretion" in the reference list for a complete list of the sources. For dairy cows the nitrogen and manure excretion are calculated based on milk production (see table 5.14). Because average milk production has increased during the reporting period, the manure and nitrogen excretion has also increased. For the other animal groups the data on manure and nitrogen excretion are given in table 5.15 and table 5.16, respectively. The data are estimated values per head, year and box. That is, the excretion if one, hypothetically, assumes that an animal of a specific animal category would stay in the box for a year. Total annual excretion per animal category is then estimated by multiplying these values with the estimated annual average population. Naturally, the number of animals in the different categories/age classes will vary somewhat during a year. I.e. piglets will grow and enter the next growth class. However, we use the value from the farm register as an approximation of the annual average. Due to a more intense swine production, the yearly excretion for sows and pigs for meat production were updated in 2001. All emission factors used in the calculations are presented in table 5.17.

Table 5.9. Livestock stable periods (months)

Year	Dairy cows	Suckler cows	Heifers	Bulls and steers	Calves	Sheep, horses, goats	Rein-deer	Poultry, Swine and Fur-bearing animals
1990	7.2	6.2	6.5	7.6	7.8	6	0	12
1995	7.2	6.2	6.5	7.6	7.8	6	0	12
2000	7.2	5.8	6.1	7.6	7.6	6	0	12
2005	6.9	4.9	5.6	8.4	7.6	6	0	12
2010	7.2	5.5	5.8	8.8	8.2	6	0	12
2015	7.3	5.8	6,0	9.8	8.2	6	0	12
2016	7.3	5.5	5.9	9.2	8.1	6	0	12
2017	7.3	5.5	5.9	9.2	8.1	6	0	12

[235] Swedish Board of Agriculture. Hästhållning i Sverige 2016.

Table 5.10. Liquid waste management systems (fractions)

Year	Dairy cattle	Suckler cows	Heifers	Bulls and steers	Calves	Pigs for meat production	Other swine	Sheep, goats, horses, reindeer and fur-bearing animals	Laying Hens, Chickens	Slaughter Chickens, Turkeys
1990	0.23	0.16	0.16	0.19	0.20	0.44	0.44	0	0.25	0.00
1995	0.31	0.21	0.22	0.26	0.26	0.63	0.63	0	0.25	0.00
2000	0.39	0.13	0.13	0.16	0.16	0.80	0.26	0	0.25	0.00
2005	0.51	0.06	0.20	0.22	0.19	0.91	0.32	0	0.21	0.00
2010	0.57	0.11	0.22	0.29	0.17	0.91	0.60	0	0.12	0.00
2015	0.60	0.10	0.25	0.31	0.16	0.81	0.49	0	0.09	0.00
2016	0.64	0.11	0.26	0.38	0.21	0.84	0.54	0	0.09	0.00
2017	0.64	0.11	0.26	0.38	0.21	0.83	0.54	0	0.09	0.00

Table 5.11. Solid waste management systems (fractions)

Year	Dairy cattle	Suckler cows	Heifers	Bulls and steers	Calves	Pigs for meat production	Other swine	Sheep, goats	Reindeer	Fur-bearing animals	Horses	Laying Hens, Chickens	Slaughter Chickens, Turkeys
1990	0.52	0.29	0.30	0.35	0.36	0.54	0.45	0.5	0	1	0.48	0.55	0.00
1995	0.44	0.23	0.25	0.29	0.29	0.35	0.26	0.5	0	1	0.48	0.55	0.00
2000	0.35	0.28	0.29	0.37	0.37	0.19	0.67	0.5	0	1	0.48	0.55	0.00
2005	0.22	0.19	0.17	0.27	0.23	0.07	0.46	0.5	0	1	0.48	0.73	0.00
2010	0.16	0.20	0.15	0.26	0.22	0.08	0.32	0.5	0	1	0.48	0.88	0.00
2015	0.11	0.20	0.12	0.25	0.16	0.17	0.45	0.5	0	1	0.48	0.78	0.00
2016	0.07	0.15	0.09	0.13	0.14	0.16	0.29	0.5	0	1	0.48	0.90	0.00
2017	0.07	0.15	0.09	0.13	0.14	0.16	0.29	0.5	0	1	0.48	0.90	0.00

Table 5.12. Deep litter waste management systems (fractions). Categorised as "Other" in the CRF-tables.

Year	Dairy cattle	Suckler cows	Heifers	Bulls and steers	Calves	Pigs for meat production	Other swine	Sheep, goats, reindeer, Fur-bearing animals	Horses	Laying Hens, Chickens	Slaughter Chickens, Turkeys
1990	0.01	0.07	0.08	0.09	0.09	0.02	0.11	0	0.02	0.20	1.00
1995	0.01	0.07	0.08	0.09	0.09	0.02	0.11	0	0.02	0.20	1.00
2000	0.01	0.08	0.08	0.10	0.10	0.01	0.07	0	0.02	0.20	1.00
2005	0.00	0.16	0.10	0.20	0.22	0.01	0.22	0	0.02	0.07	1.00
2010	0.01	0.14	0.11	0.19	0.29	0.01	0.07	0	0.02	0.00	1.00
2015	0.01	0.17	0.12	0.22	0.34	0.02	0.06	0	0.02	0.13	1.00
2016	0.01	0.19	0.12	0.23	0.30	0.01	0.17	0	0.02	0.01	1.00
2017	0.01	0.19	0.12	0.23	0.30	0.01	0.17	0	0.02	0.01	1.00

Table 5.13. Anaerobic digestion and composting waste management systems (fractions). Affects only cattle, swine and horses.

	Anaerobic digestion				Composting
Year	Dairy cattle	Non-dairy cattle	Swine	MCF for digesters	Horses
1990	0.00	0.00	0.00	0.00	15.00
1995	0.00	0.00	0.00	0.00	15.00
2000	0.04	0.02	0.14	10.73	15.00
2005	0.10	0.04	0.32	10.67	15.00
2010	0.23	0.10	0.79	10.63	15.00
2015	1.15	0.53	4.28	10.73	15.00
2016	1.13	0.54	4.29	10.73	15.00
2017	1.16	0.54	4.32	10.73	15.00

Table 5.14. Manure production and nitrogen excretion from dairy cows

Year	Manure production (kg VS DM/day/head)	Nitrogen excretion (kg/year/head)
1990	5.07	102.0
1995	5.19	110.5
2000	5.29	119.4
2005	5.32	124.3
2010	5.33	126.3
2015	5.35	131.0
2016	5.36	131.3
2017	5.36	132.2

Table 5.15. Manure production from other animal groups

Animal group	Manure production (kg VS DM/day
Suckler cows	2.30 (in stables) 3.17 (during grazing)
Heifers	2.26
Bulls and steers	2.26
Calves < 6 months	0.60
Calves > 6 months	0.97
Sows	0.64 (1990-2001) 0.69 (as from 2002)
Boars	0.45
Pigs for meat production	0.37
Piglets	0.044

Data from the Swedish Board of Agriculture

Table 5.16. Nitrogen excretion from other animal groups

Animal group	Nitrogen kg/year/ head	Comment	Updated values on nitrogen prod. used from 2002, kg/ year/head	Comment
Suckler cows	63			
Heifers	47			
Bulls and steers	47			
Calves	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	1.2			
Sheep	14	Ewes incl. 1.8 lambs		
Lambs	0			
Goats	13	Does incl. 1.8 kids		
Kids	0			
Horses	48			
Laying hens	0.60	0.8 prod. cycles/ year		
Turkeys	0.69	2.3 prod. cycles/ year		
Chickens	0.22	2.2 prod. cycles/ year		
Slaughter Chickens	0.29	8.5 prod. cycles/ year		
Fur-bearing animals	4.59			
Reindeer	10			

Data from the Swedish Board of Agriculture

5.3.2.1 EMISSIONS OF METHANE (INCLUDING EXCRETION FROM GRAZING ANIMALS) (CRF 3.B(A))

The IPCC tier 2 methodology is used for estimating methane from manure management for cattle and swine, including excretions from grazing animals. The corresponding tier 1 methodology is used for the other animal groups. The formula to calculate the emission factors for each livestock group, *i*, according to IPCC guideline's tier 2 methodology is:

$$EF_i = VS_i \times B_{0i} \times 0.67 \times \sum_j MCF_j \times MS_{ij}$$

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_j is the conversion factor for methane production, given a specific manure management system j (where grazing animals are considered as one of the systems). MS_{ij} is the fraction of animal manure handled using manure system j.

The B_{0i} and MCF factors used are the default values from the IPCC guidelines, except for the country specific MCF for liquid manure and digesters. For liquid manure the value 3.5 % is used. This value is developed by Rodhe et al. (2009) and is showed to be more appropriate for Sweden's cool conditions. This study measured GHG emissions for one year in three pilot-scale plants with similar conditions to full-scale storage regarding slurry temperature, climate and filling/emptying routines. The study concluded that 3.5 % is an appropriate MCF value for the storage of liquid manure in Sweden, which has an average temperature clearly below the definition of "Cool" in the IPCC guidelines. For digesters the MCF:s (table 5.13) are estimated based on formula 1 in table 10.17 in the 2006 guidelines. The parameters used to estimate the MCF:s are mainly from two studies. Rodhe et al. (2015)[236] investigated the greenhouse gas emissions from storage of digested and non-digested cattle slurry. The following parameters are obtained from that study; $MCF_{storage,digestate}$=25%, B_0 for digestate is assumed to be 45% out of B_0 for untreated manure and the estimation that 10% of the total VS is consumed during the digestion process. From Lantz & Björnsson[237] the following parameters are obtained; the average B_0 in the manure before treatment is estimated assuming 37% of the manure used as substrate in the digesters is from swine, and the remaning from cattle; The methan leacked during digestion averages 0.05 % of the produced methane and the dry weight of the substrate is 8.6 % of the wet weight. In addition to these a specific methane potential of 200 m^3 CH_4/tonne VS is used[238] and the flare efficiency for the methane flared is estimated to be 90 %. Only emissions from on farm digesters are accounted for in the agricultural sector, while emissions from co-digesters are accounted for in the waste sector. The reason we include emissions from on farm digesters in the agricultural sector is that; (i) these biogas plants use almost exclusively manure as substrate, (ii) The manure is stored on the premises, both before and after digestion, and (iii) the digestate is almost exclusively used as fertiliser.

[236] Rodhe et al. (2015)

[237] Lantz, M. & Björnsson, L. 2016

[238] Ahlberg-Eliasson et al. 2017

The reported emissions in the CRF tables are sometimes aggregated. Hence, the implied emission factor for, e.g. "non-dairy cattle" will depend not only on different manure management systems and stable periods over the years, but also on the relative composition of the subgroup. The implied emission factor will therefore vary between years.

When studying the trends for the implied emission factor (IEF) there is a distinctly increasing trend for both non-dairy and dairy cattle. This is caused by a decreased use of solid manure storage systems. For non-dairy cattle this is counteracted by an increased use of deep litter systems, and for dairy cattle, an increased use of liquid systems.

Table 5.17. Emission factors for manure management

Manure Management System/Animal category	**Emission factors for CH_4**	**Note**
MCF Solid manure	2 % of B_0	1
MCF Liquid manure	3.5 % of B_0	2
MCF Deep litter	17 % of B_0	1
MCF Digesters	See table 5.13	4
MCF Composting	0.5 % of B_0	1
MCF Pasture/Range/Paddock	1 % of B_0	1
Dairy Cattle - volatile solid	87 % of manure production (DM)	3
Dairy Cattle – B_0	0.24 m^3 CH_4/kg VS	1
Non-Dairy Cattle –VS	87 % of manure production (DM)	3
Non-Dairy Cattle – B_0	0.18 m^3 CH_4/kg VS	1
Swine – volatile solids	87 % of manure production (DM)	3
Swine – B_0	0.45 m^3 CH_4/kg VS	1
Sheep – emission	0.19 kg CH_4/animal/yr	1
Goats – emission	0.13 kg CH_4/animal/yr	1
Horses – emission	1.56 kg CH_4/animal/yr	1
Poultry (Layers) – emission	0.03 kg CH_4/animal/yr	1
Poultry (Broilers) – emission	0.02 kg CH_4/animal/yr	1
Poultry (Turkeys) – emission	0.09 kg CH_4/animal/yr	1
Fur-bearing animals	0.68 kg CH_4/animal/yr	1
Reindeer – emission	0.36 kg CH_4/animal/yr	1
Manure Management System	**Emission factors for N_2O (% N_2O-N of total N)**	
Liquid manure	0.5 %	1
Solid manure	0.5 %	1
Deep litter	1 %	1
Digesters	0 %	1
Composting	0.01 %	1
Pasture/Range/Paddock (Cattle)	2 %	1
Pasture/Range/Paddock (Sheep & other animals)	1 %	1

MCF=Methane Conversion Factor. B_0=maximum methane producing capacity for manure.
(1) IPCC 2006 Guidelines. (2) Rodhe et al. 2009. (3) Dustan 2002. (4) National.

5.3.2.2 DIRECT EMISSIONS OF NITROUS OXIDE FROM MANURE MANAGEMENT (EXCLUDING EXCRETION FROM GRAZING ANIMALS) (CRF 3.B(B))

N_2O from manure management is estimated with the IPCC Guidelines, tier 2 methodology. Default emission factors from the IPCC Guidelines are used in combination with national activity data. The emission of N_2O from manure management is calculated as:

$$N_2O = \sum_S \left(\sum_T N_T \times Nex_T \times MS_{(T,S)} \right) \times EF_S \times {}^{44}/_{28}$$

where N_T is the number of heads 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, $MS_{(T,S)}$ is the fraction of total annual excretion for each livestock category T managed in manure management system S in the country (excluding pasture, range and paddock manure that is reported under 3.D). Even though dairy cattle generally spends the summer on pasture, part of the manure is still produced in the stable during milking and if spending the nights in the stables. This manure is excluded from the pasture, range and paddock manure and instead allocated to the appropriate manure management system. Stable periods and manure management systems are the same as used in the methane calculations (table 5.9, table 5.10, table 5.11 and table 5.12). The emission factors are described in table 5.17. In the CRF tables, where some animal subgroups are aggregated, the implied emission factors for nitrogen excretion rate changes over the years, depending on the relative size of the respective subgroups aggregated.

5.3.2.3 INDIRECT EMISSIONS OF NITROUS OXIDE FROM MANURE MANAGEMENT

The indirect emissions of nitrous oxide due to volatilisation of nitrogen from manure are reported under two different categories, 3.B and 3.D.b. The indirect emissions from manure management are reported in 3.B, and the indirect emissions from application of manure as fertiliser are reported in 3.D.b (see section 5.4.2).

To estimate the indirect emissions in sector 3.B we use the tier 2 method. That is, we use the ammonia emissions from the national ammonia emission inventory together with the default emission factors for NOx from the EMEP/EEA Guidebook 2016, to estimate the amount of nitrogen volatilised (i.e. $N_{volatilization-MMS}$). For a summary of the ammonia emission model, see below under the paragraph "The national ammonia emission inventory". The indirect N_2O emissions are then estimated with the default EF_4 from the 2006 IPCC guidelines.

$$N_2O = N_{volatilisation-MMS} \times EF_4 \times {}^{44}/_{28}$$

All indirect emissions from manure management due to leaching and runoff are reported under agricultural soils (i.e. 3.D.b), and the notation key IE (Included Elsewhere) is used in 3.B. However, the nitrogen leaching from storage of manure are considered low, because Swedish law regulates that the storage must be designed to minimize the leaching and runoff from manure into the environment. Anyhow, the model used to estimate nitrogen loss from leaching and runoff (see sector 5.4.2.2.2) will also capture this part, but is instead reported in sector 3.D.b.

5.3.2.3.1 Volatile nitrogen losses from manure management

To estimate the total amount of nitrogen remaining after storage, i.e. the amount available for application to soils, the volatile nitrogen losses during storage as N_2O as well as NOx and N_2 are needed to take into account. To estimate the fraction of nitrogen lost as NOx the default emission factors from the EMEP/EEA Guidebook are used, i.e. 0.01 % and 1% of total ammoniacal nitrogen in slurry and solid manure, respectively. The amount lost as N_2O and N_2 is calculated using the difference between the fractions in table 10.22 and table 10.23 in the 2006 guidelines (table 5.18).

Table 5.18. Default values from 2006 guidelines for nitrogen lost as N_2O, N_2 and leaching and run-off from manure management.

Animal group	Manure management system	Default fraction of N lost as N_2O, N_2 and leaching and run-off
Dairy cattle	Liquid/Slurry	0
Dairy cattle	Solid storage	0.10
Dairy cattle	Deep bedding	0.10
Other cattle	Liquid/Slurry	0
Other cattle	Solid storage	0.05
Other cattle	Deep bedding	0.10
Swine	Liquid/Slurry	0
Swine	Solid storage	0.05
Swine	Deep bedding	0.10
Poultry	Poultry with litter	0.10
Other animals	Solid storage	0.03
Other animals	Deep bedding	0.10

5.3.2.3.2 The national ammonia emission inventory

The estimate of nitrogen lost as ammonia are mainly built on data collected through Statistics Sweden's survey on use of fertilisers and animal manure in agriculture [239]. 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[240]. As from 2005, regional results are published at the web-site of Statistics Sweden[241]. In short, the calculations are made as follows:

$$A = (V + L + S)$$
$$V = D \times N \times P \times F(v)$$
$$L = D \times N \times P \times (1 - F(v)) \times F(l)$$
$$S = D \times N \times P \times T \times (1 - F(v)) \times (1 - F(l)) \times F(s)$$

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)

[239] Statistics Sweden, MI 30-series.

[240] Swedish Environmental Protection Agency 1997

[241] Statistics Sweden, MI 37-series.

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 animals
N = production of nitrogen, kg, per type of animal, year and handling[242]
P = stable periods[243]
T = Proportion of ammoniacal nitrogen
F(v) = emission of nitrogen through stable ventilation, % of total nitrogen content in stable manure[244].
F(l) = emission of nitrogen during storing, % of total nitrogen content in stable manure after ventilation losses[245].
F(s) = emission of nitrogen during spreading, % of ammoniacal nitrogen content in stable manure after ventilation and storing losses[246].

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[247]. Data on ventilation-, storage- and spreading-losses originate from the Swedish Board of Agriculture and from Swedish Institute of Agricultural and Environmental Engineering. See the Swedish Informative Inventory Report to the LRTAP Convention for a detailed description of the calculations and used emission factors[248].

5.3.3 Uncertainties and time-series consistency

Due to more intense swine production, the nitrogen production for sows and pigs for meat production was updated in 2002. The time series for the implied emission factor have some steep steps. This is mainly an effect of that the surveys on the distribution of different manure management systems are only done biannually and that a small relative difference in that survey have a significant effect on the emissions because the emission factors differ considerably between different systems.

5.3.4 Source-specific QA/QC and verification

Annual increase or decrease is verified for the whole time series for all sub sources to decide that all annual changes are reasonable. We compare the times series for the emission with the time series for the activity data to confirm that are in agreement. We regularly conduct crosschecks of country-specific factors against the IPCC defaults. We annually utilize experts from the Swedish board of agriculture to conduct expert peer review of the methods used and we have regular meetings with authorities that provide activity data to the inventory to ensure that the quality of the data are of satisfactory quality and that they in turn use appropriate QC methods.

[242] Swedish Board of Agriculture 1995; Swedish Board of Agriculture 2000; Swedish Board of Agriculture 2001

[243] Statistics Sweden, MI 30-series.

[244] Swedish Board of Agriculture 2005

[245] Swedish Institute of Agricultural and Environmental Engineering 2002

[246] Swedish Institute of Agricultural and Environmental Engineering 2002

[247] Statistics Sweden, MI 30-series.

[248] http://www.ceip.at/ms/ceip_home1/ceip_home/status_reporting/

5.3.5 Source-specific recalculations

- The complete time series for number of goats have been revised, due to updated data from the Swedish Board of Agriculture.
- The Sami parliament of Sweden updated the time series for number of reindeer.
- There was a minor recalculation for 2016 bacause of revised data from the Swedish Dairy Association on total milk delivered in 2016.
- Emissions from digesters and composting are now implemented in the inventory.

The total effect of the recalculations in 3.B for the two most recent recalculated years was a decrease of the estimated emissions with 0.98 % (5.89 kt CO_2-eq) and 0.90 % (5.41 kt CO_2-eq) for 2015 and 2016, respectively.

5.3.6 Source-specific planned improvements

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

5.4 Agricultural Soils (CRF 3.D)

Since the subsectors included under agricultural soils represent relatively different processes they are divided into separate paragraphs and treated independently in the key categories analyses. Table 5.19 gives an overview of all emission factors used in this sector.

Table 5.19. Emission factors for N_2O emissions from soils

Direct emissions from soils	**Emission factor** % N_2O-N of N-supply	**Note**
Mineral fertiliser	1 %	1
Manure	1 %	1
Crop residue	1 %	1
Manure during Pasture/Range/Paddock	See table 5.16	1
Background emission due to cultivation	**Kg N_2O-N/ha/yr**	
Cultivation of Histosols	13	2
Indirect emissions from soils	**% N_2O-N of N-supply**	
Atmospheric Deposition	1 % of emitted N	1
Nitrogen Leaching and run-off	0.75 % of N lost from leaching	1

(1) 2006 IPCC Guidelines, (2) 2013 IPCC Wetlands supplement.

5.4.1 Direct Soil Emissions (CRF 3.D.a)

5.4.1.1 SOURCE CATEGORY DESCRIPTION

This category includes the direct emission of nitrous oxide from managed soils. In terms of magnitude, the most important emissions are the ones from application of inorganic N fertilisers and cultivation of histosols. Also included in this category are emissions from crop residues, application of animal manure, grazing animals, use of sewage sludge and application of other organic fertilisers and mineralization/immobilization associated with loss/gain of soil organic matter. The summary of the latest key category assessment, methods and EF used, and information on completeness are presented in table 5.20.

Table 5.20. Summary of source category description for the entire category CRF 3.D.a, according to approach 1.

CRF	**Gas**	**Key Category Assessment 2017, excluding LULUCF)**			**Method**	**EF**	**All sources estimated**
		Level	**Trend**	**Qualitative**			
3.D.a.1	N_2O	X	X		T2	CS	Yes
3.D.a.2.a Animal manure	N_2O	X	X		T2	CS	Yes
3.D.a.2.b Sewage sludge	N_2O		X		T1	D	Yes
3.D.a.2.c Other	N_2O		X		T1	D	Yes
3.D.a.3	N_2O	X	X		T1	D	Yes
3.D.a.4	N_2O	X	X		T2	CS	Yes
3.D.a.5	N_2O	X	X		T2	CS	Yes
3.D.a.6	N_2O	X	X		T1	D	Yes

CS - Country Specific. T1 - tier 1. T2 - tier 2. D - Default.

5.4.1.1.1 Nitrous oxide emissions from inorganic N fertilisers (CRF 3.D.a.1)

Emissions from inorganic fertilisers are calculated as:

$$N_2O\ emission = N_{FERT} \times EF_1 \times 44/28$$

The estimated emissions are based on amount of nitrogen in mineral fertilisers sold annually in Sweden (N_{FERT}). Statistics on sales of fertilisers, recalculated into nitrogen quantities, are published annually by Statistics Sweden (table 5.21).

Table 5.21. Activity data used to estimate the direct soil emissions from inorganic and organic fertilisers.

Year	N in inorganic fertilisers (t)	N in applied organic fertilisers (t)	N in sewage sludge (t)	N in other organic fertilisers (t)	Fraction of N volatilised as NH_3 during storage of animal manure	Fraction of N volatilised as N_2O, NOx, N_2 and lost through leaching and run-off during storage of animal manure	Fraction of N treated in co-digesters
1990	224 500	76 628	1 180	1 700	0.2079	0.1031	0.0000
1995	198 300	79 788	2 304	1 700	0.1957	0.0869	0.0000
2000	189 400	75 488	1 758	1 800	0.1959	0.0836	0.0012
2005	161 568	73 806	1 053	1 743	0.1960	0.0711	0.0029
2010	168 000	72 257	2 224	2 712	0.1931	0.0649	0.0060
2015	190 200	71 411	2 802	4 386	0.1930	0.0639	0.0262
2016	186 000	71 476	3 149	5 358	0.1872	0.0579	0.0258
2017	198 460	71 064	3 149	5 358	0.1885	0.0585	0.0271

Statistics on fertilisers and sludge are from Swedish Board of Agriculture and Statistics Sweden.

5.4.1.1.2 Nitrous oxide from organic N fertilisers (CRF 3.D.a.2)

To estimate the N_2O emission from organic N fertilizers, the default methodology according to the IPCC Guidelines is used in combination with national estimates of N content in manure, sewage sludge and other organic fertilizers, respectively. The formula used to calculate N content in animal manure applied to soils (F_{AM}) is:

$$F_{AM} = \sum_T N_T \times Nex_T \times (1 - Frac_{LossMS}) \times (1 - Frac_{PRP}) \times (1 - Frac_{co\text{-}digesters})$$

Where N_T is the number of heads 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, $Frac_{LossMS}$ is the amount of N lost during storage as NH_3, NOx and N_2 (table 5.21), $Frac_{PRP}$ is the fraction of the nitrogen in pasture, range and paddock manure and $Frac_{co\text{-}digesters}$ is the fraction of manure treated in co-digesters (and accounted for in the waste sector). To complete the annual amount of nitrogen applied to soils in 3.D.a.2, this value is complemented with N content in the much smaller sources, sewage sludge and other organic fertilizers applied to soils. F_{ON} then denotes then the total amount of nitrogen applied. Statistics on the use of sludge have been collected intermittently by Statistics Sweden and the Swedish EPA from sewage treatment plants (table 5.21). The N content in other organic fertilizers applied to soils is estimated from Statistics Sweden's survey on "Use of fertilisers and animal manure in agriculture" (table 5.21). The N_2O emissions are then estimated as:

$$N_2O\ \text{emissions} = F_{ON} \times EF_1 \times 44/28$$

5.4.1.1.3 Urine and dung deposited by grazing animals (CRF 3.D.a.3)

To estimate the N_2O emissions from urine and dung deposited by grazing animals the default emission factor of 2 % is used for cattle and the default emission factor of 1 % is used for sheep, goats, horses and reindeer. No other animal categories are applicable in this category. The emissions are calculated as:

$$emissions = \sum_{Ti} N_{Ti} \times Nex_{Ti} \times Frac_{PRP_{T,i}} \times EF_{3PRP,i} \times 44/28$$

N_T is the number of animals of type *T* in the country, Nex_T is the N-excretion of animals of type *T*, $Frac_{PRP}$ is the fraction of the manure allocated to pasture, range and paddock (table 5.22), EF_3 is the default emission factor, where *i* decide which emission factor group the animal category belongs to (i.e. "cattle, poultry and pigs" or "sheep and other animals"). The nitrogen excretion for the different animal groups is presented in table 5.14 and table 5.16.

Table 5.22. Waste management systems, fraction of manure deposited on pasture, range and paddock.

Year	Dairy cattle	Suckler cows	Heifers	Bulls and steers	Calves	Swine	Sheep, Goats	Reindeer	Horses	Poultry	Fraction of total amount of N excreted on pasture ($Frac_{PRP}$)
1990	0.25	0.48	0.46	0.37	0.35	NO	0.50	1.00	0.50	NO	0.30
1995	0.25	0.48	0.46	0.37	0.35	NO	0.50	1.00	0.50	NO	0.31
2000	0.25	0.52	0.49	0.37	0.37	NO	0.50	1.00	0.50	NO	0.32
2005	0.26	0.59	0.54	0.30	0.37	NO	0.50	1.00	0.50	NO	0.33
2010	0.25	0.54	0.52	0.26	0.31	NO	0.50	1.00	0.50	NO	0.32
2015	0.25	0.52	0.50	0.19	0.32	NO	0.50	1.00	0.50	NO	0.31
2016	0.24	0.54	0.51	0.24	0.33	NO	0.50	1.00	0.50	NO	0.32
2017	0.24	0.54	0.51	0.24	0.33	NO	0.50	1.00	0.50	NO	0.32

Data from Statistics Sweden's survey "Use of fertilisers and animal manure in agriculture".

5.4.1.1.4 Crop residue (CRF 3.D.a.4)

To estimate the emissions of N_2O from nitrogen circulation from crop residues, both above- and below-ground residues are taken into account. From crops harvested green we assume no above-ground residues exept stubble. To estimate above- and below-ground nitrogen, respectively, we use the following equations together with a combination of data in table 11.2 in the IPCC 2006 guidelines and country specific data where available. The data on fraction of residues removed builds on a survey from 2012[249] on how straw and tops from different crops are used.

$$Above\text{-}ground\ N_{(T)} = Crop_{(T)} \times\ Area_{(T)} \times R_{AG(T)} \times N_{AG(T)} \times Frac_{Renew(T)} \times \left(1 - Frac_{Remove(T)}\right)$$

$$Below\text{-}ground\ N_{(T)} = Crop_{(T)} \times\ Area_{(T)} \times R_{BG(T)} \times N_{BG(T)} \times Frac_{Renew(T)}$$

Where $R_{AG(T)}$ is the ratio of aboveground residues dry matter to harvested yield (i.e. $AG_{DM(T)}/Crop_{(T)}$), and $R_{BG(T)}$ the corresponding value for belowground residues. $Crop_{(T)}$ is the annual yield of crop *T*, $N_{AG(T)}$ and $N_{BG(T)}$ are the fractions of nitrogen

249 Statistics Sweden, 2012.

in crop residues, above- and below-ground, respectively. $Frac_{remove(T)}$ is the fractions of crop residues that are removed from the field and $Frac_{renew(T)}$ is the fraction of total area under crop *T* that is renewed annually. The total annual amount of nitrogen in crop residues is then the sum of these both parameters summed over all crops (i.e. F_{CR}). See table 5.23 for all parameters that are used in the calculation of total N-content in crop residues. For cereals, national factors are used for the fraction of aboveground residues and the corresponding N-content[250]. For other crops, a combination of national factors and IPCC default values are used[251]. The estimated activity data used as input to the emission calculations are presented in table 5.24.

Table 5.23. Data used for calculating nitrogen input from crop residues.

Crop	Fraction of dry matter content	Ratio of above-ground residues dry matter R_{AG}	Fraction of N in above-ground crop residues (N_{AG})	Fraction of crop residues removed ($Frac_{remove}$)	Ratio of below-ground residues to above-ground biomass (R_{BG-BIO})	Fraction of N in below-ground crop residues (N_{BG})	Fraction renewed annually ($Frac_{Renew}$)
Winter wheat	0.86	0.875	0.0051	0.12	0.23	0.009	1
Spring wheat	0.86	0.9625	0.0044	0.1	0.28	0.009	1
Winter rye	0.86	1.075	0.0059	0.22	0.22	0.009	1
Winter barley	0.86	0.875	0.0077	0.22	0.22	0.014	1
Spring barley	0.86	0.825	0.0077	0.1	0.22	0.014	1
Oats	0.86	0.8875	0.0073	0.1	0.25	0.008	1
Mixed grain	0.86	0.8625	0.0075	0.27	0.22	0.009	1
Triticale	0.86	0.975	0.0076	0.12	0.22	0.009	1
Sugar beets	0.2	0.66	0.0225	0.007	0.2	0.014	1
Winter rape	0.91	1.71	0.0107	0.055	0.22	0.009	1
Spring rape	0.91	1.38	0.0107	0.055	0.22	0.009	1
Winter turnip rape	0.91	1.71	0.0107	0.055	0.22	0.009	1
Spring turnip rape	0.91	1.38	0.0107	0.055	0.22	0.009	1
Oil flax	0.91	1.3	0.0143	0.57	0.22	0.009	1
Potato	0.2	0.4	0.0325	0.013	0.2	0.014	1
Peas	0.85	0.91	0.0118	0.014	0.19	0.008	1
Peas for conservation	0.85	0.91	0.0118	0	0.19	0.008	1
Broad bean	0.85	0.88	0.0118	0.014	0.19	0.008	1
Brown bean	0.85	0.91	0.0118	0.022	0.19	0.008	1
Grass-clover mixtures	0.835	0.25	0.024	0	0.54	0.016	0.2
Lay for seed, no clover	0.835	0.84	0.0109	0.35	0.22	0.009	1
Maize	0.86	1	0.0094	0.19	0.22	0.007	1
Green fodder (cereals)	0.3	0.25	0.02	0	0.54	0.012	1
Green fodder (maize)	0.3	0.04	0.02	0	0.54	0.007	1
Green fodder (other)	0.3	0.15	0.02	0	0.54	0.016	1
Pasture ground	0.835	0.4	0.024	0	0.54	0.016	0.2

[250] Mattson, 2005.

[251] Andrist Rangel et al. 2016 and IPCC Guidelines 2006.

Table 5.24. Activity data for estimating N_2O emissions from crop residues.

Year	Total harvested product dry matter (tonnes)	Total above-ground residues dry matter (tonnes)	Total below-ground residues dry matter (tonnes)	Total N content in above-ground residues (tonnes)	Total N content in below-ground residues (tonnes)
1990	12 082 005	7 455 929	3 720 533	53 865	42 762
1995	9 391 111	5 584 200	2 780 236	41 083	32 987
2000	9 758 691	6 013 779	3 033 197	42 431	34 608
2005	9 228 346	5 645 272	2 880 687	40 523	33 224
2010	9 640 280	5 414 828	2 817 646	38 122	32 839
2015	11 678 070	7 031 352	3 652 320	46 280	41 320
2016	10 683 887	6 364 799	3 355 040	44 216	38 097
2017	11 359 846	6 911 602	3 621 215	47 540	41 024

Data on total crop yields are from the Swedish Board of Agriculture. Report series JO16.

5.4.1.1.5 Mineralization/immobilization associated with loss/gain of soil organic matter (CRF 3.D.a.5)

Management change of land can cause loss of soil organic C through oxidation and, simultaneously, mineralisation of N that can be converted to N_2O through nitrification and denitrification. The loss of N due to mineralisation is calculated for all land use categories and all land use change categories. The estimation of loss or gain of C (i.e. ΔC) is performed independently in eight different region using the ICBM-model as described in chapter 6. The emissions from cropland remaining cropland are reported here and the other categories are reported in the LULUCF sector. The reported annual N_2O emission from nitrogen mineralisation is calculated according to the 2006 IPCC guidelines, where *i* is the eight different production areas in Sweden.

$$N_2O = \sum_{LU_i} \left[\Delta C_{Mineral,LU_i} \times 0.1\right] \times EF_1 \times {}^{44}/_{28}$$

5.4.1.1.6 Cultivation of organic soils (CRF 3.D.a.6)

In a literature survey assigned by the Swedish EPA, it was suggested that the background emission from organic soils vary with different crops. The emissions were also considered higher from ploughed soils than from pasture or temporary grasslands. The suggested emission factors were 6 and 1 kg N_2O-N ha-1, respectively. However, since a Swedish/Finnish research group concluded that not enough data exists to generate reliable emission factors for different soil managements and soil types, the value from the wetlands supplement to the 2006 IPCC guidelines of 13 kg N_2O -N/ha is implemented in the inventory. The area of organic soils has only been estimated intermittently, the two latest referring to the situation in 2008[252] and 2015[253]. The result shows that the decline in organic soil area is slightly slower relative to the decline in the total agriculture land area. Hence, to get the trend correct, we calculated the different fraction of organic soil to total agriculture land in 2008 and 2015. The resulting slope was then used to extrapolate the fraction of organic soil before 2007 and after 2015. The result of

[252] Berglund, Berglund & Sohlenius, 2009

[253] Pahkakangas 2016

this was that the organic soil area was estimated to 4.87 % and 4.90% of total agriculture land, in 1990 and 2017, respectively.

$$N_2O = Area_{Histosols} \times EF \times {}^{44}/_{28}$$

5.4.1.1.7 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 agriculture and Statistics Sweden. Data has been collected in the same way from the producers and retailers since the early 1960s. Statistics on the use of fertiliser and manure have been collected biannually since the end of the eighties. Because the sales statistics also includes some smaller quantities of fertilisers sold for use outside the agricultural sector, the estimated nitrogen content in sold products has for most years been slightly higher. Differences could also arise due to storage of fertilisers between years, this should however even out in the long run. The decrease of amount of sold fertilisers in 2009 is due to an overconsumption in 2008 due to a dropped tax on fertilisers. 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 are used in the inventory. Another advantage of the sales statistics is that it is updated annually.

Historically, statistics on the use of sewage sludge have been published irregularly and in different reports, and the time series for the earlier years in the time series has been created through interpolation and extrapolation. Gradually the quality of the data has increased and is now of adequate quality.

5.4.1.1.8 Source-specific QA/QC and verification

Annual increase or decrease is verified for the whole time series for all sub sources to decide that all annual changes are reasonable. We compare the times series for the emission with the time series for the activity data to confirm that are in agreement. We regularly conduct crosschecks of country-specific factors against the IPCC defaults. We annually utilize experts from the Swedish board of agriculture to conduct expert peer review of the methods used and we have regular meetings with authorities that provide activity data to the inventory to ensure that the quality of the data are of satisfactory quality and that they in turn use appropriate QC methods.

5.4.1.1.9 Source-specific recalculations

- The complete time series for number of goats have been revised, due to updated data from the Swedish Board of Agriculture.
- The Sami parliament of Sweden updated the time series for number of reindeer.
- There was a minor recalculation for 2016 bacause of revised data from the Swedish Dairy Association on total milk delivered in 2016.
- Emissions from digesters and composting are now implemented in the inventory.

- As a consequence of the method used by the Swedish national inventory of forests (see 6.3.1.1) the total area of mineral- and organic soils has been updated for several years.
- The data on applied amount of sludge in 2016 have been updated.
- The time series for emissions from crop residues have been revised.

The total effect of the recalculations in 3.D.a for the two most recent recalculated years was an increase of the estimated emissions with 0.04 % (1.02 kt CO_2-eq) and a decrease with 0.30 % (8.51 kt CO_2-eq) for 2015 and 2016, respectively.

5.4.1.1.10 Source-specific planned improvements

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

5.4.2 Indirect Emissions (CRF 3.D.b)

5.4.2.1 SOURCE CATEGORY DESCRIPTION

In addition to the direct emissions from managed soils, indirect emissions also occur. The two pathways of indirect emissions from soils are through volatilization of nitrogen as NH_3 and NO_X, and through leaching and runoff of nitrogen. These emissions occur from, (i) application of synthetic fertilisers, (ii) application of manure and other organic fertilisers, (iii) crop residues, and (iv) nitrogen mineralisation. In addition to these sources, indirect emissions also occur from manure management, these emissions are described above.

To estimate the indirect N_2O emissions from atmospheric deposition we use the tier 1 methodology from the guidelines in combination with the default emission factors from the EMEP/EEA air pollutant emission inventory guidebook 2016 concerning the fraction of N that volatilise as NOx from inorganic and organic fertilisers, as well as NH_3 from inorganic fertilisers. For the fractions of NH_3 that volatilise from organic fertilisers we use country specific values. The estimation of the emissions from nitrogen leaching and run-off is made with a country specific methodology. The summary of the latest key category assessment, methods and EF used, and information on completeness, are presented in table 5.25.

Table 5.25. Summary of source category description for the entire category CRF 3.D.b, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
3.D.b.1	N_2O	X			CS	D	Yes
3.D.b.2	N_2O	X	X		CS	D	Yes

CS - Country Specific. T1 - tier 1. D - Default.

5.4.2.2 METHODOLOGICAL ISSUES

5.4.2.2.1 Atmospheric deposition from agricultural soils

The formula used to estimate N_2O-N from atmospheric deposition is:

$$N_2O\text{-}N = [(F_{SN} \times Frac_{GASF}) + (F_{ON} \times Frac_{GASM}) + (F_{PRP} \times Frac_{GASG})] \times EF_4$$

Where F_{SN} is the annual amount of inorganic N fertiliser applied to soils. F_{ON} is the annual amount of managed animal manure, sewage sludge and other organic N fertiliser applied to soil. $Frac_{GASF}$ is the fractions of N that volatilises from inorganic fertilisers. The amount that volatilise differs between different types of fertilisers[254] (table 5.26). In table 5.27 the amount of nitrogen in sold ammonia-emitting products are shown, which directly explain the variation in the $Frac_{GASF}$ between different years. $Frac_{GASM}$ describe the amount of nitrogen that volatilises from application of organic N fertilisers (table 5.28) and $Frac_{GASG}$ describe the fractions of N excreted on pastures that volatilises (table 5.29). Both these fractions are estimated by the model used for the national ammonia emission inventory.

Table 5.26. Emissions of ammonia from different fertiliser types.

Fertiliser	Volatilised as ammonia (g NH_3/kg N)
Anhydrous ammonia	19
Ammonium nitrate (AN)	15
Ammonium phosphate	50
Ammonium sulphate (AS)	90
Calcium ammonium nitrate (CAN)	8
Ammonium solutions (AN)	98
NK mixtures	15
NP mixtures	50
NPK mixtures	50
Other straight N compounds	10
Urea	155

[254] EMEP/EEA air pollutant emission inventory guidebook 2016

Table 5.27. Amount of nitrogen in inorganic fertilisers (t).

Year	Anhydrous ammonia	Ammonium nitrate (AN)	Ammonium phosphate	Ammonium sulphate (AS)	Calcium ammonium nitrate (CAN)	Ammonium solutions (AN)	NK mixtures	NP mixtures	NPK mixtures	Other straight N compounds	Urea	Proportion of emitted fertiliser-N ($Frac_{GASF}$)
1990	0	28 877	0	3 797	65 151	913	2 221	15 596	56388	48828	2 729	0.0218
1995	0	25 507	0	3 354	57 548	806	1 962	13 776	51319	43129	899	0.0211
2000	0	18 429	0	1 966	58 474	1 101	2 216	11 440	50957	44516	301	0.0203
2005	68	6 561	574	653	76 931	27	1 636	7 954	59030	7895	239	0.0219
2010	0	10 511	0	513	93 535	669	1 390	2 540	52815	5565	462	0.0193
2015	0	15 266	0	902	106 196	30	767	991	60259	4933	856	0.0191
2016	0	13 670	0	1 395	95 546	1 328	694	1 092	62240	9148	887	0.0205
2017	0	12 155	1 616	1 386	104 022	1 319	625	39	63588	13185	525	0.0197

Statistics on fertilisers are from Swedish Board of Agriculture.

Table 5.28. Amount of nitrogen in organic N fertilisers.

Year	Amount of nitrogen in animal manure applied to soils (t)	Amount of nitrogen in sewage sludge applied to soils (t)	Amount of nitrogen in other organic fertilisers applied to soils (t)	Fraction of applied organic N fertilisers that volatilises ($Frac_{GASM}$)
1990	76 628	1 180	1 700	0.1721
1995	79 788	2 304	1 700	0.1739
2000	75 488	1 758	1 800	0.1738
2005	73 806	1 053	1 743	0.1725
2010	72 257	2 224	2 712	0.1669
2015	71 411	2 802	4 386	0.1691
2016	71 476	3 149	5 358	0.1616
2017	71 064	3 149	5 358	0.1611

Table 5.29. Amount of nitrogen excreted on pasture by grazing animals.

Year	Amount of nitrogen in urine and dung deposited by grazing animals (t)	Fraction of nitrogen from grazing animals that volatilises ($Frac_{GASG}$)
1990	44 244	0.0765
1995	46 660	0.0766
2000	46 724	0.0769
2005	47 580	0.0765
2010	45 252	0.0761
2015	43 208	0.0758
2016	43 988	0.0759
2017	44 565	0.0758

5.4.2.2.2 Nitrogen Leaching and run-off

The national estimate of nitrogen leaching is estimated by the Swedish University of Agricultural Sciences and calculated from the SOILNDB model[255], which is a part of the SOIL/SOILN model[255]. This model is primarily used for the reporting to the Helsinki commission (HELCOM) to calculate Sweden's emissions of nitrogen and phosphorus to the Baltic Sea. The model was first developed during the 1980s in order to describe nitrogen processes in agricultural soils[256]. Since then the model has been elaborated and tested on data from controlled leaching experiments. These tests show that the model estimates the leaching from soil with good precision[257]. By using national data on crops, yields, soil, use of fertiliser/manure and spreading time, the leaching is estimated for 22 regions. The regions are based on similarities in agricultural production areas. On average data from this model has been published about every five years, intermittent years have been interpolated (Table 5.30). When 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. This model is not developed to individually estimate the nitrogen leakage that derives from manure management or from managed soils, consequently all emissions from leaching and runoff are reported here and the notation key IE (included elsewhere) is reported in sector 3.B.

Table 5.30. Parameters used to estimate indirect emissions from nitrogen leaching and run-off.

Year	Average N leaching per hectare (kg/ha)*	Total amount of nitrogen lost from leaching and run-off (t)	Fraction of nitrogen lost through leaching and run-off (FracLEACH)
1990	24.6	75 825	0.1651
1995	21,0	64 049	0.1303
2000	20.5	61 980	0.1238
2005	18,0	53 942	0.1406
2010	18,0	52 779	0.1418
2015	19,0	53 792	0.1346
2016	19,0	53 437	0.1323
2017	19,0	53 055	0.1138

* Estimated with the SOIL/SOILN model.

To estimate the implied $Frac_{LEACH}$, which is reported as additional information in the CRF tables for 3.D, the leached nitrogen according to the national model, is divided by the sum of applied nitrogen in inorganic fertilisers, organic fertilisers (including sewage sludge and other organic fertilisers), amount of N deposited by grazing animals, above- and below-ground crop residues and amount of N mineralised in mineral soils. This quotient varies between 0.18 and 0.11 for different years, which is in the uncertainty range of the IPCC Guidelines' default value of $Frac_{LEACH}$ (default=0.3 with the uncertainty range 0.1-0.8).

[255] Johnsson, 1990; Swedish EPA, 2002; http://www.naturvardsverket.se/Documents/publikationer/978-91-620-5995-8.pdf

[256] Johnsson et al., 1987.

[257] Swedish EPA, 2002b.

5.4.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The average nitrogen leaching from agricultural soils per hectar, is estimated by the Swedish University of Agricultural Sciences. The value for 1990 is calculated from an investigation that estimated nitrogen leaching for the years 1985 and 1994, however, only for the southern part of Sweden. So the value used is corrected to apply to the whole of Sweden. The reason for the continuous decrease between 1999 and 2005 is believed to mainly be dependent on an increase in the area of catch crops. However, an increased awareness of the eutrophication problem has also led to changes in fertilising patterns. This model is considered to be the best available in Sweden, taking many relevant factors into account. Since statistics on the use of fertilisers and manure are produced every second or third year,[258] it is not possible to update the average leaching more frequently than that. However, due to economic reasons, the data has only been published intermittently.

5.4.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Annual increase or decrease is verified for the whole time series for all sub sources to decide that all annual changes are reasonably. We compare the times series for the emission with the time series for the activity data to confirm that are in agreement. We regularly conduct crosschecks of country-specific factors against the IPCC defaults. We annually utilize experts from the Swedish board of agriculture to conduct expert peer review of the methods used and we have regular meetings with authorities that provide activity data to the inventory to ensure that the quality of the data are of satisfactory quality and that they in turn use appropriate QC methods.

5.4.2.5 SOURCE-SPECIFIC RECALCULATIONS

- The complete time series for number of goats have been revised, due to updated data from the Swedish Board of Agriculture.
- The Sami parliament of Sweden updated the time series for number of reindeer.
- There was a minor recalculation for 2016 bacause of revised data from the Swedish Dairy Association on total milk delivered in 2016.
- Emissions from digesters and composting are now implemented in the inventory.
- The data on applied amount of sludge in 2016 have been updated.

The total effect of the recalculations in 3.D.b for the two most recent recalculated years was a decrease of the estimated emissions with 0.06 % (0.16 kt CO_2-eq) and an increase with 0.12 % (0.33 kt CO_2-eq) for 2015 and 2016, respectively.

5.4.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

[258] Statistics Sweden, MI 30-series.

5.4.3 CO_2 emissions from liming (CRF 3.G)

5.4.3.1 SOURCE CATEGORY DESCRIPTION

Lime is used in agriculture and horticulture to mitigate acidification and used for structural liming to improve soil properties. The amount applied is from 2010 based on a survey among farmers on the usage of lime[259]. Prior to that, the applied amount was instead estimated from the quantities lime sold for agricultural and horticultural purposes and lime from sugar mills and steel production. This statistics was produced yearly by Statistics Sweden[260]. The statistics on use of lime is also produced by Statistics Sweden every second year.

Table 5.31. Summary of source category description for the entire category CRF 3.G, according to approach 1.

CRF	Gas	Key Category Assessment 2017 (approach 2, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
3.G	CO_2				T1	D	Yes

CS Country Specific. T1 tier 1. D Default.

5.4.3.2 METHODOLOGICAL ISSUES

The tier 1 method from the guidelines is used together with default emission factors. The applied quantities are separated into dolomite ($CaMg(CO_3)_2$) and limestone (CaCO3), where dolomite and Mg-lime are reported as dolomite and all other categories are reported as limestone. All quantities are recalculated into amount of dry matter (table 5.32). The emissions are calculated as:

$$CO_2 = (M_{Limestone} \times EF_{Limestone}) + (M_{Dolomite} \times EF_{Dolomite}) \times \frac{44}{12}$$

Where:

$M_{Limestone}$ is the annual applied amount of calcic limestone,
$M_{Dolomite}$ is the annual applied amount of calcic dolomite,
$EF_{Limestone}$ is the emission factor for limestone (0.12),
$EF_{Dolomite}$ is the emission factor for dolomite (0.13).

Table 5.32. Annual amount of limestone and dolomite applied to agricultural soils (t).

Year	Limestone	Dolomite
1990	255 860	127 600
1995	299 425	83 300
2000	251 850	101 500
2005	165 110	91 200
2010	211 830	62 640
2015	206 190	67 960
2016	227 466	55 838
2017	227 466	55 838

[259] Statistics Sweden, MI30 series. (www.scb.se/mi1001)

[260] Statistics Sweden, MI30 series. (www.scb.se/mi1001)

5.4.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

From 2010, there was a change in the estimation method for the applied amount of lime in agriculture. Between 1990 and 2009, the amount is estimated from the quantity lime sold for agricultural and horticultural purposes plus lime from sugar mills and steel production. This was produced from a survey among all distributors of lime in Sweden. As from 2010, the applied amount is instead estimated from a survey among farmers where they are asked about their usage of lime in the previous year. The reason for the change was that the usage of liming products that was not sold through distributors were becoming more common. For example, by-products from paper mills that sometimes were given for free to the farmers and consequently not included in the sale statistics. Between 2010 and 2012, both surveys were run in parallel to examine the difference between the two estimates. The comparison also confirmed the suspicion that the usage statistics results in higher amounts. However, these by-products have only been largely available in the end of the time-series, so the overall trend has not been affected by this.

5.4.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Annual increase or decrease is verified for the whole time series for all sub-sources to decide that all annual changes are reasonably. We compare the times series for the emission with the time series for the activity data to confirm that are in agreement. We regularly conduct crosschecks of country-specific factors against the IPCC defaults. We annually utilize experts from the Swedish board of agriculture to conduct expert peer review of the methods used and we have regular meetings with authorities that provide activity data to the inventory to ensure that the quality of the data are of satisfactory quality and that they in turn use appropriate QC methods.

5.4.3.5 SOURCE-SPECIFIC RECALCULATIONS

The applied amount for 2016 was updated because these values were not published until after the production of submission 2018. The total effect of the recalculation was an increase of the estimated emissions with 2.91 % (3.58 kt CO_2-eq).

5.4.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

5.4.4 CO_2 emissions from urea application (CRF 3.H)

5.4.4.1 SOURCE CATEGORY DESCRIPTION

During urea manufacturing CO_2 is removed from the atmosphere. This CO_2 is subsequently emitted when adding the urea to soils during fertilisation. The emissions from this category are small in Sweden because the use of urea is limited. When recalculated into fertiliser N, the nitrogen in urea corresponds to some 0.5% of the total amount of nitrogen applied from inorganic fertilisers in 2016.

Table 5.33. Summary of source category description for the entire category CRF 3.H, according to approach 1.

CRF	Gas	Key Category Assessment 2017 (approach 2, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
3.H	CO_2				T1	D	Yes

CS Country Specific. T1 tier 1. D Default.

5.4.4.2 METHODOLOGICAL ISSUES

Data on the annual use of urea is from sales statistics are published annually by Statistics Sweden (see table 5.27). The tier 1 method from the guidelines is used to estimate the emissions with the IPCC default emission factor (0.2 t of C/t of urea).

$$CO_2 = Tonnes\ urea/yr \times EF \times 44/12$$

5.4.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The same data source as for the calculation of direct emissions of N_2O from inorganic N fertilisers is used. Hence, the description of the time series consistency is found above under that paragraph.

5.4.4.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Annual increase or decrease is verified for the whole time series for all sub sources to decide that all annual changes are reasonably. We compare the times series for the emission with the time series for the activity data to confirm that are in agreement. We regularly conduct crosschecks of country-specific factors against the IPCC defaults. We annually utilize experts from the Swedish board of agriculture to conduct expert peer review of the methods used and we have regular meetings with authorities that provide activity data to the inventory to ensure that the quality of the data are of satisfactory quality and that they in turn use appropriate QC methods.

5.4.4.5 SOURCE-SPECIFIC RECALCULATIONS

No recalculation has been made in this category since last submission.

5.4.4.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

6 Land Use, Land-Use Change and Forestry (CRF sector 4)

6.1 Overview of LULUCF

Sweden reports carbon stock changes from Forest land, Cropland, Grassland, Settlements and peat production areas under Wetlands. Except from peat production areas, Wetlands and Other land are considered unmanaged[261].

The reporting also includes emissions and removals from the harvested wood products pool (HWP), N_2O emissions associated with nitrogen fertilization of Forest land (4[I]), N_2O and CH_4 emissions from drained organic soils and CH_4 emissions from drainage ditches on these soils (4[II]), CO_2 from dissolved organic carbon (DOC), N_2O emissions due to mineralisation caused by land use conversions or management change (4[III]), indirect N_2O emissions (4[IV]) as well as N_2O and CH_4 emissions from biomass burning (4[V])[262]. The extent of reporting of carbon pools, emissions, methodological tiers and result from the key category assesment for the LULUCF-sector is summarized in Table 6.1.

Table 6.1.a and 6.1.b Status of reporting of carbon pools, other emissions, methodological tiers and key categories according to approach 1, CRF 4

6.1.a	Carbon pools				Other emissions				
	Living biomass	Litter	Dead wood	Soil carbon mineral/organic[1]	4(I)	4(II)	4(III)[2]	4(IV)	4(V)
4. LULUCF	-	-	-	-	-	-	-	T2	-
4.A.1 (Forest Land remaining Forest Land)	T3	T3	T3	T3/T2	T1	T1	T2	-	T1
4.A.2 (Land converted to Forest Land)	T3	T2	T2	T2	NO	T1	T2	-	NO
4.B.1 (Cropland remaining Cropland)	T3	T3	T3	T3/T1	IE	T1	IE	-	IE
4.B.2 (Land converted to Cropland)	T3	T2	T2	T2	IE	T1	T2	-	IE
4.C.1 (Grassland remaining Grassland)	T3	T3	T3	T3/T1	NO	T1	T2	-	T1
4.C.2 (Land converted to Grassland)	T3	T2	T2	T2	NO	T1	T2	-	IE
4.D.1 (Wetlands	NA	NA	NA	NA/T1	NA	T1	NA	-	NA

[261] On a request from the ERT, emissions/ removals from changes in living biomass and mineral soils are now reported for Forest land converted to Other land – even though such land is considered unmanaged.

[262] CO_2-emissions from biomass burning are included as stock changes in the Living biomass pool.

6.1.a	Carbon pools				Other emissions				
	Living biomass	Litter	Dead wood	Soil carbon mineral/organic[1]	4(I)	4(II)	4(III)[2]	4(IV)	4(V)
remaining Wetlands)									
4.D.2 (Land converted to Wetlands)	NA	NA	NA	NA	NA	NA	NA	-	NA
4.E.1 (Settlements remaining Settlements)	T3	NE	NE	NE	NO	NE	NE	-	IE
4.E.2 (Land converted to Settlements)	T3	T2	T2	T2	NO	NE	T2	-	IE
4.F Other land	NA	NA	NA	NA	NA	NA	NA	-	NA
4.F.2.1 Forest land converted to Other land	T3	NA	NA	T2	NA	NA	NA	-	NA
4.G HWP	T3	-	-	-	-	-	-	-	-

[1] Includes DOC for organic soils, [2] Includes N_2O and CH_4 from drained organic soils and CH_4 from ditches.

6.1.b	Key category assessment		
	Gas	Level	Trend
4 A 1 Forest land remaining forest land	CO_2	X	X
4 A 2 1 Cropland converted to forest land	CO_2	X	X
4 A 2 4 Settlements converted to forest land	CO_2	X	X
4 A Drained organic soils	CH_4	X	X
4 A Drained organic soils	N_2O	X	X
4 B 1 Cropland remaining cropland	CO_2	X	X
4 B Drained organic soils	CH_4	X	X
4 C 1 Grassland remaining grassland	CO_2	X	X
4 C 2 1 Forest land converted to grassland	CO_2	X	X
4 D 1 1 Peat extraction remaining peat extraction	CO_2	X	X
4 E 1 Settlements remaining settlements	CO_2		X
4 E 2 1 Forest land converted to settlements	CO_2	X	X
4 E 2 2 Cropland converted to settlements	CO_2	X	X
4 G Total HWP from domestic harvest	CO_2	X	X

6.1.1 Emission/removals in LULUCF 1990-2017

In 2017 the net removal from the Land Use, Land-Use Change and Forestry sector (LULUCF) was estimated to -43 727 kt CO_2 including net removals in harvested wood products and to -37 014 kt CO_2 when excluding net removals in harvested wood products. The net removal decreased from 2016 to 2017 by 810 kt CO_2.

There is a small but not very significant long-term trend with increasing net removals in the LULUCF-sector as a whole. There are inter-annual variations in different subcategories but also long-term trends due to land-use changes, for instance the total area used for crop production is continuously decreasing.

Although inter-annual fluctuations in harvest rates are quite large, the long term trend of increase in harvest rates has levelled off in the last years resulting in a slightly increasing sink in living biomass. This is also due to a significant increase in gross removals (growth) in Sweden which currently amount to around 126[263] Mm^3 stemwood (approx. 173 Mt CO_2 whole tree biomass per year). In 2017 the gross stemwood harvest was approximately 90.9[264] Mm^3.

6.1.1.1 LAND USE CATEGORIES AND EMISSON/REMOVALS IN CARBON POOLS

Forest is the largest land-use category in Sweden. The total forest area (using the FAO forest definition) is 28 Mha. The productive forests (where annual stem wood production per hectare and year is larger than 1 m^3), on which most of the reported changes in carbon pools occur, is 23 Mha[265]. Of these 23 Mha, 4 Mha is formally or voluntary set-aside from timber production for conservation purposes.

Harvest of trees is more or less restricted to productive forests. There has been a continuous increase in felling during the reported period peaking in 2005 (due to wind throws originating from a severe storm). After that the annual felling has been more or less constant. The growth rate has also increased steadily. However, harvest fluctuates considerably between years due to changes in demand for forest products.

The largest carbon stocks are found in the living biomass and soil organic carbon pools on Forest land. The largest annual stock change is the change in the living biomass pool (Figure 6.1 and 6.2). Due to increases in the living biomass pool net removal of between 23-39 Mton CO_2-eq. is reported for Forest land every year during the period.

The dead organic matter pool was a net source all years except for one year during the reported period, whereas the soil organic carbon resulted in net removals during all years except for two years of the reported period. Some soils are sources whereas others are sinks.

[263] Average of 2013-2017. Based on data from the NFI

[264] Based on data from the Foret agency

[265] Swedish University of Agricultural Sciences, 2011

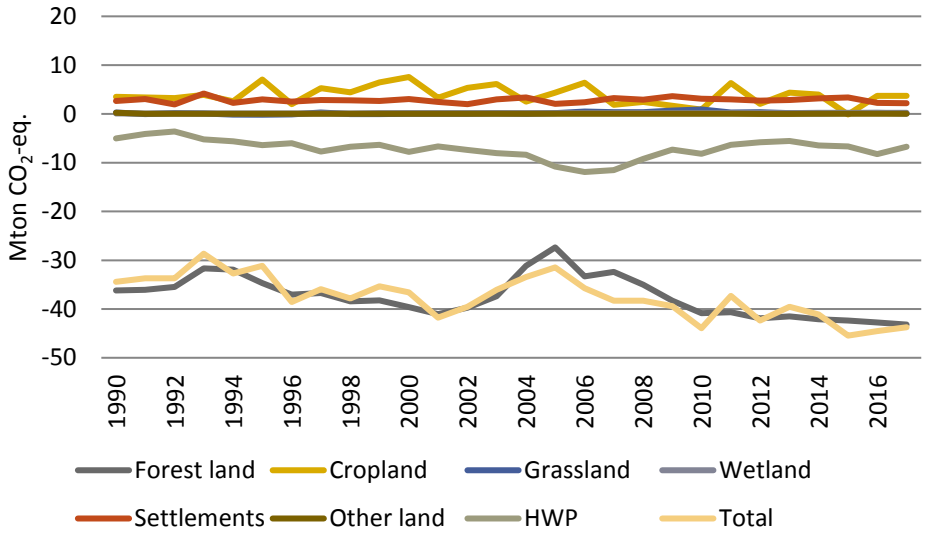

Figure 6.1. Net emissions/removals of GHG in the LULUCF sector from different land-use categories and HWP (which is reported separately) and the total for the sector.

The HWP pool is an important sink which follows the interannual fluctuations in living biomass as can be seen in figure 6.2. Increased harvests results in increases in the HWP pool and at the same time reduces the net removals of CO_2 in the living biomass pool.

The major source within the LULUCF-sector is the emissions from drained organic soils (Histosols) on Forest land and on Cropland. An area of about 4.0 Mha of the Forest land is classified as Histosols and around 1.0 Mha of the Histosols are drained. The Cropland area on Histosols is estimated to approx. 140 kha and all of that area is drained. The emissions from Histosols on cropland previously dominated the emissions but after a revision of emission factors, a continuous decline in cropland area and the inclusion of non-CO_2 emissions from Histosols, drained Histosols on forest land have now become the most important source.

There has been considerable variations in the reported sink for the soil organic carbon pool on mineral soils between submissions. These variations are partly caused by random variation in the sample. Since the total pool is huge and the changes in the pool are comparatively small the numbers are sensitive to random variation when small changes are multiplied by large areas. It can be noted that a change of 0.1 % in the pool is equivalent to more than 3 000 kt CO_2. The variation between years is reduced due to the method for interpolation and extrapolation of data. However, variation between submissions may still be substantial. The variation has decreased with time when more plots are re-inventoried. Since Submission 2017 results from the ongoing third forest soil inventory cycle (2013-2022) are used in the calculations. This year the results from 2015 are added to the data. This means that for 30 % of the plots there are now results from 3 sampling occasions. A summary of emissions/ removals is found in Tables 6.2a and 6.2b.

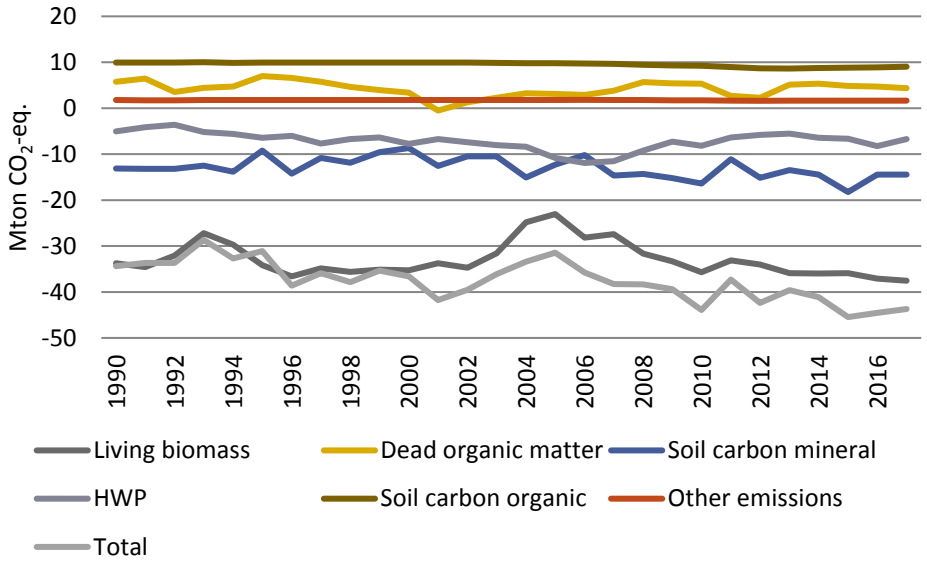

Figure 6.2. Net removals/emissions of GHG in the LULUCF sector from different carbon pools, other emissions (including CH_4 and N_2O from different sources), HWP and the total for the sector.

6.1.1.2 OTHER EMISSIONS 4(I), 4(II), 4(III), 4(IV) AND 4(V)

Data for categories commented below are presented in Table 6.2.b. Emissions of N_2O from nitrogen fertilization of forest land increased steadily from 2002 to 2010 but have decreased since then, simply due to a decrease in the use of fertilisers in forestry.

Emissions of N_2O and CH_4 from Histosols show no trend between 1990 and 2006, therafter the emissions decrease. This is due to a decrease in the area of drained organic forest soils, the reasons for this decrease in area are under investigation in an on-going project. Emissions from Wetlands used for peat extraction increases slightly over the entire reported period du to a slight long term trend in the production area and a steady increase in the production of horticultural peat. Emissions of non-CO_2 gases from drained soils include emissions from soils as well as direct emissions from ditches. The total emission of non-CO_2 gases from drained organic soils amount to 1 476 kt CO_2 eq. in 2017, which is a decrease from 1 649 kt CO_2 eq. in 1990 in line with the decrease in drained organic forest soils area. Note that N_2O emissions from Cropland are reported in the agriculture sector.

Emissions of CO_2 from DOC reported from Histosols follow the same trend as the non-CO_2 emissions for all land use categories as they are based on the same area estimates.

N_2O emissions from mineralisation due to land use conversion and management change which is included for all land use change categories as well as land use categories (except Cropland remaining cropland) shows a slightly increasing trend until 2007 due to the accumulations of areas in land use change categories but levels off thereafter since land that has been 20 years in the transition categories is moved to the new land-use categories.

The burned area, which strongly drives the emissions from biomass burning, shows no trend. Except for 2014, the emissions from these categories correspond to less than 0.2 Mt CO_2-eq. per year during the entire period 1990-2017 (including CO_2 emissions that otherwise are reported IE as an emission from living biomass). A summary of emissions/ removals is found in Tables 6.2a and 6.2b.

Table 6.2.a. Summary of net removals (-)/emissions (+) in living biomass (LB), dead wood, litter, dead organic matter (DOM), soil organic carbon (SOC) and harvested wood products (HWP) per land use category. Note that carbon stock change in organic soils also includes DOC.

6.2a	Net emissions / removals (minus=removal) [Mt CO_2]																				
	Forest land					Cropland				Grassland				Wet-land SOC	Settlement				Other land			HWP
				SOC				SOC				SOC					SOC			SOC		
	LB	Dead wood	Litter	Min	Org	LB	DOM	Min	Org	LB	DOM	Min	Org		LB	DOM	Min	Org	LB	Min	Org	
1990	-36.1	-4.2	10.1	-13.7	6.1	-0.1	0.0	0.0	3.4	0.2	-0.2	0.1	0.3	0.1	2.0	0.1	0.5	0.0	0.2	0.0	0.0	-5.0
1995	-35.7	-3.1	10.1	-13.7	6.2	-0.1	0.0	3.6	3.4	-0.3	-0.2	0.1	0.3	0.1	1.9	0.2	0.8	0.0	0.0	0.0	0.0	-6.4
2000	-36.6	-6.7	9.9	-13.9	6.1	0.0	0.0	4.0	3.3	-0.3	-0.2	0.1	0.3	0.1	1.6	0.3	1.0	0.0	0.0	0.0	0.0	-7.8
2005	-22.9	-9.5	12.4	-14.9	6.1	-0.3	0.0	1.1	3.3	-0.2	-0.2	0.2	0.2	0.2	0.3	0.4	1.2	0.0	0.0	0.0	0.0	-10.8
2010	-37.5	-7.3	12.4	-15.4	5.5	-0.3	0.0	-2.3	3.2	0.6	-0.2	0.1	0.3	0.2	1.4	0.3	1.2	0.1	0.0	0.0	0.0	-8.2
2011	-34.3	-9.8	12.3	-15.4	5.2	-0.1	0.0	3.0	3.2	0.0	-0.1	0.1	0.2	0.2	1.2	0.3	1.2	0.1	0.0	0.0	0.0	-6.3
2012	-34.8	-10.2	12.2	-15.4	5.0	-0.2	0.0	-1.1	3.2	0.0	-0.1	0.2	0.2	0.2	1.0	0.3	1.2	0.1	0.0	0.0	0.0	-5.8
2013	-36.7	-7.6	12.5	-16.1	5.0	-0.2	0.0	1.2	3.2	-0.1	-0.1	0.2	0.2	0.2	1.1	0.3	1.2	0.1	0.0	0.0	0.0	-5.5
2014	-36.9	-7.9	13.1	-16.7	5.1	-0.2	0.0	0.9	3.1	-0.2	-0.1	0.2	0.2	0.2	1.4	0.3	1.2	0.1	0.0	0.0	0.0	-6.5
2015	-37.0	-7.3	12.0	-16.4	5.1	-0.2	0.0	-3.3	3.1	-0.1	-0.1	0.2	0.2	0.2	1.5	0.3	1.2	0.2	0.0	0.0	0.0	-6.7
2016	-37.3	-7.4	11.9	-16.4	5.1	-0.1	0.0	0.5	3.1	-0.1	-0.1	0.2	0.2	0.2	0.4	0.3	1.3	0.2	0.0	0.0	0.0	-8.2
2017	-37.3	-7.7	11.8	-16.4	5.2	-0.1	0.0	0.5	3.1	-0.2	-0.1	0.2	0.2	0.2	0.2	0.3	1.2	0.4	0.0	0.0	0.0	-6.7

Table 6.2.b. Summary of other emissions. The total LULUCF removal is expressed as CO_2-eq. and includes both carbon stock changes and other emissions.

6.2b	Other emissions [kt substance]								Total LULUCF
	Fert.	Drainage		Min.	Ind.	Biomass burning			Mt CO_2-eq
	4 (I)	4(II)		4(III)	4(IV)	4 (V)			
Year	N_2O	CH_4	N_2O	N_2O	N_2O	CO_2	CH_4	N_2O	
1990	0.16	18.78	3.96	0.20	0.03	IE	0.0820	0.0006	-34.4
1995	0.06	18.82	3.97	0.30	0.01	IE	0.0768	0.0005	-31.1
2000	0.06	18.87	3.97	0.39	0.01	IE	0.1406	0.0010	-36.6
2005	0.07	18.64	3.89	0.50	0.01	IE	0.2377	0.0016	-31.5
2010	0.19	17.98	3.64	0.47	0.03	IE	0.0338	0.0002	-43.9
2011	0.12	17.64	3.52	0.46	0.02	IE	0.1015	0.0007	-37.3
2012	0.11	17.28	3.36	0.49	0.02	IE	0.0455	0.0003	-42.4
2013	0.06	17.30	3.41	0.51	0.01	IE	0.1178	0.0008	-39.6
2014	0.05	17.38	3.47	0.52	0.01	IE	1.2127	0.0083	-41.1
2015	0.08	17.45	3.52	0.52	0.01	IE	0.0669	0.0005	-45.5
2016	0.07	17.41	3.51	0.53	0.01	IE	0.1224	0.0008	-44.5
2017	0.06	17.29	3.50	0.52	0.01	IE	0.0885	0.0006	-43.7

6.2 Land-use definitions and the classification systems used and their correspondence to the land use, land-use change and forestry categories

6.2.1 Forest land

Sweden has defined Forest land according to the Global Forest Resources Assessment (FAO/FRA) 2005[266]. Forest land is land with a tree crown cover (or equivalent stocking level) of more than 10 % 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.
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[267]). Even if all these requirements are fulfilled, the land is only considered Forest land if the predominant land use is forestry. All Forest land is considered managed, i.e. even protection of forests in nature reserves is considered as management.

6.2.2 Cropland

Cropland is defined as regularly tilled agricultural land and all Cropland is assumed managed.

6.2.3 Grassland

Grassland is defined as agricultural land that is not regularly tilled and all Grassland is assumed managed. In the Swedish inventory this corresponds to natural grazing land.

6.2.4 Wetlands

Generally, Wetlands is assumed unmanaged and is defined as mires and areas saturated by fresh water. However, an area of approx. 10 000 ha isused for peat extraction is included under Wetlands and therefore assumed managed.

6.2.5 Settlements

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.

6.2.6 Other land

Other land is defined as all land not covered by the other land-use definitions above. It includes most of the mountain area in northwest Sweden. Other land is assumed unmanaged.

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

[267] FCCC/CP/2001/13/Add.1, p 58

6.2.7 The connection between national and reported land use categories

The reported land use categories are based on 12 (originally 16) national land use categories (Table 6.3) monitored by the Swedish National Forest Inventory.

Table 6.3. National Land Use Categories (used in the NFI) and their connection to the UNFCCC Land Use Categories. The area estimate in this example is based on both temporary and permanent sample plots representing the average 2013-2017.

National Land Use Category (NFI) Area [1000 ha]	Forest land	Other wooded land	Bare unprod. Land	Other land	Total	Additional Explanation and corresponding UNFCCC-category (in bold).
1. Productive Forest land	23503				**23503**	Land which hosts a potential yield of stem-wood exceeding one cubic metre per hectare and year. **Forest land.**
2. Grazing Land				509	**509**	Not regularly cultivated, **Grassland.**
3. Arable Land				2822	**2822**	Regularly cultivated, **Cropland.**
4. Mire	2174	1173	1785		**5132**	Land which hosts a potential yield of stem-wood lower than one cubic metre per hectare and year, **Forest land (if forest according to FAO) or Wetlands (larger part).**
5. Rock Surface	678	129	144		**952**	Rocky or stony areas, **Forest land** or **Other land**.
6. Sub alpine Coniferous Woodland	873	88	20		**982**	Land-zone usually located between 1 and 7. **Forest land (if forest according to FAO) or Other land**
7. High Mountain	915*			4061**	**4976**	Usually unstocked or sparsely stocked, **Forest land (if forest according to FAO) or Other land**
9. Road and Railroad				512	**512**	For permanent use. Not only roadway and rail but also other connected areas as embankments, **Settlements**
10. Power line Within Forest				148	**148**	Minimum width 5 m, **Settlements**
13. Urban Land				1133	**1133**	Settlements of many different kinds. **Settlements**
14. Other land				63	**63**	Different kinds of land that is not covered by Other land use categories. Examples: gravel pits, halting places and slalom slopes, **Settlements**
15. Freshwater				4460	**4460**	Lakes, rivers, creeks, canals, pounds etc. Minimum width of 2 m, **Wetlands.**
UNFCCC-categories *FL*	*28145*				***28145***	
CL				*2822*	***2822***	
GL				*509*	***509***	
WL		*1173*	*1785*	*4460*	***7417***	
S				*1856*	***1856***	
OL		*218*	*165*	*4061*	***4443***	
Total	**28145**	**1390**	**1949**	**13708**	**45192**	

The land use categories "Protected area nature reserve", "Other climate impediment" and "Military impediment" are included in other land use categories and the land use category "Sea" is not reported at all. An area of 915 kha (*) of High mountains (**) is assumed to be Forest land but no measurements of living biomass or other carbon pools are made in the field in these areas. Thus no carbon stock changes of living biomass is reported on this land. Observe that this example is based on both temporary and permanent sample plots representing average 2013-2017. Thus, the total land area in table 6.3 is not exactly the same as the total reported area in the CRF-tables.

6.2.8 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 to 2013. After 2013 only net changes can be estimated since 2013 is currently the last year with a full sample record (see section 6.2.9).

All land areas are included in the field inventory except high mountains and urban land. The latter land-use categories are inventoried by remote sensing to be able to correctly determine areas. It is assumed that their relative importance for the Swedish carbon budget is negligible. Two of the five inventory-years in the ongoing inventory cycle (2016 and 2017) include field inventoried plots also in the high mountain area. The plan is that all sample plots in the high mountains will be inventoried in field until 2020 and succesively re-inventoried in five-year cycles.

A few historical inconsistencies in the land-use category assessment have been identified and corrected. In the past (until 2003), protected areas ("Protected Area, Nature Reserve"; see section 6.2.7) were not regularly inventoried. From 2003 and onwards this areas are included in the land-use categories where it belongs. Usually there are data from at least one field inventory of "protected areas" earlier than 1990, but for some areas there are no data available. If no historical data are available, the change in carbon pools in former "protected areas" is assumed to be zero from 1990 to 2002. From 2003 and onwards 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 assessments in earlier inventories has been re-evaluated. A description on the treatment of former protected areas, re-evaluation of the assessment of land-use and the methodology for correcting inconsistencies in the land-use category assessment are described in more detail in the methodology section.

6.2.9 Land use and land-use change matrix

The land use and land-use change matrix in Table 6.4 is based on all of the 30000 (1990-2013) sample plots in the inventory. For example, the total area of Forest land remaining Forest land and conversions to Forest land (4.A.1 + 4.A.2.1 + 4.A.2.2 + 4.A.2.3 + 4.A.2.4 + 4.A.2.5) was 28186.14 kha in 2013. This implies that, given the sample, the land-use matrix is consistent with reported areas[268]. Due to a five-year inventory cycle, we can only provide a full record of data for the years 1990-2013. Therefore, land use for recent years (2014-2017) is extrapolated

[268] Given sample, the consistency is valid for up to 15 significant figures but this is not the same as accuracy of the estimator. Uncertainty of estimates is stressed in chapter 6.4.3

1, 2, 3 or 4 years depending on the inventory cycle, respectively. In the CRF Table 4.1, land use and land-use change matrices for recent years (2014-2017) are based on measured net land use per year and crude assumptions about land use conversions.

Table 6.4. Land Use Categories 2012, 2013 and gross and net land use transfers 2012-2013 (based on about 30 000 permanent sample plots inventoried 1983-2016).

Area [kha]	"From" Year 2012	"To" Year 2013					
		Forest Land	Crop-Land	Grass-Land	Wet-Land	Settle-Ments	Other Land
F	28171.99	28162.36	0.08	2.69	0.00	6.87	0.00
C	2889.52	7.73	2863.42	9.71	1.20	7.45	0.00
G	505.44	4.99	0.00	499.71	0.00	0.74	0.00
W	7413.79	0.13	0.00	0.26	7410.21	2.67	0.52
S	1847.53	10.94	0.84	0.35	0.00	1835.30	0.00
O	4298.91	0.00	0.00	0.00	0.00	0.00	4298.91
Sum		**28186.14**	**2864.34**	**512.71**	**7411.41**	**1853.13**	**4299.44**

6.3 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

6.3.1 The Swedish National Forest Inventory (NFI) and the Swedish Forest Soil Inventory (SFSI).

The Swedish National Forest Inventory (NFI[269]) and the Swedish Forest Soil Inventory (SFSI[270]) are integrated in the same sample design, using the same permanent sample plots.

The NFI plots are re-inventoried every fifth year and the SFSI plots are re-inventoried every tenth year since changes in the soil are expected to be slower than changes in living biomass. Moreover, topsoil cores are only taken at every second sample plot and deeper 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-measurements and changes in the litter and soil organic carbon pools are based on the SFSI-measurements.

The NFI/SFSI is an annual, systematic, cluster-sample inventory of Sweden's forests (Figure 6.3 and 6.4). 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 than that in the northern part of the country (there is stronger autocorrelation 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 region. Each year, about 6000 permanent survey sample plots are inventoried in the field. On each circular sample plot, with a radius of 10 or 20 m depending on the assessed variable, information is collected about the trees, the stand and the site. The main focus of the NFI is on monitoring forests for timber production and status of the environment.

[269] Ranneby et al., 1987

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

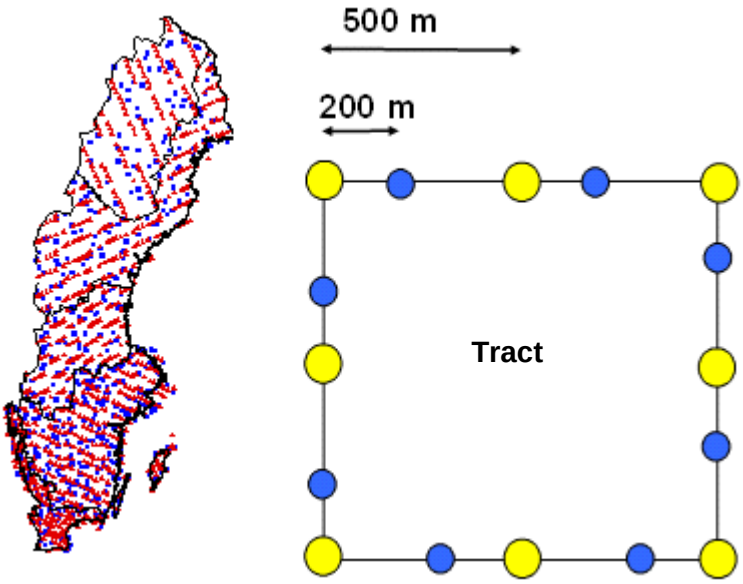

Figure 6.3. Covering the whole country of Sweden, each year a permanent sample grid (red) is re-inventoried and a temporary sample grid (blue) is inventoried. To be able to trace both gross and net land use transfers, only permanent sample plots are used in the reporting. When estimating changes of e.g. C, the accuracy is also higher using permanent then when using both temporary and permanent sampling plots. Each red dot represents a cluster of sample plots (Tract) and within Tract the yellow plots are used for the inventory while the blue plots are used for validation of harvests (estimates on up to one year old stumps).

Figure 6.4. The sample plots (red) are covering all relevant land uses. On the example above, 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 net 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 analysed for C concentration and other properties. Litter is partly estimated using data from the plot and partly modelled. Observe that the size and number of tracts differs by county. An additional sample (blue) is used for estimates of harvests.

The SFSI uses the 10-m radius sampling plot. A number of variables are recorded including general site variables, soil and humus type. The litter and different soil layers are sampled for further laboratory analysis. The O, H or A horizon[271] are sampled using an auger. The mineral soil used to be sampled in different but well defined soil 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[272] and soil samples are taken at fixed depths.

6.3.1.1 SAMPLE BASED ESTIMATIONS

The sample frame consists of a sampling grid 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 31 strata (i.e. representing counties) 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 is given a specific area weight and will consequently represent a larger area. The weighing is generated so that 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 with time but the tract will always represent the same total 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[273]. Finally the reported value on national level is estimated as the sum of the county values (for further information, see Annex 3.2).

A five year inventory cycle is used and five different samples were randomly distributed (using a systematic grid) 1983, 1984, 1985, 1986 and 1987, respectively. Each of these samples consists of around 6000 sample plots. The expected value of an estimator is theoretically the same for any given sample but to reduce sample randomness all five samples are merged. Full sets of samples are currently only available for years until 2013 and consequently only 24000, 18000, 12000 and 6000 sample plots are available for the estimates of 2014, 2015, 2016 and 2017 respectively. Five years after any reporting year, all samples have been re-inventoried covering that particular year and the full set of data can be used to produce the estimate. Therefore, the four last years of the previous report are re-calculated and revised in each submission.

Since the effect of the random variation on the estimates of areas and carbon stock changes are larger for the four most recent years (as also noted in the annual review reports), Sweden now extrapolates each of the five sample series (cycles) using the trend for the five years prior to the year of the latest actual re-measurement, to enlarge the data set for the most recent years. In Figure 6.5, the extrapolation of each sample series and its consequences on the estimates are illustrated. The effect

[271] O and H are organic soil layers and A refers to a humus rich, top mineral soil layer.

[272] http://biosoil.jrc.it/

[273] Thompson, 1992

of the extrapolation levels out "strange" area and carbon stock variations evolving from the randomness of the sampling as exemplified in Figure 6.5[274].

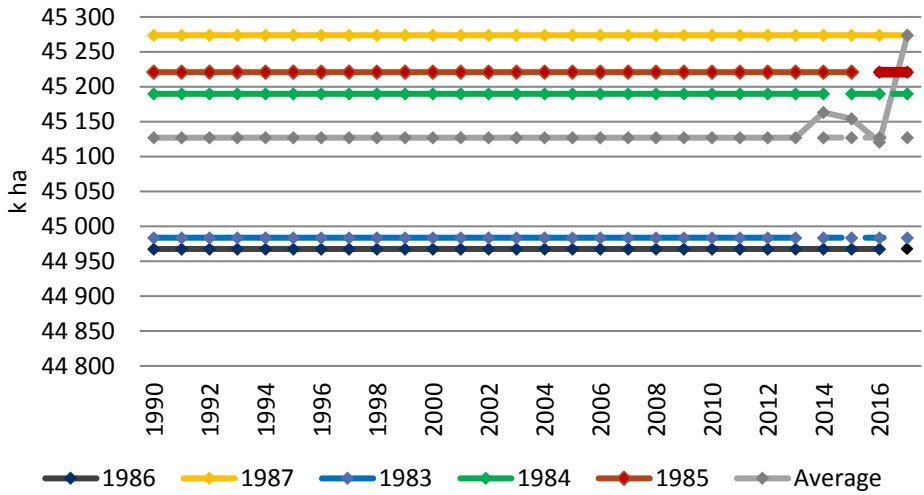

Figure 6.5. The total area of Sweden represented by five sub-samples (established in 1983, 1984, 1985, 1986 and 1987). Solid lines represent measured and dashed lines represent extrapolated values. The average solid line 1990-2017 represents average without extrapolated values and the average dashed line (2014-2017) represents the average with extrapolated values.

Sweden reports "human induced" carbon stock changes only, where "human induced" has the interpretation of "managed", i.e. the carbon stock change on unmanaged land are set to zero. However, the actual stock in living biomass on unmanaged land is considered when calculating stock changes after conversions between unmanaged and managed land and vice versa. This is possible since trees are inventoried on almost any land. All areas, managed or unmanaged, are reported. On request by reviewers, emissions/ removals from changes in living biomass are now reported for Forest land converted to Other land (considered unmanaged).

6.3.1.2 THE LULUCF-REPORTING DATABASE

Around 30 000 permanent sample plots are used for the area based sampling. 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 fifth year thereafter. If no land-use change has been identified for a plot, the land-use of years between consecutive inventories is held constant. If land use conversions are identified in field, the change in land use is set to the anticipated year of the conversion (see 6.3.1.3 and Table A.3.2.1 in Annex 3:2) or randomly. Biomass pools for years between inventories are linearly interpolated.

6.3.1.3 LAND USE TRANSFERS

If a land use conversion is identified and if all trees have been harvested between consecutive inventories, the biomass is assumed to drop to zero the anticipated year of harvest. The land use conversion and the harvest are matched to the same year. Otherwise, land use conversions are assumed to occur at a random year between

[274] This improvement and the information provided is a response to reviewers (ARR 2011)

consecutive re-measurements. Every plot that is converted to another land-use category is reported for 20 years in the land-use change category. After 20 years the plot will be reported in the category 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 new land-use transfer category. Since information on previous land use has been recorded, it is possible to trace land-use transfers that have occurred since 1983/1987. Consequently it is possible to decide how many years a sample plot has belonged to a certain land-use category to which land-use category it was converted already from or even before the start of the reporting period (1990). This means that some land use transfer categories include areas converted already before 1990.

The FAO definition of Forest land was introduced in the Swedish NFI in 1998. Until 1998 Forest land was assessed based on the national definition[275] of Forest land. Therefore, land-use categories have to be re-assessed for the period 1990-1997. There are two main types of cases of re-assessments 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 6.4) 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 6.4) 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. This automatic rule is valid before 2003, but after this year, a land-use category could only be changed manually if traces of human activities are identified in the field. For the 2018 submission, all conversions from/ to Forest land and from/ to Wetlands or Other land, were carefully studied. The result was that many assumed "artificial" land-use conversions were removed. Another example of the first type is when a recreation forest close to a city has been converted from Settlements (section 6.2.7, national land-use category 13, "Urban land", not measured for living biomass) to Forest land and the new land-use category consists of old trees. This has been

[275] The Swedish national definition of productive forest land used in national forest statistics defines productive forest land as land where the production is (or have the potential to reach) at least 1 cubic meter per hectare and year.

corrected so the land-use is assumed as Forest land at 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.

6.3.2 Other sources of information for activity data

In addition to the NFI, information on specific activities is used as land use activity data for some of the reported categories. These are:

- The Swedish Civil Contingencies Agency for areas of wildfires
- The Swedish Forest Agency for areas of controlled burning,
- The Swedish Geological Survey for areas of peat extraction

6.4 Description of categories (CRF 4A, 4B, 4C, 4D, 4E, 4F and 4G)

6.4.1 Definition of carbon pools and other sources

6.4.1.1 LIVING BIOMASS (CRF 4A, 4B, 4C, 4D, 4E AND 4F)

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[276]. Other 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 assessed for all land-use categories in the field inventory and reported for Forest land remaining Forest land, conversions to Forest land, Cropland remaining Cropland, conversions to Cropland, Grassland remaining Grassland, conversions to Grassland, Settlements remaining Settlements, conversions to Settlements and Forest converted to Other land. The latter is due to natural transition from managed land to unmanaged land..

6.4.1.2 DEAD ORGANIC MATTER CRF-TABLES (CRF 4A, 4B, 4C, 4D, 4E AND 4F)

Dead organic matter has been divided into dead wood and litter for Forest land. For the rest of the reported categories dead wood and litter is reported aggregated as dead organic matter.

6.4.1.2.1 Dead wood (CRF 4A, 4B, 4C, 4D, 4E and 4F)

Dead wood is defined as fallen dead wood, snags or stumps including coarse and smaller roots down to a minimum "root diameter" of 2 mm. Dead wood of fallen dead wood or snags should have a minimum "stem diameter" of 100 mm (at the smaller end) and a length of at least 1.3 m. Dead wood of stumps with corresponding roots are reported under Forest land remaining Forest land (and Forest management under the Kyoto Protocol), while fallen dead wood and snags are reported for all relevant land-use categories.

6.4.1.2.2 Litter (CRF 4A, 4B, 4C, 4D, 4E and 4F)

Litter includes all non-living biomass not classified as dead wood, 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.

[276] Swedish University of Agricultural Sciences, 2011

6.4.1.3 SOIL ORGANIC CARBON (CRF 4A, 4B, 4C, 4D, 4E AND 4F)

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[277]. The carbon pool considered is soil organic carbon down to a depth of 0.5 m measured from top of the mineral soil. Thus soil carbon is also measured when the soil is classified as a Histosol, emissions are based on emission factors (see below). In cropland mineral soils, only the topsoil (depth of 0.25 m) is considered for carbon stock change calculations.

6.4.1.4 HWP (CRF 4G)

Harvested wood products are defined as all wood material leaving the harvest site. Reported emissions from the HWP-carbon pool are based on pool changes of three product categories; sawn wood, wood based panels, and paper products, wood used for energy are considered to oxidize instantaneously when removed from site. The system covers only HWP from Swedish forests no matter where they are consumed (production approach).

During recent years, stem volume corresponding to about 63 Mton CO_2 has been removed from the forest each year of which about half have been refined to one of the three product categories. The rest has been used to produce energy. About 80 % of all harvested wood are consumed abroad and 20 % domestically.

6.4.1.5 DIRECT N_2O EMISSIONS FROM N FERTILIZATION (CRF 4(I))

To increase the forest production, some older forest stands on mineral soils are occasionally fertilized – normally around ten years before final felling. Thus, we assume that fertilization occur only on Forest land remaining Forest land. In 1990, the fertilized forest area was estimated to 69 200 ha[278]. Since then, the annual fertilized area decreased for some years. In recent years, this area has varied a lot and peaked in 2010. The fertilized area was about 25 100 ha in 2017. The activity data (areas) are based on an annual questionnaire sent to approximately 70 large-scale forest companies and a sample of 2000 small forest owners. This information is part of the official statistics of Sweden and is collected by the Swedish Forest Agency. Large-scale forestry, defined as forest companies with more than 10 employees or owners of more than 5000 ha Forest land, contributes with approximately 90 % of fertilizer related emissions of N_2O and small-scale forestry with the remaining 10 % of the emissions. To estimate the total annual emission, area figures are multiplied with normal average amount of fertilizer N applied per hectare (ca 150 kg N per hectare). The normal average amount N applied per hectare is obtained from the companies that are distributing the fertilizer. There are only a few companies in this business.

6.4.1.6 N_2O AND CH_4 EMISSION FROM DRAINAGE AND REWETTING AND OTHER MANAGEMENT OF ORGANIC SOILS (CRF 4(II))

N_2O from drained organic soils are included in the reporting. These emissions occur when the water table is lowered on organic soils, thereby causing a mineralisation of organic matter and nitrification or denitrification of nitrogen which leads to N_2O emissions. Drainage was used extensively during the early part of the 20th century as a way to increase productivity. The practice has more or less

[277] Food and Agriculture Organization of the United Nations, 1994.

[278] Swedish Forest Agency, 2012

stopped due to the prohibition of new drainage. The exceptions are the so called "protective drainage" that is applied after logging as a temporary measure to lower ground water level and the drainage of peatland for peat extraction.

Emissions of CH_4 from these soils are mostly occurring from the drainage ditches. On the drained soil itself, emissions of CH_4 are lower than it would be if the soil was not drained.

6.4.1.7 N_2O EMISSIONS FROM NITROGEN MINERALIZATION/IMMOBILIZATION ASSOCIATED WITH LOSS/GAIN OF SOIL ORGANIC MATTER RESULTING FROM CHANGE OF LAND USE OR MANAGEMENT OF MINERAL SOILS (CRF 4(III))

The conversion of land to other land uses is usually associated with a temporary increase in the mineralization of organic matter. Even management change of land causing loss of carbon is assumed to contribute to this mineralisation. Part of the released N may be converted to N_2O through denitrification. The loss of N due to mineralisation is calculated for all land use categories and all land use change categories. The release of N_2O is based on the carbon losses from the soil. Emissions of N_2O from cropland remaining cropland is reported in the agriculture sector.

6.4.1.8 INDIRECT NITROUS OXIDE (N_2O) EMISSIONS FROM MANAGED SOILS (CRF 4(IV))

In addition to the direct emissions of N_2O from managed soils that occur through a direct pathway (i.e., directly from the soils to which N is applied), emissions of N_2O also take place through two indirect pathways. The first one is the volatilisation of N following the application of synthetic and organic N fertilisers and the second one leaching and runoff of N from managed land.. The indirect emissions are calculated using the results from direct emissions of N_2O (4(I) and 4(III)).

6.4.1.9 N_2O, CH_4 AND CO_2 FROM BIOMASS BURNING (CRF 4(V))

Forest fires are rare in Sweden. Wildfires have been monitored by the Swedish Civil Contingencies Agency since 1996[279] and the area of wildfires has varied from 400 to 13 000 ha yr^{-1}. Controlled burning to improve regeneration of trees after clear-cutting is monitored by a complete record from 1990 and onwards (Swedish Forest Agency). Controlled burning as part of nature conservation measures is monitored from 2006. In recent years, an area of approximately 300-3000 ha is burnt annually after clear cutting and 100-2000 ha is now annually burnt for nature conservation. The Swedish Civil Contingencies Agency (former 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, forests in the mountain area and park areas. "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 aboveground living and dead biomass inventoried by the NFI by matching national definitions to the definition by the Swedish Civil Contingencies Agency. The area of wildfires is probably

[279] Swedish Rescue Services Agency, 2004

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.

6.4.2 Methodological issues

6.4.2.1 BASE METHODOLOGY (CRF 4A, 4B, 4C, 4D, 4E AND 4F)

Sweden reports emission/removals from carbon pools mainly according to the stock change method. The stock change method is combined with a sample-based inventory design which makes it possible to estimate errors of the stock change estimates. The Swedish National Forest Inventory (NFI[280]) has monitored the living biomass pool since 1983 and the dead wood pool since the mid-1990-ies. The Swedish Forest Soil Inventory (SFSI) has inventoried the soil organic and litter pools since 1993. A particular advantage with the Swedish NFI is that it has been undertaken using permanent sample plots on all relevant land use categories, which makes it possible to monitor net gains/removals in carbon pools for all land-use categories in a consistent and transparent manner (for further details, see Annex 3:2). The SFSI uses the same permanent sample plots as the NFI but soil sampling is only made on Forest land and Grassland.

6.4.2.2 METHODOLOGY LIVING BIOMASS (CRF 4A, 4B, 4C, 4D, 4E AND 4F)

A national methodology (Tier 3) is used. The aboveground biomass per fraction is estimated by applying Marklund's[281] biomass functions to trees on permanent sample plots of the NFI[282]. The belowground biomass is estimated by using Peterssons and Ståhl's[283] biomass functions on biomass data from the same trees as for the aboveground biomass. The conversion factor 0.50 is used to convert biomass to carbon[284]. Estimates of the change in the the carbon pools are based on repeated measurements. Data for years beteween the repeated measurements are interpolated and for four of five inventory cycles, data for the most recent reporting years are extrapolated. The stock change of for example year 2000 is calculated as the difference in stock between year 2000 and year 1999. Since the estimates are based on representative allometric single tree regression functions or on direct measurements, a low risk of bias is assumed.

6.4.2.3 DEAD ORGANIC MATTER CRF-TABLES (CRF 4A, 4B, 4C, 4D, 4E AND 4F)

Dead organic matter has been divided into dead wood and litter for Forest land. For the rest of the reported categories dead wood and litter is reported aggregated as dead organic matter.

[280] Swedish University of Agricultural Sciences, 2011

[281] Marklund, 1987 and 1988

[282] Ranneby et al., 1987

[283] Petersson and Ståhl, 2006

[284] Sandström et al., 2007

6.4.2.3.1 Methodology dead wood CRF-tables (CRF 4A, 4B, 4C, 4D, 4E and 4F)

A national methodology (Tier 3) is used to estimate the dead wood pool. 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, Scots pine, birch and other broadleaves. The volume is measured by the NFI. The methodology is further described in the Annex to NIR, chapter 3.1.5.

Belowground dead wood originating from stump and root systems of harvested trees is reported based on indirect measurements of harvest. The harvest is estimated based on estimates of growth (stem volume, from measurements of increment bore cores of sample trees) converted to CO_2-eq. minus the net change in the living biomass carbon pool. Growth is estimated by the National Forest Inventory and represents "productive forest land" while the net change in the living biomass pool represents all Forest land (FAO-definition). As a consequence of this, the annual inflow to the stump carbon pool might be slightly underestimated. The harvest of stems is converted to stump and root biomass by conversion factors.The conversion factors are based on estimates of stem volume[285] and stump and root biomass[286] applied to sample trees representing the standing stock of Swedish forests. The decay of stumps is modelled[287] by simple decomposition rate functions. The described methodology is consistently used during the reported period. Emissions from stump and root systems originating from years earlier than 1990 are estimated using a similar methodology applied on stump and root systems from the years 1853-1989.

6.4.2.3.2 Methodology litter CRF-tables (CRF 4A, 4B, 4C, 4D, 4E and 4F)

A national methodology (Tier 3) is used to estimate the litter pool. The pool includes different sub-pools (litter and the organic soil horizon)).

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 in field but calculated as 15 % of the aboveground dead wood measured according to 6.4.2.3.1. Litter fall is calculated using empirical functions based on 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 through the O or H horizon sample which is taken on an area basis, weighed and analysed for carbon content (for further details, see Annex 3:2).

6.4.2.4 METHODOLOGY SOIL ORGANIC CARBON (CRF 4A, 4B, 4C, 4D, 4E AND 4F)

The change in the soil organic carbon pool is estimated using different approaches depending on the land use. For Forest land and Grassland on mineral soils,

[285] Näslund 1947

[286] Petersson and Ståhl, 2006

[287] Melin et al., 2009

estimates are based on repeated soil sampling in combination with pedotransfer functions. For forest and grassland Histosols the emission estimates are based on emission factors in combination with area estimates of different sub-categories. For Cropland the ICBM model[288,289] is used to calculate changes in the soil organic carbon stock on mineral soils. Emissions from cropland Histosols are estimated using an emission factor and the area of cropland Histosols.

6.4.2.4.1 Forest land and Grassland on mineral soils (CRF 4.A.1 and 4.C.1)

The method is a Tier 3 method. The estimates are based on repeated measurements of several variables on the NFI plots. The basic function used to determine the amount of carbon in a soil layer is based on the soil carbon concentration in a certain soil layer and the amount of fine earth. The amount of fine earth is dependent on the bulk density and the volume fraction of gravel, stones and boulders in the soil (for further details, see Annex 3:2).

6.4.2.4.2 Forest land and Grassland on organic soils (CRF 4.A.1 and 4.C.1)

The method is a Tier 1 method. Changes in the soil organic carbon pool on organic soils are calculated by the use of emission factors. The emission factors rely on estimates of emissions divided into two different classes of nutrient status and two different climate regimes. The nutrient status is determined by using ground vegetation on the sampling plots while climate is divided geographically. Emission factors are taken from the IPCC 2013 supplement for Wetlands[290] (for further details, see Annex 3:2). Data on emissions from grasslands are scarce and most often taken from studies looking at intensively used grasslands where nutrients are commonly applied. For this reason, the emission factors for Grasslands provided in the IPCC 2013 supplement for Wetlands were put aside in favour of those applied on Forest land. Swedish Grasslands included in the reporting only consist of natural pastures which are considered to be closer to Forest land according to the soil conditions.

6.4.2.4.3 Cropland on mineral soils (CRF 4B)

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[291]. 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[292](for further details see Annex 3:2).

[288] the Introductory Carbon Balance Model

[289] Andrén & Kätterer, 2001

[290] IPCC 2014

[291] Andrén & Kätterer, 2001.

[292] Eriksson 1997,1999

6.4.2.4.4 Cropland on organic soils (CRF 4B)

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 area. The total area of organic soils under agricultural production has been estimated in national surveys[293,294]. The area of organic soil in these studies has been linked to the changes in total cropland area so that decreasing cropland area proportionally affects the area of cropland on organic soils (for further details see Annex 3:2).

6.4.2.5 METHODOLOGY FOR DEAD WOOD, LITTER AND SOIL ORGANIC CARBON FOR CONVERSION BETWEEN LAND-USE CLASSES CRF-TABLES 4A.2.1-5, 4B.2.1-5, 4C.2.1-5, 4D.2.1-3, 4E.2.1-5 AND 4F.2.1-5

The method to estimate the emission/removals in the dead wood, litter 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 in combination with the land-use change area. For further details see Annex 3:2.

6.4.2.6 HWP (CRF 4G)

The methodology used is a Tier 3 method developed from the Tier 2 described in the IPCC 2006 guidelines. The calculation of emissions from HWP is based on carbon stock changes.

Products originating from Swedish forests are included regardless of where the products are consumed, which means that the import is excluded while the export is included. This is denoted *the production approach* in the IPCC guidelines.

Separate stock changes for the three categories sawn wood, wood based panels and paper products are calculated. Separate calculations are also undertaken for products consumed abroad and products consumed domestically.

The stock change depends on the difference between inflow of carbon in new products and outflow of discarded products, and is calculated using equation 12.1 from the IPCC 2006 GL. The outflow is calculated as a fraction of the previous year's pool and therefore a pool must be calculated in order to estimate an outflow. To achieve this, historical data mainly from the Swedish Forest Agency regarding production and trade starting from 1900 is used to build a pool for each product category. The period of data available is dependent on when the product first occurred, in some cases data is only available at the first occurrence of a product. In other cases data is first collect in a later phase and back-casting using a proportional decrease is applied. The outflow is calculated using the half-life as an independent variable, and the half-lives applied are 35 years for sawn wood, 25 years for wood based panels, and 2 years for paper.

The inflow of carbon in new products was estimated using data regarding production and trade from the Swedish Forest Agency. A series of equations were developed to exclude imported carbon from each step of the refinement chain for

[293] Berglund and Berglund, 2009

[294] Pahkakangas S. Berglund Ö.,Lundblad M., Karltun E. 2016

each product category. The general form of the equations is pdh=p*[(crm-irm)/crm] where p=production, dh=domestic harvest, c=consumption, rm=raw material and i=import. Statistics for paper include paper made from pulp and paper made from recovered paper (RP). The origin of RP is unclear. It is possible to exclude RP of non-domestic origin from the domestic production of paper (although imported RP might originally come from exported paper), but following exported paper is more complex. About 90 % of the paper produced in Sweden is exported and, after being consumed abroad, is used to produce new paper abroad. To include paper from recovered paper of domestic origin used abroad to produce new paper, the quota [production of RP/consumption of paper] in the EU (to which about 75 % of the paper produced in Sweden is exported) is multiplied with the outflow of discarded paper. The product is added to next year's inflow of paper from pulp.

The conversion factors applied are 0.62 t per m³ for wood based panels, 0.42 t per m³ for sawn wood, and 0.9 t woody biomass per t of paper. Carbon content for each category is set to 0.5. The conversion factor for wood based panels was calculated as a mean value for the different panel categories produced, weighted with respect to produced volumes of the different categories respectively. A corresponding methodology was applied to sawn wood, i.e. a weighted mean value of wood densities for the harvested wood species, mainly Scots pine and Norway spruce, was calculated. Production of paper in tonnes was multiplied with 0.9 to adjust for added non-wood compounds during the manufacturing process. No such adjustment was made in cases when the inflow consisted of pulp instead of paper, for example, exported pulp.

The amount of HWP put into landfills[295] is assumed to be 0.

6.4.2.7 CO_2 EMISSION FROM PEAT EXTRACTION (CRF 4D)

The method used to estimate CO_2 emission from peat extraction areas is a Tier 2 approach. A limited area (around 10 000 ha) is used for peat extraction 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 is calculated as the product of the extracted area and an emission factor (for further details see Annex 3:2). The off-site emissions from horticultural peat are reported assuming that the carbon is gradually oxidised over time. A country specific method has been used for the calculations (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 (for further details see Annex 3:2).

6.4.2.8 DIRECT N_2O EMISSIONS FROM N FERTILIZATION (CRF 4(I))

A Tier 1 methodology is used. All fertilization is assumed to occur on Forest land remaining Forest land[296]. In year 1990 calcium nitrate ($Ca(NO_3)_2$) was the

[295] Since 2004 it is prohibited to put combustable and organic waste on land-fills. Naturvårdsverkets föreskrifter och allmänna råd om hantering av brännbart avfall och organiskt avfall (NFS2004)

[296] 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.

dominant fertilizer but thereafter the fertilizer have been based on ammonium nitrate with 50 % NO_3-N and 50 % NH_4-N. The reported annual emission is calculated as the product of the applied amount and the emission factor (for further details see Annex 3:2).

6.4.2.9 N_2O AND CH_4 EMISSIONS FROM DRAINAGE OF SOILS AND CH_4 FROM DITCHES (CRF 4(II))

A Tier 1 methodology is used and the reported figures refer to N_2O and CH_4 for each land use category with different emission factors depending on nutrient status and climate and multiplied with corresponding areas. Emissions of CH_4 include emissions from the soil itself and from the ditches multiplied with the fraction of ditches. N_2O and CH_4 from peat extraction land is also reported under 4(II) using the same area as reported for peat extraction under 4.D and corresponding emission factors. For further information and the emission factors used, see Annex 3:2.

6.4.2.10 N_2O EMISSIONS FROM NITROGEN MINERALIZATION/IMMOBILIZATION ASSOCIATED WITH LOSS/GAIN OF SOIL ORGANIC MATTER RESULTING FROM CHANGE OF LAND USE OR MANAGEMENT OF MINERAL SOILS (CRF 4(III))

A Tier 2 methodology is used. The reported annual N_2O emission from nitrogen mineralisation associated with loss of carbon resulting from land use change or change in land use of mineral soil is calculated according to equation 11.8 in IPCC 2006 GL (IPCC[297]) using partially country specific parameters (for further details see Annex 3:2).

6.4.2.11 INDIRECT NITROUS OXIDE (N_2O) EMISSIONS FROM MANAGED SOILS (CRF 4(IV))

A Tier 2 method is used to calculate the indirect emissions based on the use of fertilizers and mineralisation equation 11.9 and 11.10 in IPCC 2006 GL. The reported annual N_2O indirect emissions are based on the amount of added fertiliser and the mineralisation of N and assumptions on the volatilization and leaching of N_2O.

6.4.2.12 EMISSIONS FROM BIOMASS BURNING (CRF 4(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. The exact location of the burned areas is not registered by the Civil Contingencies Agency (6.4.1.8) but the fires in tree covered areas are matching areas defined as Forest land. The NFI register if a fire has occurred on the sampling plot. This data has been used for verification and this far no fire has been identified on land converted to Forest land. Thus we believe it is reasonable to report fires in former tree covered areas under Forest land remaining Forest land. Fires on non-tree covered areas are not separated into land use. However, the definition is closest to the definition of Grassland and, thus, all fires on non-tree covered areas are reported under Grassland remaining Grassland. Calculations are based on the amount of biomass per area, burned area and emission factors. To avoid double-counting, CO_2 emissions from wildfires and controlled burning are included in

[297] Intergovernmental Panel on Climate Change, 2006

carbon stock changes in living biomass (for further details see Annex 3:2). Sweden assumes that 25 % of the pre-fire biomass stock is combusted during the fire. This is in line with the IPCC 2003[298] GPG but the IPCC 2006 GPG suggest emission factors that are a little bit higher. However, Sweden finds a combusted proportion of 25 % more realistic. This proportion is based on subjective observations (in the field) of remaining biomass after several wildfire events in Sweden such as the example in Figure 6.6.

Figure 6.6. Post-fire biomass after Swedish forest fire in the county Västmanland 2014.

6.4.3 Uncertainties and time series consistency

Since the Swedish reporting system of the LULUCF-sector mainly is based on sampling, a national method is used to estimate the overall uncertainty. Uncertainties in the reported estimates arise from random and systematic errors. Random errors dominate the uncertainty for the part of the living biomass, dead organic matter and soil organic pools that are calculated based on sampling data whereas systematic errors dominate the uncertainty for other emissions/removals. Uncertainties per greenhouse gas is found in the Annex to NIR, Table A.3.2.15

Random errors could be estimated by straight forward 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 are therefore induced by expert opinion and using the default error values according to IPCC [299].

6.4.3.1 LIVING BIOMASS (CRF 4A, 4B, 4C, 4D, 4E AND 4F)

The accuracy of the living biomass pool estimates 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.

[298] Intergovernmental Panel on Climate Change, 2003

[299] Intergovernmental Panel on Climate Change, 2006

Research by Ståhl et al. (2014)[300] and Breidenbach et al. (2014)[301] indicate that the influence of model errors could be expected to be less than 1 % of the total error budget. Estimates for reporting years 1990-2013 are based on approximately 30000 sample plots and with a corresponding estimated standard error of 3.4 Mt CO_2/year (relative standard error of -10 %). The estimate of uncertainty is quite stable between years but the relative estimates vary due to changes in net removals. Estimates for reporting years 2014, 2015, 2016 and 2017 are based on measurements on approximately 24000, 18000, 12000 and 6000 sample plots, respectively, combined with extrapolated data. This extrapolation increases the accuracy substantially, but to avoid a potential risk of systematic errors we also gradually update extrapolated data using data from re-measured sample plots (see Annex 3:2 for further details).

6.4.3.2 DEAD WOOD AND LITTER (CRF 4A, 4B, 4C, 4D, 4E AND 4F)

Estimates of dead organic matter are based on sampled data from the litter pool and dead wood pool from the NFI and the MI. There is probably a small error in the estimates of dead wood due to incorrect measured volumes and 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 previous submissions the accuracy of litter estimations 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 1993-2002 (first inventory), from 2003-2012 (second inventory) and from 2013 - 2015 (the third inventory). Changes are interpolated for each plot between inventories. Litter pool changes for 2016 and 2017 are extrapolated from the measured data. The sample error for the measured part of the litter carbon pool is calculated similarly to the living biomass calculation. The sample error for the litter fraction on mineral soils is estimated to be 0.32 ton C ha^{-1}. The dead wood measurements are from the period 1995 to 2017. Estimates of changes of dead wood in stumps on Forest land are indirectly based on harvest from growth minus net change in living biomass (both data sources from the NFI). The harvest rate is approximately verified by harvest statistics from production statistics (Swedish Forest Agency). The conversion from harvested stem volume to stump biomass may introduce a small systematic error.

6.4.3.3 SOIL ORGANIC CARBON (CRF 4A, 4B, 4C, 4D, 4E AND 4F)

The sample error for the soil organic carbon pool is calculated similarly to the living biomass calculation. The sample error for soil carbon on mineral soils is estimated to be 0.82 ton C ha^{-1}. A problem associated with 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

[300] Ståhl et al., 2014.

[301] Breidenbach et al., 2014.

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 emission factor to 40 %. The uncertainty in activity data (carbon stock changes) for CO_2 emission from mineralization when extracting peat is judged to 25 % and the uncertainty due to errors in the emission factor is judged to 60 %.

One of the major difficulties in reporting changes in DOM and SOC is that the pools is very large and the changes small in comparison to the pools. As seen in Figure 6.7 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 lower 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.

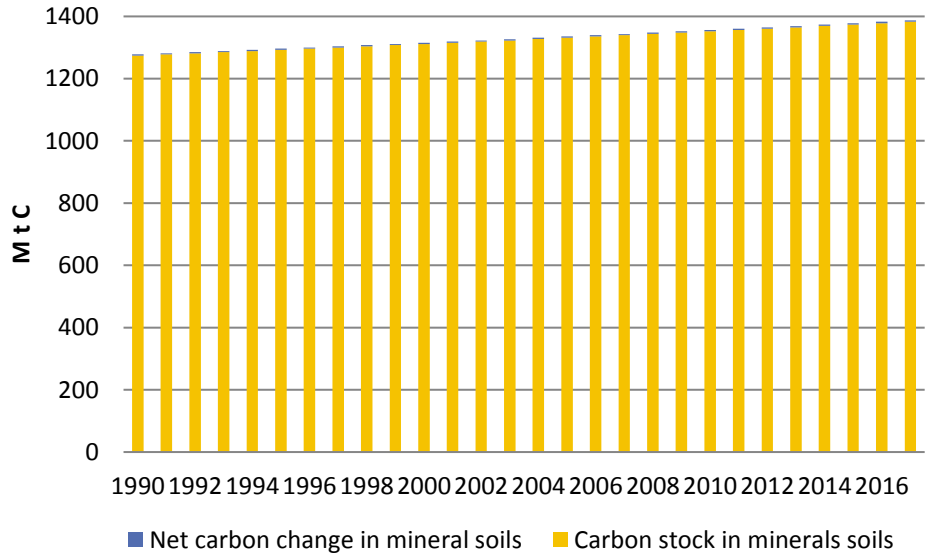

Figure 6.7. The reported change in soil carbon on mineral soils (blue bar) and the corresponding stock (yellow bar) for Forest land remaining Forest land.

6.4.3.4 HWP (CRF 4G)

Uncertainties in the data, conversion factors and oxidation of depleted products affect the HWP-estimates.

6.4.3.4.1 Data

Data from 1900 and onwards was used. The removals and HWP-production were crosschecked by the quota [(calculated total production of HWP of domestic harvest including black liquor and sawmill residues used for energy)/(removals of industrial round wood)]. The quota varied between 98 % and 107 % and averaged 102 % during 1990-2013, indicating a slight overestimation of the HWP-

production. The production of black liquor was assumed to be equal to the production of chemical pulp of domestic origin. That is a rather rough assumption that causes some of the deviation.

6.4.3.4.2 Conversion factors

Wood density for round wood used by the sawmill- and wood based panels industry was set to 0.42 t/m^3. More than 99 % of the round wood used by the sawmills in Sweden was from Norway spruce (55 %) and Scots pine (45 %), and the density for the two conifers was calculated using data from the NFI and models for stem volume and stem biomass. The resulting density was compared to data from the literature. Either sawn wood or wood based panels was split into subcategories. Since sawn wood is produced from two conifers of similar density there is no reason to calculate separately for different species. Wood based panels (WBP) are produced in such low quantities that subcategories would have very low impact on the result. Further, the only WBP produced in Sweden at present is particle board and plywood. The conversion factor used for paper was 0.45. It was crosschecked as the quota between domestic production of paper (from pulp only, not from recovered paper) of domestic origin and domestic consumption of pulp of domestic origin. Thus, the reliability of the conversion factors should be acceptable.

6.4.3.4.3 Oxidation

The half-life's used for the different product categories is by far the most uncertain component in the calculations. Therefore the uncertainty was estimated using varying half-life's. The half-life's was increased and decreased by 20 %, and the uncertainty was estimated as the difference between the calculations using adjusted half-life's and the calculations using the default half-life's. A Monte Carlo analysis was used to estimate a mean standard deviation for the total emission which was converted to the uncertainty reported in Table 10.10.

6.4.3.5 OTHER EMISSIONS (CRF 4(I) TO 4(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.

4(I): 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 the emission factor should be in the range 0.25 % to 6 % and the interpretation is that a badly chosen emission factor could lead to an error that is much larger than 25 %.

4(II): For emissions from drainage, the error in activity data is judged to 25 %. The uncertainty in the emission factors is mainly based on the confidence intervals presented by the IPCC. The uncertainty in the emission factors for N_2O and for CH_4 is both above 100 %.

4(III): The accuracy of estimates of N_2O emissions from mineralization associated with change in management or land-use 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. Therefore, the uncertainly level is suggested to be 100 %, also taking into account the uncertainties in IPCC default values.

4(IV): For the indirect emissions the error in activity data corresponds to the error from the fertilization estimates and to the mineralisation. The uncertainty in the emission factors for indirect N_2O emissions is well above 100 %.

4(V): 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 likely 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. According to the points raised in the discussion above on uncertainties in CO_2 emissions from biomass burning, the uncertainty of N_2O and CH_4 emissions from biomass burning are assumed to be 100 % (Managing uncertainties: A.1.4).

6.4.3.6 COMPLETENESS

Each source/sink category has been reported only once. This is mainly ensured by using only one source of information for the overall land area representation. One source of activity data is overlapping the area estimate from the NFI (peat extraction areas) but this is handled by reduscing the area of permanent Wetland with the peat extraction area.

Sweden reports carbon stock changes in all carbon pools and all other emissions for all land use categories that are considered managed (Forest land, Cropland, Grassland, Settlements and a small area of Wetland) and for which methods are provided in the IPCC 2006 GL. The notation key "NO" is used when there is no observed occurrence for a certain category (i.e. uncommon land use changes) and when the reported activity does not result in emissions/removals. The notation key "IE" is used when it is not possible to separate emissions/removals on relevant land use categories and according to the use of the stock change method. In the latter case either gains or losses are reported "IE". The notation key "NA" is used for emissions/removals from unmanaged land. The notation key "NE" is used for categories not estimated and comprises categories that currently are optional to report.

6.4.4 Category-specific time series consistency, verification and QA/QC

6.4.4.1 TIME SERIES CONSISTENCY AND VERIFICATION

The time series of changes in carbon stocks for the living biomass pool is consistently measured from 1990 and onwards. The trend has been validated and confirmed by the default method (growth minus losses) but the level of the annual net removals could not be verified. We assume that most of the discrepancy could be explained by the basic biomass expansion factors applied using the default method. The time series for the dead wood pool (lying and standing) extrapolates data in the beginning of the period and this is because the inventory did not begin until the mid-1990th. Due to a relative high sampling error and a five-year inventory cycle, a trend is reported and thus it is quite difficult to match emissions/removals from dead wood to the correct year. This trend is estimated using a five-year, four-year, three-year, two-year and one-year running average for years 2013, 2014, 2015, 2016 and 2017, respectively. When based on a five-year running average, the data is fixed for future reporting and should represent reported

year. The dead wood pool constitutes a small net removal. This could partly be explained by the fact that, since 1990, an increasing amount of dead wood and snags have been left after harvest, however, no proper validation has been made. Another reason may be that the inflow of new dead wood has increased from gradually more frequent windstorms and wildfires. But again, no proper validation exists.

The time series of the dead wood pool is measured since 1994 with only minor changes in sampling methodology. The dead wood from stumps has consistently been measured indirectly from growth minus net removal from change in living biomass and verified by indirect measurements from harvest statistics. The reported removal average out annual fluctuations and is therefore in agreement with the reported changes in living biomass, while the annual variation in removals is larger using validation data (Figure 6.8).

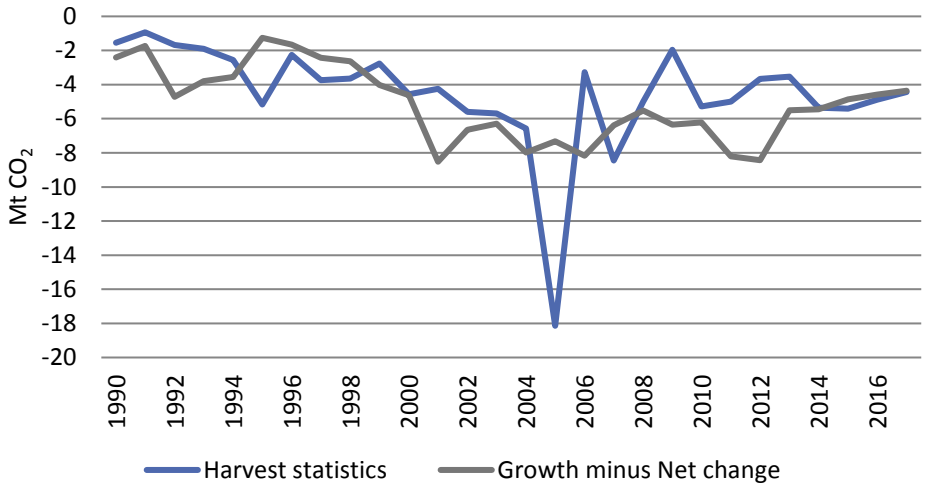

Figure 6.8. The reported net-removal from stumps (part of dead wood) is indirectly calculated from growth minus net-removal from living biomass (inflow) minus modelled decomposition (outflow). The validating net-removal from stumps is based on harvest statistics (inflow) minus modelled decomposition (outflow).

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 with respect to soil carbon pool estimates have not revealed any systematic differences. 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 changes with respect to the rate of change between the models and the measurements[302].

[302] Ortiz *et al.* 2009.

6.4.4.2 QUALITY ASSURANCE (QA)

The quality assurance system of the data collection within NFI used for the UNFCCC and Kyoto reporting has been described by the Swedish University of Agricultural Sciences[303]. These routines were improved during 2006 . SLU also works closely with the Swedish EPA to enhance the QA/QC.

6.4.4.3 QUALITY CONTROL (QC)

An internal quality control has been performed. 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.

6.4.5 Source-specific Recalculations

Recalculations can be divided into several categories of which the two first ones can be considered "ordinary" recalculations due to the applied methodology using random sampling.

The first category is recalculations due to updated NFI-data which mainly affects the estimates for the previous four years as described in section 6.3.1.1. Small corrections of historical land use changes may affect estimates for earlier years, especially for categories using area as activity data.

The second category is recalculations related to extended datasets for litter and soil from the MI. Since the whole dataset is included using extrapolation and interpolation techniques this may generate updated data for the entire time series.

The third category is when new activity data (not related to NFI or MI) or emission factors have become available (i.e. better sales statistics, information on biomass burning or emission factors related to land-use change).

The fourth category is when the methods have been improved.

The fifth category is when an obvious computational error has been detected in the calcualtions and needs to be corrected.

6.4.5.1 LAND USE

Due to extrapolation, areas of land use and land-use change have been updated for recent years (6.3.1.1 and 6.4.5.2). From submission 2018, the NFI monitors Forest land in the mountain area in the field (mainly Other land). This is made for two inventory cycles while an area of 915 kha of Other land is reported as Forest land for each of the three remaining cycles. This will not change the reported change in living biomass yet, but probably slightly in the future (see also 6.2.8). Both these re-calculations are considered ordinary.

[303] Karltun *et al*., 2005.

6.4.5.2 LIVING BIOMASS

To improve the accuracy of estimates in the current submission, the living biomass pool and areas have been recalculated for the years 2013-2017. Each estimate for these years is now based on 6000 more sample plots and incomplete inventory cycles have been extrapolated to 2017, see also section 6.3.1.1 and figure 6.9.This is considered an ordinary re-calculation.

The total effect of the recalculation on Living biomass on Forest land remaining forest land is illustrated in Table 6.5a and Figure 6.9.

6.4.5.3 DEAD WOOD, LITTER AND SOIL ORGANIC CARBON

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 2017 due to introduction of more re-inventoried sample plots from the SFSI. Data from the third inventory starting in 2013 have been used in this submission for the calcuation of carbon stock changes in litter and mineral soils. Measured data up to 2015 was available this year. That means that changes are calculated based on three separate measurements in time on 30% of the plots.

Emissions from organic soils as well as carbon pool changes for land-use change categories have been recalculated due to updated activity data from the NFI (areas) and the SFSI (areas of Histosols and drained soils). It was observed that emissions from DOC was omitted for Forest land remaining forest land in the previous submission. This was corrected in this submission.

Emissions and removals from mineral and organic soils for land use change categories have been recalculated in Submission 2019 since data on on peat cover from the NFI was recalculated.

On a request from ERT, Soil carbon stock changes on Forest land converted to Other land is now concidered in the reporting (even if Sweden considers such land unmanaged).

6.4.5.4 NON-CARBON EMISSIONS

No recalculations have been made for nitrogen emissions from nitrogen fertilization (4I). Recalculations have been made for non-carbon emissions (4II) from drained organic soils due to slightly adjustments in activity data (areas). Due to recalculations of the carbon stock changes, e.g. the activity data to calculate emissions from mineralisation associated with land use change or change in management all estimates under (4III) have been updated. No changes in underlying activity data for wildfires (4V) have been made.

The recalculations are summarized in Table 6.5.a. and Table 6.5.b.

6.4.5.5 HWP

No recalculations have been made.

Table 6.5.a. and Table 6.5.b. Recalculations of carbon stock changes and other emissions between submission 2018 and submission 2019 in the LULUCF-sector. Positive numbers indicate an increase in emissions or a decrease in removals and negative numbers indicate an increase in removals or a decrease in emissions.

6.5a	Difference in carbon stock changes between Submission 2018 and 2019 [Mt CO_2]																					
	Forest land					Cropland				Grassland				Wet-land SOC	Settlement				Other land			HWP
				SOC				SOC				SOC					SOC			SOC		
	LB	DW	Litter	Min	Org	LB	DOM	Min	Org	LB	DOM	Min	Org		LB	DOM	Min	Org	LB	Min.		
1990	0.27	-0.06	0.11	0.20	0.56	0.00	0.00	0.00	0.04	0.02	0.16	0.25	0.00	0.00	0.01	0.00	0.00	-0.01	-0.03	NA	NA	0.00
1995	0.24	-0.05	0.11	0.20	0.56	0.00	0.00	0.00	0.04	0.02	0.16	0.24	0.00	0.00	0.01	0.00	-0.02	-0.01	0.00	NA	NA	0.00
2000	0.26	-0.05	0.11	0.20	0.56	0.00	0.00	0.00	0.04	0.02	0.16	0.24	0.00	0.00	0.03	0.00	-0.02	-0.01	0.00	NA	NA	0.00
2005	0.15	-0.03	0.11	0.20	0.56	0.00	0.01	0.00	0.03	-0.01	0.16	0.24	0.00	0.00	0.00	0.00	-0.02	0.10	0.00	NA	NA	0.00
2012	0.17	-0.03	0.11	0.20	0.56	0.00	0.01	0.00	0.03	0.00	0.16	0.24	0.00	0.00	0.06	0.00	-0.02	-0.01	0.00	NA	NA	0.00
2013	0.17	-0.03	0.11	0.20	0.54	0.00	0.01	-0.01	0.03	0.00	0.15	0.24	0.00	0.00	-0.01	0.00	-0.02	-0.02	0.00	NA	NA	0.00
2014	0.10	-0.01	0.11	0.20	0.54	0.00	0.01	0.00	0.03	0.00	0.15	0.24	0.00	0.00	-0.12	0.00	-0.02	-0.02	0.00	NA	NA	0.00
2015	0.11	-0.01	0.10	0.20	0.54	0.00	0.01	0.00	0.02	0.00	0.15	0.27	0.00	0.00	0.01	0.00	-0.02	-0.02	0.00	NA	NA	0.00
2016	0.13	-0.02	0.10	0.20	0.54	0.00	0.01	0.00	0.02	0.00	0.15	0.26	0.00	0.00	0.00	0.00	-0.02	-0.02	0.00	NA	NA	0.00

6.5 b	Other emissions [k ton substance]								Total	
	Fert.	Drainage		Mineralisation	Indirect	Biomass burning				
	4 (I)	4(II)		4 (III)	4 (IV)	4 (V)				
Year	N_2O	CH_4	N_2O	N_2O	CO_2	CO_2	N_2O	CH_4	[Mt CO_2-eq]	[%]
1990	0.0	0.1	0.0	0.0	0.0	NA	0.0	0.0	1.5	4
1995	0.0	0.0	0.0	0.0	0.0	NA	0.0	0.0	1.4	4
2000	0.0	0.0	0.0	0.0	0.0	NA	0.0	0.0	1.4	4
2005	0.0	-0.1	0.0	0.0	0.0	NA	0.0	0.0	1.5	5
2012	0.0	-0.1	0.0	0.0	0.0	NA	0.0	0.0	0.7	2
2013	0.0	-0.2	0.0	0.0	0.0	NA	0.0	0.0	-1.3	-3
2014	0.0	-0.2	0.0	0.0	0.0	NA	0.0	0.0	-0.9	-2
2015	0.0	-0.1	0.0	0.0	0.0	NA	0.0	0.0	-0.6	-1
2016	0.0	-0.1	0.0	0.0	0.0	NA	0.0	0.0	-1.6	-4

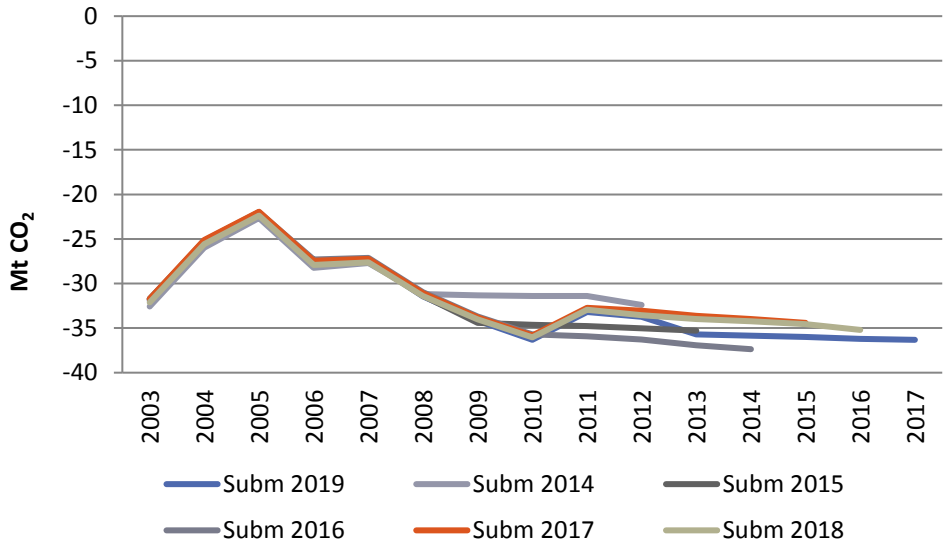

Figure 6.9. Reported living biomass on Forest land remaining forest land (4A1) according to different submissions. The values (the five latest reported years) are continuously recalculated.

6.4.6 Planned improvements

There are no planned improvements for the next submission, but new research and successive development of methods may result in improvements the coming years.

7 Waste (CRF sector 5)

7.1 Overview of sector

In this sector, the most important emissions of greenhouse gases are those of methane (CH_4) from Solid waste disposal, CRF 5.A. Other sources of greenhouse gases are Biological treatment of solid waste, CRF 5.B and Wastewater treatment and discharge, CRF 5.D, from where emissions of methane and nitrous oxide (N_2O) are reported. In addition, emissions of carbon dioxide (CO_2), methane CH_4), nitrous oxide, nitrogen oxides (NO_X), sulphur dioxide (SO_2), non-methane volatile organic compounds (NMVOC) and carbon monoxide (CO) are reported from (hazardous) Waste incineration, CRF 5.C.

Greenhouse gas emissions in CO_2-eq. from the waste sector has decreased constantly since the early 1990s (Figure 7.1), mainly because of decreasing quantities of organic waste deposited at landfills, which has reduced emissions of methane from landfills. Also, the quantities of recovered landfill gas were increasing from 1990 until 2003. Methane emissions from landfills (CRF 5.A) are by far the most important source of emissions of greenhouse gases in this sector. Biological treatment of solid waste (CRF 5.B) is the only subsector that shows an increasing trend on greenhouse gas emissions. The activities (both composting and anaerobic digestion of solid waste) have increased since the early 1990s in order to reduce quantities of solid waste to landfills.

For nitrous oxide there has 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.

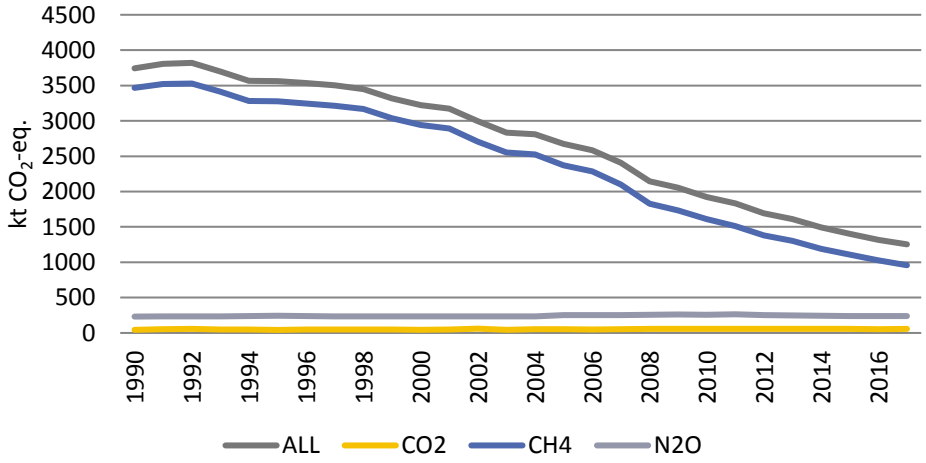

Figure 7.1. Total emissions of all greenhouse gases calculated as CO_2-eq. from CRF 5 Waste.

Figure 7.2 shows that greenhouse gas emissions from the Waste sector (CRF 5) largely come from solid waste disposal (CRF 5.A). Methane in sub-sector 5.A represents between 91.4 % and 67.1 % of the total reported greenhouse gases in the

Waste sector during the period 1990 – 2017. Emissions of greenhouse gases from waste incineration are small, 5.1 % of the emission of CRF 5 in 2017.

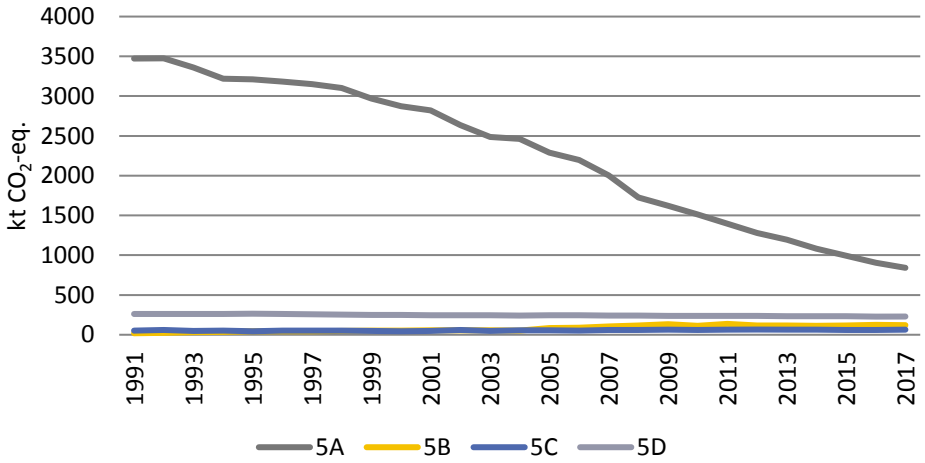

Figure 7.2. Total emissions of all greenhouse gases calculated as CO_2-eq. from the different waste sub-sectors (5A – Solid waste disposal, 5B – Biological treatment of solid waste, 5C – Incineration and open burning of waste, 5D Wastewater treatment and discharge).

7.1.1 Biogas production in Sweden

According to a survey[304] by the Swedish Energy Agency completed by Avfall Sverige & SMED on biogas production and utilization, the production of biogas in Sweden in 2017 was 2 104 GWh, which is equivalent to 151 kt of methane. The corresponding amount in 2005 was 1 285 GWh (equivalent to 92.2 kt of methane)[305]. Most of the biogas is produced within the Waste sector (CRF 5). See further below in the CRF 5.A, CRF 5.B and CRF 5.D sections.

[304] Swedish Energy Agency, 2018

[305] Swedish Energy Agency, 2007

7.2 Solid waste disposal (CRF 5.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 quarrying industry, mining waste is by far the most dominating single waste category in generation of waste and landfilling. In year 2016, 90.9 % of the landfilled waste (or 49.9 Mt of 53.9 Mt) was mining waste.

An overview of waste streams in Sweden in year 2016 is presented in Figure 7.3.

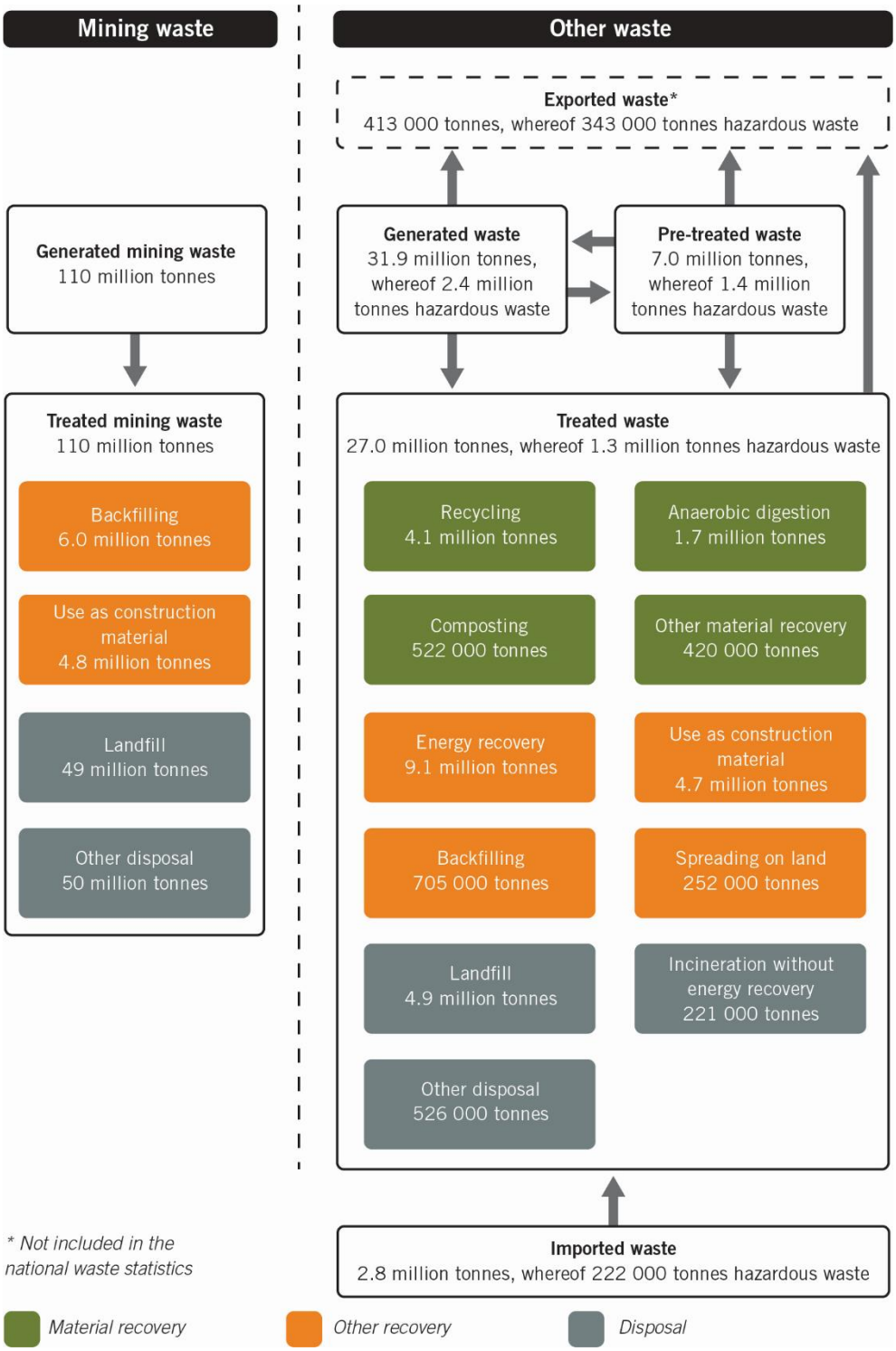

Figure 7.3. Waste streams in Sweden 2016 according to the Swedish EPA[306].

[306] Swedish EPA 2018

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 0.5 % of the generated household waste was deposited in 2017[307] which can be compared with 43.8 % in 1990. The remaining part of the generated household waste in 2017 was either incinerated (50.2 %), recycled (33.8 %) or treated biologically (15.5 %).

Today, landfilling is used for waste fractions that cannot be treated by other waste management practices like recycling, biological treatment or waste incineration. Landfilling of household waste was conducted at 36[308] sites in 2017.

7.2.1 Legislation and policies

Practises regarding landfills were regulated in 1969. Since then, the unmanaged (or illegal) landfills are very uncommon in Sweden.

Depositing has become an expensive waste management solution for disposal of waste. Since January 1st 2000, there is taxation on depositing, currently 500 SEK[309] per t 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 combustible 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.

At the end of 2008, a new EU regulation for deposition came into force and almost 50 % of landfills for municipal waste were closed, according to the trade association Avfall Sverige – Swedish Waste Management.

Sweden has some concerns about the unmanaged waste: *littering.* This occurs in particular around recycling stations. Other kinds of littering of organic waste are the disposal of smaller amounts of garden waste from households in nature or that residuals from the hunted animals are disposed in situ. When littering is discovered however, the clean-up is performed or the cost for the clean-up is paid by the responsible operator. If the responsible operator cannot be found, the relevant municipality is responsible to perform the clean-up of the site.

7.2.2 Managed waste disposal sites (CRF 5.A.1)

7.2.2.1 SOURCE CATEGORY DESCRIPTION

Sweden is reporting data on emissions of methane (CH_4) from CRF 5.A.1.a Managed waste disposal sites: Anaerobic.
For methane from CRF 5.A.1.b Managed waste disposal sites: Semi-aerobic and CRF 5.A.2 Unmanaged waste disposal sites, Sweden is reporting NO (not

[307] Avfall Sverige / Swedish Waste Management 2018

[308] Avfall Sverige / Swedish Waste Management 2018

[309] Avfall Sverige / Swedish Waste Management 2015

occurring), since there are no known semi-aerobic[310] or unmanaged waste disposal sites for organic waste or municipal solid waste in use[311] 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 7.1.

Table 7.1. Summary of source category description, CRF 5.A.1, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
	CO_2	NA	NA		NA, NO	NA, NO	NA
5.A.1	CH_4	X	X		T2	D, CS	Yes
	N_2O	NA	NA		NA	NA	NA

CS (Country Specific), D (Default), T2 (Tier 2).

7.2.2.2 METHODOLOGICAL ISSUES

7.2.2.2.1 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 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 2017.

[310] Sundqvist, 2014

[311] Nygren, 2010

Table 7.2 Methane emission from Swedish landfills according to IPCC FOD method, deposited MSW*, sludges and total (excl. mining waste), 1990-2005.

Year	Gas emissions FOD method kt CH_4	Deposited MSW* in kt	Deposited sludge from wastewater handling and pulp industry containing DOC in kt, (wet weight)	Total deposited waste (excl. mining waste)** in kt
1990	137	2 323	1 400	5 563
1991	139	2 223	1 262	5 161
1992	139	2 203	1 174	4 977
1993	134	2 199	1 086	4 824
1994	129	2 166	860	4 547
1995	128	1 974	850	4 330
1996	127	1 857	880	4 145
1997	126	1 843	975	4 203
1998	124	1 678	700	3 868
1999	119	1 756	620	3 853
2000	115	1 529	587	3 720
2001	113	1 488	514	3 488
2002	105	1 338	341	3 006
2003	99	1 034	223	2 688
2004	98	811	113	2 380
2005	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 7.2 presents emissions and waste data used for the years before 2006. The waste data are from various sources and uses national waste categories. These waste categories are different from the ones used currently in Sweden.

Table 7.3. Methane emission from Swedish landfills according to IPCC FOD method, deposited solid waste (containing Degradable Organic Carbon), sludges containing DOC and total (incl. mining waste), 2006-2017.

Year	Gas emissions FOD method kt CH_4	Deposited solid waste (containing DOC)* in kt	Deposited industrial effluent sludges and common sludge containing DOC* in kt, (dry matter)	Total deposited waste (excl. mining waste)* in kt	Total deposited mining waste* in kt
2006	88	1 249	38	2 573	61 800
2007	80	1 144	31	3 197	60 450
2008	69	1 039	24	3 820	59 100
2009	65	871	30	3 567	51 500
2010	61	648	34	3 314	43 900
2011	56	656	29	3 211	59 450
2012	51	664	23	3 108	75 000
2013	48	609	27	3 401	78 400
2014	43	555	30	3 693	81 800
2015	40	595	23	4 295	65 350
2016	36	635	15	4 897	48 900
2017	34	635	15	4 897	48 900

* Activity data and statistics for 2006, 2008, 2010, 2012, 2014 and 2016 are from Sweden's reporting to the Commission according to the Waste Statistic Regulation. Activity data and statistics for 2007, 2009, 2011, 2013, 2015 and 2017 are interpolated/extrapolated values.

Table 7.3 is presenting emissions and waste data used from 2006. The waste data are from Sweden's reporting to the Commission according to the Waste Statistic Regulation and uses waste categories as defined in the regulation.

Landfill gas extraction

Methane recovery is of great importance for the final emissions of methane in Sweden. 2006 Guidelines recommends that methane recovery should only be reported when references documenting the amount of methane recovery are available, which is the case in Sweden. In Sweden, landfills started to extract landfill gas in 1983 (a single plant). The business increased until year 2003 when gas was recovered in 72 plants. Information on recovered gas (in energy units) is provided by Avfall Sverige and converted to quantity (t) by Statistics Sweden (see Table 7.4).

In year 2017, landfill gas was extracted at 71 landfills[312] whereof 40 were active landfills. 8.6 % of the produced biogas in Sweden was produced at landfills. The biogas production (collected gas) on landfills decreased from 457 GWh to 181 GWh between 2005 and 2017, since the amounts of deposited organic waste has decreased significantly the past years, due to the implementation of waste treatment policies. About 29 % of the biogas produced[313] (collected gas) at landfills was flared in 2017 (see Table 7.5).

[312] Avfall Sverige / Swedish Waste Management & SMED 2018

[313] Avfall Sverige / Swedish Waste Management & SMED 2018

Biogas from landfills is mainly used for heating but also for production of electricity. In year 2017, about 1.4 GWh was used as vehicle fuel, which is an increasement from year 2015 by 1.2 GWh.

Table 7.4. Recovered and flared methane from landfill gas, t.

Year	Recovered and flared gas	Year	Recovered and flared gas
1982	0 [1]	2003	36 449 [5]
1983	NE [2]	2004	30 135[5]
1990	12 000 [3]	2005	29 418[5]
1991	12 210 [3]	2006	24 567[6]
1992	14 430 [3]	2007	24 553[6]
1993	20 800 [4]	2008	28 381[6]
1994	27 500 [4]	2009	24 784[6]
1995	30 000 [4]	2010	22 048[6]
1996	30 000 [5]	2011	20 468[6]
1997	30 000 [5]	2012	19 457[6]
1998	30 000 [5]	2013	17 387[6]
1999	33 000 [5]	2014	16 865[7]
2000	34 000 [5]	2015	15 895[7]
2001	32 400 [5]	2016	14 913[7]
2002	35 947 [5]	2017	12 977[7]

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), 2007-2014, 7) Avfall Sverige (Swedish Waste Management) & SMED, 2015-2018.

Table 7.5 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. Emissions from flaring and the utilization of the landfill is reported in CRF 1.

Table 7.5. Energy recovery and flaring at landfills in Sweden, MWh[314].

Year	2005	2010[1]	2015[1]	2016[1]	2017[1]
Energy recovery	340 000	267 994	157 681	160 085	128 761
Whereof prod. of electricity	20 000	20 450	17 017	9 570	17 856
Flaring	70 000	39 293	63 858	47 758	52 104
Total	**410 000**	**307 287**	**221 946**	**221 946**	**180 865**

1) Avfall Sverige (Swedish Waste Management) & SMED, 2015-2018

[314] Avfall Sverige (Swedish Waste Management)

Other parameters

The Methane Correction Factor (MCF) for modern Swedish landfills is equal to one (1.0) (Table 7.6). Waste management was centralised during the 1970s. Before 1980, landfills were smaller and presumably less compact. Information that helps establish the MCF (cover material, mechanical compacting and levelling of waste) is missing. For calculations before 1980 the 2006 Guidelines default value for uncategorized SWDS was used. This value is the same as the former IPCC default value.

The IPCC default value 50 % is used for the methane content in landfill gas (F) (Table 7.6). 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.[315] 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 7.6 Other used parameters in the methane emission calculations.

Parameter	Value	Motivation
MCF - 1979	0.6	IPCC Uncategorized SWDS
MCF 1980 -	1	IPCC Managed - anaerobic(*)
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.[316] An assumption is therefore made that before 1976, 37 % of all deposited household waste was burned.

7.2.2.2.2 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.

[315] Börjesson, 2000

[316] 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 and later by Swedish Forest Industries Federation. 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).

7.2.2.2.3 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") establishes rules and content for the reporting of waste statistics to the EU. 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 for the year 2004.

The treatment of waste is to be reported by treatment method categories. The method of treatment relates to various recovery and disposal operations ("R and D codes") are compiled into 6 different groups. Group 4, "Disposal operations: Land filling, deep injection, surface impoundment, permanent storage and others", is relevant for "Solid waste disposal, CRF 5A".

The Swedish EPA is responsible for the reporting in accordance with the regulation. So far, waste data has been reported for the reference years 2004, 2006, 2008, 2010, 2012, 2014 and 2016. No waste statistics on landfilling are compiled for the intermediate years by the Swedish EPA.

In 2010, a study[317] was carried out in order to analyse possibilities to use the reported waste data to WStatR for the calculations of CH_4 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 descriptions 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).

[317] Edborg, Stenmarck, Sundquist & Szudy, 2010

Relevant waste categories (those who are containing Degradable Organic Carbon) were chosen, and the DOC content of the chosen waste categories was investigated by analysing the statistical source material in cooperation with waste experts. Interpolations and extrapolations have been made for the intermediate years.

Estimation of DOC content
Official waste statistics in Sweden that is reported in accordance with WStatR to Eurostat, uses the Waste Statistical Nomenclature (EWC Stat) as nomenclature for the statistical waste categories. This is the case for all member states in the European Union. The EWC Stat codes are statistical aggregates of various sub codes called LoW codes (List of Waste codes). In the European Union, The List of Waste nomenclature contains more than 800 unique codes

In Sweden, the official waste statistics are produced by collecting microdata by using "LoW"codes. Since "LoW" is very detailed, it is also possible to estimate the DOC content (fraction of DOC) very accurate on the EWC Stat-level.

The national statistical waste database, which is used for storage of microdata and production of official waste statistics, has been the source of information when estimating the DOC-values for the EWC Stat-codes. The reference year 2008 was chosen for the microdata, since it was (at the time of the analysis) regarded as the most complete and suitable set of microdata regarding the degree of use of LoW in the national statistical waste database.

EWC Stat codes with conceivable DOC content were chosen and the related microdata was extracted from the database. For each EWC Stat code, information on the identification of landfills, LoW codes and quantities of waste were gathered. The DOC content for each LoW code was judged by waste experts based on its definition and, in some cases, by studying the environmental reports from where the information of the microdata originated. When the DOC content for each LoW code was set for all LoW codes within each EWC Stat code, the DOC content for the EWC Stat code was estimated by weighting the DOC content of the LoW codes. This was done by using the information on the waste quantity for each LoW code. The quantification of uncertainty associated with the DOC values is made by waste expert judgements (see further in section "Uncertainties and time –series consistency").

The procedure of estimation of DOC content has so far been repeated twice since the reference year 2008. The first time was for the statistical reference year 2010 due to changes made by Eurostat of the definition of some of the EWC-stat codes. An investigation on the DOC-contents for these EWC-Stat codes was necessary. The second time was for the statistical reference year 2016 to update the estimations of the DOC-content.

7.2.2.2.4 WASTE CATEGORIES, 1980-2005

Household waste, sludge and garden waste
Table 7.7 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 7.7. Deposited household waste, garden waste and sludge (kt) and DOC content (fraction).

	Household waste (and similar)		Garden waste		Sludge from wastewater treatment, wet weight	
Year	Quantity	DOC content	Quantity	DOC content	Quantity	DOC content
1980	1 450[1]	..	..	..	..	..
1985	1 040[2]	..	..	..	..	..
1986	1 020[3]	..	..	..	..	..
1988	1 080[4]	..	..	..	..	..
1990	1 400[5]	0.20[17]	70[5]	0.17[19]	900[5]	0.07[20]
1994	1 380[6]	..	80[6]	0.17[19]	610[6]	0.07[20]
1995	1 200[7]	0.19[17]	60[7]	0.17[19]	540[7]	0.07[20]
1996	1 110[8]	..	70[8]	0.17[19]	470[8]	0.07[20]
1997	1 150[8]	0.18[18]	50[8]	0.17[19]	455[8]	0.07[20]
1998	1 020[9]	..	45[9]	0.17[19]	490[9]	0.07[20]
1999	972.5[10]	..	45[10]	0.17[19]	490[10]	0.07[20]
2000	869.5[11]	0.18[18]	53[11]	0.17[19]	345[11]	..
2001	880[12]	..	44[12]	0.17[19]	330[12]	..
2002	820[13]	..	40[13]	0.17[19]	215[13]	..
2003	575[14]	..	33[14]	0.17[19]	155[14]	..
2004	380[15]	0.16[18]	0*		102[15]	..
2005	210[16]	..	0*		58[16]	..

1) Swedish EPA, 1983. 2) Statistics Sweden, 1988; RVF. 3) RVF, 1988. 4) RVF, 1990.
5) Statistics Sweden, 1992. 6-16) RVF, 1996-2006. 17) Ohlsson, T, 1998. 18) RVF, 2005:5.
19) IPCC 1996, Reference manual. 20) Sweco Viak, 2000-08-30.

* Included in household waste from reference year 2004.
.. Interpolated/extrapolated value

The composition of household waste has been investigated in many studies over the years. Ohlsson[318] 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[319] for 1990 and 1995 are presented in Table 7.8. The composition in the years between the surveys is interpolated. It should be pointed out that this type of analysis contains an unknown variation, and the source of error may be large. Ohlsson also shows that different studies may differ greatly in methods and results.

In 2005, another overview of household waste composition was published.[320] Different fractions of household waste from southern Sweden have been analysed

[318] Ohlsson, 1998 and REFORSK, 1998

[319] Ohlsson, 1998

[320] RVF, 2005

with the same methodology in 3 different years (1997, 2000 and 2004), see further in Table 7.8.

Table 7.8. 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 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.

Methane potentials for sludges

The IPCC gives no gas potential for deposited sludge (already treated, for example, by anaerobic digestion) from wastewater treatment. The content of Degradable Organic Carbon (DOC) in sludge from wastewater treatment is approximately 7 %.[321] The gas potential of the sludge is reduced by 50 % because it is treated.[322] By using formulas for L_0given in 2006 IPCC Guidelines the gas potential can be calculated to 24 kg/t of sludge.

For wastewater sludge from the pulp industry, a national value of 45 kg methane /t of waste is used.[323]

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.[324] 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

[321] Recounted from RVF, 1996.

[322] Sweco Viak, 2000.

[323] Swedish EPA, 1993.

[324] Profu, 2004.

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;[325] the waste groups found to generate methane in landfills are presented in Table 7.9. The most important subgroup here is sludge from the pulp industry and the other subgroups are mainly from the food industry. The gas potentials stated in the report are based on literature studies and rotting experiments. The gas potentials are used in the methane calculations for 1990.

[325] Swedish EPA, 1993

Table 7.9. Organic industrial waste, early 1990s (Swedish EPA, 1993).

Waste category	Produced quantity, kt/yr	Deposited fraction, %	Deposited quantity, kt/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 slaughterhouses	45	8	3.6	0.28
Entrails	30	5	1.5	0.09
Manure from slaughterhouses	10	5	0.5	0.03
Draff	5.5	0.5	0.0275	0.03
Waste from sugar beet industry	100	0.5	0.5	0.02
Waste from potato industry	46	0.5	0.23	0.01
Returned bread	13	3	0.39	0.11
Mycelia waste	2	1	0.02	0.01
Scrows waste	5.5	100	5.5	0.8
Waste from fishing industry	-	50	0	0.5
Whey	1 000	0	0	0
Tinned foods industry	53	50	26.5	1.55
Total:				
Sludge from pulp industry	-	-	500	31.5
Other	-	-	43.6	4.5

Data on deposited sludge from the pulp industry is available from a survey carried out annually from 1994 up to year 2000 by the Swedish EPA. In 2004, data on deposited sludge from the pulp industry is taken from the Swedish Forest Industries Federation. Data for the intermediate years have been interpolated. The reports contain detailed information on waste and waste treatment for each pulp and paper producer. Intermediate values (1991-1993) have been interpolated (Table 7.10).

Table 7.10. Values of deposited wastewater sludge from the pulp industry, wet weight.

Year	Quantity kt/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[326]. In accordance with the report, the deposited waste categories are presented in Table 7.11. The gas potentials were calculated by Sweco Viak.

Table 7.11. Organic Industrial Waste 1996.

Waste category	Deposited quantity, kt/yr	Gas potential, Mm^3 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.[327] In 1998, about 6,000 t of paper and wrapping material were deposited. This quantity is added each year to the industrial waste already noted.

[326] Swedish EPA, 1996

[327] Statistics Sweden, 2000

Composition of deposited waste

Table 7.12 illustrates the estimated composition of deposited waste (excl. mining waste) 1990-2005.

Table 7.12. Composition of deposited waste (%).

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

7.2.2.2.5 Used statistics on deposited waste, 1952-2014

Used statistics 1952-2005

Table 7.13 shows the activity data 1952-2005 used in the calculations of methane emissions from solid waste disposal on land.

Table 7.13. 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, (kt)	Deposited park and garden waste, (kt)	Deposited organic industrial waste(**), (kt)	Deposited industrial waste (not industry specific), organic fraction(**), (kt)	Deposited construction and demolition waste, organic fraction(**), (kt)
1952	290	76 %	37 %	992	58	56	207	63
1954	290	76 %	37 %	1005	59	56	215	66
1956	290	76 %	37 %	1018	60	56	226	70
1958	290	76 %	37 %	1030	60	56	234	73
1960	290	76 %	37 %	1041	61	56	250	77
1962	290	76 %	37 %	1056	62	56	272	80
1964	290	76 %	37 %	1072	63	56	301	83
1966	290	76 %	37 %	1088	64	56	325	87
1968	290	76 %	37 %	1105	65	56	345	90
1970	290	76 %(*)	37 %	1122	66	56	364	94
1972	290	76 %	37 %	1129	66	56	372	97
1974	290	66 %	37 %	987	67	56	406	101
1976	290	66 %	30 %	1109	67	56	452	116
1978	290	58 %	15 %	1186	67	56	517	145
1980	-	-	0 %	1450(*)	68	56	628	177
1982	-	-	-	1300	68	56	627	182
1984	-	-	-	1100	68	56	579	161
1986	-	-	-	1020(*)	68	56	602	165
1988	-	-	-	1080(*)	69	56	624	170
1990	-	-	-	1400(*)	70(*)	56	622	175
1992	-	-	-	1390	75	58.2	554	126
1994	-	-	-	1380(*)	80(*)	60.3	564	82
1996	-	-	-	1110(*)	70(*)	62.5	536	78
1998	-	-	-	1020(*)	45(*)	62.5	477	73
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 7.14. Overview over used statistics on deposited waste and interpolated/extrapolated values: Sludge, wet weight.

Year	Deposited sludge from waste water treatment, (kt)	Deposited sludge from pulp industry, (kt)
1952	748	500
1956	768	500
1960	786	500
1964	809	500
1968	834	500
1972	852	500
1976	862	500
1980	871	500
1984	875	500
1988	890	500
1992	750	424
1996	470(*)	410(*)
2000	345(*)	242(*)
2001	330(*)	184
2002	215(*)	126.3
2003	155(*)	68
2004	102(*)	10.5(*)
2005	58(*)	0(*)
2005	58(*)	0(*)

(*) Taken from statistical sources. Other values are interpolated or extrapolated.

Used statistics 2006-2009

Table 7.15 shows waste statistics for 2006 and 2008 used in the calculations of methane emissions from solid waste disposal on land. Waste statistics for 2007 and 2009 are interpolated/extrapolated. It also shows estimated DOC content for each waste category.

Table 7.15. Overview over used statistics* 2006 and 2008 on deposited waste, kt, and estimated DOC content, %.

EWC-Stat code	Description of waste categories	2006(*)	2008(*)	DOC content
03.1	Chemical deposits and residues	C	176.946	2
03.2	Industrial effluent sludges: Dry matter	11.914	10.580	9
05.	Health care and biological wastes: Hazardous	C	0.004	8
05.	Health care and biological wastes	C	0.010	8
07.2	Paper and cardboard wastes	38.977	2.296	36
07.5	Wood wastes	C	1.840	40
07.6	Textile wastes	0.228	0.972	24
09A	Animal and vegetal wastes *(excl. 09.11 & 09.3)*	11.548	6.058	15
09.11	Animal waste of food preparation and products	0.303	0.343	15
09.3	Animal faeces, urine and manure	0.372	0.075	9
10.1	Household and similar wastes	203.821	119.986	18
10.2	Mixed and undifferentiated materials	482.743	222.442	3.1
10.3	Sorting residues	311.483	507.599	2.5
11A	Common sludges *(excl. dredging spoils)*: Dry matter	26.383	13.142	28
	Total	**1 428.879**	**1 146.601**	

* Waste statistics for 2006 and 2008 are from Sweden's reporting to the Commission in accordance to the Waste Statistic Regulation.. (C: Confidential)

Used statistics 2010-2015

Table 7.16 shows waste statistics for 2010, 2012 and 2014 used in the calculations of methane emissions from solid waste disposal. Waste statistics for 2011, 2013, 2015 are interpolated/extrapolated. The EWC-stat codes as well as the DOC content differs a bit compared to those in Table 7.15. This is due to changes in the EWC-stat codes implemented in the 2010 year data. Due to the changes in EWC-codes there was also an investigation on the DOC-contents regarding the codes changed[328].

Table 7.16. Overview over used statistics* 2010, 2012 and 2014 on deposited waste, kt, and estimated DOC content, %

EWC-Stat code	Description of waste categories	2010(*)	2012(*)	2014(*)	DOC cont.
02A	Chemical wastes	85.300	93.600	126.000	5
03.2	Industrial effluent sludges: Dry matter	1.280	7.780	19 100	12.5
03.2	Industrial effluent sludges: Dry matter Hazardous	7.000	10.400	9.590	2
05.	Health care and biological wastes: Hazardous	0	0	0	8
05.	Health care and biological wastes	0	0	0	8
07.2	Paper and cardboard wastes	0.560	0	0	36
07.5	Wood wastes	0.060	6.460	4.390	40
07.6	Textile wastes	0	0	0.580	24
09.1	Animal and mixed food waste	1.180	0.400	0.250	13
09.2	Vegetal wastes	2.300	0.240	0.070	20
09.3	Animal faeces, urine and manure	0	0	0	9
10.1	Household and similar wastes	17.000	26.800	21.900	18
10.2	Mixed and undifferentiated materials	262.000	289.000	116.000	8.5
10.3	Sorting residues	280.000	247.000	286.000	2.5
11A	Common sludges *(excl. dredging spoils)*: Dry matter	26.200	5.310	1.560	28
	Total	**682.880**	**686.990**	**585.440**	

* Waste statistics for 2010, 2012 and 2014 are from Sweden's reporting to the Commission in accordance to the Waste Statistic Regulation.

[328] Sundqvist & Szudy, 2012

Used statistics 2016-2017

Table 7.17 shows waste statistics for 2016 used in the calculations of methane emissions from solid waste disposal. Waste statistics for 2017 extrapolated. The EWC-stat codes are the same as for the period 2010-2015, but some of the DOC content differs a bit compared to those in Table 7.16. This is due to updates[329] of some of the DOC-content estimates from the statistical reference year 2016.

Table 7.17. Overview over used statistics* 2016 on deposited waste, kt, and estimated DOC content, %

EWC-Stat code	Description of waste categories	2016(*)	DOC cont.
02A	Chemical wastes	158 000	0.99
03.2	Industrial effluent sludges: Dry matter	5.600	0.17
03.2	Industrial effluent sludges: Dry matter Hazardous	7.780	0
05.	Health care and biological wastes: Hazardous	0	8
05.	Health care and biological wastes	0	8
07.2	Paper and cardboard wastes	0	36
07.5	Wood wastes	0	40
07.6	Textile wastes	0.040	15
09.1	Animal and mixed food waste	0.060	14.1
09.2	Vegetal wastes	0	20
09.3	Animal faeces, urine and manure	0	9
10.1	Household and similar wastes	26.700	3.4
10.2	Mixed and undifferentiated materials	206.000	3.1
10.3	Sorting residues	244.000	2.3
11A	Common sludges *(excl. dredging spoils)*: Dry matter	1.870	28
	Total	**650.050**	

* Waste statistics for 2016 are from Sweden's reporting to the Commission in accordance to the Waste Statistic Regulation.

7.2.2.3 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.

Since 2006, a new data source is used for all waste quantities and DOC values (see further in section Waste statistics in Sweden, 2006 and onward). The use of a new

[329] Sundqvist & Szudy, 2018

data source has led to lower uncertainties since the data on DOC now can be estimated with better precision. The uncertainty for emission year 1990 for AD is 40 % which compared with 25 % for 2017, while the uncertainty of EF remains 50 %. This means the uncertainty has decreased from the base year (1990) to the most recent year (2017), which illustrates the improvements that has been made by using the new data source.

The time series in the waste sector are calculated consistently and in line with the 2006 Guidelines. When statistics are not produced annually, interpolation and extrapolation have been necessary tools for imputation.

7.2.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

7.2.2.4.1 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.

7.2.2.4.2 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.

7.2.2.5 SOURCE-SPECIFIC RECALCULATIONS

Emissions of methane from CRF 5.A Solid waste disposal has been recalculated for the years 2010-2011 due to minor corrections of historical data, and for the years 2015-2016 due to the availability of new data on landfilled waste and new estimates on DOC content for some of the waste categories. It resulted in 0% to -0.45% lower emission for the years 2010-2016.

7.2.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan. Therefore no activities are specified in this section.

7.3 Biological treatment of solid waste (CRF 5.B)

In Sweden, biological waste treatment such as composting and anaerobic digestion of solid waste are common waste management practices.

Biological treatment of waste has a long tradition in Sweden, but the interest and importance has varied during the years. Already during the 1950's there were three more technically advanced composting plants in operation, treating unsorted household waste. However, the waste composition changed during the 50's and the composting plants were closed down due to operational problems.

The next composting period started around 1975, and during the next ten years about 14 more advanced plants were built. These were based on a technology similar to what today is called Mechanical-Biological-Treatment (MBT). These were built with governmental subsidies (50 % of the investment). It was difficult to find markets for the products from these plants (compost, RDF and metals) and the plants have difficult operational problems. One after one the plants closed down and around 1990 there were only a few plants still in operation. Of importance in this context may be that from the 1980's all waste treatment plants were equipped with weighing-machines and computerized registering systems.

In the beginning of the 1990's there were an increasing interest for composting source separated household waste, as food waste and garden waste. Several plants were put in operation, and some of the earlier MBT plants were reconstructed to manage source separated biowaste. The role of composting of source-separated biowaste become more and more important during the 1990's and several new plants were put in operation. The growth of composting also was encouraged by a landfill tax that was put in action from 2000. Composting also continued to grow in the beginning of the 2000's, encouraged by increased landfill tax and bans on landfilling of combustible waste from 2002 and on organic waste from 2005. The standards of the composting plants also was raised when the problems of emissions of methane (CH_4) and nitrous oxide (N_2O). From around 2005 all compost plants treating food waste were obliged to have a closed process, collecting and treating the off-gases from the compost. From 2005 the composting has been at a rather constant level, but with some changes between the years. Since then about 400 000 – 600 000 t have been composted annually[330].

Anaerobic digestion has an old tradition in Sweden. It became common during the 1970's and 1980's to stabilize sewage sludge from sewage treatment plants (which was connected to an expansion of the sewage treatment systems in the country. The biogas was usually used as a fuel in the district heating system. During the 1990's there was a growing interest for biogas as vehicle fuel to substitute diesel oil and petrol, for examples in buses and cars, connected to the global warming discussions, and a general campaign from the government and parliament to decrease the dependence of fossil oil.

The interest for biogas was also transferred to waste management. The first anaerobic digestion plant for *source-separated biowaste from household* were put

[330] Avfall Sverige / Swedish Waste Management 2010-2018

into operation in the fall of 1994, though co-digestion of *manure*, *waste from food production* and sometimes *sludge from municipal wastewater treatment plants* were practiced before that. The already mentioned landfill ban for organic waste and the increasing landfill tax urged on the development. There were also governmental subsidies available for projects aiming at reducing the use of fossil fuel. However, there were some operational problems connected with the first period of anaerobic digestion, but from about 2008 the problems have been solved and the amount to anaerobic digestion is increasing. In 2017[331] the amount of waste to anaerobic digestion were 1 562 210 t, and is forecasted to continue to increase some years in the future.

Of interest in this context is that both the compost and the digestate are used. The compost is mostly used as raw material for garden soil and similar. The digestate is to more than 97 %[332] used as fertilizer by farmers.

Data on composted amounts of waste are available since at least 1990, while data on amounts of waste to anaerobic digestion are available since 1995, when anaerobic digestion of source-separated biowaste from household started.

Biogas production at anaerobic digestion plants
In 2017, 46.9 % of the produced biogas in Sweden was produced at anaerobic treatment plants for solid waste. The biogas production at these plants increased by 12 237.5 % from 1990 to 2017. 6.1 % of the biogas produced at anaerobic treatment plants for solid waste was flared in 2017, and 86.7 % was upgraded into fuel for vehicles. Emissions from flaring and the utilization of the biogas is reported in CRF 1.

7.3.1 Composting (CRF 5.B.1) and anaerobic digestion at biogas facilities (CRF 5.B.2)

7.3.1.1 SOURCE CATEGORY DESCRIPTION

Sweden is reporting data on emissions of methane (CH_4) and nitrous oxide (N_2O) from CRF 5.B.1 Composting, and methane from CRF 5.B.2 Anaerobic digestion at biogas facilities. Emissions from home composting are not estimated.

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 7.18.

[331] Avfall Sverige / Swedish Waste Management 2018

[332] Avfall Sverige / Swedish Waste Management 2010

Table 7.18. Summary of source category description, CRF 5.B, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
5.B.1	CO_2	NA	NA		NA	NA	NA
	CH_4	X	X		T1	D	Yes
	N_2O	X	X		T1	D	Yes
	CO_2	NA	NA		NA	NA	NA
5.B.2	CH_4				T1, T2	D, CS	Yes
	N_2O	NA	NA		NA	NA	NA

CS (Country Specific), D (Default), T1 (Tier 1), T2 (Tier 2).

7.3.1.2 METHODOLOGICAL ISSUES

7.3.1.2.1 Methodologies used

Equations 4.1 and 4.2 in The 2006 IPCC Guidelines for National Greenhouse Gas Inventories are used when calculating methane and nitrous oxide emissions (see below).

Methane

EQUATION 4.1
CH_4 EMISSIONS FROM BIOLOGICAL TREATMENT

$$CH_4\ Emissions = \sum_i (M_i \bullet EF_i) \bullet 10^{-3} - R$$

Where:

CH_4 Emissions = total CH_4 emissions in inventory year, Gg CH_4

M_i = mass of organic waste treated by biological treatment type *i*, Gg

EF = emission factor for treatment *i*, g CH_4/kg waste treated

i = composting or anaerobic digestion

R = total amount of CH_4 recovered in inventory year, Gg CH_4

Nitrous oxide

EQUATION 4.2
N_2O EMISSIONS FROM BIOLOGICAL TREATMENT

$$N_2O\ Emissions = \sum_i (M_i \bullet EF_i) \bullet 10^{-3}$$

Where:

N_2O Emissions = total N_2O emissions in inventory year, Gg N_2O

M_i = mass of organic waste treated by biological treatment type *i*, Gg

EF = emission factor for treatment *i*, g N_2O/kg waste treated

i = composting or anaerobic digestion

7.3.1.2.2 Emission factors used

Default emission factors from Table 4.1 in 2006 Guidelines (according to the changes in 9th Corrigenda for the 2006 IPCC Guidelines, July 2015) are used in the calculations (see Table 7.19) with an exception of the country-specific emission

factors used from year 2006 when calculating methane emissions from anaerobic digestion (see Table 7.20).

Table 7.19. Default emission factors used

Type of biological treatment	IPCC Default CH_4 Emission Factors (g CH_4/kg waste treated) on a wet weight basis.	IPCC Default N_2O Emission Factors (g N_2O/kg waste treated) on a wet weight basis.
Composting	4	0.24
Anaerobic digestion at biogas facilities	0.8 (Year 1990-2005)	Assumed negligible

The emissions of nitrous oxide from CRF 5.B.2 Anaerobic digestion at biogas facilities are reported as NA (not applicable) since the 2006 Guidelines assumes that the emissions are negligible.

Table 7.20. Country-specific emission factors used; CRF 5.B.2 Anaerobic digestion at biogas facilities.

Year	CH_4 Emission Factors (g CH_4/kg waste treated) on a wet weight basis.
2006	1.6[1]
2007	1.7[2]
2008	1.9[3]
2009	1.7[4]
2010	1.0[5]
2011	1.3[6]
2012	1.1[7]
2013	1.1[8]
2014	1.1[9]
2015	1.1[10]
2016	1.1[11]
2017	1.1[12]

1-7) are calculated with data from Sammanställningar av mätningar inom Frivilligt Åtagande, 8-12) are extrapolated from 7).

The country-specific emission factors are higher than the default factor, and covers the additional emissions that come with upgrading the generated methane into fuel for vehicles. The upgrading of methane into fuel for vehicles in this sector has increased from 4.92 kt to 61.42 kt (or 1 148 %) from year 2005 to year 2017[333].

7.3.1.2.3 Statistics used as activity data

The statistics used as activity data is produced by Swedish Waste Management (Avfall Sverige former RVF). The data is judged to be of high quality.

[333] Swedish Energy Agency, 2018

Table 7.21. Composted waste and waste to anaerobic digestion.

Year	Composted waste kt (wet weight)	Waste to anaerobic digestion, kt (wet weight)
1990	70 950[1]	..
1991	..	..
1992	..	..
1993	..	..
1994	..	..
1995	246 000[2]	44 650[2]
21996	..	..
1997	235 000[3]	..
1998	..	..
1999	280 000[4]	..
2000	290 000[5]	..
2001	..	..
2002	301 525[6]	220 316[6]
2003	293 188[7]	223 463[7]
2004	273 952[8]	244 374[8]
2005	459 830[9]	258 070[9]
2006	452 390[10]	283 730[10]
2007	515 290[11]	356 090[11]
2008	568 700[12]	405 580[12]
2009	630 500[13]	535 930[13]
2010	566 210[14]	661 620[14]
2011	690 100[15]	555 050[15]
2012	558 831[16]	695 940[16]
2013	528 470[17]	945 550[17]
2014	467 920[18]	1 227 990[18]
2015	418 340[19]	1 616 110[19]
2016	476 138[20]	1 614 920[20]
2017	450 362[21]	1 562 210[21]

1) Svensk Avfallshantering 1990, 2) Naturvårdsverket: Aktionsplan Avfall, 3) Svensk Avfallshantering 1998, 4) Svensk Avfallshantering 2000, 5) Svensk Avfallshantering 2001, 6-8) Svensk Avfallshantering 2005, 9-13) Svensk Avfallshantering 2010, 14-21) Svensk Avfallshantering 2011-2018.

Waste to anaerobic digestion increased by 181 % from 2011 to 2017. Some municipalities have changed treatment method for biological waste from composting to anaerobic digestion. The number of anaerobic digestion plants increased from 16 to 35 during this period.

7.3.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The used uncertainties are presented below.

7.3.1.3.1 Methane

Composting

Emission factor "CH_4 Emission Factors (g CH_4/kg waste treated) on a wet weight basis: ± 30 % (Expert judgement).

Activity data “Fraction of MSW sent to composting facility”: ± 5 % (Expert judgement).

Anaerobic digestion at biogas facilities
Emission factor “CH_4 Emission Factors (g CH_4/kg waste treated) on a wet weight basis: ± 25 % (Expert judgement).

Activity data “Fraction of MSW sent to anaerobic digestion at biogas facilities”: ± 5 % (Expert judgement)

7.3.1.3.2 Nitrous oxide

Composting
Emission factor “N_2O Emission Factors (g N_2O/kg waste treated) on a wet weight basis:± 50 % (Expert judgement).

Activity data “Fraction of MSW sent to composting facility”: ± 5 % (Expert judgement)

The time series in the waste sector are calculated consistently and in line with the 2006 Guidelines. When statistics are not produced annually, interpolation and extrapolation have been necessary tools for imputation.

7.3.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

7.3.1.4.1 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.

7.3.1.5 SOURCE-SPECIFIC RECALCULATIONS

Recalculation of methane emissions from composting has been made for the year 2016 due to a minor correction of data on composted waste. The recalculation resulted in decreasement of methane emissions and nitrous oxide of less than 0.00 % for the year 2016.

7.3.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan. Therefore no activities are specified in this section.

7.4 Incineration and open burning of waste (CRF 5.C)

7.4.1 Waste incineration (CRF 5.C.1)

7.4.1.1 SOURCE CATEGORY DESCRIPTION

Sweden has one plant for incineration of hazardous wastes. Emissions from incineration of hazardous waste, and in later years also MSW (Municipal solid waste) and industrial waste, from this plant are reported in CRF 5.C.1. The fossil and biogenic fraction of CO_2 emissions are, according to the IPCC 2006 Guidelines, reported separately. 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 7.21.

Table 7.22. Summary of source category description, CRF 5.C, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources Estimated
		Level	Trend	Qualitative			
5.C	CO_2				T3	PS	Yes
	CH_4				T2	PS	Yes
	N_2O				T2	PS	Yes

PS Plant Specific. T2 Tier 2. T3 Tier 3.

7.4.1.2 METHODOLOGICAL ISSUES

For this source category, the methodology and time series consistency are in line with the 2006 IPCC Guidelines.

Emissions from incineration of hazardous waste, and in later years also MSW and industrial waste, from one large plant are reported in CRF 5.C. 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, NO_X and CH_4 are measured continuously in the fumes at the plant. The reported emissions CO, SO_2, NO_x and particles are adjusted in accordance to IED by the facility. NMVOC are until 2007 as reported by the facility. For 2007 - 2015 are the NMVOC emissions calculated, based on IEF for 2007 and yearly incinerated amounts of waste. For 2016 and 2017 the NMVOC emissions have been obtained directly from the facility.

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 presented in Table 7.22, emissions of CO_2 from incineration of biogenic waste are reported in CRF 5.C.1.1.b and CO_2 from incineration of non-biogenic waste are reported in CRF 5.C.1.2.b. Emissions of CH_4 and N_2O from incineration of biogenic and non-biogenic waste are reported in CRF 5.C.1.2.b.

Table 7.23. Notation keys for emissions reported in CRF 5.C.

CRF	Greenhouse gas source and sink categories	CO_2		CH_4 and N_2O	
		Notation key	Emissions included in CRF	Notation key	Emissions included in CRF
5.C.1.1.a	Biogenic municipal solid waste	IE	5.C.1.1.b	IE	5.C.1.2.b
5.C.1.1.b	Biogenic other waste (hazardous)	Emissions reported		IE	5.C.1.2.b
5.C.1.2.a	Non-biogenic municipal solid waste	IE	5.C.1.2.b	IE	5.C.1.2.b
5.C.1.2.b	Non-biogenic other waste (hazardous)	Emissions reported		Emissions reported	

As a consequence of increased capacity, the emissions from 2003 are increased compared to earlier years. Only a minor part (1 – 2 %) of the total amount of waste incinerated for energy purposes in Sweden are incinerated in the facility included in 5.C. 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, NMVOC and CO.

In submission 2013 the time series of reported biogenic and fossil CO_2 was revised. For the years 2008, 2009, 2010 and 2011 the company has, beside total emissions of CO_2, also reported CO_2 with respect to biogenic or fossil origin. The company has based their reporting of biogenic and fossil CO_2 on a detailed study performed in 2008. In this study they found that 63 % of the totally emitted CO_2 had biogenic origin. This finding is in good agreement with published results from a Swedish study showing that about one third of the carbon in solid waste is of fossil origin[334]. As the mixture of incinerated wastes has been almost the same for all years from 2003, when the new incinerator was taken into operation, the company considered this biogenic percentage of the totally emitted CO_2 to be valid also for the years 2003 to 2008. For the period before 2003 the company considers reported CO_2 emissions to be almost 100 % fossil.[335]

Before 2008 occasional measurements of CH_4 in the flue gas was performed. The company reported CH_4 emission around 1.1 t for 2008. This information, together with information of incinerated amounts of waste 1990 until 2007, has been used for estimating a time series 1990 – 2008 for emissions of CH_4 in CRF 5C. For 2008 – 2017 reported CH_4 emissions are based on continuous measurements in the flue gas. Also N_2O from waste incineration is reported for the whole time series. The estimates are based on occasional measurements of the N_2O concentrations in the flue gas together with information on yearly flue gas volumes 2003 – 2017. For 1990 until 2002 the volumes are not known and for these years the flue gas

[334] Swedish Waste Management. RAPPORT U2012:05. Determination of the fossil carbon content in combustible municipal solid waste in Sweden.

[335] Personal communication, Hanna Eriksen, Hanna.Eriksen@sakab.se, 2012-08-23

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 7.23.

Table 7.24. Activity data and emission factors used for estimations of CH_4 and N_2O emissions in CRF 5.C.

Year	Total amounts of incinerated waste	Flue gas volume	N_2O	CH_4
	kt	1000 m^3	EF, g/1000 m^3	IEF, kg/kt
1990	30	220 674*	15.00	7.73**
1995	33	240 637*	15.00	7.73**
2000	28	205 778*	15.00	7.73**
2005	126	1 099 338	15.00	7.73**
2010	115	1 007 061	15.00	7.84
2011	163	1 229 605	15.00	6.09
2012	158	1 194 418	15.00	7.81
2013	153	1 128 670	15.00	7.73
2014	153	1 201 632	15.00	5.27
2015	155	1 162 650	15.00	3.58
2016	148	1 133 767	15.00	4.78
2017	150	1 158 546	15.00	6.67

* = estimated volume
** = IEF for 2008 used for estimations 1990 - 2007

7.4.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

In 2006 IPCC Guidelines is stated that if a default value for emission factor is used the uncertainty has been estimated to be ± 100 % 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 %.

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 7.22 the implied emission factor (IEF) for CH_4 varies slightly. Reported emissions for 2008 – 2017 are based on continuous measurements and the reason for the variation may be explained by variations in the composition of the incinerated waste.

7.4.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

7.4.1.5 SOURCE-SPECIFIC RECALCULATIONS

Activity data for 2016 was updated due to new information from the company. This resulted in a decrease of the activity data with 3 % but no changes in emissions of greenhouse gases. No other source-specific recalculations were performed.

7.4.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

7.4.2 Open burning of waste (CRF 5.C.2)

7.4.2.1 SOURCE CATEGORY DESCRIPTION

In Sweden, accidental fires of landfills and storages of waste fractions occur, resulting in emissions of CO_2, CH_4 and N_2O. However, as there is no recorded statistics of the annual amount of waste consumed by these fires, emissions cannot be estimated with satisfactory certainty.

The 2006 IPCC Guidelines provide default methods for estimating activity data only for countries in which the urban population is below 80 % of total population. Otherwise one can assume that no open burning of waste occurs in the country. As the Swedish urban population is larger than 80 % no default method for estimating activity data exists.

A rough estimation suggests that collected emissions of CO_2, CH_4 and N_2O amounted to about 4 kt CO_2-eq. in 2002, based on assumptions of the fossil carbon content of the waste, default emission factors and statistics on landfill fires in 2002 collected in a report from 2003[336]. Corresponding statistics are however not available for other years and since legislative changes have resulted in large changes in the waste fraction compositions; this information cannot be assumed to be valid for later years. As the estimated emissions for 2002 are below 0.05 % of national emissions (below 31 kt CO_2-eq) they can be considered insignificant, and as the effort to collect data is disproportionate to the emission levels, the emissions are reported as "Not Estimated" in line with the UNFCCC reporting guidelines.
Small scale waste burning of garden waste also occurs in Sweden, however as only biogenic materials are burned in these fires, no fossil CO_2 emissions occur. Emissions of CO, SO_2, NO_x and NMVOC from small scale waste burning of garden are calculated with emission factors from EMEP/EEA Guidbook 2016.

[336] Bränder i avfall vid deponier och förbränningsanläggningar (2003) RVF rapport 2003:11, ISSN 1103-4092

7.5 Wastewater treatment and discharge (CRF 5.D)

In Sweden, wastewater treatment is practised both in municipal wastewater treatment plants, in private wastewater systems and in some industries. Both methane and nitrous oxide are emitted from these activities.

There are almost 500 municipal 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. These wastewater treatment plants also receive wastewater from industries without internal wastewater treatment.
There are also a number of smaller plants or private plants of varying standard.[337] In addition, there are also approximately 1.3 million people in Sweden not connected to any wastewater treatment plant. This population is connected to on-site treatment.

The industrial wastewater is treated both internally and in municipal wastewater treatment plants. The industries with internal wastewater treatment are situated both by the coast and in the inland.

The majority of the wastewater treatment facilities (municipal and industrial) in Sweden are using aerobic processes, where no methane is supposed to be generated because of the use of aeration in the wastewater treatment process. In 2017 there were only six (6) facilities using anaerobic wastewater treatment processes in Sweden, all of them are in the food industry and in the pulp and paper industry (for more information, see below on biogas production).

Biogas production at municipal and industrial wastewater treatment facilities
Considerable quantities of heat and bioenergy are recovered from sewage and wastewater.[338] Anaerobic wastewater treatment and anaerobic digestion of sludge generates methane for production of electricity, heating, vehicle fuel and for local gas distribution networks. Some of the methane is flared.

Municipal wastewater treatment facilities
In 2017, 35.8 %[339] of the produced biogas in Sweden was produced at wastewater treatment plants (anaerobic digestion of sludge). The biogas production at wastewater treatment plants (anaerobic digestion of sludge) increased by 34.7.8 % from 2005 to 2017. 11.0 % of this biogas was flared and 61.0 % was upgraded into fuel for vehicles in 2017.

Industrial wastewater treatment facilities

[337] Swedish EPA & SMED, 2003

[338] Ministry of the Environment, 2001.

[339] Swedish Energy Agency, 2018

There are no activities such as anaerobic digestion of sludge from industrial wastewater treatment in Sweden.[340] In year 2017, four facilities in the food industry and two facilities in the pulp and paper industry practiced anaerobic wastewater treatment. 5.9 % of the produced biogas in Sweden was produced in these industries. The biogas production at these industries increased by 98.4 % from 1990 to 2017. 23.2 % of the biogas produced was flared. At the moment, no methane is upgraded into fuel for vehicles within these activities.

Emissions from flaring and the utilization of the biogas is reported in CRF 1.

7.5.1 Domestic wastewater (CRF 5.D.1) and Industrial wastewater (CRF 5.D.2)

7.5.1.1 SOURCE CATEGORY DESCRIPTION

Sweden is reporting data on emissions of methane (CH_4) and nitrous oxide (N_2O) from CRF 5.D.1 Domestic wastewater and CRF 5.D.2 Industrial wastewater.

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 7.25.

Table 7.25. Summary of source category description, CRF 5.D, according to approach 1.

CRF	Gas	Key Category Assessment 2017, excluding LULUCF)			Method	EF	All sources Estimated
		Level	Trend	Qualitative			
5.D.1	CO_2	NA	NA		NA	NA	NA
	CH_4				T2	CS	Yes
	N_2O	X	X		T1	D, CS	Yes
5.D.2	CO_2	NA	NA		NA	NA	NA
	CH_4				T2	CS	Yes
	N_2O				T1	D	Yes

CS (Country Specific), D (Default), T1 (Tier 1), T2 (Tier 2).

[340] Memo "*Occurrence of treatment of sludge by anaerobic digestion in Swedish industries", Statistics Sweden, 2011* "

7.5.1.2 METHODOLOGICAL ISSUES

7.5.1.2.1 Methodologies used (CH_4)

Equations 6.1 and 6.4 in The 2006 IPCC Guidelines for National Greenhouse Gas Inventories are used when calculating methane emissions (see below).

Domestic wastewater (CRF 5.D.1)

EQUATION 6.1
TOTAL CH_4 EMISSIONS FROM DOMESTIC WASTEWATER

$$CH_4\ Emissions = \left[\sum_{i,j}\left(U_i \bullet T_{i,j} \bullet EF_j\right)\right](TOW - S) - R$$

Where:

CH_4 Emissions = CH_4 emissions in inventory year, kg CH_4/yr

TOW = total organics in wastewater in inventory year, kg BOD/yr

S = organic component removed as sludge in inventory year, kg BOD/yr

U_i = fraction of population in income group *i* in inventory year, See Table 6.5.

$T_{i,j}$ = degree of utilisation of treatment/discharge pathway or system, *j*, for each income group fraction *i* in inventory year, See Table 6.5.

i = income group: rural, urban high income and urban low income

j = each treatment/discharge pathway or system

EF_j = emission factor, kg CH_4 / kg BOD

R = amount of CH_4 recovered in inventory year, kg CH_4/yr

Industrial wastewater (CRF 5.D.2)

EQUATION 6.4
TOTAL CH_4 EMISSIONS FROM INDUSTRIAL WASTEWATER

$$CH_4\ Emissions = \sum_i \left[(TOW_i - S_i)\,EF_i - R_i\right]$$

Where:

CH_4 Emissions = CH_4 emissions in inventory year, kg CH_4/yr

TOW_i = total organically degradable material in wastewater from industry *i* in inventory year, kg COD/yr

i = industrial sector

S_i = organic component removed as sludge in inventory year, kg COD/yr

EF_i = emission factor for industry *i*, kg CH_4/kg COD for treatment/discharge pathway or system(s) used in inventory year

If more than one treatment practice is used in an industry this factor would need to be a weighted average.

R_i = amount of CH_4 recovered in inventory year, kg CH_4/yr

For methane emissions from industries with anaerobic wastewater treatment, Sweden has chosen a country-specific method to estimate the emissions. By using statistical information on generated energy, produced quantities of methane are calculated. According to wastewater treatment expertise[341], the loss of CH_4 in the energy recovery process should be within the range of 1-2 %. The upper value (2 %) of the loss is used as emission factor.

[341] Ek, 2014

7.5.1.2.2 Emission factors used (CH_4)

Domestic wastewater (CRF 5.D.1)

B_0: The maximum methane producing capacity (B_0) is set to 0.25 kg CH_4/kg BOD (equals to 0.1 kg CH_4/kg COD).
In the 2006 Guidelines, default value of B_0 = 0.6 kg CH_4/kg BOD is given. Theoretically; 1 kg BOD (or degradable COD) gives 0.35 m^3 CH_4. Based on the specific weight of CH_4, this gives 0.25 kg CH_4/ kg BOD. This is the absolute maximum theoretical value; whereas 0.6 kg CH_4/kg BOD cannot be correct. Our recommendation is that the default value in 2006 Guidelines should be modified.

MCF: The methane correction factor (MCF) for "anaerobic stabilisation" (which is the only system generating methane in the subsector) is estimated to 0.7.

EF: The emission factor (EF=B_0*MCF) is calculated to 0.175 kg CH_4/kg BOD.

Industrial wastewater (CRF 5.D.2)

B_0: The maximum methane producing capacity (B_0) is set to 0.1 kg CH_4/kg COD (equals to 0.25 kg CH_4/kg BOD).
In the 2006 Guidelines, default value of B_0 = 0.25 kg CH_4/kg COD is given. Theoretically; 1 kg BOD (or degradable COD) gives 0.35 m^3 CH_4. Based on the specific weight of CH_4 this gives 0.1 kg CH_4/ kg COD. This is the absolute maximum theoretical value; whereas 0.25 kg CH_4/kg COD cannot be correct. Our recommendation is that the default value in 2006 Guidelines should be modified.

MCF: The methane correction factor (MCF) for "anaerobic stabilisation" is estimated to 0.7.

EF: The emission factor (EF=B_0*MCF) is calculated to 0.07 kg CH_4/kg COD.

For the country-specific method, the estimate of the loss of CH_4 in the energy recovery process is[342]:
-5 % for year 1990-2000,
-descending for year 2001-2009,
-2 % from year 2010 and onwards.
Example: In 2016, 128 GWh[343] (or 9.2 kt CH_4) was recovered. By using the value 2 % as the leakage factor, the emission of CH_4 is calculated to 0.184 kt for 2016.

7.5.1.2.3 Statistics used as activity data (CH_4)

Domestic wastewater (CRF 5.D.1)

Activity data for methane emissions from domestic wastewater treatment (5D1) is basically data on population in two categories (A and B):
(A) population connected to wastewater treatment facilities >25 pe and
(B) population connected to wastewater treatment facilities <25 pe.

[342] Szudy, Ek, Linné, Olshammar, 2017

[343] Swedish Energy Agency, 2017

(A) is calculated by using the total population in Sweden minus (B). The population not connected to wastewater discharge system (B) is the estimate based on data[344] for 1995, 2000 and 2005 (1 300 000 people).

Industrial wastewater (CRF 5.D.2)
Data on COD load in the food industry (which is the only industry relevant in the calculations where Equation 6.4 in 2006 Guidelines is used) needs to be derived. A removal efficiency of COD of 90 % is assumed in the food industry (the same as at domestic WWTPs). The reported COD load in the food industry, after treatment, was 594 t year 2010[345], which gives a number of 5 940 t before treatment. The reported COD load in the food industry, is assumed the same for all years. The amount of imported food products to Sweden have increased but at the same time period, the amount of exported products has increased as well, as well as the overall food consumption.

Activity data for the country-specific method are statistical data on energy recovery from anaerobic processes. Data published by the Swedish Energy Agency are available for year 2005-2017. For 1990, 1995 and 2000 data on biogas production at wastewater treatment facilities has been compiled within a project[346] for investigating historical data on biogas production. See further in section "Biogas production at wastewater treatment facilities".

7.5.1.2.4 Methodologies used (N_2O)

Equations 6.7 in The 2006 IPCC Guidelines for National Greenhouse Gas Inventories are used when calculating nitrous oxide emissions for both centralized wastewater treatment processes and from nitrogen in effluent (see below).

EQUATION 6.7
N_2O EMISSIONS FROM WASTEWATER EFFLUENT

$$N_2O\ Emissions = N_{EFFLUENT} \bullet EF_{EFFLUENT} \bullet 44 / 28$$

Where:

N_2O emissions = N_2O emissions in inventory year, kg N_2O/yr
$N_{EFFLUENT}$ = nitrogen in the effluent discharged to aquatic environments, kg N/yr
$EF_{EFFLUENT}$ = emission factor for N_2O emissions from discharged to wastewater, kg N_2O-N/kg N
The factor 44/28 is the conversion of kg N_2O-N into kg N_2O.

7.5.1.2.5 Emission factors used (N_2O)

The 2006 Guidelines emission factor (0.005 N_2O-N/kg N) is used for:
Effluent from WWTPs > 2000 pe
Effluent from WWTPs < 2000 pe
Effluent from industrial wastewater

[344] Statistics Sweden MI 11 SM 0701, Korrigerad version

[345] Statistics Sweden MI 22 SM 1201

[346] Szudy, Ek, Linné, Olshammar, 2017

A national emission factor (0.0074 N_2O-N/kg N) is used for direct (or internal) N_2O emissions from biological nitrogen removal in WWTPs >2000 pe. The national value[347] is based on six annual environmental reports from two WWTPs > 2000 pe, where the amount of nitrogen in inlet converted to N_2O was reported.

7.5.1.2.6 Statistics used as activity data (N_2O)

National statistics on nitrogen in discharged wastewater from municipal wastewater treatment plants and industries are used as activity data.

Domestic wastewater (CRF 5.D.1)

According to Swedish environmental protection law, all municipal wastewater treatment plants designed for more than 2,000 person equivalents, including industry, must report their discharges in environmental reports delivered to their supervision agency. Data from these reports is compiled and national statistics is published every second year by the Swedish EPA.[348]. The production time for these publications varies, and sometimes the statistics is not available until two years after the reference year.

Table 7.26. Discharges of nitrogen from large municipal wastewater treatment plants (from treatment of domestic, commercial and industrial waste water).

Year	Municipal wastewater treatment plants (t)
1990	26 200
1992	25 310
1995	25 940
1998	21 376
2000	18 977
2002	18 036
2004	17 779
2006	18 347
2008	18 433
2010	17 419
2012	17 120
2014	15 743
2016	15 414

Source: MI 22 SM, Swedish EPA and SMED

The statistics on influent and discharges of nitrogen excludes municipal wastewater treatment plants designed for less than 2,000 person equivalents, and people in rural areas, who are not connected to municipal wastewater treatment. CO_2 The nitrogen load per person for the population excluded in the statistics is assumed to be the same as for persons connected to WWTPs >2000, and is estimated after subtraction of the 20 % industrial load. The fraction of industrial and commercial co-discharged protein has a default = 1.25, meaning that the per capita load after the industrial load has been subtracted is 1/1.25 = 80 %. The number of people

[347] Westling, Tjus & Ek, 2014

[348] Statistics Sweden, MI 22 SM, Swedish EPA and SMED.

connected to WWTPs < 2000 is estimated by subtracting total population in Sweden with the number of people connected to WWTPs > 2000 pe.

Industrial wastewater (CRF 5.D.2)

Data from environmental reports from industrial wastewater handling is compiled to statistics and published every second year (except statistics on the pulp- and paper industry, which is available yearly). The industrial 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. The production time for these publications varies, and sometimes the statistics is not available until two years after the reference year.

Table 7.27. Discharges of nitrogen from mining and quarrying and manufacturing industries: Pulp and paper industry (total), Oil refineries (total), Chemical industry (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), (t)

Year	Pulp and paper (tot.)	Oil ref. (tot.)	Chemical (inl.)	Chemical (coast.)	Iron and steel (inl.)	Iron and steel (coast.)	Food (inl.)	Food (coast.)	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	..	..	..	..	..
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	..	..	..	..	..	..	..	..	..	..
2010	2 590	45	205	140	769	84	96	25	0	4	321
2011	2500	..	..	..	..	..	..	..	..	..	..
2012	2560	30	178	133	700	84	86	17	0	2	310
2013	2325	..	..	..	..	..	..	..	..	..	..
2014	2470	30	179	138	490	77	101	25	0	0	610
2015	2550	..	..	..	..	..	..	..	..	..	..
2016	2 185	31	177	107	430	117	88	30	0	0	677
2017	2 289										

Source: NV 4657, NV 4434, NV 4657, NV 4924, NV 4987, NV 5114, Swedish Forest Industries Federation, MI 22 SM, Swedish EPA and SMED

7.5.1.3 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 used uncertainties are presented below.

7.5.1.3.1 Methane

Domestic wastewater

Emission factor "Maximum CH_4 producing capacity (B_0)": ± 30 % (Default)
Emission factor "Fraction treated anaerobically": ± 10 % (Default: Centralized well managed plant, digester, reactor)
Activity data "Human population": ± 5 % (Default)
Activity data "BOD per person": ± 30 % (Default)
Activity data "Correction factor for additional industrial BOD discharged into sewers": ± 20 % (Default)

Industrial wastewater

Emission factor "Maximum CH_4 producing capacity (B_0)": ± 30 % (Default)
Emission factor "Methane correction factor (MCF)": ± 20 % (Expert judgement)
Activity data "Total organic degradable material in wastewater (TOW)": ± 10 % (Expert judgement)

7.5.1.3.2 Nitrous oxide

Domestic wastewater

Emission factor "kg N_2O-N/kg N": ± 50 % (Expert judgement)
Activity data "Total nitrogen in influent and effluent" ± 10 % (Expert judgement)

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.
2006 Guidelines states that "Large uncertainties are associated with the IPCC default emission factors for N_2O from effluent. Currently insufficient field data exist to improve this factor. Also, the N_2O emission factor for plants is uncertain, because it is based on one field test." At the moment 50 % is used for the emission factors for N_2O". It is referred as an expert judgement.

Industrial wastewater

Emission factor "kg N_2O-N/kg N": ± 50 % (Expert judgement)
Activity data "Total nitrogen in influent and effluent" ± 10 % (Expert judgement)

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.
2006 Guidelines states that "Large uncertainties are associated with the IPCC default emission factors for N_2O from effluent. Currently insufficient field data exist to improve this factor. Also, the N_2O emission factor for plants is uncertain,

because it is based on one field test." At the moment 50 % is used for the emission factors for N_2O". It is referred as an expert judgement.

The time series in the waste sector are calculated consistently and in line with the 2006 Guidelines. When statistics are not produced annually, interpolation and extrapolation have been necessary tools for imputation.

7.5.1.4 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.

7.5.1.5 SOURCE-SPECIFIC RECALCULATIONS

Emissions of nitrous oxide from CRF 5.D.1 Domestic wastewater and CRF 5.D.2 Industrial wastewater has been recalculated for years 2015 and 2016 to the availability of new data on discharges of nitrogen and population connected to municipal wastewater treatment plants. The recalculations resulted in decreasement of nitrous oxide from -1.4 % to 2.9 % for the years 2015-2016.

7.5.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

8 Other

Not applicable for Sweden.

9 Recalculations and improvements

The recalculations performed are due to comments and implemented recommendations from the national and international review teams, and national prioritizations. Some recalculations have been done to correct for small errors in earlier inventories detected during the work with the present inventory. The explanations and justifications for the recalculations made in this submission since the previous submission, together with descriptions on their implications for the emission levels, are given in more detail in the sector-specific chapters.

Below, a summary description of the most significant revisions of methods and data are described by sector.

9.1 Explanations and justifications for recalculations

9.1.1 Energy, CRF 1

9.1.1.1 STATIONARY COMBUSTION

In submission 2019, activity data and emission factors for CH_4, CO and NMVOC from biomass combustion within 1.A.4.b was separated into modern and traditional technology for the whole time series in order to capture the phasing out of old technology. The revision is described more in detail in Annex 2.

Emission factors for CO_2 for combustion of waste, peat and landfill gas were revised. An additional plant also started to report the biogenic and fossil fuels fraction which is now included in the inventory for the emission factor for waste.

NCV and CO_2 emission factor for natural gas was revised and harmonized with the Swedish energy balances.

Several NCVs for the refinery gases in 1.A.1.b were revised and reallocations of liquefied natural gas from stationary combustion to the IPPU-sector (CRF 2) were made.

Regarding 1.A.2.a and 1.A.1.c, a revision of the fraction of emissions by fuels type was made. The emissions are based on the reported emissions at total level for the largest iron and steel production plants.

Due to lack of information on the shares of emissions between CRF 1 and CRF 2 and difficulties in separating energy and process emission data, two facilities within 1.A.2.c were allocated to CRF 2 in submission 2019.

As for CRF 1.A.2.f, emission factors for N_2O, CH_4, CO, SO_2 and NOx have been revised regarding residual fuel oil, petroleum coke and coal in order to be in line with the major revision of emission factors within the industry sector that was implemented in submission 2018.

9.1.1.2 MOBILE COMBUSTION

In submission 2019, a significant revision was done regarding the volumes of natural gas and biogas consumption by road traffic for the year 2014 in particular, corresponding to updated data on the national fuel deliveries. In order for the thermal values and CO_2 emission factors for natural gas to better comply with The Swedish Energy Agency (STEM), new data were also collected from the Danish Energinet for the whole time series.

A redistribution of FAME between road traffic and working machineries in submission 2019 has led to an increased share of fossil fuel for working machinery. In summary, public transportation was allocated a larger share of biofuels within the road traffic sector and furthermore the road traffic sector as a whole increased its biofuel share in relation to working machinery. Within the road traffic sector, a larger share of biogas was also reallocated from passenger cars to buses while the share of natural gas consumption for buses consequently decreased.

The model for working machinery has been updated regarding the following aspects in submission 2019:

- revised load factors as well as fuel consumption for wheel loaders,
- increased number of road rollers for the whole time period,
- revised load factors and a revised fuel consumption for mining trucks,
- increased number of counterbalanced trucks for the whole period,
- snow groomers have been added to the model and mainly allocated to CRF 1A4a,
- revised number of snowmobiles and 4-wheelers as well as their distribution of engine types (2-stroke / 4-stroke in the model,
- updated allocation key in the model, resulting in a reallocation of the diesel consumption from CRF 1A3e (Other transportation) to 1A2g (Industry).

The revised model has affected the emissions of greenhouse gases from off road vehicles in the following CRF codes: CRF 1.A.g.vii, 1.A.3.eii, 1.A.4.aii, 1.A.4.bii and 1.A.4.cii. For more information, se each chapter above.

The fuel consumption for leisure boats has been adjusted as from 2005. This is due to a revision of the assessed fuel consumption from the leisure boat survey in 2010 and the implementation of the result from a leisure boat survey in 2015. The implictions of these adjustments is an increased gasoline consumption for 2005-2016 while the consumption of diesel has decreased for the same period.

The emissions of CO, NMVOC, NOx and SO2 from pipeline transport (CRF 1A3ei) were estimated for the first time in submission 2019. National calorific values and emission factors were used. The emission factors used are the same as for stationary combustion of natural gas in CRF 1A4a.

9.1.1.3 FUGITIVE EMISSIONS

Emissions from the natural gas transmission network (fugitives as well as venting) have been recalculated due to new methane measurement results available.

Emissions from flaring at refineries have been revised, and part of the emissions earlier reported in CRF 1.B.2 have been allocated to chemical industries (CRF 2.B) and pulp and paper industries (CRF 2.H) where they occur, in accordance with the 2006 IPCC Guidelines.

9.1.2 Industrial processes and product use, CRF 2

As a result of a cross-sectoral control procedure further described in section 1.3.5.1, CO_2 and NO_x emissions have been reallocated from CRF 1.A.2.c to CRF 2.B.10.a. This includes emissions from one large cracker plant. Due to these reallocations and other corrections, CO_2 and NO_x emissions reported in CRF 2.B.10.a increase by about 706 kt and 0.45 kt, respectively.

The model for calculating emissions of HFCs and PFCs from refrigeration and air conditioning (CRF 2.F.1) in Sweden, have been updated. This update includes:

- adding of amounts imported in products 1990-2017 (affecting reported emissions in 2.F.1.a, 2.F.1.c and 2.F.1.f)
- change of factors used for emission estimates for light duty vehicles, 1993-2016. Earlier, factors for heavy duty vehicles were used, now the same factors as for passenger cars are used. Leads to decreased yearly emissions for light and heavy duty vehicles between less than 1 kton to 17 kton CO_2 eq (for 2016).
- minor corection in emission estimates for MAC in buses 1990-1995 (< 0.001 kton CO_2 eq).
- correction of numer of built passenger cars with HFC-134a 2010-2016 and introduction of HFO-1234yf from 2012. This leads to decreased emissions of less than 1 kton CO_2 eq for 2010 and 2011 and between 2 and 18 kton CO_2 eq for 2012 and 2016, respectively.
- introduction of emission estimates for MAC in working machinery and off road vehicles 2000-2017. This leads to increased emissions of between 2 kton CO_2 eq in 2000 and up to around 12 kton CO_2 eq in later years.

In 2.H.2 new emission factors from EMEP/EEA Emission Inventory Guidebook 2016 have been implemented for all different components except spirits. This led to an update for the whole time series. Since the EF in EMEP/EEA Guidebook 2016 includes abatement of 90 % the emissions have decreased significantly. Also activity data, thus affecting reported NMVOC emissions, have been updated, due to new information for statistics available at Statistics Sweden's website, for 1996-2016. The recalculations resulted in decreased NMVOC emissions of between -4.1 to -2.2 kt.

9.1.3 Agriculture, CRF 3

Since submission 2018 the only major change in methodology is that we now include emissions from digesters and composting in the inventory. However, in terms of emissions, the effect of this was limited. Other revisions are that the time series for number of goats and reindeer have been revised. See under the paragraphs, source-specific recalculations, in the agriculture chapter for a complete list of all recalculations.

9.1.4 LULUCF, CRF 4

The major difference between the two latest submissions for the LULUCF-sector is due to an ordinary update according to the methodology used. In addition there is updates related to HWP, N-mineralisation and identification of land use change.

An observed error in the previous submission of the calculation of emissions from drained organic soils was corrected. Emissions from DOC was omitted by mistake in previoous submission for Forest land remaining forest land.

9.1.5 Waste, CRF 5

Emissions of methane from CRF 5.A Solid waste disposal has been recalculated for the years 2010-2011.

Recalculation of methane emissions from CRF 5.B.1 Composting has been made for the year 2016.
Emissions of nitrous oxide from CRF 5.D.1 Domestic wastewater and CRF 5.D.2 Industrial wastewater has been recalculated for years 2015 and 2016.

For more detailed information on recalculations: see the sections “Source-specific recalculations” in chapter “Waste (CRF sector 5)”.

9.2 Implications for emission levels

See Table 9.1 below.

Table 9.1. Recalculations of GHG emissions between submission 2018 and submission 2019 by CRF sector and total.

Year	Recalculation difference													
	Total (excl. LULUCF)		Total (incl. LULUCF)		CRF 1		CRF 2		CRF 3		CRF 4		CRF 5	
	kt CO_2-eq.	%	kt CO_2-eq.	%	kt CO_2-eq.	%	kt CO_2-eq.	%	kt CO_2-eq.	%	kt CO_2-eq.	%	kt CO_2-eq.	%
1990	-211	-0.3%	1 319	3.7%	-730	-1.4%	491	6.9%	28	0.4%	1 530	-4.3%	0	0.0%
1991	-212	-0.3%	1 312	3.6%	-710	-1.3%	490	7.1%	8	0.1%	1 525	-4.3%	0	0.0%
1992	-224	-0.3%	1 322	3.7%	-757	-1.4%	513	8.1%	21	0.3%	1 546	-4.4%	0	0.0%
1993	-244	-0.3%	1 171	2.8%	-726	-1.4%	474	7.2%	8	0.1%	1 415	-4.7%	0	0.0%
1994	-243	-0.3%	1 241	3.1%	-793	-1.4%	545	7.8%	5	0.1%	1 484	-4.3%	0	0.0%
1995	-260	-0.4%	1 116	2.7%	-838	-1.5%	572	7.8%	7	0.1%	1 376	-4.2%	0	0.0%
1996	-229	-0.3%	992	2.7%	-862	-1.5%	626	8.9%	7	0.1%	1 221	-3.1%	0	0.0%
1997	-226	-0.3%	1 144	3.3%	-868	-1.6%	641	9.0%	1	0.0%	1 369	-3.7%	0	0.0%
1998	-222	-0.3%	1 142	3.4%	-877	-1.6%	644	8.8%	11	0.2%	1 364	-3.5%	0	0.0%
1999	-170	-0.2%	1 234	3.7%	-618	-1.2%	439	5.9%	9	0.1%	1 404	-3.8%	0	0.0%
2000	-166	-0.2%	1 222	4.0%	-878	-1.8%	702	9.2%	9	0.1%	1 388	-3.7%	0	0.0%
2001	-133	-0.2%	1 234	4.8%	-882	-1.7%	737	9.6%	12	0.2%	1 367	-3.2%	0	0.0%
2002	-141	-0.2%	1 211	4.2%	-930	-1.8%	774	9.8%	15	0.2%	1 352	-3.3%	0	0.0%
2003	-138	-0.2%	1 311	4.0%	-883	-1.7%	731	9.6%	14	0.2%	1 450	-3.9%	0	0.0%
2004	-96	-0.1%	1 248	3.6%	-939	-1.8%	831	10.3%	12	0.2%	1 344	-3.9%	0	0.0%
2005	-135	-0.2%	1 378	4.1%	-949	-1.9%	802	10.0%	12	0.2%	1 513	-4.6%	0	0.0%
2006	-105	-0.2%	1 288	4.4%	-928	-1.9%	815	10.2%	8	0.1%	1 393	-3.7%	0	0.0%
2007	-113	-0.2%	1 108	4.3%	-916	-1.9%	799	10.1%	4	0.1%	1 221	-3.1%	0	0.0%
2008	-132	-0.2%	842	3.6%	-855	-1.9%	716	9.4%	7	0.1%	974	-2.5%	0	0.0%
2009	-143	-0.2%	934	5.2%	-823	-1.9%	675	11.9%	5	0.1%	1 077	-2.7%	0	0.0%
2010	-129	-0.2%	565	2.9%	-980	-2.0%	843	11.2%	7	0.1%	694	-1.6%	0	0.0%
2011	-117	-0.2%	34	0.1%	-944	-2.1%	819	11.6%	7	0.1%	151	-0.4%	0	0.0%
2012	-108	-0.2%	558	4.0%	-897	-2.1%	782	11.6%	7	0.1%	666	-1.5%	0	0.0%
2013	-48	-0.1%	-1 340	-7.8%	-903	-2.2%	840	12.6%	15	0.2%	-1 292	3.4%	0	0.0%
2014	-35	-0.1%	-888	-6.5%	-853	-2.2%	820	12.5%	-1	0.0%	-853	2.1%	0	0.0%
2015	-294	-0.5%	-884	-9.9%	-1 092	-2.8%	803	12.3%	-4	-0.1%	-590	1.3%	-2	-0.1%
2016	50	0.1%	-1 518	-15.3%	-890	-2.4%	959	13.9%	-9	-0.1%	-1 568	3.7%	-10	-0.8%

9.3 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.

Comparded to the assigned amount, the emission estimate for the base year in submission 2019 is about 627 kt CO_2-eq. lower. Data on assigned amount will eventually be updated after the review of EU:s initial report.

Table 9.2. Difference between initially calculated Base year emissions and Base Year emissions submission 2019 by GHG, excluding LULUCF.

GHG	Base Year* emissions Submission 2015 (kt CO_2 eq.)	Base Year* emissions Submission 2019 (kt CO_2 eq.)	Difference between Base Year emissions Submission 2019 and Assigned Amount (kt CO_2 eq.)
CO_2	57 547	57 446	-101
CH_4	7 990	7 422	-568
N_2O	5 841	5 759	-82
F-gases	680**	803	123
Total	**72 057****	**71430**	**-627**

*1995 for F-gases and 1990 for other GHG emissions (excluding LULUCF), ** as corrected by the ERT during the review of the Initial report for the second commitment period.

In Table 9.3 it can be seen that in submission 2018 the trend from the base year to 2016 shows a 26% decrease. It can also be seen that the recalculation of the GHG emissions in submission 2019 did not change the size of this trend.

Table 9.3. Impact on emission trends (base year to 2016) due to recalculations of GHG emissions between submission 2018 and submission 2019 by GHG, excluding LULUCF.

Trend Base Year* to 2016				
GHG	**Submission 2018**		**Submission 2019**	
	kt CO_2 eq.	**%**	**kt CO_2 eq.**	**%**
CO_2	-14 938,3	-25%	-14 863	-26%
CH_4	-2 856,0	-39%	-2 868	-39%
N_2O	-1 124,5	-20%	-1 190	-21%
F-gases	175.6	22%	434,4	54%
Total	**-18 919**	**-26%**	**-18 487**	**-26%**

*1995 for F-gases and 1990 for other GHG emissions (excluding LULUCF)

9.4 Recalculations and other changes made in response to the UNFCCC review process

In Table 9.4 the two latest UNFCCC review report recommendations (review of submission 2016 and 2017 respectively) are presented together with the status of implementation in Sweden and references to sections in this NIR. There was no UNFCCC review in 2018 of submission 2018.

Information on responses and implementation of UNFCCC review report recommendations included in the previous Swedish submissions are available in previous Swedish NIR's.
http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8812.php

Table 9.4 Status of implementation of each recommendation listed in the most recently published individual UNFCCC review report, including reasons for not implementing such a recommendation, and reference to relevant section of this NIR.

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/ section in the NIR
G.5 General - CRF tables	In the 2017 annual submission the Party reported emissions and/or AD as confidential for a large number of categories in the energy sector (1.A.1.a, 1.A.1.b, 1.A.2.a, 1.A.2.b, 1.A.2.c, 1.A.2.d, 1.A.2.e and 1.A.2.f) and in the IPPU sector (2.B.5.b, 2.B.10, 2.C.1.c, 2.C.1.e, 2.C.7.c and 2.H.1). The ERT recommends that Sweden make efforts to progress the collection of consent from plant operators and to strive to report transparent data in future annual submissions while maintaining data confidentiality.	FCCC/ARR /2017/SWE	Sweden has made efforts to collect consent from plant operators during 2018, which have led to decreased confidentiality in our data. Efforts to reduce confidentiality will continue in 2019 and onwards.	
G.4 General - NIR	The ERT noted that NIR table 9.5, “Provisional main findings reported by the ERT during the 2016 technical review of the annual submission of Sweden”, reported some issues as “not considered” although the issues have been resolved in the NIR. Examples of these are ID#s G.1, E.1 and L.5 in table 3 above. The ERT recommends that Sweden update table 9.5 of the NIR annually in order to reflect the actual status of the implementation of previous recommendations in the latest annual submission.	FCCC/ARR /2017/SWE	This table is no longer relevant and has been removed in submission 2019.	

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/ section in the NIR
E.9 1.A. Fuel combustion – sectoral approach – solid, liquid and gaseous fuels – CO2, CH4 and N2O	The Party reported that, because plant-specific data were adopted for the emission estimates for categories 1.A.1.a, 1.A.1.b, 1.A.2.a, 1.A.2.b, 1.A.2.c, 1.A.2.d, 1.A.2.e and 1.A.2.f, AD and CO2, CH4 and N2O emissions for these categories were reported as confidential (NIR, pp.130, 134, 136, 138, 141, 144, 146, 148, 149 and 151; CRF tables 1A(a)s1 and 1A(a)s2). During the review, the Party made available to the ERT, confidentially, a printout of CRF tables 1A(a)s1 and 1A(a)s2 containing data, including the confidential data, for all subcategories for the most recent three years. The ERT noted the progress achieved by the Party and that more energy data have become available from the Swedish Energy Agency – including energy balance sheets, "Energy in Sweden facts and figures" (a yearly collection of energy statistics published on the Swedish Energy Agency website), and monthly and quarterly energy surveys. The ERT recommends that Sweden enhance the transparency of reporting by exploring ways to minimize the number of categories reported as confidential while protecting the confidentiality of company data, for example by: (1) using weighted average EFs for one industry instead of directly citing each facility's data; (2) collecting consent from plant operators and reporting emissions in the CRF tables and NIR not as confidential information; or (3) for categories where AD and emissions are reported as confidential, maintaining AD as confidential but reporting emissions. The ERT also recommends that Sweden improve the transparency of the submission by providing clarification in the NIR on the key AD sources (the EU ETS, the national annual energy balance and other operator data provided to the inventory agency or obtained from annual environmental reports) and their use to derive estimates for the GHG inventory, for example, by using a schematic diagram to illustrate how the data are combined.	FCCC/ARR /2017/SWE	Sweden has made efforts to collect consent from plant operators during 2018, which have led to decreased confidentiality in our data. Efforts to reduce confidentiality will continue in 2019 and onwards. As from submission 2019, new tables (A2.1 and A.2.2) have been included to illustrate how the different data sources are combined in the GHG inventory.	Annex 2

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/ section in the NIR
E.10 1.A.2.a Iron and steel – solid fuels– CO2	The IEFs for CO2 emissions from solid fuels for iron and steel production have fluctuated considerably since 2006 (e.g. 214.5/170.2 t/TJ for 2005/2006, 221.3/165.6 t/TJ for 2008/2009), while for the years earlier than 2006 they were relatively stable at about 215 t/TJ. The ERT recommends that Sweden explore in more detail the causes of the trend of IEFs for CO2 emissions from this category and update the explanation in the NIR for the next submission.	FCCC/ARR /2017/SWE	The reason for the interannual variability of the IEF for coke oven gas and blast furnace gas are the amounts that vary in time. Between 1990 and 2002 this variability is not seen since the shares of coke oven gas and blast furnace gas were constant due to aggregated activity data. The share of the gases was constant within the same oven. Since 2003 the proportion of gases are enabled due to disaggregated activity data. The reason for the indroduced variability of data from 2003 is due to that the facility started to measure emissions at a finer level than before.	1.A.2.a

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/ section in the NIR
I.11 2. General (IPPU) – CO2, CH4 and N2O	The ERT noted that the reporting in the NIR and the CRF tables across several IPPU categories was not fully consistent and in some cases undermined the transparency of the submission for key and non-key categories. Specifically, the ERT noted that: (a) The AD and IEF for CO2 emissions from 2.D.2 (paraffin wax use) were missing from the CRF tables for all years (the cells were blank). (b) The AD for 2.B.5.b (calcium carbide production) were reported using the notation key “C” (confidential) in 2015, but in response to questions during the review, the Party explained that this was an error. (c) The NIR (section 4.3.2.1) states that data for 2.B.2 (nitric acid production) in 2015 could not be reported owing to confidentiality issues; therefore, the data were omitted from NIR table 4.9 but the emissions, AD and IEF were provided in CRF table 2(I).A-Hs1. (d) When comparing the AD, IEF and emissions for 2.A.2 (lime production) in the NIR (table 4.5) (for conventional lime plants) with the data in CRF table 2(I).A-Hs1 (for all of category 2.A.2, including lime production for the sugar industry and the paper and pulp industry), the IEF for the non-conventional lime production source categories was an implausibly high outlier in 2015 (1.82 t/t compared The ERT recommends that Sweden correct the errors in the NIR and the CRF tables, specifically: provide the AD and the CO2 IEFs across the time series for 2.D.2 (paraffin wax use); remove the comment on confidentiality in the NIR and present time-series data in the NIR tables for 2.B.2 (nitric acid production); and correct the AD in the CRF table for 2015 for 2.A.2 (lime production). The ERT also recommends, in order to improve comparability, that the Party: report emissions from calcium carbide production in 2.B.5.b; present the AD, CO2 and CH4 IEFs transparently; and report the emissions from the use of acetylene in accordance with the 2006 IPCC Guidelines.	FCCC/ARR /2017/SWE	AD and IEF for 2.D.2 have been included in the CRF tables, the NIR text for 2.B.2 has been corrected and the AD for 2.A.2 has been corrected in the CRF tables. Activity data for 2.B.5.b has presented in more detail in NIR.	See CRF Table2(I).A-Hs2, NIR section 4.3.2, CRF Table2(I).A-Hs1 and NIR section 4.3.5.

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/ section in the NIR
I.12 NIR – NF3	The amount of NF3 emissions is reported as “NA” in the NIR (table ES.1) and CRF tables 10s5 and 10s6. During the review, Sweden explained that NF3 emissions are not occurring and that the notation key for NF3 will be corrected to “NO” in the NIR of the next submission. The ERT recommends that Sweden use the notation key “NO” for NF3 both in the NIR (table ES.1) and in the CRF tables.	FCCC/ARR /2017/SWE	Notation key for NF3 has been corrected in Table ES.1 in the NIR. Despite efforts, Sweden was unable to include the correct notation key in the CRF tables, due to technical reasons.	See NIR Table ES.1
I.13 2.A.2 Lime production – CO2	The NIR (section 4.2.2.4) presents a comparison of AD for lime production from Statistics Sweden and the Swedish Lime Association and Swedish Lime Industry. The ERT noted that emission estimates from lime production are based directly on operator-reported emissions from the EU ETS for recent years, with the reported AD back-calculated using IPCC default EFs and impurity values (as described in section 4.2.2.2.1 of the NIR). The ERT recommends that Sweden improve the transparency of the submission by describing more clearly in the NIR the category-specific QA/QC and verification undertaken; for example, by presenting a summary of the findings of the 2015 study, while maintaining data confidentiality, and noting the results of consultation with data providers to explain observed differences in AD and emission data among the various data sources.	FCCC/ARR /2017/SWE	Comparisons between reported data from EU-ETS and national statistics (from Statistics Sweden and from the Swedish Lime Assocication) have been performed and the results are presented in NIR.	NIR section 4.2.2.4

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/ section in the NIR
I.14 2.A.4 Other process uses of carbonates – CO2	The NIR describes many sources of data and calculations for a range of industries that use limestone and dolomite (usually based on annual environmental reports by operators), and AD and emissions are reported across the IPPU sector, in accordance with the 2006 IPCC Guidelines. However, the ERT noted that, although a lot of data is collected from individual industries, the risk of gaps in the overall data remains, and this is a key concern for the quality and completeness of the IPPU estimates. The ERT noted that the Party does not report on any overall quality checks on annual consumption of limestone and dolomite (i.e. to compare the sum of the reported limestone and dolomite by individual industries with the national balance of limestone and dolomite from production, import and export statistics, and with data on consumption of limestone and dolomite from industries within Sweden). The ERT also noted that, according to the 2006 IPCC Guidelines, this category should include emissive uses of carbonates in addition to limestone and dolomite (volume 3, section 2.5.1.2 refers to table 2.1, which includes several carbonates). The ERT recommends that Sweden access the available data (i.e. the EU ETS data set that is currently used for the national inventory) and top-down data from national statistical agencies on production, imports, exports and known consumption of carbonates in order to assess any potential underreporting of emissions owing to incomplete coverage of emissive uses of carbonates, and report in the NIR on the comparison between: (1) the AD of limestone and dolomite reported in the inventory across all categories; and (2) the AD of total emissive uses of carbonates, which is derived from imports plus production minus exports and known uses.	FCCC/ARR /2017/SWE	Data from Statistics Sweden on import and export of carbonates has been compared to production data provided by the Geological Survey of Sweden (SGU) and known use included in the national inventory. When calculating carbonate use based on clinker production ib CRF 2.A.1 the comparison shows a good coverage of carbonate use included in the inventory. The margin of error is however bigger than the amount reported in CRF 2.A.4. which makes this comparison difficult and less reliable.	4.2.4.4

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/ section in the NIR
I.15 2.B.10 Other (chemical industry) – CO2	The NIR (section 4.3.10) states that emissions from chemical and petrochemical production are all reported under 2.B.10 owing to difficulties in separating these emissions. However, the NIR (section 4.3.10.2) also states that for “some chemical industries” the CO2 emissions are reported in the energy sector and the CO2 emissions are derived directly from environmental reports from individual companies, using a tier 3 method. The ERT noted that there was a recalculation in the 2017 submission owing to the addition of emissions from two companies, of a total of about 70 installations reported under 2.B.10, leading to recalculations ranging from 16 to 30 per cent across the time series. The ERT recommends that Sweden improve the comparability of the submission by reporting the chemical category emissions in line with the 2006 IPCC Guidelines, including reporting emissions from ethylene production in the IPPU sector, and reporting on progress and any recalculations in the next submission. The ERT also recommends that the Party improve transparency by describing more clearly in the NIR: (a) The methodology, including the information provided to the ERT during the review, to clarify the allocation of emissions from the production of secondary fuels obtained from feedstocks and also from the combustion of process off-gases and residues where they are transferred to other source categories (including in the energy sector); (b) Data reconciliation checks for chemicals, for example by presenting information on: (i) A comparison of emissions reported in the national inventory across 2.B and 1.A with operator data from the EU ETS or environmental reports; (ii) A comparison of AD from the chemical installations with the national energy balance for primary and secondary fuels, so as to provide detailed data for ERTs to assess the accuracy and completeness of the inventory while protecting commercially confidential data.	FCCC/ARR /2017/SWE	Description of a new strategy for emission allocation between CRF 1 and 2 for the chemical industry developed in submission 2019 and the QC procedure including the cross-sectoral control tool has been added in the NIR.	1.3.5; 4.3.10.4

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/ section in the NIR
I.16 2.C.1 Iron and steel production – CO2	The NIR (section 3.2.9.2.1) states that detailed carbon mass balances and energy balances for integrated steelworks were provided in annex 3.4, but this information was not included in that annex of the NIR. Furthermore, the NIR does not provide information on the allocation of emissions from process gas (from iron and steel production) use in co-located plants in other industries (e.g. power plants in 1.A.1.a), or on the reconciliation of AD of these process gases with the national energy balance. Emissions of CO2 are estimated using a tier 3 method, using operator data, but no supporting data (e.g. the coking coal CEF time series) are presented in the NIR. This lack of transparency prevented the ERT from being able to assess the completeness and accuracy of the 2015 emissions and AD for the iron and steel industry across the IPPU and energy sectors. The ERT recommends that Sweden improve transparency by reviewing and updating the descriptions in the NIR of: (a) The methodology for estimating emissions from iron and steel production; (b) Data reconciliation checks for integrated steelworks, for example by presenting information on: (i) A comparison of emissions reported in the national inventory across 1.A.1.a, 1.A.1.c, 1.A.2.a, 1.B.1.c and 2.C.1.b with operator data from the EU ETS or environmental reports; (ii) A comparison of AD from the integrated steelworks with the national energy balance for primary and secondary fuels, so as to provide sufficient detail for ERTs to assess the accuracy and completeness of the submission while protecting commercially confidential data. The ERT also recommends that Sweden improve the transparency of the key input data that govern the emission estimates from integrated steelworks by reporting a full time series of the coking coal CEF used to generate the emission estimates, including references for the data sources across the time series. The ERT notes that if these data cannot be published in future submissions because of commercial confidentiality concerns, then these data may be provided solely to the ERT for the purpose of the review.	FCCC/ARR /2017/SWE	The methodology description in NIR was updated for Submission 2019. It is now structured as follows: A) the overview of the production processes and plant stations; B) distribution of the total CO2 emissions for national reporting (including distribution of the activity data and emissions across 1.A.1.a, 1.A.1.c, 1.A.2.a, 1.B.1.c and 2.C.1.b based on the environmental reporting and communication with facilities, description of the data sources used, and relevant abstracts from Gustafsson et al.2011); C) Verification with data reported to ETS. This structure is supposed to clarify that the reported emissions are calculated by the facilities and derived from their environmental reports per plant station/CRF-code. ETS reporting cannot be used to make emission checks across CRF-codes as it does not provide data in the same format but rather the total input and output carbon flows. However, ETS reporting and carbon mass-balances derived from facilities' ETS reports are used for emission verification. Carbon content and calorific value of the coking coal was summarized and the relevant time-series for both facilities were compiled within a development project during the fall of 2018. Due to data confidentiality, these time series cannot be displayed here but can be provided to reviewers upon request.	4.4.1.2.2

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/ section in the NIR
I.17 2.C.1 Iron and steel production – CO2	The ERT noted that the 2015 carbon and energy balance information for integrated steelworks include data on the CEFs and NCVs for coking coal and coke oven coke across the two integrated steelworks that are inconsistent; for example, data for coking coal across the two plants are identical for NCVs but have a difference of about 11 per cent for CEFs. The ERT also noted that in CRF table 1.A(c), the comparison of the reference approach and sectoral approach for solid fuels in 2015 indicates that the AD in energy terms are 30 per cent lower in the sectoral approach although CO2 emissions are 19 per cent higher. The ERT recommends that Sweden make efforts to harmonize and improve the accuracy of the data reported by the steelworks operators and the Swedish Energy Agency and report on progress in the next NIR, including that it: (a) Provide full details of AD and emissions for all source categories affected across energy and IPPU, including data on fuel NCVs and CEFs. If these data cannot be published in future submissions because of commercial confidentiality concerns, then these data may be provided solely to the ERT for the purpose of the review, so as to facilitate assessment of completeness and accuracy of the reporting; (b) Report on any recalculations to emissions and AD across the time series of sources in the energy and IPPU sectors affected by the integrated steelworks (i.e. 1.A.1.a, 1.A.1.c, 1.A.2.a, 1.B.1.c and 2.C.1.b); (c) Present a clear plan of tasks and associated time frames for completing the improvements if they are not achieved in time for the 2018 annual submission; (d) Report on the comparison between the reference approach and sectoral approach for solid fuel energy use and emissions, and outline changes in the overall comparison as a result of improvements in the harmonization of NCVs and AD for solid fuels between steelworks operators and the Swedish Energy Agency.	FCCC/ARR /2017/SWE	a) Detailed information on AD and emissions are updated in NIR for concerned source categories within both the Energy and IPPU sector. NCV and EF are compiled but not published in NIR. This information will be sent to reviewers upon request. b) Reporting on recalculations across AD, EF, NCV and emissions is done annually. Significant recalculations are also found in chapter 9 in the NIR. c) and d) Swedish inventory compliers has an ongoing project together with the Swedish Energy Agency in order to reduce the differences between RA and SA. Within this project the two integrated steelworks are included. It has been confirmed that there are differences in how the integrated steelworks report their used amounts of carbon to the various reporting instances that form the base for the Energy Balances. For submission 2020 the dialogue with the integrated steelworks will continue to investigate the reason for the discrepancies in amounts of AD reported. In addition, the discrepancies in NCV and EF will be discussed with the Swedish Energy Agency in order to reduce uncertainty in emissions due to NCV.	a) Section 3.2.9 and 4.4.1 and Annex 2 and 4. b) Recalculation sections and chapter 9. c) and d) This is further described in Annex 4, regarding the comparison of Reference Approach and Sectoral Approach for Solid Fuels.

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/ section in the NIR
I.18 2.C.7 Other (metal industry) – CO2	The Party reported limited data and methodological details for the emission estimates from one NFM smelter and one lead recycling plant in Sweden, and the ERT noted that, similar to the issues above (ID#s I.15 and I.17), the transparency of the reporting on energy use and emissions between the energy and IPPU sectors is limited in the NIR. The NIR (section 4.4.7.2) includes details of research conducted in 2015 to improve the estimation method, with improvements implemented in the 2016 submission following a review of energy and emission data at the NFM smelter using EU ETS data. During the review, the Party provided the confidential data for the 2015 emissions, and also the confidential report on the review in 2015 of data for the NFM smelter (Yaramenka and Mawdsley, 2015). The ERT commends the Party on its extensive efforts to improve the emission estimates through recent research and to develop the 'CRF1–CRF2' balance sheet, and encourages the Party to continue its research as well as provide the balance sheet to future ERTs as it will significantly improve the transparency of the sector estimates and the completeness of the reporting on the energy and IPPU sectors. The ERT recommends that Sweden further improve the reporting of category 2.C.7 (other (metal industry)) emissions to bring them in line with the 2006 IPCC Guidelines by transparently reporting energy use and emissions between the energy and IPPU sectors, and that it report on progress and any recalculations in the NIR.	FCCC/ARR /2017/SWE	Description of the QC procedure including the cross-sectoral control tool has been added in the NIR.	1.3.5; 4.4.7.4

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/ section in the NIR
I.19 2.D.3 Other (non-energy products from fuels and solvent use) – CO2	The Party updated the reporting for urea use as a catalyst in CRF table 2(I)A.Hs-2 with new estimates for 1990–1994; emissions for these years had previously been reported as “NE” (see ID# I.5 in table 3). The ERT noted, however, that the Party did not document in the NIR any of the method changes (e.g. extrapolation approach to fill the data gap), the NIR did not include any mention of the recalculations, and the NIR (table 4.33) still reports “NE” for 1990. The ERT recommends that Sweden report in the NIR the method, source data, assumptions and extrapolation back to 1990 related to urea use as a catalyst, and correct the discrepancies between the NIR and the CRF tables in order to clarify in the NIR that emissions are estimated for 1990.	FCCC/ARR /2017/SWE	Text has been added to the NIR that explains the method, source data, assumptions and the extrapolation back to 1990 related to urea use as a catalyst.	See NIR section 4.5.3.2.3.

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/ section in the NIR
I.20 2.F.1 Refrigeration and air conditioning – HFCs and PFCs	This issue follows on from ID# I.8 in table 3 above. The Party reported emissions of HFCs and PFCs from commercial refrigeration, industrial refrigeration, stationary air conditioning and heat pumps, all aggregated under 2.F.1.a (commercial refrigeration). In 2015, the weighted-average product life factor across all gases was 2.08 per cent, which is one of the lowest factors of all reporting Parties. The ERT noted that this factor was much lower than product life factors in neighbouring countries. The ERT also noted that while the weighted-average product life factor falls within the range of factors provided in the 2006 IPCC Guidelines (volume 3, chapter 7, table 7.9) for stand-alone commercial refrigeration (1–15 per cent) and stationary air conditioning and heat pumps (1–10 per cent), the product life factor is well below the range of factors presented for medium and large commercial refrigeration (10–35 per cent) and industrial refrigeration (7–25 per cent). The ERT recommends that Sweden update the product life factors in the next annual submission, either by utilizing new country-specific factors, providing supporting evidence for their use, or by applying default factors from the 2006 IPCC Guidelines, while ensuring that time-series consistency is maintained in the Swedish F-gas model. If this is not achieved before the 2018 submission, the ERT recommends that the Party report on progress of F-gas model improvement and present a clear plan of tasks and associated time frames for their completion. The ERT also recommends that Sweden include the new data on F-gases in pre-filled units imported into the country.	FCCC/ARR /2017/SWE	Work is ongoing. All updates and changes between submissions are described in NIR.	NIR section 4.7

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/ section in the NIR
I.21 2.F.1 Refrigeration and air conditioning – HFCs and PFCs	The Party reported EFs for initial charging of commercial refrigeration in the NIR (table 4.42) that were inconsistent with the rates presented in CRF table 2(II)B.Hs-2; for example, for 1995 the NIR states 5.7 per cent and the CRF table 3.5 per cent. The ERT noted that the initial charge in NIR table 4.42 is 3.5 kg, and considered that this may indicate either a typographical error in the NIR or an incorrect leakage rate applied in the Swedish refrigeration and air-conditioning model. The ERT recommends that Sweden report emissions from heat pumps separately under 2.F.1.f, including any details of recalculations from the redesign of the refrigeration and air-conditioning model. The ERT encourages Sweden to ensure that the changes in reporting are subject to rigorous QA/QC in order to ensure that leakage rates for individual subapplications are applied correctly in the model, and to ensure consistency between the NIR and the CRF tables.	FCCC/ARR /2017/SWE	Emissions from commercial and industrial refrigeration and stationary air-conditioning were in prior to Submission 2018 reported together in 2.F.1.a (commercial refrigeration). Starting with Submission 2018 these emissions are allocated to commercial refigeration (2.F.1.a), industrial refrigeration (2.F.1.c) and stationary air-conditioning (2.F.1.f). Leakage rates and lifetimes have been changed from national factors to default factors from 2006 IPCC Guidelines for 2.F.1.a, 2.F.1.c and 2.F.1.f. Calculations of emissions from heat pumps, reported in 2.F.1.f, are however calculated using national emission factors.	NIR section 4.7
A.1 3. General (agriculture) – CH4 and N2O	In the sections “source-specific recalculations” in the agriculture chapter of the NIR, the reasons for recalculations of each emission source were provided. Further, the impact of the recalculations on total emissions by source and by gas was provided in the CRF tables. However, the Party did not report in the NIR the quantitative impact of the recalculations on the trend in emissions at the category, sector and national level, in accordance with the UNFCCC Annex I inventory reporting guidelines. During the review, Sweden explained that the qualitative explanation for the recalculation was provided in the NIR (sections 5.2.5, p.314; 5.3.5, p.322; 5.4.1.1.9, p.329; and 5.4.2.5, p.334). The quantitative comparison was reported in the CRF tables.	FCCC/ARR /2017/SWE	Resolved.	See under the paragraphs, Source-specific recalculations .

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/ section in the NIR
A.2 3.A.1 Cattle – CH4	The Party reported the unit for milk delivered by dairy cattle in the NIR (p.313, table 5.6) incorrectly. The ERT noted that the unit for total milk delivered is tonne and that the figures for the whole time series are too small for national total milk production. During the review, the Party explained that the unit is not correct. It should be 1,000 t. The ERT recommends that Sweden correct the unit used for total milk delivered.	FCCC/ARR /2017/SWE	Resolved.	See table 5.6
A.3 3.B.3 Swine – CH4 and N2O	The ERT noted that in the 2017 annual submission, the Party reported the liquid waste manure management system (fraction) for “Pigs for meat production” as 0.95, and for “Other swine” as 0.58, in 2013 and 2014. However, in the 2016 submission, the liquid waste manure management system (fraction) for “Pigs for meat production” was 0.97, and for “Other swine” was 0.74, for 2013 and 2014. Solid waste manure management systems and deep litter manure management systems fractions for “Pigs for meat production” and “Other swine” were also different in the two submissions. The ERT noted that there is no explanation in the NIR for such changes between these two recent submissions. The ERT recommends that Sweden report on any recalculations that have an impact on manure management systems for swine.	FCCC/ARR /2017/SWE	Resolved. All recalculations made between the two latest submissions are now described in the NIR.	See the paragraph, 5.3.5 Source-specific recalculations .

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/ section in the NIR
A.4 3.D.b.1 Atmospheric deposition – N2O	The Party reported the emissions of ammonia from eight fertilizer types in the NIR (p.331, table 5.24); however, the source for the emission estimates of ammonia from these fertilizer types was not provided. The unit for FracGASF (kg NH3/kg N) (p.331, table 5.24) is incorrect. Also, the Party did not report emissions of ammonia from "Other NK and NPK fertilizers" in the NIR (p.331, table 5.24), while in NIR table 5.25, the amount of N in "Other NK and NPK" is about 30 per cent of total N in inorganic fertilizers (e.g. 32.9 per cent in 1990 and 32.1 per cent in 2015). The ERT noted that reporting the derived weighted average FracGASF in table 5.25 is not transparent if the emissions of ammonia from "Other NK and NPK" are not provided in table 5.24. The ERT recommends that Sweden improve the transparency of its reporting by providing in the NIR: (1) the data sources for emissions of ammonia from all fertilizers; (2) the correct units for FracGASF; and (3) the emissions of ammonia from "Other NK and NPK fertilizers".	FCCC/ARR /2017/SWE	Resolved.	See table 5.26 and 5.27.
L.6: 4.A Forest land – CO2	The Party reported in the NIR (annex 3, p.96) that for organic soils (CRF table 4.A), EFs are applied without any consideration to carbon inputs from litter, but in CRF table 4.A, carbon stock changes in litter are reported. The ERT recommends that Sweden delete the erroneous wording in the NIR (annex 3, p.96) that states carbon inputs from litter were not considered.	FCCC/ARR /2017/SWE	The text in the NIR has been improved. Also note that the litter pool in the CRF tal is not subdivided for mineral and organic soils.	

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/ section in the NIR
L.7: 4.A Forest land	The ERT recommends that Sweden: (a) Report transparently the change of forest land to wetlands and other land, and the change from wetlands and other land to forest land, as well as the accompanying gains and losses in the carbon pools when methods are provided in the 2006 IPCC Guidelines, by providing information on whether a land-use change from forest land is caused by the fact that the national requirements for forest land are no longer met or by the fact that the dominant land use is no longer forestry, and, in cases where the allocation of the land under forest land was not “temporary unstocked” but the land use really changed, considering using a subcategory for this land-use change; (b) Document and report the procedure describing when forest land changes to other land, taking into consideration that the definition of forest land use by the Party does not restrict forest land to productive forest and that the 2006 IPCC Guidelines also include, under managed land, land that performs ecological or social functions; (c) Improve transparency by reporting in the NIR how the carbon pools other than biomass are estimated in case of a land-use change from unmanaged land to managed forest land; (d) Report on the improved national system of rules for the assessment of land-use changes.	FCCC/ARR /2017/SWE	a) The “predominant land use” is included in the FAO definition of forest land and thereby in the “national requirements for forest land” (6.2.1). Forest land can temporary be unstocked 10.1.2. b) In 10.4.1, we consider all conversions from Forest land to other managed land as direct human induced. Forest land may also be naturally degraded (10.1.5). All Forest land is considered managed (broad definition 6.2.1). c) If unmanaged land is converted to Forest land its always reported (see e.g. CRF or 6.3.1.1). d) Se 6.4.1.1	

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/ section in the NIR
L.8: 4.C Grassland – CO2	The ERT recommends that the Party improve the transparency of its reporting by providing information on the choice of the country-specific CO2 EF for drained organic soil in grassland	FCCC/ARR /2017/SWE	The text has been improved.	See Annex 3:2, section 1.1.8.
L.9: 4 (II)	The ERT recommends that the Party improve transparency by reporting in the NIR: (1) that the ditches reported under category “9. Road and railroad” are ditches alongside roads and railroads only; and (2) that the EF per ha for all ditches is country-specific, because the area of ditches is estimated based on a factor for the fraction of the drained area (i.e. 2.5 per cent for forest land and 5 per cent for grassland and cropland) and this factor is applied to the country-specific EF by land use.	FCCC/ARR /2017/SWE	The text has been improved.	See table 6.3

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/ section in the NIR
L.10: 4(V) Biomass burning – CO2, CH4 and N2O	The ERT recommends that Sweden improve the transparency of its reporting by providing information on how it estimates the country-specific value (25 per cent) for the pre-fire biomass stock that is combusted during a fire.	FCCC/ARR /2017/SWE	The text has been improved.	See 6.4.2.12
W.2 5.C.1 Waste incineration – indirect gases	In CRF table 5, the Party reports indirect gases from waste incineration. The ERT noted that these gases are not mentioned in the NIR (chapter 9). During the review, the Party explained that sulfur dioxide, nitrogen oxides and carbon monoxide are continuously measured in flue gases and reported by the incineration facility in the yearly environmental reports. NMVOC emissions were as reported by the incineration facility until 2007. From 2007 and onwards the NMVOC emissions were calculated based on the IEF for 2007 and yearly incinerated amounts of waste. Documentation of emission estimates of indirect GHGs will be included in the NIR of the 2018 submission. The ERT recommends that Sweden improve the transparency of its reporting by presenting information on the emission estimates of indirect GHGs from waste incineration in the NIR.	FCCC/ARR /2017/SWE	Documentation of emission estimates of indirect GHGs have been included in the NIR.	See NIR section 7.4.1
KL.7: Article 3.3 activities	The ERT recommends that Sweden improve transparency by revising the comment to table NIR-2 to clarify that the extrapolation of areas for land use and land-use conversion is done using the trends and not using extrapolated land-use conversions for individual plots.	FCCC/ARR /2017/SWE	Sweden is now reporting the land use matrices. The "on plot basis" is removed from 6.1.1.1 and is explained in Annex 1.3.3	Annex 1.3.3

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/ section in the NIR
KL.8: Forest management	The ERT recommends that Sweden report information that supports the assumption that land-use changes from forest to wetlands or other land (if they happen) are not taking place in combination with deforestation activities.	FCCC/ARR /2017/SWE	The text has been amended in line with the recommendation.	See 10.3.1.1.3

PART 2: SUPPLEMENTARY INFORMATION REQUIRED UNDER ARTICLE 7, PARAGRAPH 1

10 KP-LULUCF

10.1 General information

Sweden provides supplementary information under Article 7 of the Kyoto Protocol (KP) for the Land Use, Land-Use Change and Forestry sector. The requested information is further specified in decision 16/CMP.1, 2/CMP.8, 6/CMP.9 and the Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (IPCC[349]).

Sweden reports and accounts for Afforestation and Reforestation (AR) and Deforestation (D) under article 3.3 and Forest management (FM) under article 3.4.

Sweden has elected commitment period accounting for LULUCF for the second commitment period.

All carbon pools are reported as well as CO_2 and non- CO_2 emissions associated to the different reported activities. Direct N_2O emissions from N fertilization and emissions from forest fires are reported only under FM. Forests reported under AR are still to young to be fertilized. Forest fires –both natural and wildfires– are uncommon and, this far, has not been registered on ARD-land. Controlled burning is assumed not to occur on ARD land. Emissions of N_2O and CH_4 form drained organic soils and CH_4 emissions from ditches are reported for drained and rewetted organic soils under relevant activities. N_2O emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions and management change in mineral soils are also reported for relevant activities (AR, D, FM) (see Tables 10.1, 10.2 and 10.3).

Table 10.1. Status of reporting under KP-LULUCF with comments.

Table		Status of reporting
NIR-1	SUMMARY TABLE	R
NIR-2	LAND TRANSITION MATRIX	R
NIR-2.1	LAND TRANSITION	NA, all forest land reported (no definition of “natural forest” or “planted forest” provided by COP/MOP or IPCC)
NIR-3	KEY CATEGORIES	R
4(KP)Recalculations	RECALCULATIONS	R
4(KP)	SUMMARY TABLE	R
4(KP-I)A.1	AR	R
4(KP-I)A.1.1.	AR, NATURAL DISTURBANCES	NA this year
4(KP-I)A.2	D	R, the voluntary subdivision is currently D(Cropland), D(Grazing land) and D(Settlements). If D-land is further

[349] Intergovernmental Panel on Climate Change, 2014

Table		Status of reporting
		converted to either Wetlands, Other land or Forest land such land is reported as D (Settlements). This far, such multi-step transitions of land are uncommon.
4(KP-I)A.2.1.	D, OTHERWISE 3.4	R, D with secondary classification AR or FM
4(KP-I)B.1	FM	R
4(KP-I)B.1.1	FM, FMRL and TECHNICAL CORRECTION	R
4(KP-I)B.1.2	FM, CEF	NA, Carbon equivalent forests not relevant for Sweden
4(KP-I)B.1.3	FM, NATURAL DISTURBANCES	NA, this year
4(KP-I)B.2	CM	NR, not elected
4(KP-I)B.3	GM	NR, not elected
4(KP-I)B.4	REVEGETATION	NR, not elected
4(KP-I)B.5	WDR	NR, not elected
4(KP-I)C	HWP	R
4(KP-II)1	N-FERTILISATION	R (FM)
4(KP-II)2	DRAINED AND REWETTED SOILS	R (FM, AR, D)
4(KP-II)3	MINERALIZATION DUE TO LAND USE CONVERSION	R (FM, AR, D)
4(KP-II)4	BIOMASS BURNING	R, [Wildfires: NO(D), NO(AR), R(FM),]; [Controlled burning: NO(D), NO(AR), R(FM)]

Table 10.2. Status of reporting carbon pools under the KP.

Activity		CHANGE IN CARBON POOL REPORTED						
		Above-ground biomass	Below-ground biomass	Litter	Dead wood	Soil		HWP
						Mineral	Organic	
Article 3.3 activities	AR	R	R	R	R	R	R	R
	D	R	R	R	R	R	R	IO
Article 3.4 activities	FM	R	R	R	R	R	R	R
	CM	NR	NR	NR	NR	NR	NR	
	GM	NR	NR	NR	NR	NR	NR	
	RV	NR	NR	NR	NR	NR	NR	
	WDR	NR	NR	NR	NR	NR	NR	

Table 10.3. Status of reporting GHG sources.

Activity		GREENHOUSE GAS SOURCES REPORTED							
		Fertilization	Drained, rewetted and other soils		Nitrogen mineralization in mineral soils	Indirect N_2O emissions from managed soil	Biomass burning		
		N_2O	CH_4	N_2O	N_2O	N_2O	CO_2	CH_4	N_2O
Article 3.3 activities	AR	NO	R	R	R	NO	NO	NO	NO
	D	NO	R	R	R	NO	NO	NO	NO
Article 3.4 activities	FM	R	R	R	R	R	IE	R	R
	CM		NR		NR		NR	NR	NR
	GM		NR		NR		NR	NR	NR
	RV	NR	NR	NR	NR	NR	NR	NR	NR
	WDR	NR	NR	NR		NR	NR	NR	NR

10.1.1 Emissions/removals from AR, D and FM

The activities Afforestation and Reforestation (AR) and Deforestation (D) are quite rare in Sweden compared to the entire forest land area, each representing additionally a little bit more than 10 kha annually in average. Due to the steadily increasing total area, AR shows an increasing trend in removals due to increased growth whereas emissions from D are more reliant on the amount of biomass harvested on the annual deforested areas. The estimated area under Forest management (FM) is 27.9 Mha and is slightly decreasing (Tables 10.4, 10.5, 10.6 and 10.7).

Table 10.4. Summary of net removals (-)/emissions (+) in aboveground living biomass (LBa), belowground living biomass (LBb), dead wood, litter, and soil organic carbon (SOC) per Article 3.3 activity.

	AR [Mton CO_2]						D [Mton CO_2]					
	LBa	LBb	Dead wood	Litter	SOC Min	SOC Org	LBa	LBb	Dead wood	Litter	SOC Min	SOC Org
2013	-0.913	-0.299	-0,021	-0,270	0,090	0,139	1.025	0.347	0,000	0,465	0,725	0,079
2014	-0.953	-0.313	-0,026	-0,266	0,082	0,139	1.075	0.359	-0,001	0,453	0,686	0,089
2015	-0.979	-0.321	-0,027	-0,275	0,081	0,150	1.160	0.407	-0,001	0,459	0,685	0,090
2016	-1.017	-0.334	-0,034	-0,285	0,082	0,151	0.445	0.156	-0,001	0,471	0,668	0,096
2017	-1.049	-0.345	-0,042	-0,289	0,078	0,147	0.155	0.055	-0,001	0,469	0,663	0,101

Table 10.5. Summary of net removals (-)/emissions (+) in aboveground living biomass (LBa), belowground living biomass (LBb) dead wood, litter, and soil organic carbon (SOC) per Article 3.4 activity.

	FM (Mton CO_2)					
	LBa	LBb	Dead wood	Litter	SOC Min	SOC Org
2013	-26.9	-8.69	-7.574	12.596	-16.169	4.512
2014	-26.9	-8.71	-7.910	13.102	-16.828	4.611
2015	-27.0	-8.73	-7.272	12.021	-16.523	4.652
2016	-27.1	-8.77	-7.391	11.896	-16.515	4.650
2017	-27.1	-8.78	-7.648	11.745	-16.510	4.648

Table 10.6. The accumulated area under activities AR, D and FM.

(kha)	AR	D	FM
1990	12.3	13.9	28127.2
1991	22.1	28.7	28112.3
1992	27.0	37.3	28103.8
1993	41.1	54.8	28086.4
1994	50.0	63.9	28077.2
1995	58.0	73.4	28067.9
1996	70.4	82.4	28059.0
1997	75.6	95.4	28046.0
1998	80.9	105.2	28039.3
1999	95.0	117.5	28027.0
2000	101.0	128.8	28016.3
2001	108.8	136.1	28010.7
2002	113.6	145.6	28001.2
2003	121.5	154.1	27994.5
2004	132.0	169.4	27980.0
2005	139.5	172.3	27979.2
2006	149.8	179.2	27984.0
2007	167.8	191.8	27983.0
2008	181.1	201.8	27979.0
2009	196.0	215.9	27974.8
2010	219.2	231.6	27960.3
2011	239.3	244.1	27952.8
2012	262.4	256.7	27940.4
2013	281.4	266.3	27931.3
2014	298.0	279.0	27918.6
2015	316.9	291.4	27906.4
2016	336.2	305.0	27893.0
2017	356.1	314.1	27883.9

Table 10.7. Emissions of non- CO_2 gases from reported activities emission [kt] for AR, D and FM for the first, second and third year of the second commitment period.

	Year	4(KP-II)1 kt N_2O	4(KP-II)2 kt CH_4	4(KP-II)2 kt N_2O	4(KP-II)3 kt N_2O	4(KP-II)4 kt N_2O	4(KP-II)4 kt CH_4
AR	2013	-	0.146	0.058	0.023	-	-
	2014		0.146	0.058	0.021	-	-
	2015		0.156	0.061	0.021		
	2016		0.167	0.066	0.021		
			0.171	0.068	0.020		
D	2013	-	0.048		0.144	-	-
	2014		0.046		0.137	-	-
	2015		0.050		0.137		
	2016		0.055		0.135		
			0.054		0.134		
FM	2013	0.065	8.151	3.066	-	0.001	0.110
	2014	0.062	8.246	3.123		0.008	1.189
	2015	0.091	8.329	3.176		0.000	0.066
	2016	0.080	8.327	3.175		0.001	0.119
	2017	0.069	8.324	3.174		0.001	0.079

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 of LULUCF (chapter 6). The estimates of emissions/ removals and areas are based on permanent sample plots inventoried by the Swedish National Forest Inventory covering all land and fresh water areas. A major difference from the UNFCCC reporting is that the living biomass pool is separated into aboveground and belowground living biomass in the reporting under the KP. Only emissions/removals on land under the activities AR, D and FM are reported under the KP.

10.1.2 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 deforested 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 carbon stock changes in living biomass may be reported under any land use category (activity).

The definition of Forest land is consistent with former reporting under the UNFCCC and to other international bodies such as the FAO. 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 normally used for most assessments and reporting of the Swedish forest situation to other bodies. In both cases the expected values of estimates are the same but estimates might vary from randomness of the sample.

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. The KP-reporting of FM and AR harmonize (areas) virtually with the UNFCCC-reporting of Forest land and land converted to Forest land. However, land that is converted from Forest land to another land use category could either be reported under D or under FM depending on the definition of D. Since Sweden consider only conversion to managed land as D, Forest land converted to Wetland or Other land (both unmanaged) are reported under FM (KP) but under Forest converted to Wetland/Other land under the UNFCCC. This explains the small difference in area between FM+AR and Forest land+land converted to Forest land (see Table 10.5b).

Under the Kyoto Protocol it is central to distinguish between definitions of land use categories, activities and spatial assessment units (Figure 10.1). The definition of Forest land includes criteria for 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 each sample plot represents a certain area in the estimation algorithm so that all sample plots together represent the total land and fresh water area of Sweden. The Swedish NFI has the advantage that the sample frame covers all land- categories required for the UNFCCC-reporting. This is essential when both gross and net land use transfers over time have to be traced.

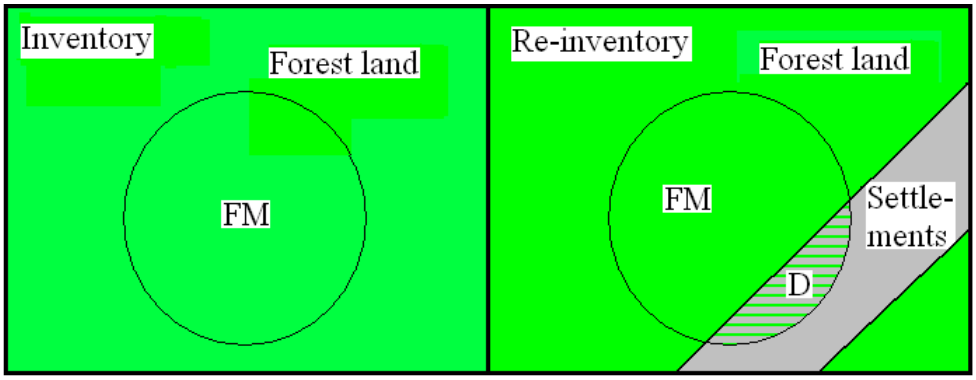

Figure 10.1. Example distinguishing the concepts of land use category, activities under the Kyoto Protocol, and spatial assessment unit in the Swedish sample based inventory. At the first inventory, only the land use category Forest land exists in an area but at the re-inventory part of the Forest land 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.

10.1.3 Elected activities under Article 3, paragraph 4, of the Kyoto Protocol

For the accounting of LULUCF-activities under article 3.4 during the second commitment period, no voluntary activity has been elected.

10.1.4 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 forest land area is regarded managed) to Cropland, Grasslands or Settlements (all land under these three categories are assumed managed). Afforestation/ Reforestation (AR) are defined as land use conversions in the opposite direction (Figure 10.2). Land use categories are strictly defined (see NIR chapter 6.2) and land use conversions are observed in field using a five-year inventory cycle. The approximately 30 000 permanent sample plots where laid out between 1983 and 1987 and have thereafter been re-inventoried in a consistent way (Figure 10.3). If the land use of a sample plot or part of a sample plot is assessed as converted between consecutive inventories the conversion is assumed to occur at a random year between the re-measurements. 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 10.1.1). Land could only be reported under one activity or none (to avoid double counting). Land use conversions are confirmed in field.

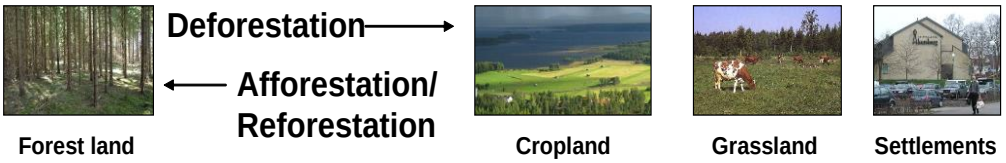

Figure 10.2. D is defined as land use conversions from Forest land (managed) to another managed land use class (all Cropland, Grasslands and Settlements are assumed managed). AR are defined as land use conversions in the opposite direction (C, G or S to F)

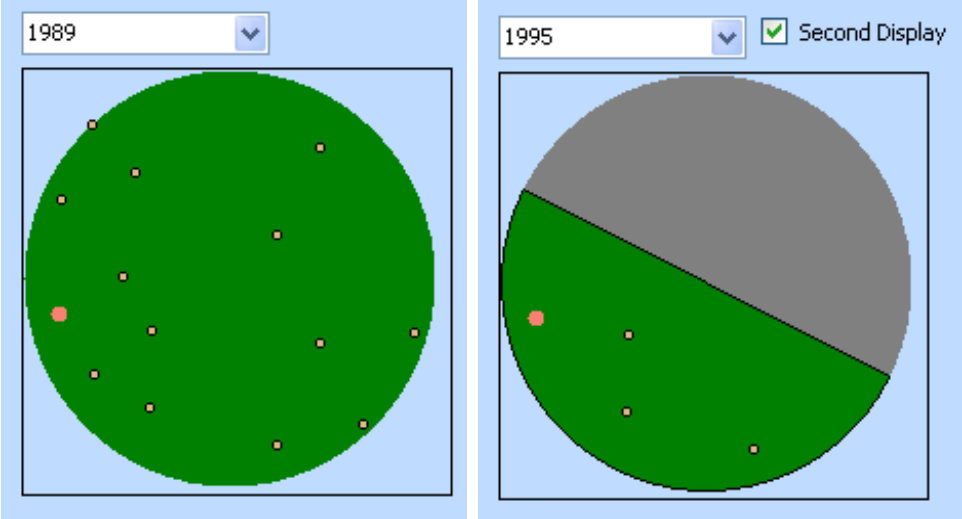

Figure 10.3. The figure shows data for a specific sample plot in the Swedish LULUCF-database. The individual tree biomass on approximately 30 000 permanent sample plots are matched to land use and traced back to before the base year in a consistent way. Applying area based sampling all 30000 permanent 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 deforested between 1991 and 1992. The positioning of trees is central when matching carbon stock changes in living biomass to activity (about 75 % of deforested 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.

10.1.5 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. From 1990, land under D cannot leave this category and may therefore have secondary classification AR, FM or none. From 1990, land under AR can only leave this category for D. Land under AR usually has secondary classification FM (if reported under Forest land remaining Forest land or conversion to Forest land under the UNFCCC) or none if converted to unmanaged land. From 1990, land areas under FM that are naturally degraded cannot leave the category and remain under FM. FM has no secondary classification. Some land use conversions are very uncommon and thus some of the above described combinations may not exist.

10.2 Land-related information

10.2.1 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 close to 0 m^2 could be detected. The same "Spatial assessment unit" has consistently been used in both the UNFCCC and the KP-reporting (Figure 10.1).

10.2.2 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.

The accumulated AR and D-areas steadily increase by time when estimates are based on a full set of inventory plots (30 000 plots). However, if the estimate is based only on the most recently re-measured plots (6000 plots, this might not always be the case. This is due to the five-year inventory cycle, where the estimates for the five most recent years are based on a decreasing number of plots. To avoid a risk of an incorrect decrease in AR and D area and to improve the accuracy of the estimates, inventory cycles without a full record to 2017 are extrapolated (see 6.3.1.1 and Figure 6.6). The extrapolations of areas and living biomass are based on the trend of the five previous years to the actual year. Several options to make this extrapolation have been used in the past but the method chosen has the advantage that the total land and fresh water area is constant over time. "Five years" is chosen as a trade-off between being enough to reduce random variation and be reasonably up to date. In each submission, data for the four last years of the previous report are re-calculated to limit a potential small risk of bias induced by the extrapolation (a pilot study by historical data indicated that the result of re-calculated data using measured full records of sample plots does not deviate significantly from extrapolated data). IPCC recommends a five-year inventory cycle and to re-calculate data when the intention is to improve the accuracy. Chapter two in IPCC 2006 GL describes that extrapolation is a valid approach to improve estimates for years with missing data. The methodology has also the advantage to improve the accuracy of estimates. The extrapolation has one disadvantage that the NIR-2 table cannot be filled in appropriately, because we find it inaccurate to extrapolate areas of land use conversions. Thus the net areas per

activity are exactly the same in the NIR-2 table as in other tables but the transfers between activities are based on the four most recent years (2013-2017).

10.2.3 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 (Figure 2.2.1 and Table 2.2.1 in the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the KP) for reporting emissions/removals under article 3 of the KP (Figure 10.4a and 10.4b). In practice a sample frame of approximately 30 000 permanent sample plots is covering all relevant managed land in Sweden (see chapter 6). The sample frame is divided into 31 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. This information is confidential due to sampling reasons. However, on request (i.e., in connection with an in country review) it is possible 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 10.4a and b).

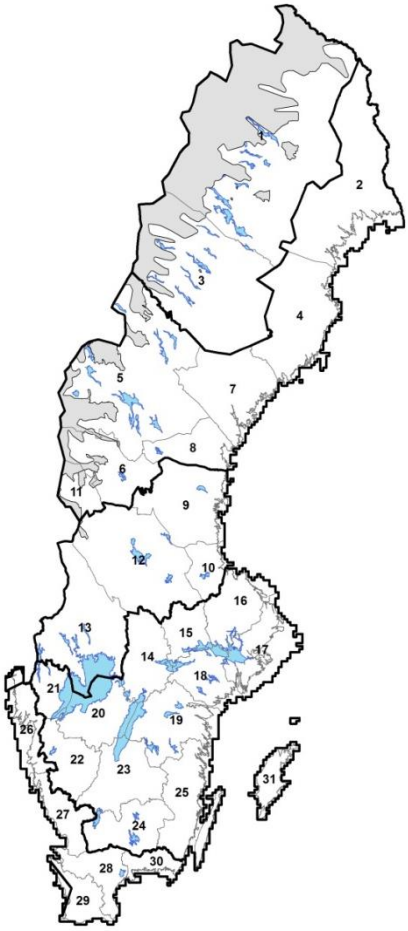

Figure 10.4a. The country is divided into five regions with similar sample design and within 31 strata used for stratification.

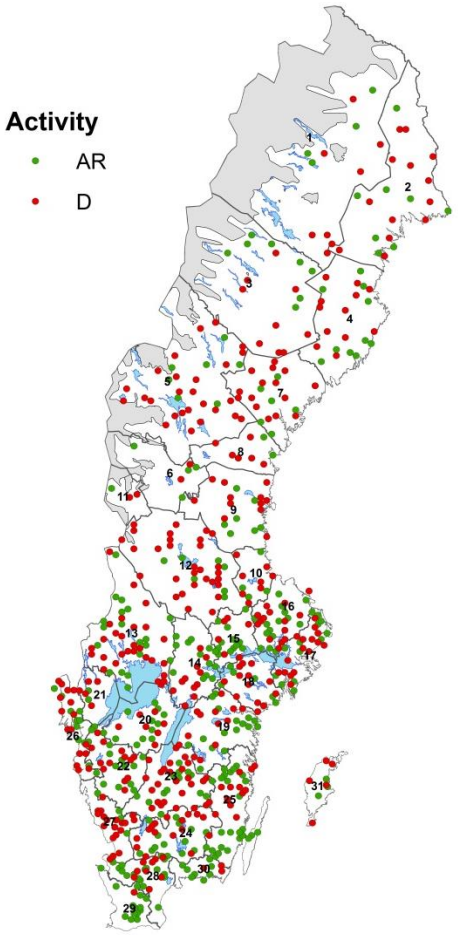

Figure 10.4b. The location of sample plots partly or completely reported under AR and D in Sweden (1990-2017). (On request from the 2013 in country review, the figure is now presenting AR and D per stratum).

10.3 Activity-specific information

10.3.1 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.

10.3.1.1 DESCRIPTION OF THE METHODOLOGIES AND THE UNDERLYING ASSUMPTIONS USED

10.3.1.1.1 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 6.4 + 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 6.4 + Annex 3:2) using the area distribution associated with the reported activities under the Kyoto protocol (ARD and FM).

All methods used for Living biomass is Tier 3, Litter, Dead wood for FM is Tier 3 and Tier 2 for other activities. Soil organic carbon on mineral soils for FM is Tier 3 whereas it is Tier 2 for ARD. Organic soils for all activities are calculated using a Tier 1 approach.

10.3.1.1.2 Other emissions

Emissions of CO_2, N_2O and CH_4 are estimated in the same way as under the UNFCCC (see 6.4). The estimates of N_2O emissions from fertilisers are based on activity data over used quantities combined with emission factors with no information of the actual geographical distribution of fertilizer used. The fertilization is strictly regulated by the Forestry act and no fertilizer is assumed to be 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 4(I)) should correspond to the reported figure under FM (TABLE 4(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 4(II)), N_2O and CH_4 emissions from drained and rewetted organic soils (TABLE 4(KP-II)2) are now reported. The emission factors used are the same as used for the UNFCCC-reporting where AR corresponds to managed land converted to Forest land, D to land converted from Forest land to manged land and FM to Forest land remaining Forest land.

The reporting of N_2O emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions and management change in mineral soils (TABLE 4(KP-II)3) are reported for AR, D and FM. The same methods are used as for the UNFCCC-reporting.

All forest fires (TABLE 4(KP-II)4) are reported under FM and this figure should correspond to the figure reported under UNFCCC (UNFCCC, TABLE 4(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.

Indirect emissions of N_2O are calculated as in the UNFCCC-reporting (based on application of fertilisers and mineralisation of N) but included under (TABLE 4(KP-II)1)) together with the direct emissions.

10.3.1.1.3 Activities and the relationship to UNFCCC-categories

Kyoto Protocol Article 3.3 activity areas are accumulated from 1990 and onwards and, normally, do not leave the class.

AR areas may increase due to conversions from managed land (Cropland, Grassland and Settlement) to Forest land and decrease due to land use conversions in the opposite direction. These areas are reported under deforestation. D can only increase by land use change from Forest land to Cropland, Grassland or Settlement. FM areas can increase due to land use change from unmanaged land (Wetland and Other land) and decrease by land use conversions to Cropland, Grassland or Settlement (reported under D). Thus, land uses conversions from Forest land, reported under FM, to unmanaged land remains in the FM reporting. This implies that Forest land remaining Forest land plus Land converted to Forest land under the convention reporting is not exactly the same as Forest management plus AR during the commitment period, since FM will not decrease when Forest land is converted to unmanaged land while Forest land remaining forest land will (Figure 10.5a-d). In addition, 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 before the base year and is therefore not suitable to, for example, compare D under the Kyoto Protocol with Forest land converted to Cropland, Grassland or Settlements under UNFCCC. Using conversions from Forest land as a "proxy" for D has led to several misunderstandings when assessing the outcome of the UNFCCC and the KP reporting.

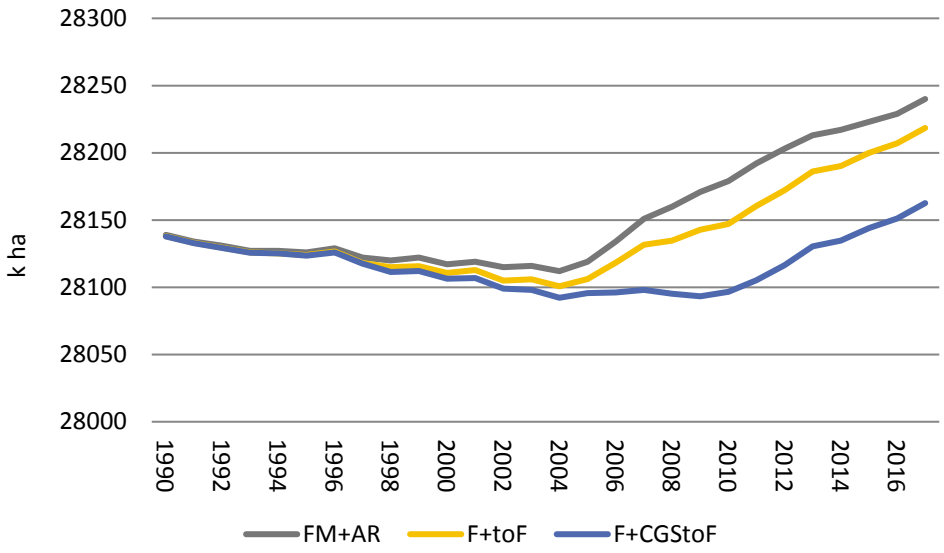

Figure 10.5a. Explaining the deviance between FM+AR and F+toF: In 1990 FM and AR (in practice always with secondary classification FM) constitute the same area as Forest land remaining Forest land+Cropland converted to Forest land+Grassland converted to Forest land+Settlement converted to Forest land+Wetlands converted to Forest land+Other land converted to Forest land. After 1990, land under FM converted to unmanaged land is still reported under FM but not as Forest land under the UNFCCC. In similarity, the same may be valid for AR (AR converted to unmanaged land) but no such conversions have yet been registered.

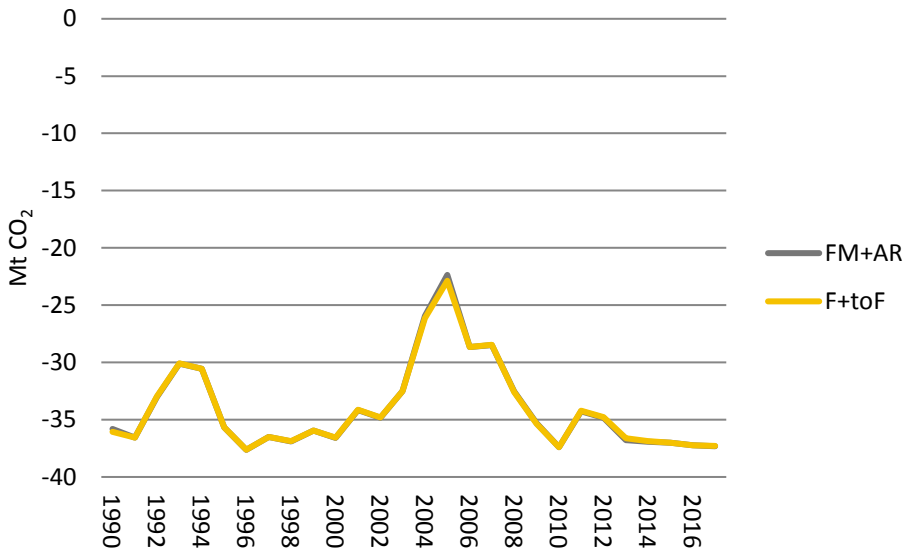

Figure 10.5b. For change in living biomass [Mton CO_2/year] the reported removal is very similar for FM+AR and F+toF –even after 2003 when the automatic rule for correcting inconsistency in land use conversions was removed. (The FM+AR graph is behind the F+toF graph).

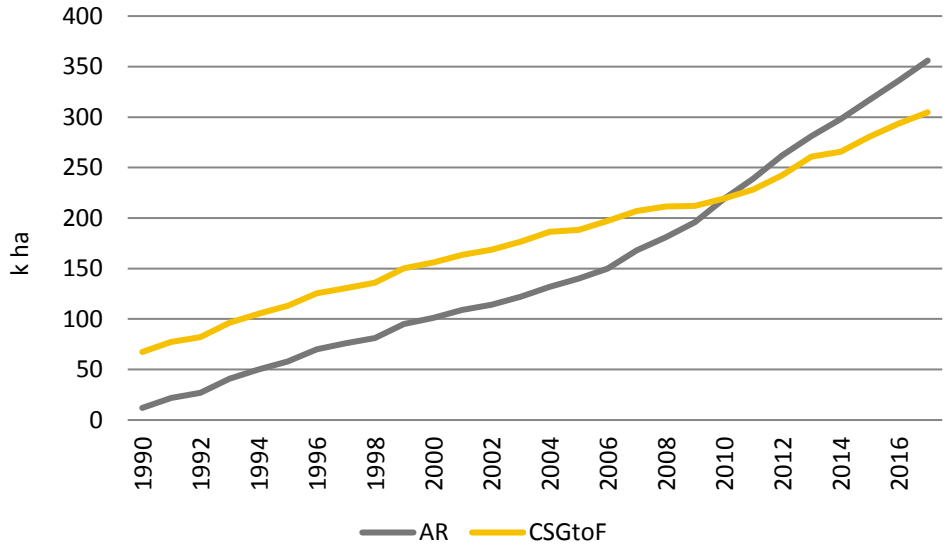

Figure 10.5c. AR is accumulated from 1990 and (more or less) never leaves this category, while Cropland, Grassland or Settlements converted to Forest land under the UNFCCC already exists 1990 (normally from 1983-1987). After 20 years (around 2003-2007) converted land under the UNFCCC is reported under the category it was transferred to (Forest land remaining Forest land).

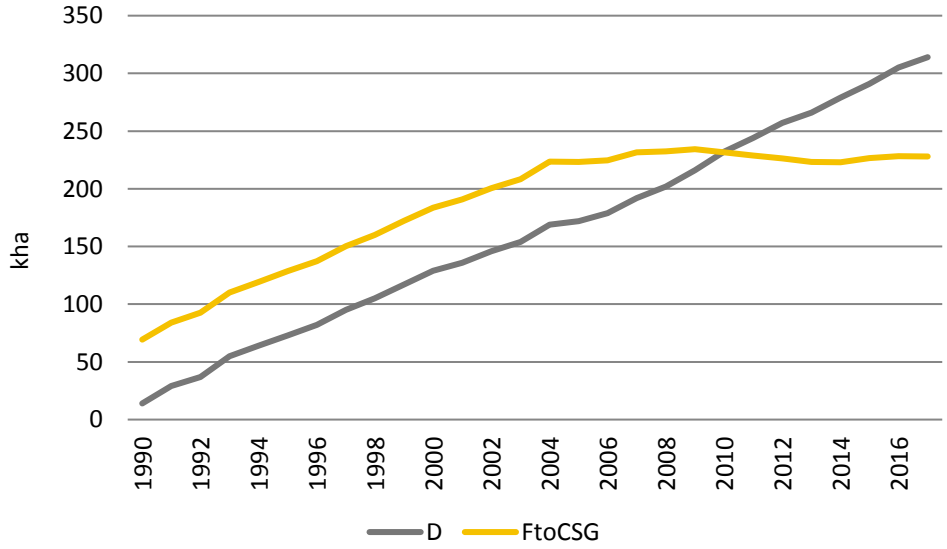

Figure 10.5d. D is accumulated from 1990 and never leaves this category, while Forest land converted to Cropland, Grassland or Settlements under the UNFCCC already exists 1990 (normally from 1983-1987). After 20 years (around 2003-2007) converted land under the UNFCCC is reported under the category it was transferred to.

10.3.1.2 POOLS REPORTED UNDER ARTICLE 3.3 AND ELECTED ACTIVITIES UNDER ARTICLE 3.4

Sweden reports and accounts for all carbon pools (aboveground biomass, belowground biomass, litter, dead wood, soil organic carbon and HWP) as well as for all non-carbon pool emissions.

10.3.1.3 NATURAL DISTURBANCES

Sweden has indicated the intention to apply the provision to exclude emissions from natural disturbances. Emissions from natural disturbances in 2013, 2014, 2015, 2016 and in 2017 did not exceed the background level+ the margin for neither Afforestation/Reforestation under article 3.3 nor for Forest management under article 3.4.

10.3.1.3.1 Identification of lands subject to the exclusion due to natural disturbances

Referring to decision 2/CMP.8, Annex II, paragraph 2 (f) (i), lands subject to the exclusion due to natural disturbances, including their georeferenced location, year and types of disturbances shall be identified. No land was subject to exclusion in years 2013, 2014, 2015, 2016 or 2017.

10.3.1.3.2 Annual emissions and subsequent removals areas excluded from the accounting;

Referring to decision 2/CMP.8, Annex II, paragraph 2 (f) (ii), the estimation of annual emissions resulting from natural disturbances and the subsequent removals during the commitment period in areas excluded from the accounting shall be described. No land was subject to exclusion in 2013, 2014, 2015, 2016 or in 2017.

10.3.1.3.3 Land-use change occurring on lands for which the Natural disturbances provision apply

Referring to decision 2/CMP.8, Annex II, paragraph 2 (f) (iii), Parties shall show that no land-use change has occurred on lands for which the provisions contained in decision 2/CMP.7, annex, paragraph 33, are applied and explain the methods and criteria for identifying any future land-use changes on those land areas during the second commitment period. No land was subject to exclusion in 2013, 2014, 2015, 2016 or in 2017.

10.3.1.3.4 Demonstration that the events or circumstances related to excluded emissions from Natural disturbances were beyond the control of the Party

Referring to decision 2/CMP.8, Annex II, paragraph 2 (f) (iv), Parties shall demonstrate that the events or circumstances were beyond the control of, and not materially influenced by, the Party in the commitment period, by demonstrating practicable efforts to prevent, manage or control the events or circumstances that led to the application of the provisions contained in decision 2/CMP.7, annex, paragraph 33. No land was subject to exclusion in 2013, 2014, 2015, 2016 or in 2017.

10.3.1.3.5 Efforts taken to rehabilitate, where practicable, the land for which the natural disturbances provisions are applied

Referring to decision 2/CMP.8, Annex II, paragraph 2 (f) (v), Parties shall demonstrate efforts taken to rehabilitate, where practicable, the land for which the provisions contained in decision 2/CMP.7, annex, paragraph 33, are applied. No land was subject to exclusion in 2013, 2014, 2015, 2016 or in 2017.

10.3.1.3.6 Salvage logging

Referring to decision 2/CMP.8, Annex II, paragraph 2 (f) (vi), Parties shall show that emissions associated with salvage logging were not excluded from accounting. No land was subject to exclusion in 2013, 2014, 2015, 2016 or in 2017.

10.3.1.4 HWP

The methodology used for accounting for net emissions from the HWP pool was identical to the method used for the reporting of HWP under the UNFCCC described in chapter 6 with the exception of the exclusion of HWP originating from deforestation (D) events. The methodology was also in agreement with decision 2/CMP.7 and the KP-supplement. According to paragraph 31 in decision 2/CMP.7, HWP resulting from D shall be accounted for on the basis of instantaneous oxidation. Thus, HWP from D was subtracted from the total production of HWP from Swedish forests, resulting in HWP from forest management (FM), during 1990-2017 by estimating: i) the deforested area, ii) harvested volume on the deforested area, iii) the sawlog fraction, iii) the volume of sawn wood, iv) the volume of woodchip, v) the fractions of sawn wood, paper and wood based panels from D. The deforested area was derived from the NFI, and the harvested volume from D was calculated: (mean volume/ha)*(deforested area, ha). Mean volumes for Swedish forests were calculated using NFI-data. D was assumed to occur irrespective of forest developmental stage and therefore the mean volume was used to estimate the harvested volume.

Functions were used to calculate the proportion of industrial roundwood and proportion of sawlogs by using min top diameter, min sawlog diameter, and basal area weighted mean diameter for the whole country as independent variables[350]. Min top diameter was set to 5 cm, and min sawlog diameter to 13 cm. Basal area weighted mean diameter for each year was calculated for all trees measured on forest land by the NFI. Pulpwood proportion was calculated as: [(proportion of industrial round wood) – (proportion of sawlogs)]. The estimated harvested volume from D was multiplied with the proportions of each assortment in order to obtain the harvested volume of sawlogs and pulpwood. The volume of sawnwood from D was calculated by multiplying the volume of sawlogs with the exchange of sawnwood from sawlogs within FM, and was subtracted from the total inflow of sawnwood. Woodchips are made from the remaining fraction of the sawlogs adding the pulpwood volume and constitutes the raw material for paper and wood based panels. The quota chipsD/chipstotal was used to exclude inflow of paper and wood based panels from D.

HWP from AR was reported as not occurring, since no harvest were detected on areas subjected to AR since 1990.

10.3.1.5 INFORMATION ON WHETHER OR NOT INDIRECT AND NATURAL GHG EMISSIONS AND REMOVALS HAVE BEEN FACTORED OUT

Sweden does not factor out effects from elevated carbon dioxide concentrations above pre-industrial levels, indirect nitrogen deposition, the dynamic effects of age structure resulting from activities prior to 1 January 1990. However, the accounting for Forest management using a reference level equals out such effects since they are included both in the reference level and in the reported figures.

[350] Ollas, 1980

10.3.1.6 CHANGES IN DATA AND METHODS SINCE PREVIOUS SUBMISSIONS (RECALCULATIONS)

Changes in reported data and methods follow the changes as described in section 6.4.5 for the UNFCCC-reporting of LULUCF.

Table 10.8. Differences in areas between submission 2018 and 2019.

(Mha)	Submission 2019			Submission 2018			Difference [%]		
	AR	D	FM	AR	D	FM	AR	D	FM
2013	0.281	0.266	27.931	0.304	0.270	27.910	-7.4%	-1.4%	0.1%
2014	0.298	0.279	27.919	0.323	0.284	27.896	-7.7%	-1.8%	0.1%
2015	0.317	0.291	27.906	0.343	0.296	27.885	-7.6%	-1.5%	0.1%
2016	0.336	0.305	27.893	0.363	0.311	27.870	-7.4%	-1.9%	0.1%
2017	0.356	0.314	27.884						

Table 10.9. Differences in reported change in living biomass between submissions.

(Mt CO_2 yr^{-1})	Submission 2019			Submission 2018			Difference		
	AR	D	FM	AR	D	FM	AR	D	FM
2013	-1.21	1.37	-35.6	-1.31	1.79	-36.0	0.10	-0.42	0.47
2014	-1.27	1.43	-35.7	-1.39	1.51	-33.8	0.12	-0.08	-1.89
2015	-1.30	1.57	-35.7	-1.44	1.00	-33.9	0.14	0.57	-1.78
2016	-1.35	0.60	-35.9	-1.51	1.26	-34.2	0.16	-0.66	-1.73
2017	-1.39	0.21	-35.9						

10.3.1.7 UNCERTAINTY ESTIMATES

Estimates of carbon stock changes are based on the same underlying data as the reporting under the UNFCCC. These estimates originate mainly from a sampling design with the intention to keep systematic errors as low as possible. The systematic error is reduced by using representative functions, by direct measurements in field and at laboratory. We assume that the major source of uncertainty arise from random variation 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. From submission 2013, Sweden provides separate formal estimates of uncertainty of AR and D, respectively.

Based on 30000 sample plots the accuracy of estimates of carbon stock changes for ARD activities are certain in absolute but uncertain in relative terms. The estimated accuracy (Standard Error) for living biomass for AR and D is around 0.2 and 0.5 Mt CO_2 per year, respectively. This is valid when estimates are based on all 30000 sample plots. However, if based on one year sample (6000 plots), the estimated accuracy (Standard Error) for living biomass for AR and D is much higher and to increase the accuracy Sweden uses extrapolated data for the most recent years. Since ARD is quite uncommon in Sweden and quite close to zero the relative error might be large. The corresponding estimated accuracy for FM is 3 Mt CO_2 per year

(when based on 6000 sample plots, around 7 Mt CO_2 per year). 3 Mt CO_2 per year should be compared with a total stock of more than 4000 Mt CO_2 (relative error 0.07 %). For other carbon pools than living biomass, the uncertainty is based on assumptions[351].

Table 10.10. Estimated and assumed uncertainty for KP-activities (Uncertainty=2•relative "standard error").

		2·Relative Standard Error, %		
Activity	**Category**	**CO_2**	**N_2O**	**CH_4**
FM	Living biomass	21	-	-
	Dead organic matter	50	-	-
	Soil organic carbon	35	-	-
	Direct and indirect, 4(KP-II)1	-	50	-
	Drainage, 4(KP-II)2		100	100
	Biomass burning, 4(KP-II)4	-	100	100
	HWP, 4G	25	-	-
AR	Living biomass	30	-	-
	Dead organic matter	50	-	-
	Soil organic carbon	35	-	-
	Drainage, 4(KP-II)2		100	100
	Mineralisation, 4(KP-II)3		100	
D	Living biomass	-86	-	-
	Dead organic matter	50	-	-
	Soil organic carbon	35	-	-
	Drainage, 4(KP-II)2		100	100
	Mineralisation, 4(KP-II)3	-	100	-

10.3.1.8 INFORMATION ON OTHER METHODOLOGICAL ISSUES

There are currently no methods identified that needs further clarification than those already explained.

[351] This section is an amendment due to a request from reviewrs (ARR 2011) to improve the information on uncertainties in estimates of ARD.

10.4 Article 3.3

10.4.1 Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2020 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 10.2). Land use categories are strictly defined (see NIR chapter 6.2) and land use conversions are confirmed in field at consecutive inventories. The estimates are based on area sampling using the approximately 30 000 permanent sample plots (see chapter 6 for further details on the NFI). The inventory has 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 deforestation. This is also valid for the choice to actively abandon managed land in favour for the management of forests (afforestation/reforestation). 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. Few such reversed-conversions have been identified.

The NFI is used to confirm that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2020 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 year of conversion is randomly distributed.

10.4.2 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 for instance a new road, a power line or other land use preceding the definition of forest is located on the former Forest land, the plot is considered D. 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.

10.4.3 Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested

Annually, about <200 kha[352] of Forest land is 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 in field (see 10.4.2).

[352] Swedish University of Agricultural Sciences, 2010

10.5 Article 3.4

10.5.1 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 (not reported as AR) and land areas with precedence classification FM is reported under Article 3.4 FM. The area under FM is quite stable over the reported period. Land reported under AR usually has secondary classification FM. Since all land use categories, including Forest land, are consistently monitored in field since 1983 it is possible to trace back all land use categories and land use conversions to at least 1990. Land under activity FM is accumulated from 1990 but could leave the category for D at any time. If land under activity FM is converted to unmanaged land by natural degradation it will remain classified as FM in the reporting. "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).

10.5.2 For Parties included in Annex I that elect cropland management and/or grazing land management and/or revegetation and/or wetland drainage and rewetting, anthropogenic GHG emissions by sources and removals by sinks for each year of the commitment period and for the base year

Not applicable (not elected)

10.5.3 Information that demonstrates that emissions by sources and removals by sinks resulting from forest management under Article 3, paragraph 4, and any elected activities under Article 3, paragraph 4, are not accounted for under activities under Article 3, paragraph 3;

Land can only be reported under one activity or none (see section 10.1.4). Using the precedence conditions: D, AR, FM, or no activity, makes it possible to check that a sample unit is reported only once under one activity. The sum of areas is the same every year and secondary classification is also checked. Finally, the consistent sample based design from before 1990 and onward makes it simple to avoid overlaps and by mistake exclude land.

10.5.4 Information on how all emissions arising from the conversion of natural forests to planted forests are accounted for in accordance with any supplementary methodological guidance developed by the IPCC and adopted by the CMP;

Not relevant for Sweden. There is no official definition of "natural forests" in Sweden or by the IPCC. On the other hand since all forest land is assumed managed all forests are also reported.

10.5.5 Information that demonstrates methodological consistency between the reference level and reporting for forest

management during the second commitment period, including the area accounted for, the treatment of harvested wood products, and the accounting of any emissions from natural disturbances;

The coverage of pools and other emissions in the Forest management reference level (FMRL) was consistent with the information provided in the 2011 National inventory report according to the UNFCCC-LULUCF format with three carbon pools. However, due to technical reasons the boundaries between pools according to KP-LULUCF in the historical data and the projected data differ slightly.

Emissions and removals from harvested wood products in the projection were calculated using the same methodology as for the historical data at that time. The numbers include HWP data also for article 3.3-activities. This is consistent with the methodology in the projection of living biomass, which includes all forest land. Natural disturbances as reported at the time for the submission of the FMRL were also included in the estimate. For further information of the development of the FMRL, see the official submission from 2011[353].
Since the submission of the FMRL, the mandatory reporting of Forest management has been amended to include emissions/removals from the harvested wood products pool (HWP), DOC and non- CO_2 emissions from organic soils, mineralization due to management change and indirect N_2O and induced the need to perform a technical correction (see further information below).

10.5.6 Any technical corrections made pursuant to decision 2/CMP.7, annex, paragraph 14, to ensure consistency between the reference level and reporting for forest management during the second commitment period

Following decision 2/CMP.7 and the guidance to identify the need for a technical correction in section 2.7.6 of the IPCC 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol[354] Sweden has performed a technical correction for the forest management reference level. In this submission the correction was calculated due to the following reasons:

- Carbon stock change in Living biomass representing the period 2005-2009 has been updated due to slightly revised data from the NFI.
- The historical dataset for Soil organic carbon and litter representing the period 2000-2009 has been updated using new inventory data from the soil inventory.
- The historical dataset used to calculate average values for 2000-2009 has been revised due to revised areas of forest remaining forest land and the area of drained organic soils. Ths revision affects the estimates of CO_2, DOC, N_2O and CH_4 (including diches) from drained organic soils.
- As the area of reported FM area decrease over time, the FMRL and the corresponding TC has been weighted using the relationship between the extrapolated area for FM for the years 2017-2020 and the area used in the simulations of the FMRL.

All of the issues, except the area issue, listed above affects the historical estimates and the projected values.

[353] Anonymous 2011

[354] IPCC 2014

The forest management reference level was recalculated to -32.2 Mt CO_2-eq. and the technical correction applied to the original value was estimated to 9.2 Mt CO_2-eq. Table 10.11 illustrates the differences in the different components included in the reference level.

Table 10.11. Background data for the technical correction of the forest management reference level.

Forest management (Submission 2011)		Reported	Projection		
		2007	2015	2020	2013-2020
Living biomass	Mt CO_2	-19.55	-23.66	-22.80	
Litter	Mt CO_2	-1.42	-1.37	-0.60	
Dead wood	Mt CO_2	-10.26	-6.51	-5.38	
Soil organic carbon	Mt CO_2	-5.76	-5.58	-5.48	
Fertilisation (N_2O)	Mt CO_2-eq	0.04	0.03	0.03	
Biomass burning (N_2O, CH_4)	Mt CO_2-eq	0.03	0.07	0.07	
HWP	Mt CO_2	-9.52	-5.59	-4.67	
TOTAL EXCL. HWP	Mt CO_2-eq	-36.95	-37.09	-34.23	
TOTAL WITH HWP	Mt CO_2-eq	-46.47	-42.61	-38.83	
FM area	Kha	28 076	28 180	28 180	
FMRL	**Mt CO_2 -eq**				**-36.06**
FMRL with HWP	**Mt CO_2-eq**				**-41.34**
Forest management (Submission 2019)		**2007**	**2015**	**2020**	**2013-2020**
Living biomass	Mt CO_2	-27.65	-23.66	-22.80	
Litter	Mt CO_2	12.17	11.74	12.51	
Dead wood	Mt CO_2	-8.55	-6.51	-5.38	
Soil organic carbon	Mt CO_2	-9.70	-9.26	-9.80	
Fertilisation (N_2O)	Mt CO_2-eq	0.04	0.03	0.03	
Drainage (N_2O, CH_4)	Mt CO_2-eq	1.29	1.31	1.31	
Biomass burning (N_2O, CH_4)	Mt CO_2-eq	0.003	0.01	0.01	
HWP	Mt CO_2	-11.19	-7.04	-5.16	
TOTAL	Mt CO_2-eq	-32.40	-26.35	-24.12	
TOTAL WITH HWP	Mt CO_2-eq	-43.59	-33.38	-29.28	
FM area	Kha	27 983	27 906	27 847	
FMRL	Mt CO_2-eq				**-25.56**
FMRL with HWP	**Mt CO_2-eq**				**-32.0**
Difference (Submission 2011-Submission 2018)		**2007**	**2015**	**2020**	**2013-2020**
Living biomass	Mt CO_2	8.1	0	0	
Litter	Mt CO_2	-1359	-13.11	-13.11	
Dead wood	Mt CO_2	-1.71	0	0	
Soil organic carbon	Mt CO_2	3.94	3.68	4.32	
Fertilisation (N_2O)	Mt CO_2-eq	0	0	0	
Drainage (N_2O, CH_4)	Mt CO_2-eq	-1.29	-1.24	-1.24	
Biomass burning (N_2O, CH_4)	Mt CO_2-eq	0.03	0.06	0.06	
HWP	Mt CO_2	1.67	1.45	0.49	
TOTAL	Mt CO_2 -eq	-4.55	-10.74	-10.11	
TOTAL WITH HWP	Mt CO_2-eq	-2.88	-9.23	-9.55	
FM area	Kha	93	274	333	
Technical correction	**Mt CO_2-eq**				**10.5**
Technical corr. with HWP	**Mt CO_2-eq**				**9.3**

10.6 Other information

10.6.1 Key category analysis for Article 3.3 activities and any elected activities under Article 3.4

The IPCC 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (2.3.6) recommends that whenever a category is identified as key under the UNFCCC the associated activity under the KP should also be treated as a Key-Category. If the correspondence between the UNFCCC categories and the KP activity is poor, a qualitative assessment is recommended. The correspondence could be based on Table 2.1. 1 (ibid.).

Sweden defines land use conversions from Cropland, Grassland and Settlements to Forest land as AR and land use conversions in the opposite direction as D. Forest land remaining Forest land and Wetland or Other land converted to Forest land are assumed to correspond to the activity FM. Thus, the Key-category analysis indicates that FM, AR and D are Key categories for the Kyoto Protocol. All these activities are monitored using higher Tiers. Forest land converted to Settlements for N_2O is also identified as a Key-category and is assumed to correspond to D. This category is monitored using Tier 2.

10.7 Information relating to Article 6

Information relating to Article 6 is provided in Annex 6:1 and 6:3.

10.8 Coming improvements

See section 6.4.6.

11 Information on accounting of Kyoto units

11.1 Background information

Each Party must include information on its aggregate holdings and transactions of Kyoto Protocol units in its annual report. The reporting will be submitted according to the special report standard, the Standard Electronic Format (SEF) with the annual inventory on 15 April. Sweden began the annual reporting in 2009.

Sweden's Standard Electronic Format report for 2018 containing the information required in paragraph 11 of the annex to decision 15/CMP.1 The SEF will be submitted to the UNFCCC Secretariat electronically.

11.2 Summary of information reported in the SEF tables

Annual Submission Item	Party provided content
15/CMP.1 annex I.E paragraph 11: Standard electronic format (SEF)	Sweden's Standard Electronic Format report for 2018 will contain the information required in paragraph 11 of the annex to decision 15/CMP.1. See document/file RREG1_SE_2018_2_1.xlsx, RREG1_SE_2018_2_1.xml and RREG1_SE_2018_2_1.zip

11.3 Discrepancies and notifications

Annual Submission Item	Party provided content
15/CMP.1 annex I.E paragraph 12: List of discrepant transactions	No discrepant transactions per DES response code exists in the SE registry year 2018. Refer to Separate Electronic Attachment “SIAR Reports 2018-SE v 1.0 xls” Worksheet R2.
15/CMP.1 annex I.E paragraph 13 & 14: List of CDM notifications	No CDM notifications were received by the National Registry during the 2018 reporting period, pursuant of 15/CMP.1 annex I.E paragraphs 13 & 14. Refer to Separate Electronic Attachment “SIAR Reports 2018-SE v 1.0.xls” Worksheet R3.
15/CMP.1 annex I.E paragraph 15: List of non-replacements	No non-replacements occurred during the 2018 reporting period, pursuant of 15/CMP.1 annex I.E paragraph 15. Refer to Separate Electronic Attachment “SIAR Reports 2018-SE v 1.0.xls” Worksheet R4.
15/CMP.1 annex I.E paragraph 16: List of invalid units	No invalid units exist as at 31 December 2018, pursuant of 15/CMP.1 annex I.E paragraph 16. Refer to Separate Electronic Attachment “SIAR Reports 2018-SE v 1.0.xls” Worksheet R5.
15/CMP.1 annex I.E paragraph 17: Actions and changes to address discrepancies	No actions and changes to address discrepancies have been performed during the reported period due to that no discrepancies occurred.

11.4 Publicly accessible information

Annual Submission Item	Party provided content
15/CMP.1 annex I.E Publicly accessible information	The following information is now deemed publicly accessible and as such is available via the homepage of the SE registry and Swedish Energy Agency – https://www.energimyndigheten.se/en/sustainability/eu-ets---implementation-in-sweden/the-swedish-emissions-trading-registry/public-information/ or via the link directly to the account holder information. In accordance with the requirements of Annex E to Decision 13/CMP.1, all required information for a Party with an active Kyoto registry is provided with the exceptions as outlined below **Account Information (Paragraph 45) and Account holders authorised to hold Kyoto units in their account (Paragraph 48)** In light of the amendments introduced by Article 78 of the revised Registries Regulation that came into force in October 2010 and 2013 and for security reasons, it is considered that the representative identification information as required in paragraph 45 and paragraph 48 is held as confidential. Since there are no provisions in Swedish law on which kyoto unit types legal entities are authorised to hold in the Swedish National Registry, It is difficult to provide a list of legal entities authorized to hold party holding accounts. All legal entities (person or organisation) authorized to participate in the Swedish national registry under the Kyoto mechanisms, must have a separate holding account for each legal entity according to the Data Exchange Standards (DES). The list of legal entities that currently have party holding accounts in the Swedish registry can be found through a report tool on the following public website: https://www.energimyndigheten.se/en/sustainability/eu-ets---implementation-in-sweden/the-swedish-emissions-trading-registry/public-information/ **JI projects in Sweden (Paragraph 46)** No Article 6 (Joint Implementation) projects have been reported for conversion to ERU under an Article 6 project. The list of the conversion that occurred in the Swedish registry can be found through a report on the following public website:

Annual Submission Item	Party provided content
	https://www.energimyndigheten.se/en/sustainability/eu-ets---implementation-in-sweden/the-swedish-emissions-trading-registry/public-information/ **Holding and transaction information of units (Paragraph 47)** Holding and transaction information is provided on a holding type level, due to more detailed information being declared confidential by EU Regulation. Publicly available information via the following link, https://www.energimyndigheten.se/en/sustainability/eu-ets---implementation-in-sweden/the-swedish-emissions-trading-registry/public-information / Article 6 of EU Regulation 389/2013/EC, provides that “All information, including the holdings of all accounts and all transactions made, held in the registries and the Community independent transaction log shall be considered confidential for any purpose other than the implementation of the requirements of this Regulation, Directive 2003/87/EC or national law.” Paragraph 47c The total quantity of ERUs issued and converted on the basis of Article 6 projects (Joint Implementation), are displayed in the public accessible information on the web site. Paragraph 47e Sweden does not perform LULUCF activities and therefore does not issue RMUs Paragraph 47g No ERUs, CERs, AAUs and RMUs have been cancelled on the basis of activities under Article 3, paragraphs 3 and 4 in 2018. Paragraph 47h No ERUs, CERs, AAUs and RMUs have been cancelled following determination by the Compliance Committee that the Party is not in compliance with its commitment under Article 3, paragraph 1 in 2018. Paragraph 47j No ERUs, CERs, AAUs and RMUs have been retired 2018. Paragraph 47k

Annual Submission Item	Party provided content
	Sweden did not carry over ERUs, CERs, and AAUs from the previous commitment period, no carry over for ERUs, CERs, and AAUs are reported. Paragraph 48 List of legal entities authorized by Party provided via the following link https://unionregistry.ec.europa.eu/euregistry/SE/public/reports/publicReports.xhtml

The previous Annual Review recommendations	**No recommendations regarding changes in registry for 2018. FCCC/ARR/2017/SWE.**

11.5 Calculation of the commitment period reserve (CPR)

11.5.1 Assigned Amount

The individual assigned amount for Sweden was established at 315 554 578 assigned amount units (AAUs), in accordance with the notification of the terms of the agreement to fulfil the commitment jointly by the European Union, its Member States, and Iceland (Council decision (EU) 2015/1339). Sweden's assigned amount was defined as the sum of the annual emission allocations for the period 2013 – 2020 determined pursuant to decision No 406/2009/EC. That amount, based on global warming potential values from the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, was determined under Annex II to Commission decision 2013/162/EU and adjusted by Commission Implementing decision 2013/634/EU.

Since Sweden's land-use change and forestry did not constitute a net source of greenhouse gases in 1990, no addition has been made in regards to that sector. Article 3.7bis of the Kyoto Protocol states that parties for whom land-use change and forestry constituted a net source of greenhouse gas emission in 1990 shall include in their 1990 emissions base year those equivalent emissions minus removals by sinks for the purpose of calculating its assigned amount.

11.5.2 Commitment Period Reserve (CPR)

Parties are required by decision 11/CMP.1 under the Kyoto Protocol and paragraph 18 of decision 1/CMP.8 to establish and maintain a commitment period reserve as part of their responsibility to manage and account for their assigned amount. The commitment period reserve equals: (i) the lower of either 90 % of a Party's assigned amount pursuant to Article 3(7bis), (8) and (8bis), or (ii) 100 % of its most recently reviewed inventory, multiplied by 8.

According to definition (i), the commitment reserve would amount to 90 % of Sweden's assigned amount, which is equal to 283 999 121 t of CO_2-eq.

According to definition (ii), the commitment period reserve would amount to eight times the sum of the most recent greenhouse gas inventory. The commitment period reserve according to definition (ii) based on submission 2019 of the greenhouse gas inventory is reported in Table 11.1.

The commitment period reserve is therefore established in line with definition (i), amounting to 283 999 121 assigned amount units.

Table 11.1. The commitment period reserve.

Year	Inventory Total (t CO_2-eq.)	Commitment Period Reserve according to definition (ii) (t CO_2-eq.)
2013	55 537 398	444 299 181
2014	53 836 241	430 689 927
2015	53 690 357	429 522 860
2016	52 892 716	423 141 728
2017	52 660 267	421 282 140

11.6 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 10 of the NIR. For 2017 the activities under article 3.3 constituted a net source of about 0.01 Mt CO_2eq. and Forest management under article 3.4 constituted a net removal of 49 Mt CO_2eq. According to section C and paragraph 13 in 2/CMP.7 "For the second commitment period, additions to the assigned amount of a Party resulting from forest management under Article 3, paragraph 4, and from forest management project activities undertaken under Article 6, shall not exceed 3.5 % of the base year greenhouse gas emissions excluding land use, land-use change and forestry pursuant to Article 3, paragraphs 7 and 8, or any amendments thereto, times the duration of the commitment period in years.". 3.5 % of the base year emission is 2.5 Mt CO_2eq/year and for the entire second commitment period the additions to the assigned amount resulting from Forest management can be up to 20 Mt CO_2eq. However it may be noted that Sweden has elected commitment period accounting.

12 Information on changes in national system

No changes to the national system has been made.

13 Information on changes in national registry

The following changes to the national registry of SE have therefore occurred in 2018. Note that the 2018 SIAR confirms that previous recommendations have been implemented and included in the annual report.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(a) Change of name or contact	None
15/CMP.1 annex II.E paragraph 32.(b) Change regarding cooperation arrangement	No change of cooperation arrangement occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(c) Change to database structure or the capacity of national registry	The versions of the EUCR released after 8.0.8 (the production version at the time of the last Chapter 14 submission) introduced minor changes in the structure of the database. These changes were limited and only affected EU ETS functionality. No change was required to the database and application backup plan or to the disaster recovery plan. The database model is provided in Annex A. No change to the capacity of the national registry occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(d) Change regarding conformance to technical standards	Changes introduced since version 8.0.8 of the national registry are listed in Annex B. Each release of the registry is subject to both regression testing and tests related to new functionality. These tests also include thorough testing against the DES and were successfully carried out prior to the relevant major release of the version to Production (see Annex B). No other change in the registry's conformance to the technical standards occurred for the reported period.
15/CMP.1 annex II.E paragraph 32.(e) Change to discrepancies procedures	No change of discrepancies procedures occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(f) Change regarding security	No changes regarding security occurred during the reported period.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information	A change to the list of publicly available information occurred during the reported period. New URL to publicly available information, https://www.energimyndigheten.se/en/sustainability/eu-ets---implementation-in-sweden/the-swedish-emissions-trading-registry/public-information/
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	The registry internet address changed during the reported period. The new URL is https://unionregistry.ec.europa.eu/euregistry/SE/index.xhtml.
15/CMP.1 annex II.E paragraph 32.(i) Change regarding data integrity measures	No change of data integrity measures occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(j) Change regarding test results	Changes introduced since version 8.0.8 of the national registry are listed in Annex B. Both regression testing and tests on the new functionality were successfully carried out prior to release of the version to Production. The site acceptance test was carried out by quality assurance consultants on behalf of and assisted by the European Commission.

14 Information on minimization of adverse impacts in accordance with Article 3, paragraph 14

The Swedish reporting of information regarding minimizations of adverse impacts in accordance with Article 3, paragraph 14 of the Kyoto Protocol is presented below. The outline follows that of decision 15/CMP.1 § 23 and § 24.

14.1 Changes in information provided under Article 3, paragraph 14

No new information has been added to this report.

14.2 Paragraph 23

Each Party included in Annex I shall provide information relating to how it is striving, under Article 3, paragraph 14, of the Kyoto Protocol, to implement its commitments mentioned in Article 3, paragraph 1, of the Kyoto Protocol in such a way as to minimize adverse social, environmental and economic impacts on developing country Parties, particularly those identified in Article 4, paragraphs 8 and 9, of the Convention.

According to the provisions of Article 2 of the Kyoto Protocol, each party with quantified commitments under the Protocol is to introduce policies and measures to achieve the emission reductions to which it has made a commitment. The measures implemented are to be compatible with overarching objectives of sustainable development. Measures which would mean that all greenhouse gases regulated by the Protocol can decrease and cover all sectors of society are emphasised. The parties to the Kyoto Protocol are to aim to introduce policies and measures so that adverse effects are minimised. Such effects include adverse effects of a changed climate, effects on international trade and social, environmental and economic effects on other parties, particularly on developing countries.

In connection to the implementation of policies and measures in Sweden, an impact assessment is carried out, including an environmental impact assessment as a basis for decision-making. Such an analysis as far as possible also includes assessing the risk of adverse effects in other countries. Formulation of proposals for changes of policy instruments is undertaken in a consultation procedure that makes it possible for operators concerned to give their comments on the proposals. Suggestions of new rules or guidelines that may affect trade with other countries shall be notified within the EU and be alerted under the WTO's rules. This process makes it possible for other countries to influence the design of proposals for changed policy instruments and highlight any negative side effects that may arise.

Further, under Sweden’s policy for global development (PGD), all policy areas are to interact in a coherent way so that the country can make an effective contribution

to equitable and sustainable global development. When decisions in a given policy area are judged to affect this goal of equitable and sustainable global development, an impact assessment has to be carried out. The policy's two perspectives – a rights perspective and the perspective of poor people on development – are to serve as a guide. In the framework of the PGD, coordination and collaboration take place, for example, through a reference group on trade policy at the Ministry for Foreign Affairs. Regular meetings of this group, which includes representatives of business, the Swedish International Development Cooperation Agency (Sida) and civil society organizations have created a basis for broad consultation on trade policy.

The Swedish research activities, as indicated in Chapter 8 of Sweden's seventh National Communication on Climate Change (NC 7), among other things contribute to a sustainable global development. There are several examples of interdisciplinary research efforts focused on improving knowledge of effects globally (socially, economically and ecologically) of large-scale introduction of measures to reduce greenhouse gas emissions. Because of Sweden's focus on increased use of bioenergy, both through increased domestic production but also through imports in particular from developing countries, this area has been specially prioritised in systems-science research in the country.

Results from research have already influenced, and will in future influence, the development of policy. The special sustainability criteria devised for vehicle biofuels under the EU Renewables Directive is one such example.

Both positive and negative effects must be taken into account. Sweden contributes to a number of measures that may have positive effects on the prospects of developing countries adapting to climate change and implementing their own measures to reduce their greenhouse gas emissions. A description is given in Chapter 7 of NC 7 of such efforts in the areas of technology transfer, capacity building and support for adaptation measures.

Finally Sweden wishes to emphasise that its climate strategy with its broad focus on many different types of measures covering the majority of sectors of society (both in and outside the country) and all greenhouse gases governed by the Kyoto Protocol has a form which fundamentally limits (minimises) the risk of adverse effects.

14.3 Paragraph 24 (a)

Annex II Parties shall incorporate information on how they give priority to the following actions:
(a) The progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse-gas-emitting sectors, taking into account the need for energy price reforms to reflect market prices and externalities

Sweden has to a large extent reformed the energy markets and phased out any market imperfections. The market price on electricity is deregulated and governed by the balance between demand and supply on a cross-border electricity market. In Sweden fossil fuels used outside the EU emissions trading scheme (ETS) is subject to a carbon dioxide tax to reflect the external cost. In EU ETS it is mainly the price of allowances that reflects the external effect of carbon dioxide emissions and the market failure.

14.4 Paragraph 24 (b)

Removing subsidies associated with the use of environmentally unsound and unsafe technologies.

Sweden does not extract oil, natural gas or coal, and therefore, has no subsidies on these fuels. With the introduction of the EU ETS for carbon dioxide emissions a cost has been imposed on environmentally harmful technologies such as fossil fuel based heat- and electricity production and industries.

14.5 Paragraph 24 (c)

Cooperating in the technological development of non-energy uses of fossil fuels, and supporting developing country Parties to this end

The chemical industry including refineries contributes to a fairly small share of the overall Swedish industrial production. This technological field is not a high priority in the Swedish research policy.

14.6 Paragraph 24 (d)

Cooperating in the development, diffusion, and transfer of less-greenhouse-gas-emitting advanced fossil-fuel technologies, and/or technologies, relating to fossil fuels, that capture and store greenhouse gases, and encouraging their wider use; and facilitating the participation of the least developed countries and other non-Annex I Parties in this effort
Sweden has an almost fossil free heat- and power production and therefore don’t give priority to research and technology development in the field of advanced fossil based techniques for electricity and heat production technology. Since there is an automotive industry in Sweden, research programmes in the areas of hybrid technologies, automatic control systems for more energy-efficient internal combustion engines and the use of diesel oil for hydrogen production have been carried out over a long period of time. The programmes are designed in particular to contribute to reduced fuel consumption for road vehicles. A development which

is also of value for more fuel efficient passenger- and goods transport in non-Annex 1 countries, particularly those who are dependent on imports of oil, diesel and petrol.

Carbon Capture and Storage technology has in recent years been given priority in the Swedish research and climate policy.

Since 2014, geological storage of carbon dioxide is allowed in Sweden in accordance to an ordinance (Förordning (2014:21) om geologisk lagring av koldioxid), and the Geological Survey of Sweden (SGU) is the supervisory agency. The SGU also monitors advances in the CCS area – both in terms of legislation and of research and development. Further, SGU participates in European networks and research partnerships on CCS.

At the EU level, the European Union has decided to invest in the development of CCS technology and support the establishment of demonstration plants with the aim to enhance the development of CCS technology. One example of an EU financed project is a project called White Rose, in Great Britain, which includes the reduction of cabon dioxide emissions by 90 % from a coal power plant, transport on land and in the sea, as well as storage under the north part of the North Sea. White Rose is funded by the European NER300 programme, which is a fund set up by the European Commission to encourage low-carbon energy projects.

14.7 Paragraph 24 (e)

Strengthening the capacity of developing country Parties identified in Article 4, paragraphs 8 and 9, of the Convention for improving efficiency in upstream and downstream activities relating to fossil fuels, taking into consideration the need to improve the environmental efficiency of these activities

Sweden contribute to technology development in developing countries through development assistance and CDM projects, see chapter 4 of Sweden's seventh National Communication on Climate Change. The focus on transfer of technologies is primarily on energy efficiency technologies and on the introduction of renewable energy, but also to contribute to capacity-building. By providing knowledge about how CDM projects evolve, are administered and implemented for approval, which Sweden has made in African countries, the ability to inter alia obtain technology that enhances the efficiency of fossil fuel-intensive activities as well as other climate-related environmental technology projects improves.

14.8 Paragraph 24 (f)

Assisting developing country Parties which are highly dependent on the export and consumption of fossil fuels in diversifying their economies

Sweden assists developing countries which are dependent on imports for its fossil fuel consumption with the transfer of more energy-efficient technologies, renewable energy technologies and capacity-building which enhances diversification of the economy in these countries (see chapter 7 of NC 7). Inter alia, the Government has signed cooperation agreements on environmental or energy technology with a number of countries, among them the United States, Brazil,

China, Russia and India. Special emphasis within the frame of this cooperation has been given to the field of environmental and energy technologies, including sustainable urban planning.

In addition to development cooperation projects, Sweden is engaged in CDM projects in biomass based electricity generation, wind energy, biogas production, hydro-electric power production and energy efficiency projects which contribute to economic development and diversification of the economy in fossil fuel dependent developing countries. Capacity-building about how CDM projects evolve, are administered and implemented for approval, which Sweden has made in African countries, support a greater diversification of the economy in the countries concerned. (see chapter 4 of NC7).

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16 Units and Abbreviations

t	1 (metric) tonne = 1 megagram (Mg) = 10^6 g
toe	tonne oil equivalent 1 toe = 41.87 GJ
Mg	1 megagram = 10^6 g = 1 tonne
Gg	1 gigagram = 10^9 g = 1 kilotonne (kt)
Tg	1 teragram = 10^{12} g = 1 megatonne (Mt)
TJ	1 terajoule
A	
AR	Afforestation and Reforestation
ARTEMIS	Assessment and Reliability of Transport Emission Models and Inventory Systems
AWMS	Animal Waste Management System
C	Carbon or Confidential
CH_4	Methane
EMIR	Emissions database of the county administrative boards
ERT	Expert Review Team
CFCs	Freons
CKD	Cement kiln dust
CO	Carbon monoxide
	Carbon dioxide
COP	Conference Of the Parties
CORINAIR	EMEP/CORINAIR Emission Inventory Guidebook
CRF	Common Reporting Format
D	Deforrestation
DOM	Dead organic matter
SOC	Soil organic carbon
EC	Environmental Class
EAA	European Aluminium Association
EEA	European Environment Agency
EF	Emission Factors
EU	European Union
EMV	Emission Model for Road Traffic
ETS	Emission Trading Scheme
FAME	Fatty Acid Methyl Ester (earlier called RME)
F-gases	Fluorinated gases (HFCs, PFCs, SF_6)
FM	Forest management
FMV	Swedish Defence Material Administration
FAO	Food and Ariculture Organisation of the UN
FOD model	IPCC First Order Decay model
FOI	Swedish Defence Research Agency
FORTV	Swedish Fortification Department
FRA	Forest Resource Assesment
FRA	National Defence Radio Institute
FTP	Federal Test Procedure
GHG	Greenhouse gases
Good Practice Guidance	IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories IPCC NGGIP
GWP	Global Warming Potential
Halocarbons	Organic compounds containing one or more halogens

HBEFA	Handbook Emission Factors for Road Transport
HWP	Harvested Wood products
HFCs	Hydrofluorocarbons
IE	Included Elsewhere
IEA	International Energy Agency
IEF	Implied Emission Factors
Industrial statistics	Industrial energy statistics
IPCC	Intergovernmental Panel on Climate Change
IPCC Guidelines	Revised 1996 Guidelines for National Greenhouse Gas Inventories
IPCC EFDB	IPCC Emission factor data base
ISIC	International Standard Industrial Classification of All Economic Activities
IVL	IVL Swedish Environmental Research Institute AB
Jernkontoret	Swedish Steel Producers' Association
KemI	The Swedish Chemicals Agency
KP	the Kyoto protocol
LPG	Liquefied Petroleum Gas
LTO	Landing and Take-Off
LUCF	Land-use change and forestry
LULUCF	Land-use, land-use change and forestry
MI	Markinventeringen (Swedish soil inventory)
MSW	Municipal solid waste
N_2O	Nitrous oxide
NAP	Swedish national allocation plan
NA	Not Applicable
NBF	National Board of Forestry
NCV	Net Calorific Value
NE	Not Estimated
NFI	National Forest Inventory
NIR	National Inventory Report
NMVOC	Non Methane Volatile Organic Compounds
NO	Not Occuring
NO_X	Nitrogen oxides
NSFSV	National Survey of Forest Soils and Vegetation
MTC	Motor Test Center
O_3	Ozone
PA	Production approach
PAH	Polycyclic aromatic hydrocarbons
PDCA	Plan, Do, Check, Act
PFCs	Perfluorocarbons
QA/QC	Quality assurance and Quality control
Quarterly statistics	Quarterly fuel statistics
RIS	Riksinventeringen av skog (national forest inventory)
RME	Rapeseed Methyl Ester fuel
RVF	Swedish Association of Waste Management
SF_6	Sulphur hexafluoride
SDC	Forest indusry information association
SGU	Geological Survey of Sweden
SJV	Swedish Board of Agriculture
SLU	Swedish University of Agricultural Sciences

SMED	Swedish Environmental Emissions Data
SMHI	Swedish Meteorological and Hydrological Institute
STA	Swedish Transport Administration
STAg	Swedish Transport Agency
SO_2	Sulphur dioxide
SPBI	Swedish Petroleum and Biofuel Institute
Swedish EPA	Swedish Environmental Protection Agency
TSP	Total amount of suspended particles
TPS	Technical Production System
UNFCCC	United Nations Convention on Climate Change
VBA	Visual Basic for Applications
VETO	Mechanistic model for simulations on road traffic
VTI	Swedish Road- and Transport Research Institute
WBCSD	World Business Council for Sustainable Development
WRI	World Resource Institute