National Inventory Document Sweden 2025

Greenhouse Gas Emission Inventories 1990-2023

Submitted under the United Nations Framework Convention on Climate Change and the Paris Agreement

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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.

The National Inventory Document (NID) for the year 2023 (submission 2025) 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 2023, and descriptions of methods used to produce the estimates. The combined effect of various greenhouse gases has been calculated using global warming potential factors from the Fifth Assessment report of the IPCC (GWP AR5). The methods used to calculate emissions and removals are in accordance with the IPCC 2006 Guidelines for National Greenhouse Gas Inventories, 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, 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 Climate and Enterprise.

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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 (United Nations Framework Convention on Climate Change - 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 ett nationellt fastställt bidrag till att nå avtalets mål. Ambitionen i bidragen ska skärpas successivt samt förnyas eller uppdateras vart femte år. Sveriges bidrag ingår i EU:s bidrag om att minska nettoutsläppen av växthusgaser inom unionen med minst 55% till 2030 jämfört med 1990. En global översyn för att följa upp framstegen mot avtalets mål sker vart femte år, från och med 2023. Principer för uppföljning och rapportering av parternas nationellt fastställda bidrag etablerades 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, beslutades vid COP24 i Katowice samt vid COP26 i Glasgow. Det innebär att det för första gången finns en gemensam uppsättning rapporteringsriktlinjer för uppföljning och rapportering för alla länder. Första rapporteringen under Parisavtalet skedde 2024.

Innan Parisavtalet trädde i kraft 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. Kyotoprotokollet har haft två åtagandeperioden 2008 till 2012 och 2013 till och med 2020. Skillnaden mellan Parisavtalet och Kyotoprotokollet är 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 Annex I-parterna 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. 2022 levererade Annex -1 parter med ett åtagande den sista växthusgasinventeringen med de siffror som sedan ligger till grund för bokföring och avräkning. Under hösten 2022 skedde den slutliga granskningen av underlaget. Under 2023 skedde slutliga fullgörandet och Annex –1 parter med ett åtagande har rapporterat en "True-up period report". EU och medlemsländerna har klarat sitt åtagande om att minska utsläppen med 20% jämför med 1990.

Enligt FN:s klimatkonventions fjärde och tolfte artiklar ska 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 Document – NID) för år 2025 utgör den årliga rapporteringen enligt FN:s klimatkonvention och Parisavtalet. 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 under Parisavtalet. Rapporten innehåller den nationella växthusgasinventeringen för perioden 1990 till 2023 samt beskrivningar av metoderna som använts för att ta fram statistiken. Metoderna som använts följer FN:s klimatpanels riktlinjer för nationell växthusgasinventering från 2006, IPCC:s tilläggsriktlinjer för våtmarker samt de uppdaterade 2006 riktlinjerna från 2019. Växthusgasinventeringen är densamma som rapporteras till EU under Styrningsförordningen (2018/1999/EG) och som ligger till grund för uppföljning emot Sveriges åtagande under EU:s klimatpaket, Fit for 55.

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 2023, 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 (CRT 1) och i industriprocesser och produktanvändning (CRT 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 Tables – CRT), på FN:s klimatkonventions begäran.

S 2. Översikt av utsläpps- och upptagstrender per gas

De totala utsläppen av växthusgaser i Sverige var 44,4 miljoner ton koldioxidekvivalenter år 2023 (exklusive LULUCF) (Tabell S.1 och Tabell S.2). Jämfört med 2022 är det en minskning med knappt 2%. Utsläppen har minskat med 38% mellan 1990 och 2023. Nedan beskrivs först utsläppstrender per gas jämfört med totalen (exklusive LULUCF) följt av korta beskrivningar av trenden inom LULUCF.

De totala utsläppen av koldioxid (CO_2) 2023 var 35,5 miljoner ton vilket motsvarar cirka 80% av de totala utsläppen av växthusgaser. Energisektorn, inklusive transporter, stod för 84% av de totala koldioxidutsläppen och är därmed den största källan till koldioxidutsläpp i Sverige. Utsläppen av koldioxid 2023 var 38% lägre än 1990 och knappt 2% lägre än 2022.

Utsläppen av metan (CH_4) var 4,6 miljoner ton koldioxidekvivalenter år 2023 vilket motsvarar drygt 10% av de totala utsläppen av växthusgaser. Metanutsläpp kommer framför allt från jordbruket, avfallsdeponier och från förbränning av fossila bränslen inom energisektorn. Sedan 1990 har utsläppen av metan minskat med 45%, vilket främst beror på minskade utsläpp inom avfallssektorn och till viss del på minskade utsläpp från jordbrukssektorn. Mellan 2022 och 2023 har metanutsläppen minskat med 1,4%.

De totala utsläppen av lustgas (N_2O) 2023 var 3,4 miljoner ton koldioxidekvivalenter, vilket motsvarade knappt 8% av de totala utsläppen av växthusgaser. Utsläpp av lustgas härrör huvudsakligen från jordbrukssektorn (cirka 75% av totala lustgasutsläppen). Sedan 1990 har utsläppen av lustgas minskat med cirka 28%. År 2023 minskade lustgasutsläppen med 3,5% jämfört med 2022.

De totala utsläppen av fluorerade växthusgaser (PFCs, HFCs och SF_6) var 0,8 miljoner ton koldioxidekvivalenter år 2023 vilket motsvarar cirka 2% av de totala utsläppen av växthusgaser. Utsläppen är 2023 är 33% 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 de senaste åren. Mellan 2022 och 2023 var minskningen cirka 7%.

Nettoupptaget för sektorn markanvändning, förändrad markanvändning och skogsbruk (LULUCF) fortsatte att ligga på en relativt hög nivå 2023 och var cirka 31 miljoner ton koldioxidekvivalenter. Det innebär att de totala utsläppen av växthusgaser i Sverige inklusive LULUCF var omkring 13 miljoner ton koldioxidekvivalenter år 2023 (Tabell S.1 och Tabell S.2). Storleken i nettoupptaget beror främst på förhållandet mellan kolinlagringen i växande skog och mark och avgången (avverkning och naturlig nedbrytning av organiskt material). Så länge kolinlagringen (tillväxten) är större än avgången erhålls ett nettoupptag. Kolpoolsförändringen på skogsmark dominerar resultatet i sektorn. Utöver ett stort nettoupptag av koldioxid så ingår även utsläpp av metan och lustgas från sektorn. Det totala nettoupptaget har varierat över tid men ligger nu ungefär 47% lägre än 1990.

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

Växthusgasutsläpp	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
CO_2 inkl. LULUCF	-3 660	2 514	-7 793	-6 111	-10 357	-13 511	-4 340	263	840	2 649
CO_2 exkl. LULUCF	57 417	59 487	54 892	53 787	53 029	43 310	36 622	38 568	36 121	35 543
CH_4 inkl. LULUCF	9 089	9 019	8 434	7 628	6 580	5 766	5 332	5 284	5 247	5 179
CH_4 exkl. LULUCF	8 473	8 418	7 847	7 055	6 045	5 260	4 811	4 759	4 711	4 644
N_2O inkl. LULUCF	5 813	5 580	5 309	4 930	4 801	4 567	4 653	4 572	4 625	4 506
N_2O exkl. LULUCF	4 692	4 484	4 206	3 842	3 751	3 569	3 562	3 458	3 494	3 371
HFCs	6	129	725	1 045	1 064	1 059	889	852	817	758
PFCs	511	478	338	366	169	32	59	45	34	31
SF6	105	139	122	156	65	55	38	40	39	38
NF3	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Ospecificerat HFCs och PFCs	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total (inkl. LULUCF)	11 863	17 859	7 136	8 014	2 322	-2 033	6 631	11 055	11 601	13 162
Total (exkl. LULUCF)	71 203	73 135	68 132	66 252	64 123	53 284	45 982	47 722	45 215	44 386

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

Källor till utsläpp & sänkor	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
1. Energy	52 409	54 292	49 476	48 156	47 411	38 105	32 020	33 290	30 844	30 435
2. Industrial Processes and Product Use	7 226	7 566	7 994	8 423	8 046	7 107	6 279	6 947	6 856	6 578
3. Agriculture	7 294	7 202	6 964	6 548	6 385	6 432	6 450	6 329	6 412	6 318
4. LULUCF	-59 340	-55 276	-60 996	-58 238	-61 801	-55 317	-39 351	-36 666	-33 614	-31 224
5. Waste	4 275	4 075	3 698	3 125	2 282	1 639	1 233	1 156	1 103	1 056
6. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Totalt (inkl. LULUCF)	11 863	17 859	7 136	8 014	2 322	-2 033	6 631	11 055	11 601	13 162
Totalt (exkl. LULUCF)	71 203	73 135	68 132	66 252	64 123	53 284	45 982	47 722	45 215	44 386

S 3. Översikt av utsläppstrender per sektor

Utsläppen av växthusgaser i Sverige per sektor visas i Tabell S.2 ovan. Nedan beskrivs utsläppstrender per sektor och andelen av totalen (exklusive LULUCF). Därefter följer en kort beskrivning över vilka källor som används för inventeringen för olika sektorer.

Utsläppen från energisektorn (CRT 1), inklusive transporter, var cirka 30 miljoner ton koldioxidekvivalenter 2023, vilket motsvarar 69% av de totala utsläppen. Trenden för perioden 1990 till 2023 visar på minskade utsläpp om 42%. Utsläppsminskningen beror huvudsakligen på minskad oljeanvändning för uppvärmning av bostäder och lokaler som ingår i ”Övrig-sektorn” (CRT 1A4). Inom ”Övrig-sektorn” har utsläppen minskat med 82% sedan 1990 till omkring 2 miljoner ton koldioxidekvivalenter 2023. Utsläppen i energisektorn var 1% lägre 2023 jämfört med 2022.

Energiindustrins (CRT 1A1) totala utsläpp var 8,4 miljoner ton koldioxidekvivalenter 2023, vilket är 15% lägre med jämfört med 1990. Energiindustrin domineras av el- och fjärrvärmeproduktionen (CRT 1A1a) som stod för 5,4 miljoner ton koldioxidekvivalenter 2023, vilket är 31% lägre än 1990. Utsläppen från el- och värmeproduktionen varierar mellan åren, framför allt på grund av vädrets (temperatur och nederbörd) påverkan på utsläppen. Utsläppen från el- och fjärrvärmeproduktionen var 4% lägre år 2023 jämfört med 2022, vilket berodde på minskad användning av fossila bränslen främst till följd av högre elpriser. Utsläpp från förbränning i raffinaderier (CRT 1A1b) och koksverk (CRT 1A1c) var 3,0 miljoner ton koldioxidekvivalenter 2023.

Utsläpp från förbränning inom tillverkningsindustrin och byggsektorn (CRT 1A2) minskade med knappt 2% mellan 2022 och 2023. Utsläppen har minskat med motsvarande 46% sedan 1990, men varierar mellan åren med förändrade produktionsvolymer som är kopplade till konjunktursvängningar. Utsläppsminskningen sedan 1990 beror till största delen på minskad oljeanvändning, som delvis kan förklaras av en övergång till el och biobränslen.

Utsläppen från transportsektorn (CRT 1A3) står för en tredjedel av de nationella utsläppen av växthusgaser. Utsläppen från transportsektorn var 13,9 miljoner ton koldioxidekvivalenter under 2023, varav ungefär 12,8 miljoner ton från vägtransporter. Utsläppen från transportsektorn minskade med 0,7% mellan 2022 och 2023. Utsläppen var 30% lägre 2023 jämfört med 1990. Utsläppsminskningen över tid i sektorn beror i hög grad på att andelen biobränsle som används inom vägtrafiken har ökat under perioden, och att fordonen har blivit mer energieffektiva. Utsläppsminskningen har dock samtidigt dämpats av att trafikarbetet har ökat.

Utsläppen av växthusgaser från industriprocesser och produktanvändning (CRT 2) uppgick till 6,6 miljoner ton koldioxidekvivalenter år 2023, vilket motsvarar drygt 19% 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 cirka 4,1% lägre 2023 jämfört med 2022. Trenden för perioden 1990–2022 visar på en stabilisering sedan 2011 med undantag för 2020 där utsläppen minskade till följd av produktionsstopp, delvis orsakade av covid-19-pandemin. Utsläppen hade 2023 minskat med knappt 9% jämfört med utsläppen 1990. Utsläppen från produktanvändning var dubbelt så stora 2023 jämfört med 1990, men visar på en minskande trend sedan 2004.

År 2023 var växthusgasutsläppen från jordbrukssektorn (CRT 3) ca 6,3 miljoner ton koldioxidekvivalenter vilket motsvarar drygt 14% av Sveriges totala utsläpp. Av dessa var cirka 58% metan, knappt 40% lustgas och resten koldioxid. Utsläppen från jordbrukssektorn har minskat med knappt 1 miljon ton koldioxidekvivalenter sedan 1990 vilket innebär cirka 13% lägre utsläpp. Minskningen beror framför allt på effektivisering och reducerad djurhållning (främst av mjölkkor och grisar) och i mindre utsträckning på minskad användning av mineralgödsel. Utsläppen har varit på en mer stabil nivå under den senaste tioårsperioden. Mellan 2022 och 2023 minskade utsläppen från sektorn med 1,5% (motsvarande 0,09 miljoner ton koldioxidekvivalenter). Det förklaras främst av låga skördar 2023 vilket gav lägre lustgasutsläpp från skörderester på jordbruksmark.

Nettoupptaget för sektorn markanvändning, förändrad markanvändning och skogsbruk (LULUCF - CRT 4) har under 2023 uppskattats till cirka 31 miljoner ton koldioxidekvivalenter. Mellan 2022 och 2023 har nettoupptaget minskat med 7 %. Större delen av nettoupptaget sker i kolpoolerna mineraljord och levande biomassa. Den dominerande markkategorin är skogsmark och det är där som det stora nettoupptaget av koldioxid sker. Skogsmark utgör 69% av Sveriges landareal. Inom denna marktyp har totala nettoupptaget varierat under hela perioden från 1990 till och med 2023 och i snitt varit runt 55 miljoner ton koldioxidekvivalenter. Sedan 2010 har dock nettoupptaget i levande biomassa minskat från omkring 60 miljoner ton koldioxid till runt 32 miljoner ton koldioxid 2023. Nettoupptaget i avverkade träprodukter har under samma period ökat något men var 2023 5 miljoner ton koldioxid vilket är en minskning sedan 2022. De största utsläppen inom sektorn kommer från organogen mark på alla markkategorier och 2023 var detta utsläpp knappt 13 miljoner ton koldioxid. Åkermark, Betesmark, Bebyggd mark och Våtmark har alla nettoutsläpp 2023. Nettoutsläppen från åkermark har dock en minskande trend.

Utsläppen från avfallssektorn (CRT 5) har minskat med ca 75% jämfört med 1990. 2023 var de totala utsläppen från avfallssektorn drygt 1 miljoner ton koldioxidekvivalenter, vilket motsvarar ungefär 2% av de totala växthusgasutsläppen. Från 2022 till 2023 minskade utsläppen med 4,3% till följd av fortsatt minskade utsläpp från avfallsdeponier. Utsläppen från avfallssektorn domineras av metangas från avfallsdeponier. Metangasutsläpp står för 67% av utsläppen i sektorn. Förbud har införts att deponera avfall och successivt har man övergått till framför allt förbränning av avfall för energiåtervinning. Utsläpp från förbränning av avfall för produktion av el och värme allokeras till energisektorn och inte till avfallssektorn.

Källorna som används för aktivitetsdata och/eller utsläppsdata i inventeringen för olika sektorer presenteras i Tabell S.3. Utsläppsstatistiken är hämtad direkt från dessa datakällor eller beräknade baserat på aktivitetsdata.

Tabell S.3. CRT-sektorer och datakällor som används i inventeringen.

CRT	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 och SPIN[1]-databasen 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

[1] Substances in Preparations in Nordic Countries

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	Enhet	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
NO_X	kt	287	256	221	192	167	146	115	114	110	104
NMVOC	kt	367	279	223	205	178	159	139	136	139	138
SO_2	kt	103	71	44	34	28	17	15	15	15	14
CO	kt	1 093	935	641	491	406	331	286	286	274	267

Utsläppen av kväveoxider (NO_X) var 104 kiloton år 2023. Energisektorn står för 75% av totalen medan industriprocesser och produktanvändningssektorn och jordbrukssektorn står för 13% respektive 12%. NOx-utsläpp har minskat med 64% sedan 1990. Mellan 2022 and 2023 minskade utsläppen med knappt 4,8%. Minskningen 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 bidragit till minskningen.

Utsläppen av flyktiga organiska ämnen utom metan (NMVOCs) var 138 kton år 2023. 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 bidrog med 47% respektive 30% av Sveriges totala utsläpp av NMVOC. Jordbrukssektorn bidrog med ca 22% av utsläppen. NMVOC-utsläpp har minskat kraftigt med 62% sedan 1990. Under 2023 minskade utsläppen med 1% jämfört med 2022. Den största minskningen av NMVOCs har skett inom transportsektorn där utsläppen 2023 är cirka 91% lägre än 1990. Här minskade utsläppen med cirka 2% mellan år 2022 och 2023. Inom produktanvändningssektorn har NMVOC-utsläppen minskat med 41% jämfört med 1990. De stora minskningarna inom båda sektorerna beror på introduktionen av nya avgasreningskrav för fordon samt minskade utsläpp från användning av lösningsmedel.

Utsläppen av kolmonoxid (CO) har minskat med 76% sedan 1990 och utgjorde totalt cirka 267 kton 2023. Utsläppen har minskat med knappt 3% mellan 2022 och 2023. Nästan 89% av kolmonoxidutsläppen kommer från energisektorn, varav 29% från transporter och 52% från småskalig uppvärmning av bostäder, lokaler och inom jordbrukssektorn. Resten av utsläppen kommer från produktanvändningssektorn, där stod metallindustrin för 5,4% och massa- och pappersindustrin för 11%. Utsläppen av CO har minskat kraftigt genom åren. Detta beror på att nya bilar är försedda med katalysatorer, som omvandlar CO och kolväte till CO_2 och vattenånga.

Utsläppen av svaveldioxid (SO_2) var 14 kton år 2023 vilket innebär 86% lägre utsläpp jämfört med 1990. Mellan 2022 och 2023 minskade utsläppen med cirka 2%. År 2023 kom drygt hälften (56%) av utsläppen från industriprocesser och produktanvändningssektorn, såsom metallproduktion och pappersmassaindustrin. Utsläpp från energisektorn, framför allt från el- och fjärrvärmeproduktion och tillverkningsindustrier och konstruktionssektorn, utgjorde samma år cirka 43%. Den långsiktiga reduktionen av utsläppen beror främst på en övergång till bränslen med lägre svavelhalt samt att skatt på svavel i olja och 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 (United Nations 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 net emissions within the union by at least 55 percent by 2030 compared to 1990. A global stocktake of the progress towards achieiving the goal of the agreement takes place every five years, from 2023 and onwards. Principles for monitoring and reporting of the parties' nationally determined contributions were established in Paris. A year later, a sufficient number 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, was adopted at COP24 in Katowice and COP26 in Glasgow. This means that for the first time there is a common set of reporting guidelines for monitoring and reporting for all countries. The first reporting under the Paris Agreement takes place in 2024.

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 Kyoto protocol has had two commitment periods 2008 – 2012 ans 2013 – 2020.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. 2022 the last greenhouse gas inventory under the Kyoto protocol was submitted by Annex-I parties and for parties with a commitment this submission will form the base for the accounting and compliance. During autumn 2022 the final review under the Kyoto protocol took place. In 2023, the actual fulfillment took place and Annex -1 parties with a commitment have reported a "True-up period report". EU and all member states have fulfilled the commitment to reduce the emissions with 20% compared to 1990.

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 Document (NID) for the year 2025, constitutes the annual submission under UNFCCC and the Paris agreement. 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 and also under the Paris agreement. It contains national greenhouse gas emission inventories for the period 1990 to 2023, 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 in some cases the updated 2006 guidelines from 2019, and also the IPCC supplementary guidelines for Wetlands (*the 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*). This National Inverntory Report is also reported under EU legislation (Governance reulation 20178/1999/EG) and is the basis for follow-up against Sweden's commitment under the EU's climate package, Fit for 55.

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 2023, 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 (CRT 1) and industrial processes and product use (CRT 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 (CRT) as requested by the UNFCCC together with this report.

ES 2. Summary of national emission and removal trends per gas

Total greenhouse gas emissions in Sweden excluding LULUCF, expressed in CO_2-equivalents, were about 44.4 million tonnes in 2023, excluding LULUCF (Table ES.1 and Table ES.2). Total emissions 2023 have decreased by a bit less than 2% compared to 2022 and decreased by about 38% compared to 1990. Below, emission trends per gas compared to the total (excluding LULUCF) are first described, followed by brief descriptions of the trend within LULUCF.

The total emissions of carbon dioxide (CO_2) 2023 were 35.5 million tonnes of carbon dioxide equivalents which corresponds to about 80% of the total emissions of greenhouse gases. The energy sector, including transport, accounted for 84% of the overall carbon dioxide emissions, which makes it the largest source of carbon dioxide in Sweden. The emissions of CO_2 2023 were 38% lower than 1990 and nearly 2% lower than 2022.

Methane (CH_4) emissions were 4.6 million tonnes of carbon dioxide equivalents by 2023, which corresponds to approximately 10% of total greenhouse gas emissions. Methane emissions are mainly from agriculture, landfills and burning of fossil fuels in the energy sector. Since 1990, methane emissions have decreased by 45%, mainly due to measures in the waste sector. The agricultural sector also shows reduced emissions. Between 2022 and 2023, the total methane emissions have decreased by 1.4%.

Nitrous oxide emissions (N_2O) were 3.4 million tonnes of carbon dioxide equivalents in 2023 and accounted for about 8% of total greenhouse gas emissions. Emissions of nitrous oxide originate mainly from the agricultural sector (approximately 75%). Since 1990 there has been a decrease in N_2O emissions with about 28%. In 2023 the emissions of N_2O decreased with 3.5% compared to 2022.

Emissions of fluorinated greenhouse gases (PFCs, HFCs and SF_6) were 0.8 million tonnes of carbon dioxide equivalents by 2023, which accounts for about 2% of total greenhouse gas emissions. The emissions in 2023 are 33% 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 decrease in the later years. Emissions dropped by 7% between 2022 and 2023.

The net removal within the land use, land-use change and forestry (LULUCF) sector remained at a relatively high level in 2023 and was 31 million tonnes of carbon dioxide equivalents. This means that the total emissions of greenhouse gases in Sweden, including LULUCF, were around 13 million tonnes of carbon dioxide equivalents in 2023 (Table ES.1 and Table ES.2). The size of the net removal depends mainly on the ratio between the carbon storage in growing forest and soil and the loss (harvest and natural decomposition of organic matter). As long as the carbon storage (growth) is greater than the loss, a net removal is obtained. The carbon stock change on forest land and the living biomass pool, dominates the result in the sector. In addition to a large net removal of carbon dioxide, emissions of methane and nitrous oxide from the sector are also included. The total net removal has varied over time but is now approximately 47% lower than in 1990.

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

GREENHOUSE GAS EMISSIONS	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
CO_2 incl. LULUCF	-3 660	2 514	-7 793	-6 111	-10 357	-13 511	-4 340	263	840	2 649
CO_2 excl. LULUCF	57 417	59 487	54 892	53 787	53 029	43 310	36 622	38 568	36 121	35 543
CH_4 incl. LULUCF	9 089	9 019	8 434	7 628	6 580	5 766	5 332	5 284	5 247	5 179
CH_4 excl. LULUCF	8 473	8 418	7 847	7 055	6 045	5 260	4 811	4 759	4 711	4 644
N_2O incl. LULUCF	5 813	5 580	5 309	4 930	4 801	4 567	4 653	4 572	4 625	4 506
N_2O excl. LULUCF	4 692	4 484	4 206	3 842	3 751	3 569	3 562	3 458	3 494	3 371
HFCs	6	129	725	1 045	1 064	1 059	889	852	817	758
PFCs	511	478	338	366	169	32	59	45	34	31
SF6	105	139	122	156	65	55	38	40	39	38
NF3	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Unspecified HFCs and PFCs	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total (incl. LULUCF)	11 863	17 859	7 136	8 014	2 322	-2 033	6 631	11 055	11 601	13 162
Total (excl. LULUCF)	71 203	73 135	68 132	66 252	64 123	53 284	45 982	47 722	45 215	44 386

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

GHG SOURCE & SINK CATEGORIES	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
1. Energy	52 409	54 292	49 476	48 156	47 411	38 105	32 020	33 290	30 844	30 435
2. Industrial Processes and Product Use	7 226	7 566	7 994	8 423	8 046	7 107	6 279	6 947	6 856	6 578
3. Agriculture	7 294	7 202	6 964	6 548	6 385	6 432	6 450	6 329	6 412	6 318
4. LULUCF	-59 340	-55 276	-60 996	-58 238	-61 801	-55 317	-39 351	-36 666	-33 614	-31 224
5. Waste	4 275	4 075	3 698	3 125	2 282	1 639	1 233	1 156	1 103	1 056
6. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total (incl. LULUCF)	11 863	17 859	7 136	8 014	2 322	-2 033	6 631	11 055	11 601	13 162
Total (excl. LULUCF)	71 203	73 135	68 132	66 252	64 123	53 284	45 982	47 722	45 215	44 386

ES 3. Summary of national emission and removal trends per sector

The emissions of greenhouse gases in Sweden per sector are shown in Table ES.2 above. Emission trends per sector and the share of the total (excluding LULUCF) are described below. This is followed by a brief description of which sources are used for the inventory for various sectors.

Emissions from the energy sector (CRT 1), including transport, were approximately 30 million tonnes of CO_2-equivalents in 2023, which corresponds to about 69% of the overall national greenhouse gas emissions. The trend for the period 1990-2023 shows a general reduction in emissions of approximately 42%. 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” (CRT 1A4). Emissions in “Other Sectors” have decreased by 82% to approximately 2 million tonnes of CO_2-equivalents in 2022. Emissions decreased by 1% between 2022 and 2023 in the energy sector.

Greenhouse gas emissions from energy industries (CRT 1A1) were approximately 8.4 million tonnes in 2023, which is 15% lower compared to 1990. The energy industries are dominated by electricity and district heating production (CRT 1A1a) with emissions of 5.4 million tonnes of CO_2-equivalents in 2023, which is 31% 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 were 4% lower in 2023 compared to 2022, due to decreased usage of fossil fuels mainly as a result of higher electricity prices. Emissions from combustion in Petrolium Refining (CRT 1A1b) and Manufacture of solid fuels (CRT 1A1c) were 3.0 million tonnes of carbon dioxide equivalents in 2023.

Emissions from manufacturing industries and construction (CRT 1A2) decreased with 2% in 2023 compared to the previous year. These emissions have decreased by 46% compared to 1990, but generally fluctuate with production volumes that are closely related to the economic development. The decrease in emissions since 1990 is mainly due to the decreased use of oil products, which can partly be explained by a shift towards electricity and biofuels.

Emissions from the transport sector (CRT 1A3) correspond to approximately one third of the national emissions of greenhouse gases. In 2023, emissions were 13.9 million tonnes, of which approximately 12.8 million tonnes were from road transportation. Emissions from the transport sector decreased by 0.7% between 2022 to 2023. Emissions were 30% lower in 2023 compared to 1990. The reduction in emissions in the sector during the period is primarily due to the fact that the proportion of biofuels used in road traffic has increased during the period, and that vehicles have become more energy efficient. However, the reduction in emissions has been dampened by an increase in traffic.

Greenhouse gas emissions from the industrial processes and product use (CRT 2) were 6.6 million tonnes CO_2-equivalents in 2023, representing approximately 19% 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 about 4.1% lower in 2023 compared to 2022. The trend for the period 1990-2022 shows a stabilization since 2011 with the exception of 2020 where emissions decreased as a result of production stoppages, partly caused by the covid-19 pandemic. Emissions decreased by 9% compared to 1990. Emissions from product use were twice as high in 2023 compared to 1990, although they show a decreasing trend since 2004.

In 2023, the total greenhouse gas emissions from the agricultural sector (CRT 3) were about 6.3 million tonnes of CO_2-equivalents, which corresponds to 14% of the total greenhouse gas emissions in Sweden. Of these, about 58% were methane, 40% nitrous oxide and the rest CO_2. Emissions from the agricultural sector have decreased by nearly 1 million tonnes of CO_2-equivalents since 1990, which means about 13% lower emissions. The reduction is due to several factors such as reduced number of animals (especially dairy cows and pigs) and decreased use of nitrogen-mineral fertilizers (until around 2010). Between 2022 and 2023, emissions from the sector decreased by about 1.5% (corresponding to about 0.1 million tons of CO_2-equivalents). This was mainly explained by low harvests in 2023, which resulted in lower nitrous oxide emissions from crop residues on agricultural land.

In 2023, the total net removal in the sector land use, land-use change and forestry (LULUCF) was estimated to 31 million tonnes CO_2-equivalents. During the period 1990 until 2023, total net removals was on average 55 million tonnes of CO_2- equivalents. Between 2022 and 2023 the total net removal decreased with 7%. The majority of the net removals are in the carbon pools mineralsoils and living biomass and the dominating category is forest land. Forest land accounts for 69% of Sweden's land area. Within forest land, the total net removal has varied during the period from 1990 to 2023 and has been on averaged 55 million tonnes of CO_2-equivalents. Since 2010 the net removal in living biomass for forest land has decreased from about 60 million tonnes of CO_2-eq to about 32 million tonnes of CO_2-equivalents in 2023. The total net removal in harvested wood products has increased slightly during the same period but with a small decrease in 2023 and is 5 million tonnes of CO_2- equivalents 2023. The highest net emissions are from organic soils on all land categories and in 2023 the net emissions were almost 13 million tonnes of CO_2- equivalents. Cropland, Grassland, Settlement and Wetlands all constituted net emissions in 2023. The emissions at croplands show a decreasing trend.

Emissions from the waste sector (CRT 5) have decreased by about 75% compared to 1990. In 2022, total emissions from the waste sector were just over 1.05 million tonnes of carbon dioxide equivalents, which corresponds to approximately 2% of total greenhouse gas emissions. From 2022 to 2023, emissions have been reduced by 4.3% due to continued reduced emissions from landfills. Emissions from the waste sector are dominated by methane gas from waste landfills. Methane emissions account for 66% of emissions. A ban has been introduced on landfills 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.

The sources used for activity data and/or emission data in the inventory for different sectors are presented in Table ES.3. Emission statistics are taken directly from these data sources or calculated based on activity data.

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

CRT	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 and the SPIN[2] database,
		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

2 Substances in Preparations in Nordic Countries

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 emissions but reported separately. They are shown in Table ES.4.

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

Gas	Unit	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
NO_X	kt	287	256	221	192	167	146	115	114	110	104
NMVOC	kt	367	279	223	205	178	159	139	136	139	138
SO_2	kt	103	71	44	34	28	17	15	15	15	14
CO	kt	1 093	935	641	491	406	331	286	286	274	267

Emissions of nitrogen oxides (NO_X) were about 104 kt in 2023. The energy sector accounted for 75% of the total emissions, while the industrial processes and product use sector as well as the agricultural sector accounted for about 13% and 12% respectively. The emissions in 2023 were about 64% lower compared to 1990 and nearly 4.8% lower than in 2022. This reduction is mainly due to restrictions of the EU road vehicle emission regulation standards. The increased use of district heating and the "NO_X charge" introduced in the early 1990s have also contributed to the reduction in emissions of NO_X.

A total of about 138 kt of non-methane volatile organic compounds (NMVOCs) were emitted in 2023. About 47% of the emissions derived from the industrial processes and product use sector. The energy sector and the agricultural sector contributed with 30% and 22%, respectively. Since 1990, NMVOC emissions have decreased by 62%. Emissions in 2023 are about 1% lower compared to 2022. The largest reduction comes from the transport sector, in which emissions decreased by 91% compared to 1990 and by 2% compared to 2022. Emissions in the product use sector have been reduced by 41% since 1990. The main reason for the reduction is the introduction of stricter emission standards in the EU regulation for road vehicles and lower NMVOC emissions from solvents.

The aggregated emissions of carbon monoxide (CO) have decreased by 76% since 1990 and were around 267 kt in 2023. Emissions in 2023 were 3% lower than in 2022. About 89% of CO emissions came from the energy sector, of which 29% came from the transport sector and 52% from small-scale combustion in residential heating, premises and in the agricultural sector. The rest of the emissions derived from metal industry (5.4%) and pulp and paper industry (11%). Emissions of CO have decreased substantially over the years due to new fuel-driven vehicles sold in Sweden that are equipped with catalytic converters that convert CO and unburned hydrocarbons to CO_2 and water vapor.

Sulphur dioxide emissions (SO_2) were about 14 kt in 2023 and have decreased by 86% since 1990. Between 2022 and 2023 emission decreased by about 2%. More than half of SO_2 emissions (56%) are derived from the industrial processes and product use sector, mainly from metal production and the pulp industry. The energy sector was responsible for 43% of emissions in 2023, in which electricity and district heating production and manufacturing industries and construction were the main contributors. The reduction of emissions since 1990 is mainly due to a transition to lower sulphur fuels, as well as tax on sulphur in fossils fuels introduced in 1991.

PART 1: ANNUAL INVENTORY SUBMISSION 2024

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 (CRT) and a National Inventory Document (NID). The submission is prepared in accordance with the reporting guidelines 24/CP.19 under the UNFCCC.

This report constitutes Sweden's NID for submission 2025. The report contains information on Sweden's inventories for all years from 1990 to 2023, 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). In autumn 2020 the second commitment period of the Kyoto Protocol came into force just before the last year of the commitment period (2013 – 2020) ended. During 2023 the compliance of the second commitment period took place.

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).

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 National emission targets

1.1.3.1 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 (Figure 1.1) and a climate policy council. For more information about the climate policy framework, see Sweden’s Seventh National Communication on Climate Change.

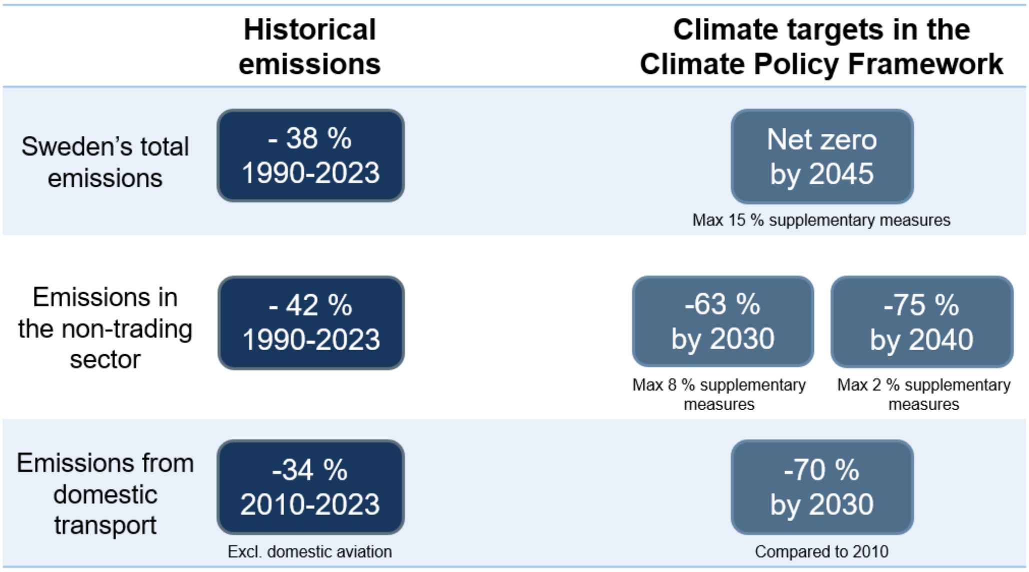

Figure 1.1. Sweden's national targets and historical emission up to 2023.

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 to 2010. Domestic aviation[3] 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 countries in accordance with article 6 in the Paris agreement and negative emissions (for example bio-CCS). International accounting guidelines will be followed in order to account for these measures.

1.1.3.2 EFFORT SHARING DECISION: EU MEMBER STATES EMISSION TARGETS

The EU has decided on climate targets that apply to the entire Union. All countries that are part of the EU must participate and contribute to meet the climate goals and the EU's contribution to the Paris Agreement. The EU's overall climate goal is to be climate neutral by 2050 at the latest. In 2030, the EU's net emissions must be at least 55 percent lower than they were in 1990.

[3] The emissions only includes CO_2.

The Effort Sharing Regulation (ESR) establishes binding annual greenhouse gas emission targets for Member States for the period 2021–2030. These targets concern emissions from sectors not included in the EU Emissions Trading System (EU ETS) such as transport, buildings, agriculture and waste. In order to reach the 55 percent target, emissions in the ESR sector must be reduced by 40 percent compared to 2005. This target has been distributed among the member countries based on the countries' GDP/capita level. According to the distribution, Sweden will reduce the greenhouse gas emissions by 50 percent by 2030 compared to 2005.

1.2 Institutional arrangements

Under Article 5 of the Kyoto Protocol each party in Annex 1 had 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 Monitoring Mechanism Regulation was replaced in 2018 by the Governance regulation (2018/1999/EG) and from 2023 the new rules applies to the greenhousegas inventory. The system is also relevant for the National inventory arrangements decided on in 24/CP.19 and also for the Paris agreement in accordance with 18/CMA.1.

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 national system has now been updated to fulfil the requirements under the Paris agreement and under EU law.

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 second commitment period under the Kyoto Protocol and the EU Monitoring Mechanism Regulation 525/2013/EC. The ordinance has been updated again and now to fullfill the requirements under the Paris agreement and under EU law, the Governance regulation (2018/1999). It also includes other improvements needed on the national level. The new ordinance came into force in 2021, 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 Climate and Enterprise, the Swedish Environmental Protection Agency and other government agencies and consultants. Sections 10-27 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 1.2 and Table 1.1 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.

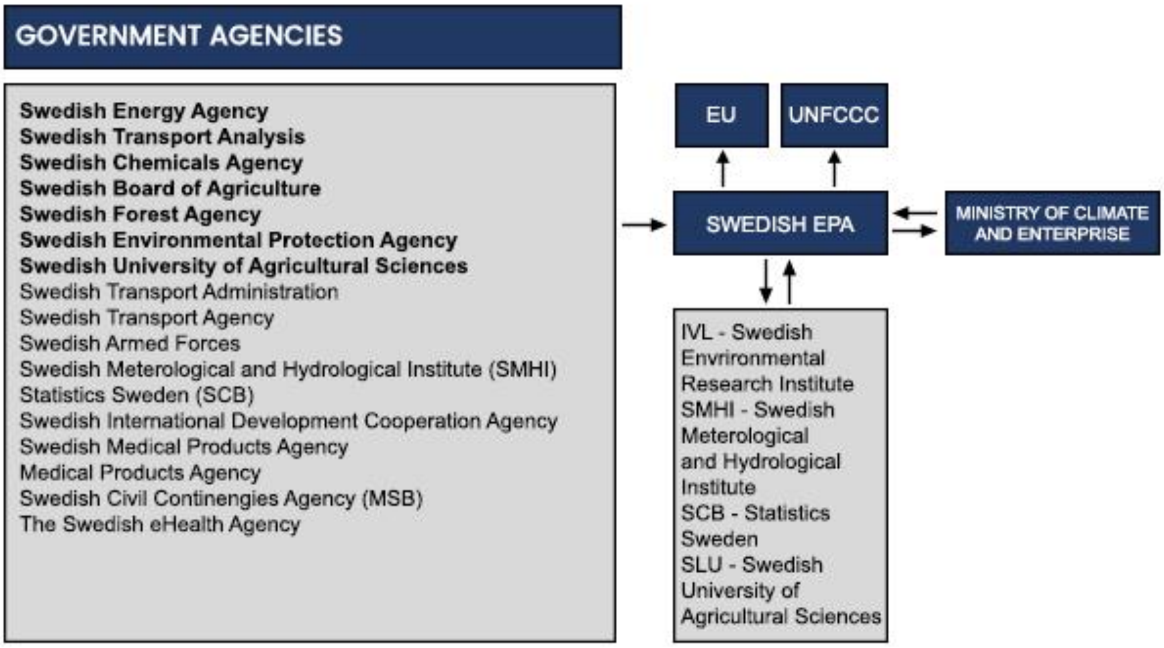

Figure 1.2. The Swedish national system on climate reporting.

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 Climate and Enterprise 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 Swedish Ministry of Climate and Enterprise and – on behalf of the Swedish Ministry of Climate and Enterprise – 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 Mr. Joel Bengtsson.

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), the Swedish EPA.	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)[4], 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.

After a procurement in 2022 the contract with the consortium SMED was renewed for the period (2023 – 2030). The structure of the consortium is the same as the previous period with agency agreements for the national agencies (SMHI, SCB and SLU) and a

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

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 inventory except for some parts of the introduction, the trend section in the NID (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 agricultural 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 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 methodological guidelines drawn up by the Intergovernmental Panel on Climate Change (IPCC) and the UNFCCC reporting guidelines. 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. 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.

Figure 1.3. Structure of the quality system.

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[5]. The QA/QC plan also includes a scheduled time frame describing the different stages of the

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

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.

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[6]. 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). Source-specific quality assurance procedures for Tier 2 and Tier 3 methodologies are described in the QC checklists (appendix 5 to the manual) and in the work documentation (appendix 4). It also includes descriptions of roles and responsibilities, of databases and models, work manuals for each CRT 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.

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

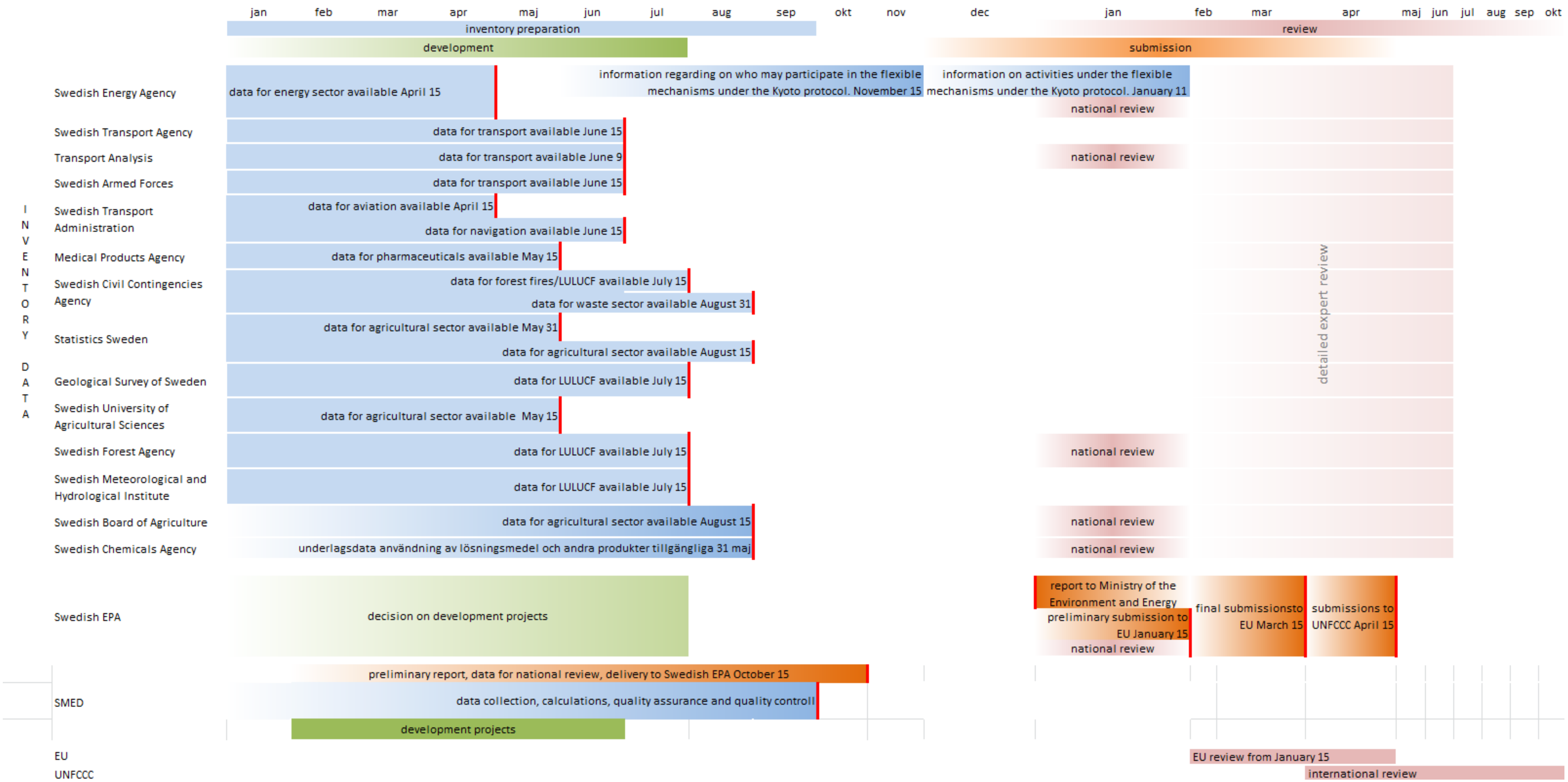

Figure 1.4. Overview of the Swedish GHG inventory planning, preparation and management.

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 2022 submission. In addition, SMED comprises several national experts and senior researchers involved in specific development projects.

Sweden actively takes part in the UNFCCC annual review process of greenhouse gas inventories. SMED has a few lead reviewers and at least one expert reviewer for each sector (Energy, Indusustrail Processes and Product Use, Agriculture, LULUCF, and Waste). Experience gained from participation in the UNFCCC reviews feeds into the process of improving the Swedish greenhouse gas inventory and helps to keep up-to-date when changes are made to relevant UNFCCC and IPCC guidelines.

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 which 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 collects data and information (as set out in Ordinance on Climate Reporting (2014:1434)) for the greenhouse gas emissions and removals 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 review process.

1.3.4.1 ENERGY- STATIONARY COMBUSTION

Energy industries: Data from Quarterly fuel statistics (KvBr), 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 (KvBr), a sample survey conducted by Statistics Sweden. In some cases data from the Energy use in the manufacturing industry (ISEN) or ETS is used as a complement. All data is at plant level and by fuel type. For some petrochemical plants and cement industry plants, data from the European Union Emission Trading Scheme (ETS) is used.

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 Swedish Energy Agency, and emission factors provided by 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 Swedish Transport Administration, the Swedish Transport Agency 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, hydrogen production, and burning of make-up coke at refineries, activity data and CO_2 emissions from ETS are used for 2005 and later. For earlier years, national statistics and implied emission factor for CO_2 are used. For non-CO_2 emissions, emissions from environmental reports (if available) or 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 Swedish Transport Administration.

For flaring of coke oven gas at primary iron and steelmaking facilities, amounts of flared gas are obtained from environmental reports, and national emission factor for CO_2 is applied. Fugitive emissions from coke production at the same facilities are calculated from coke production values provided in environmental reports.

Emissions from charcoal production are calculated based on production statistics from Food and Agriculture Organization of the UN.

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, data from the SPIN database (Substances in Products in the Nordic Countries), 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), Statistics Sweden (SCB) and the Swedish environmental reporting portal 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, provided estimates of deposited organic fractions of industrial waste until year 2005.

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

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).

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

CRT		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.
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 Association for most years 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 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.

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 CRT 1 and 2 and to ensure that total emissions are accounted for across the entire inventory, by facility. When allocating emissions to respective CRT 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 CRT 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 is used on an annual basis.

When inventory data are compiled by SMED, detailed diagrams of trends are produced, together with tables showing the detailed data and a comparison with last years submission. A review and QA/QC of trends and recalculations is then performed sectorwise by sector experts at the Swedish Environmental Protecion Agency and from SMED, at meetings where questions and explanations of data, trends and recalculations are discussed. The review meetings are documented, including if any revisions to the data are needed.

When reviewed and final data from the database have been imported into the CRT tables, SMED's inventory staff responsible for the reporting database checks that the tables are correct.

The NID is reviewed by the SMED coordinator before delivery to the Swedish EPA.

Before delivery of the inventory to the Swedish EPA the SMED coordinator checks serve as both quality control and quality assurance in accordance with the 2006 IPCC guidelines.

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 NID and the CRT 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.

Together with Denmark, Finland, Norway and Island, Sweden arranges annual expert meetings 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 10).
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 and March 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 2021 are reported in early 2023.

1.3.5.4 DATA STORAGE

A system for handling data related to the inventory, entitled Technical Production System (TPS)[7], 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 CRT-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 CRT Reporter for submission to the EU and UNFCCC. CRT-tables are then generated using the export function in CRT 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 described 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

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

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 NID are continuously addressed in response to questions raised by national experts during the national peer review, and in response to previous ERT recommendations.

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

Sector/CRT category	Implemented improvement	Quality criteria (TCCCA)	Need identified by	Reference to NID section
1A2gvii/1A3e/ 1A4a/1A4b/1A4c	Revised operation hours	Accuracy	National experts	3.2.15/3.2.21-23
1.B.2.B.4	Leakage emissions from LNG terminals are included in accordance with 2019 Refinement.	Completeness	National experts	3.3.2
1.B.2.B.6	Post-meter emissions are included in accordance with 2019 Refinement.	Completeness	National experts	3.3.2
3.D.a.3. Urine and dung deposited by grazing animals	Emission factors are updated in accordance with 2019 Refinement.	Accuracy, transparency	National experts	5.4.1.2.9
4.A-F.2	Re-evaluation of CSC factors for land use change categories.	Accuracy, transparency	ERT	NID. Annex 3:2
5.A.1	Updated DOC values for year 2020	Accuracy	National experts	7.2.2.5
5.D.1	Implementation of the IPCC default value of Bo and other improvements for CH_4	Accuracy	ERT	7.5.1.5

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.

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)[8], environmental reports[9], 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)[10]. In some cases, the methodologies prescribed in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines)[11] and the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (Good Practice Guidance)[12], IPCC´s supplementary guidelines for Wetlands (WL GL[13]) 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).[14]

For an overview of the methods used in all sectors, see Summary 3 in the CRT tables and in each sector section, where a detailed explanation on data sources and methodologies is given.

The combined effect of various greenhouse gases has been calculated using global warming potential factors (GWP) according to decision 5/CMA.3 to the Paris Agreement and presented in Annex 8.4 to the NID. 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. Decision 5/CMA.3 refers to the use of GWP from the Fifth Assessement report of the IPCC.

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

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[8] See Annex 8.1

[9] See Annex 8.3

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

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

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

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

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

1.5 Brief description of key categories, including for UNFCCC

1.5.1 GHG inventory (including and excluding LULUCF)

According to the 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 using two different approaches. The difference between the two approaches is that Approach 2 assessments besides magnitudes also account for emission uncertainties, whereas Approach 1 does not. 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 results from key category analysis by both approaches are summarized in Table 1.4 below and are also presented in each source category section (3-7) as well as in CRT table 7. In Annex 1, the methodology is discussed in more detail. Detailed background tables (Table A1.1 – A1.8), according to the 2006 IPCC Guidelines and the 2019 refinements, are also found in Annex 1.

Table 1.4. Approach 1 and approach 2 key categories 2023 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			L,T	L,T
1 A 1 a Public Electricity and Heat Production: Gaseous Fuels	CO_2	L,T		L,T	
1 A 1 a Public Electricity and Heat Production: Liquid Fuels	CO_2	L,T		L,T	T
1 A 1 a Public Electricity and Heat Production: Peat	CO_2	T	T	L,T	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 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: Other Fuels	N_2O			L	
1 A 1 b Petroleum refining: Gaseous Fuels	CO_2	L,T		L,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		L	L
1 A 2 a Iron and Steel: Gaseous Fuels	CO_2			L,T	
1 A 2 a Iron and Steel: Liquid Fuels	CO_2	L,T		L,T	L
1 A 2 a Iron and Steel: Solid Fuels	CO_2	L,T		L,T	L
1 A 2 b Non-ferrous metals: Liquid Fuels	CO_2			L	
1 A 2 c Chemicals: Gaseous Fuels	CO_2			L,T	
1 A 2 c Chemicals: Liquid Fuels	CO_2	L,T		L,T	
1 A 2 c Chemicals: Other Fuels	CO_2				T

IPCC Source Category	GHG	Including LULUCF		Excluding LULUCF	
		App. 1	App. 2	App. 1	App. 2
1 A 2 c Chemicals: Solid Fuels	CO_2			T	
1 A 2 d Pulp, Paper and Print: Liquid Fuels	CO_2	L,T	T	L,T	L,T
1 A 2 d Pulp, Paper and Print: Other Fuels	CO_2		L		L
1 A 2 d Pulp, Paper and Print: Solid Fuels	CO_2	T		T	
1 A 2 e Food Processing, Beverages and Tobacco: Gaseous Fuels	CO_2	T		L,T	
1 A 2 e Food Processing, Beverages and Tobacco: Liquid Fuels	CO_2	T		L,T	T
1 A 2 e Food Processing, Beverages and Tobacco: Solid Fuels	CO_2			T	
1 A 2 f Non-metallic minerals: Liquid Fuels	CO_2	L,T		L,T	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	T	L,T	L,T
1 A 2 g vii Off-road vehicles and other machinery: Liquid Fuels	CO_2	L,T	L	L,T	L
1 A 2 g viii Other: Liquid Fuels	CO_2	L,T	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,T
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				L,T
1 A 3 b i Road Transportation, Cars: Gasoline	CH_4	T	T	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	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: 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				L
1 A 3 b iv Road Transportation, Motorcycles: Gasoline	CO_2			L	
1 A 3 d Domestic Navigation: Gas/Diesel Oil	CO_2	L,T		L,T	
1 A 3 d Domestic Navigation: Residual Oil	CO_2	L		L	L
1 A 3 e Other Transportation: Total	CO_2	L,T	T	L,T	L,T
1 A 4 a Commercial/Institutional: Gaseous Fuels	CO_2	L,T		L,T	L
1 A 4 a Commercial/Institutional: Liquid Fuels	CO_2	L,T	T	L,T	T
1 A 4 b Residential: Biomass	CH_4		T		L,T
1 A 4 b Residential: Biomass	N_2O				L
1 A 4 b Residential: Liquid Fuels	CO_2	L,T	T	L,T	L,T
1 A 4 c Agriculture/Forestry/Fisheries: Domestic Heating Oil	CO_2	T	T	T	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		T	
1 B 2 a Oil	CO_2	T		T	
1 B 2 c Venting and flaring	CO_2			T	T

IPCC Source Category	GHG	Including LULUCF		Excluding LULUCF	
		App. 1	App. 2	App. 1	App. 2
2 A 1 Cement Production	CO_2	L,T	L	L,T	L
2 A 2 Lime Production	CO_2	L		L,T	
2 B 10 Other	CO_2	L,T		L,T	L
2 B 10 Other	N_2O				T
2 B 2 Nitric Acid Production	N_2O	T		T	T
2 C 1 Iron and Steel Production	CO_2	L,T	L	L,T	L
2 C 2 Ferroalloys production	CO_2	L		L,T	
2 C 3 Aluminium production	CO_2	L		L	
2 C 3 Aluminium production	PFCs	T		T	T
2 C 7 Other	CO_2	L		L	
2 D 1 Lubricant use	CO_2	L	L	L	L,T
2 F 1 Refrigeration and air conditioning	HFCs	L,T	L,T	L,T	L,T
2 H 1 Pulp and paper	N_2O			L	
3 A 1 Dairy cattle	CH_4	L,T	L,T	L,T	L,T
3 A 1 Non-dairy cattle	CH_4	L,T	L,T	L,T	L,T
3 A 2 Sheep	CH_4			L	L
3 A 4 Horses	CH_4	L	L	L	L
3 A 4 Raindeer	CH_4			L	L
3 A 4 Swine	CH_4				L
3 B 1 Dairy cattle	CH_4			L	L
3 B 1 Dairy cattle	N_2O		T	T	L,T
3 B 1 Non-dairy cattle	CH_4		L	L	L,T
3 B 1 Non-dairy cattle	N_2O			L	L
3 B 4 Poultry	CH_4				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	L	L	L,T
3 D a 2 c Other organic fertilizers applied to soils	N_2O				L,T
3 D a 3 Urine and dung deposited by grazing animals	N_2O		L		L
3 D a 4 Crop residues applied to soils	N_2O	L	L,T	L,T	L,T
3 D a 5 Mineralization/immobilization associated with loss/gain of soil organic matter	N_2O				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	L,T	L	L,T
3 G Liming	CO_2	L		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		-	-

IPCC Source Category	GHG	Including LULUCF		Excluding LULUCF	
		App. 1	App. 2	App. 1	App. 2
4 A 2 3 Wetlands converted to forest land	CO_2	L,T	L,T	-	-
4 A 2 4 Settlements converted to forest land	CO_2	L,T	T	-	-
4 A Drained organic soils	CH_4	L	L	-	-
4 A Drained organic soils	N_2O	L	L	-	-
4 B 1 Cropland remaining cropland	CO_2	L,T	L,T	-	-
4 B 2 1 Forest land converted to cropland	CO_2	L,T	L,T	-	-
4 B Drained organic soils	CH_4	L	L,T	-	-
4 C 1 Grassland remaining grassland	CO_2	L	L	-	-
4 C 2 1 Forest land converted to grassland	CO_2	L,T	L,T	-	-
4 C 2 2 Cropland converted to grassland	CO_2	T	T	-	-
4 D 1 1 Peat extraction remaining peat extraction	CO_2	L,T	L,T	-	-
4 D 2 3 1 Forest converted to wetlands	CO_2	T	T	-	-
4 E 1 Settlements remaining settlements	CO_2	L,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 F 2 Land Converted to Other Land	CO_2	T	T	-	-
4 G Total HWP from domestic harvest	CO_2	L	L	-	-
5 A 1 Managed waste disposal sites	CH_4	L,T	L,T	L,T	L,T
5 C 1 Waste Incineration	CO_2			L	
5 D 1 Domestic wastewater	CH_4	L	L	L	L,T
5 D 1 Domestic wastewater	N_2O	L	L	L	L

L=Level, T=Trend.

1.6 Information on QA/QC

See section 1.3.

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 (CRT 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 (CRT 2)
- data on sold medicines from Swedish eHealth Agency.
- data from the Swedish portal for environmental reporting (CRT 2, 5C)

A thorough confidentiality analysis, using a P%-rule[15], 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 CRT-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 not 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 CRT-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

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

stationary combustion (CRT 1) and industrial processes and product use (CRT 2), which have been classified with the notation key Confidential (C).

Sweden is working continuously with improving the transparency of our reporting and strives to minimize the extent of confidentiality in inventory data. This is done by contacting all companies that causes confidentiality issues by email and/or phone. This has led to a decrease in the number of companies causing confidentiality issues. Whenever consent has not been acquired and the companies have a large impact on the number of confidential data points, Sweden also set up meeting with the companies. Unfortunately, this did not change the outcome for submission 2025, since there are a few companies not being able to consent to publishing of the data due to their internal policy. In submission 2025, allocation between codes were again implemented in order to reduce the amount of "C" values in the CRT-tables (affecting CRT codes 1A1b and 1B).

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".

The methodology is based on 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.

Uncertainties have been estimated for the base year 1990 and 2023 for the direct greenhouse gases CO_2, CH_4, and N_2O, and for F-gases. Uncertainties are presented as 95% confidence intervals.

When reporting the results in the NID, 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 aim at showing what parts of the inventory are especially important and/or weak. This is important information when planning future inventories and, above all, when 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. In every development project, uncertainties in estimated activity data and emission factors are overhauled and revised when needed.

1.7.1.1 RESULTS

The results of the uncertainty calculations according to the approach 1 for the base year (1990) and 2023 are presented in Annex 7. The overall uncertainty for the base year and latest reporting year, 2023 GHG emissions (in CO_2-eq., excl. LULUCF) in Sweden is calculated to be ±4.52% (1990) and ±3.13 % (2023), respectively (Figure 1.5). A considerable part of the overall uncertainty stems from uncertainty in the agricultural sector (CRT 3). The national total emissions have considerably higher uncertainty with LULUCF included (±87.1% in base year and ±55.4 % in 2023), mainly because of the large and hard-to-estimate net removals in LULUCF (Figure 1.5).

Table 1.5 shows the ten sources with the largest uncertainty contributions in the inventory for 2023, excluding LULUCF.

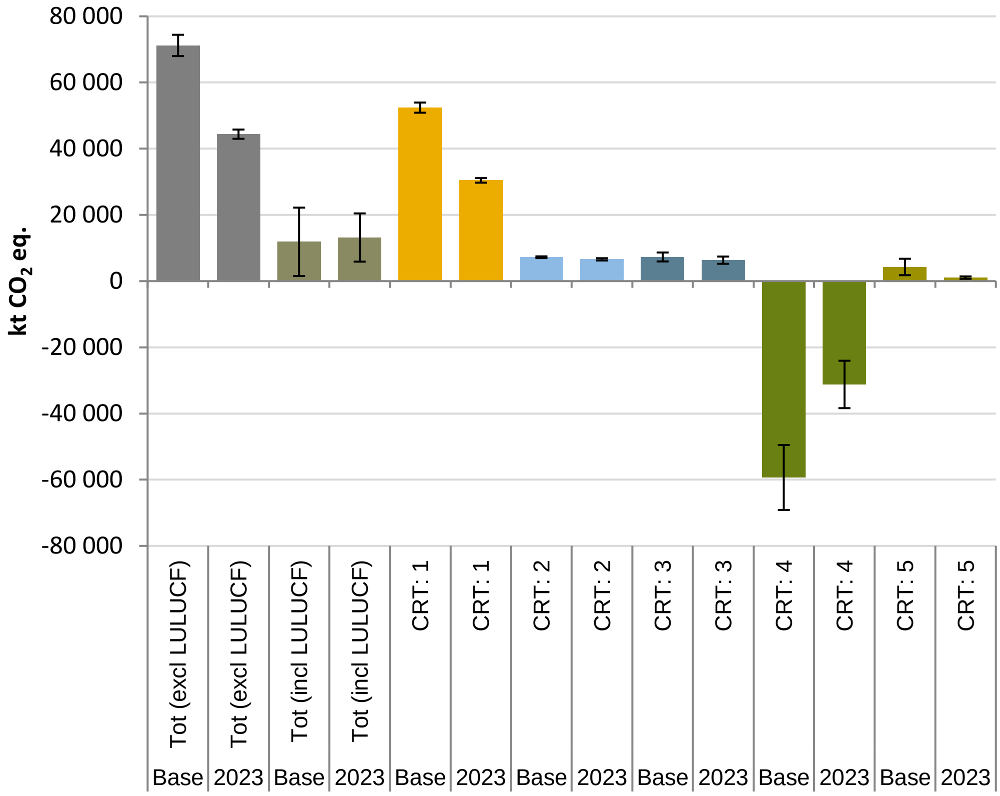

Figure 1.5. Estimated greenhouse gas emissions and uncertainties (95% confidence intervals) in years 1990 and 2023: national total emissions (excl. and incl. LULUCF) and by sector.

Table 1.5. The ten sources with the largest uncertainty contributions in the Swedish inventory for 2023, excluding LULUCF (Contribution to level approach 2).

IPCC Source Category	GHG	Year 2023 emissions or removals (kt CO_2-eq.)	Combined uncertainty (%)	Relative contribution to variance in year 2023 (%)
3 D a 1 Inorganic N fertilizers	N_2O	766.3	80.2	7.8%
1 A 1 a Public Electricity and Heat Production: Other Fuels	CO_2	2994	15.7	6.0%
3 A 1 Non-dairy cattle	CH_4	1610	25.5	5.2%
3 D a 6 Cultivation of organic soils (i.e. histosols)	N_2O	477.6	85.1	5.2%
3 D b 1 Atmospheric deposition	N_2O	98.16	400.5	5.0%
2 F 1 Refrigeration and air conditioning	HFCs	733.3	39.0	3.6%
3 B Indirect N2O emissions	N_2O	67.81	400.5	3.4%
5 A 1 Managed waste disposal sites	CH_4	470.8	55.9	3.3%
3 A 1 Dairy cattle	CH_4	1263	20.6	3.3%
1 A 3 b i Road Transportation, Cars: Gasoline	CO_2	4895	5.0	3.1%
Total				**45.9%**

The uncertainty of the trend of national total greenhouse gas emissions, excluding LULUCF, was ± 1.9%. The uncertainty in the trend is a percentage point range, relative to the inventory trend and should be interpreted as ± 1.9% is the estimated percentage point difference compared to the general trend. Thus, there is a 95% probability that the decrease in GHG emissions in Sweden (excluding LULUCF) between 1990 and 2023 (-37.7% or -26.8 Mt CO_2-eq.) is in the interval -38.4% to -37.0%.

Estimates of carbon stock changes 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 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

The estimates are in accordance with the requirements concerning completeness as laid out in the 2006 IPCC Guidelines.

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 or for sources where no IPCC default methodology exists (see Annex 5, Table A5.1).

The estimated emissions from solvent and product use are considered to be complete, as national data from the Products Register and the SPIN[16] database is used in the inventory.

1.8.4 Agriculture

All relevant agricultural emissions and sources are reported in the inventory. Reindeer, which sometimes are 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. Their relative importance for the Swedish GHG inventory is assessed to be very 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 as 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 (which is about 30 kt CO_2 eq.). Emissions are estimated to be insignificant in

[16] Substances in Preparations in Nordic Countries

relation to the amount of effort it would require to obtain activity and emission data. All other data are complete.

Emissions from home composting of food waste and garden waste are not estimated due to the lack of data on composted garden waste. However, by using the available data on home composted food waste year 2023 (38 000 tonnes wet weight), the total emissions (methane and nitrous oxide) amounts to 6.67 kilotonnes CO_2-eq. Sweden's greenhouse gas emissions year 2023 (Total (without LULUCF)) in submission 2025 was 44 385.97 kt CO_2-equivalents. 6.67 kilotonnes CO_2-eq. equals 0.015% of the national total GHG emissions, which is below the threshold of significance (0.05%).

2 Trends in greenhouse gas emissions

2.1 Total greenhouse gas emissions and removals

In 2023, total greenhouse gas emissions (excluding LULUCF) in Sweden amounted to 44.4 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.

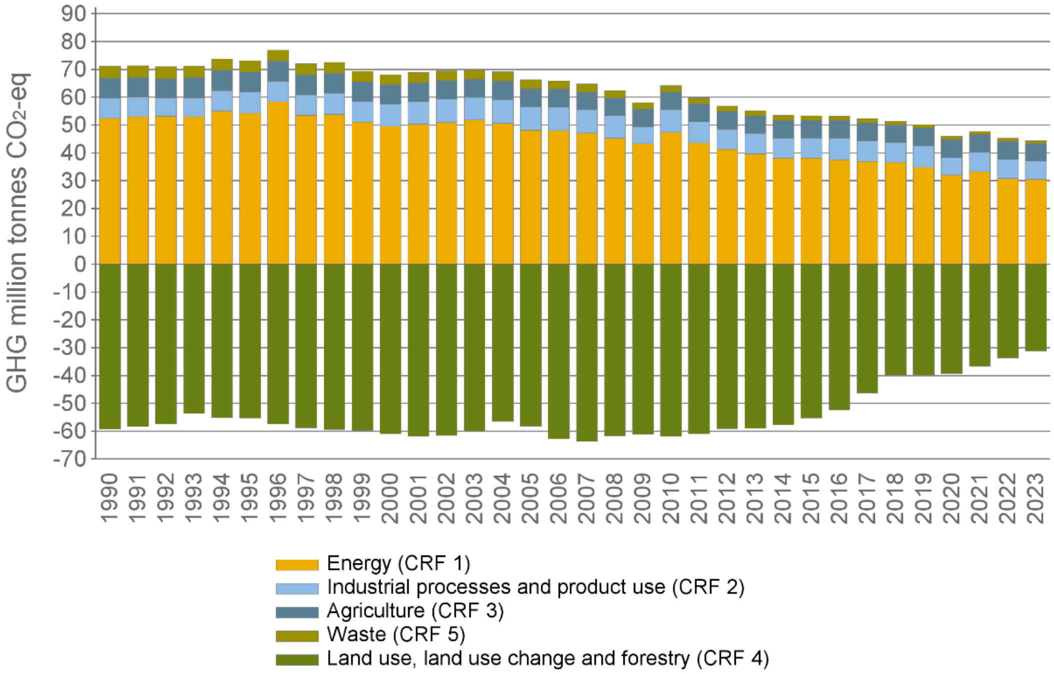

Figure 2.1. Total emissions and removals of greenhouse gases calculated as CO_2-eq. from Land use, land use change and forestry (LULUCF, CRT 4) and the other sectors (CRT 1, 2, 3 and 5), 1990-2023.

Total emissions have decreased by 38% (about 26.8 Mt CO_2-eq.) between 1990 and 2023. The energy sector contributed the most to the overall decrease in emissions, with a reduction of about 22 Mt CO_2-eq. between 1990 and 2023, primarily through reductions of about 9 Mt in the residential, commercial/institutional and agriculture, forestry and fisheries subsectors (CRT 1.A.4), about 6.2 Mt in the transport sector (CRT 1.A.3), 5 Mt in manufacturing industries and construction (CRT 1.A.2) and 1.4 Mton in energy industries (CRT 1.A.1). The main reason to decreased emissions from the residential and commercial/institutional sectors is 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 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. Other sectors also contributed to the overall decreased emissions during the period; waste (CRT 5) by 3.2 Mt, agriculture (CRT 3) by 1 Mt and industrial processes and product use (CRT 2) by 0.6 Mt.

Between 2022 and 2023 the total greenhouse gas emissions decreased by a bit less than 2% (about 0.8 Mton CO_2-eq.) Approximately half of the decrease in emissions (about 0.4 Mton) can be related to lower emissions from the energy sector. Here the largest reduction was seen for energy industries but there were also reductions for manufacturing industries and construction as well for transport, whereas there were increased emissions from other sectors. There were also reduced emissions from industrial processes and product use (about 0.3 Mton), agriculture (about 0.1 Mton) and from the waste sector (about 0.05 Mton).

The land use, land-use change and forestry sector (LULUCF, CRT 4) has generated annual net removals during the whole inventory period (1990-2023). The net removals show substantial annual fluctuations. During the last decade there has been a decreasing trend. In 2023 the net removal was about 31 Mton CO_2-eq. which is 47% lower than 1990 and 7% (2.4 Mton) lower than 2022.

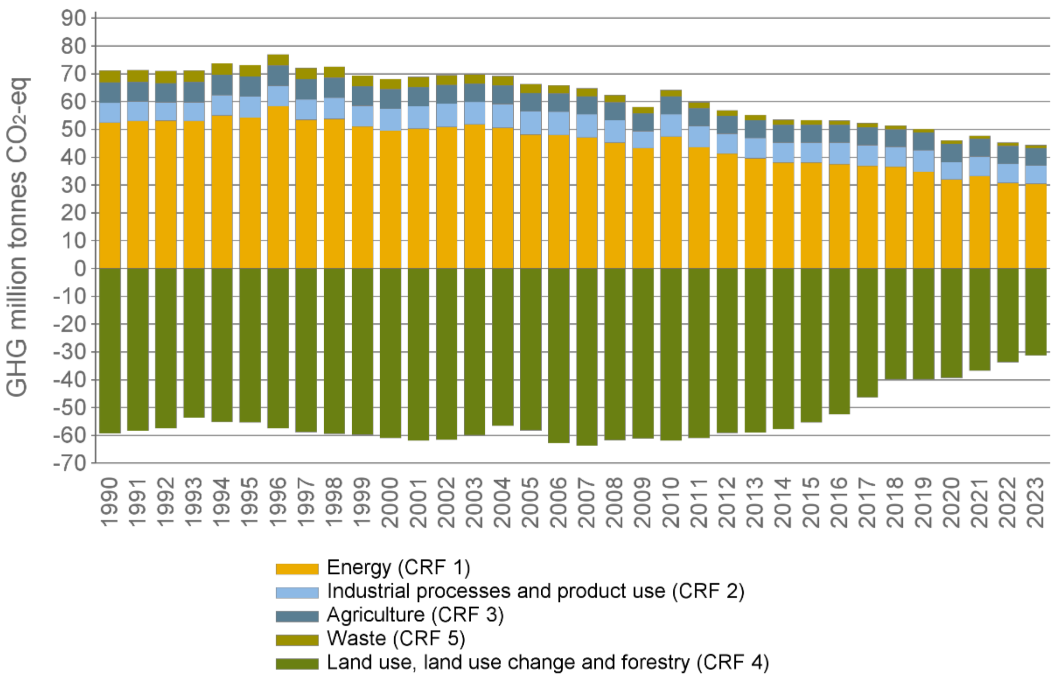

Figure 2.1.1 Total emissions and removals of greenhouse gases calculated as CO_2-eq. from Land use, land use change and forestry (LULUCF, CRT 4) and the other sectors (CRT 1, 2, 3 and 5), 1990-2023.

2.1.1 Overview of emissions by sector

Figure 2.2 shows the greenhouse gas emissions from different sectors in 2023. The energy sector (CRT 1) is comprised by emissions from transport (CRT 1.A.3), which accounted for 32% of the total emissions, energy industries (CRT 1.A.1), 19% of total emissions, and combustion in manufacturing industries and construction (CRT 1.A.2), 13% of total emissions. Emissions from fugitive emissions (CRT 1.B) accounted for 0.2% of total emissions, and other sectors (CRT 1.A.4) for 4.4% of total emissions. Industrial processes and product use (CRT 2) accounted for 15%, agriculture (CRT 3) for 14% and waste (CRT 5) for 2.4% of total emissions.

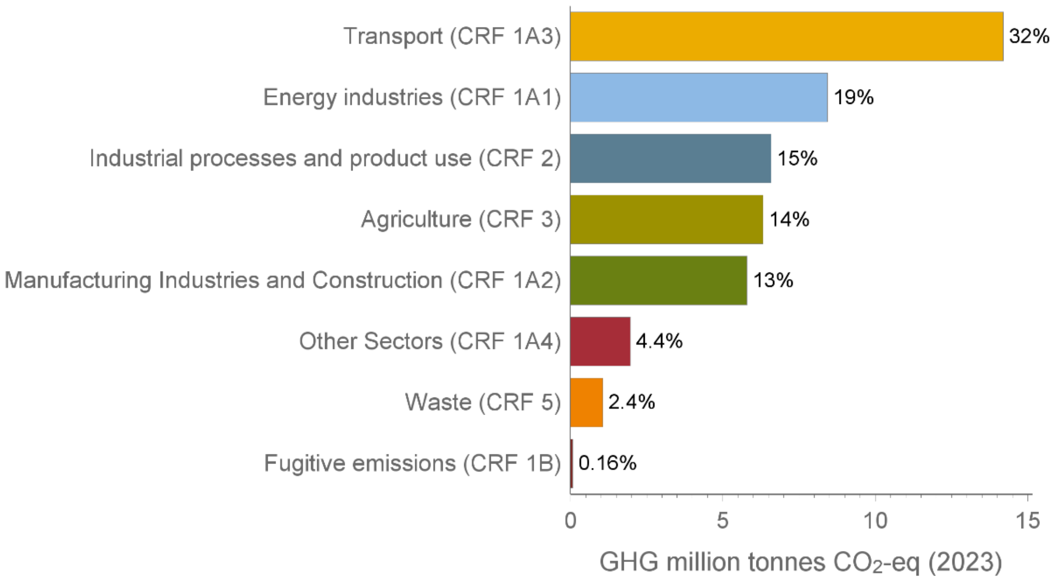

Figure 2.2. Greenhouse gas emissions by sector, 2023.

The historical trends (1990-2023) of the largest emission categories are shown in Figure 2.3.

Emissions from transport (CRT 1.A.3) are dominated by road transport. The emissions were lower in 2023 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. Between 2022 and 2023 the emissions were reduced with about 0.1 Mton CO_2-eq. The reduction in emissions occurred in road traffic and it was the emissions from passenger cars that were lower. Increased electrification and a higher proportion of biofuel in petrol contributed to the reduction, even though emissions from trucks increased slightly. The fact that emissions from trucks increased was due to lower admixture of biofuel in diesel. The latter was also the main explanation to the increase in emissions in other sectors (CRT 1.A.4).

Emissions from energy industries (CRT 1.A.1) 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. Between 2022 and 2023 emissions from energy industries were reduced with about 0.2 Mton CO_2-eq.

despite colder weather and thus greater heating needs in 2023 than in 2022. The reason for the reduction in emissions was that fossil-based electricity production decreased.

Emissions from IPPU (Industrial Processes and Product Use, CRT 2) 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. Between 2022 and 2023 the emissions from this sector were reduced with about 0.3 Mton CO_2-eq. and the main reason was lower production, especially in the iron and steel industry as well as the mineral industry, as a result of the current recession. The latter was also the main explanation to the decrease in emissions in manufacturing industries and construction (CRT 1.A.2).

Emissions from agriculture (CRT 3) have decreased slightly since 1990 mainly due to increased efficiency and a decrease in livestock numbers and to a lower extent also due to reduced amounts of fertilizers used. The last decade, however, emissions from agriculture have remained rather constant. Between 2022 and 2023 the emissions from this sector decreased with about 0.1 Mton CO_2-eq. and the main explanation was lower emissions from agricultural soils due to lower harvest and thus, less crop residues left in fields.

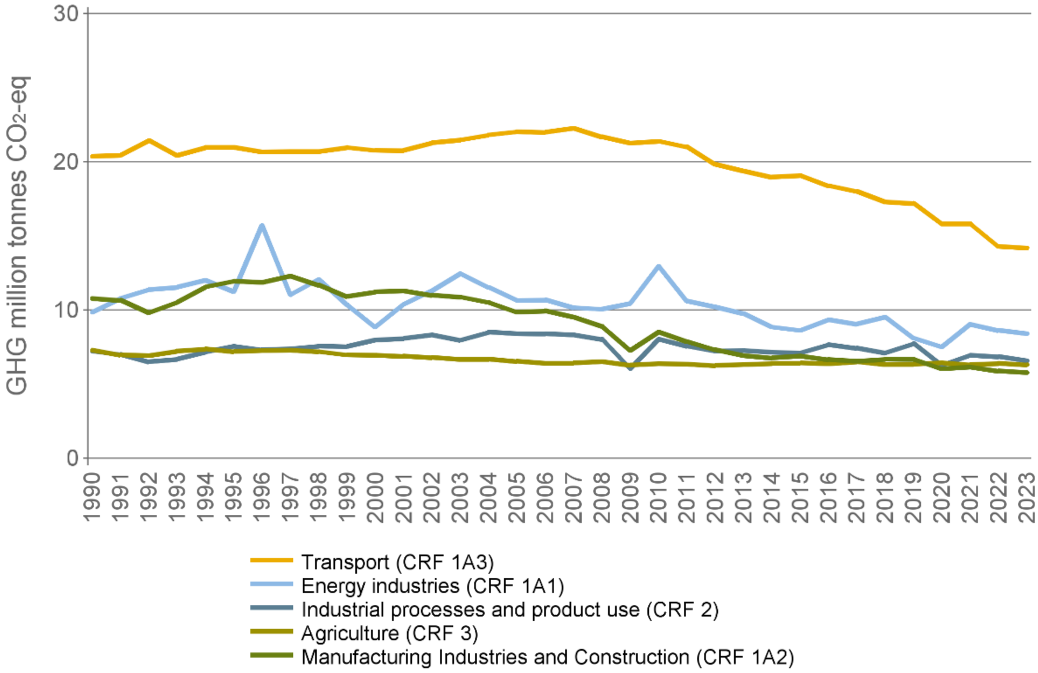

Figure 2.3. Total emissions of all greenhouse gases calculated as CO_2-eq. for transport (1A3), energy industries (CRT 1A1), Industrial processes and product use (CRT 2), agriculture (CRT 3) and manufacturing industries and construction (CRT 1A2), 1990-2023.

2.2 Description and interpretation of emission trends by gas

In 2023, emissions of carbon dioxide (CO_2) amounted to 35.5 Mt in total, which is equivalent to about 80% of total greenhouse gas emissions (excl. LULUCF), see Figure 2.4. Methane (CH_4) accounted for 4.6 Mt of CO_2-eq. (about 10%), nitrous oxide (N_2O) accounted for 3.4 Mt (about 8%), fluorinated greenhouse gases 0.8 Mt (about 2% of total emissions). The shares of the different greenhouse gases have remained stable over the period 1990 to 2023.

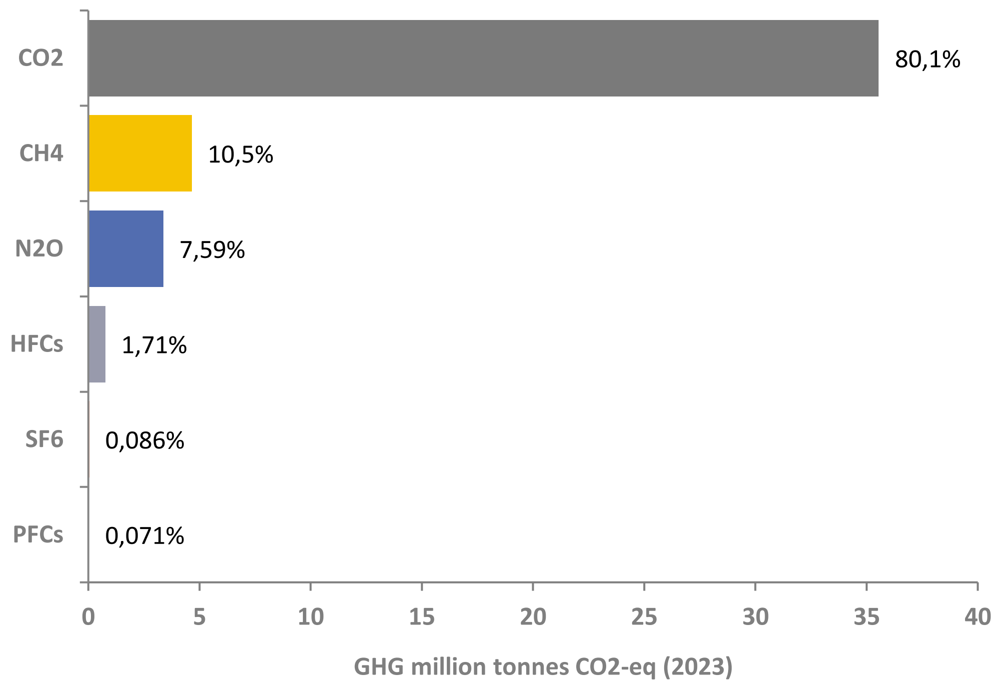

Figure 2.4. Share of greenhouse gases of total emissions in CO_2-eq, in 2023.

2.2.1 Carbon dioxide (CO_2)

In 2023, the carbon dioxide (CO_2) emissions in Sweden amounted to 35.5Mt 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 (CRT 1). Another important source is the raw material used in the industry processes. Emissions of carbon dioxide were 38% lower in 2023 than in 1990.

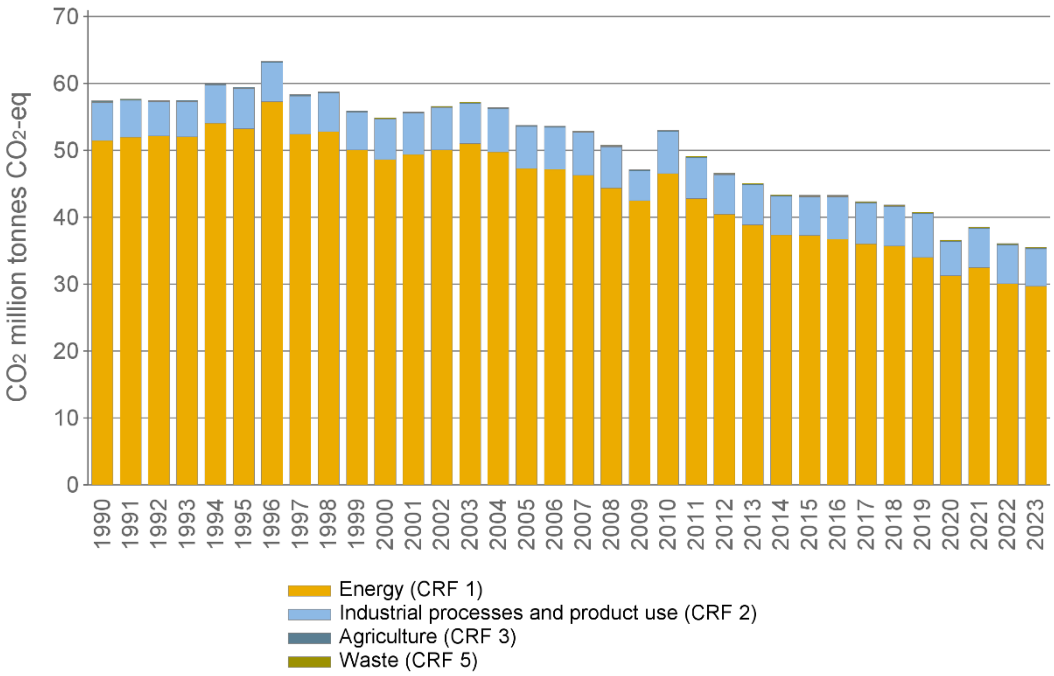

Figure 2.5. Total emissions of carbon dioxide 1990-2023 (excluding LULUCF).

2.2.2 Methane (CH_4)

The total emissions of methane (CH_4), excluding emissions from LULUCF, were 4.6 Mt CO_2-eq. in 2023, see Figure 2.6. The main sources of methane are agriculture (CRT 3) (79%), the waste sector (CRT 5) (16%) and the combustion of fossil fuels in the energy sector (CRT 1) (5%). Emissions of methane have decreased by 45% 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 has decreased its emissions of methane by 82% between 1990 and 2023, while emissions in the agricultural sector dropped by 7% during the same period.

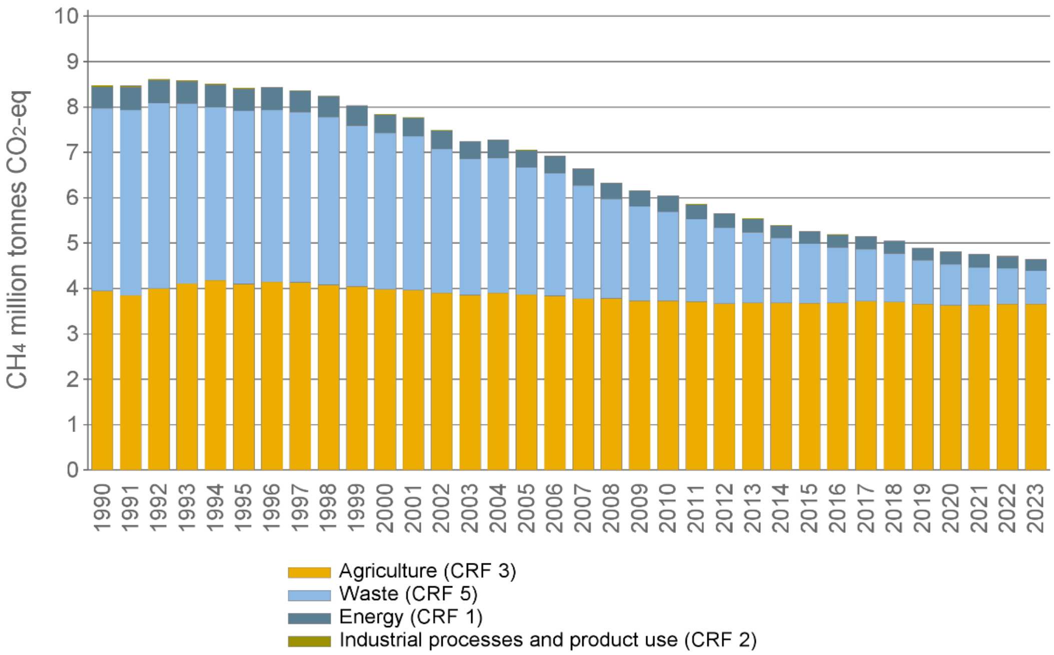

Figure 2.6. Total emissions of methane (CH_4) by sectors 1990-2023 (excluding LULUCF).

2.2.3 Nitrous oxide (N_2O)

In 2023, emissions of nitrous oxide (N_2O) amounted to 3.4 Mt CO_2-eq. (excl. LULUCF), see Figure 2.7. Compared to 1990, the overall emissions of N_2O have decreased by 28%. The main source of nitrous oxide emissions is the agricultural sector (CRT 3), which accounted for 75% of the emissions in 2023. Other emissions arise from the energy sector (CRT 1, 15%), industrial processes and product use (CRT 2) and the waste sector (CRT 5). The industrial processes and product use sector accounts for the largest part of the decrease in emissions of nitrous oxide and has dropped by approximately 83% during the period. Emissions in the agricultural sector dropped by 21% during the same period.

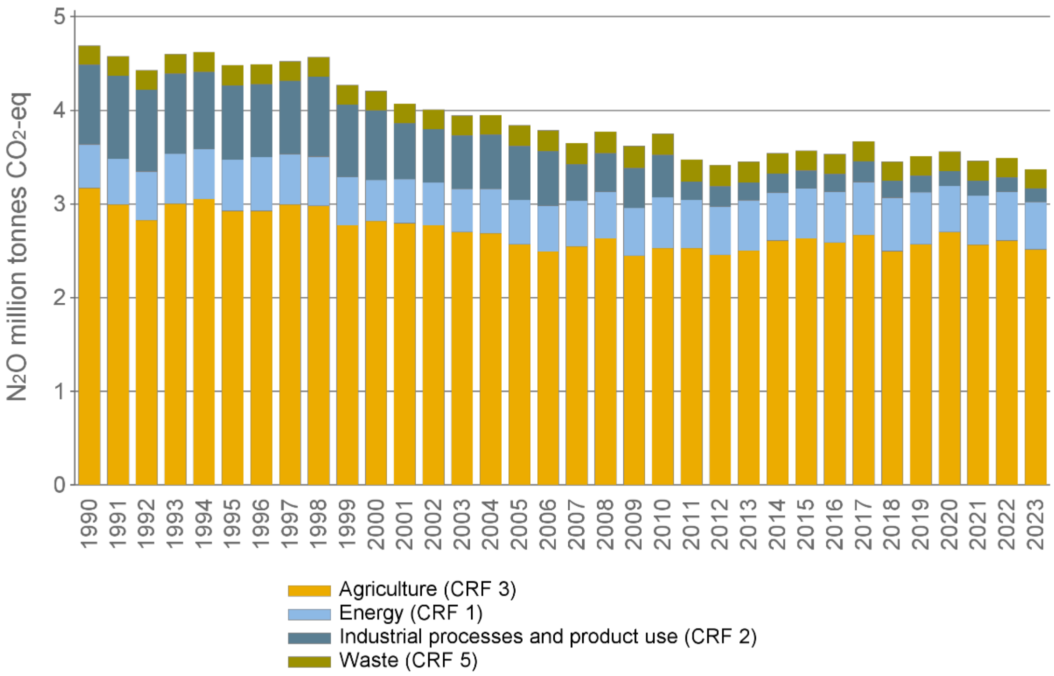

Figure 2.7. Total emissions of nitrous oxide (N_2O) by sectors 1990-2023 (excluding LULUCF).

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 greenhouse gases are only reported in the industrial processes and product use sector (CRT 2).

Total emissions of fluorinated greenhouse gases in 2023 amounted to 0.8 Mt CO_2-eq, see Figure 2.8, and accounted for about 2% of total greenhouse gas emissions. There has been a large increase in emissions since 1990, from around 0.6 Mt of CO_2-eq. in 1990 to almost 1.6 Mt in 2007, but since then the emissions have decreased. The overall increase is mainly due to increased emissions of HFCs, which accounted for 92% of the total fluorinated greenhouse gases in 2023.

The emissions of HFCs increased by 0.8 Mt of CO_2-eq. between 1990 and 2022 (an increase of 126%), 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 in recent years a decrease in emissions. Emissions dropped by about 7% between 2022 and 2023.

PFCs emissions, on the other hand, have decreased by 94% during the period 1990 to 2023. Emissions of SF_6 decreased by 64% between 1990 and 2023. However, there are inter-annual fluctuations throughout the period.

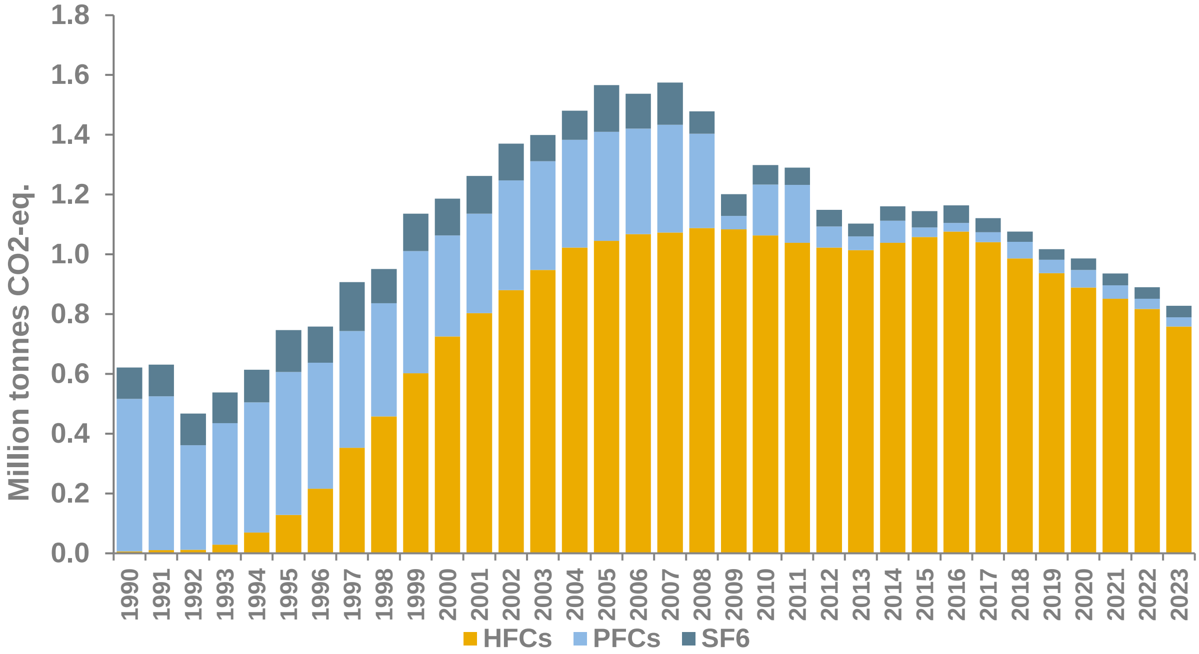

Figure 2.8. Total emissions of HFC, PFCs and SF_6, 1990-2023 (excluding LULUCF).

2.3 Emissions by CRT sector

2.3.1 Energy (CRT 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 by 42%. The main reason is due to 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 with more than 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) and fugitive emissions.

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

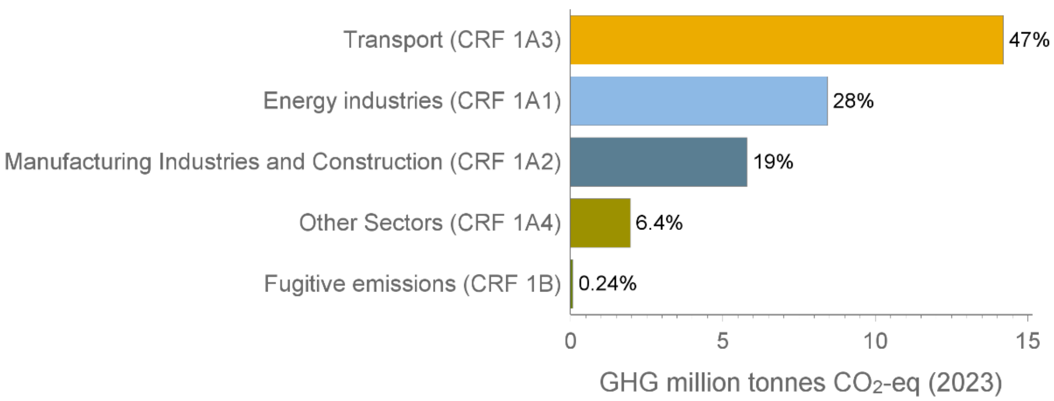

Figure 2.9. Share of emissions within the Energy sector, by subsector in 2023.

Total emissions in the energy sector have decreased over the period 1990-2023, from 52.4 to 30.4 Mt CO_2-eq (Figure 2.10). This is a decrease of 42% which mainly depends on a decreased use of fossil fuels in residential and commercial/institutional, included in "Other Sectors" (CRT 1A4), manufacturing industries and construction (CRT 1A2) and in recent years, Transports (1A3). Between 2022 and 2023 there was 1% decrease in emissions within the energy sector, mostly because of a decrease of emissions from energy industries.

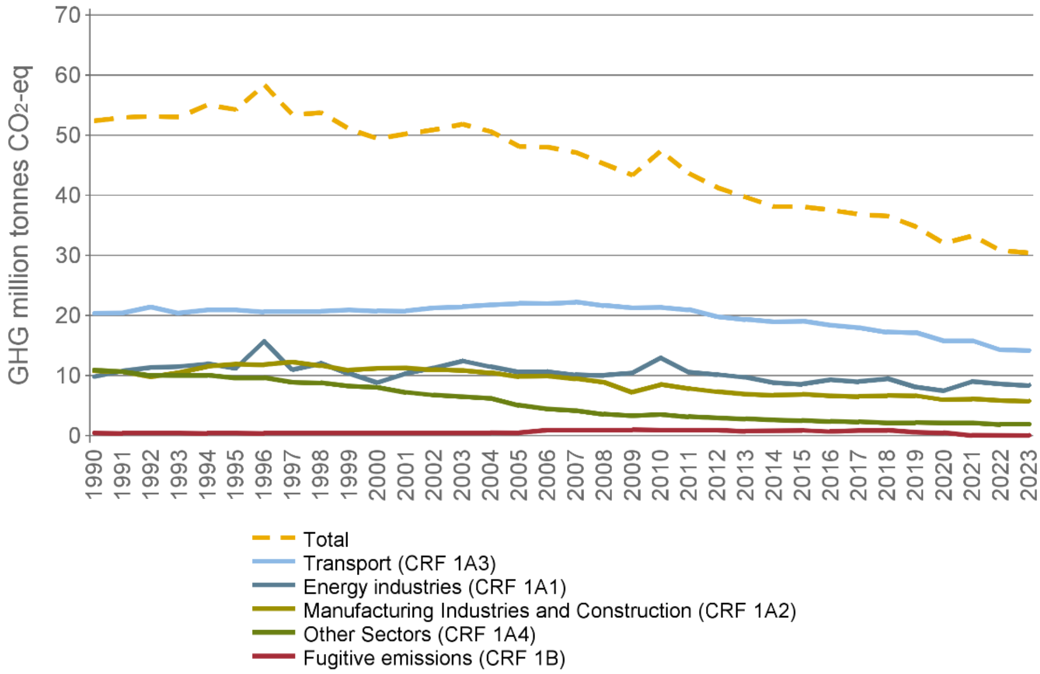

Figure 2.10. Emissions from the Energy sector, total and by subsector, in 2023.

2.3.1.1 ENERGY INDUSTRIES (CRT 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 (CRT 1A1a). In 2023, there was a decrease in emissions from the energy industries around 3% compared to 2023. 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, these emissions are 31% lower than in 1990, even though the supply of district heating has increased with around 50% in the same period. Emissions from production of electricity and heat production totaled to 5,4 Mt of CO_2-eq. in 2023.

Total emissions from energy industries (CRT 1A1) were 8.4 Mt CO_2-eq. in 2023 (Figure 2.11), which is 15% lower than in 1990. Electricity and heat production (CRT 1A1a) account for the larger part of the emissions with 64% (5.4 Mt) in 2023. Emissions from Refineries (1A1b) amounted to 2.7 Mt in 2023 and Manufacture of solid fuels (CRT 1A1c) amounted to 0.4 Mt.

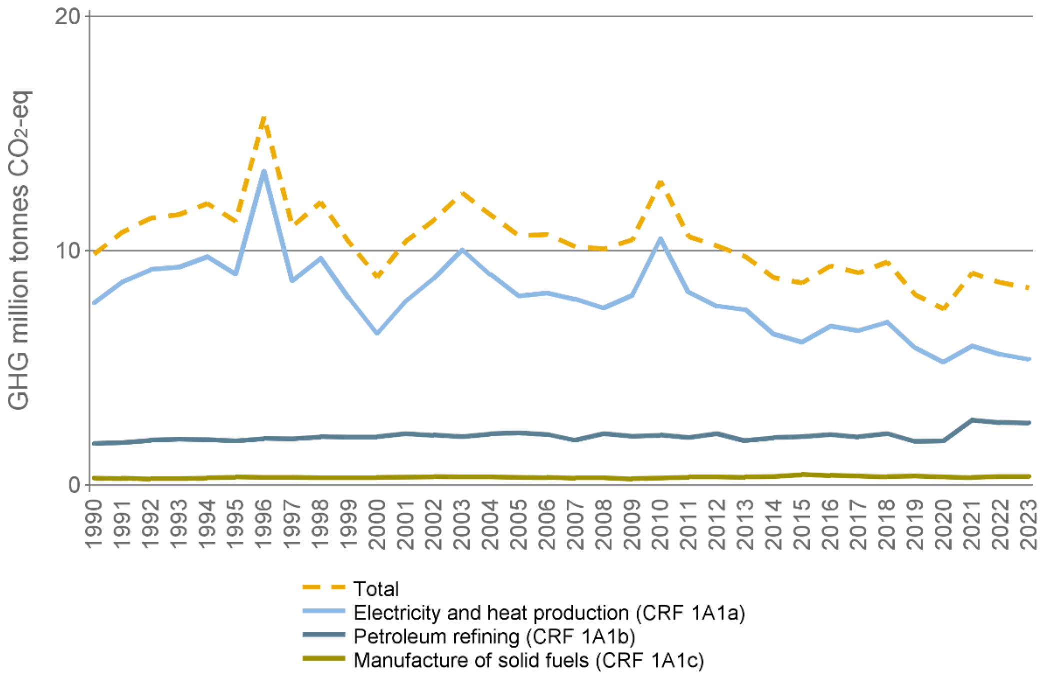

Figure 2.11. Emissions from Energy industries by subsector and total, 1990-2023.

2.3.1.1.1 Electricity and heat production (CRT1A1a)

Emissions from production of electricity and heat production totalled 5.4 Mt of CO_2-eq. in 2023. The emissions from electricity and heat production vary over time but have been reduced by 31% between 1990 and 2023. There is a decrease in emissions in 2023 of almost 4% compared to 2022 due to decrease usage of fossil fuels, mainly because of higher electricity prices which lead to less fossilbased electricity production.

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. However, in the latest years electricity prices and fuel prices also contribute to yearly fluctuations.

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.

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 have increased compared to 1990.

The production of district heating generates the largest greenhouse gas emissions in this sector. Since 1990 the supply of district heating has increased by around 50%. Even so, the 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 transition to waste fuels have also led to a decrease in emissions, however now the majority of the emissions in the sector come from waste. It is mostly waste from fossil plastic that contributes to the emissions from waste inceneration.

2.3.1.1.2 Refineries (CRT 1A1b)

Emissions from refineries amounted to 2.7 Mt CO_2-eq. in 2023.
The emissions mainly originate from 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, but emissions have in recent years been quite stable. The large increase in emissions seen in 2021-2023 compared to 2020 from petroleum refining (CRT 1A1b) can be explained by the fact that emissions from fugitive emissions from fuel (CRT 1B) have been allocated to petroleum refining due to prevailing confidentiality rules (see section 2.3.1.5). Emissions in 2020 were unusually low, mainly due to low demand and reduced production due the restrictions from covid-19-pandemic. In 2014 the emissions for gaseous fuels increased. This was due to that the combustion of liquified natural gas had been implemented in one of the refineries.

2.3.1.1.3 Manufacturing of solid fuels (CRT 1A1c)

Emissions from manufacture of solid fuels (CRT 1A1c) amounted to 0.4 Mt CO_2-eq. in 2023. Emissions from manufacturing of solids (1A1c) have increased since 1990, by 24%. Compared to 2022 emissions decreased by 15% in 2023. Emissions in this category emerge from the production of coke to be used in blast furnaces for production of iron. The trend for emissions therefore follows a similar pattern as emissions from iron and steel production industry.

2.3.1.2 MANUFACTURING INDUSTRIES AND CONSTRUCTION (CRT 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 5.8 Mt CO_2-eq. in 2023 (Figure 2.13). Emissions in 2023 were 46% lower than in 1990. Emissions in 2023 decreased by 2% compared to 2022. 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.

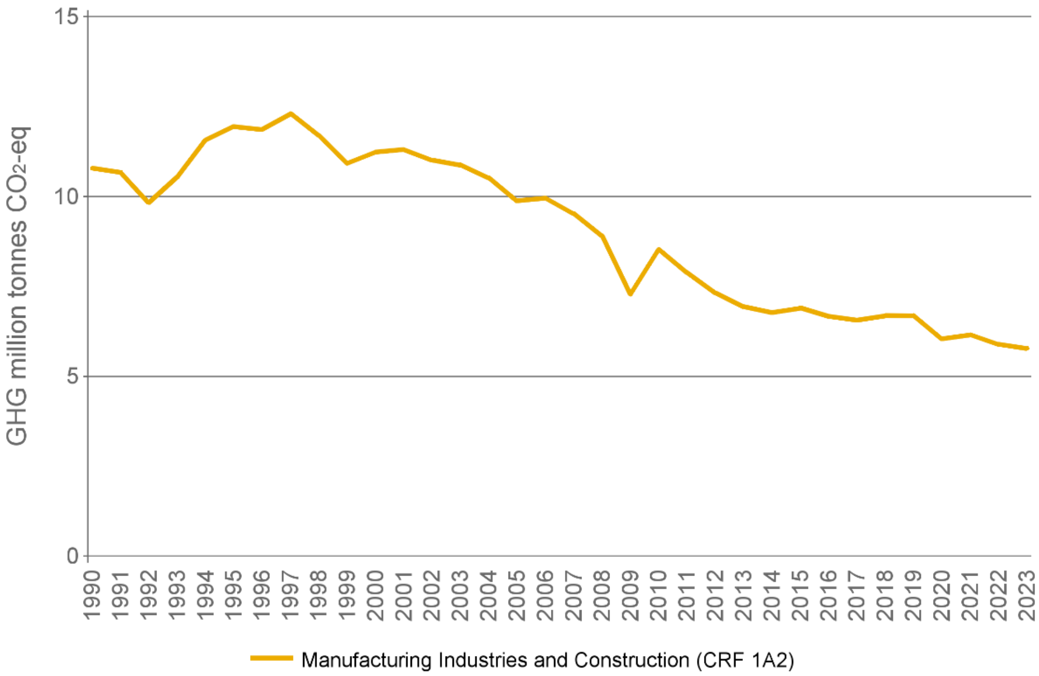

Figure 2.13. Total emissions from manufacturing industries and construction (CRT 1.A.2), 1990-2023.

A small number of energy-intensive industries account for a large share in the sector's greenhouse gas emissions. The iron and steel industry (CRT 1A2a), the non-metallic minerals industry (CRT 1A2f) and chemicals (CRT 1A2C) account for 22%, 17% and 12% respectively of the emissions in 2022 (Figure 2.14).

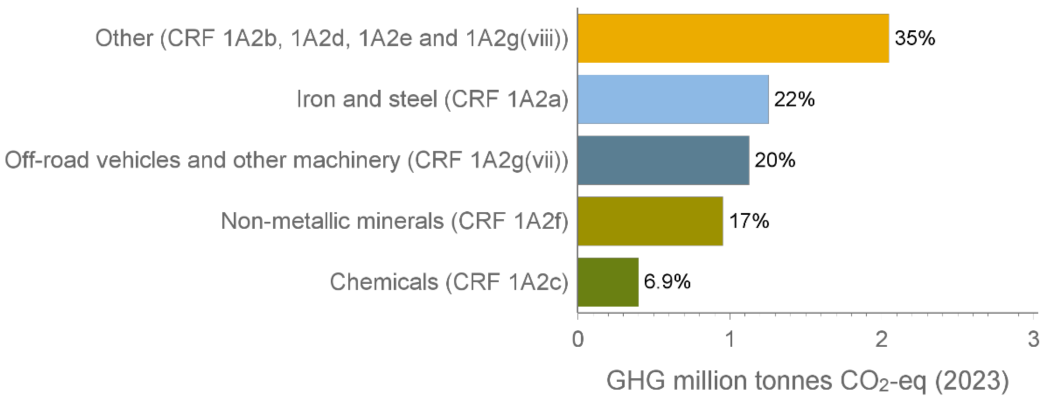

Figure 2.14. Emissions from the Energy sector; Manufacturing industries and construction in year 2023.

Other manufacturing industries, including non-metallic metals (CRT 1A2f), paper, pulp and print (CRT 1A2d), food processing, beverages and tobacco (CRT 1A2e), and stationary combustion in other industries (CRT 1A2g(viii)), show overall decreasing emissions between 1997 and 2015 (Figure 2.15).

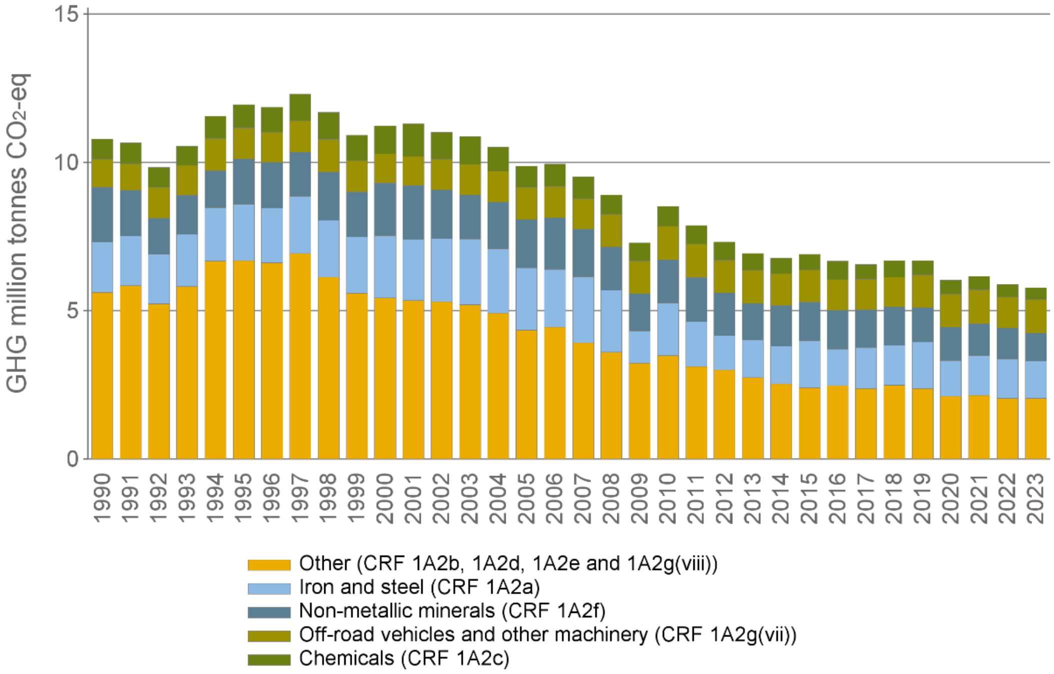

Figure 2.15. Emissions from combustion in manufacturing industries by subsectors, 1990-2023.

The emission level of non-metallic minerals (CRT 1A2f) is significantly lower in 2023 than in 1990 due to high emissions from use of coal in 1990-1991.
The decreasing emissions shown for the iron and steel industry (CRT 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[17] as well as the covid-19-pandemic during 2020. 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 section 3.2.9.

Emissions from chemicals (CRT 1A2c) and non-ferrous minerals (CRT 1A2b) have yearly variations in response to market fluctuations but the long-term trends have remained relatively stable since 1990.

2.3.1.3 TRANSPORT (CRT 1.A.3)

Most of the emissions in this subsector come from road traffic, mainly from cars and heavy-duty vehicles. The emissions from cars have decreased between 2009 and 2023, with the exception of a slight increase between 2014 and 2015. The decrease in emissions

[17] Jernkontoret, 2015

is largely due to increased use of biofuels and increased energy efficiency. In 2023 emissions decreased despite a slight increase in traffic.

Emissions from heavy duty vehicles follow the fluctuations of economic activity. They increased, in general, from the mid-1990s to 2008 and subsequently started to decrease.

Emissions from transport include emissions from domestic aviation (CRT 1A3a), road transport (CRT 1A3b), railways (CRT 1A3c), national navigation (CRT 1A3d) and other working machinery and off-road equipment (CRT 1A3e). The sub-sectors' shares of the total emissions of the sector are shown in Figure 2.16. In 2023, the greenhouse gas emissions from road transport were 12.8 Mt, 0.4 Mt from domestic aviation, 0.7 Mt from domestic navigation and 0.3 Mt from working machinery. Emissions from railways were less than one tenth Mt in 2023.

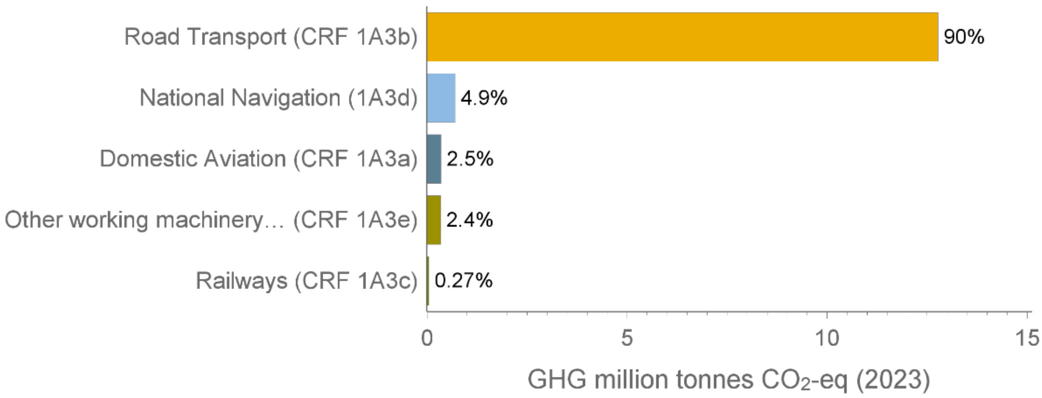

Figure 2.16. Share of emissions from sub sectors in the transport sector 2023.

Carbon dioxide accounts for the largest share of greenhouse gas emissions from the transport sector. Methane emissions were 0.04 Mt CO2- eq. in 2023 and have fallen 80% since 1990 as a result of better exhaust emissions control. Nitrous oxide emissions totalled 0.2 Mt of CO2-eq. in 2023. From 1990 to 1995 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 started to increase again from 2007 and onwards due to an increased number of diesel cars. The increasing trend leveled off in 2019.

2.3.1.3.1 Road transport

Emissions from road transport includes emissions from passenger cars (CRT 1A3b i), light duty vehicles (CRT 1A3b ii), heavy goods vehicles (1A3b iii), buses (CRT 1A3b iii) and mopeds and motorcycles (CRT 1A3b iv). The emissions in 2023 and the share of the emissions from road traffic are shown in Figure 2.17. Emissions from road transport by sub-sector are shown in Figure 2.18.

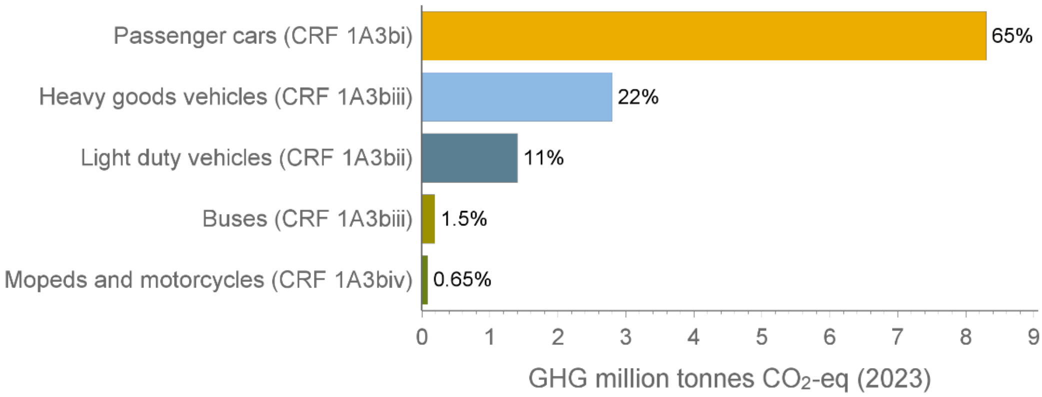

Figure 2.17. Share of emissions from subsectors of road transport in 2023.

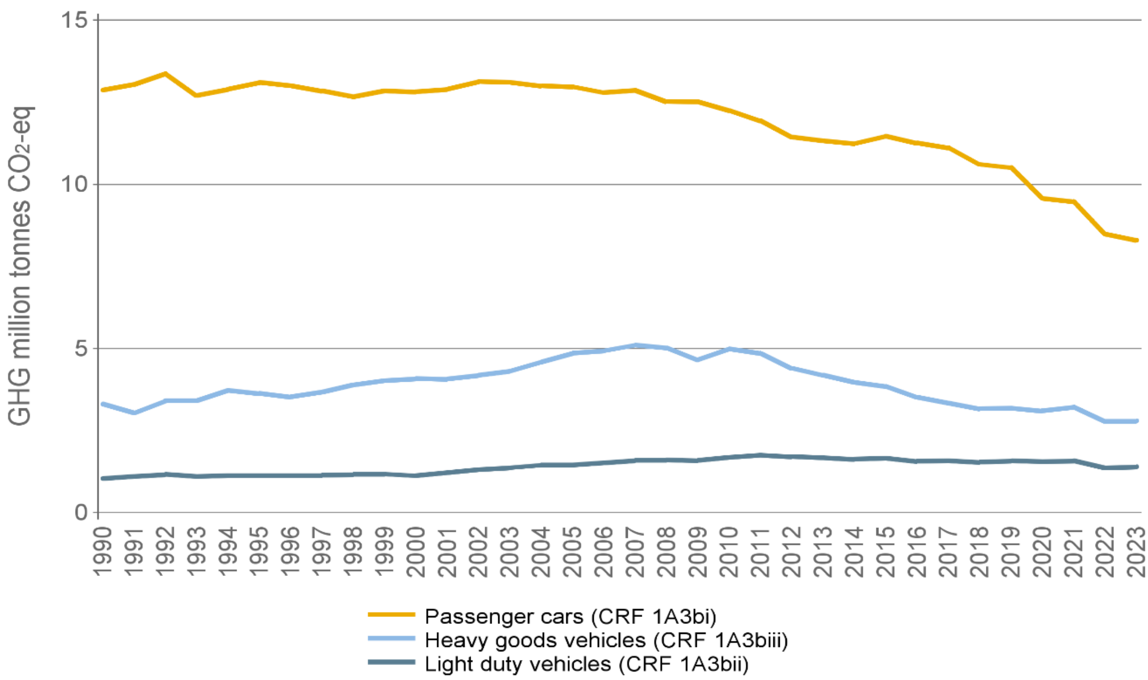

Figure 2.18. Emissions from road traffic by sub-sector, 1990-2023.

Emissions from passenger cars were 8.3 Mt CO_2-eq. in 2023, which is 36% lower than in 1990. Emissions from passenger cars were on a relatively constant level until 2007 when they started to decrease. Besides a slight increase between 2014 and 2015 the emissions have decreased since 2009. Until 2007 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 in emissions after 2007 is much due to increased use of renewable fuels and more energy efficient vehicles. In 2023 emissions decreased despite a slight increase in traffic.

Emissions from heavy duty vehicles were 2.8 Mt CO_2-eq. in 2023. Since 2011 emissions have declined due to more efficient vehicles and a larger share of renewable fuels.

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 early 2000, with the largest reduction between 2005 and 2012. From 2012 and onwards the energy efficiency rate has leveled off due to the increased share of four-wheel drive vehicles among new cars.[18] In recent years the average carbon emissions from new cars have decreased due to the increased number of sold electric vehicles.

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 was principally boosted by the fact that from 2004 until July 1st of 2018 they were exempted from carbon dioxide tax and energy tax, along with a law from 2006 requiring every major petrol station to provide a renewable fuel. From the second half of 2018 and onwards biofuels which are low-blended in fossil fuel are no longer exempted from caron dioxide tax. Large-scale blending of ethanol into petrol began in 2003, with the result that almost all petrol sold in Sweden now contains 5% ethanol. Blending of biodiesel, such as FAME and HVO, into diesel has also increased considerably during recent years. High-blended biofuels with lower levels of fossil fuels are still exempted from energy tax and carbon dioxide tax.

2.3.1.3.2 Domestic aviation, national navigation and railways

In 2023, emissions from domestic aviation totalled 0.4 Mt of CO2-eq, see Figure 2.20, which is 49% lower than the level in 1990. Emissions have varied during the period since 1990. The large increase in emissions from domestic aviation since 2021 is a rebound effect after the large decrease during the covid-19-pandemic. Emissions are still lower than pre-pandemic levels.

Emissions from national navigation were 0.7 Mt of CO2-eq. in 2023, see Figure 2.20. This is 51% higher than in 1990 and 0.5% higher than in 2022, emissions have varied since 1990 but with an increasing trend.

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 were 40 kt of CO_2-eq. (Figure 2.20) in 2023.

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[18] Swedish Transport Administration, 2015

18 Trafikverket, 2018

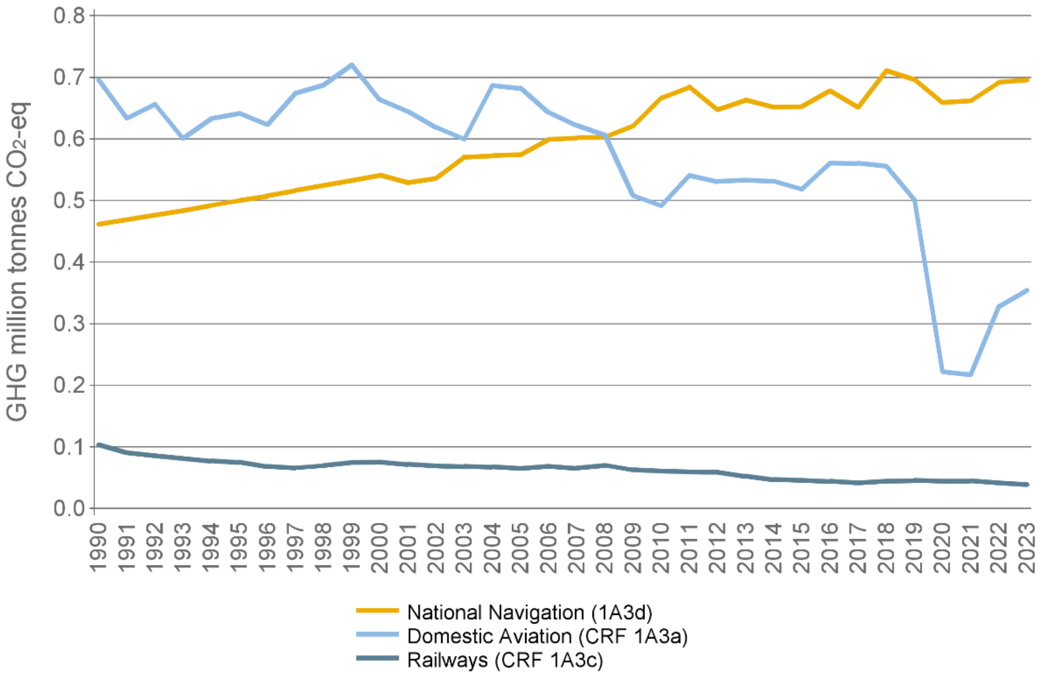

Figure 2.20. Emissions of greenhouse gas in CO_2 eq. from aviation, navigation and railways, 1990-2023.

2.3.1.4 OTHER SECTORS (CRT1A4)

In other sectors, emissions have decreased by 82% during 1990-2023 mainly 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. Emissions increased by 1% between 2023 and 2023 due to increased emissions from off-road vehicles and other machinery.

Combustion for heating purposes within the residential (CRT 1A4b), commercial/institutional (CRT 1A4a) and agriculture, forestry and fisheries sectors (CRT 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, see Figure 2.21.

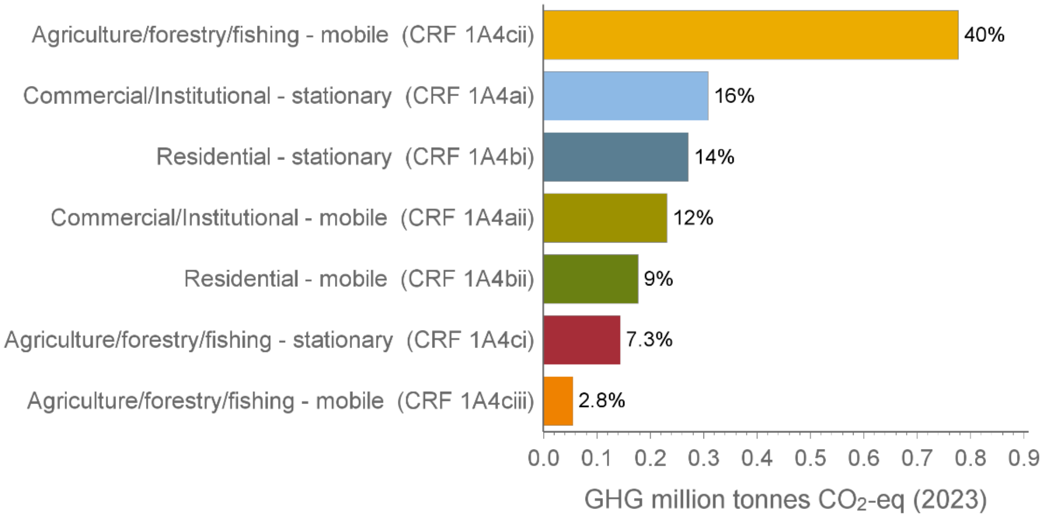

Figure 2.21. Share of emissions within Other sectors by subsector in 2023, with mobile and stationary combustion shown separately for each subsector.

Emissions in Other sectors were approximately 2.0 Mt of CO_2-eq. in 2023. The reduction is due to a strong decrease in emissions in the commercial/institutional and residential (CRT 1A4a and 1A4b) sectors between 1990 and 2023 (Figure 2.22) of 81 and 93%, respectively. In comparison with 2022 the total emissions from the residential sector decreased with 2%. Emissions from the commercial/institutional sector increased with 2% between 2022 and 2023. The emissions from agriculture, forestry and fisheries (CRT 1A4c) increased by 2% in 2023 and were 1.0 Mt CO_2-eq., which is 42% less than in 1990.

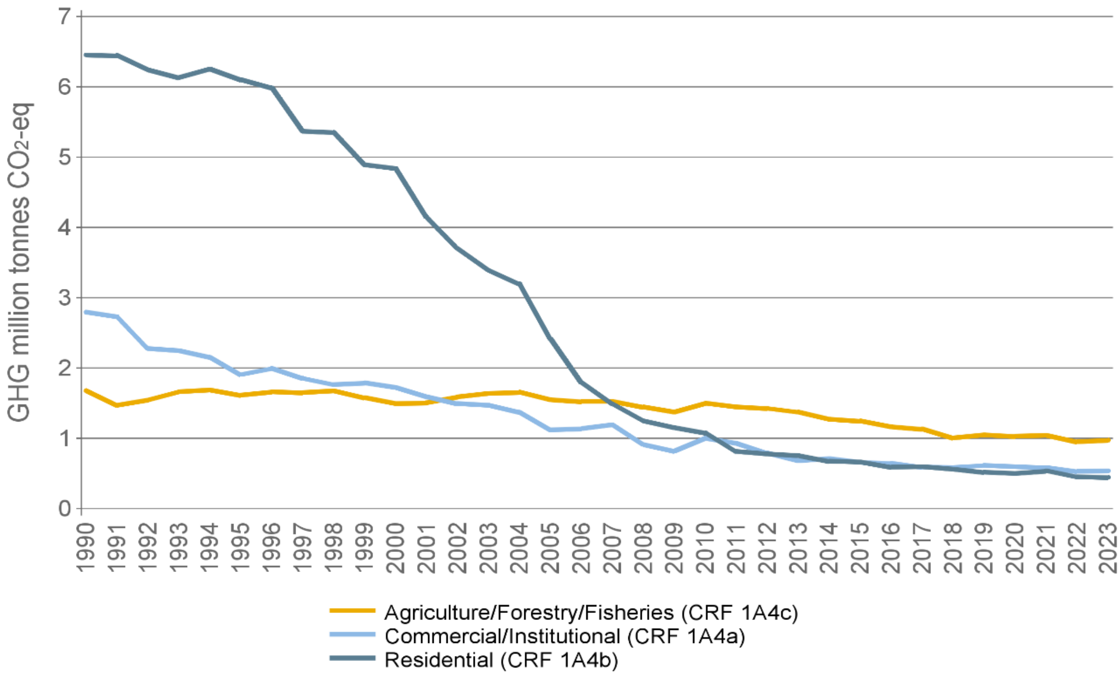

Figure 2.22. Emissions from Other sectors, total and by subsector, 1990-2023.

Distribution between stationary and mobile combustion sources, as well as total emissions, is shown in Figure 2.23 below.

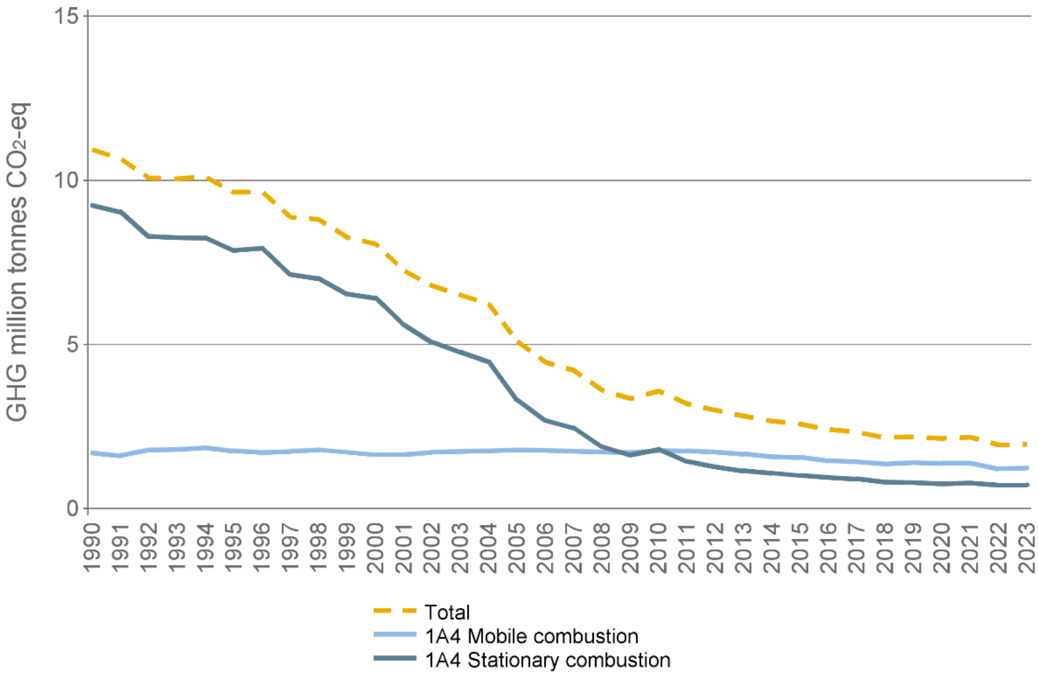

Figure 2.23. Emissions from mobile combustion, stationary combustion and emissions in total, 1990-2023.

Emissions from working machinery and off-road vehicles (mobile combustion) have decreased by 27% in total since 1990. Emissions from the residential sector (CRT 1A4b) were 30% lower in 2023 compared to 1990 and were 0.18 Mt of CO_2-eq. in 2023, see Figure 2.24. Emissions from mobile combustion in agriculture were 16% lower in 2023 compared to emission levels in 1990. Emissions from mobile combustion in forestry (1A4c) have varied over the years and were around 26% lower in 2023 compared to 1990, see Figure 2.24. In the commercial/institutional sector (CRT 1A4a) emissions from mobile combustion have varied during the period and were 9% lower in 2023 compared to 1990. In fisheries (CRT 1A4c) the emissions have been declining during the past decades, following the trend with a shrinking fleet of fishing vessels in Sweden. Emissions from mobile combustion from fishing were 73% lower in 2023 compared to 1990. 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. The model is described in Annex 2.

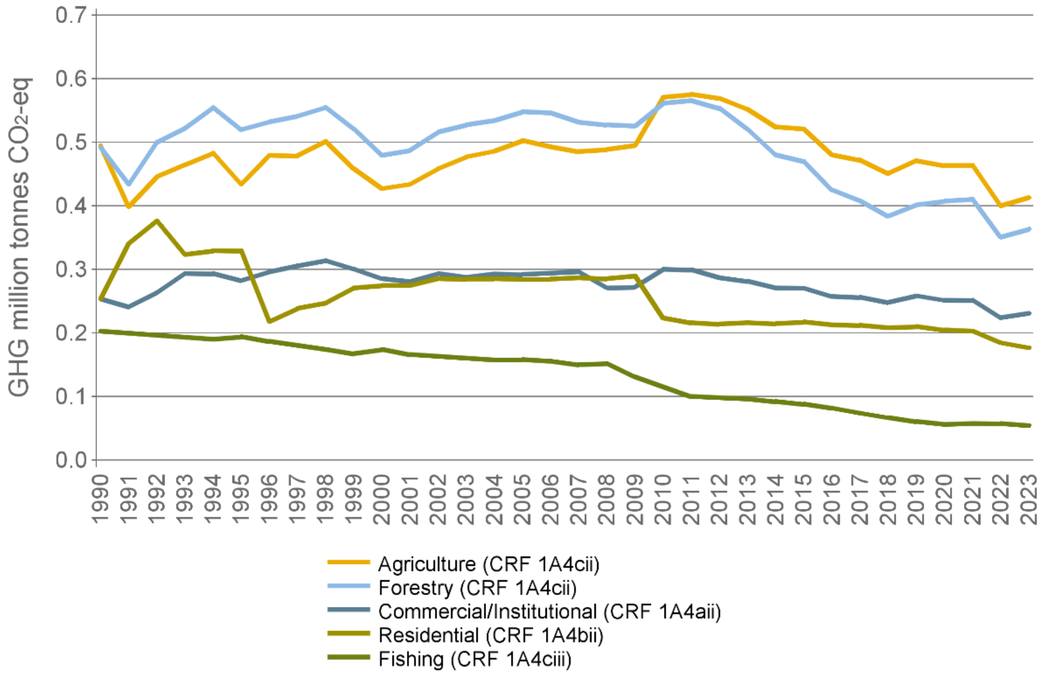

Figure 2.24. Emissions from off-road vehicles and other machinery in each subsector, 1990-2023.

In the residential sector (CRT 1A4b), the emissions from stationary combustion have decreased by 96% since 1990, and in the commercial/institutional sector (CRT 1A4a) emissions from stationary combustion have decreased by 88%. Emissions from stationary combustion in agriculture, forestry and fisheries (CRT 1A4c) are small and have decreased by 71% compared to 1990. Due to problems with available updated activity data for the last year for stationary combustion in this sector, the activity data for 2022 is used also for 2023. Emissions from stationary combustion within each subsector are shown in Figure 2.25.

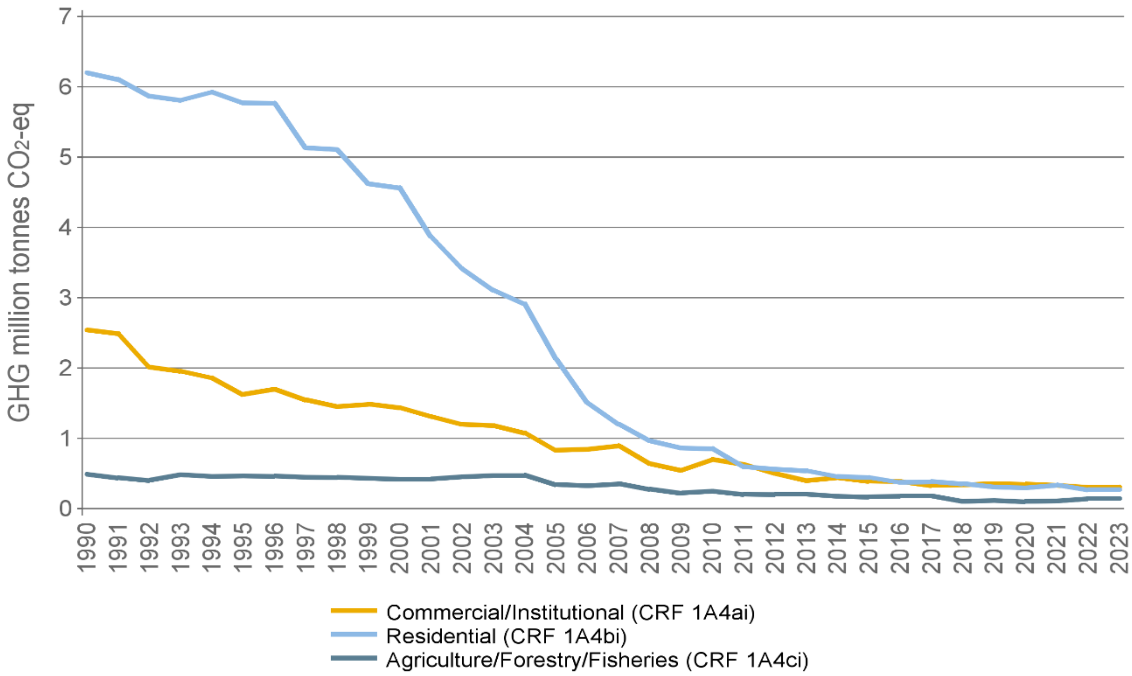

Figure 2.25. Emissions from stationary combustion in each subsector, 1990-2023.

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 2.26. 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.

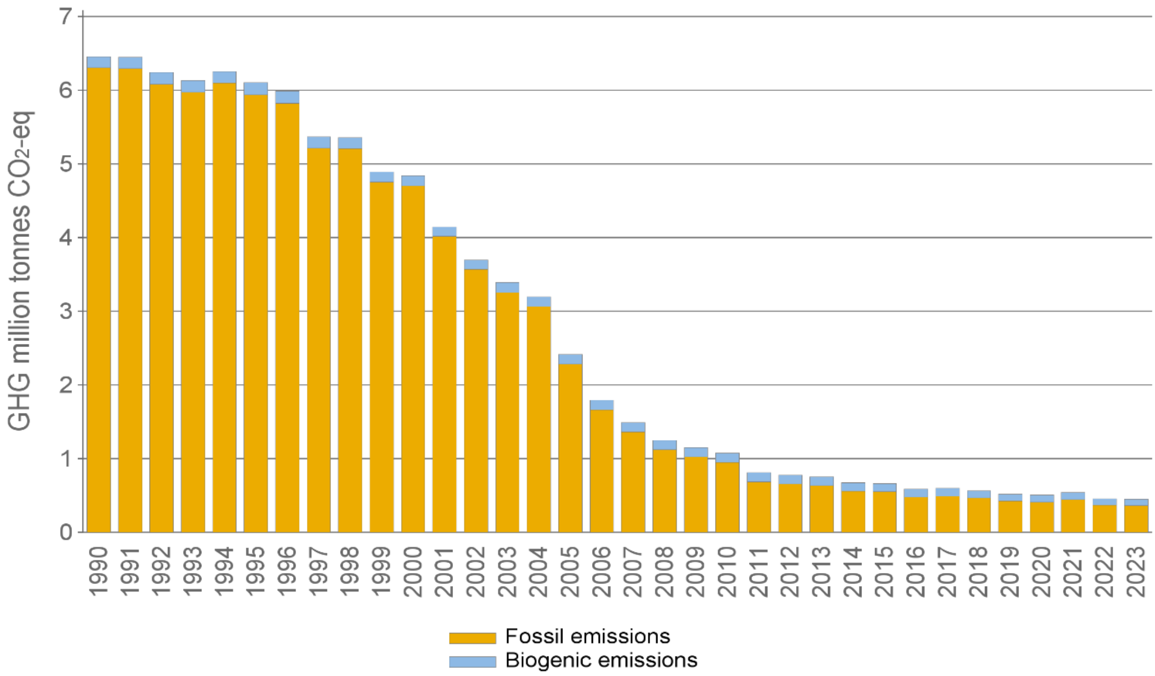

Figure 2.26. Emissions from Residential sector (1A4b) fossil and biogenic, stationary combustion, 1990-2023.

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 Annex 8:2.

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.

2.3.1.5 FUGITIVE EMISSIONS FROM FUELS (CRT1B)

Fugitive emissions occur for example in processing, storage and use of fuels, flaring of gas, transmission and distribution of gas.

Emissions were around 0.05 Mt of CO_2-eq. in 2022. The extensive decrease in emissions seen in 2021 and 2022 compared to 2020 from fugitive emissions (CRT 1B) is due the fact that a major part of the emissions have been allocated to petroleum refining (CRT 1A1b) due to prevailing confidentiality rules (see section 2.3.1.1.2).

The decrese in emissions during 2019 (Figure 2.27) is mainly an effect of reduced production due to maintenance at two facilities. During 2020, demand from the sector has been low due to the covid-19-pandemic, and therefore production has also been low. The increase of fugitive emissions from oil (CRT 1B2a), observed in the time series from 2006, is related to the establishment of hydrogen production facilities at two oil refineries.

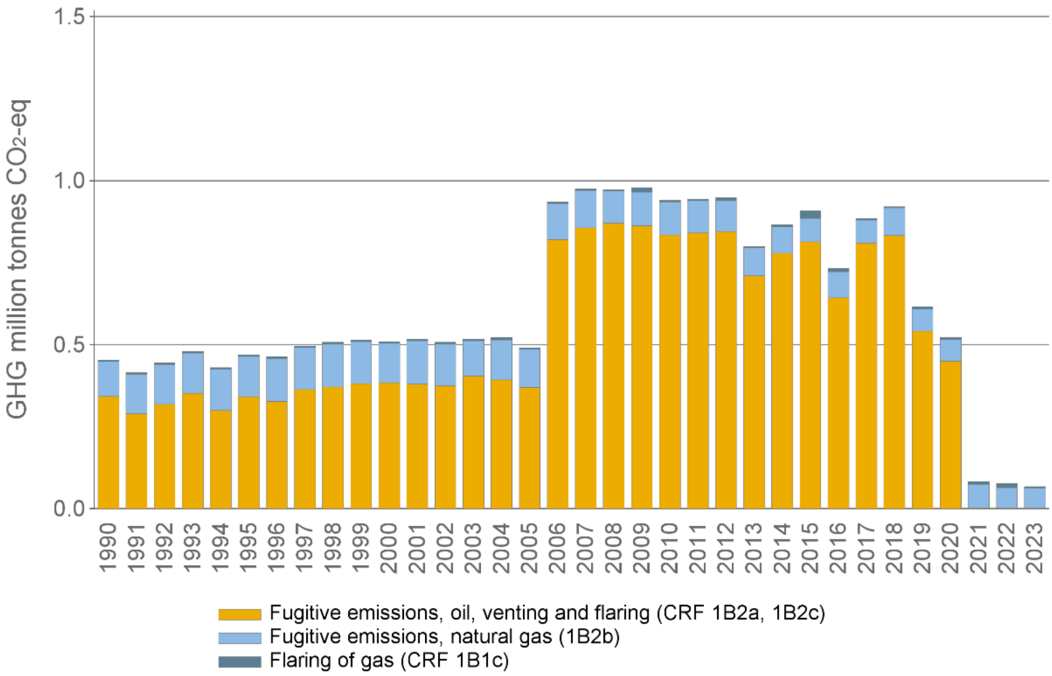

Figure 2.27. Emissions of greenhouse gases from fugitive emissions, total and by major subsectors, 1990-2023.

2.3.2 Industrial processes and product use (CRT sector 2)

Greenhouse gas emissions within the sector industrial processes and product use (CRT 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. Production levels in response to market fluctuations is the main reason for fluctuations within the sector. Emissions from the industrial processes and products use sector represented 15% of the total national emissions in 2023, The main sources of emissions in the industrial processes and product use sector are 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 CRT 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 CRT 1A1a, see further discussion in section 3.2.9.

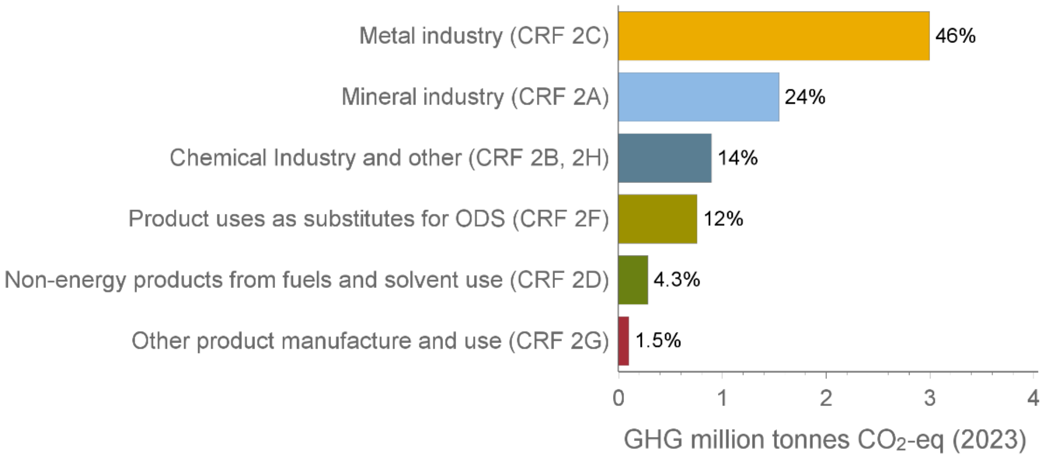

Figure 2.28. Emissions from the industrial processes and product use, 2023.

Greenhouse gas emissions from the industrial processes and product use sector have decreased by 9% in 2023, compared to 1990. Emissions from the sector did however increase during the 90's and early 00's but peaked in 2004 and has since had an overall decreasing trend with some interannual variations, see Figure 2.29

Greenhouse gas emissions from industrial processes (CRT 2A, 2B, 2C, 2E, 2H) have many interannual variations, but show an overall decreasing trend since 1995. Between 2022 and 2023, emissions decreased with 4% (see Figure 2.29). This were mainly caused by emission reductions within the metal industry (2C) and within the mineral industry (2A). Greenhouse gas emissions from product use (CRT 2D, 2F, 2G) showed an increasing trend that has stabilised since 2004, with a small decrease. Nevertheless, greenhouse gas emissions from product use were about twice as high in 2023 compared to 1990.

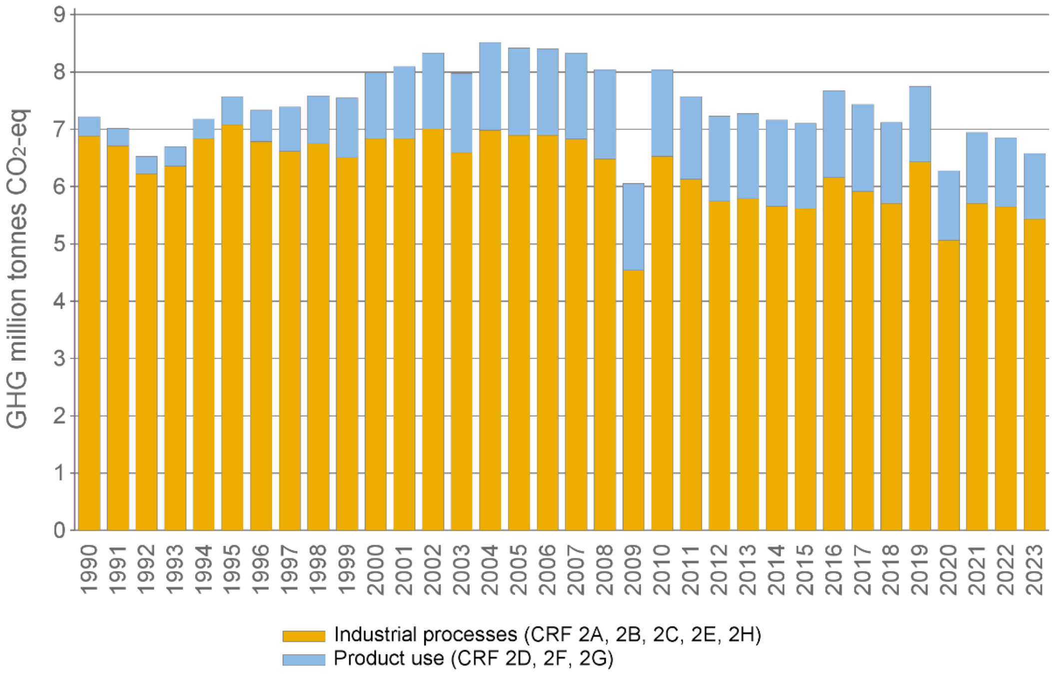

Figure 2.29. Emissions from the industrial processes (CRT 2A, 2B, 2C, 2E, 2H) and product use (CRT 2D,2F,2G), 1990-2023.

2.3.2.1 EMISSIONS PER GAS

Carbon dioxide (CO_2) dominates the emissions of this sector with 5.6 Mt of CO_2-eq. in 2023, representing 83% 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 0.14 Mt of CO_2-eq. in 2023 and mainly originate from the production of nitric acid. In 2023, the N_2O emissions have decreased by 83% since 1990. Emissions of fluorinated gases were 0.8 Mt of CO_2-eq. in 2023 and have increased by 25% 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[19,20]. More information on fluorinated gases is provided in section 2.2.4.

[19] EU, 2014

[20] EU, 2012

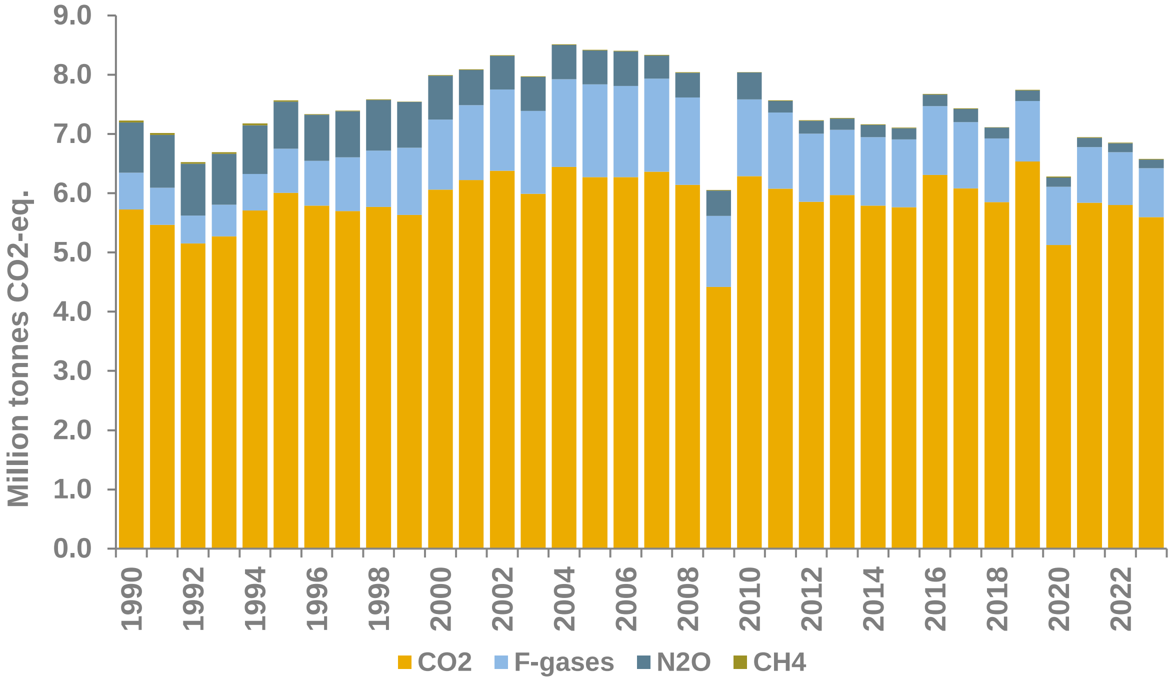

Figure 2.30. Emissions from the industrial processes and product use sector per gas, 1990-2023.

2.3.2.2 INDUSTRIAL PROCESSES (CRT 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.

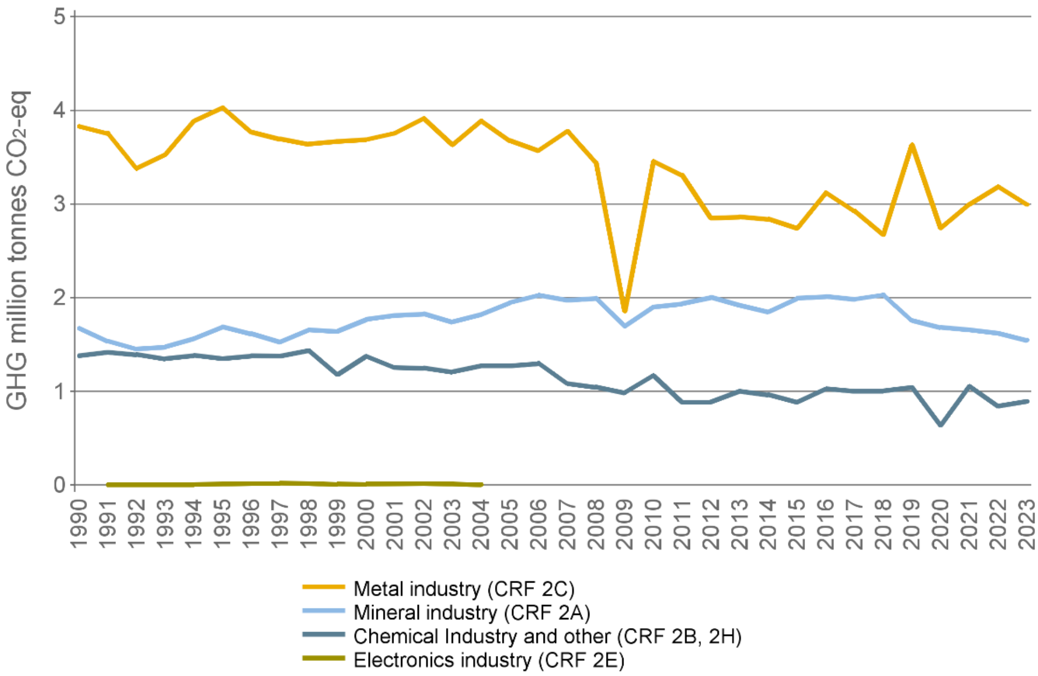

Figure 2.31. Emissions from industrial processes, per subsector, 1990-2023.

The subsector with the largest emissions is the metal industry (2C) with 46% of the industrial process and product use sector's total emissions in 2023, 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). However, prior to 2020, the emissions started reaching pre-recession levels. The increase in emission was due to increased production of iron and steel.

Production of aluminium (CRT 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[21] since 2007.

Mineral industry (2A) is the second largest subsector, accounting for 24% of the sector's (CRT2) total emissions in 2023, see Figure 2.31. Cement production (2A1) accounts for 17% of the sector's (CRT2) total emissions. The industry also includes production lime (2A2) and glass (2A3).

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[22]. The new technology has resulted

[21] Ny Teknik, 2014

[22] Yara, 2007

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 14% of the sector's total emissions in 2023.

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

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

Greenhouse gas emissions from product use (CRT 2D, 2F, 2G) represent 2% of the national total emissions in 2023. 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 2023, the emissions in this subsector (2D, 2F, 2G) accounted for around 1.1 Mt of CO_2-eq, which represents 18% of the total emissions from industrial processes and product use. The emissions have more than doubled 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[23]. 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 were 0.4 Mt of CO_2-eq in 2023 and represented 4% of the industrial processes and product use sector.

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 2023. The trend was increasing until 1995 but has since gradually decreased, with a total decrease of 37% since 1990.

[23] Swedish Chemicals Agency, 2017

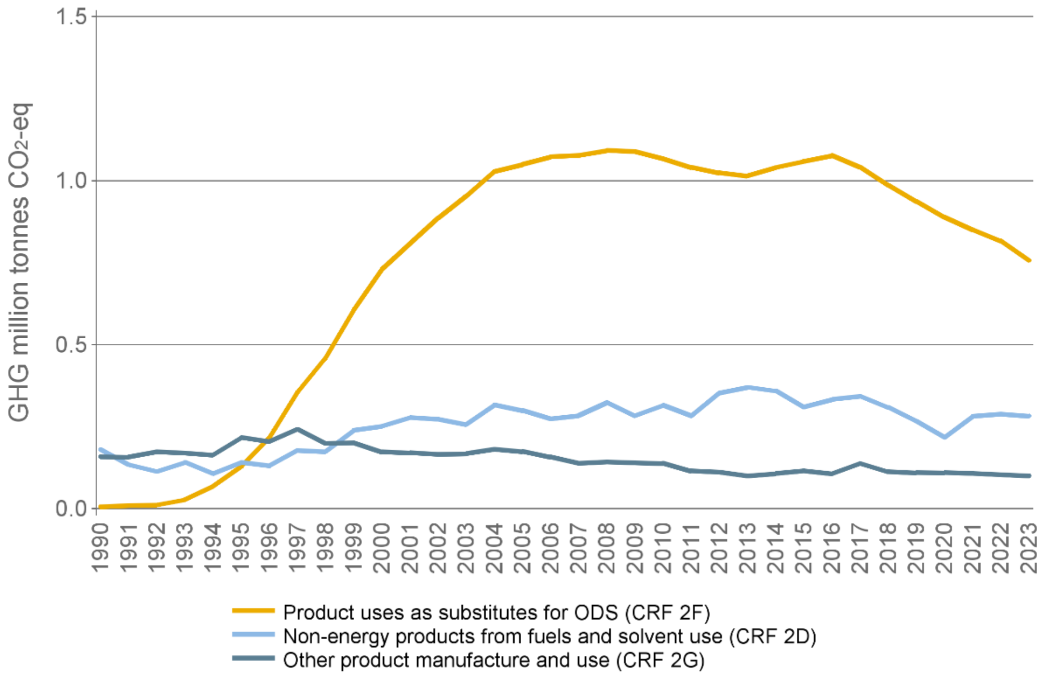

Figure 2.32. Emissions from product use, per subsector, 1990-2023.

2.3.3 Agriculture (CRT 3)

The main sources of greenhouse gas emissions from the agricultural sector are methane from enteric fermentation of livestock, nitrous oxide and methane from manure management and nitrous oxide from agriculture soils. Liming and urea application emit a small amount of carbon dioxide. The aggregated emissions from the sector in 2023 was about 6.3 Mt CO_2-eq., which equals about 14% of the total national greenhouse gas emissions (excluding LULUCF). In addition, there are emissions related to agricultural activities that are reported in other sectors (energy use in the energy sector and emissions and removals of carbon dioxide on agricultural soils in LULUCF).

Emissions in the agricultural sector in 2023 were about 13% lower compared to the emissions 1990. This corresponds to a decrease of about 1 Mt CO_2-eq. The emission reduction was mainly due to increased efficiency and a decline in livestock numbers, especially dairy cattle and swine. Some of the decreasing trend can be explained by a decrease in emissions from agricultural soils, particularly from the reduced use of mineral fertilizers. During the last decade, the emissions have been on a more stable level. In 2023, the overall emissions decreased by about 1.5% compared to the previous year (Figure 2.33). The decrease in emissions in 2023 was mainly due to reduced emissions of nitrous oxide from agricultural land and here the main reason for lower emissions was the low crop yield, which resulted in a lower amount of crop residues in the field. A lower decomposition of organic matter on mineral soils also contributed to reduced nitrous oxide emissions.

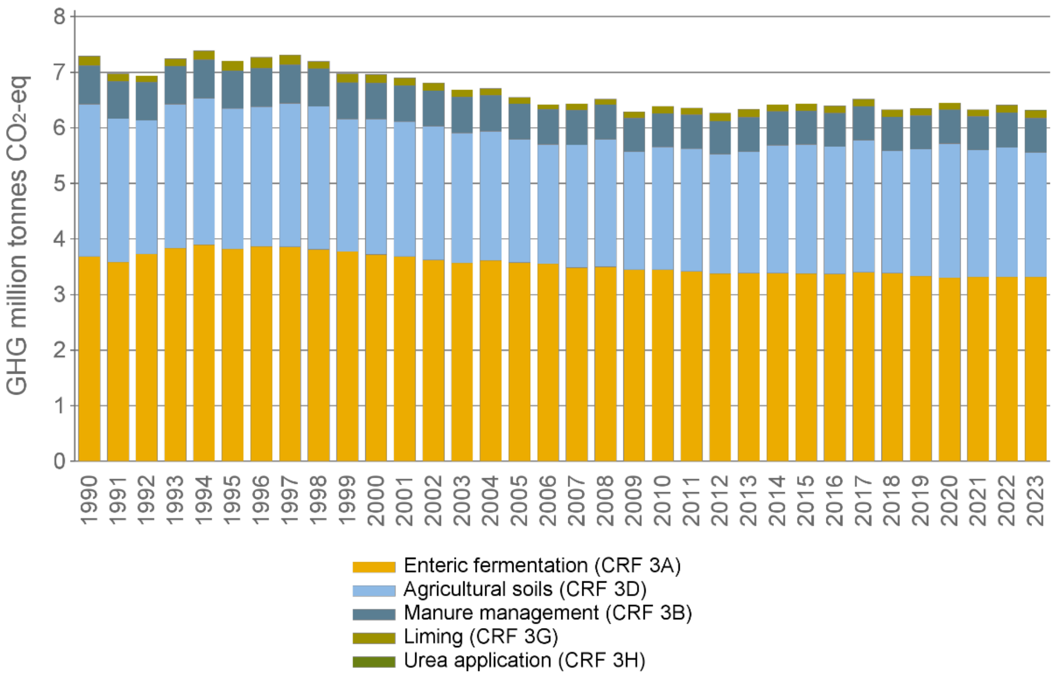

Figure 2.33. Emissions from agricultural subsectors 1990-2023.

Enteric fermentation (3A) and agricultural soils (3D) are the dominant sources of the greenhouse gas emissions in the sector, and in 2023 they accounted for about 53% and 35% of the emissions, respectively. Manure management (3B) and liming (3G) accounted for about 10% and 2% of the sector's emissions, respectively. Emissions from urea application (3H) is very small (Figure 2.34).

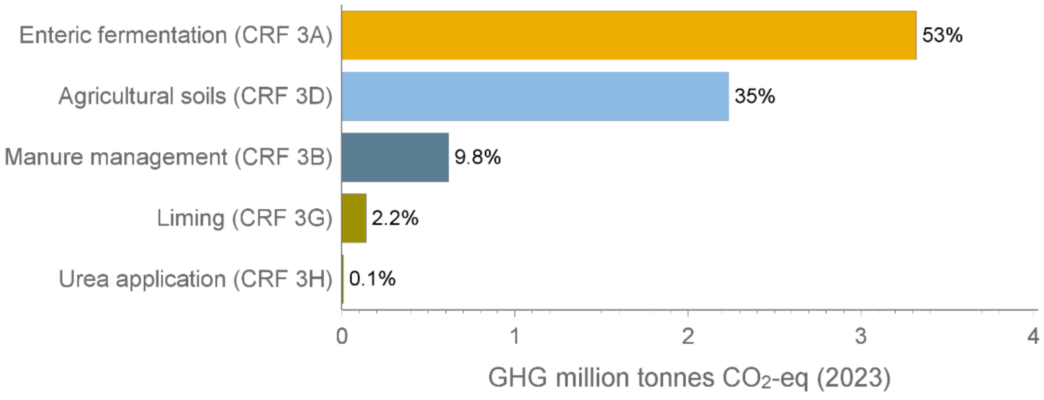

Figure 2.34. Emissions of greenhouse gases in the agricultural sector in 2023.

Animal husbandry and crop production are major sources of non-CO_2 greenhouse gas emissions (CH_4 and N_2O). In 2023, the agricultural sector accounted for 79% and 75% of the total national emissions (excluding LULUCF) of CH_4 and N_2O, respectively. Approximately 58% of the sector's emissions come from CH_4, about 40% from N_2O and about 2% from CO_2. The trend of the emissions per greenhouse gas can be seen in Figure 2.35.

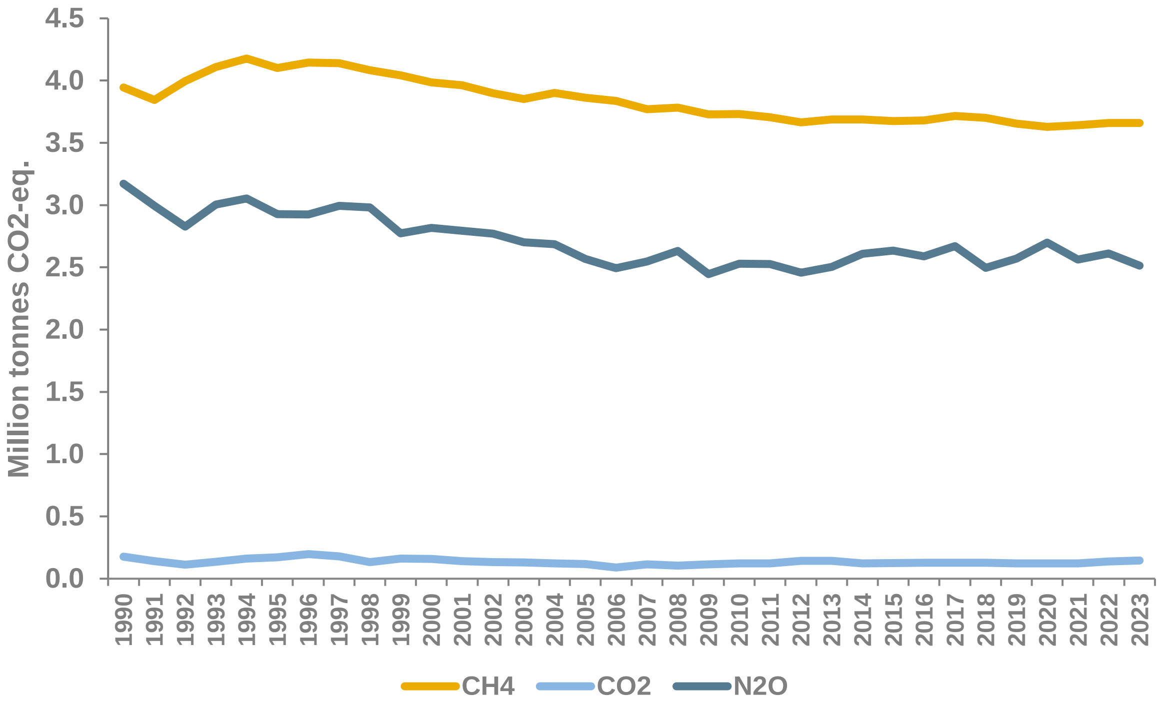

Figure 2.35. Emissions from agricultural sector per greenhouse gas 1990-2023.

2.3.3.1 ENTERIC FERMENTATION (CRT 3A)

The aggregated CH_4 emissions from enteric fermentation (3A) in 2023, were about 3.3 Mt CO_2-eq. which corresponds to about 53% of the sector's emissions (Figure 2.34). Cattle is the main source of emissions from enteric fermentation, accounting for about 87% of the total. The emissions from enteric fermentation in 2023 were about 10% (0.4 Mton CO_2-eq.) lower compared to 1990 levels (Figure 2.33). In 2023 the emissions were about 0.1% (3 kton CO_2-eq.) higher than in 2022.

The main driver for emission reduction since 1990 is a decline in livestock numbers, mainly dairy cattle, whose population has decreased steadily during this period[24]. For this reason, emissions from enteric fermentation from dairy cattle dropped by about 30% since 1990. Higher milk production per dairy cow gives lower CH_4 emissions per kg milk produced. The trend in Sweden is that the number of dairy cows has been reduced by nearly half since 1990, whereas the milk production per cow has increased with over 50%

[24] Jordbruksverket 2023. Lantbrukets djur i juni 2023 Slutlig statistik - Jordbruksverket.se

during the same time period. Therefore, the total amount of milk produced has not been affected to the same degree. The production has become more efficient through improved feeding, breeding and animal health. Cows with a higher production have a larger feed intake and thus emits more methane through enteric fermentation. Even so, the large decrease in the number of dairy cows has led to reduced methane emissions from dairy cattle. In 2023 the emissions from dairy cattle increased by 2% compared to 2022, although the total number of cattle decreased slightly. The explanation to this increase in emissions, despite a small decrease in the number of dairy cows, was the increased milk production per cow.

Emissions of CH_4 from non-dairy cattle (includes suckler cows as well as bulls, steers, heifers and calves from both dairy and beef cattle production) has increased by about 14% since 1990. This can by explained by an increase in the number of animals in this category during the same period. Especially, there has been a major increase in the number of suckler cows. In 2023 the emissions from non-dairy cattle decreased by less than 1% compared to 2022 due to a reduction in number of animals in this category.

2.3.3.2 MANURE MANAGEMENT (CRT 3B)

In 2023, the aggregated emissions from manure management (3B) were about 10% (or approx. 0.6 Mt CO_2-eq.) of the emissions from the agricultural sector (Figure 2.34). The distribution was about 55% CH_4 and 45% N_2O. The total emissions from manure management in 2023 was about 11% lower than in 1990 (Figure 2.33). The reduction in emissions is mainly due to a reduced number of dairy cows and swine and to some extent also to improved storage of manure. During the same time period there has been an increase in emissions from especially non-dairy cattle and poultry (due to increased numbers of especially suckler cows and broilers), but also from horses and sheep.

In 2023, more than one-third (37%) of the emission from manure management originated from non-dairy cattle and these emissions have increased by 37% since 1990, due to increased beef production. Emission from manure management of dairy cattle and swine in 2023 were about 22% and 9%, respectively. These emissions have decreased since 1990, mainly due to reduced population sizes. Emissions from poultry accounted for 12% in 2023, which is an increase by 130% since 1990 due to an increased poultry population size. The rest of the emissions from manure management originated from other animal categories (such as sheep, goats, horses) and from indirect emission, i.e., atmospheric deposition.

In 2023 the emissions from manure management were about 1.5% (9 kton CO_2-eq.) lower than in 2022. This was mainly due reductions in numbers of most animal categories and thus less manure to store.

2.3.3.3 AGRICULTURAL SOILS (CRT 3.D)

Agriculture soils (3D) is the largest source of the national N_2O emissions. Emissions are mainly derived from the supply and conversion of nitrogen from the use of inorganic fertilizers, cultivation of organic soils, crop residues and animal manure applied to soils or deposited by grazing animals. Other sources include emissions from other organic fertilizers, such as sewage sludge, as well as indirect emissions from atmospheric deposition and nitrogen leaching and run-off.

In 2023, emissions from agriculture soils (3D) were about 2.2 Mt CO_2-eq.and accounted for 35% of the sector's total (Figure 2.34). Emissions have decreased by about 19% since 1990 (Figure 2.33). The main reasons are reduced use of especially mineral fertilizers (until about 10 years ago when this trend was stabilized), a reduction in cultivated area of organic soils as well as less agricultural land overall. Within the agricultural sector the yearly variation in emissions is usually largest from agricultural soils, partly due to the variation in sales of inorganic N-mineral fertilizers and in harvest resultats.

The use of inorganic N-fertilizers has a large effect on the emissions and is based on sales statistics. Since 1990, emissions from the use of inorganic N-fertilizers declined as sales have fallen. However, the sales of, and thus also the emissions from, inorganic fertilizers have started to increase again since around 2012. One explanation is an increased area of autumn sown, high yielding crops which requires more nutrients. Further, the general trend with larger harvests in later years have also increased the need of fertilizers. However, there is a large yearly variation in sales of, and thus the emissions from, fertilizers. Factors that can affect the sales of fertilizers a certain year includes prices of fertilizers and crops, harvest yields and the amount of saved fertilizers from previous year.

Between 2022 and 2023 there was a decrease in emissions from agricultural soils by about 4%. The main reason for lower emissions was the low crop yield in 2023, which resulted in a lower amount of crop residues in the field. A lower decomposition of organic matter on mineral soils also contributed to reduced nitrous oxide emissions. Sales of nitrogen in mineral fertilizers for the 2022/2023 fertilizer year were on a similar level[25] as the previous fertilizer year and had little effect on the change in emissions.

2.3.3.4 LIMING (CRT 3.G) AND UREA APPLICATION (CRT 3.H)

Liming and the use of urea fertilizers give rise to emissions of carbon dioxide in the agricultural sector. Liming is mainly applied to counteract acidification, improve soil structure and to reduce phosphorus losses. Total emissions of CO_2 from liming were about 0.14 Mton in 2023, which is about 2% of the sector's emission (Figure 2.34). The emissions from liming have decreased by about 20% since 1990. However, there is some yearly variation. For example, in the years 2022 and 2023 the emissions from liming were somewhat higher than in 2021.

The amount of urea used in Sweden is generally small compared to many other countries because urea is a slow release fertilizer, which does not fit well in areas with a short growing season in northern latitudes such as Sweden. With some yearly variation the emissions from urea show a downward trend compared to 1990. However, in 2023 the estimated CO_2 emissions from urea application were around 7 kton, which was unusually high.

[25] SCB, 2024. Statistiskt meddelande Försäljning av mineralgödsel för jord- och trädgårdsbruk 2022/23

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

This sector consists of source and sink categories linked to land use, land use change and forestry. The total net removal was 31 million tonnes of CO_2-eq. in 2023. 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 on forest land and amounted to almost 32 million tonnes of CO_2-eq in 2023, followed by harvested wood products with total net removals of 5 million tonnes of CO_2-eq. The largest net emissions in this sector occur in settlements, cropland and wetlands. This sector has been a net sink the whole period from 1990 until 2023.

Sweden reports carbon stock changes from forest land (CRT 4 A), cropland (CRT 4B), grassland (CRT 4C) and settlements (CRT 4E) and associated land-use transfers and also a small part of wetlands (CRT 4D) where peat extraction occurs on already drained peat lands. These land use categories are considered managed. Since 2019 Sweden also report on other land since the ERT recommended us to do so. Sweden report on land change from managed land to unmanaged land. Since 2023 Sweden has included carbon stock change from mountainous forest land. Sweden have also updated the methodology for estimating carbon stock change in mineral soils on forest land, grassland and cropland. When it comes to organic soils on cropland, we updated the area in 2023 and the emissions factors for this submission 2025. This year Sweden has updated the method for calculating living biomass, mineral soils and emissions factors for drained organic soils. More on this in the LULUCF chapter below.

The calculation of net emissions and removals in the LULUCF sector also includes HWP (Harvested Wood Products) (CRT 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 69% of the total Swedish land area.

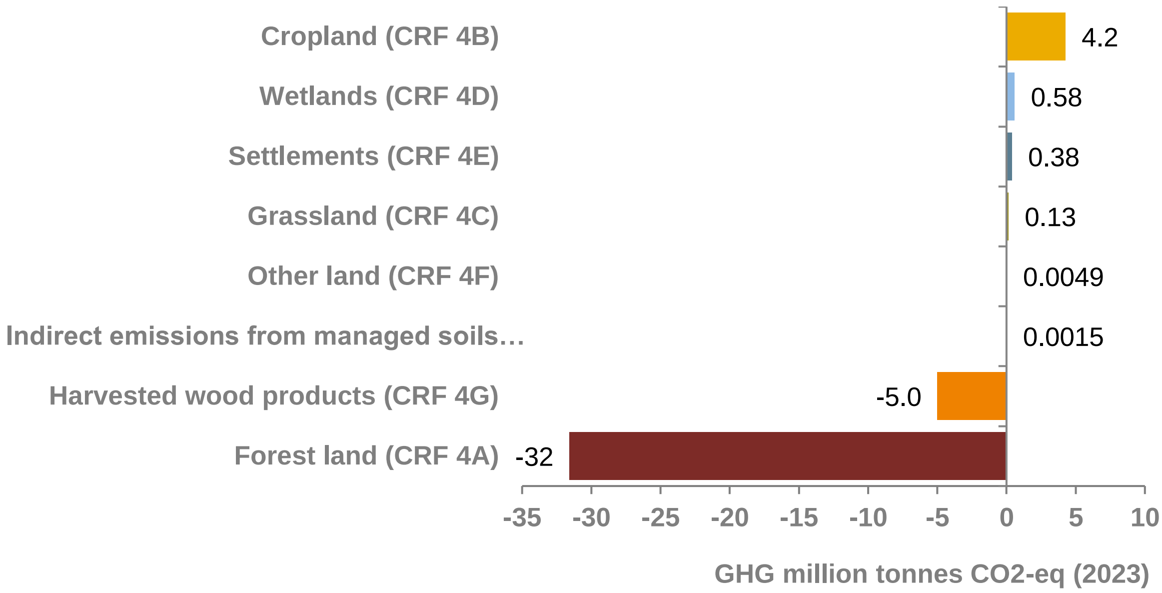

Figure 2.36. Emissions (+) and removals (-) in the LULUCF sector; for the categories, Forest land (CRT4A), Cropland (CRT 4B), Grassland (CRT 4C), Wetland (CRT 4D), Settlements (CRT4F) and HWP (CRT 4G) in 2023.

Net emissions and net removals per category

The LULUCF sector has generated annual net removals in Sweden during the whole period 1990-2023 (Figure 2.36 and 2.37). In 2023, total net removal from the sector was estimated to 31 million tonnes of CO_2-eq. During the period total net removals have varied between around 31 to 64 million tonnes of CO_2-eq. The total net removal in 2023 was 7% lower than in 2022. 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 and mineral soil constitute the major parts of these changes, followed by carbon stock changes in dead organic matter.

Net removals in this sector are heavily influenced by growth rate for living biomass, harvests and natural disturbances such as storms, drought and fires on forest land.

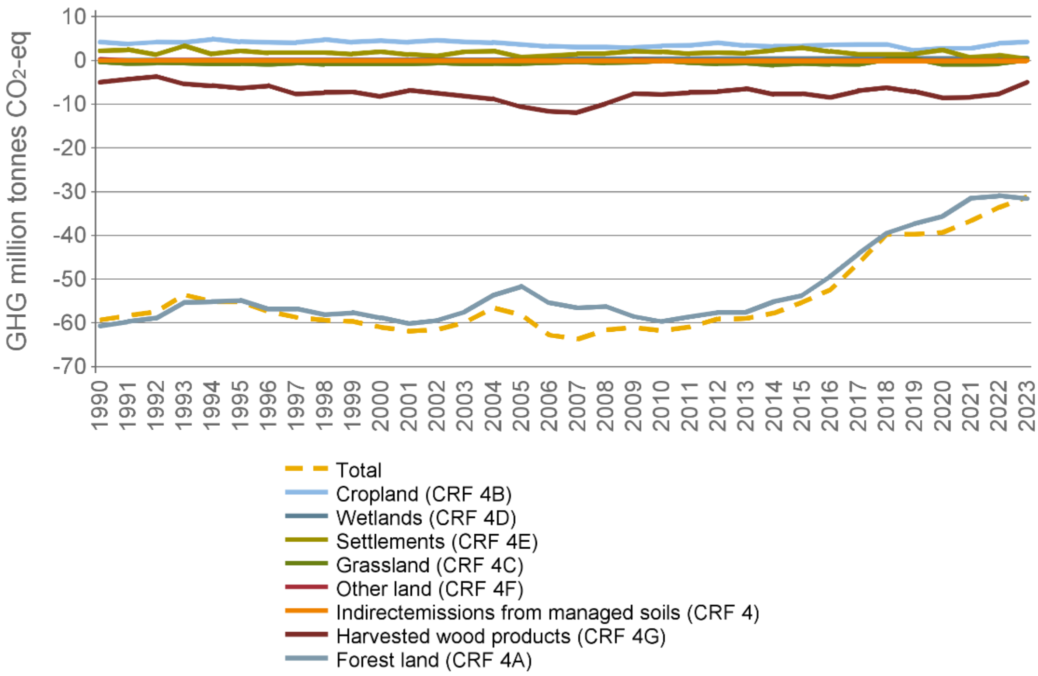

Figure 2.37. Net emissions (+) and removals (-) of greenhouse gases in the LULUCF sector from different land-use categories and total net removals for the LULUCF-sector, 1990-2023.

The lowest net removal in living biomass in forest land was 4 million tonnes of CO_2-eq in 2023 and the highest was about 40 million tonnes of CO_2-eq. in 1991. Between 2013 and 2023 the total net removal on forest land decreased by nearly 26 million tonnes of CO_2-eq. The decrease in net removal in living biomass is due to a decrease and slowing down in forest growth, high harvest and high mortality. In 2005 and 2007 there were decreases in the net removal 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, a decrease in the living biomass results mostly in an increase in the HWP-pool. The HWP-pool was a bit smaller in 2023 than in 2022, around 5 million tonnes of CO_2-eq.

Inter-annual fluctuations in harvest rates are large. In 2023 the gross harvest was approximately 90 Mm^3 stemwood [26]and this is a decrease of 6 Mm^3 stemwood since 2022. Gross removal (growth) in Sweden shows an increasing trend in the first part of the period 1990 – 2023 but during the latest years the increase rate has slowed down and flattened out[27]. Since harvest level is below growth there is still a ~~steady~~ carbon stock in living biomass, which has prevailed since the beginning of the 21th century, but the trend is negative. The mineral soil pool on forest land is a steady net removal. In 2023 the net removal was 20 million tonnes of CO_2-eq. The carbon stock change in mineral soil is hard to estimate since the pool is very large and the changes very small, which entails high uncertainties. The emissions from organics soil on forest land has increased over the period 1990 – 2023 and in 2023 the emissions amounted to 8 million tonnes of CO_2-eq..

[26] https://www.skogsstyrelsen.se/statistik/statistik-efter-amne/avverkning/

27 Officiell statistik om den svenska skogen | Sveriges lantbruksuniversitet, SLU (mynewsdesk.com)

The categories grassland and wetlands account for very small areas and small net emissions and especially compared to forest land. The net emissions and 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 2023. In 2023 it was a net source of about 0.1 million tonnes of CO_2-eq (uncertainties are big). The emissions from wetlands are due to drainage of organic soils for peat production and decay of peat for cultivation. The net emissions in 2023 were 0.6 million tonnes of CO_2-eq. The peat production for energy has decreased but the peat production for cultivation has increased.

The largest net emissions in this sector come from cropland and settlements. Net emissions from cropland have been almost 4 million tonnes of CO_2-eq. as a mean value between 1990 and 2023. The annual variation in net emissions in cropland is connected to the variation in mineral soils. The variations in mineral soils depend on variations in the total area grown and the areas of which crops that are grown between years, together with the variation in climatic conditions (air temperature and precipitations). The total net emission in 2023 was a bit more than 4 million tonnes of CO_2-eq. The emissions from the cultivation of drained organic soils have been decreasing since the areal has decreased. Emissions from drained organic soils are the largest source in this land use category and in 2023 the net emissions amounted to 3.6 million tonnes of CO_2-eq.

Total net emissions from settlements were on average 1.8 million tonnes of CO_2-eq during the period 1990 to 2023. The highest total net emission was in 2015 and amounted to nearly 3 million tonnes of CO_2-eq. Emissions are mainly caused by urbanisation and establishments of power lines and forest roads and in connection with harvest of living biomass.

Net emissions and net removals by carbon pool

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 (Figure 2.38).

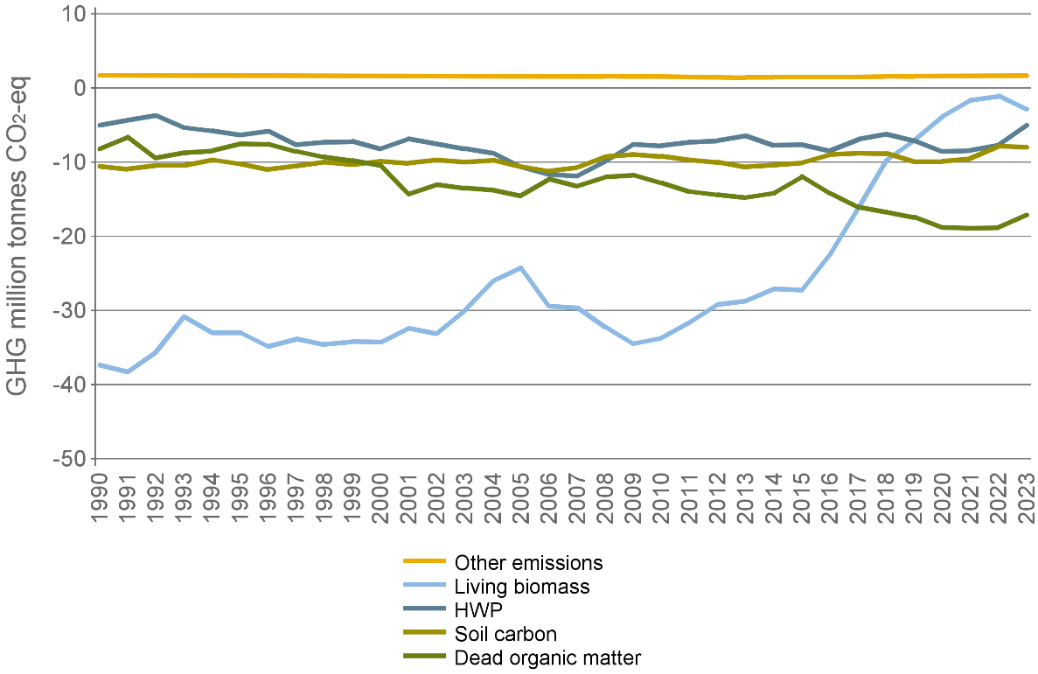

Figure 2.38. Emissions (+) and removals (-) of carbon dioxide from different carbon pools, 1990-2023.

Net removals in living biomass and mineral soil are significant and primarily given by the net removals on primarily forest land. The net removal in the carbon pool living biomass in 2023 was almost 3 million tonnes of CO_2-eq. and this is a bit higher than in 2022 when the total net removal in living biomass was 1.5 million tonnes of CO_2-eq. The lowest net removal for living biomass since 1990 was observed in 2022. The low total net removal in living biomass depends on low growth rate, high harvest and high mortality (increased by bark beetles). 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 stock of timber the year after the storm. The net removal in the pool HWP was about 5 million tonnes of CO_2-eq. in 2023 and this is a decrease since 2022 The HWP carbon stock has on average been 7,3 million tonnes of CO_2-eq. increased during 1990 until 2023. The stock covariates with the harvest[28].

The uncertainty of estimates in the LULUCF sector is generally larger than in other CRT sectors in the inventory and the uncertainties are generally larger for the smaller categories (area) in the LULUCF sector than for larger ones. For more information, please read in NID annexes.

[28] https://www.skogsstyrelsen.se/statistik/statistik-efter-amne/avverkning/

2.3.5 Waste (CRT 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 (CRT 5) include emissions from solid waste disposal (CRT 5A), wastewater treatment and discharge (CRT 5D), biological treatment of solid waste (CRT 5B) and incineration and open burning of waste (CRT 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 1.05 Mt CO_2-eq. in 2023, or 2% of the national total of greenhouse gas emissions. Out of this, approximately 0.41 Mt CO_2-eq. came from solid waste disposal.

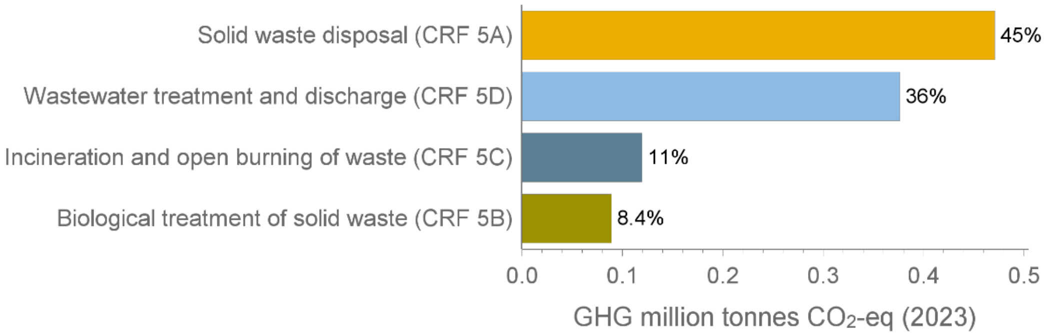

Figure 2.39. Share of emissions from sub sectors in the waste sector 2023.

Emissions in the sector are predominantly methane (CH_4), 70% in 2023, as seen in Figure 2.40. Emissions of methane from the waste sector have decreased by 82% in the period 1990 to 2023, due to an increased level of collection and management of methane gas from landfills and reduced amounts of organic material being deposited in landfills.

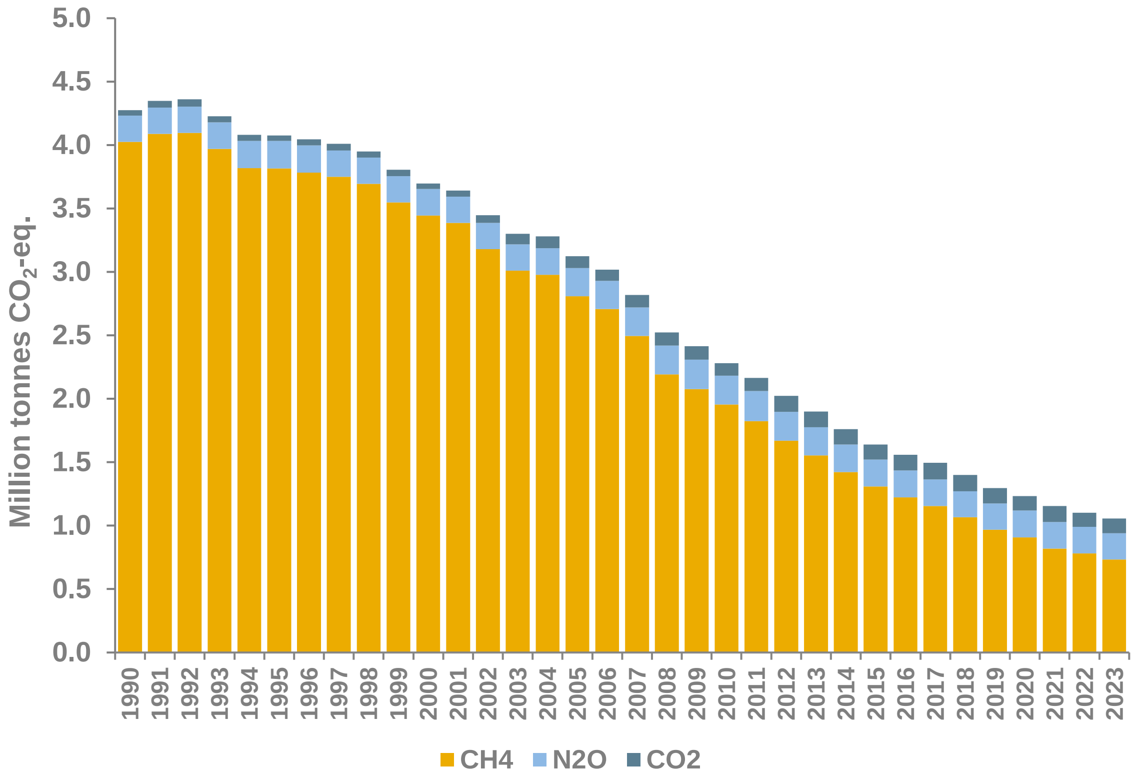

Figure 2.40. Emissions from the waste sector, per gas, 1990-2023.

In 2023, nitrous oxide (N_2O) emissions amounted to 20% of the greenhouse gas 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 (CO_2) emissions, 11% of the sectors' emissions in 2023. 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.

Emissions from the waste sector have decreased by 75% 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 88% between 1990 and 2023.

While emissions from wastewater treatment and discharge increased by 1% from 1990 until 2023, emissions emanating from biological treatment of solid waste and incineration and open burning of waste both show increasing trends from 1990 to 2023, by 597% and 167% respectively.

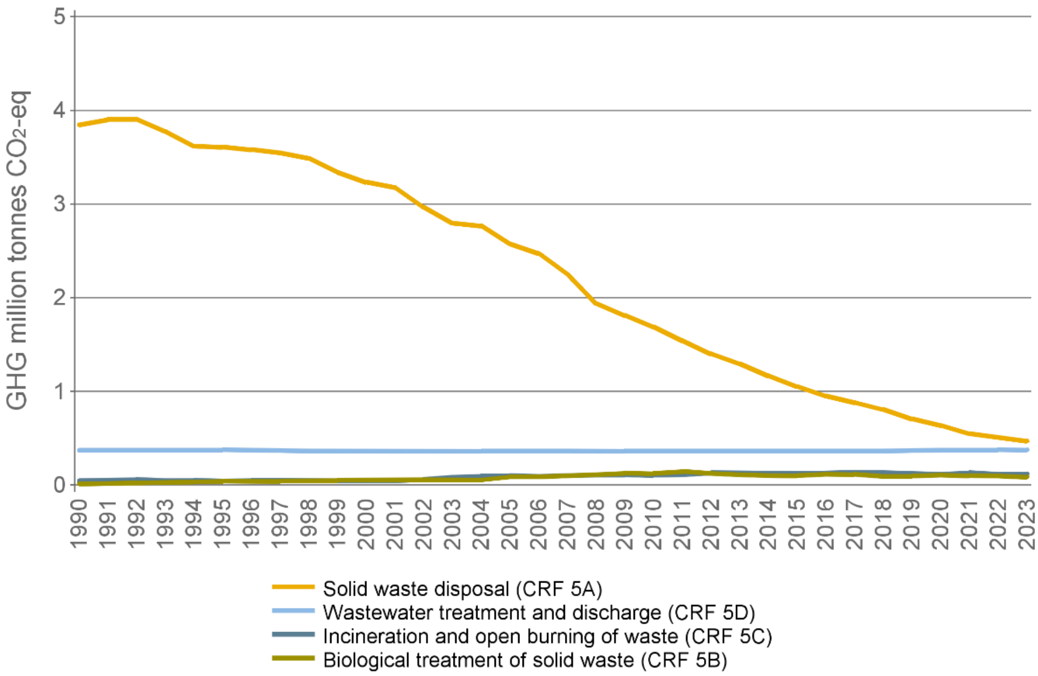

Figure 2.41. Emissions from the waste sector, per subsector, 1990-2023.

2.3.5.1 SOLID WASTE DISPOSAL (CRT 5A)

In 2023, 54% of the emissions from the waste sector came from solid waste disposal (CRT 5A). Between 2022 and 2023 the emissions decreased by 8% 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, CRT 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)[29]. A tax on depositing waste in landfills was introduced in 2000[30]. Bans on landfill disposal of combustible waste (in 2002) and organic material (in 2005) have also been introduced[31]. These bans contributed to substantial shifts in Swedish waste management. The landfilling of other types of waste has also fallen sharply.

[29] Swedish EPA, 2017

[30] Avfall Sverige, 2017

[31] Swedish EPA, 2012

Finally, the obligation for municipal waste planning that was introduced in 1991[32] 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 (CRT 5D)

About 36% 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 2023. Wastewater treatment facilities have been continuously improved since the late 1960s[33]. Emissions from Swedish wastewater treatment and discharge have decreased by approximately 10% 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 (CRT 5B)

Biological treatment of solid waste accounted for 8% of the total emissions in the waste sector in 2023 (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 by almost 597% since 1990, especially in recent years when also production of biogas using anaerobic digestion was scaled up[34]. 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 (CRT 5C)

In 2023, 11% 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 (CRT 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 Protocol commitments. Greenhouse gas emissions from international shipping and aviation, also known as international bunkers, are considerably larger than those from domestic shipping and

[32] Swedish EPA, 1991

[33] Swedish EPA, 2009

[34] Swedish Energy Agency, 2015

aviation. In 2023, they amounted to 7.6 Mt of CO_2-eq, which is an decrease of 15% since 2022 (Figure 2.42). The increase in emissions from international aviation is a result of increased air traffic after the covid-19-pandemic. Greenhouse gas emissions from international shipping continued to decrease during 2023.

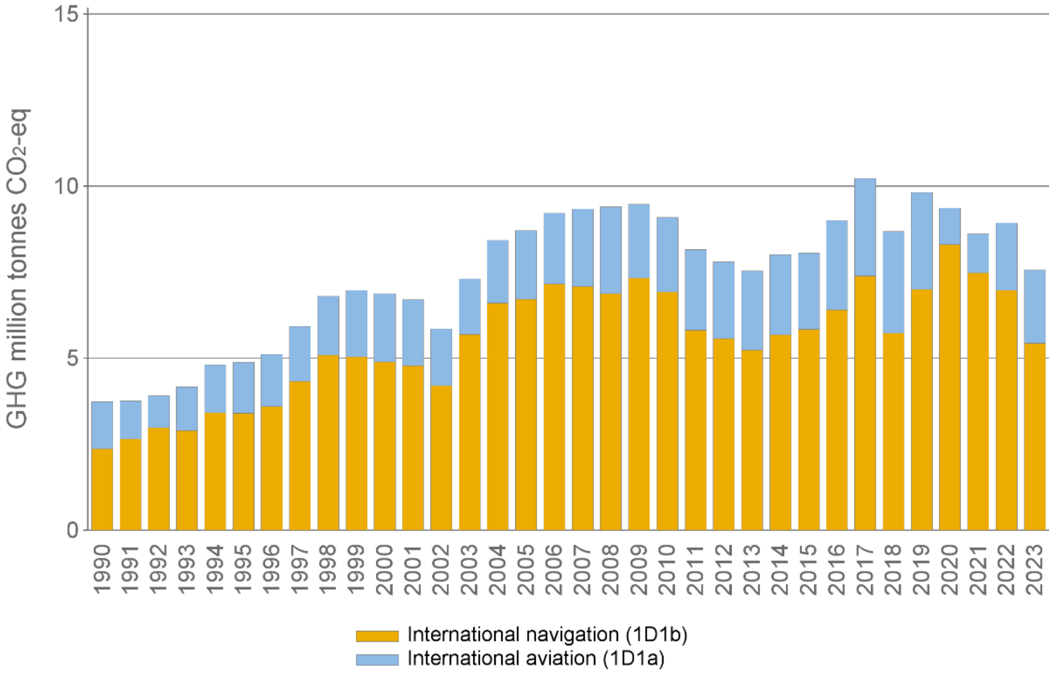

Figure 2.42. Emissions from international bunkers, total and per subsector, 1990-2023.

Emissions from international shipping reached a total of 5.4 Mt of CO_2-eq. in 2023. This is a decrease by 22% compared to 2022, and a doubling of emissions compared to 1990. Fluctuations in bunker volumes between years are also dependent on fuel prices in Sweden compared to the prices in ports in other countries.

Greenhouse gas emissions from international aviation bunkers were 2.1 Mt of CO2-eq. in 2023. This is an increase of 9% compared to 2022, and 56% higher than in 1990. The large increase in emissions from international aviation between 2022 and 2023 is a rebound effect after the covid-19-pandemic. Emissions are still not back at pre-pandemic levels. Emissions from international bunkering of aviation have varied over time, but the trend points to a rise in these emissions, owing to growth in international travel.

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 138 kt of non-methane volatile organic compounds (NMVOCs) were emitted in 2023. Approximately 47% of the emissions was derived from the industrial processes and product use sector (CRT 2). The shares of the energy sector (CRT 1) and the agricultural sector (CRT 3) were about 30% and 22%, respectively. The remaining emissions (0.2%) were derived from the waste sector.

Within (CRT 2) most of the NMVOCs emissions were derived from solvent use (2D3), accounting for 41% of the national total in 2023. Most of the emissions in CRT 1 were derived from Other sectors (1A4) and the transport sector (1A3) as well as from fugitive emissions of oil and natural gas (1B) and accounted for about 9,4%, 9.5% and 2.3% of the national total, respectively. Emissions from manure management (3B) accounted for about 16% of the national total in 2023, see Figure 2.43.

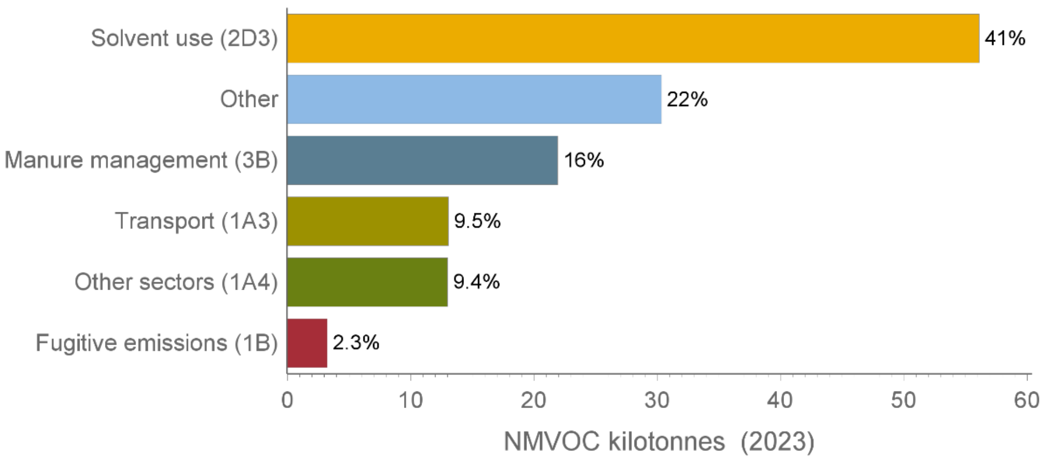

Figure 2.43. Emission sources of NMVOC in 2023 (kt).

The aggregated emissions of NMVOCs have declined by approximately 62% since 1990. Most of the emission reduction occurred in the energy sector (CRT 1) followed by the industrial processes and product use sector (CRT 2. The aggregated emissions in 2023 decreased by approximately 1% compared to 2022 and most of the decrease occurred in CRT 2, see Figure 2.44.

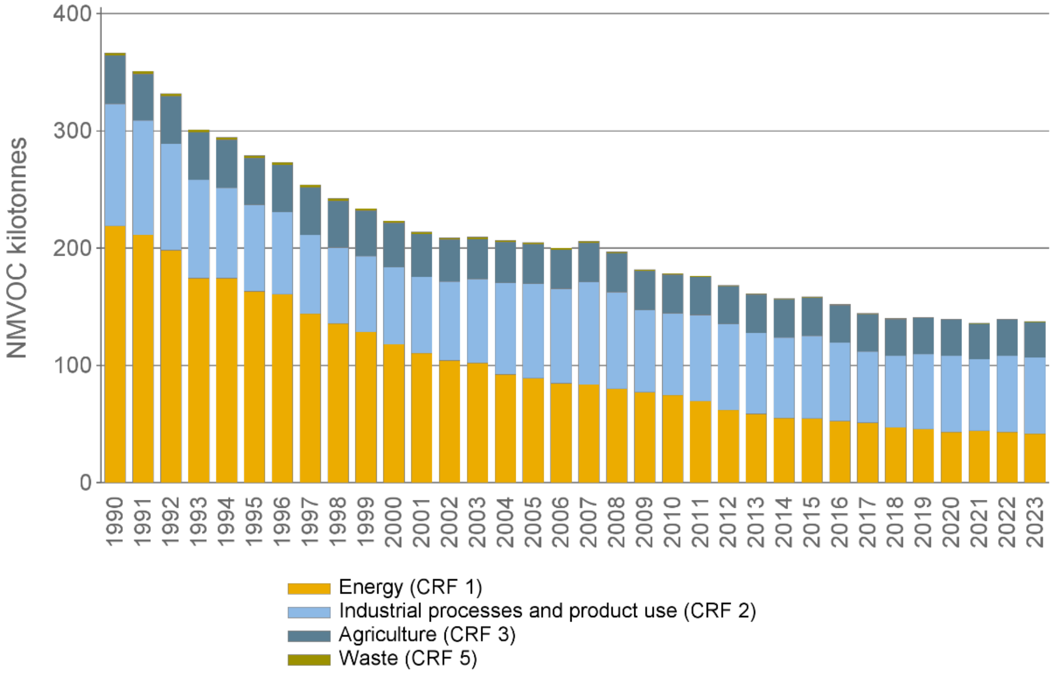

Figure 2.44. Emission trends of NMVOC 1990-2023 (kt).

Within the energy sector, the largest reduction of NMVOCs emissions occurred in the transport sector (CRT 1A3) as emissions decreased by about 91% since 1990. The main reason behind the reduction was the introduction of stricter emission standards in the EU regulation for road vehicles. Between 2022 and 2023, emissions from the transport sector decreased by 2%. Emissions from oil refineries (1B) have also decreased since 1990; by 89% due to technological improvements in the sector.

Since 1990, NMVOCs emissions from solvent use (2D3) have decreased by 38% due to national abatement measures, such as the reduction of solvents content in paints and coatings. Emissions from the agricultural sector (CRT 3) have declined by about 26% since 1990, mainly due to decreased numbers of livestock and hence reduced amounts of manure, especially from dairy cattle and swine.

2.4.2 Nitrogen oxides (NO_X)

In 2023, the total emissions of NO_X were about 104 kt. The energy sector (CRT 1) accounted for most of the emissions (75%). The industrial processes and product use sector (CRT 2) and the agricultural sector (CRT 3) were responsible for about 12% each. Emissions from the waste sector (CRT 5) were insignificant.

In 2023, the transport sector (1A3) and the manufacturing industries and construction (1A2) were responsible for 41% and about 13%, respectively, while the shares of the heat production and public electricity sector (1A1a) and Other sectors (1A4) contributed 12% and 8% respectively, of the total emissions.

The pulp and paper industry (2H1) was the major source of NO_x emission in the CRT 2 sector. Most of the emissions in the agricultural sector were derived from agricultural soils (3D), see Figure 2.45.

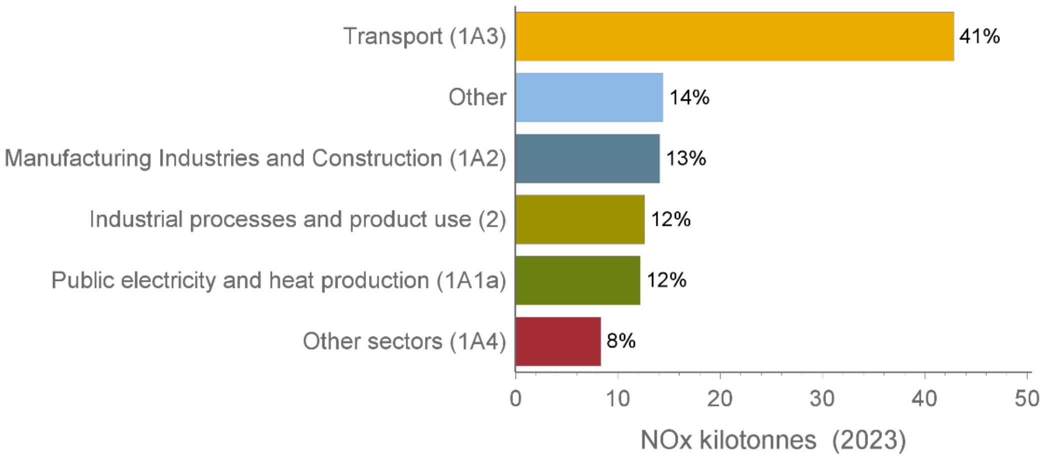

Figure 2.45. Emission sources of NO_x in 2023 (kt).

Since 1990, the aggregated NO_X emissions have declined by 64% and the emissions in 2023 were 4.8% lower compared to the previous year, see Figure 2.46. NO_x emissions from the transport sector (1A3) have declined by about 75% since 1990. Between 2022 and 2023, emissions from the transport sector decreased by 7%, mainly from road transportation. 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.

NO_X emissions from energy industries (1A1) have been reduced by about 21% since 1990. However, the annual NO_X emission from (1A1) varies due to variable weather conditions. Weather influences the demand for heating of houses, public and commercial buildings, resulting in emission patterns that mirror the inter-annual variability of weather. The increased use of district heating and the introduced "NO_X charge" in the early 1990s have also contributed to reduction of NO_X emissions.

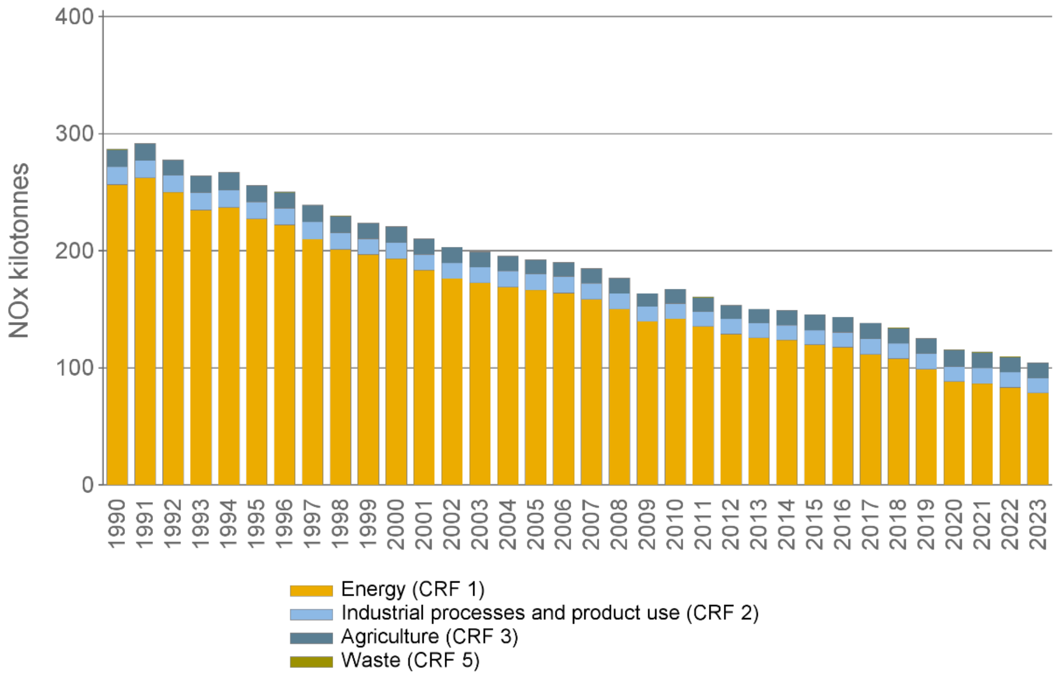

Figure 2.46. Emission trends of NO_X 1990-2023 (kt).

Emissions of NO_x from the industrial processes and product use sector (CRT 2) have decreased by about 18% since 1990. Mineral- chemical- and metal industries were responsible for the reduction. Since 1990, emissions from the agricultural sector have declined by 14% due to reduced use of N-fertilizer and the reduction of the amount of manure following a decreasing number of livestock, especially in dairy cattle and swine. There have also been improvements in manure management at the national level.

2.4.3 Carbon monoxide (CO)

The aggregated emissions of carbon monoxide (CO) have decreased by 76% since 1990 and were around 267 kt in 2023. Emissions in 2023 were 3% lower than 2022.

In 2023, the energy sector (CRT 1) accounted for most of the emissions (89%). Most of the remaining emissions were derived from the industrial processes and product use sector (CRT 2). Emissions from the waste sector (CRT 5) were insignificant.

In 2023, Other sectors (1A4, mainly residential heat production (1A4b) and commercial /institutional (1A4a)) accounted for 52% of the total emissions. The share of the transport sector (1A3) was 29%. Emissions from manufacturing industries and construction (1A2) and the industrial processes and product use sector (mainly metal industry (2C) and pulp and paper industry (2H1)), accounted for about 5.4% and 11%, respectively of the emissions in 2023, see Figure 2.47.

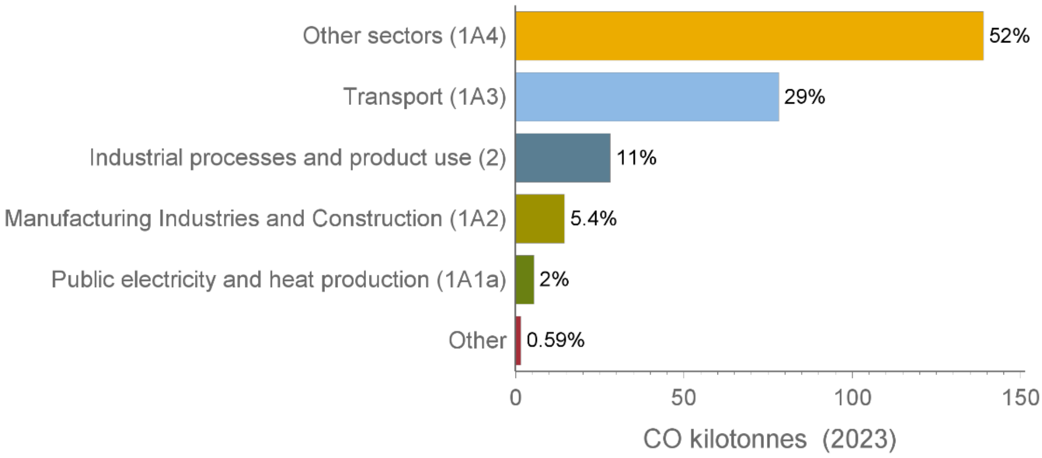

Figure 2.47. Emission sources of CO in 2023 (kt).

Since 1990, emissions from the energy sector (CRT 1) have declined by 78% of which the transport (1A3) was responsible for most of the reduction. This was achieved as new fuel-driven vehicles sold in Sweden have been equipped with catalytic converters that convert CO gas and other unburned hydrocarbons to CO_2 and water vapor. Emissions of CO from the industrial processes and product use sector (CRT 2) have increased by about 28% since 1990, mainly from aluminum production (2C3) and pulp and paper industry (2H1), due to increased production, see Figure 2.48.

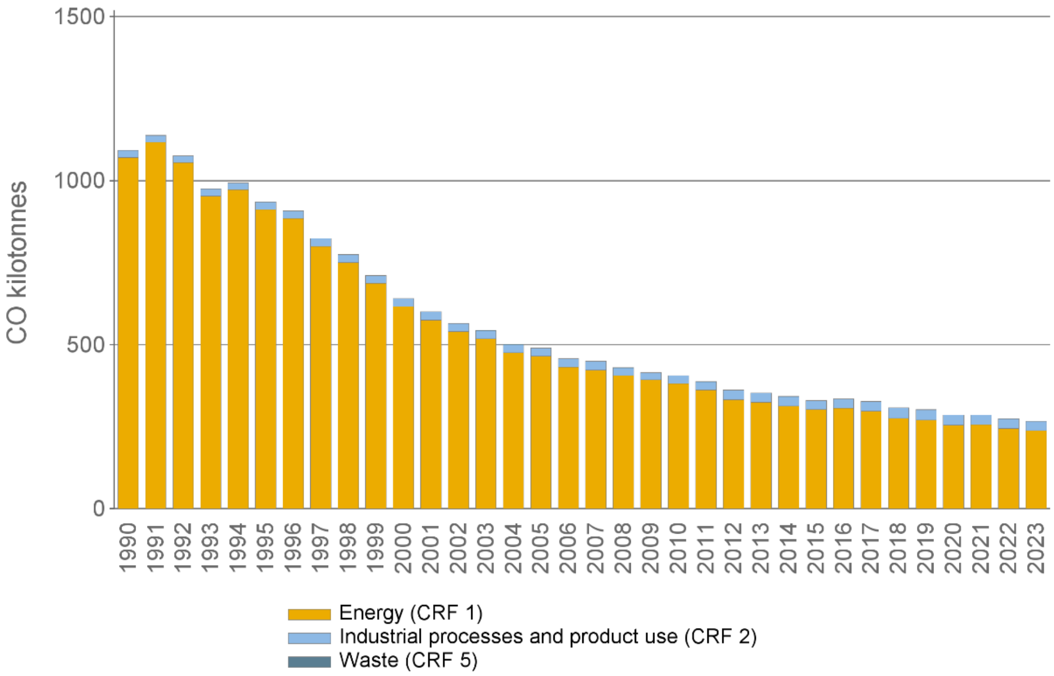

Figure 2.48. Emission trends of CO 1990-2023 (kt).

2.4.4 Sulphur dioxide (SO_2)

Emissions of SO_2 have decreased from about 103 kt in 1990 to about 14 kt in 2023, a reduction of 86%. Emissions in 2023 were about 2% lower than the previous year. In 2023, almost 43% of the emitted SO_2 was derived from the energy sector (CRT 1), while the industrial processes and product use sector (CRT 2) was responsible for the remaining emissions (56%). Emissions from the waste sector (CRT 5) was insignificant.

Most of the SO_2 emissions were derived from Metal industry (2C) and public electricity and heat production (1A1a), accounting for 28% and 16%, respectively. The manufacturing industries and construction sector (1A2) was responsible for 16% and the Other sectors (1A4) for 4.3% of the total emissions in 2023. The transport sector accounted for 2.6% of the emissions. see Figure 2.49.

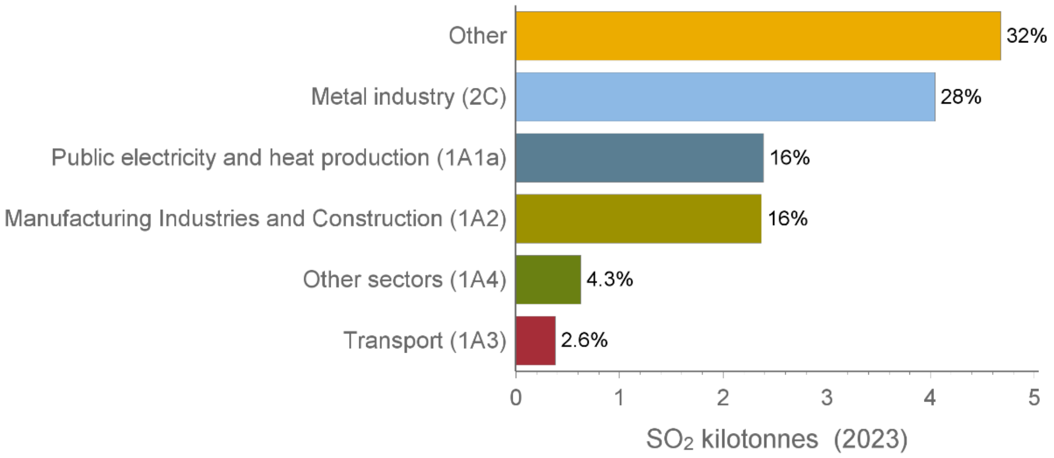

Figure 2.49. Emission sources of SO_2 in 2023 (kt).

Emission of SO_2 from the transport (1A3) has declined by 97% since 1990, see Figure 2.50. A similar trend can be observed in other subsectors within the energy sector, such as the energy industries (1A1), the manufacturing industries and construction (1A2) and Other sectors (1A4), which have declined between 84% and 88%. Emissions from the industrial processes and product use sector (CRT 2) have also declined by 76% since 1990. The main reason for the reduction of emission was a transfer from fuels with high-sulfur content to very low-sulfur content fuels. A tax on sulfur, introduced in 1991, has been important in this transition.

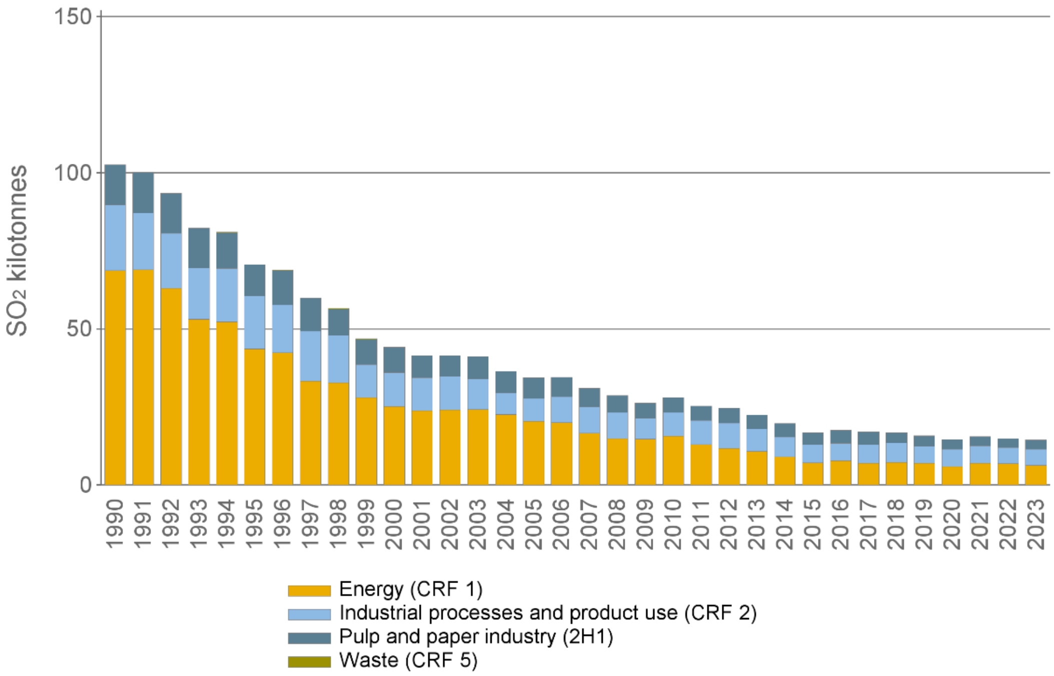

Figure 2.50. Emission trends of SO_2 1990-2023 (kt).

The pulp and paper industry (2H), metal industry (2C) and the mineral industry (2A) were responsible for most of the SO_2 emission reduction within CRT 2. Domestic navigation (within Water-borne navigation CRT 1A3d) contributed a little more than 1% of the aggregated SO_2 emissions in 2023 and has decreased by 95% compared to 1990, due to a switch to oils with lower sulphur content.

3 Energy (CRT sector 1)

3.1 Overview of sector

The energy sector includes emissions from fuel combustion (CRT 1.A) and fugitive emissions from fuel production and handling (CRT 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[35].

As can be seen in Figure 3.1, in the energy sector, emissions of CO_2 contribute about 98% of the total greenhouse gas emissions (in CO_2-eq.) in 2023. Emissions of total greenhouse gases from the energy sector have decreased by 42% from 52 409 kt CO_2-eq. in 1990 to 30 435 kt CO_2-eq. in 2023, mainly due to reduced fossil fuel consumption in the residential sector (CRT 1.A.4) and the transport sector (CRT 1.A.3) (Figure 3.2).

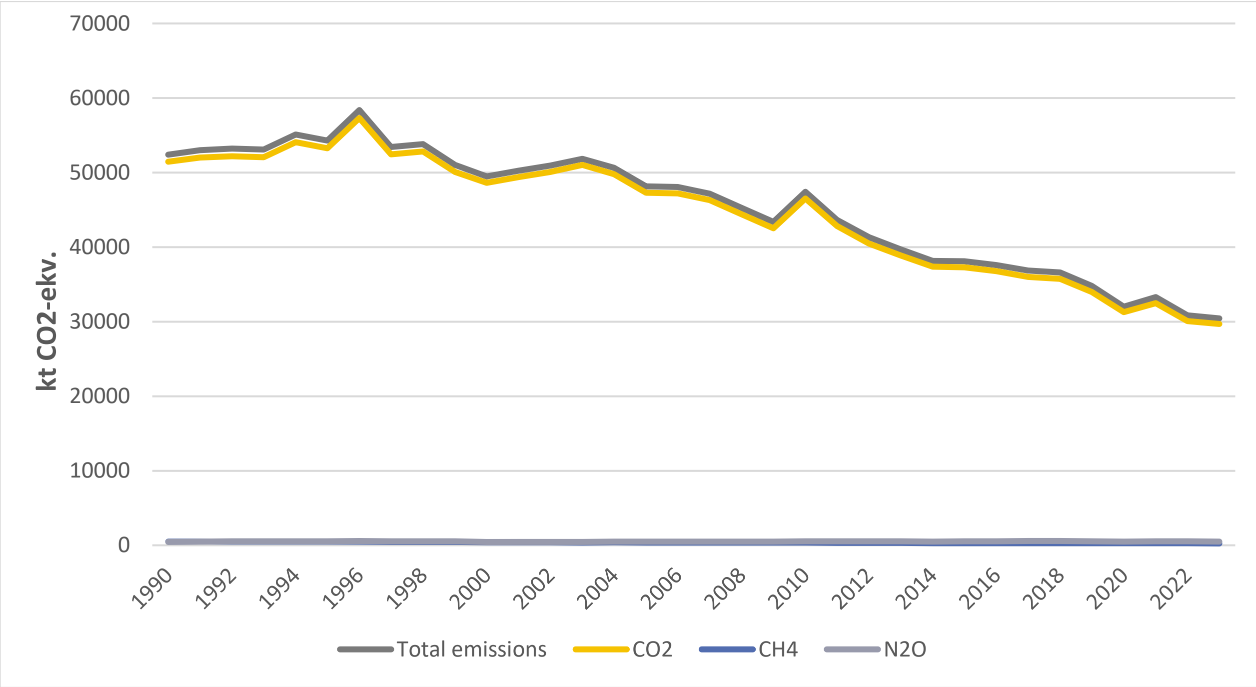

Figure 3.1. Total emissions of all greenhouse gases calculated as Gg CO_2-eq. from CRT 1 Energy.

35 Ministry of the Environment, 2001

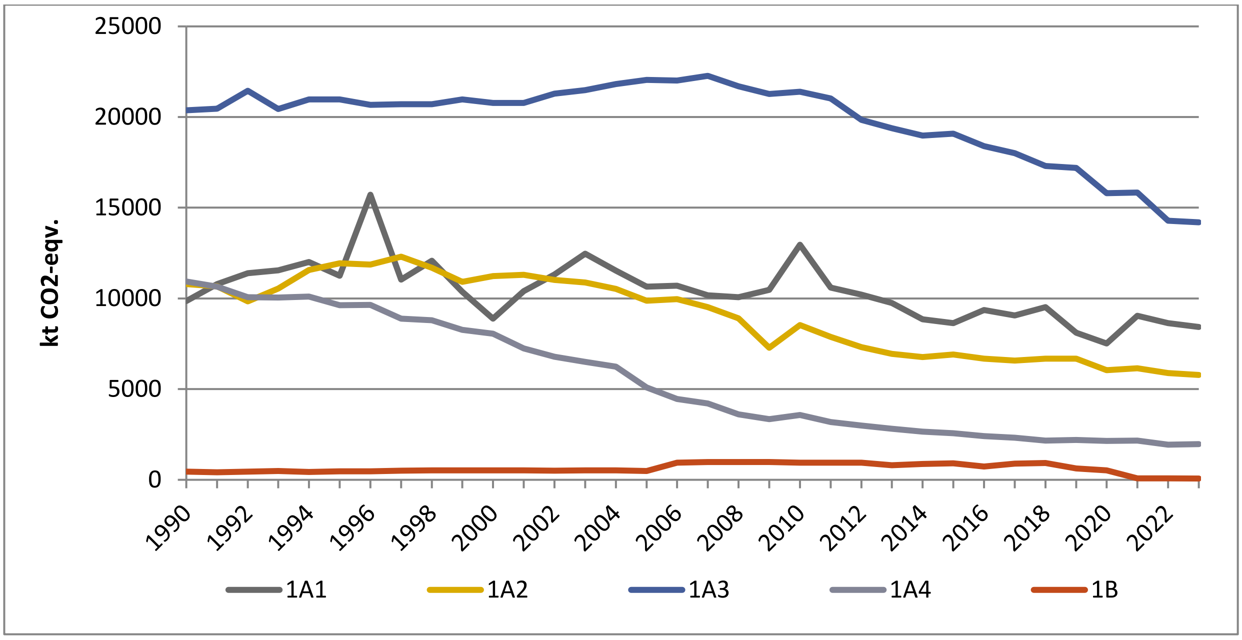

Figure 3.2. Total emissions of all greenhouse gases calculated as CO_2-eq. from the different sub-sectors within the Energy sector. 1A1 Energy industries. 1A2 Manufacturing industries and construction. 1A3 Transport. 1A4 Other sectors. B Fugitive emissions.

As shown in Figure 3.2, the transport sector (CRT 1.A.3) accounts for the largest part of the GHG emissions from the energy sector. Emissions from public electricity and heat production (CRT 1.A.1) varies mainly because of temperature variations between years. As mentioned earlier, the emissions from residential heating (CRT 1.A.4) are decreasing due to a shift from usage of heating oils to district heating. In manufacturing industries and construction (CRT 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 CRT 1.A.1 in 1996 and 2010 are mostly due to the cold winters those years 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 covid pandemic influenced almost all sectors and led to a decrease in emissions in 2020. The increase of emissions between 2020 and 2021 are due to increased consumption of liquid and gaseous fuels in the energy production sector. There are two refinery facilities producing hydrogen. One started in the 1980s. The increase in fugitive emissions from oil and natural gas (CRT 1.B.2) from 2006 is caused by the other facilitiy that put into operation full scale production of hydrogen.

3.2 Fuel combustion (CRT 1.A)

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

CRT 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.

CRT 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 CRT 1.A.2, but apart from that, CRT 1.A.2 includes only stationary combustion.

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

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

CRT 1.A.5, emissions from **other combustion**.

Emissions from **International aviation and international navigation (international bunkers) and multilateral operations**, CRT 1.D, are not included in the national total.

Emissions from fuel combustion in Sweden are, if not 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 the 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 for example the case for coal and coke in the metal industry. Emissions from these fuels are thus accounted for under CRT 2 and methods used are described in section 4.

3.2.1 Comparison of the sectoral approach with the reference approach

The 2006 IPCC Guidelines states that it is good practice to compare the sectoral bottom-up estimation of emissions from fuels with a top-down approach based on fuels supply statistics. Figure 3.3 shows the differences in fuel consumption and CO_2 emissions between the Reference and Sectoral Approach for all fossil fuels 1990-2023.

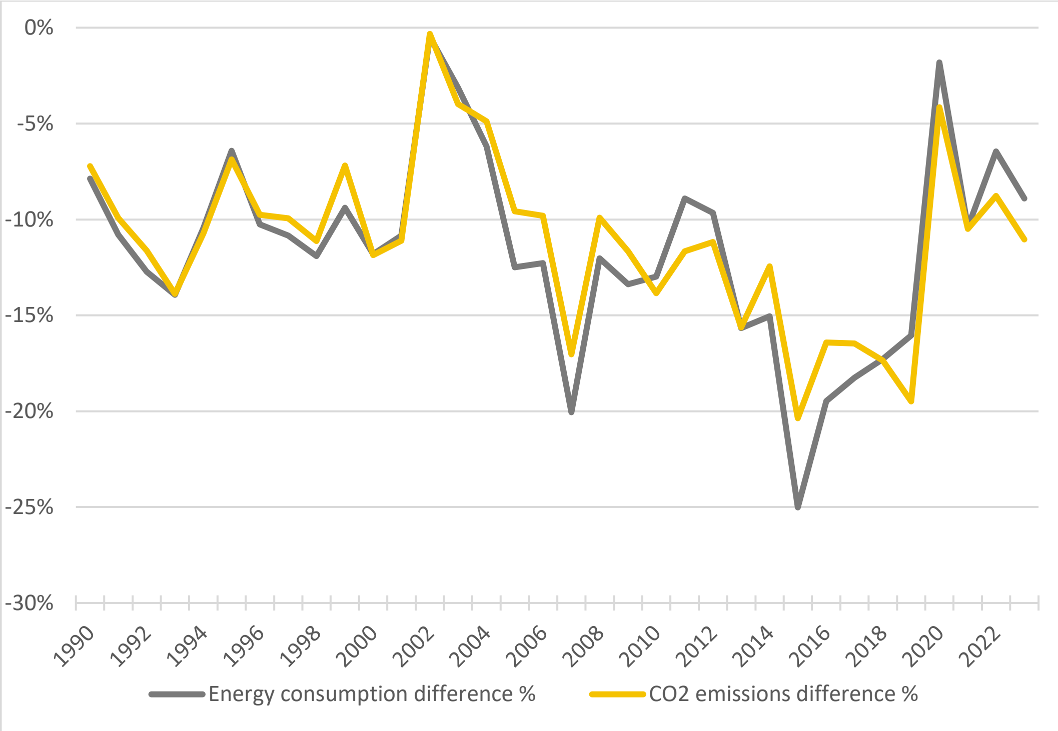

Figure 3.3. Differences between Reference Approach and Sectoral Approach (Reference minus Sectoral expressed as percent of sectoral approach).

Fuel consumption and CO_2 emissions from the reference approach differ with more than 2% from the sectoral approach for most years. However, the energy consumption and emissions in reference approach is mostly lower than the sectoral approach. This is mainly due to differences in definitions of fuels for non-energy purposes between the Swedish energy balances and the 2006 IPCC Guidelines, as well as large statistical differences in fuel supply reported in the Swedish energy balances but not taken into account in the reference approach. A more detailed discussion on the reference approach and the differences compared to the sectoral approach is provided in Annex 4.

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 CRT 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. 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 corona pandemic had a profound impact on international aviation in 2020.

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

Bunker fuel for aviation 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.

The emissions from both domestic and international aviation, reported to the UNFCCC, are based on activity 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.

In 2020, the corona pandemic had an unprecedented impact on international aviation, causing emissions to fall below the levels of 1990 for the first time since 1993. In 2023, the increase in greenhouse gas (GHG) emissions from international aviation seen in 2022 continued but were still below pre-pandemic levels. The GHG emissions from international aviation were 2137 kt CO_2-eq. in 2023, which is a 56% increase compared to 1990 and an increase by 9% since 2022. See Figure 3.4 below. In 2023, emissions from international aviation have rebounded strongly from the corona pandemic but are still below 2019 levels. Biogenic jet kerosene is included in the emissions calculations from 2018, but the Swedish government did not introduce a mandatory reduction obligation until the year 2021. The same emission factors are used for biogenic as for fossil jet kerosene.

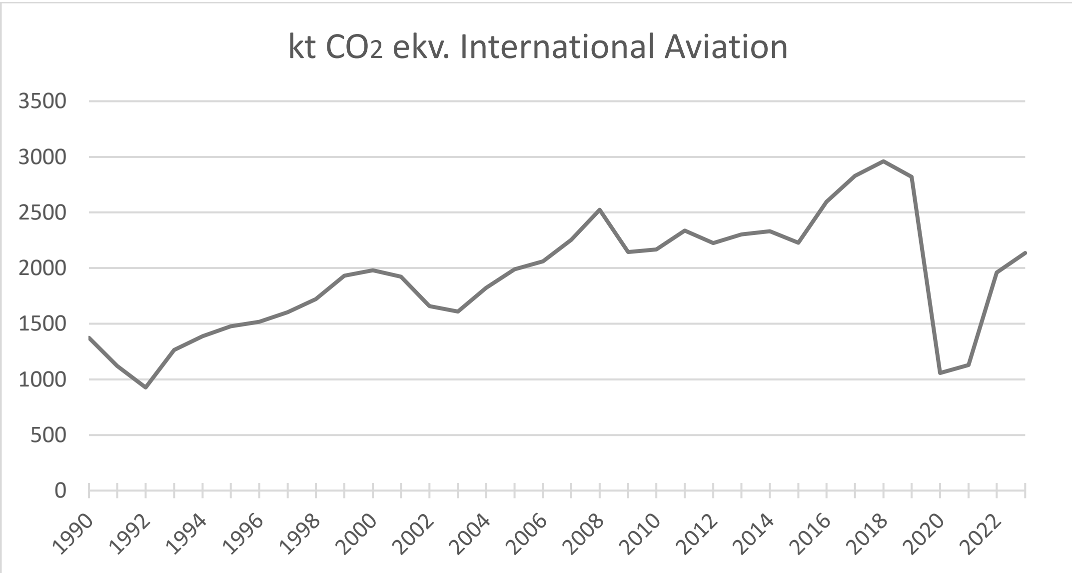

Figure 3.4. Total emissions of all greenhouse gases calculated as CO_2 eq. from international aviation 1990-2023 (kt).

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[36].

Due to the fact that Swedish airports generally are smaller than international airports in other countries; taxi times are much shorter for domestic flights as well as climb-out and take-off times compared to the International Civil Aviation Organization (ICAO) standards that the IPCC guidelines follow[37]. As a result, the traffic from Swedish airports consumes less fuel and gives rise to less emissions.

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 statistics from the monthly survey on supply and delivery of petroleum products from Statistics Sweden (see Annex 2).
This is in line with 2006 IPCC Guidelines, and data of good quality exists from 1995 and onwards.

Net calorific values and emission factors for CO_2 and SO_2 are obtained from FOI. 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[38]. 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.

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

[37] Gustafsson, 2005.

[38] In EMEP/EEA Guidebook 2016 and 2019 the methodology has changed and requires more precise input data. Therefore, Sweden still uses the methodology descibed in the 2013 edition.

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, CRT 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.

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. Fluctuations in bunker volumes between years are also dependent on fuel prices in Sweden compared to ports in other countries. See chapter 2.3.6. for more information.

The emissions from international navigation are estimated applying Tier 2 and the emissions of GHG from international shipping was 5 434 kt CO_2-eq. in 2023. This is a decrease by 22% compared to 2022 but the emissions of greenhouse gases have more than doubled since 1990. The total emissions of all greenhouse gases calculated as CO_2-eq. from international navigation can be seen in Figure 3.5.

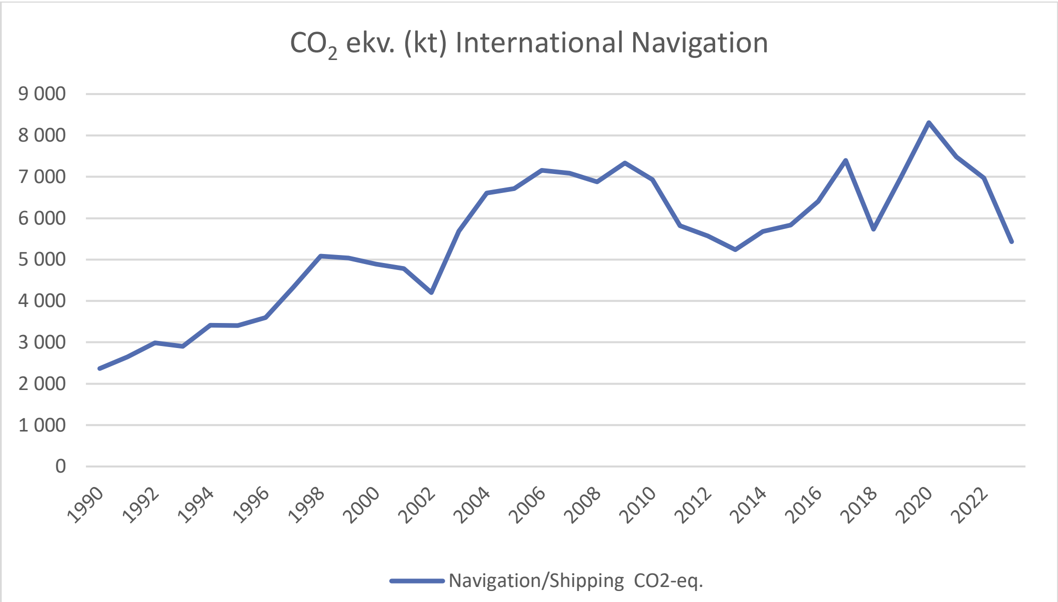

Figure 3.5. Total emissions of all greenhouse gases calculated as CO_2 eq. from international navigation 1990-2023 (kt).

The split between fuel used for national and international navigation, except for leisure boats, was based on the monthly survey on supply and delivery of petroleum products[39] until submission 2020. However, as it was problematic for fuel suppliers to separate fuel distributed to national respectively international navigation, the monthly survey of fuel supply statistics was revised in 2018. The reported fuel for national and international navigation was merged in the survey to represent the total fuel supply for navigation.

As from submission 2020, the fuel consumption by international navigation is estimated as the difference between the fuel used by domestic navigation, which is based on the Shipair model, and the total supply of fuel for navigation in the monthly survey of fuel supply statistics. For more information regarding the methodology for domestic navigation, see section 3.2.19.2. The exception to the rule is the consumption of liquefied natural gas (LNG), which is based on a survey.

The use of LNG as a shipping fuel increased rapidly until 2021 but has since declined due to increasing gas prices. The volumes of LNG are small compared to other fuels in international navigation, but the amount of LNG has a big impact on the methane emissions from shipping due to methane slip. A survey to estimate the use of LNG by shipping has been conducted annually since 2020 and shows a consumption of LNG since 2018. The Shipair model can distinguish LNG powered ships and their consumption of LNG is subtracted from the Shipair model to avoid double counting, as this data is taken from the LNG survey. The emission factors for LNG are based on a study from 2020[40].

3.2.2.3 MULTILATERAL OPERATIONS, CRT 1.D.2

Emission from multilateral operations should be reported separately as a memo item in CRT 1.D.2, in accordance with 2006 IPCC Guidelines.

The fuel for military operations abroad is, according to information from the National Defence, not bought in Sweden but in the country where the operation takes place and therefore not included in the Swedish inventory.

3.2.3 Feedstocks and non-energy use of fuels

The carbon in fuels used for non-energy purposes should not be reported under the fuel combustion activities in the CRT 1A. The 2006 IPCC Guidelines group fuels used for non-energy purposes in three categories: feedstocks, reductants and other non-energy products. In Sweden, examples of fuels used for non-energy purposes are coal and coke for iron and steel production processes, natural gas and naphtha as feedstock in refineries and chemical industries, bitumen for asphalt making, and lubricants and paraffin waxes as products use.

Fuel quantities 1990-2023 on feedstocks, reductants and other non-energy use of fuels reported in CRT 1Ad are based on data on fuels used for CO_2 emission estimation in CRT 1B and CRT 2, i.e. based on several types of data sources.
The carbon emission factors used in CRT 1Ad is consistent with those used in other parts of the emission inventory.

[39] Statistic Sweden. Monthly fuel, gas and inventory statistics. See annex 2 for more information regarding different surveys.

[40] Hult, C. et al. 2020. Emission factors for methane engines on vehicles and ships

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[41]. There are, however, several facilities with newly acquired environmental permits or in process for acquiring environmental permits for carbon capture[42].

3.2.5 Country-specific issues

No country-specific issues are reported in this submission.

3.2.6 Public electricity and heat production (CRT 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. Sweden is also expanding its proportion of wind power, which is increasing every year. Wind power effects the electricity balance and is also affected by the weather. The power generated by wind power might need the use of reserve power in cases of limited wind. For reserve power, in some cases fossil fuels are used. Only a small share of the electricity production is based on fuels used in conventional power plants. Public electricity and heat use vary between years, due to variations in ambient temperatures for instance. In addition, production of electricity based on fuels depends to a large extent on the actual weather conditions. Years with dry weather and cold winters have a significant effect on the use of fuel in electricity production since less electricity can be produced by means of hydropower and more electricity is needed for heating. The largest emissions from electricity production were thus in 1996, due to very dry and cold weather. 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 had 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.

Since submission 2015, CRT 1.A.1.a is split in three categories according to the 2006 IPCC 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

[41] Geological Survey of Sweden, 2010.

[42] Swedish Environmental Protection Agency 2025-02-20.

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. Between 2013 and 2022, the consumption of natural gas in this sector decreased by 90%, which resulted in a notable decrease in emissions for this sector total.

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, 23% of fuels used were biomass including biogenic waste, and 5% was fossil waste. In 2022, 77% of all fuels used for district heating were biomass (including the biogenic fraction of waste), while waste (fossil fraction) accounted for 15%[43]. These proportions have been quite similar during the last six years.

Since 1990, there has been a large increase in the use of district heating from 89 PJ (1990) to 198 PJ (55.1 TWh 2023)[44] but, due to the more frequent use of biomass, greenhouse gas emissions from district heating were lower in 2023 than in 1990.

The number and distribution of Swedish power stations in 2023 are presented in Table 3.1[44]. 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 power stations 2023.

Type of plants	Number of plants	Gross Production GWh	Gross Production TJ
Total power stations	258 216	166 078	597 881
Power generation not based on fuels	258 033	103 583	372 899
Wind power	5 497	34 245	123 282
Hydropower	910	66 240	238 464
Solar power	251 626	3 098	11 153
Power generation based on fuels	183	62 495	224 982
Nuclear power	3	48 470	174 492
Conv. thermal power	180	14 025	50 490

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.

[43] 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

[44] Statistics Sweden/Swedish Energy Agency EN11SM 2001 (Electricity supply, district heating and supply of natural and gasworks gas 2023.).

Table 3.2. Summary of source category description, CRT 1A1a, according to approach 1.

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

3.2.6.2 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 CRT 1.A.1.a is the Quarterly fuel statistics (KvBr), 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 CRT 1A1a.

The most important fuels in recent years are wood fuels followed by solid waste. Greenhouse gas emission factors for wood are national[45]. 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.
Since the Quarterly fuel statistics (KvBr) do not contain information on the fossil versus biogenic fractions of the waste, these fractions have been investigated separately. Emission factors for fossil and biogenic CO_2 were calculated using data collected by the Swedish Waste Management Association specifically for this purpose. Since 2015, eight facilities measured biogenic CO_2 emissions in the flue gas using the ^{14}C method[46], creating a better basis for national emission factors than estimates of waste content. The new facility-specific emission factors are used to calculate emissions from each of the eight waste incinerators that measure biogenic CO_2 in flue gases, and weighted averages in respect to energy consumption are used for the rest of Sweden. The emission factor was updated for the years after 2015 (based on nine and ten facilities measuring the biogenic fraction, respectively).

The net calorific value (NCV) for waste varies due to the heterogenous nature of waste. In conjunction with the update of the emission factors, the national NCV was updated according to a survey made by the Swedish Waste Management Association that included specific data from 21 waste incineration facilities, covering 80-90% of the total

45 Boström et al, 2004.

46 The ^{14}C method measures the ^{14}C isotope in the flue gases. ^{14}C only exist in biogenic material as the isotope over time decays to mainly ^{12}C, wich is the isotope found in fossil material.

incinerated waste. The resulting NCV was assumed to represent all incinerated waste in Sweden. However, the NCV values used were the ones reported from the facilities to the Quarterly fuel statistics (KvBr).

In emission year 2023, the fractions of biogenic and fossil waste for the eight largest plants were 53% and 47% respectively. These fractions vary in time and are applied since year 2015. The proportions 64% biogenic and 36% fossil are applied for the emission years from 1990 to 2014 for all plants. For the other plants, not included in the ETS[47], the average emission factor from the eight largest plants is used with a one year delay.

Emissions from energy plants integrated with the iron and steel industry are allocated to CRT 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 CRT 1.A.1.a due to confidentiality reasons. These emissions are however extremely small and thus this reallocation from CRT 1.A.1.c does not affect any trends or conclusions on CRT level.

Due to confidentiality reasons:

- Liquid and gaseous fuels activity data and emissions are reported as C in CRT-tables in the codes 1.A.1.a.ii and 1.A.1.a for 2023.

3.2.6.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The Quarterly fuel statistics (KvBr) 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 other fuel types due to the variable supply of energy gases from the iron and steel industry. As blast furnace gas has a much higher CO_2 EF than other solid fuels, the share of blast furnace gas has a very large influence on the aggregate CO_2 IEF for solid fuels. As the production in the iron and steel industry was much lower in 2009 than in other recent years, the share of blast furnace gas in CRT 1.A.1.a dropped, which explains the drop in CO_2 IEF for solid fuels in 1.A.1.a in 2009. The IEF for N_2O varies between the years. 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 further discussed in Annex 2. There is no reliable information

[47] Stripple et al, 2014.

about the composition of municipal waste in the 1990's, so the composition calculated by Stripple et al (2014)[48] is used for all years as described above.

Emissions of NO_X and SO_2 in relation to fuel consumption fluctuate slightly between years due to variations in the 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. Wood 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 CRT 1.A.1.a.

The activity data uncertainties are relatively low, 2% for all fuel groups except for other fossil fuels that are 3%. The CO_2 emission factor uncertainties are 2-5% for Liquid fuels, 10% for Solid fuels and 30% for Other fossil fuels and Peat and 30% for Biomass. The uncertainty values are assigned by staff at Statistics Sweden and are based on expert judgements made on fuel type that were aggregated to fuel group.

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 Good Practice Guidance section 8.1.7.4 applicable to this sector are used. The activity data has been subject to QA/QC procedures prior to the publishing of Quarterly fuel statistics (KvBr). 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 CRT-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).

A comparing study[49] from 2011 concluded that the Quarterly fuel statistics (KvBr) is of very good quality, and also the only data source that is ready in time for use for the last emission year.

[48] Stripple et al. 2014

[49] Andersson,M., Eklund, V., Gerner, A., Gustafsson, T. Quality assurance of calculations for Reference approach. SMED Report 2012.

3.2.6.5 SOURCE-SPECIFIC RECALCULATIONS

In submission 2025, a revision and correction of one plant specific emission factor was conducted which resulted in revised emissions.

The recalculations in 1.A.1.a occurred for the years between 2015 and 2023. The correction of the emission factor for the combustion plant resulted in decreased emissions. The maximum decrease was 0.6% (32.63 kt CO_2-eq year 2020) the minimum decrease was 0.05% (3.52 kt CO_2-eq year 2018). For year 2022 the decrease was 0.5% (32.03 kt CO_2-eq).

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 (CRT 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 CRT 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; four facilities have hydrogen production plants (one of them was taken in use in 2020), and four of the facilities have sulphur recovery plants. The five refineries account for more than 99% of the fuel consumption and emissions reported in CRT 1.A.1.b. In addition to the refineries, there are a few small manufacturers of e.g. lubricants which are also classified as International Standard Industrial Classification (ISIC) 23200. The emissions from these plants are also reported in CRT 1.A.1.b.

The fuel consumption in this sector consists mainly of refinery gas (liquid fuels), which is a by-product in the refining process. The energy use in this sector is between 26000 TJ (2019) and 38800 TJ (2015).

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, CRT 1.A.1.b, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1A1b	CO_2	X (Gaseous fuels, 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

Activity data for the five refineries was collected directly from each company for 1990-1999, since the Energy use in the manufacturing industry (ISEN) and Quarterly fuel statistics (KvBr) 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, i.e. before the EU Emission Trading System (EU-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 the EU-ETS are used for four refinery plants for 2005 and 2007[50]. 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 EU-ETS data is considered to be very high for all five of the refineries, and thus this is the primary data source for the GHG inventory. However, most of the refineries report refinery gas and natural gas aggregated to the EU-ETS, 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 EU-ETS[51] 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 (KvBr) are used together with national emission factors.

Due to confidentiality reasons:

- Reported emissions from the refineries under CRT 1B are included in 1A1b for emissions all years between 2021 and 2023.
- Liquid and gaseous fuels activity data and all emissions are reported as C in the CRT code 1.A.1.b.

[50] Backman & Gustafsson, 2006.

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

3.2.7.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The use of many different sources for this sector could lead to consistency problems. Data used in the inventory has been 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 uncertainties for stationary combustion were revised in submission 2020 and set on fuel group aggregation level. The uncertainty values are assigned by staff at Statistics Sweden and are based on expert judgements made on fuel type that were aggregated to fuel group. The uncertainty of the activity data for Liquid fuels is around 2%, but the uncertainty of the NCV is unknown, so the total uncertainty for the activity data was estimated to 10%. The uncertainty of the activity data for Gaseous Fuels is lower, 2%.

3.2.7.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

In general, the same QA/QC procedures are used for CRT 1.A.1.b as for 1.A.1.a described above. For each of the five refineries, EU-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" (Not occurring) 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 CRT 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.

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

3.2.7.5 SOURCE-SPECIFIC RECALCULATIONS

No recalculation occurred in this sector in submission 2025.

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 (CRT 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[52]. 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 emission from the activity is derived from small companies that are included in the emission estimates from small industries (CRT 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 aggregated data. Hence, the CH_4 emissions from charcoal production are reported in CRT 1.A.2.g. The notation key for CH_4 emissions in 1.A.1.c is reported as IE. Fugitive emissions from charcoal production are reported in CRT 1.B.1.b.

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

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

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1A1c	CO_2	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 CRT 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 (CRT 2.C.1.2.).

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

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 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 relative 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 within the same oven due to aggregated activity data. There is no new measurement technique introduced in 2003. The reason for the introduced variability of data from 2003 is due to the facility starting to measure emissions at a finer level than before. The constant proportions of the gases are used for 1990-2002 but not for the years 2003 onwards, since the facility started to report the fuel types at finer level than before (for 1990-2002, only the total amounts of fuels are available, without division into coke oven gas, LD gas, BF gas). Sweden has tried to retrieve the detailed information on the amounts of the gases for 1990-2002 without success – it was therefore decided to extrapolate average values of the shares calculated for the period 2003-2007. The data for 1990-2002 is thus already disaggregated using actual information from 2003 onwards – and the assumption on the constant values of shares results in much lower variation in the IEF for 1990-2002 than for the years from 2003 onwards, when the actual data and different shares for different years are used. In submission 2021 Sweden tried again to retrieve the detailed AD at finer level with no result. The information needed of distribution of internal gases and energy consumed is of bad quality and would require large resources to retrieve. However, the total emissions are known and believed to have good certainty, which leaves to the decision that introducing estimated variability in the 1990-2002 time series will increase the overall uncertainties.

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. The uncertainty values are assigned by staff at Statistics Sweden and are based on expert judgements made on fuel type that were aggregated to fuel group.

3.2.8.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

3.2.8.5 SOURCE-SPECIFIC RECALCULATIONS

No recalculation occurred in this sector in submission 2025.

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 (CRT 1.A.2.a)

3.2.9.1 SOURCE CATEGORY DESCRIPTION

The iron and steel industry are, 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 2023, the production of raw steel was 4.3 Mt[53], and decreased with 3% compared to 2022. Emissions from iron and steel companies with less than 10 employees are allocated to CRT 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, CRT 1.A2a, according to approach 1.

CRT	Gas	Key Category Assessment, 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, liquid fuels, solid fuels)		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

3.2.9.2 METHODOLOGICAL ISSUES IRON AND STEEL, CRT 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 Energy use in the manufacturing industry (ISEN) for 1990-1996 and 2000-2002, and from Quarterly fuel statistics (KvBr) for 1997-1999 and 2003 onwards, further described in Annex 2.

Emissions reported from primary steel works and other iron and steel works are reported in both CRT 1.A.2.A and in CRT 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 CRT 2.C.1.a (secondary steel) and CRT 2.C.1.b (primary pig iron and steel).

Due to confidentiality reasons, activity data and emissions of CO_2 emissions, CH_4 and N_2O for liquid fuels and biomass are reported as C in the CRT-tables in 2020.

[53] The Swedish Steel Producers´ Association, 2023-01-26. Stålåret 2023 – en kort översikt. 2023. https://www.jernkontoret.se/globalassets/publicerat/stal-stalind/stalaret-2023---en-sammanstallning-fran-jernkontoret.pdf

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 CRT 1.A.1.a.

Table 3.6. Allocation of fuel consumption and CO_2 emissions in 2023 from iron ore based iron and steel industry to different CRT codes.

CRT	Plant station	CO_2 emissions (kt)	Energy consumption (TJ)
1.A.1.a	Power and Heat Production (sold amount of energy gases)	1 589	6 565
1.A.1.c	Coke Oven	373	4 163
1.A.2.a	Combustion in Rolling Mills + Power and Heat Production	565	2 877
1.B.1.c	Flare in Coke Oven (COG)	6	111
2.C.1.b	Blast Furnace + Steelworks (including Flaring of BFG and LD-gas)	2 026	8 290
NA	Products and losses	NA	31 368
Total		**4 557**	**53 374**

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 NID due to confidentiality reasons.

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

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 (KvBr). 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 CRT 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 CRT 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. See also section 3.2.8.3. 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 introduced 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. The uncertainty values are assigned by staff at Statistics Sweden and are based on expert judgements made on fuel type that were aggregated to fuel group.

3.2.9.4 SOURCE SPECIFIC QA/QC AND VERIFICATION

In general, the same QA/QC procedures are used for CRT 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 and established procedure for annual cross-sectoral control of reported emissions on a facility level is being conducted annually to improve emission allocation between the energy sector (CRT 1.A) and IPPU (CRT 2). In case of discrepancies, they are easily identified and further investigated regarding potential gaps or double-counting using a developed quality control tool. 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 2025 the emission factor of natural gas was corrected for 2019 which resulted in an increase of emissions by 0.27 kt CO_2-eq (0.02%).

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 (CRT 1.A.2.b)

3.2.10.1 SOURCE CATEGORY DESCRIPTION

This source category covers combustion-related emissions from five aluminium producers (ISIC 27420), three copper producers (ISIC 27440) and three facilities producing various other metals.

As for all subcategories to CRT 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 be used. Emissions from companies with less than 10 employees are allocated to CRT 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 1.A.2.b and the aluminium producers account for 32-45%. The most common fuel is LPG (44-61% in recent years), followed by heating oils and natural gas.

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, CRT 1A2b, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.2.b	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

3.2.10.2 METHODOLOGICAL ISSUES

Activity data is taken from Energy use in the manufacturing industry (ISEN) for 1990-1996 and 2000-2002, and from Quarterly fuel statistics (KvBr) 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.

Due to confidentiality reasons activity data, CH_4 and N_2O emissions for gaseous fuels and biomass are reported as C in the CRT tables for 1.A.2.b.

3.2.10.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As for CRT 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 CRT 1.A.2.b, and CO_2 from LPG accounts for most of the uncertainty. The uncertainty values are assigned by staff at Statistics Sweden and are based on expert judgements made on fuel type that were aggregated to fuel group. The uncertainty of AD and CO_2 is 5% for all fuel groups.

3.2.10.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The same QA/QC procedures are used for CRT 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[54].
Quality control and established procedure for annual cross-sectoral control of reported emissions on a facility level is being conducted annually to improve emission allocation between the energy sector (CRT 1.A) and IPPU (CRT 2). In case of discrepancies, they are easily identified and further investigated regarding potential gaps or double-counting using a developed quality control tool. For further detailed information see section 1.3.5 concerning QA/QC and Verification in general.

3.2.10.5 SOURCE-SPECIFIC RECALCULATIONS

In submission 2025 emission factor of natural gas was corrected for 2019 which resulted in an increase of emissions by 0.1 kt CO_2-eq (0.09%).

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 (CRT 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 use 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. For 2023, liquid fuels account for about 59% of the energy, solid fuels for 1%, gaseous fuels for 14%, other fossil fuels for 8% and biomass for 18%.

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

[54] Skårman et.al, 2008.

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

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

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.2.c	CO_2	X (Gaseous fuels, Liquid fuels)	X(Gaseous fuels, Liquid 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

3.2.11.2 METHODOLOGICAL ISSUES

Activity data is, with exceptions mentioned below, collected from Energy use in the manufacturing industry (ISEN) for 1990-1996 and 2000-2002, and from Quarterly fuel statistics (KvBr) 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 2006 IPCC Guidelines.

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

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.

In submission 2023, the combustion of carbide furnace gas was reallocated to CRT 1A2c from 2B10a (IPPU sector), according to the results from a developing project regarding improvements of the allocation of stationary and process-based emissions between CRT 1 and 2[56]. The reallocation resulted in increased emission from liquid and gaseous fuels.

3.2.11.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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 2008 was higher than in 1990. However, since 2008 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 CRT 1.A.2.c is 25-27 PJ.

As noted by the ERT, the implied emission factors for “other fuels” vary, 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 CRT 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.

[56] Helbig, T., Yaramenka, K., Josefsson Ortiz, C., Guban, P. 2022. Omallokering för Borealis. SMED memorandum.

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. The uncertainty values are assigned by staff at Statistics Sweden and are based on expert judgements made on fuel type that were aggregated to fuel group. The uncertainty of AD is 2-5% for all fuel groups except for Other Fossil Fuels that is 10%. Uncertainty of CO_2 emission factors is high, 100%, for Other Fossil Fuels, 30% for Biomass and 5% for the other fuel groups.

3.2.11.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

In general, the same QA/QC procedures are used for CRT 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 EU ETS data are used for verification of the estimates based on energy statistics.

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

3.2.11.5 SOURCE-SPECIFIC RECALCULATIONS

In submission 2025 emission factor of natural gas was corrected for 2019 which resulted in an increase of emissions by 0.45 kt CO_2-eq (0.1%).

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.

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

3.2.12.1 SOURCE CATEGORY DESCRIPTION

In 2021, there were 50 paper mill and pulp industry plants and 120 sawmills (production capacity >10 000 m^3/year) in Sweden. In total, they produced 8.9 Mt of paper, 19 Mm^3 of sawn timber and 11.7 Mt of pulp[57]. 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 the share of energy from biomass fuels has increased, from 82% of fuel consumption in 1990 to 96% in 2023 at the same time as liquid fuels has decreased from 15% of total fuel consumption in 1990 to 3.5% in 2023. As for CRT 1.A.2 in general, emissions from companies with less than 10 employees are allocated to CRT 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.

[57] The Swedish Forest Industries Federation, 2022-11-29. 2022. https://www.skogsindustrierna.se/skogsindustrin/skogsindustrin-i-korthet/fakta--nyckeltal/

Table 3.9. Summary of source category description, CRT 1A2d, according to approach 1.

CRT	Gas	Key Category Assessment, 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	-	-		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 CRT 2.H.1 according to the IPCC Guidelines (see chapter 4.9). Although emissions from combustion of black liquor are regarded to be process-related, the amount of combusted black liquor and related CO_2 emissions are reported in CRT 1.A.2.d in order to account for the biogenic CO_2 emissions in the memo item “CO_2 emissions from biomass”. Activity data for fuels reported in CRT 1.A.2.d is collected from Energy use in the manufacturing industry (ISEN) for 1990-1996 and 2000-2002, and from Quarterly fuel statistics (KvBr) for 1997-1999 and 2003 and later. For more details on these surveys, see Annex 2.

Due to confidentiality reasons:

- Activity data for liquid fuels and other fossil fuels are reported as C in CRT-tables in the CRT code 1.A.2.d for 2023.
- Emissions of CH_4, CO_2, N_2O for the 1.A.2.d code for liquid fuels and other fossil fuels are reported as C in the CRT-tabels for 2023

3.2.12.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As for CRT 1.A.2 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 the fuel mix. In the 1990s, petroleum coke was used in some facilities, and in the latest years, combustion of residual fuel oil has decreased somewhat. Fuels classified as “other fuels” are scarcely occurring in this CRT category, and as in 1.A.2.c, 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 has 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 wood fuels and CO_2 from residual fuel oil are the greatest contributors to the aggregate uncertainty in this sector (except for biogenic CO_2 from Biomass). The uncertainty values are assigned by staff at Statistics Sweden and are based on expert judgements made on fuel type that were aggregated to fuel group. The activity data uncertainty is lowest for Biomass and Other Fossil Fuels with 8-10%. The N_2O emission factor uncertainty for wood is 40% and the CO_2 emission factor for Liquid Fuels is 5%.

3.2.12.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

In general, the same QA/QC procedures are used for CRT 1.A.2.d as for 1.A.1.a and 1.A.2.a – 1.A.2.c described above.

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

3.2.12.5 SOURCE-SPECIFIC RECALCULATIONS

In submission 2025 emission factor of natural gas was corrected for 2019 which resulted in an increase of emissions by 0.11 kt CO_2-eq (0.01%).

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 (CRT 1.A.2.e)

3.2.13.1 SOURCE CATEGORY DESCRIPTION

The food and drink industry are the third largest branch of industry measured as production value and number of employees. There are about 4600 companies, of which only around 650 have more than 10 employees[58]. 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. Lately, the use of gaseous fuels is decreasing from 45-49% to 32% in 2023 biomass is increasing steadily from 2% 1990 to 44% in 2023, liquid fuels account for about 23% in 2023 of the total fuel consumption. As for CRT 1.A.2 in general, emissions from companies with less than 10 employees are allocated to CRT 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.

[58] The Swedish Food Federation 2025-02-20

Table 3.10. Summary of source category description, CRT 1A2e, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.2.e	CO_2	X (Gaseous fuels, Liquid fuels)	X (Gaseous fuels, Liquid 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

3.2.13.2 METHODOLOGICAL ISSUES

Activity data is collected from Energy use in the manufacturing industry (ISEN) for 1990-1996 and 2000-2002, and from Quarterly fuel statistics (KvBr) for 1997-1999 and 2003 and later. National emission factors are used. For more details on these surveys and emission factors see Annex 2.

Due to confidentiality reasons:

- Activity data for liquid fuels and other fossil fuels are reported as C in CRT-tables in the CRT code 1.A.2.e for 2023.
- Emissions of CH_4, CO_2, N_2O for the 1.A.2.e code for liquid fuels and other fossil fuels are reported as C in the CRT-tabels for 2023.

3.2.13.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As for CRT 1.A.2 in general, time series consistency despite the changes in activity data source is discussed in Annex 2. The IEFs vary slightly 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. The uncertainty values are assigned by staff at Statistics Sweden and are based on expert judgements made on fuel type that were aggregated to fuel group. Activity data uncertainty is 5% for all fuel groups except for Other Fossil Fuels which is 10%. CO_2 emission factor uncertainty varies between the fuel groups with highest for Other Fossil Fuels, 100%, 30% for Biomass and 5% for the other fuel groups.

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 and established procedure for annual cross-sectoral control of reported emissions on a facility level is being conducted annually to improve emission allocation between the energy sector (CRT 1.A) and IPPU (CRT 2). In case of discrepancies, they are easily identified and further investigated regarding potential gaps or double-counting using a developed quality control tool. For further detailed information see section 1.3.5 concerning QA/QC and Verification in general.

3.2.13.5 SOURCE-SPECIFIC RECALCULATIONS

There was a reallocation in the sub-sector in submission 2025 affecting all submission years. Due to new information from a company in the sub-sector we reallocated solid fuel use to 2.H.2. The company has informed that solid fuels was used in the production processes but by mistake reported as combustion for all years 1990-2023. The recalculations resulted in lower emissions in the sub-sector. Largest absolute decrease occurred in 2006 21.9 kt CO_2-eq (3.4%) the largest percentage decrease occurred in 2016 20,1 CO_2-eq (5.1%), 2022 decreased by 12.3 kt CO_2-eq 5%.
In submission 2025 emission factor of natural gas was corrected for 2019 which resulted in an increase of emissions by 0.96 kt CO_2-eq (0.62%).

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 (CRT 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 EFs used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.11.

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

CRT	Gas	Key Category Assessment, 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 methodology is used for emissions from stationary combustion for CRT 1.A.2.f, because country-specific emission factors for the source category and fuel for each gas are used.

Activity data is collected from Energy use in the manufacturing industry (ISEN) for 1990-1996 and 2000-2002, and from Quarterly fuel statistics (KvBr) 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 (KvBr).

National emission factors are used, except for CO_2, where emission factors at facility level from EU ETS are used for the largest cement production plants. These emission factors were revised and updated in submission 2021[59]. The revised emission factors for CO_2 are made only for the years 2010-2018, since the emission factors before 2010 are not divided in fraction of biomass and fossil fuels. For more details on these surveys and emission factors see Annex 2.

Due to confidentiality reasons:

- Activity data for solid fuels and other fossil fuels are reported as C in CRT-tables in the CRT code 1.A.2.f for 2023.
- Emissions of CH_4, CO_2, N_2O for the 1.A.2.f code for solid fuels and other fossil fuels are reported as C in the CRT-tabels for 2023.

3.2.14.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As for CRT 1.A.2 in general, time series are considered consistent despite the changes in activity data source as discussed in Annex 2. The IEFs vary slightly 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. The uncertainty values are assigned by staff at Statistics Sweden and are based on expert judgements made on fuel type that were aggregated to fuel group.

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 and established procedure for annual cross-sectoral control of reported emissions on a facility level is being conducted annually to improve emission allocation between the energy sector (CRT 1.A) and IPPU (CRT 2). In case of discrepancies, they are easily identified and further investigated regarding potential gaps or double-counting using a developed quality control tool. For further detailed information see section 1.3.5 concerning QA/QC and Verification in general.

3.2.14.5 SOURCE-SPECIFIC RECALCULATIONS

In submission 2025 emission factor of natural gas was corrected for 2019 which resulted in an increase of emissions by 0.71 kt CO_2-eq (0.06%).

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 (CRT 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 CRT Reporter due to confidentiality reasons.

[59] Josefsson Ortiz, C. & Guban, P. 2020. Revidera AD och EF för Cementa för CO_2-utsläpp. SMED PM.

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, stationary combustion within all companies with less than 10 employees regardless of branch, and stationary combustion within the construction sector. The Quarterly fuel statistics (KvBr) 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. For 2023, 42% of total GHG emissions from working machinery are reported in CRT 1.A.2.g.vii. In 2023, GHG emissions from working machines in this subsector have increased by 9% compared to 2022 and by 20% since 1990.

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.

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, CRT 1A2g, according to approach 1.

CRT	Gas	Key Category Assessment, 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	-	-		M	CS	Yes
	N_2O	-	-		M	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)		T1/T2	CS	Yes
	CH_4	-	-		T1/T2	CS	Yes
	N_2O	-	-		T1/T2	CS	Yes

CS Country Specific. T1 Tier 2. T2 Tier 2. T3 Tier 3. M Model.
* 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.

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.

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 Energy use in the manufacturing industry (ISEN) for 1990-1996 and 2000-2002, and from the Quarterly fuel statistics (KvBr) 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 CRT 1.A.2.g. Activity data is provided by the Swedish Energy Agency[60]. 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[61]. 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.

The fuel statistics for the last emission year, based on preliminary Energy Balance is not readily available in time for the emission calculations. As of submission 2022, the activity data is estimated using the previous year’s value per fuel type and year at total energy consumption level for ISIC 10-37 with less than 10 employees, construction industry and the Other sector (CRT 1.AA.4)[62]. The estimated energy consumption is then distributed within the sectors according to the same fuel consumption distribution as the previous year. For more detailed information about the extrapolation models and the effects on GHG emissions of deviances from the models see Annex 2. The activity data for the last inventory year will be revised next coming submission, as the Energy Balance will then be published and definitive.

Due to confidentiality reasons:

- Activity data for solid fuels and liquid fuels are reported as C in CRT-tables in the CRT code 1.A.2.g for 2023.
- Emissions of CH_4, CO_2, N_2O for the 1.A.2.g code for solid fuels and liquid fuels are reported as C in the CRT-tabels for 2023.

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

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

[62] Helbig, T. & Josefsson Ortiz, C. 2021. Uppdateringar av utsläppsberäkningar för småskalig biomassaeldning inom övrigsektorn (CRT/NFR 1A4) 2017-2021. SMED Rapport Nr 19 2021.

3.2.15.2.2 Mobile combustion/Working machinery

Emissions from mobile combustion in CRT 1.A.2.g refer to working machinery used in industry, including for example tractors, dumpers, cranes, excavators, trucks, 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.[63]

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[64].

Emissions from working machinery are also reported under CRT 1.A.3.eii, 1.A.4.aii, 1.A.4.bii and 1.A.4.cii, in line with IPCC Guidelines, see Table 3.13.

Table 3.13. Distribution of emissions from off-road vehicles and other machinery.

Category	CRT	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. The uncertainty values are assigned by staff at Statistics Sweden and are based on expert judgements made on fuel type that were aggregated to fuel group.

As for stationary combustion in CRT 1.A.2 in general, time series consistency despite the changes in activity data source is discussed in Annex 2. As for other categories in CRT 1.A.2, the IEFs vary slightly between years due to variations in the fuel mix. In earlier submissions, the EC (European Commission) has asked for clarification of the drop in

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

[64] See Annex 2, section "1.4 Allocation of fuels for mobile combustion" for more information."

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

The amount of low-blended biofuel used by working machinery and road traffic is allocated proportionally to the amount of fossil gasoline and diesel consumed in each subsector. The model estimated consumption of fossil gasoline and diesel by working machinery is decreased by the amount of ethanol respectively FAME/HVO allocated to the subsector in question. In 2004, the consumption of gasoline by working machinery decreased noticeably as a result of an increase in the amount of ethanol allocated to working machinery, due to a large increase in the national deliveries of low-blended ethanol. The same phenomenon took place between 2017 and 2018 as a result of a sudden increase of the ethanol sold on the Swedish market.

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 sector 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

In submission 2025, there is a revision of activity data for year 2022 for ISIC 10-37 with less than 10 employees and the construction industry as the data was updated to the final energy balance statistics. In submission 2025 emission factor of natural gas was corrected for 2019 which resulted in an increase of emissions by 0.32 kt CO_2 equivalents (0.03%).

The total effect of the recalculations in 1.A.2.g for 2022 was an increase of 10 kt CO_2-eq (0.92%).

3.2.15.5.2 Mobile combustion

A development project[65] regarding annual machine operating hours was conducted during 2023. The project was conducted based on testing and inspection data from the certified organisation Swedish machine testing. The project involved testing data from year 2019-2023 for machinery such as wheel loaders, excavators, dumpers and more. Included in the same project was also a study on operating hours of tractors. The study analysed the registered operating hours between change in ownership.

[65] Jerksjö, M. Genomsnittlig årlig driftstid för entreprenadmaskiner och traktorer. SMED PM 2024

It was concluded that previously used machine hours were overestimated and thus the recalculations resulted in increased emissions throughout the time series.

An example of a notable change that was made in the non-road mobile machinery model was revising the operating hours for machine year 0 (the year a machine is brought into operation). The previous calculations assumed that a machine operates a full year during the calendar year when it is put into operation. The new model settings assume approximately half the operating time for many machine types.

The changes resulted in recalculations of emissions throughout the time series.

On average the CO_2-emissions decreased 8% during 1990-2022 due to the recalculations.

The complete reference to the project report regarding annual average operating hours (Jerksjö, M.2024) is stated in the reference section in Annex 2, chapter 2.6.

3.2.15.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

The machine stock in the NRMM will be updated for wheel loaders and excavators during the next submission. The updates will be implemented as a result of a study carried out based on the national vehicle register. The changes will manly affect the older machines in the stock as data shows that the NRMM assumes a slightly incorrect scrapping rate of machines.

Further 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 (CRT 1.A.3.a)

3.2.16.1 SOURCE CATEGORY DESCRIPTION

Activity data is presently provided for a total of 39 airports with regular and/or charted air traffic in Sweden. The national government administers 10 of these airports, while the remaining 29 are private and/or administered by local governments.[66] The emissions of greenhouse gases (GHG) from national aviation in 2023 were 354 kt CO_2-eq., which is an increase by 8 % since last year and a decrease by 49 % compared to 1990.

The corona pandemic had a severe impact on domestic civil aviation during 2020 and 2021. In 2022, there was a substantial increase in emissions from civil aviation and this increase continues into 2023. The emissions from domestic aviation have gradually decreased since 1990 while the emissions from international aviation have increased.

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.

[66] Trafikanalys. 2022. Luftfart 2021. https://www.trafa.se/luftfart/

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

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

T1 Tier 1. 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, tier 2 for SO_2 and Tier 3 to estimate the emissions of 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.

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

The Swedish Transport Agency (STAg) is responsible for reporting the GHG emissions from aviation, but the fuel consumption and emissions are modeled by the Swedish Defence Research Agency (FOI) on behalf of STAg. The model and the methodology are described in a published report[67]. The STAg provides FOI with input data for the model 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, which originates from “ICAO Engine Exhaust Emission Data Bank”, is also used in the emission model. The fuel consumption and the emissions are estimated for both the cruise phase as well as for the LTO cycle (landing and take-off), which is defined as aircraft movements below 3000 feet.

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 as well as climb-out and take-off times compared to the International Civil Aviation Organization (ICAO) standards which the IPCC guidelines follow[68]. The air traffic at Swedish airports thus consumes less fuel and emits less emissions.

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

[68] Gustafsson, 2005.

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 modeled fuel consumption and emissions are adjusted to be in line with the total deliveries of aviation fuel in Sweden[69], which is in line with the IPCC 2006 guidelines.

Emissions of CO_2 from aviation gasoline are based on the fuel consumption and thermal values as well as emission factors from 2006 IPCC Guidelines. Emissions of SO_2 from aviation gasoline are based on country-specific emission factors. CO_2 and SO_2 emissions from aviation kerosene are based on thermal values and emission factors from the Swedish defense research agency (FOI).

Thermal values and emission factors for CO_2 and SO_2 are based data from FOI. The values are identical for all years. The emissions are split into domestic and international aviation based on the mean value for LTO cycles for domestic and international flights in 1995-2000. Emissions of CO for 1990-1994 are based on 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 determined 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 yearly report 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 are consequently included.

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

The estimated emissions of HC are split into NMVOC and CH_4, based on the ratio given in EMEP/EEA guidebook 2013[70]. Emissions of N_2O from LTO are estimated by using the number of LTO cycles reported by STAg and default emission factors from EMEP/EEA guidebook 2013. Emissions of N_2O from cruise are based on the fuel consumption for the cruise phase and default emission factors from the EMEP/EEA 2013 Guidebook.

Biogenic jet kerosene was introduced on the Swedish market in 2018. However, the government did not establish a mandatory reduction obligation for jet fuel until 2021 and hence there was no mandatory admixture of the biojet before 2021. Currently, the same emission factors are used for biojet as for fossil jet kerosene, since jet kerosene is a highly controlled product with narrow specifications as to its chemical properties.

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[69] Monthly fuel, gas and inventory statistics. Statistic Seden.

[70] EMEP/EEA air pollutant emission inventory guidebook 2013. In the 2016 and 2019 edition of the EMEP EEA Guidebook, the methodology has changed. Sweden still uses the methodology described in the 2013 edition.

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 in section 3.2.16.2.

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

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

3.2.16.5 SOURCE-SPECIFIC RECALCULATIONS

- During 2024, Statistics Sweden performed a project aiming to investigate the validity of net calorific values and emission factors in the mobile energy subsector. As a result, the net calorific value for fossil jet kerosene has been updated from 35.28 to 34.85 GJ/m^3, the emission factor for CO_2 from fossil and biogenic jet kerosene was updated from 78.5 to 73.45 ton/TJ and emission factor for SO_2 from fossil and biogenic jet kerosene was updated from 0.0236 to 0.0232 ton/TJ. This update was performed in order to align the emission factors of SMED with those used by the Swedish Defence Research Agency (FOI) in their emission model for aviation.
- In submission 2025, the monthly fuel deliveries indicated that the amount of delivered jet kerosene had decreased compared to 2022. Since most other indicators, such as number of flights and passengers indicated increasing air traffic, it was decided that the monthly fuel deliveries can’t be relied on for the year 2023. As a result, the fuel consumption for aviation was extrapolated from year 2022 to 2023 with the same percentual increase as the fuel consumption estimated by FOI.
- The consumption of jet kerosene was overestimated for the years 1990-2017 in previous emission estimations and this was corrected in submission 2025.

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 (CRT 1.A.3.b)

3.2.17.1 SOURCE CATEGORY DESCRIPTION

Road transport is a significant source of greenhouse gases (GHG) and contributes to 29% of the total emissions of GHG from all sectors (excluding LULUCF) in Sweden. The emissions of GHG from road transportation were about 12 767 kt CO_2-eq. in 2023, which accounts for approximately 77% of the total emissions of GHG from mobile combustion in Sweden. The emissions of GHG from road transportation in 2023 has decreased by 1% since 2022 and by 29% since 1990.

Road transport includes six vehicle categories: A-tractor cars, Passenger cars, Buses, Heavy goods vehicles (HGV), Light commercial vehicles (LCV) and Mopeds & Motorcycles. A-tractor cars were added as a new category in submission 2024. Gasoline was previously the most common fuel used for road transportation, but as from 2011 the amount of diesel used by road traffic surpassed gasoline as can be seen in Figure 3.6 below[71]. The increasing consumption of diesel by road traffic is primarily explained by a shift from gasoline to diesel cars, but also by an increased consumption of diesel by HGV and LCV. The total consumption of fossil diesel by HGV and LCV corresponds to 54 % of the total consumption by road traffic in 2023, while passenger cars use around 44 %. The consumption of fossil diesel is demonstrating a decreasing trend since 2011.

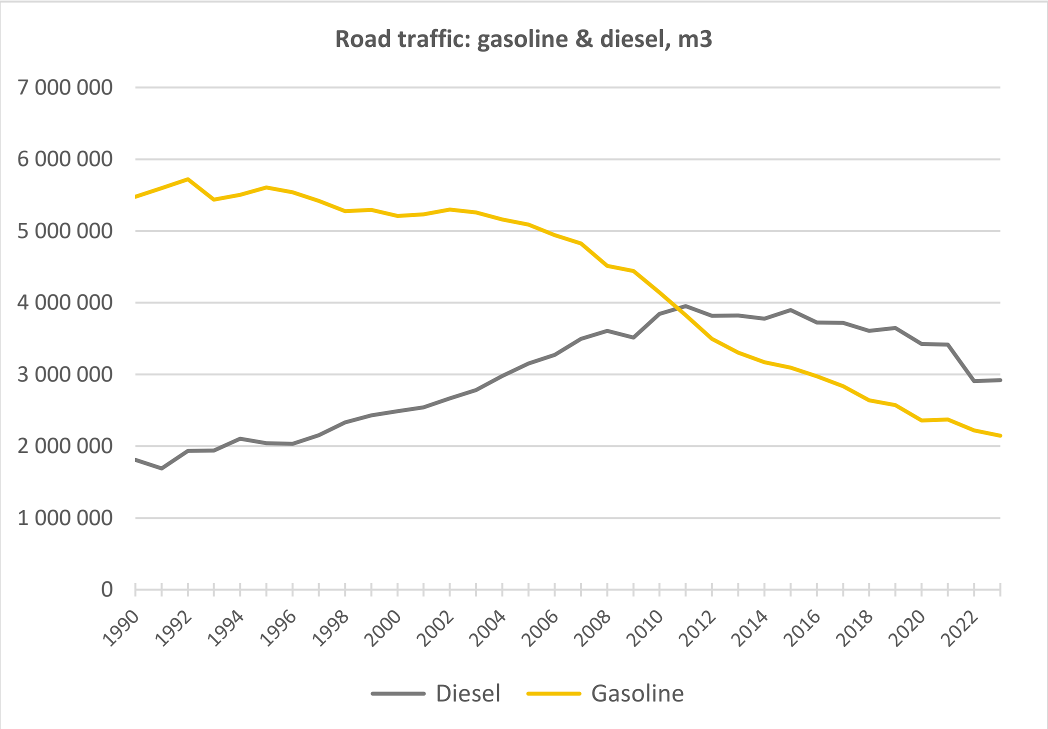

Figure 3.6. Consumption of fossil gasoline & diesel by road traffic 1990-2023 (m^3).

[71] When writing gasoline and diesel; it’s implied that it is fossil gasoline and fossil diesel

The consumption of fossil diesel by HGV increased by 66% between 1990 and 2007, when it peaked (Figure 3.7). The decline of fossil diesel consumption has occurred despite the fact that the total distance driven annually by HGV has remained relatively stable (Figure 3.9), thanks to an increasing share of biofuels. In 2023 the consumption of diesel by HGV was 14 % lower than in 1990. The consumption of diesel by LCV has increased by approximately six times since 1990. The consumption of fossil diesel by passenger cars increased between 1996 and 2019, surpassing the consumption by heavy trucks in 2015. Since 2020, there has been a steep decline in passenger cars' consumption of fossil diesel.

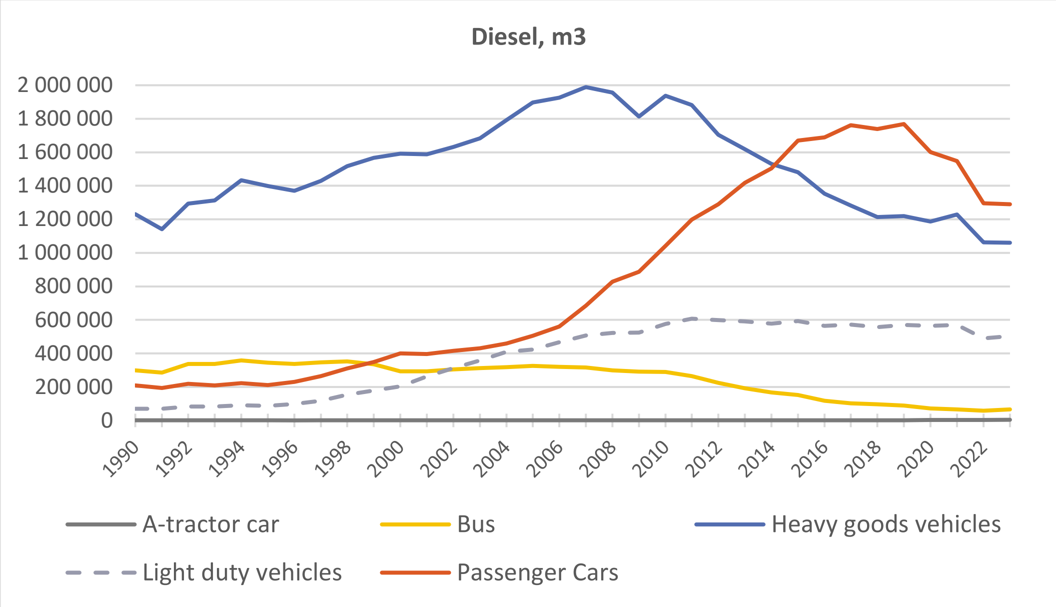

Figure 3.7. Consumption of diesel by vehicle type 1990-2023 (m^3).

The gasoline consumption has a decreasing trend for all vehicles, which can be seen in Figure 3.8.

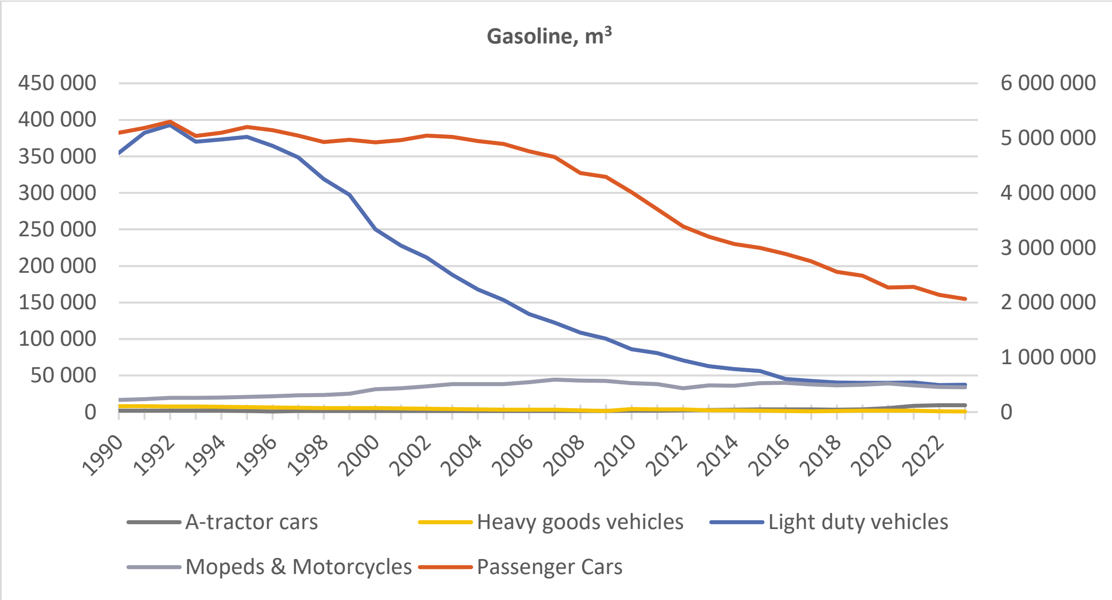

Figure 3.8. Consumption of gasoline by vehicle type 1990-2023 (m³). Passenger car consumption shown on secondary y-axis.

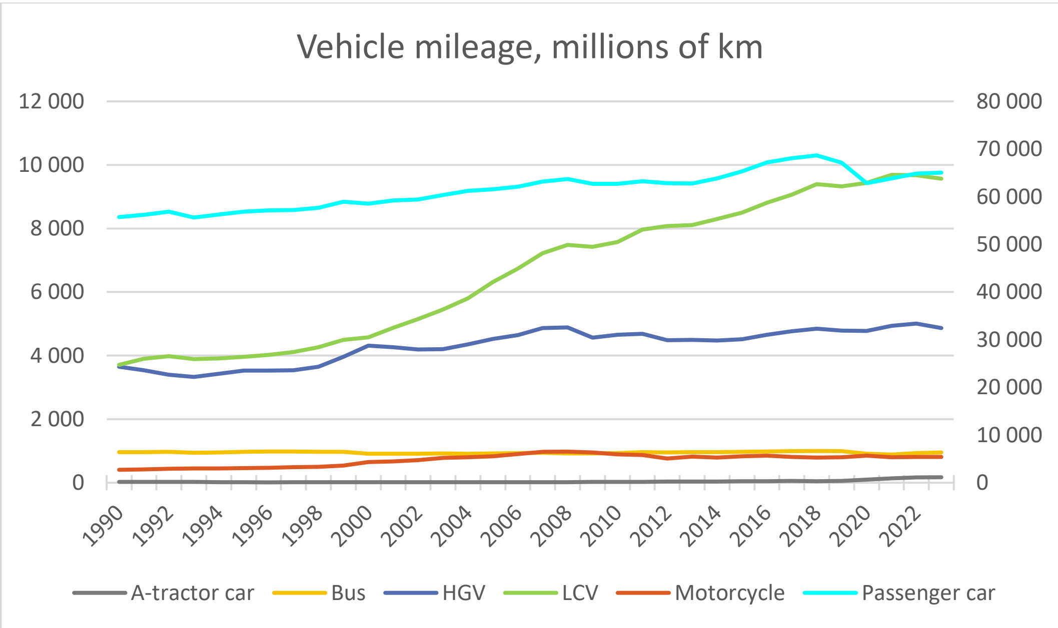

Figure 3.9 Vehicle mileage by vehicle type 1990-2023 (million kilometres). Passenger car mileage shown on secondary y-axis.

The total consumption of liquid biofuels (FAME/HVO[72] and ethanol/ETBE) has increased more than tenfold since 2003, when large-scale blending of ethanol in petrol began. The increasing production and use of biofuels was initiated by advantageous policy regulations and tax reliefs for biofuels[73]. The amount of biogas used by road traffic

[72] FAME=Fatty Acid Methyl Ester; HVO= Hydrogenated Vegetable Oil

[73] Swedish Energy Agency, 2013.

has to a great extent replaced the consumption of natural gas by road traffic and has increased significantly since it was introduced on the market although it was not introduced at the same time for all vehicle types, e.g. HGV and LDV did not start using biogas until 2012 and 2016, respectively (see figure 3.10 and figure 3.11).

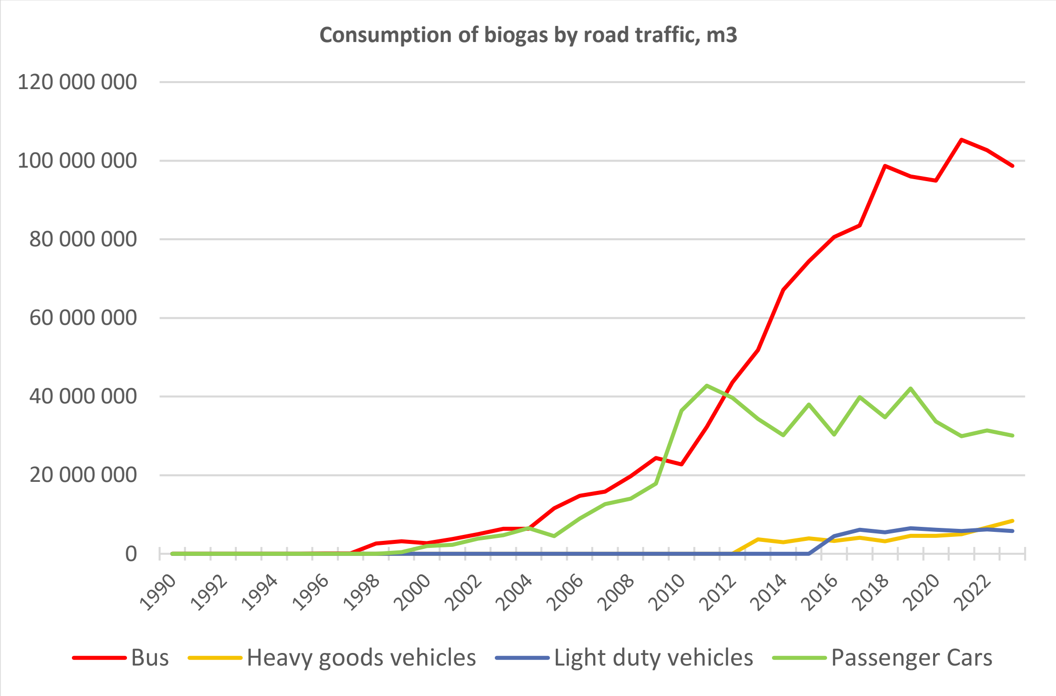

Figure 3.10. Consumption of Biogas by vehicle type in road traffic, 1990-2023 (m^3).

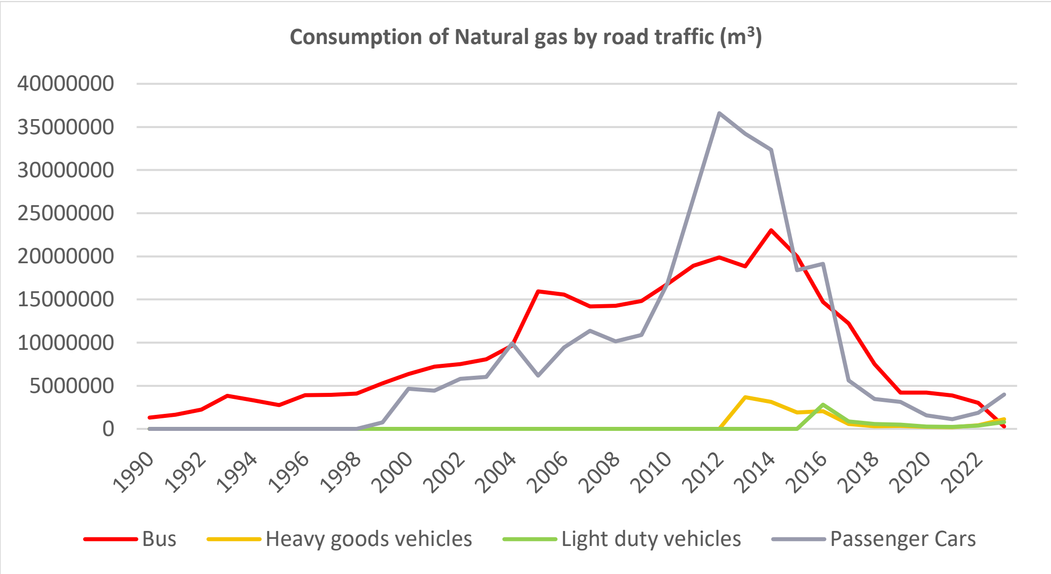

Figure 3.11. Consumption of Natural gas by vehicle type in road traffic, 1990-2023 (m^3).

The major part of ethanol used by road transportation in Sweden is used as a blending component for gasoline. Large-scale blending of ethanol in petrol began in 2003. The total amount of ethanol used for road traffic nearly tripled between 2003 and 2011 (see Figure 3.12), but then started to decline as a result of a shift from gasoline cars to diesel cars. Just about all 95-octane petrol was sold as E5 (5% ethanol) fuel before the 1st of August 2021, when the ethanol level was raised to 10% with the introduction of E10. This measure was taken in order to achieve Sweden's national goal to reduce GHG emissions from transport by 70% before 2030. An increased admixture of biofuels provides a means to reduce the emissions of fossil CO_2 from existing vehicles without any shift in technology.

Pure and highblended ethanol is used by ethanol buses and by E85 vehicles (flexi fuel vehicles)[74]. The ethanol used by E85 vehicles and buses peaked in 2011 respectively 2012 and then started to decline. A decreasing trend can also be seen for low-blended ethanol from 2005 to 2020 due to the decline of gasoline cars. The use of low blended ethanol in gasoline rose sharply in 2021 and 2022 as a result of the introduction of E10. In 2023, the consumption of ethanol is somewhat lower than in 2022. This reduction is a result of a lower consumption of gasoline (Figure 3.12).

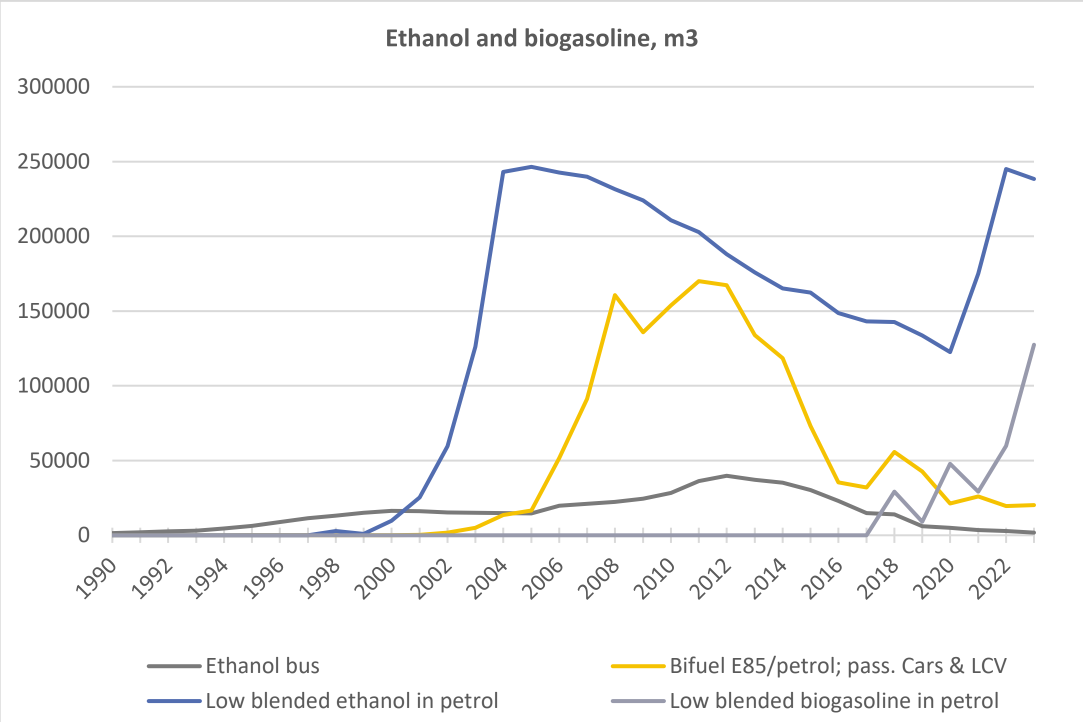

Figure 3.12. Consumption of ethanol and biogasoline by road traffic 1990-2023 (m^3).

Large-scale blending of FAME in diesel began in 2007/2008. The consumption of HVO for road traffic started in 2012, both as a blending component and as 100% renewable fuel. The Swedish reduction obligation was introduced in 2018. In the first year, the obligation stipulated an admixture of at least 19.3% biofuels in diesel. This percentage has gradually increased and in 2023 the admixture is 30.5%. The total use of FAME and HVO by road traffic has tenfolded since 2009 (see Figure 3.13 and 3.14). This is mainly the result of a growing trend for diesel cars with a rising fraction of low blended FAME/HVO and an increasing trend for trucks and buses that run on 100% renewable diesel.

74 E85 passenger cars, light duty vehicles and heavy goods vehicles.

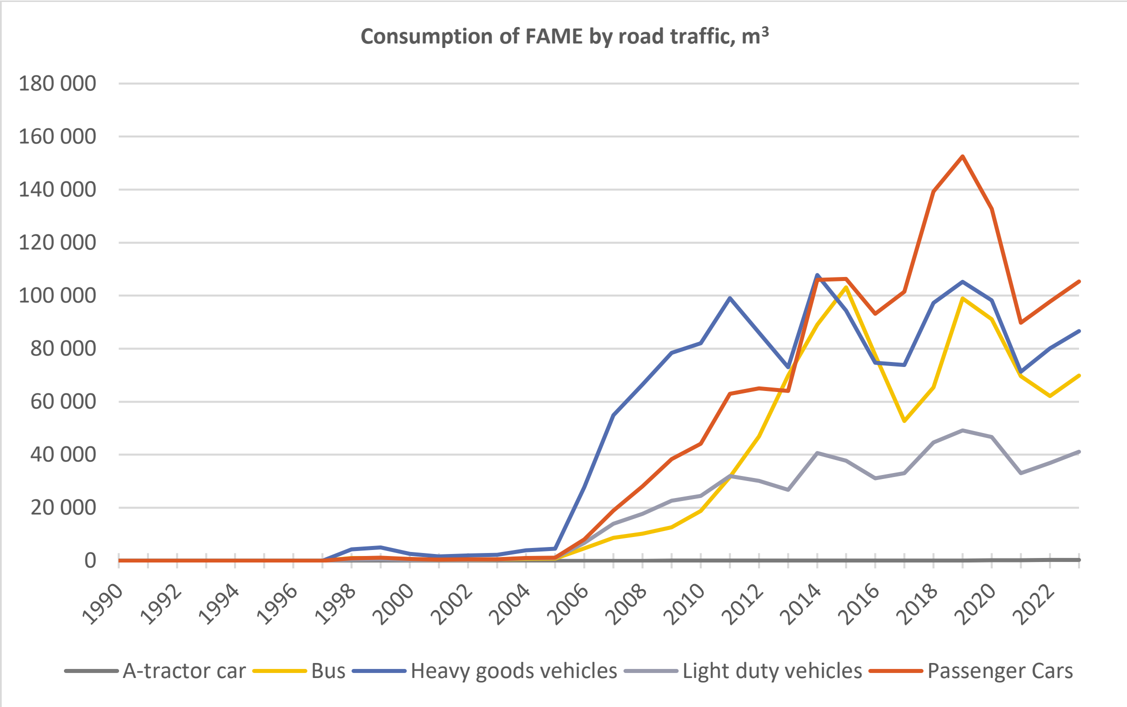

Figure 3.13. Consumption of FAME by vehicle type in road traffic 1990-2023 (m^3).

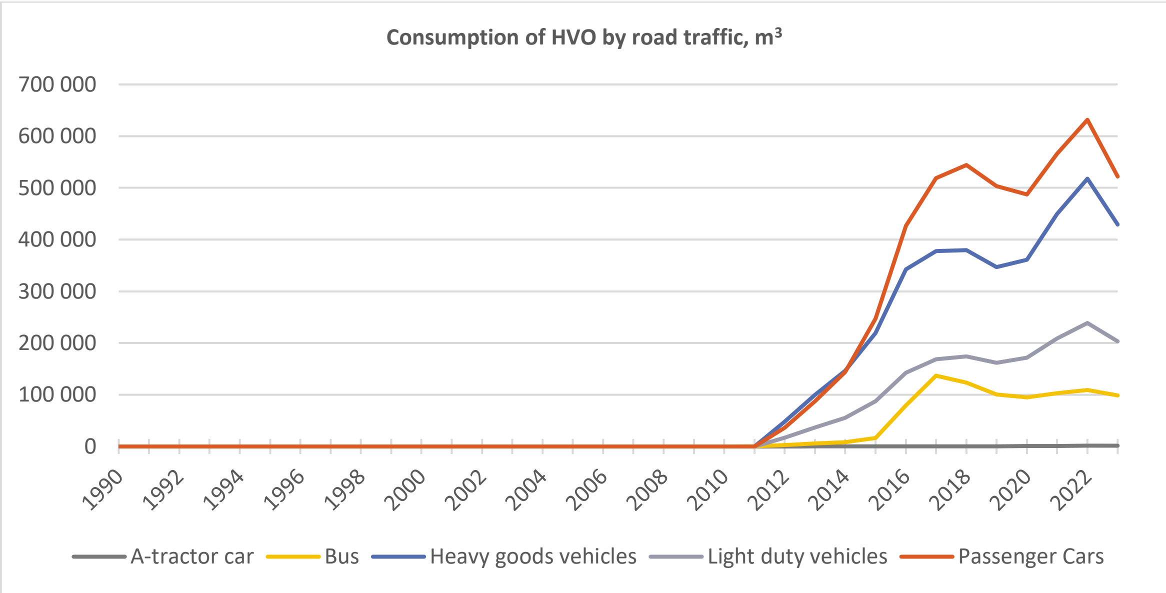

Figure 3.14. Consumption of HVO by vehicle type in road traffic 1990-2023 (m^3).

The summary of the latest key category assessment, methods and EF used, as well as 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, CRT 1A3b, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.3.b Cars	CO_2	X (Diesel, Gasoline)	X (Diesel, Gasoline)		T2	CS	Yes
	CH_4	-	X (Gasoline)		T1, M	CS, D	Yes
	N_2O	-	X (Gasoline)		T1, M	CS, D	Yes
1.A.3.b Light duty trucks	CO_2	X (Diesel, Gasoline)	X (Diesel, Gasoline)		T2	CS	Yes
	CH_4	-	-		M	CS, D	Yes
	N_2O	-	-		M	CS	Yes
1.A.3.b Heavy duty trucks and buses	CO_2	X (Diesel)	X (Diesel)		T2	CS	Yes
	CH_4	-	-		M, T2	CS, D	Yes
	N_2O	-	-		M	CS	Yes
1.A.3.b Motorcycles	CO_2	X (Gasoline)	-		T2	CS	Yes
	CH_4	-	-		M, T2	CS, D	Yes
	N_2O	-	-		M	CS	Yes

CS Country Specific, D Default, T1 Tier 1, T2 Tier 2, T3 Tier 3, M Model
* 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 is used by the Swedish Transport Administration (STA) to estimate the fuel consumption and emissions from road traffic and was updated from version 4.1 to version 4.2 in submission 2023.

The fuel consumption estimated by HBEFA is adjusted to be in line with the national fuel statistics. For 1990-2017, data from the survey “Monthly fuel, gas and inventory statistics” is used for this purpose. A revised version of the survey was introduced in 2018, but uncertainties regarding the quality of the statistics resulted in a change of data source and data collected and reported according to the “Swedish fuel quality act” is used as from 2018.[75]

In the monthly fuel survey, data is collected from oil companies and other sellers who keep stocks of petroleum products and coal as well as liquid biofuels. The survey also collects stock data from companies with a large consumption of oil in the manufacturing industries and energy industries. As the same oil companies are obliged to collect and report fuel data under the “Swedish fuel quality act” which is used as data source for 2018-2022, the time series is still considered consistent. The amount of diesel, gasoline and liquid biofuels[76] collected and reported by the monthly survey and the “Swedish fuel quality act” has only differed by ~1-2% from the data reported under the “Swedish fuel quality act” for the last years. Therefore, despite the use of another data source for 2018-

[75] https://www.energimyndigheten.se/en/sustainability/sustainable-fuels/fuel-quality-act/

[76] Diesel, gasoline, FAME, HVO, Ethanol and ETBE.

2022 than för previous years, the activity data used in submission 2024 is considered to be consistent and of good quality.[77]

The fuel consumption and emissions for road traffic are allocated by fuel type and the following vehicle categories: A-tractor cars, passenger cars, light commercial vehicles (LCV), heavy goods vehicles (HGV), buses and mopeds & motorcycles. The road traffic emission model HBEFA used by Sweden, 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, diesel, ethanol and FAME/HVO are based on the fuel consumption, country-specific thermal values and emission factors provided by the Energy Agency and "Drivkraft Sverige" which are shown in Annex 2.[78,79,80,81]

The emissions of CO_2 from natural gas and biogas are based on thermal values and emission factors from the Danish Energinet[82] respectively AGA. Emissions of CO_2 from biogas, ethanol and HVO are reported as 100% biomass and not included in the national totals as well as the majority of the FAME and ETBE used. A small part of FAME and ETBE are considered fossil and the emissions of CO_2 from the fossil part of FAME and ETBE are included the national emissions of CO_2[83]. The emission of CO_2 from the fossil share of FAME and ETBE are reported under "Other fossil fuels" in the CRT tables. See section 3.2.17.5.2 for more information.

Emissions of SO_2 are based on the actual sulphur content for the different environmental classes of petrol and diesel fuel. Data on the sulphur content is provided by the Swedish Transport Administration (STA) and based on estimates made by the Swedish National Road and Transport Research Institute (VTI) for the years 1990-2001 and on fuel analysis from "Drivkraft Sverige" for 2001 and the following years[84].

The emissions of CH_4, N_2O, CO, NMVOC and NO_X from 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/HVO 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 estimate the emissions of N_2O from ethanol buses. These emissions are calculated 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 using

[77] Eklund, V. et al. 2019. Analys och implementering av data från nya MåBra.

[78] https://drivkraftsverige.se/

[79] Paulrud, S., Fridell, E., Stripple, H., Gustafsson, T., 2010.

[80] Värmevärden och densiteter (energimyndigheten.se)

[81] Helbig, Eklund, Mawdsley m.fl. 2021, Utv. Proj. "SMED memo CO2 emission factor for fossil diesel fuel" (fr.o.m. 1996.)

[82] https://ens.dk/ansvarsomraader/co2-kvoter/stationaere-produktionsenheder/co2-rapportering-og-returnering

[83] Eklund, V. Gerner, A. SCB. 2019. Fossil inblandning i biobränsle.

[84] Directive 98/70/EC of the European Parliament and of the Council of 13 October 1998 relating to the quality of petrol and diesel fuels.

activity data on delivered amounts of natural gas and biogas for road transport and country specific emission factors[85].The activity data for natural gas and biogas is based on the survey "Deliveries of natural gas and biomethane for transport".[86]

The bottom-up estimated fuel consumption and the CO_2 emissions by HBEFA and the Swedish Transport Administration (STA) differ from those reported to the UNFCCC, which are adjusted to be in line with the national deliveries of fuel. 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 account for emissions which derives from fuel purchased in Sweden. The fuel consumption and the CO_2 emissions reported to UNFCCC, are consequently adjusted to be in line with national statistics on supply and deliveries of fuel. 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 CRT.

Fuel bought in	Traffic on Swedish roads	Traffic in Sweden, not on roads	Traffic to/from other country	Traffic in other countries
Sweden	CRT 1.A.3.b STA	CRT 1.A.3.b	CRT 1.A.3.b * STA to the Swedish border	CRT 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 CRT 1A3b.

Emissions of greenhouse gases from the use of LPG by road traffic was 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 a country-specific thermal value and emission factor, while emission factors from the IPCC 2006 guidebook are used to estimate the emissions of CH_4 and N_2O. The emissions are minor and represent only 0.02-0.03% of emissions of CO_2-eq. from road transportation considering the whole time series. As from 2018, these emissions are included in stationary combustion and reported as "IE", as data on LPG no longer is separated between stationary and mobile combustion.

In the UNFCCC 2020 review, Sweden was recommended to report emissions from lubricants combusted in two-stroke engines. However, as GHG emissions from lubricants combusted in two-stroke engines are estimated to be below 0.0184% of the Swedish national GHG emissions and hence below the threshold of significance, Sweden does not consider this a prioritized issue.

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.

[85] Paulrud, S., Fridell, E., Stripple, H., Gustafsson, T., 2010.
[86] https://www.scb.se/en/finding-statistics/statistics-by-subject-area/energy/energy-supply-and-use/deliveries-of-natural-gas-and-biomethane-for-transport/

One important basic parameter for the HBEFA model is vehicle-km, which is calculated using another model[87]. This other model is based on the mileage driven by the vehicle noted at time of the annual motor vehicle inspection test of the vehicle (MOT[88]).
A passenger car that goes through MOT in the beginning of 2023 has driven the most part during 2022. 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, there will be a delay in the modeled development of vehicle mileage as opposed to statistics on fuel consumption.

In 2018 a revised version of the survey “monthly fuel, gas and inventory statistics” was introduced, but uncertainties regarding the quality of the statistics were identified and data from the survey has therefore not been used for 2018-2022. Instead, data regarding diesel, gasoline and biofuels which are collected and reported according to the “Swedish fuel quality act” is used for 2018-2022. Despite the change of data source, the activity data used in submission 2024 is considered to be consistent and of good quality. See section 3.2.17.2 for more information.

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

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

3.2.17.5 SOURCE-SPECIFIC RECALCULATIONS

For submission 2025, the following changes have been made to the HBEFA road model:

- Calibration of fuel consumption by LCV, gas-fueled passenger cars and gasoline-fueled plug-in hybrids, which entails an increased fuel consumption for all three vehicle categories.
- The method for allocation of the number of kilometres driven between different fuels for passenger cars has been updated for the years 2000-2022. The update resulted in an increased energy consumption from gasoline between 2007 and 2012 but a decrease between 2014 and 2020. The opposite is true for diesel cars. Furthermore, the energy consumption from gas-fueled cars increased throughout the updated period.
- Age dependent number of kilometres driven for passenger cars and LCV for the years 2016-2022. In short, this project entails a re-allocation of driven kilometres from newer to older euro classes. As a result, CH_4 emissions from passenger cars and LCV increase, mainly because of more kilometres driven by older gasoline vehicles. Gasoline consumption increases for 1-1.5% during the period.

In addition to the changes made in the road model HBEFA, the following changes have been made:

[87] Vehicle - km statistics are produced by Statistics Sweden on behalf of the ministery of transport analysis (TRAFA)

[88] Ministry of Transport test, originally a British abbreviation.

- For the years 2020-2022, the net calorific value for biogasoline has been updated. Before, the update the value was 31.71 GJ/m^3 for these years, after the update it's 32.15, 31.57, 31.71 and 31.96 respectively, for the years 2020, 2021, 2022 and 2023.
- The emissions from diesel- and gasoline vehicles estimated in the road emission model HBEFA were previously only allocated to the fossil component of the fuel mix. The emissions have now been proportionally allocated to both the fossil and biogenic fuels used by these vehicles. This means that the emissions from the fossil diesel and gasoline used by diesel and gasoline vehicles decrease and the emissions from biofuels increase for all years with a consumption of low-blended biofuels.
- FAME and HVO used in road traffic (and by working machinery) were in previous submissions aggregated into FAME in the emission calculations. From submission 2025 they are separated. As FAME and HVO have slightly different calorific values and emission factors for CO_2, the emission estimation of biogenic was CO_2 affected. Overall, the effect of this change on emissions is very small.

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.

3.2.18 Railways (CRT 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 is not included in this sector according to IPCC's guidelines. Production of electricity is accounted for in CRT 1.A.1.a, regardless of where it is consumed.

The consumption of diesel for railways has had a decreasing trend since 1990. As a consequence, the emissions of CO_2-eq. have declined by 62% from 1990 (103 kt) to 2023 (39 kt). In 2023, the emissions decreased from 41 kt to 39 kt CO_2-eq compared to 2022.

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, CRT 1.A.3.c, according to approach 1.

CRT	Gas	Key Category Assessment, 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. The Swedish Transport Administration (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[89] and various emission factors. Country-specific emission factors are used to estimate the emissions of CO_2[90][91] and SO_2[92].

Emissions of CH_4 and N_2O are estimated with emission factors from EMEP/EEA Guidebook 2019 for all engines, since they are not regulated by EU directives which regulate an upper limit for emissions. The threshold limits for CO and NO_X are used as emission factors for all emissions from engines that comply with the EU emission standards Stage IIIA and Stage IIIB.[93] For engines introduced before the implementation of EU emissions standards, the emission factors from EMEP/EEA guidebook 2019 are used to estimate emissions of CO and NO_X.

The conversion of g/kWh to g/litre is based on the fuel consumption factors in Table 3-5 in the EMEP/EEA Guidebook 2019 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 CRT 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

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

[89] The Swedish Energy Agency is responsible for statistics regarding the rail fuel consumption since 2017; previously Transport Analysis (a Swedish government agency for transport policy analysis).

[90] Utv. Proj. "SMED memo CO2 emission factor for fossil diesel fuel", IVL 2021,

[91] Paulrud, Fridell, Stripple & Gustafsson, 2010. Uppdatering av klimatrelaterade emissionsfaktorer

[92] Drivkraft Sverige. 2023. https://drivkraftsverige.se/

[93] http://www.dieselnet.com/standards/eu/nonroad.php#rail

3.2.18.5 SOURCE-SPECIFIC RECALCULATIONS

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 (CRT 1.A.3.d)

3.2.19.1 SOURCE CATEGORY DESCRIPTION

In 2023, the emissions of greenhouse gases (GHG) from domestic navigation increased by 0.5% compared to 2022. The emissions of greenhouse gases were 696 kt CO_2-eq. in 2023, which is an increase by 51% since 1990.

The consumption of LNG by shipping was almost halved in 2023 compared to 2022 due to increasing natural gas prices. A large part of this LNG was replaced by marine gasoil in dual-fuel ships resulting in an increased consumption of marine gasoil by domestic shipping by nearly 23 percent in 2023.

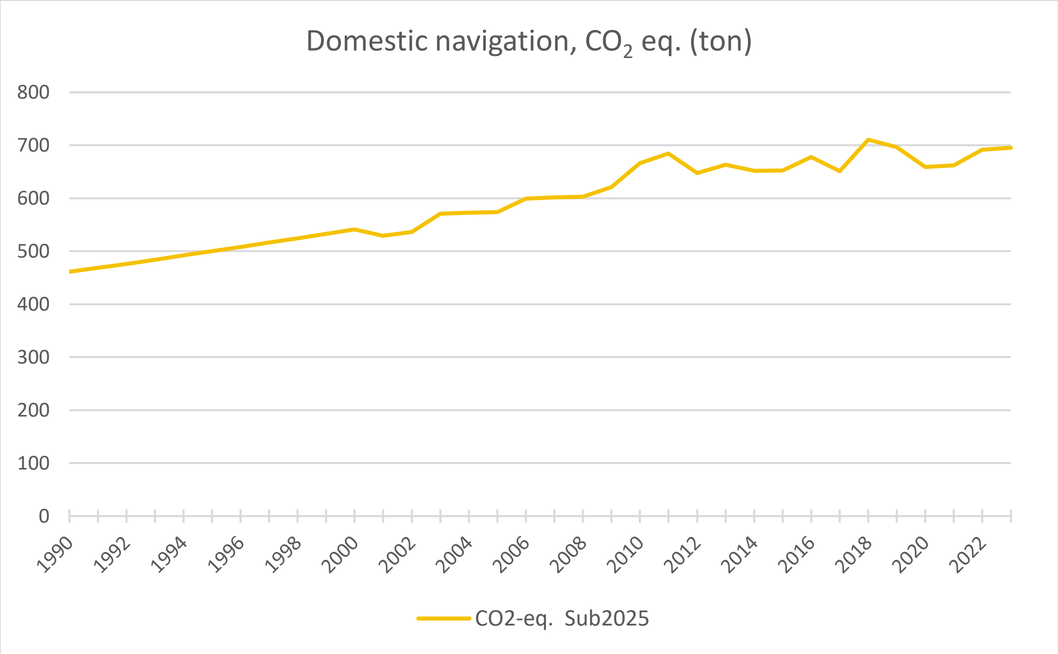

Figure 3.15. Emissions of green house gases in CO_2 eq. by national navigation in submission 2025 (including leisure boats) for 1990-2023.

An amendment to Directive 2012/33/EU introduced a mandatory use of marine fuels with a sulfur content of no more than 0.10% in sulfur control areas from the 1'st of January 2015[94, 95]. But already in 2012, the consumption of fuels with a high sulphur content started to decrease in Sweden. However, with the introduction of hybrid fuels on the market, i.e. heavy fuel oils with a reduced sulphur content, the consumption of residual

[94] DIRECTIVE 2012/33/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 November 2012 amending Council Directive 1999/32/EC as regards the sulphur content of marine fuels.

[95] https://eur-lex.europa.eu/eli/dir/2016/802/

fuel oils didn't continue to decrease as anticipated. But in 2019, a shift from residual fuel oils to LNG (liquid natural gas) can be noticed (see Figure 3.15).

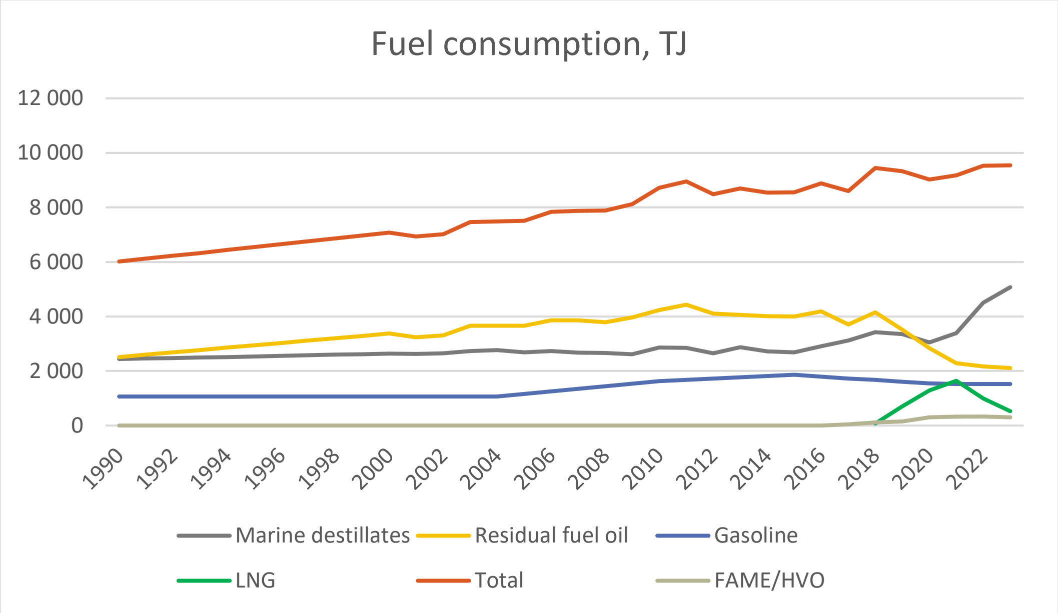

Figure 3.16. Fuel consumption by domestic navigation and fuel type (including leisure boats) 1990-2023 (TJ).

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, CRT 1A3d, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.3.d	CO_2	X (Gas/Diesel, Residual Oil)	X (Gas/Diesel)		T2	CS	Yes
	CH_4	-	-		T2	CS	Yes
	N_2O	-	-		T2	CS	Yes

T1 Tier 1. T2 Tier 2. CS Country Specific.
* 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 methodology. The fuel consumption for domestic navigation[96] is estimated by a LNG survey and the Shipair model, which is developed by the Swedish meteorological and hydrological institute (SMHI). The Shipair model is based on AIS data (Automatic Identification System),

[96] Excluding leisure boats.

which is used by ships to transmit identity and position information and shows how the ships move between different ports. Information regarding the ships such as size, engine power and type of vessel is also used by the Shipair model to estimate the amount of energy and fuel used by the ships to move between the given positions. In the Shipair model, fuel consumption in port is split equally between the voyage preceeding the port call and the following voyage.

Shipair uses the fuel allocation method described in the 4th IMO GHG study[97] to decide what fuel a ship is using. If data is lacking, Shipair, assumes that ships with a gross tonnage larger than 6000 in the Shipair database run on residual fuel oil. For ships with a tonnage less than 6000, the Shipair data is complemented with fuel statistics from a survey. The survey adresses the largest shipping actors in domestic navigation with the exception of cargo ships[98] and collects information regarding the fuel consumption by fuel type. The fuel residual between Shipair and the survey is assumed to be marine gasoil used by cargo ships. The survey is used to separate the fuel consumption for ships with a gross tonnage smaller than 6000 into different fuel types.

The use of LNG as a shipping fuel increased rapidly between 2018 and 2021. In 2022 and 2023 however, the use of LNG has declined significantly due to higher gas prices. Despite the decline, it has a significant impact on methane emissions due to methane slip. See figure 3.17. A survey to estimate the use of LNG by shipping has been conducted annually between the years 2020 and 2024[99] and shows the consumption of LNG since 2018. However, in submission 2025 a large proportion of the shipping companies failed to respond to the survey, lowering the credibility of the result. Consequently, survey data was only used for the years 2018-2020 in submission 2025. A new method has been implemented to estimate the LNG consumption for 2021-2023. The new method uses the energy consumption by LNG ships calculated by Shipair and assumes the same LNG/MGO ratio as for the dual fuel LNG vessels with the highest LNG consumption in domestic navigation. Shipair cannot calculate the energy consumption for international navigation and therefore LNG in international navigation still relies on the survey. The emission factors for LNG are based on a study from 2020[100].

[97] https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Fourth%20IMO%20GHG%20Study%202020%20-%20Full%20report%20and%20annexes.pdf

[98] EN0118, Transportsektorns energianvändning (inrikes sjöfart). Eklund, V. et al. 2019. Analys och implementering av data från nya MåBra.

[99] Eklund, V., Kellner, M. Sjöfartens förbrukning av LNG

[100] Hult, C. et al. 2020. Emission factors for methane engines on vehicles and ships

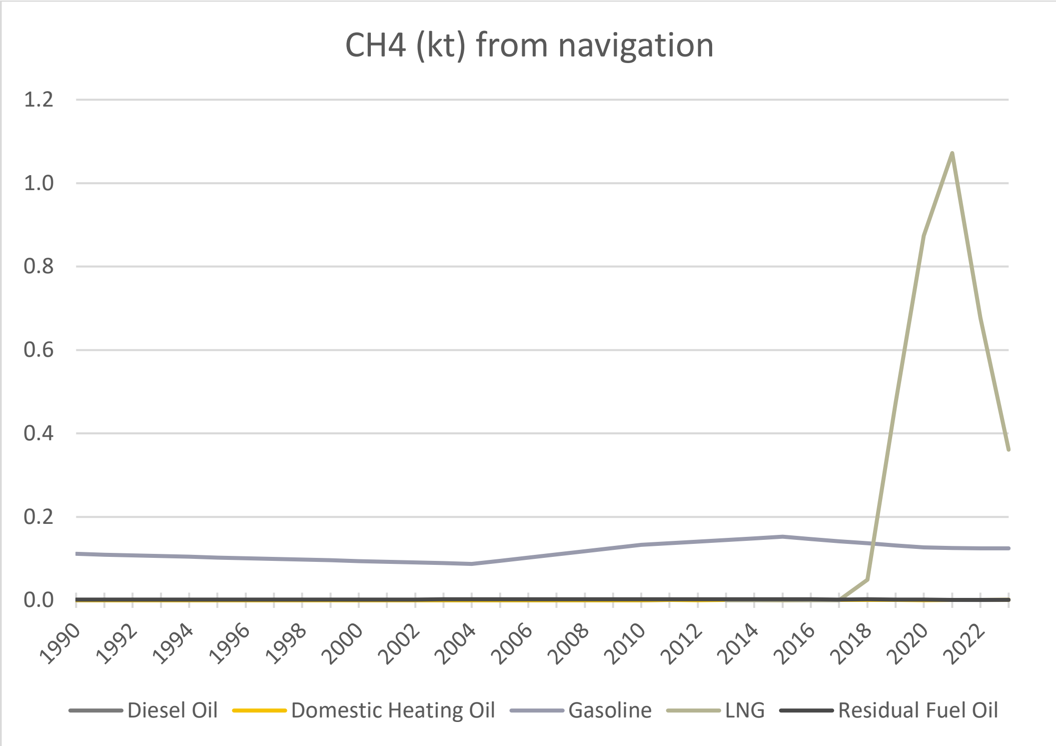

Figure 3.17. Emissions of CH_4 from navigation 1990-2023 (including leisure boats).

3.2.19.2.1 The emission factors for national navigation

The emission factors for CO_2 from diesel and marine gasoil are country-specific and based on two different studies [101, 102]. The CO_2 emission factor for residual fuel oil is based on a SMED study from 2004[103]. For LNG, the CO_2 emission factor is based on a study from 2020[104]. All other emissions factors for shipping beside CO_2 and SO_2 are based on fuel- and engine type as well as enginge age and the abatement equipment used. The engine types are divided into the following categories: slow speed diesel engine, medium speed diesel engine, high speed diesel engine, steam turbine and gas turbine as well as dual fuel engines for LNG.

Emission factors for CH_4, N_2O, CO, NMVOC, NOx and SO_2 were provided by the Swedish Maritime Administration (SMA) on a yearly basis until 2015 and by the Swedish Transport Agency (STA) as from 2016, in accordance with the Swedish climate legislation.

[101] Helbig, Tobias. 2018. Uppdatering av emissionsfaktorer för CO_2 från diesel och EO1 för sjöfart

[102] Helbig, Eklund, Mawdsley m.fl. 2021, Utv. Proj. "SMED memo CO2 emission factor for fossil diesel fuel"

[103] Cooper and Gustafsson, 2004.

[104] Hult & Winnes 2020. Emission factors for methane engines on vehicles and ships with a focus on methane emissions. IVL 2020.

There have been four surveys of recreational boats since 1990; in 2004, 2010, 2015 and 2020[105]. The surveys have been reviewed and the fuel consumption estimated in four different studies[106,107, 108,109]. The fuel consumption in between the surveys is 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.

3.2.19.2.2 The emission factors for leisure boats

Emissions of CH_4 and N_2O from *gasoline* leisure boats are based on emission factors from EMEP/EEA guidebook 2019, while country specific emissions factors are used for CO[110] as well as for NOx and NMVOC[111]. The emissions from gasoline leisure boats also depend on the ratio between 2- and 4-stroke engines and the ratio used is based on two studies from 2005[112] and 2017[113]. 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 the years 2016-2020 is assumed to be the same as for 2015. In a review, the UNFCC has recommended Sweden to report emissions from lubricants combusted in two-stroke engines. However, in 2015 such emissions constituted less than 0.0184% of Sweden’s total GHG emissions and are thus under the threshold of significance. Being insignificant, Sweden does not prioritise this issue.

Emissions of CH_4 and N_2O from the consumption of diesel by leisure boats are based on emission factors provided by the Swedish Maritime Administration up to 2015 and from the Swedish Transport Agency as from 2016. Country-specific emissions factors are used for CO[114] as well as for NOx and NMVOC[115].

[105] https://www.transportstyrelsen.se/sv/sjofart/Fritidsbatar/Statistik-och-fakta--fritidsbatar/batlivsundersokningen/

[106] Gustafsson, 2005.

[107] Eklund V. 2014.

[108] Fridell, E., Mawdsley, I., Wisell T. 2017.

[109] Per Dyfvelsten, The Swedish Energy Agency, personal communication, 2021.

[110] Fridell, E., Mawdsley, I., Wisell T. 2017.

[111] Wisell, T. 2022. Uppdaterade emissionsfaktorer för fritidsbåtar i Sverige.

[112] Statistics Sweden, 2005a.

[113] Fridell, E., Mawdsley, I., Wisell T. 2017.

[114] Fridell, E., Mawdsley, I., Wisell T. 2017.

[115] Wisell, T. 2022.

3.2.19.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The fuel consumption by domestic navigation was before submission 2020 based on the the “Monthly fuel, gas and inventory statistics” survey[116] and showed fluctuations for which it was difficult to find natural explanations.[117] In submission 2020, the methodology for both national and international navigation was revised. The new methodology is based on the Shipair model and a survey and is explained in section 3.2.19.2.

The first year covered by the Shipair method is 2013. For the years before 2013, data has been extra- or interpolated with different methodologies. The method depends on what data was available for each shipping company and is either constant, interpolation or a moving average.

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

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

3.2.19.5 SOURCE-SPECIFIC RECALCULATIONS

- Data on the consumption of LNG by domestic and international navigation has been collected through a survey to shipping companies in 2020-2024. However, in submission 2025 a large proportion of the shipping companies failed to respond to the survey, lowering the credibility of the result. Consequently, survey data was only used for the years 2018-2020 in submission 2025. A new method has been implemented to estimate the LNG consumption for 2021-2023. The new method uses the energy consumption by LNG ships calculated by Shipair and assumes the same LNG/MGO ratio as for the dual fuel LNG vessels with the highest LNG consumption in domestic navigation. Back testing for previous years has revealed that the results differ by less than 5% from the results in the survey.
- Shipair can not calculate the energy consumption for international navigation and therefore LNG in international navigation still relies on the survey. For 2021-2022, consumption of the companies that failed to respond was extrapolated with the percentual change of other shipping companies. For 2023, those companies used for extrapolation also failed to respond and the consumption was instead assumed to be the same as for 2022.
- Due to updates of the monthly fuel deliveries, the total amount of marine gasoil and residual fuel oil have decreased somewhat for the year 2022. This change only affects international navigation.

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.

[116] 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/. See Annex 2.

[117] Statistic Sweden. Monthly fuel, gas and inventory statistics. EN31SM.

3.2.20 Other transportation (CRT 1.A.3.e)

3.2.20.1 SOURCE CATEGORY DESCRIPTION

Emissions reported under CRT 1.A.3.e refer to emissions from combustion of natural gas for pipeline transport (1.A.3.e.i), off-road vehicles and other machinery (1.A.3.e.ii). Examples of working machinery included in this sector are machinery used in ports and airports as well as snow groomer machines used in ski resorts. Around 13% of total GHG emissions from working machinery are reported in CRT 1.A.3.e.ii. The emissions from working machinery is virtually unchanged compared to 2022 and has decreased by 68% 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 3.21.

Table 3.21. Summary of source category description, CRT 1A3e, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1.A.3.e	CO_2	X	X	-	T2	CS	Yes
	CH_4				M	CS	Yes
	N_2O				M	CS	Yes

M Model, T2 Tier 2, 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 1990-2023. Combustion of natural gas for pipeline transport of natural gas in Sweden is only known from 2013, but not for the period 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 increase 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 Tier 2 national emission factors as for stationary combustion of natural gas in sector 1.A.4.a.

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.[118]

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[119].

Emissions from off-road vehicles and other machinery are also reported under CRT 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	CRT	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 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 amount of low-blended biofuel used by working machinery and road traffic is allocated proportionally to the amount of fossil gasoline and diesel consumed in each subsector. The model estimated consumption of fossil gasoline and diesel by working machinery is decreased by the amount of ethanol and FAME/HVO, respectively, allocated to the subsector in question. In 2004, the consumption of gasoline by working machinery decreased noticeably as a result of an increase in the amount of ethanol

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

[119] See Annex 2, section “1.4 Allocation of fuels for mobile combustion” for more information.”

allocated to working machinery, due to a large increase in the national deliveries of low-blended ethanol. The same phenomenon took place between 2017 and 2018 as a result of a sudden increase of the ethanol sold on the Swedish market.

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 for working machinery was implemented for 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

- Sweden has previously not been able to update the amount of gas burnt for pipeline transport for two years (2021, 2022) due to lack of data. In submission 2025 however, Sweden has received data for 2021 and 2022 along with data for 2023.

- The CO_2 emission factor for natural gas has been updated from 56.89, 55.52 and 55.52 ton/TJ for the years 2019, 2021 and 2022 respectively, to 56.54, 55.47 and 56.38 ton/TJ.

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 (CRT 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. GHG emissions in this category have increased by 2% compared to 2022 and decreased by 81% since 1990.

Around 9% of total GHG emissions from working machinery are reported in CRT 1.A.4.a.ii. The emissions from working machinery make up 43% of the total emissions in this category. The emissions from working machines increased 3% compared to 2022 but has decreased about 9 % since 1990.

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 2022 it was around 6 300 TJ. Liquid fuels account for most of the decrease. The share of liquid fuels in 1990 was about 95% and the corresponding share in 2022 was about 21.1%.

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 3.23.

Table 3.23. Summary of source category description, CRT 1A4a, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.4.a	CO_2	X (Gaseous fuels, Liquid fuels)	X (Gaseous fuels, Liquid fuels)		T2	CS	Yes
	CH_4	-	-		T2, M	CS	Yes
	N_2O	-	-		T2, M	CS	Yes

CS Country Specific. T1 Tier 1, T2 Tier 2. M Model
* 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 CRT 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. Since submission 2020, biomass activity data and emission factors are separated into traditional and modern technology for the whole time series[120]. 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.

The activity data and emission factors for CH_4, CO and NMVOC from biomass combustion within 1.A.4.a are separated into modern and traditional combustion technology for the whole time series in order to capture the phasing-out of old technology[121]. The revision is described more in detail in Annex 2.

The activity data for the last emission year (2023), is the same as for 2022. The reason for estimating the activity data is due to that the preliminary Energy Balance compiled by the Swedish Energy Agency, is delivered too late in the process of compiling the GHG inventory and that the last years activity data is often revised in the definitive Energy Balances. For more detailed information about the extrapolation effects see Annex 2. The activity data for the last inventory year will be revised next coming submission, as the Energy Balance will then be published and definitive.

[120] Helbig, T. Kindbom, K. Jonsson, M. 2019. Uppdatering av nationella emissionsfaktorer för övrig sektor. SMED rapport no 12 2019.

[121] Helbig, T., Kindbom, K. Jonsson, M. 2019. Uppdatering av nationella emissionsfaktorer för övrig sektor. SMED rapport no 12 2019.

3.2.21.2.2 Mobile combustion/Working machinery

Emissions from mobile combustion in CRT 1.A.4.a refer mainly to gardening machines for professional use, wheel loaders, excavators 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. [122]

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[123].

Emissions from working machinery are also reported under CRT 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	CRT	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	Wheel loaders, excavators, garden machinery, eg 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.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.

3.2.21.3 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. The uncertainties for stationary combustion are revised in submission 2020 and set on fuel group aggregation level. The uncertainty values are assigned by staff at Statistics Sweden and are based on expert judgements made on fuel type that were aggregated to fuel group.
Activity data uncertainty is 20% for Liquid Fuels and 10% for all other fuel groups. The large activity data uncertainty is due to the use of data from the annual energy balances.

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

[123] See Annex 2, section “1.4 Allocation of fuels for mobile combustion” for more information.”

CO_2 emission factor uncertainty is highest for Biomass (30%) and lowest for Liquid Fuels, (1%).

The implied emission factor for CO_2 for liquid fuels in CRT 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 kg/GJ 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 amount of low-blended biofuel used by working machinery and road traffic is allocated proportionally to the amount of fossil gasoline and diesel consumed in each subsector. The model-estimated consumption of fossil gasoline and diesel by working machinery is decreased by the amount of ethanol and FAME/HVO, respectively, allocated to the subsector in question. In 2004, the consumption of gasoline by working machinery decreased noticeably as a result of an increase in the amount of ethanol allocated to working machinery, due to a large increase in the national deliveries of low-blended ethanol. The same phenomenon took place between 2017 and 2018 as a result of a sudden increase of the ethanol sold on the Swedish market.

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[124]. 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 CRT 1.A.4.a and 1.A.4.b[125]. 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 to stationary and mobile combustion. All diesel 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.

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.

[124] Gustafsson, et al. 2005.

[125] Paulrud et al. 2005.

In submission 2010, it was noted that the consumption of biomass, liquid fuels and gaseous fuels within this sector was higher in 2007 than in 2006 and 2008. In submission 2011, the activity data for 2007 and 2008 were revised 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 Stationary combustion

In submission 2025 there is a revision of activity data for the year 2022 for the sector as the data was updated to the final energy balance statistics. The effect of the recalculations in 1.A.4.a.i for 2022 was a decrease of 32.56 kt CO2-eq (9,63%).

The emission factor of natural gas was corrected for 2019 which resulted in an increase of emissions by 1.51 kt CO_2-eq (0.42%).

3.2.21.5.2 Mobile combustion

A development project[126] regarding annual machine operating hours was conducted during 2023. The project was conduced based on testing and inspection data for machines such as wheel loaders, front loaders and other machinery used in the commercial sector. The data originated from the certified organisation Swedish machine testing. Included in the same project was also a study on operating hours of tractors. The study analysed the registered operating hours between change in ownership. The project resulted in adjusted machine hours for tractors, wheel loaders, front loaders and other machinery used in the commercial sector. Previous machine hours were overestimated and thus the recalculations resulted in decreased emissions throughout most the time series.

For some of the early years (1990-1998) the emissions increased slightly due to corrections in the number of tractors in the segment.

On average the CO_2-emissions increased 1% during 1990-1998 and decreased 6% during 1998-2022 due to the recalculations.

The complete reference to the project report regarding annual average operating hours (Jerksjö, M.2024) is stated in the reference section in Annex 2, chapter 2.6.

3.2.21.1 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

The machine stock in the NRMMM will be updated for wheel loaders and excavators during the next submission. The updates will be implemented as a result of a study carried out based on the national vehicle register. The changes will manly affect the older

[126] Jerksjö, M. Genomsnittlig årlig driftstid för entreprenadmaskiner och traktorer. SMED PM 2024

machines in the stock as data shows that the NRMMM assumes a slightly incorrect scrapping rate of machines.

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

3.2.22 Residential (CRT 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 69% between 1990 and 2022, mainly due to a continuous increase in district heating use[127]. 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 wood fuels and natural gas increased quite considerably. In recent years, the use of heat pumps has also increased significantly[128]. 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 refers to gardening machines used in households e.g. lawn mowers, hedge cutters, clearing saws and more. Also snow mobiles and all-terrain vehicles not used for professional purposes and tractors are allocated to 1.A.4.b. Around 7% of total GHG emissions from working machinery are reported in CRT 1.A.4.b.ii. GHG emissions in this sector have decreased by 4% compared to 2022 and by 30% compared to 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 3.26.

Table 3.26. Summary of source category description, CRT 1A4b, according to approach 1.

CRT	Gas	Key Category Assessment, 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	-	-		M, T2	CS	Yes
	N_2O	-	-		M, T2	CS	Yes

CS Country Specific. T1 Tier 1, T2 Tier 2, M Model.

* Shows key category (level) per fuel type

** Shows key category (trend) per fuel type

[127] Swedish Energy Agency 2020, All numbers are according to data used in the greenhouse gas inventory this submission.

[128] Swedish Energy Agency 2020, All numbers are according to data used in the greenhouse gas inventory this submission.

3.2.22.2 METHODOLOGICAL ISSUES

3.2.22.2.1 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 for the three most common combustion technologies: boiler, stoves and open fire places. Since 1998, biomass activity data is separated into wood logs, pellets/briquettes and wood chips/saw dust. Historical biomass data has been estimated by inter- and extrapolation. Since submission 2019, biomass activity data and emission factors for boilers and stoves are further separated into traditional and modern technology for the whole time series[129].

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 CRT 1.A.4.b.

Emissions arising from the use of charcoal are estimated using national statistics and default 2006 IPCC guidelines EFs.

3.2.22.2.2 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.[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 CRT 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 3.27.

[129] Helbig, T., Gustafsson, T., Kindbom, K. Jonsson, M. 2018. Uppdatering av nationella emissionsfaktorer för övrig sektor (CRT/NFR 1A4). SMED rapport no 13 2018.

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

[131] See Annex 2, section “1.4 Allocation of fuels for mobile combustion” for more information.”

Table 3.27. Distribution of emissions from off-road vehicles and other machinery.

Category	CRT	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 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.

3.2.22.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The time series for 1.A.4.b is considered to be consistent as there has not 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 issues in the activity data in biomass 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.

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. The uncertainties for stationary combustion were revised in submission 2020 and set on fuel group aggregation level. The uncertainty values are assigned by staff at Statistics Sweden and are based on expert judgements made on fuel type that were aggregated to fuel group.
Activity data uncertainty is 20% for Liquid Fuels and 10% for other fuels groups. The CO_2 emission factor uncertainty is highest for Biomass, 30%. The other fuel groups vary between 1-5%.

The amount of low-blended biofuel used by working machinery and road traffic is allocated proportionally to the amount of fossil gasoline and diesel consumed in each subsector. The model estimated consumption of fossil gasoline and diesel by working machinery is decreased by the amount of ethanol and FAME/HVO, respectively, allocated to the subsector in question. In 2004, the consumption of gasoline by working machinery decreased noticeably as a result of an increase in the amount of ethanol allocated to working machinery, due to a large increase in the national deliveries of low-blended ethanol. The same phenomenon took place between 2017 and 2018 as a result of a sudden increase of the ethanol sold on the Swedish market.

3.2.22.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

See section 3.2.21.4.

3.2.22.5 SOURCE-SPECIFIC RECALCULATIONS

3.2.22.5.1 Stationary combustion

In submission 2025 there is a revision of activity data for the year 2022 for the sector as the data was updated to the final energy balance statistics. Updated activity data was acquired for charcoal and was updated for 2021, 2022. The update resulted in decreased emissions 0.16 kt CO_2 eq for 2021 and 1.4 kt CO_2-eq for 2022. The emission factor of natural gas was corrected for 2019 which resulted in an increase of emissions by 0.3 kt CO_2-eq (0.1%).

The total effect of the recalculations in 1.A.4.b.i for 2022 was an increase of 64.76 kt CO2-eq (19,3%).

3.2.22.5.2 Mobile combustion

A development project[132] regarding annual machine operating hours was conducted during 2023. The project was conduced based on testing and inspection data from the certified organisation Swedish machine testing. The project involved testing data from year 2019-2023 for some machinery that is used in the residential sector. Included in the same project was also a study on operating hours of tractors. The study analysed the registered operating hours between change in ownership.

The project resulted in adjusted machine hours for machinery used in the residential sector. Previous machine hours were overestimated and thus the recalculations resulted in decreased emissions throughout most of the time series.

For some of the early years (1990-1995) the emissions increased due to corrections in the number of tractors in the segments.

On average the CO_2-emissions increased 1 % during 1990-1995 and decreased 8% during 1995-2022 due to the recalculations.

The complete reference to the project report regarding annual average operating hours (Jerksjö, M.2024) is stated in the reference section in Annex 2, chapter 2.6.

3.2.22.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

3.2.23 Agriculture/forestry/fisheries (CRT 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 sectors agriculture and forestry each account for approximately 40% of the total emission in this category. Around 15% arise from stationary combustion and 5 % from fishing vessels.

[132] Jerksjö, M. Genomsnittlig årlig driftstid för entreprenadmaskiner och traktorer. SMED PM 2024

Around 30% of total GHG emissions from working machinery are reported in CRT 1.A.4.c.ii/ciii. In 2023, GHG emissions from working machinery have increased by 3% compared to 2022 and decreased by 30% since 1990. The structure of the agricultural sector in Sweden is described in section 5.

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, CRT 1A4c, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.4.c	CO_2	X (Liquid fuels)	X (Liquid fuels, Solid fuels, Marine Gasoil)		T2	CS	Yes
	CH_4	-	-		M, T2	CS	Yes
	N_2O	-	-		M, T2	CS	Yes

CS Country Specific. T1 Tier 1, T2 Tier 2. M Model
* 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 CRT 1.A.4.c. Since submission 2020, biomass activity data and emission factors are separated into traditional and modern combustion technology for the whole time series[133].

In submission 2022, activity data for other biomass was revised for the time series between 1990 and 2004 according to Josefssson Ortiz & Helbig (2021)[134]. The energy consumption of other biomass for this sector had an abrubt start at 2002, which was not credible. The revision of other biomass for 1.A.4.c has increased the time series consistency by incorporating an estimated other biomass energy consumption between the years 1990 to 2004. The estimate was made after a thorough investigation of data available at different authorities gathering data for statistic production of fuel

[133] Helbig, T. Kindbom, K. Jonsson, M. 2019. Uppdatering av nationella emissionsfaktorer för övrig sektor. SMED rapport no 12 2019.

[134] Josefsson Ortiz, C. & Helbig, T. 2021. Revidera bränsleförbrukning i övrig sektor 1990-2002. SMED Memorandum 2021.

consumption from the agricultural sector. Surrogate data according to IPCC GL 2006 was used in reproducing the energy consumption for the early ears of the time series. Surrogate data used in the estimates were:

- Yearly cereal harvests
- Variation of fractions of wood fuel for heating greenhouses
- Energy consumption per ton cereal harvest or energy consumption per m^2 heated greenhouse

3.2.23.2.2 Mobile combustion

The estimated fuel consumption for fisheries is based on the following sources:

- The survey "Energianvändning inom fiskesektorn" for the years 2005, 2017 and 2022, which estimates the energy consumption by the fishing industry for each year[135,136,137].
- The Swedish fishing fleets' total installed effect in kW[138].
- The SMED report "Fiskenäringen – uppdatering av bränsleförbrukning samt emissionsfaktorer" which included an analysis of the fuel type used by the fishing industry[139].

The estimated fuel consumption for the years before and after 2005 is estimated by adjusting the fuel consumption in 2005, from the survey, based on the development in total installed capacity.

The emission factors used to estimate emissions from the fishing fleet are based on a SMED study from 2005[140], producing emission factors for NMVOC, CH_4 and N_2O for 1990-2004. These emission factors are used for the whole time series. 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.

The emission factor for CO_2, is based on a SMED report from 2021[141]. The emission factors for SO_2 from fisheries are assumed to be the same as for domestic navigation, which are updated annually by the Swedish transport agency. The emission factor for NO_X has been updated for all years in submission 2022 after a SMED study from 2021[142].

[135] Statistics Sweden, 2006. ER 2006:35. Energianvändningen inom fiskesektorn år 2005

[136] Swedish Energy Agency 2018. EN0115. Energianvändning inom fiskesektorn,

[137] Swedish Energy Agencu 2023. EN0115. Energianvändning inom fiskesektorn.

[138] Swedish Agency for Marine and Water Management (SwAM). Personal communication.

[139] Eklund, V. Kellner, M. Parsmo, R. 2021. Fiskenäringen – uppdatering av bränsleförbrukning samt emissionsfaktorer.

[140] Cooper et al., 2005a.

[141] Helbig, Mawdsley et al. 2018. SMED memo CO2 emission factor for fossil diesel fuel, 2021.

[142] Eklund, V. Kellner, M. Parsmo, R. 2021. Fiskenäringen – uppdatering av bränsleförbrukning samt emissionsfaktorer

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

Mobile combustion in CRT 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. [143]

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[144].

Emissions from off-road vehicles and other machinery are also reported under CRT 1.A.2.g vii, 1.A.3.e ii, 1.A.4.a.ii and 1.A.4.b.ii, in line with IPCC Guidelines, see Table 3.30.

Table 3.30. Distribution of emissions from off-road vehicles and other machinery.

Category	CRT	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 sharp increase in the 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

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

[144] See Annex 2, section “1.4 Allocation of fuels for mobile combustion” for more information.”

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 uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. The uncertainties for stationary combustion are revised in submission 2020 and set on fuel group aggregation level. The uncertainty values are assigned by staff at Statistics Sweden and are based on expert judgements made on fuel type that were aggregated to fuel group.

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 arises 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 and FAME, respectively. 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

3.2.23.5.1 Stationary combustion

In submission 2025 there is a revision of activity data for the year 2022 for the sector as the data was updated to the final energy balance statistics. The effect of the recalculations in 1.A.4.a.i for 2022 was a decrease of 32.22 kt CO_2-eq (28,81%).

The emission factor of natural gas was corrected for 2019 which resulted in an increase of emissions by 0.07 kt CO_2-eq (0.06%).

3.2.23.5.2 Mobile combustion

A development project[145] regarding annual machine operating hours was conducted during 2023. The project was conducted based on testing and inspection data from the certified organisation *Swedish machine testing*. The project involved testing data from year 2019-2023 for machinery such as wheel loaders, excavators and more. Included in the same project was also a study on operating hours of tractors. The study analysed the registered operating hours between change in ownership.

[145] Jerksjö, M. Genomsnittlig årlig driftstid för entreprenadmaskiner och traktorer. SMED PM 2024

The project resulted in adjusted machine hours for machinery used in the agriculture and forestry sector. Previous machine hours were overestimated and thus the recalculations resulted in decreased emissions throughout the time series.

On average the CO_2-emissions decreased 9% during 1990-2022 due to the recalculations.

The complete reference to the project report regarding annual average operating hours (Jerksjö, M.2024) is stated in the reference section in Annex 2, chapter 2.6.

The fuel consumption by the fishing fleet was estimated by a survey in 2005. For the years before and after 2005 the fuel consumption is extrapolated based on the total installed effect in the fishing fleet. However, in 2018, a new survey from the Swedish Energy Agency showed that the actual fuel consumption was somewhat lower than the consumption as estimated using this method. In 2023, yet another survey from the Swedish energy agency confirmed this[146].

Therefore, a correction factor has been introduced in submission 2025. The correction factor, consumption per installed effect, was calculated for each of the years for which there is survey data (2005, 2017 and 2022). The correction factor was then interpolated for the years in between. The introduction of the correction factor lowers the fuel consumption of the fishing fleet for all years after 2005. The difference becomes gradually bigger through the time series and for 2022 the fuel consumption is 32% lower in submission 2025 than in submission 2024 (Fig 3.18).

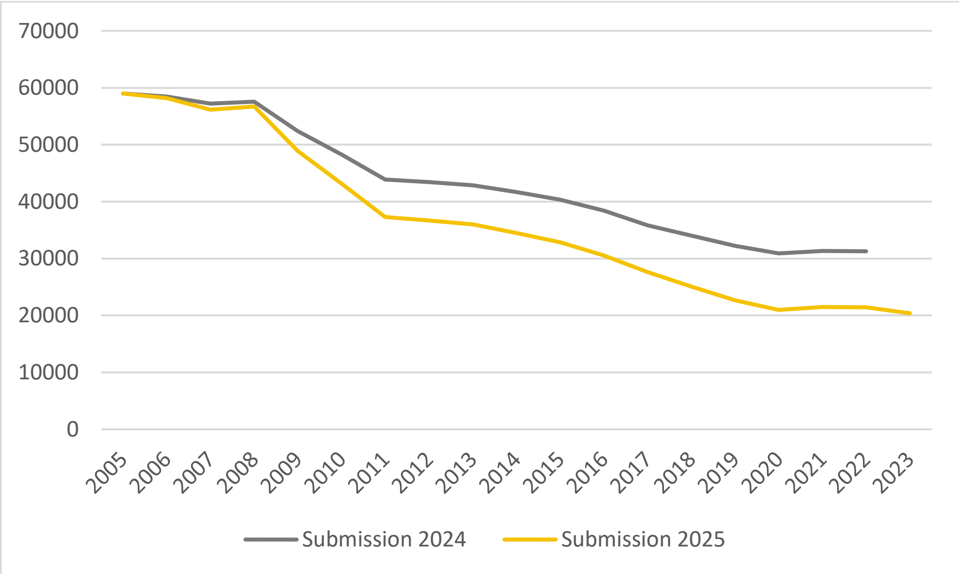

Fig 3.18. Fuel consumption of the fishing fleet (m^3) 2005-2023 in submission 2024 and submission 2025.

[146] https://www.energimyndigheten.se/statistik/officiell-energistatistik/tillforsel-och-anvandning/energianvandningen-inom-fiskesektorn/?currentTab=2

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.

3.2.24 Other stationary (CRT 1.A.5.a)

No emissions are reported in this sector.

3.2.25 Other mobile (CRT 1.A.5.b)

3.2.25.1 SOURCE CATEGORY DESCRIPTION

The emissions from military activities are included elsewhere.

3.3 Fugitive emissions from solid fuels and oil and natural gas (CRT 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 charcoal production, flaring of fuels at refinery plants, flaring of coke oven gas at coke ovens, 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 3.32 gives an overview of data sources used to calculate fugitive emissions of greenhouse gases reported in CRT 1.B.

Table 3.32. Data sources used to calculate fugitive emissions of direct and indirect greenhouse gases reported in CRT 1.B.

CRT	GHG	Activity data	Emission factors	Emissions
1.B.1.b: Charcoal production	CH_4, N_2O, CO, NO_x	Amounts of produced charcoal in FAO statistics	Default EF in Refinement 2019 to 2006 IPCC Guidelines	Calculated
1.B.1.b: Coke production	SO_2	—	—	Environmental reports
	CH_4	Amounts of produced coke in environmental reports	Default EF in Refinement 2019 to 2006 IPCC Guidelines	Calculated
	NO_x, NMVOC	Amounts of produced coke in environmental reports	Default EFin EMEP /EEA Guidebook 2019	—
1.B.1.c: COG flaring	CO_2, CH_4, N_2O, NMVOC, CO, SO_2, NO_x	Amounts of flared COG in environmental reports	National emission factor for stationary combuston of COG	Calculated
1.B.2.A.3: Oil transport	CH_4	Import/export of crude oil	Default EF in Refinement 2019 to 2006 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 (excluding flaring) in environmental reports

CRT	GHG	Activity data	Emission factors	Emissions
	CO_2	—	—	EU ETS
	CH_4, N_2O NMVOC, SO_2, CO, NO_x	Amounts of burned make-up coke in EU ETS; Amount of feed to the cracking unit	National emission factor for stationary combustion of petroleum coke; for NMVOC –default emission factor for catalyst regeneration in the EMEP/EEA Guidebook 2016	Calculated or, where available, taken from faciliteis' environmental reports; CO is estimated based on the total emissions and relative input from the cracking unit
1.B.2.A.4: Hydrogen production at refineries	CO_2	—	—	EU ETS
	CH_4, N_2O, NMVOC, CO, SO_2, NO_x	Amounts of feedstocks: naphta, LNG, refinery gases	National emission factors for stationary combustion of naphta, LNG and refinary gas; for NOx, LNG – EF specific for flaring	Calculated or, where available, taken from facilities' environmental reports
1.B.2.A.5: Fuel handling (gasoline, other fuels)	NMVOC	Volumes of fuel	EF Guidebook 2023	Calculations, Environmental reports
1.B.2.B.4*: Gas transmission	CO_2, NMVOC	Number of facilities in the Swedish network for gas storage and transmission including LNG terminal	CO_2 och NMVOC content in leaked natural gas	Calculated
	CH_4		CH_4 leakage rates	Calculated, environmental reports
1.B.2.B.5*: Gas distribution	CO_2, CH_4, NMVOC	Length of distribution networks	CO_2, CH_4 and NMVOC content in leaked natural gas	Calculated
1.B.2.B.6: Post-meter	CO_2, CH_4, NMVOC	Number of gas vehicles, appliances in commercial and residental sector, Volume of gas consumed at industrial plants/power stations	National EF for industrial leakage, EF from 2019 Refinement for gas vehicles and appliances	Calculated
1.B.2.C.1.2*: Gas venting	CO_2, CH_4, NMVOC	Amounts of natural gas vented	CO_2, CH_4 and 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 refinery gas in EU ETS; amounts of flared sulphur-rich gas from environmental reports	National emission factor for stationary combustion (NO_x, CO, SO_2) and flaring (CH_4, N_2O) of refinery gas, natural gas/LNG and hydrogen; default emission factors for flaring of refinery gas from	Calculated or, where available, taken from facilities' environmental reports

CRT	GHG	Activity data	Emission factors	Emissions
			EMEP/EEA Guidebook 2019 (NMVOC)	
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 (CRT 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 at integrated iron and steel facilities and fugitive emissions from charcoal production (both reported in CRT 1.B.1.b), as well as flaring of coke oven gas from the coke ovens (reported in CRT 1.B.1.c). CRT 1.B.1 is in fact not designed to include flaring, but since CRT 1.B.2 only refers to liquid and gaseous fuels, it is not possible to report flaring of coke oven gas in CRT 1.B.2. Flaring of blast furnace gas in the blast furnace and steel converter are reported in CRT 2.C.1 in accordance with the 2006 IPCC Guidelines.

Reported activity data is amounts of produced coke and charcoal in CRT 1.B.1.b (Mton) and amounts of flared coke oven gas (COG) (Mton) in CRT 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 CRT 1.B.1. According to environmental reports[147], 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 3.33.

Table 3.33. Summary of source category description, CRT 1B1, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.B.1	CO_2	-	-		T2	CS	Yes
	CH_4	-	--		T1, T2	CS	Yes
	N_2O		-		T1, T2	CS	Yes

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

147 SSAB, 2008, 2009, 2015

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 integrated iron and steel production 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 2019; CH_4 emissions are estimated with default emission factors specified in the 2019 Refinement to the 2006 IPCC Guidelines.

Emissions of CH_4, N_2O, CO and NO_x from charcoal production have been estimated in submission 2025 using FAO statistics[148] as activity data, and default emission factors specified in the 2019 Refinement to the 2006 IPCC Guidelines.

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 amounts 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.

The uncertainty for amounts of produced coke has been estimated to ± 5%. The emission factor uncertainty has been estimated to ±900% for CH_4.

The uncertainty for amounts of produced charcoal has been estimated to ± 100% (1990) - 70% (the latest inventory year). The emission factor uncertainty has been estimated to ±60% for CH_4 and ± 193% for N_2O.

3.3.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

See section 4.4.1 Iron and steel production (CRT 2.C.1).

3.3.1.5 SOURCE-SPECIFIC RECALCULATIONS

CRT 1.B.1.a: No source-specific recalculations have been performed in submission 2025.

CRT 1.B.1.b: CH_4 emissions from quenching and extinction at coke ovens, as well as emissions of CH_4, N_2O, CO and NOx from charcoal production have been added in submission 2025. CH_4 emissions from CRT 1.B.1.b range from 0.07 to 0.18 kt per year, while N_2O emissions – from 0.00004 to 0.0002 kt per year.

CRT 1.B.1.c: No source-specific recalculations have been performed in submission 2025.

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.

[148] FAOSTAT, Forestry Production and Trade, https://www.fao.org/faostat/en/#data/FO

3.3.2 Oil and natural gas (CRT 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 CRT 1.B.2. These activities include crude oil transport (1.B.2.A.3), activities in refineries such as catalytic regeneration, desulphurisation, storage and handling of oil and hydrogen production at oil refineries, (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, emissions of CO2 in CRT 1.B.2 were relatively constant – 350-380 kt/year. Due to the start of production of hydrogen at a large refinery in 2006, the emissions of CO2 almost 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 3.34.

Table 3.34. Summary of source category description, CRT 1.B.2, according to approach 1. 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.B.2.a	CO_2	-	X (Oil)		T3***	PS***	No, see Annex 5
	CH_4	-	-		T1	D	Yes
1.B.2.b	CO_2	-	-		T1,T2,T3	D,CS,PS	Yes
	CH_4	-	-		T1,T2,T3	D,CS,PS	Yes
1.B.2.c	CO_2	-	X (Venting and flaring)		T2	CS	Yes
	CH_4	-	-		T2	CS	Yes
	N_2O	-	-		T2	CS	Yes

CS Country Specific. PS Plant Specific. D Default. T1 Tier 1. T2 Tier 2. T3 Tier 3
* Shows key category (level) per fuel type
** Shows key category (trend) per fuel type
*** Method and EF for base year, for 2022 Method and EF is NA

3.3.2.2 METHODOLOGICAL ISSUES

For the years 2021 onwards, emissions from refineries (CRT categories 1.B.2.A.1 hydrogen production plants at refineries, 1.B.2.A.4 refining/storage, and 1.B.2.C.2.1 flaring at refineries) and the relevant activity data are included in the reporting under the category CRT 1.A.1.b (petroleum refining) due to confidentiality issues.

3.3.2.2.1 Transport (CRT 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. Imported and exported amounts of crude oil from Reference Approach are used as activity data.

In the 2006 IPCC Refinement from 2019, a default emission factor for CH_4 from crude oil transport by tankers is provided. This emission factor (0.002 t CH_4/1000 m^3) is much lower than default emission factor for oil pipelines (745 kg CH_4/PJ) applied in submission 2021 and earlier in the absence of more specific emission factor for tankers. From submission 2022, tanker-specific emission factor is used in calculations. Units of reported activity data are changed from TJ to 1000 m^3.

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.

3.3.2.2.2 Refining/Storage (CRT 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 (catalyst regeneration) (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). However, due to difficulties in compiling the CRT tables for submission 2025, incorrect activity data for 1990-2020 have been reported in Table 1.B.2. The correct figures are shown in Table 3.35.

Table 3.35. Activity data (Mt processed crude oil) at refineries.

Year	AD (Mt)	Year	AD (Mt)	Year	AD (Mt)	Year	AD (Mt)
1990	17.3	1998	20.3	2006	20.1	2014	18.9
1991	16.8	1999	19.5	2007	17.7	2015	19.9
1992	17.9	2000	20.3	2008	20.4	2016	19.6
1993	18.7	2001	19.6	2009	19.4	2017	19.5
1994	18.2	2002	19.7	2010	20.1	2018	20.3
1995	19.4	2003	19.7	2011	18.7	2019	16.9
1996	20.3	2004	20.6	2012	20.7	2020	17.5
1997	20.1	2005	19.9	2013	16.5		

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 is for two refineries based on reported data in the facilities' environmental reports. For the remaining three refineries the fugitive CH_4 emissions are estimated as 4-5% of the total fugitive VOC emission. An estimate of 5% has been provided by one refinery that refines about 50% of the crude oil in Sweden, while another refinery provided an estimate of 4%. 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 3.36, reported emissions of CH_4 and activity data can be seen.

Table 3.36. Throughput of crude oil in refineries and estimated fugitive emissions of CH_4 (t) reported in CRT 1.B.2.A.4. Due to data confidentiality, emission data for the years after 2014 cannot be displayed. Data for 2021 and 2022 is included in CRT 1.A.1.b due to data confidentiality.

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	20 068 888	469
2015	19 889 131	—
2016	19 572 799	—
2017	19 501 741	—
2018	20 325 433	—
2019	16 871 125	—
2020	17 496 688	—

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.

Since submission 2009, emissions from **combustion of cracker coke** in refineries, earlier reported in CRT 1.A.1.B, were allocated to CRT 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[149]. 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 companies' reports to the EU ETS system. Non-CO_2 emissions are calculated with the plant-specific activity data and either national emission factors (CH_4, N_2O) or default emission factors specified in the EMEP/EEA Guidebook 2016 for the catalyst regeneration stage (NMVOC). NO_x emissions from the large catalytical cracker, which accounts for >95% of make-up coke combustion in Sweden, are taken from the facility's environmental report, while for the other two facilities, default emission factors from the EMEP/EEA Guidebook 2016 are used. CO emissions from the large cracker unit are estimated based on the total facility's CO emissions (as specified in the environmental report) and the relative input of cracker feedstock to the total material input to the refinery processes. Implied emission factors calculated for this process are further used to estimate CO emissions from the other two facilities with coke combustion and catalyst regeneration processes.

Within a development project during 2018-2019[150], performed in close cooperation with the refineries, certain improvements were made in this category. In particular, national emission factor for NMVOC for stationary combustion was replaced with the default

[149] 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

[150] Yaramenka et al. 2019 Improvements in the reporting of fugitive emissions (CRT and NFR 1B), Phase II. SMED Report No 8 2019

emission factor specified in the EMEP/EEA Guidebook 2016 for the catalyst regeneration stage, emissions of NO_x from the large cracker were taken from the environmental report instead of being estimated with the national emission factor for stationary combustion of cracker coke, and consistency in the calculations was improved.

In 2020, combustion of cracker coke was significantly lower than in 2019, which resulted in the decrease of all emissions by ~70% compared to 2019 This is because the large catalytical cracker was out of operation most part of the year. In 2021, the cracker was back to normal operation conditions, and the emission increased.

Emissions from **hydrogen production plants at refineries** are since submission 2025 reported in CRT 1.B.2.A.4 in line with the *2019 refinement to the 2006 IPPC guidelines for national greenhouse gas inventories.* Since the 1980s, one of the Swedish refineries has had hydrogen production. In 2006, another refinery took a hydrogen plant into operation. Two other refineries launched hydrogen production facilities recently – one started production in 2019, another one in 2020. All four facilities apply steam reforming process to produce hydrogen, using LNG/natural gas as main feedstock (with the exception of one facility using three different feedstocks). Emissions from these facilities are reported in CRT 1.B.2.A.1 in line with the 2006 IPCC 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 CRT 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 reports to the EU ETS system from 2005 onwards – the reports contain activity data, CO_2 emissions and emission factors. For the years before 2005, CO_2 emissions are estimated using implied emission factors.

Activity data are amounts of feedstock used for hydrogen production, as reported to the EU ETS for three of four facilities. One of the plants does not report amounts of feedstock - a mixture of butane, off-gas from one of the refinery units, and LNG. Instead, to calculate CO_2 emissions reported to the EU ETS, the facility uses amounts of so called 'PSA (pressure swing adsorption) gas' - energy-poor off-gas from the hydrogen production unit [151]. PSA gas is a good proxy for activity data for this particular plant with a complicated feedstock structure; however, it is not a feedstock. For calculation of emissions other than CO_2, the amounts of feedstocks at this facility for the entire time series have been estimated based on the ratio *amount of LNG used as feedstock / corresponding amount of PSA gas* averaged over 2014-2019. Neither the exact amounts of the other two feedstocks nor the relations between the different feedstock amounts are known.

CO_2 implied emission factor for the facility reporting amounts of PSA gas as activity data to the EU ETS is not constant over time. This is due to variations in the relative amounts of LNG, butane and internal off-gas in the complicated feedstock mixture. In particular, the increase of CO_2 emissions by 11% between 2016 and 2017 is explained by a lower share of LNG in the mixture.

[151] Ortiz, C., et al.. Överlappande mellan CRT 1 och 2, SMED memorandum, 2017

Non-CO_2 emissions are calculated with plant-specific activity data and national emission factors. For two facilities, emissions of NO_x are taken from the environmental reports, while for the other two facilities, activity data and national emission factors are used. Due to lack of specific emission factors, “other petroleum fuels” emission factors are used for naphtha (except for CH_4, for which default emission factor, specified in the 2006 IPCC Guidelines for naphtha, is used), and emission factors for refinery gas are used for the mixture that includes three different feedstocks with unknown shares.

Within a development project during 2018-2019[152], efforts were made to investigate whether alternative emission factors can be used instead of currently used national emission factors for stationary combustion. The project work, performed in close cooperation with the refineries, resulted in better accounting of information available in environmental reports (often based on continuous measurements) in the emission inventories. NO_x emission factors for LNG/natural gas as feedstock, and CH_4 emission factor for naphta as feedstock were revised with respect to available (measurement) data. However, no relevant emission factors specific for hydrogen production were found in the literature.

3.3.2.2.3 Gasoline handling and distribution (CRT 1.B.2.A.5)

NMVOC emissions from Gasoline handling and distribution are reported in CRT 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[153] for the years 1990-2006 and on Concawe 03/07[154] for 2007 and onwards.

The calculation of fugitive NMVOC emissions from gasoline distribution, 1990-2023, is based on methods given by Concawe[155], 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. Previously not reported emissions from handling of other fuels (diesel, jet fuel) is included in the inventory from submission 2025 onwards. Calculations of these emissions are based on methods and emission factors in 2019 Refinement. Activity data is the annual national diesel and jet fuel (kerosene, jet gasoline) consumption.

The total NMVOC emissions from this segment amounts to about 2,9 kt NMVOC. The sub-segments “gasoline handling” and “handling at depots” each account for around 46% of the total emissions from CRT 1.B.2.A.5 while other fuel accounts for the remaining 7%.

[152] Yaramenka et al. 2019. Improvements in the reporting of fugitive emissions (CRT and NFR 1B), Phase II. SMED Report No 8 2019

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

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

[155] Concawe, 2019, report no. 4/19. Air pollutant emission estimation methods for E-PRTR reporting by refineries

3.3.2.2.4 Natural gas transmission (CRT 1.B.2.B.4)

The Swedish natural gas transmission network consists of a 600 km pipeline (extending from southern Sweden up along the west coast) connected to Dragör in Denmark and the European natural gas network. There are two injection sites for biogas injection to the transmission net. 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[156], many of the facilities are combined, e.g. valves located close to M/R stations. In 2013, a national method for estimating the Swedish emissions of natural gas was developed and described in Jerksjö et al. [157]. 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. In submission 2017, the method for estimating the emissions from the gas transmission network was revised since new measurements of methane emissions became available[158]. Methane leakage rates per hour have been measured at all major types of facilities. Estimated emission factors (see Table 3.37) have been applied to the number of facilities of each type. Emissions earlier reported as gas leakage have been re-allocated to the sector *CRT 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. Submission 2025 includes the previously not reported fugitive emissions of methane and CO_2 from LNG-terminals. There are two LNG terminals in Sweden. The emissions from this source are reported from year 2011 when the first LNG-terminal opened. Emission data used is either collected from the environmental reports (measured or calculated by companies) or, when data is lacking, estimated based on previous years' emissions.

[156] Bjur & Lindsjö, 2016

[157] 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.

[158] Jerksjö, M., Salberg, H. 2016. Mätningar av metanläckage längs svenska naturgasnätets stamledning, IVL report C202 (in cooperation with Fluxsense)

Table 3.37. Method for estimation of gas leakage from the gas transmission network.

Facility type	CH_4 EF g/hour	Number of facilities in 2022	Comment
M/R station	91	43	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
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 3.38. Information on gas composition was obtained from Swedegas and constitutes average values from the period 2006 to 2012.

Table 3.38. 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 number of the different facility types within the national gas transmission network and the LNG terminals – the numbers for the transmission network are checked with the company owing the network on the annual basis meanwhile the data for the LNG terminals are based on environmental reports. Methane leakage during gas transmission including the LNG terminals based on the recent measurements is shown in Table 3.39 below together with approximated emissions using EF for LNG terminals from 2019 Refinement.

Table 3.39. Estimated fugitive methane emissions from the gas network and LNG terminals.

Year	CH4 kt	IPCC (Refinement 2019 CH4 kt
2006	0.072	3.2
2010	0.076	3.2
2015	0.165	3.2
2020	0.123	3.2
2021	0.234	3.2
2022	0.234	3.2
2023	0.247	3.2

3.3.2.2.5 Natural gas distribution (CRT 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 (since 2016 mixed with biogas)
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[159]. 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. Activity data in terms of leakage of gasworks gas has 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

[159] 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.

composition of gas from cracking and natural gas/air mixture. The methodology is described in Jerksjö et al[160].
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[161]) 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[162].

Data on gas mixtures, sources of activity data and emission factors used for emission calculations in CRT 1.B.2.B.5 for each gas distribution network are summarized in Table 3.40.

[160] 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.

[161] Wikkerlink. 2006.

[162] 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 3.40. 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[163])		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 Emission factor for NMVOC	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.		

* 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 3.41 and Table 3.42, respectively. Information on gas composition was obtained from Stockholm Gas and Swedegas.

Table 3.41. 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

163 Wikkerlink. 2006.

Table 3.42. 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

3.3.2.2.6 Post-meter emissions (CRT 1.B.2.B.6)

Fugitive emissions of methane (CH_4), carbon dioxide (CO_2) and Non methane volatile organic compounds (NMVOC) from leakage in industry, households and commercial appliances and gas vehicles were, previously to submission 2025, not included in the inventory.

From submission 2025 a complete timeseries is reported for all emission segments.

Leakage sources in the three segments are:

Industry - Leakage from internal piping.

Appliances - Leakage from house piping and natural gas appliances such as furnaces, water heaters, stoves and ovens, and barbecues/grills.

Gas vehicles - Leakage from dead volumes during fuelling, emptying of gas cylinders of high-pressure interim storage units, for execution of pressure tests and relaxation of residual pressure from vehicles' gas tanks, or decommissioning.

Tier 1 emission factors for the segments are presented in 2019 Refinement. The emission factor for industry leakage is not used in the inventory. Instead, a more suitable national emission factor based on a couple of industry measurements are used. Table 3.43.

Table 3.43 Emission factors for the post-meter segment.

Segment	CH4	CO_2	NMVOC	Units of measure
Leakage at industrial plants and power stations.	~~*6,1~~ 1,08	~~*6,1*10^-2~~ 0,108	~~*0,19~~ 0,03	Tonnes/million m^3 gas consumed
Appliances in commercial and residential sector	3,2*10^-3	3,2*10^-5	1,0*10^-4	Tonnes/appliance
Natural gas-fuelled vehicles	3,0*10^-4	3,0*10^-6	9,3*10^-6	Tonnes/car

*Strikethrough numbers are EF from 2019 Refinement

The reported emissions from post-meter leakage in industry, appliances and from gas vehicles, are shown in Table 3.44

Table 3.44 Estimated total methane emissions from post-meter leakage.

Year	Post-meter methane leakage			
	Industry (kt)	Appliances (kt)	Gas vehicles (kt)	Total emissions (kt)
2006	0.79	0.26	0.00	1.05
2007	0.91	0.24	0.00	1.16
2008	0.86	0.23	0.00	1.09
2009	1.16	0.22	0.01	1.39
2010	1.38	0.21	0.01	1.60
2011	1.09	0.24	0.01	1.34
2012	0.92	0.23	0.01	1.16
2013	0.92	0.23	0.01	1.16
2014	0.71	0.22	0.02	0.95
2015	0.62	0.22	0.02	0.86
2016	0.80	0.22	0.02	1.04
2017	0.62	0.21	0.02	0.85
2018	0.65	0.21	0.02	0.87
2019	0.62	0.20	0.02	0.84
2020	0.54	0.20	0.02	0.75
2021	0.59	0.19	0.02	0.79
2022	0.37	0.16	0.02	0.54
2023	0.33	0.16	0.01	0.50

3.3.2.2.7 Venting (CRT 1.B.2.C.1)

In preparation of submission 2011, it was investigated whether vented emissions from refineries already were included in reported emissions in other CRT categories. The conclusion from this study was that emissions from venting at refineries most likely are included in other categories of fugitive emissions; mainly in CRT 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 onwards, emissions in CRT 1.B.2.C.1.1 and 1.B.2.C.1.3 are reported as IE (included in 1.B.2.A.4 and 1.B.2.C.2.). The fugitive CH_4 emissions from oil refineries reported in CRT 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 enter the gas flare systems.

Venting of natural gas from transmission pipelines and the storage facility, reported under CRT 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[164] but sometimes more often. Such an inspection requires so called pigging – 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. From the year 2014, 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 3.19.

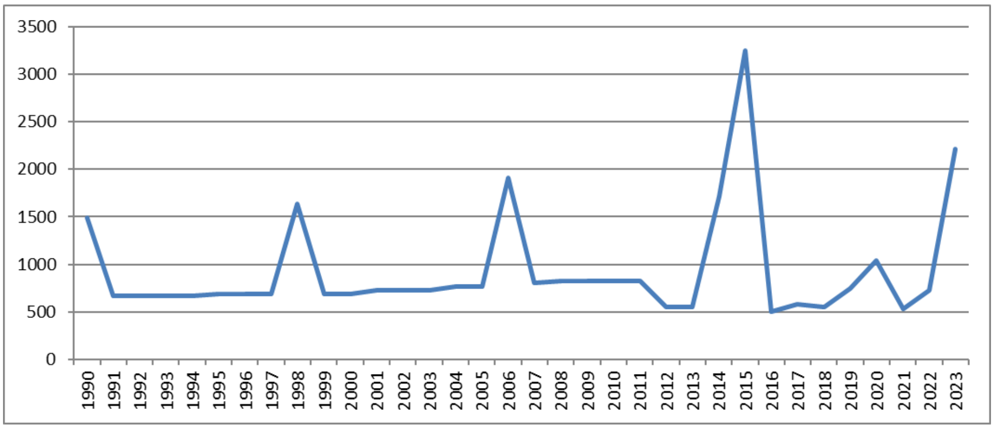

***Figure 3.19*. Gas venting at M/R stations, Nm^3 natural gas.**

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. Emissions reported by Swedegas are comparable to estimations according to the 2006 IPCC Guidelines, if the lower value of the default emission factor is used. The large emission of natural gas from the gas storage in 2013 was due to a compressor

[164]Hellström 2013-2015

failure[165]. In 2019 accidental damage during building activities resulted in an increased emissions (reported under pigging and projects, see Table 3.45). 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[166].

[165] Hellström 2013-2015

[166] 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 3.45. Estimated total methane emissions from gas storage and maintenance within the Swedish gas transmission network.

Year	Swedish gas transmission network					
	Diffuse emissions[1], (kt)	Venting[2], (kt)	Pigging and Projects[2] (kt)	Total emissions, (kt)	IPCC (2006)[3], (kt), lower value	IPCC (2006)[4], (kt), upper value
2006	0.072	0.0288	0.0007	0.101	0.084	0.465
2007	0.074	0.0324	-	0.106	0.087	0.485
2008	0.076	0.0079	-	0.084	0.080	0.444
2009	0.076	0.0026	-	0.079	0.106	0.586
2010	0.076	0.0028	-	0.079	0.142	0.788
2011	0.076	0.0028	-	0.079	0.113	0.626
2012	0.076	0.0219	-	0.098	0.097	0.541
2013	0.076	0.0686	-	0.145	0.094	0.519
2014	0.077	0.0009	0.0007	0.079	0.077	0.426
2015	0.079	0.0023	0.0017	0.083	0.070	0.388
2016	0.079	0.0018	0.0003	0.081	0.079	0.438
2017	0.079	0.0013	0.0002	0.080	0.065	0.360
2018	0.080	0.0007	0.0019	0.082	0.069	0.383
2019	0.080	0.0008	0.0106	0.091	0.069	0.381
2020	0.079	0.0006	0.0084	0.088	0.060	0.335
2021	0.079	0.0004	0.0048	0.084	0.070	0.390
2022	0.079	0.0005	0.0003	0.080	0.051	0.282
2023	0.082	0.001	0.0009	0.084	0.047	0.263

[1]Unintended emissions, leakage
[2]Intended venting within scheduled maintenance, pigging and projects
[3]2.5×10^{-5} kt per year and 10^6 Nm^3 marketable gas for storage; 66×10^{-3} kt per year and 10^6 Nm^3 marketable gas for transmission (lower value)
[4]2.5×10^{-5} kt per year and 10^6 Nm^3 marketable gas for storage; 480×10^{-3} kt per year and 10^6 Nm^3 marketable gas for transmission (upper value)

3.3.2.2.8 Flaring (CRT 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 and from natural gas transmission. For refineries reported activity data is amounts of flared gases in TJ. Emissions in this CRT category vary quite much between years due to large variations in the amount of refinery gases that needs to be flared each year. For 1990-2007, quarterly fuel statistics is used as the 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 has been used when possible. Data from the EU ETS are verified against data from environmental reports and vice versa.

In submission 2010, EU ETS data was analysed in detail. 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 rather than NO is used for flaring of natural gas, referring to emissions from flaring at refiners, reported under CRT 1.B.2.C.2.1 Oil.

Emissions from another type of flaring of natural gas – flaring in connection with gas transmission pipeline maintenance (pigging), and from specific maintenance projects, are reported for the first time in submission 2016 under CRT 1.B.2.C.2.2. From 2014, estimated annual amounts of flared gas have been obtained from the operator. For the years 2006, 1998 and 1990, estimates were made based on the 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 0.001-0.018 kt CO_2 eq. per year.

Within a development project during 2018-2019[167], flaring at refineries was investigated in detail. Efforts were made to find alternative emission factors to be used instead of national emission factors for stationary combustion. The project work, performed in close cooperation with the refineries, resulted in better accounting of facility-specific information available in environmental reports (often based on measurements) in the emission inventories. This data, where available, is prioritized in the inventory over estimates made with national emission factors for stationary combustion. Emission factors for CH_4 and N_2O were revised: new emission factors are adopted from Norwegian studies by Norwegian Oil Association[168]; they reflect conditions specific for flaring rather than for stationary combustion (lower oxidation grade, no abatement). The emission factor for NMVOC from stationary combustion (implying 0.01% unburnt hydrocarbons) was replaced with the default emission factor from the EMEP/EEA Guidebook 2023 for refinery gas flaring, implying 0.5% unburnt hydrocarbons. Other improvements include revision of estimates made for the years 1990-2004 and better accounting of facility-specific shares of refinery gas, natural gas, LNG, sulphur-rich gases and hydrogen in the flared gas mixture.

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.3: The uncertainty for the activity data have been estimated to ± 7.5%. The emission factor uncertainty for fugitive emissions of CH_4 is ±50%.

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

[167] Yaramenka et al. 2019 Improvements in the reporting of fugitive emissions (CRT and NFR 1B), Phase II. SMED Report No 8 2019

[168] OLF 1994

large uncertainties for the measurements with high inter-annual variation. Uncertainties for emission factors for cracker coke regeneration processes are estimated to ±20% for CH_4, ±5% for CO_2 and ±25% for N_2O.

For hydrogen production at refineries, all hydrogen production plants use the level 2 method to measure activity data for reporting to the EU ETS, which means that the activity data uncertainty is ± 2.5% or less. For one of the facilities, where activity data is estimated based on amounts of PSA gas, the activity data uncertainty is set at ± 10%. The emission factor uncertainties have not been available for the GHG inventory team, 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 1990, when naphtha was the main feedstock for hydrogen production, the uncertainty is set to 233%, according to the default emission factor interval for naphtha specified in 2006 IPCC Guidelines. For the N_2O emission factor, the uncertainty is set to ±25% in accordance with GPG 2000.

1.B.2.A.5: Based on Guidebook Quality Rating C, 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.B.6: The emission factor uncertainty for fugitive emissions of CH_4 is ±60%.

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 the EU ETS and are in the range ±7.5-17.5%. The total uncertainty from all fuels is ±17.5%. The emission factor uncertainties have not been available for the GHG inventory team, 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 the 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 EU ETS data is checked when possible, and when differences occur, the facilities are contacted for verification.

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: Emissions from hydrogen production at refineries were re-allocated from CRT 1.B.2.A.1 to CRT 1.B.2.A.4 in accordance with *2019 refinement to the 2006 IPCC guidelines for national greenhouse gas inventories* in submission 2025. For 1.B.2.A.1, “NO” is reported in submission 2025.

1.B.2.A.3: Minor adjustment due to correction of data year 2020, 2021. The recalculation resulted in approximately 0,0015 kt increase in CH_4 emissions for both years.

1.B.2.A.4: Emissions from hydrogen production at refineries were re-allocated from CRT 1.B.2.A.1 to CRT 1.B.2.A.4 in accordance with *2019 refinement to the 2006 IPCC guidelines for national greenhouse gas inventories* in submission 2025.

1.B.2.A.5: Emissions of fugitive NMVOC from gasoline handling have been calculated with updated/recalculated with a new updated method from Concawe (2019), previously Concawe (1986). Emissions from gasoline handling decrease with around 18% throughout the time series. Emissions from depots were not affected by the new methods.

1.B.2.B.4: Gas transmission. No recalculation of previously reported data has been made. However, new sources (LNG terminals) were added to the time series. This meant that the total emissions from 2011 onwards have been adjusted.

1.B.2.B.5: Gas distribution. No recalculations in submission 2025.

1.B.2.B.6: Post Meter leakage. No recalculations in submission 2025 as this is the first year Sweden reports these emissions.

1.B.2.C.1.2: Gas venting in transmission/distribution networks. No recalculations in submission 2025.

1.B.2.C.2.1: Flaring at refineries. No recalculations in submission 2025.

1.B.2.C.2.2: Gas flaring in gas transmission/distribution networks. No recalculations in submission 2025.

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.

4 Industrial processes and product use (CRT sector 2)

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 648 kt CO_2 eq. since 1990, from 7,226 kt CO_2 eq. in 1990 to 6,578 kt CO_2 eq. in 2023, which is a decrease of 9% (Figure 4.1). Emissions of N_2O, CH_4, PFCs and SF_6 have decreased since 1990 by 703 kt CO_2 eq., 19 kt CO_2 eq., 480 kt CO_2 eq. and 67 kt CO_2 eq., respectively. Compared to 1990, only HFCs have increased to 2023 (752 kt CO_2 eq.). Figure 4.1.1 shows that CO_2 is by far the largest contributor among the greenhouse gases in this sector in 2023, accounting for 85% of emissions. Emissions of HFCs are the second largest among the greenhouse gases in 2023 accounting for 12% of sector emissions.

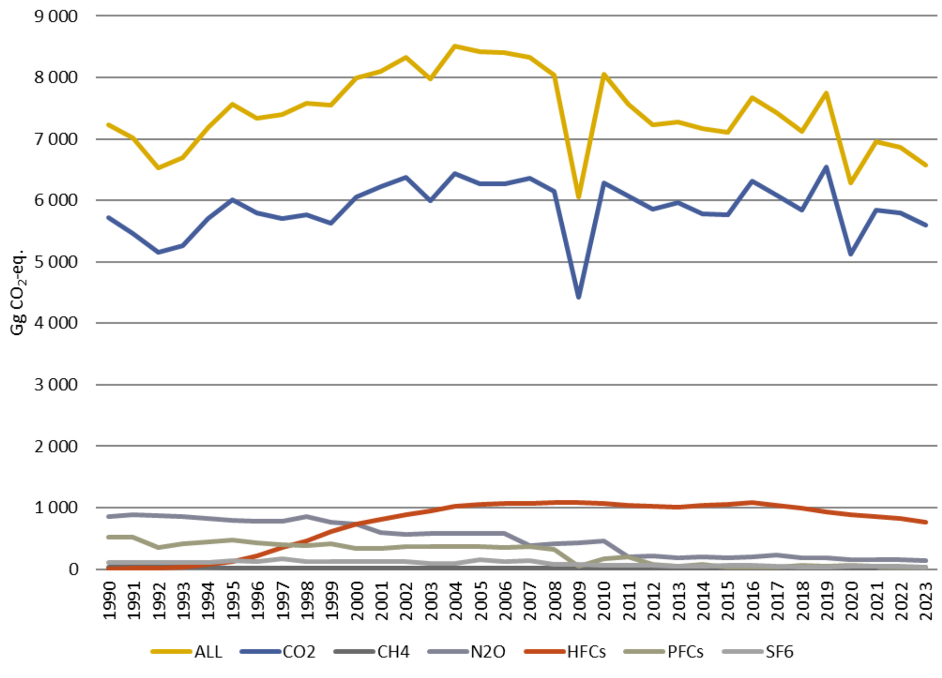

Figure 4.1.1. Total emissions of all greenhouse gases calculated as CO_2 eq. from CRT 2 industrial processes.

Among the industries within this sector, the metal industry (CRT 2.C) is the largest contributor to greenhouse gas emissions in 2023, accounting for 2996 kt CO_2 eq. or 46% (Figure 4.1.2). Emissions in CRT 2.C in 2023 have decreased by 22% (833 kt CO_2 eq.) since 1990. Figure 4.1.2 shows that there was a sharp decrease in greenhouse gas emissions from the metal industry (CRT 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. Also concerning the metal industry, Figure 4.1.2 shows a significant increase of CO_2 emissions in 2019. This increase is explained by changes in the raw material mix, as well as replacement of certain part of steel scrap with raw iron having much higher carbon content.

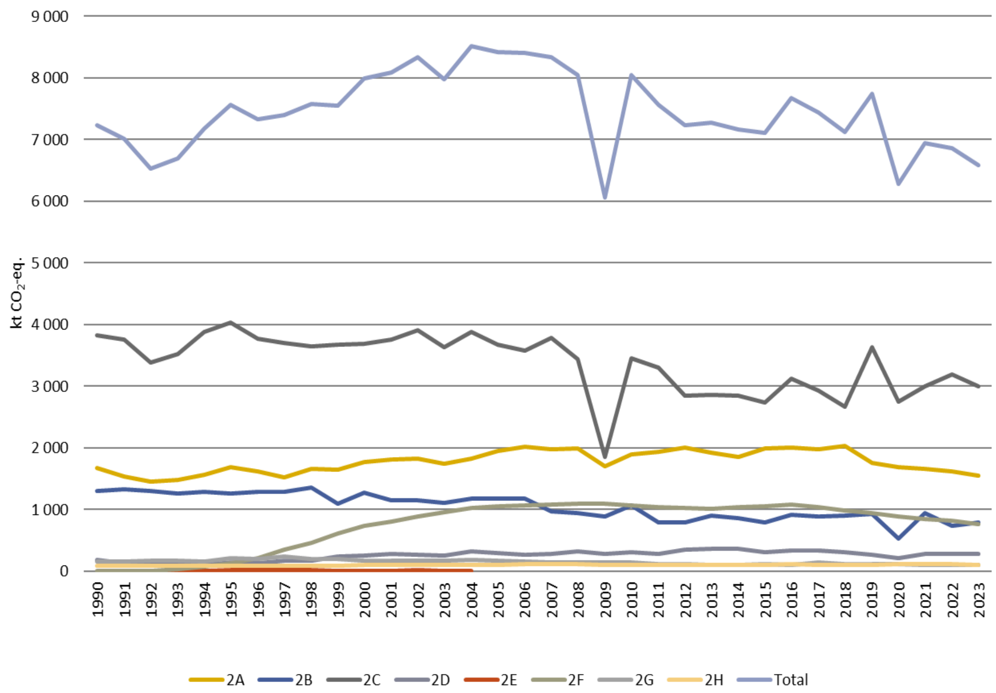

Figure 4.1.2. Total emissions of all greenhouse gases calculated as CO_2 eq. from the different Industrial processes sub-sectors. 2A Mineral products. 2B Chemical industry, 2C Metal industry. 2D Non-energy products from fuels and solvent use. 2E Electronics industry, 2F Product uses as substitutes for ODS, 2G Other product manufacture and use, 2H Other.

The second largest contributor of greenhouse gas emissions in this sector is the mineral industry (CRT 2.A) with 1548 kt CO_2 eq., or 24% of the sector emissions in 2023. Compared to 1990 there is a decrease in greenhouse gas emissions from the mineral industry (125 kt CO_2 eq.) (Figure 4.1.2). Greenhouse gas emissions from the chemical industry (CRT 2.B) have decreased 39% since 1990.

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 (CRT 2.F) have increased substantially, by 752 kt CO_2 eq., since 1990 (Figure 4.1.2). 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 (CRT 2.D) accounted for 283 kt CO_2 eq. in 2023, which is an increase of 57% since 1990.

Estimated greenhouse gas emissions from other product manufacture and use (CRT 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 2023, these emissions accounted for 100 kt CO_2 eq., which is a decrease of about 37% since 1990.

Process emissions from production of pulp and paper and mineral wool, reported in other production (CRT 2.H) accounted for 100 kt CO_2 eq. in 2023. The emissions have increased with 22% since 1990.

In CRT 2.E (electronics industry) emissions from production of semiconductors has been reported from 1990 to 2004. In 2004 the production was shut down and greenhouse gas emissions is thus reported as not occurring (NO) from 2005.

4.1 Mineral industry (CRT 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). From 2022 onwards emissions and activity data for (2.A.1) Cement production and greenhouse gas emissions from Lime production (2.A.2) are confidential and therefore not shown on a disaggregated level in either text, tables or diagrams.

4.1.1 Cement production (CRT 2.A.1)

4.1.1.1 SOURCE CATEGORY DESCRIPTION

Cement production occurred during 2023 at two facilities in Sweden (owned by one company), with one being dominant. One smaller facility owned by the same company shut down in 2019. 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 (CRT 1.A.2.g) with the exception of SO_2 which is reported in 2.A.1.

For process-related CO_2 emissions, facility data are obtained from environmental reports, the 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 CRT 2.A.1 according to the 2006 IPCC Guidelines, but accounts only for between 0.1 and 0.3% 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 4.2.1. An overview of the rationale for data sources used for key categories in the industrial processes sector is presented in Annex 3.5

Table 4.2.1. Summary of source category description, CRT 2.A.1, according to approach 1.

CRT	Gas	Key Category Assessment, 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.

4.1.1.2 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[169]. 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 2017:6[170]) for reporting to the EU ETS [171]. 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.

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

[170] NFS 2017:6 Föreskrifter om handel med utsläppsrätter.

https://www.naturvardsverket.se/lagar-och-regler/foreskrifter-och-allmanna-rad/2012/nfs-20129?_t_hit.id=Boilerplate_Episerver_Features_EpiserverFind_Models_EpiserverFindDocument/14692_sv&_t_q=nfs%202007:5

[171] Lyberg, A., Cementa, Personal communication, September 2011

Table 4.2.2 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 calculated emissions from CKD and the resulting CKD correction factor as well as CO_2 emissions from organic carbon content of raw meal. From 2022 onwards the production data and CO_2 emissions are classified.

Table 4.2.2. 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
2018	2 958	1 607	1 574	IE	NA	IE	4
2019	2 539	1 357	1 335	IE	NA	IE	4
2020	2 438	1 272	1 257	IE	NA	IE	2
2021	2 405	1 259	1 241	IE	NA	IE	3

* From 2005 incl. CKD and organic carbon content

IE - Included elsewhere. NA - Not applicable.

During 2018 - 2019, a study was conducted that aimed to estimate the uptake of CO_2 in concrete and cement. The main purpose of the study was to provide input to the national and international greenhouse gas inventories by developing new calculation models for CO_2 in the cement and concrete sector. Due to the regulations for reporting to the UNFCCC, uptake of CO_2 for these sectors at present cannot be reported. The study is described in more detail in NID Annex 8:5.

Total emissions of NOx by facility are found in the environmental reports or have been obtained directly from the company. Emissions originate mainly from fuel combustion and to a smaller extent from industrial processes. Since the CRT format does not allow for reporting NOx in CRT 2.A.1, IE is reported for NO_x in CRT 2.A.1 and all emissions are reported in CRT 1.A.2.f.

SO_2 emissions from cement production have been obtained directly from the company or from the environmental reports and are fully allocated to CRT 2.A.1 in order to avoid over- or underestimation of emissions. Reported emissions are decreasing over time since 1990. For 2020 the largest company reported a revised method to estimate SO_2 emissions, which resulted in considerably higher emissions of SO_2 in 2020 onwards. The supervisory authorities are currently assessing whether this new method or the previous method should be used by the company to estimate emissions of SO_2. Thus, for years prior to

2020, SO_2 is estimated using the old method, resulting in that reported data for SO_2 for year 2020 and onwards are not comparable to earlier years.

4.1.1.3 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 facilities, three until 2019 and two after 2019, 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 the EU ETS, and 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.

For the years 2022 and onwards, activity data and emissions are classified.

4.1.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The implied emission factor for total CO_2 is for most years somewhat higher than the 2006 IPCC Guidelines Tier 1 default value (0.52 kt CO_2/kt produced clinker). The main reason for the higher implied emission factors 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 CRT 2.A.1, which results in a further increase of the implied emission factor.

Figure 4.2.1 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 4.2.3 lists the content of CaO and MgO for the years 2008-2023 for the largest facility (accounting for an average of 76% of totally produced clinker in the years 2008-2023). The correlation between CaO and MgO content and CO_2 IEF for the largest plant is illustrated in Figure 4.2.2. In Figure 4.2.2, 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. Starting in 2017, the facility used some alternative raw materials for clinker production (for example slag). This is a possible explanation for the weaker correlation between CO_2 IEF and CaO and MgO content in the clinker, especially so for latest years.

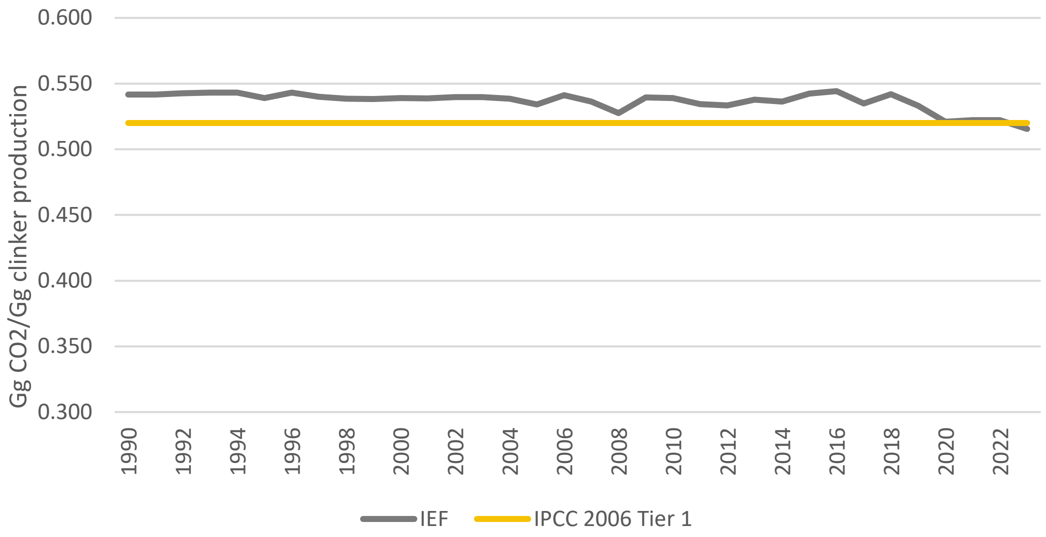

Figure 4.2.1. CO_2 IEF for total emissions from clinker production 1990-2023, excluding emissions from flue gas cleaning.

Table 4.2.3. CaO and MgO content in clinker produced in the years 2008-2023 in the largest facility (accounting for an average of 76% of totally produced clinker in the years 2008-2023).

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
2018	65.07	3.08
2019	64.88	3.42
2020	64.64	3.49
2021	64.96	3.47
2022	63.89	3.58
2023	63.64	3.66

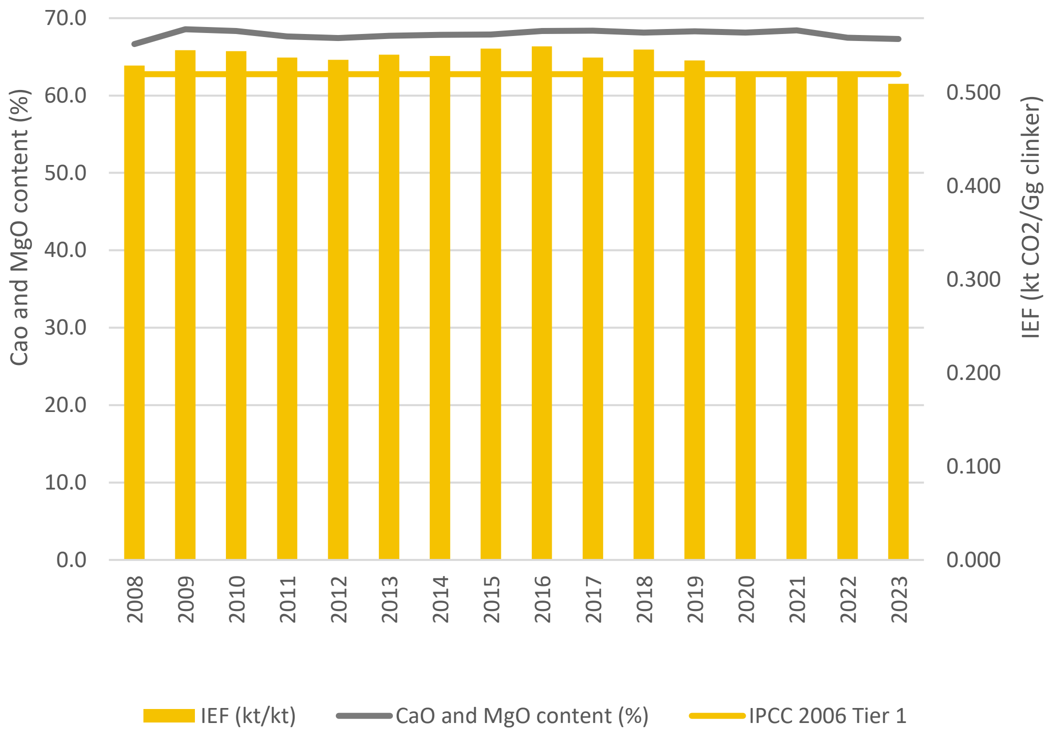

Figure 4.2.2. CO_2 IEF is compared to CaO and MgO content for respective year. Data is taken from the largest facility for the period 2008-2023 and exclude emissions from flue gas cleaning.

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 4.2.2 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.

The cement producing facilities are included in the annual quality control procedure using the cross-sectoral control tool described in NID section 1.3.5.1. CO_2 emissions reported in the energy sector (CRT 1.A.2.f) and CRT 2.A.1 are compared to total emissions reported by the facilities to the EU ETS and in the respective environmental reports. This ensures that total emissions from the facilities are neither under- or overestimated to a larger extent.

4.1.1.5 SOURCE-SPECIFIC RECALCULATIONS

No recalculations were made in submission 2025.

4.1.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.1.2 Lime production (CRT 2.A.2)

4.1.2.1 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 (from about 440 kt) and peaked in 2005 (at about 730 kt). In 2009 there was a large decrease in lime production due to the economic recession. In 2017 there was an increase in production compared to the years 2014-2016, with quantities of around 625 kt, but slightly lower compared to years 2010-2013. Lime production from 2018 onwards amounts to around 500 kt.

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 4.2.4.

Table 4.2.4. Summary of source category description, CRT 2.A.2, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.A.2	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.

4.1.2.2 METHODOLOGICAL ISSUES

4.1.2.2.1 CO_2 (kt)

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[172], it was concluded that EU ETS data and data from the Swedish Lime Association were comparable, however EU ETS data is

[172] Mawdsley, I. 2015. Change of activity data for lime production

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, where also emissions from LKD are included. Reported emissions are used directly, and activity data is calculated using emission factors and purity factors according to the 2006 IPCC Guidelines.

Sugar industry
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 used lime 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.

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. For years prior to 1999, no data on limestone are available. For those years the amounts of limestone used for production of quicklime are estimated using the quantity of coke used for lime production 1990 – 1998, together with the average ratio coke/limestone for the years 1999 to 2002. According to the company, the used limestone consists to 97% of $CaCO_3$. Between 1999 and 2017, the quantities are obtained directly from the sugar producing company. For 2018, activity data is calculated using emission factors and purities according to the 2006 IPCC Guidelines, since no data is available from the company.

Pulp and paper industry
Make-up lime is an important product in the causticizing process within the pulp and paper industry. Most facilities operate their own kilns and regenerate lime after use.

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[173], unfortunately not always in time for reporting to the UNFCCC.

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 and is used for estimations of limestone use for the years before 1995. Similarly, CO_2 emissions are estimated for

[173] Swedish Lime Association and The Swedish Lime Industry, personal communication

1990 – 1994 by using the average ratio between emitted CO_2 and used amounts of limestone for the period 1995 –2008. Based on the 2006 IPCC Guidelines, the purity of the limestone is assumed to be 95%. The corresponding figure for dolomite is 100%. 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. For these years data has been obtained from the company.

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 assumed to be 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 Table 4.2.5 together with the implied emission factor. From 2005-2021 however, activity data is calculated based on CO_2 emissions from the EU ETS, and thus the emission factor is constant. From 2022 onwards, CO_2 emissions are confidential.

Table 4.2.5. 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) (kt)	Reported CO_2 emissions (excluding emissions in sugar, pulp and carbide industry) (kt)	IEF (CO_2/quicklime + dolomitic lime) (kt/kt)
1990	367	277	0.7555
1995	350	264	0.7550
2000	513	387	0.7544
2005	665	496	0.7458
2010	620	463	0.7458
2011	619	462	0.7459
2012	579	432	0.7460
2013	594	443	0.7459
2014	507	378	0.7459
2015	516	385	0.7459
2016	529	395	0.7458
2017	578	431	0.7458
2018	479	357	0.7458
2019	454	336	0.7458
2020	483	360	0.7459
2021	466	348	0.7459
2022	527	C	C
2023	511	C	C

C - Confidental data

4.1.2.2.2 SO_2 (kt)

Emissions of SO_2 have been estimated for production of quicklime from 1990 onwards. Emissions are calculated using emission factors presented in environmental reports by one of the producers[174]. 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 2009-2023 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 CRT 2.A.2 as they are included in CRT 2.H.1.

4.1.2.3 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).

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

4.1.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Activity data reported in CRT 2.A.2 has been compared with national statistics from Statistics Sweden[175] and from the Swedish Lime Industry[176], in line with the IPPC Guidelines 2006. In addition, activity data from the EU ETS for year 2017-2021 are included in the comparison. The comparison (Figure 4.2.3) shows that national statistics from Statistics Sweden are more irregular, however for early years the agreement is good. The differences are especially large in 1998, 1999 and from 2004 and onwards. Comparison between reported activity data and activity data from the Swedish Lime Industry shows good agreement with only small differences for a few years. The last years have shown increasing divergence in reported activity data in 2.A.2 compared to activity data from the Swedish Lime Association. One reason for this divergence might be that the emission factor used to calculate activity data reported in 2.A.2 is slightly too high, which results in lower activity data as the data is calculated based on reported CO_2 in the EU ETS. The activity data reported in the EU ETS shows much better correlation to the data from the Lime Association (1-6%) for the years 2017-2021. The emission factors used in the EU ETS are lower than the standard emission factor used in the inventory. Sweden will investigate if it is more suitable to use the activity data reported in EU ETS instead of calculating the activity data based on reported CO_2 and a standard emission factor in future submissions.

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[177], Gustafsson and Gerner concluded that national statistics from Statistics Sweden would likely result in overestimated emissions, as imported quantities and calcium hydroxide are likely included in the data. The reported production volumes in the national statistics are significantly higher than both EU ETS data and the Lime Association data. The magnitude of the difference is 30-40% for many years which indicates that the national statistics is comprised by different data than the two other sources. Since the national statistics data cannot be disaggregated the data is unsuitable for comparison with the other two data sources.

In 2015 a review of CRT 2.A.2 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 since the data is verified by accredited personnel. It should be noted that the choice of activity data source does not affect the reported CO_2 in CRT 2.A.2.

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175 Statistics Sweden. Data from the Industrial production database: www.scb.se

176 Swedish Lime Association and The Swedish Lime Industry, Svenska Kalkföreningen, personal communication

177 Gustafsson, T., Gerner A. 2013. Verification of activity data for lime production.

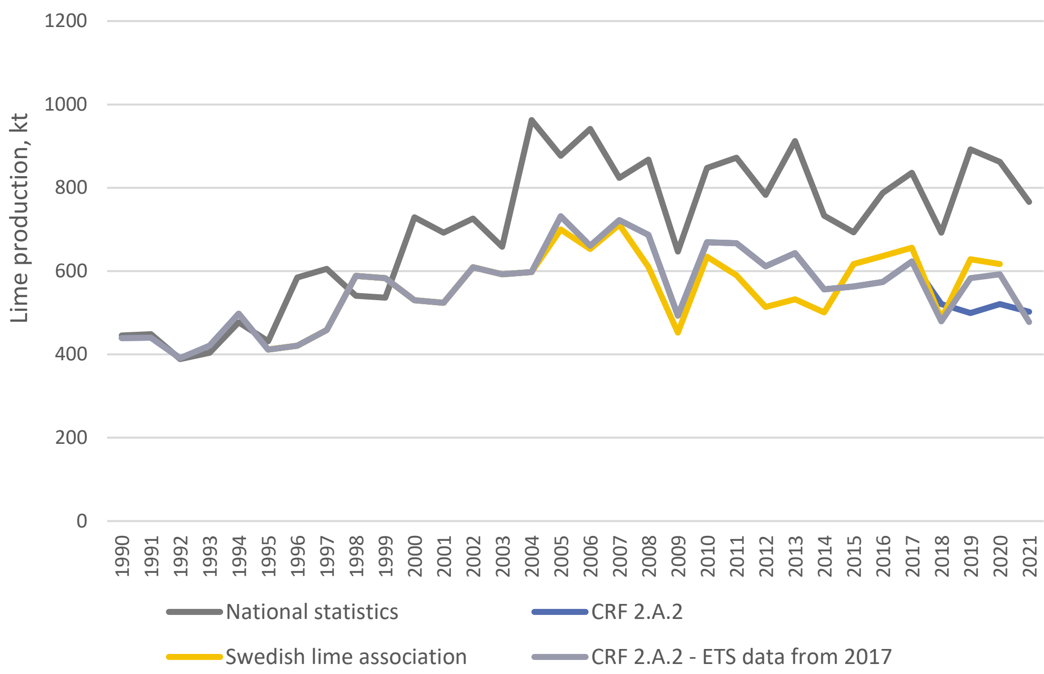

Figure 4.2.3. National total on produced amount of lime according to data from Statistics Sweden, the Swedish Lime Association and reported data in CRT 2.A.2.

The lime producing facilities are included in the annual quality control procedure using the cross-sectoral control tool described in NID section 1.3.5.1. CO_2 emissions reported in the respective energy sector and CRT 2.A.2 are compared to total emissions reported by the facilities to the EU ETS and in the respective environmental reports. This ensures that total emissions from the facilities are neither under- or overestimated to a larger extent.

4.1.2.5 SOURCE-SPECIFIC RECALCULATIONS

No recalculations were performed in submission 2025.

4.1.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.1.3 Glass production (CRT 2.A.3)

4.1.3.1 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. CRT 2.A.3 also includes glass wool production, which occurs at one facility.

From the float glass production, emissions of SO_2 and NO_X from the glass furnace are reported up until 2013 when the only float glass producer ceased production. Since the CRT tables does not allow for SO_2 or NO_X to be reported in 2.A.3 the emissions are included in 2.A.4 until 2013. 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 (CRT 1).

Emissions of CO_2 from the use of limestone, dolomite, soda ash and other carbon containing raw material in glass and glass wool production are reported under glass production. The CO_2 emissions in 2009 are lower than in adjacent years since the demand for glass was low in 2009. In addition, less glass was manufactured from raw material that year – instead, recycled glass was used to a larger extent. In 2013, one plant producing glass using 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 CRT 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 glass production 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 4.2.6.

Table 4.2.6. Summary of source category description, CRT 2.A.3, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.A.3	CO_2	-	-		T3	CS, D, PS	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.

4.1.3.2 METHODOLOGICAL ISSUES

Emissions of CO_2 from the use of limestone, dolomite and soda ash in glass production are reported in CRT 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 44% is caused by the use of soda ash and 54% on the use of limestone and dolomite. The remaining CO_2 is emitted as a result of use of other carbon containing raw materials.

Produced amounts of float and container glass has been collected from the annual environmental reports for the two major producers. Information on the quantities of glass wool produced has also been taken from the annual environmental reports. There are also small manual glass-producing facilities for which no activity data are provided. Amounts of produced container glass, flat glass, manual glass and glass wool is reported in the CRT from this submission onwards.

In Table 4.2.7 produced amounts of container glass, flat glass and glass wool, taken from the annual environmental reports, are presented together with estimated amounts of glass produced at small manual glass-producing facilities. For this estimation, default emission factor in 2006 IPCC Guidelines and reported amounts of CO_2 have been used.

Table 4.2.7. Glass production in Sweden, ton.

Year	Float glass	Container glass, large facilities	Manual glass production	Glass wool
1990	223 672	126 257	6 115	94 486
1995	262 171	101 878	6 115	53 400
2000	275 830	109 861	6 115	49 358
2005	273 144	125 477	6 056	54 091
2010	219 837	148 112	4 796	49 218
2011	245 176	160 016	4 736	48 403
2012	200 150	157 423	4 470	45 350
2013	0	155 231	4 264	44 073
2014	0	157 795	3 890	46 721
2015	0	156 206	3 890	44 105
2016	0	139 055	3 890	58 479
2017	0	172 012	3 890	60 697
2018	0	176 333	3 890	51 264
2019	0	175 771	3 890	59 170
2020	0	164 906	3 890	49 461
2021	0	175 263	3 890	57 261
2022	0	185 475	3 890	57 151
2023	0	163 078	3 890	47 536

Emissions are mainly collected from the EU ETS or from the facilities' annual environmental reports. For small glass producers, 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 percentage weight loss depending on emitted CO_2, from weight of raw material to produced amount of glass or crystal. Both estimates result in CO_2 emissions of around 0.9 kt annually.

Data on process-related NOx and SO2 emissions from glass production (reported in CRT 2.A,4) have 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 burned 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 burning of the organic binders gives rise to emissions of CO_2. In the EU ETS, CO_2 emissions from the oxymelt process, from use of soda ash and dolomite are reported since 2005 for the glass wool producer. Activity data, emission factors and CO_2 emissions data are based on information from the

EU ETS for the years 2005-2023. The corresponding information for 1990-2004 has been obtained from the company. In 1990, no oxymelt glass was used. The average emission factor, 2005-2023, is 0.138 kt CO_2/kton 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.

4.1.3.3 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.

4.1.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The two bigger glass producing facilities and the glass wool producer are included in the annual quality control procedure using the cross-sectoral control tool described in NID section 1.3.5.1. CO_2 emissions reported in energy sector (CRT 1.A.2.f) and CRT 2.A.3 are compared to total emissions reported by the facilities to the EU ETS and in the respective environmental reports. This ensures that total emissions from the facilities are neither under- nor overestimated to a larger extent.

4.1.3.5 SOURCE-SPECIFIC RECALCULATIONS

No recalculations were made in submission 2025.

4.1.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.1.4 Other process uses of carbonates (CRT 2.A.4)

4.1.4.1 SOURCE CATEGORY DESCRIPTION

In CRT 2.A.4, Sweden reports emissions from Ceramics (CRT 2.A.4.a), Other uses of soda ash (CRT 2.A.4.b) and Other (CRT 2.A.4.d) which includes the use of limestone, dolomite and sodium bicarbonate for flue gas cleaning. Non-metallurgical magnesium production does not occur in Sweden. NOx and SO_2 emissions from glass production are included in CRT 2.A.4 for relevant years since these emissions cannot be reported in CRT 2.A.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 4.2.8.

Table 4.2.8. Summary of source category description, CRT 2.A.4, according to approach 1.

CRT	Gas	Key Category Assessment, 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.

4.1.4.1.1 Ceramics (CRT 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 CRT 1.A.2.f, but CO_2 originating from the clay, the limestone and from other carbon containing material is also emitted and reported in CRT 2.A.4.a. Reported CO_2 emissions represent emissions from six facilities during the years 1990-2008 and from five facilities 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 used raw material are reported in 2.A.4.a. In 2020, the facility accounting for the majority of emissions until 2018 shut down.

4.1.4.1.2 Other uses of soda ash (CRT 2.A.4.b)

Due to difficulties in allocating emissions to their respective CRT code, all emissions from soda ash use are reported in CRT 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 and glass wool (2.A.3).

4.1.4.1.3 Other (CRT 2.A.4.d)

Other process uses of carbonates that 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. Process-related CH_4 and N_2O are not emitted during the use of these carbonates and thus reported as not applicable (NA).

4.1.4.2 METHODOLOGICAL ISSUES

Specified sub-categories under this heading are "Ceramics", "Other uses of soda ash", and "Other".

4.1.4.2.1 Ceramics (CRT 2.A.4.a)

Activity and emissions data for LECA production 1990 - 2004 is retrieved directly from the production plant, divided into emissions from clay and emissions from additives (limestone and other carbon containing material). From 2005 to 2019, the equivalent data is acquired through the EU ETS and the Swedish LECA producer's annual report. The LECA producer shut down its production during 2019.

For roofing tile, brick and ceramics production, activity and emission data from 2005 and onwards is acquired through the EU 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 data prior to 2005 is missing, the reported emissions for 2005 are linearly interpolated for 1990-2004.

Produced amounts of LECA is reported as activity data in 2.A.4.a until 2019, 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 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. From 2008, clay has contributed to between 65-75% of all process-related CO_2 emissions from LECA production, compared to 47-

58% during 1990-2003. The facility producing LECA corresponded to around 70% of yearly reported CO_2 emissions in 2.A.4 for the years the facility was in operation.

4.1.4.2.2 Other uses of soda ash (CRT 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.[178] Activity data consists of soda ash use from ten plants within several areas:

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

One chemical plant closed detergent production in 2016, which resulted in significant decrease in used amounts of soda ash 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[179] and the dominant snuff manufacturer. The emissions are calculated by applying the emission factor for soda ash and assuming a calcination fraction of 1:

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

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 to 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.

4.1.4.2.3 Other- Limestone and Dolomite use (CRT 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 CRT 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 are reported in 2.A.4.d.

Data on the use of limestone and dolomite in this source category has been acquired from environmental reports, the EU ETS and through direct contacts with the companies. Activity data for sodium bicarbonate has been collected from the EU 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

[178] Nyström, A-K. 2004. CO_2 from the use of soda ash. SMED report 61 2004.

[179] The Swedish Chemicals Agency (KemI), www.kemi.se

calculations are made by applying the emission factor for respective carbonate according to 2006 IPCC Guidelines Tier 3[180].

Formulas for CO_2 emissions from limestone, dolomite and sodium bicarbonate are as follows:

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

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

$$CO_2\ (Gg) = \frac{44.0098}{84.007} \times f\ \times sodium\ bicarbonate\ (Gg)$$

where *f* is the purity of the carbonates, set to 97% for limestone and 100% for dolomite and sodium bicarbonate.

4.1.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

In CRT 2.A.4.b (soda ash) and CRT 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 CRT 2.A.4.a (ceramics) the emission uncertainty is ±7%. The time series is consistent and complete.

4.1.4.4 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 in CRT 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 CRT 2.A.4. which makes this comparison difficult and less reliable.

Facilities reported in CRT 2.A.4 are included in the annual quality control procedure using the cross-sectoral control tool described in NID section 1.3.5.1. CO_2 emissions reported in the respective energy sector and CRT 2.A.4 are compared to total emissions reported by the facilities to the EU ETS and in the respective environmental reports. This ensures that total emissions from the facilities are neither under- nor overestimated to a larger extent.

4.1.4.5 SOURCE-SPECIFIC RECALCULATIONS

4.1.4.5.1 Ceramics (CRT 2.A.4.a)

No source-specific recalculations were performed in Submission 2025.

4.1.4.5.2 Soda ash use (CRT 2.A.4.b)

Minor recalculations were performed in Submission 2025 due to updates in activity data. This resulted in -0.00098 kt CO_2 for year 2022.

[180] IPCC. 2006 Guidelines for National Greenhouse Gas Inventories: Volume 3 section 2.5.

4.1.4.5.3 Other limestone and dolomite use (CRT 2.A.4.d)

No source-specific recalculations were performed in Submission 2025.

4.1.4.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.2 Chemical industry (CRT 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 CRT 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.

4.2.1 Ammonia production (CRT 2.B.1)

4.2.1.1 SOURCE CATEGORY DESCRIPTION

There is an annual production of about 5 kt of ammonia in Sweden, according to United Nation statistics[181]. This ammonia is not intentionally produced, but is a by-product in one chemical industry producing various chelates and chelating agents, such as EDTA, DTPA and NTA[182]. Emissions from this industry are included in CRT 2.B.5. Ammonia production, 2.B.1, is thus reported as NO.

4.2.2 Nitric acid production (CRT 2.B.2)

4.2.2.1 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. Beside emissions of N_2O, also emissions of NO_X are reported. 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 4.3.1. 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 4.3.1. Summary of source category description, CRT 2.B.2, according to approach 1.

CRT	Gas	Key Category Assessment, 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		T2	PS	Yes

T2 Tier 2. PS Plant-specific.

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

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

4.2.2.2 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 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 at the current facility. New catalytic reduction abatement equipment was installed in 2007 and 2010 which resulted in significant decreases of N_2O. 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.[183], [184].

During the later part of 2019 a new production line was taken into operation. In connection with this, the oldest production line, with higher emissions of N_2O, was shut down. As a result of this, the calculated IEF för N_2O was reduced compared to earlier years. In 2020, only the newly installed production line was in operation which resulted in a considerable decrease in emissions (Table 4.3.2).

[183] Joint Implementation Supervisory Committee, 2011. YARA Köping S2 N_2O abatement project in Sweden.pdf

[184] Joint Implementation Supervisory Committee, 2011. YARA Köping S3 N_2O abatement project in Sweden.pdf

Table 4.3.2. 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
2018	269	0.38	0.10
2019	271	0.34	0.09
2020	280	0.07	0.02
2021	C	C	0.04
2022	C	C	0.02
2023	C	C	0.02

C - Confidential data

4.2.2.3 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 IEF for N_2O 1994 – 2000 (Table 4.3.2) 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 e.g. environmental reports from the facilities, but since two of the facilities have shut down, it is no longer possible to check previously reported estimates.

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[185]. 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.

[185] European Commission, 2007

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 – 2018 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.

4.2.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The company is contacted every year 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 4.3.1), based on open UNFCCC data[186], shows similar trend in the three countries – a decrease by 85-90% compared to the level in 1990. 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 largest plants in Finland. 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.[187,188]

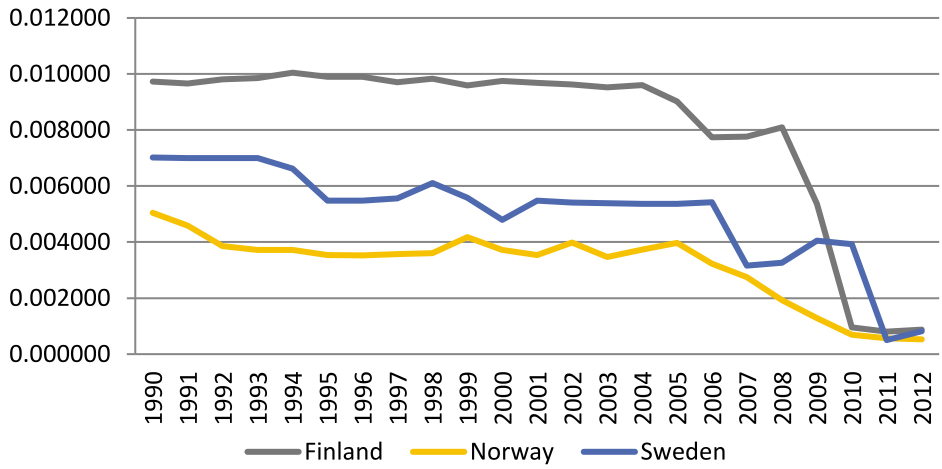

Figure 4.3.1. Implied N_2O emission factors for CRT 2.B.2 Nitric acid production in three Nordic countries, kt N_2O/Gg nitric acid.

4.2.2.5 SOURCE-SPECIFIC RECALCULATIONS

No recalculations have been performed for submission 2025.

[186] GHG data from UNFCCC http://unfccc.int/ghg_data/ghg_data_unfccc/items/4146.php , 2015

[187] Kolshus, H. Norwegian Environmental Agency. Personal communication. 2015

[188] Forsell, P. Statistics Finland. Personal communication. 2015

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 Adipic acid production (CRT 2.B.3)

4.2.3.1 SOURCE CATEGORY DESCRIPTION

No production of adipic acid occurs in Sweden, and thus NO is reported for CRT 2.B.3.

4.2.4 Caprolactam, glyoxal and glyoxylic acid production (CRT 2.B.4)

4.2.4.1 SOURCE CATEGORY DESCRIPTION

No production of caprolactam, glyoxal or glyoxylic acid occurs in Sweden, and thus NO is reported for CRT 2.B.4.

4.2.5 Carbide production (CRT 2.B.5)

4.2.5.1 SOURCE CATEGORY DESCRIPTION

Silicium carbide production does not occur in Sweden, however 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 CRT 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 4.3.3.

Table 4.3.3. Summary of source category description, CRT 2.B.5, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.B.5	CO_2	-	-		T1	D	Yes

D Default. T1 Tier 1.

4.2.5.2 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 (comprising emissions from production and use of acetylene) have been made. However, CO_2 emissions from production of quicklime at the carbide plant are reported in CRT 2.A.2 in accordance with the 2006 IPCC Guidelines.

4.2.5.2.1 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 carbide furnace gas, consisting mostly of CO, is produced as a by-product. Carbide furnace gas is further used as fuel within the facility and at the closely located steam power station; a part of the gas is also flared.

According to the 2006 IPCC Guidelines, CO_2 emissions from combusting carbide furnace gas generated in the process of calcium carbide production should be accounted in the IPPU sector and should not be included in the energy sector. All CO_2 emissions from carbide furnace gas combustion and flaring are therefore reported in CRT 2.B.5.b.

Activity data and associated CO_2 emissions from carbide production are presented in Table 4.3.4. From 2022 onwards, activity data and CO_2 emissions are confidential.

Table 4.3.4. Activity data and associated CO_2 emissions from carbide production to be reported in CRT 2.B.5.b.

Year	Activity data as produced calcium carbide, (kt)	CO_2 from the reduction of CaO to CaC_2, (kt)
1990.	54.9	59.8
1995	46.1	50.2
2000	38.1	41.5
2005	42.0	45.8
2010	34.9	38.0
2011	33.4	36.4
2012	34.6	37.7
2013	37.6	41.0
2014	37.5	40.9
2015	34.3	37.4
2016	35.9	39.1
2017	33.7	36.7
2018	35.0	38.2
2019	35.8	39.1
2020	30.0	32.7
2021	34.1	37.2
2022	C	C
2023	C	C

C – Confidential data

4.2.5.2.2 CO_2 emissions from use of calcium carbide

In the 2006 IPCC Guidelines it is stated that in addition to reporting CO_2 emissions from calcium carbide production, CO_2 originating from the use of calcium carbide for acetylene production and acetylene use in welding applications has to be reported. CO_2 emissions mainly occur at the stage of acetylene use, as follows from the equation summarizing acetylene production and use in welding applications:

$$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2\ (+\ 2.5O_2 \rightarrow 2CO_2 + H_2O)$$

Information from the calcium carbide producer in Sweden indicates that one third of the produced calcium carbide is used for acetylene production. Assuming that imported and exported amounts of calcium carbide have the same utilisation, it is possible to estimate the CO_2 emissions originating from calcium carbide use for acetylene production, including emissions from subsequent acetylene use. Annual statistics on imported and exported amounts from 1998 and onwards are available from Statistics Sweden[189]. Amounts used for acetylene production for earlier years are estimated.

[189] www.scb.se

The default emission factor presented in the 2006 IPCC Guidelines[190], 1.1 t CO_2/Mg calcium carbide used for acetylene production, has been used for the estimations. This emission factor implies that all carbon containing in calcium carbide is emitted as CO_2 when acetylene is used in e.g. welding applications. It is furthermore assumed that all produced acetylene is used within the country (no "exported" emissions). Thus, CO_2 emissions calculated for carbide use for acetylene production comprise emissions from acetylene use.

Amounts of calcium carbide used for acetylene production and associated CO_2 emissions from acetylene production and acetylene use are presented in Table 4.3.5. From 2022 onwards, this data is confidential.

Table 4.3.5. Used amounts of calcium carbide and associated CO_2 emissions from acetylene production and acetylene use, reported in CRT 2.B.5.b.

Year	Amount of calcium carbide for acetylene production, (kt)	CO_2 from acetylene production and acetylene use, (kt)
1990	7.4	8.1
1995	6.2	6.8
2000	6.0	6.5
2005	9.0	9.9
2006	7.7	8.5
2007	8.1	8.9
2008	8.5	9.4
2009	4.4	4.9
2010	5.5	6.0
2011	5.4	6.0
2012	4.0	4.4
2013	5.8	6.4
2014	6.2	6.8
2015	5.8	6.4
2016	7.5	8.2
2017	6.0	6.7
2018	6.8	7.4
2019	7.4	8.1
2020	5.7	6.3
2021	6.5	7.1
2022	C	C
2023	C	C

C - Confidential data

4.2.5.2.3 Time series reported in CRT 2.B.5.b

In Figure 4.3.2, total CO_2 emissions for the years between 1990 and 2021 are presented. For 2022 onwards, activity data and CO_2 emissions are classified.

[190] 2006 IPCC Guidelines, Volume 3: Industrial Processes and Product Use, Chapter 3: Chemical Industry Emissions, Section 3.6.2.2: Choice of Emission Factors

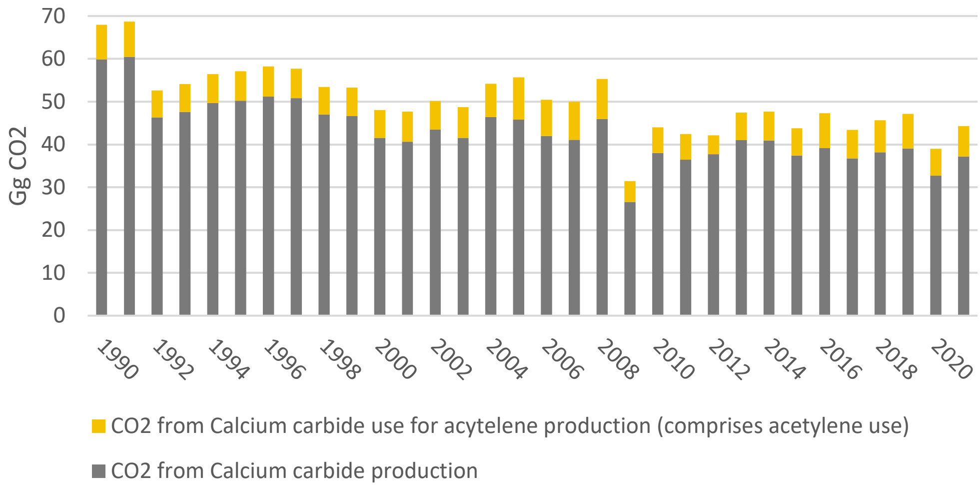

Figure 4.3.2. CO_2 emissions from production of calcium carbide, calcium carbide use for acetylene production and acetylene use.

4.2.5.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Based on expert judgements and recommendations in the 2006 IPCC Guidelines, the uncertainty of collected activity data is ±10%. Uncertainties in the default CO_2 emission factors for calcium carbide production and acetylene production and use are both ±5%.

In submission 2021, the estimation method for CO_2 emissions from combustion of carbide furnace gas was revised[191]. After the recalculations, all CO_2 emissions from carbide furnace gas combustion and flaring are reported in IPPU sector (2.B.5.b.). The recalculated CO_2 emissions have been increased unevenly during different years as noticed by the ERT during the latest UNFCCC review. This is due to emissions reported in submission 2020 (total emissions from carbide gas combustion and flaring) being calculated in direct proportion to carbide production while the corresponding emissions in submission 2021 are not. In submission 2020, emissions reported in CRT 2.B.5 were estimated for carbide gas flaring only, using the ratio "flaring time/total production time", which had no direct connection to the carbide production volumes. Another part of the emissions currently included in CRT 2.B.5 – emissions from carbide gas combustion – was in submission 2020 reported in CRT 1.A.2.c. These emissions were calculated based on amounts of combusted carbide gas reported by the facilities to the quarterly fuel statistics. This reporting was not directly linked to carbide production numbers either, and moreover, most probably was incomplete and missing for several years. This is why replacing each of these emission parts (carbide gas combustion (CRT 1.A.2.c), carbide gas flaring (CRT2.B.5.)) with total emissions (CRT 2.B.5) directly linked to carbide production numbers, resulted in uneven change in emissions.

4.2.5.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The plant producing calcium carbide is included in the annual QC procedure where the the cross-sectoral control tool is applied (see section 1.3.5.1 for further explanation).

[191] Yaramenka et al. 2020. Improvements in reporting of emissions from carbide production. SMED report No 16 2020

4.2.5.5 SOURCE-SPECIFIC RECALCULATIONS

Recalculations have been performed for year 2021 and 2022 due to updated activity data in submission 2025, which led to CO_2 emissions increasing by 0.36 kt and 0.21 kt, respectively.

4.2.5.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.2.6 Titanium dioxide production (CRT 2.B.6)

4.2.6.1 SOURCE CATEGORY DESCRIPTION

No production of titanium dioxide occurs in Sweden, and thus NO is reported for CRT 2.B.6.

4.2.7 Soda ash production (CRT 2.B.7)

4.2.7.1 SOURCE CATEGORY DESCRIPTION

In 2004 a study was carried out to collect data on soda ash use and calculate CO_2 emission[192]. From this study it became clear that no production of soda ash occurs in Sweden, and is hence reported as NO in the CRT.

4.2.8 Petrochemical and carbon black production (CRT 2.B.8)

4.2.8.1 SOURCE CATEGORY DESCRIPTION

Petrochemicals and carbon black are produced in Sweden. However, emissions from these sources are reported in CRT 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 CRT 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 CRT 2.B.8.

4.2.9 Fluorochemical production (CRT 2.B.9)

4.2.9.1 SOURCE CATEGORY DESCRIPTION

No production of fluorochemicals occurs in Sweden, and thus NO is reported for CRT 2.B.9.

4.2.10 Other (CRT 2.B.10)

4.2.10.1 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 CRT 2.B.8,

[192] Nyström, A-K. 2004. CO_2 from the use of soda ash. SMED report 61 2004.

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. Some NMVOC emissions are possibly to be reported in CRT 2.D.3, solvent use. However, since it is difficult to distinguish between process emissions and emissions from solvent use, all NMVOC from these facilities have been included in CRT 2.B.10.

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 the sub-category “Pharmaceutical industry” reported higher emissions these years. In 2017, the production process at the only facility causing emissions of N_2O within the “Pharmaceutical industry” was shut down. Since no emissions of CH_4 or CO_2 are reported from any facilities in this category, no greenhouse gas emissions are reported for this subcategory from 2018 onwards.

The total greenhouse gas emissions from the chemical industry decreased significantly in 2020. This is due to the cracker plant, which accounts for up to 80% of total emissions reported in CRT 2.B.10 in previous years, being out of operation for the larger part of 2020 due to a fire at the facility.

The SO_2 emissions reported in 2.B.10 decreased dramatically in 2004 in comparison to earlier years. This is because in December 2004, one facility producing viscose staple fibre was shut down. The annual SO_2 emissions from this facility represented between 8 and 20% of the total reported SO_2 emission in CRT 2 – Industrial Processes for the years 1990 - 2003.

CO emission from "Other inorganic chemical production" increased from below 200 tonnes in 2005 to 500 tonnes in 2006. This increase is due to unusually high CO emissions in 2006 from one facility producing PVC. In 2007, the CO emissions were very low from one facility producing PVC. The increase of CO emissions 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 4.3.6.

Table 4.3.6. Summary of source category description, CRT 2B10, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.B.10	CO_2	X	X		T3	PS	Yes
	CH_4	-	-		T1, T2, T3	PS,D,CS	No, see Annex 5
	N_2O	-	-		T2, T3	PS,CS	No, see Annex 5

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

4.2.10.2 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 from the production of several chemical products are presented and consequently the CRT Reporter is divided on those products. Since several plants in Sweden each produce several chemical products but report emissions aggregated by plant, it is not possible to report emissions in accordance with the suggested split in the CRT Reporter. In Sweden, since submission 2006 the emissions are thus 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 within chemical plants 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%.

According to the 2006 IPCC Guidelines, emissions from the combustion of fuels produced within the facility (internal make-up gases) as well as from fuels obtained from the feedstocks should be allocated to the source category in the IPPU Sector except when the fuels are used in another source category e.g. district heating. Sweden has made extensive efforts to follow the recommendations as far as possible; however, exceptions have been made for some plants, due to the fact that CO_2 emissions from these plants are very difficult to separate from other emissions from fuel use, which are to be reported in the energy sector. In those cases, all emissions are reported in the energy sector in CRT 1.A.2.C. The allocation of emissions from these plants to the energy sector affects the comparability only to a small extent, since the larger emission sources have been correctly divided between process-related and energy emissions. To what extent comparability is affected cannot be exactly quantified since plant-specific data cannot be disclosed due to confidentiality.

For some facilities, there is a certain share of emissions (derived mainly from environmental reports) allocated to CRT 2.B.10.a while the remaining emissions are reported in the energy sector. In these cases, this allocation on a plant level is done for the entire time series based on a few recent years that have been studied in detail. Emissions from the production of secondary fuels obtained from feedstocks and also from the combustion of process off-gases are reported in CRT 2.B.10 since these emissions are associated with (petro-)chemical processes and these fuels and off-gases are combusted within the same chemical processes and not combusted for e.g., district heating purposes. Secondary fuels and off-gases from the plants within the biggest petrochemical complex in Sweden located in Stenungsund are not transported to heating plants outside the complex but rather between these plants to be used as feedstocks or fuels in chemical processes. Fuels and off-gases derived from chemical processes that are combusted for energy purposes only, e.g., within district heating are registered in the quarterly fuel statistics which is used for emission calculations in CRT 1.A.2, meaning that those fuels and off-gases are accounted for in the emission inventory by default.

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 detail in the sections 1.3.5.1 and 4.2.10.4.

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 judged 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.

Production volumes in the chemical industry are related to different processes with different emission factors, meaning that summarizing them in one set of activity data would not be relevant. Activity data for CRT 2.B.10 is therefore reported as not applicable, NA.

4.2.10.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Based on expert judgements, the uncertainties of collected emissions of CO_2 from inorganic and organic chemical products as well as from base chemicals for plastic industry are ±5% for CO_2. The uncertainty of collected emissions of CH_4 is estimated to be ±100% for all chemical industries reported in CRT 2.B.10. 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.

4.2.10.4 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 CRT 1 and CRT 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[193]. 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[194]. Overall, the

[193] Gustafsson, T., Nyström, A-K., Gerner, A. Riktad kvalitetskontrollstudie av utsläpp från kemiindustrin i Sveriges internationella rapportering. SMED report 2010.

[194] Most recommendations on further investigations refer to the energy sector

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

Prior to submission 2018, a development project[195] 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 CRT 2.B.10 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 (CRT 1A) are summed up with the emissions reported in the CRT 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[196]. An allocation strategy for the chemical sector has been developed which aims at achieving a correct allocation between the sectors according to the 2006 IPCC Guidelines where possible, however making sure that total reported emissions are in accordance with plant-specific data as the main priority. In submission 2022, all CO_2 emissions from the large cracking plant and a polyethylene producing plant were reported in CRT 2.B.10.a due to difficulties in separating the amounts of fuel used for stationary combustion from fuels used in the chemical processes. In submission 2023, a development project was carried out to reallocate CO_2 emissions for these two plants between CRT 1.A.2.c and CRT 2.B.10.a. resulting in less CO_2 emissions being reported in CRT 2.B.10.a.

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 exceeds these two sources for the years 2013-2016 (Table 4.3.7). The comparison was only made for these years since EU ETS data covers fewer 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 4.3.7. 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%

[195] Ortiz, C., Jonsson, M., Yaramenka, K., Helbig, T., Danielsson, H. Överlappande mellan CRT 1 och 2, SMED memorandum, 2017

[196] Mawdsley, I., Ortiz, C. Allocation of emissions from the chemical sector between CRT/NFR 1 and CRT/NFR 2, SMED memorandum, 2018

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 is 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.[197]

4.2.10.5 SOURCE-SPECIFIC RECALCULATIONS

In submission 2025 updated activity data regarding 2022 led to increased emissions of CO_2 by 0.03 kt. Furthermore, updated information for 2022 resulted in a minor increase in emissions of NMVOC.

4.2.10.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

[197] Mawdsley, I., Ortiz, C. Allocation of emissions from the chemical sector between CRT/NFR 1 and CRT/NFR 2, SMED memorandum, 2018

4.3 Metal industry (CRT 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 and HFC used in magnesium foundries (2.C.4) and other metal production (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.

4.3.1 Iron and steel production (CRT 2.C.1)

4.3.1.1 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. Ten secondary steel plants equipped with electric arc furnaces, producing iron and steel products from scrap and one facility producing direct reduced iron are also included. Included are also emissions from one facility using a shaft furnace process to produce stainless steel from recovered flue gas dust and other waste products, and one foundry using a cupola furnace for melting cast iron. In total, there are 18 different facilities included in the estimates. Processes occurring besides the primary processes, production of secondary steel and direct reduced iron, are rolling mills, pickling and other refinement processes and one iron and steel foundry. Emissions from three 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 CRT 2.C.1. As the plants also generate emissions from fuel combustion (CRT 1.A.1.c and CRT 1.A.2.a) and fugitive emissions (CRT 1.B.1.c), the text in this section is closely connected to the text in the corresponding section in the energy section. Emissions of N_2O do occur to a small extent according to the 2006 IPCC Guidelines[198], however, CRT tables are not designed for reporting N_2O emissions from primary steel production.

In the Swedish inventory, emissions from primary iron and steel production and secondary steel production are reported separately and fed into CRT 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.

198 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 4.4.1. An overview of the rationale for data sources used for key categories in the industrial processes sector is presented in Annex 3.5.

Table 4.4.1. Summary of source category description, CRT 2.C.1, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.C.1	CO_2	X	X		T3	PS	Yes
	CH_4	-	-		T1, T2, T3	CS, D	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.

4.3.1.1.1 Secondary steel production (CRT 2.C.1.a)

Reported CO_2 emissions include emissions from reducing agents such as coke, coal and electrodes in electric arc furnaces as well as flaring of pilot fuel in secondary steel plants. Reported CO_2 emissions also include emissions from the use of limestone and dolomite in secondary steel industry.

The reported CO_2 emissions in CRT 2.C.1.a include data from eleven plants in 1990-1991, twelve plants in 1992-2003 and eleven plants from 2004 onwards. 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.

The emissions from flaring of pilot gas (included in submission 2020 as a result of a development project investigating fugitive emissions and emissions from flaring[199]), are calculated based on estimated constant fuel amounts, periodically checked with the facilities. This affects emissions from 1990 of CO_2, NO_x, NMVOC and CO. This also adds small amounts of CH_4 emissions for the whole time series.

4.3.1.1.2 Primary iron and steel production (CRT 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 CRT 2.C.1, according to the IPCC Guidelines.

During 2015, the blast furnace at one of the facilities was closed for renovation. The blast furnace was stopped for several month, and after it came into 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.

Between 2016 and 2017, the CO_2 emissions in CRT 2.C.1.b dropped while the total production of pig iron increased. This is explained by the fact that while the total emissions from the two facilities actually increased, more carbon-containing internal

[199] Yaramenka, K., Kindbom, K., Helbig, T. 2019.

gases were flared and combusted at other units than blast furnaces and steel works – these emissions are reported in the energy sector (CRT 1A).

In 2019, the CO_2 emissions in CRT 2.C.1.b increased significantly more than production. This increase is explained by disturbances in the production process at one of the facilities, which hindered possibilities to sell energy-rich process gases to external consumers for heat and power generation. Emissions from sold gases are included in the reporting within the energy sector (CRT 1.A.1.a). In 2019 however, a major part of surplus gases was flared at the iron-and-steel facility instead, which resulted in increased CO_2 emissions from the category CRT 2.C.1.b, and an increased ratio of CO_2 emissions / production volumes. In 2020, no such process disturbances occurred, so both CO_2 emissions and the ratio of CO_2 emissions / production volumes decreased. In 2021, CO_2 emissions were at roughly the same level as in 2020, and in 2022 they increased, largely due to more carbon-containing internal gases being flared in 2022. In 2023, CO_2 emissions were at the level of 2021.

4.3.1.1.3 Direct reduced iron (CRT 2.C.1.c)

There is one plant in Sweden which produces iron sponge and iron powder using direct reduction of iron ore fines in a unique process where solid coal is mixed with iron ore fines.

4.3.1.1.4 Sinter (CRT 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 produce 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.

4.3.1.1.5 Pellet (CRT 2.C.1.e)

CO_2 emissions arise mainly from the use of limestone and dolomite, and to a smaller extent from bentonite, organic binder, olivine and quartzite. 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[200], which however are not reported. Estimated emissions from combustion of fuels are included in the Energy sector (CRT 1.A.2.g). 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 has led to a reduction of the SO_2 emissions by more than 95%.

4.3.1.1.6 Other (CRT 2.C.1.f)

No emissions of CO_2 reported in this source category but small amounts of NMVOC from eight facilities are included.

[200] Wieland, M.S. 2004.

4.3.1.2 METHODOLOGICAL ISSUES

4.3.1.2.1 Secondary steel production (CRT 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 EU ETS, from the facilities' environmental reports and through contacts with the companies.

Data in the EU 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 EU ETS data for 2005 – 2008 and production data for years prior to 2005. All CO_2 emissions presented for the facilities in the EU ETS 2005 – 2023 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 EU ETS. Reported CO_2 emissions can therefore be classified to follow the 2006 IPCC Guidelines Tier 3, 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 the EU ETS for these years.

For non-CO_2 emissions, the companies' environmental reports are the main information source. NOx, 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.

4.3.1.2.2 Primary iron and steel production (CRT 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-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 the facilities as a part of their reporting to the EU ETS. Emissions are also specified in the facilities' environmental reports that are used as a primary information source for estimation of emissions from CRT 2.C.1.b and other CRT 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 EU ETS reporting, complemented with data from facilities' environmental reports. While environmental reports are used to distribute total reported CO_2 emissions to relevant CRT codes, reporting to the EU ETS provides 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 4.4.1 gives an overview of the input and output materials, the carbon flows between the different processes (plant stations), and the CO_2 emitting sources.

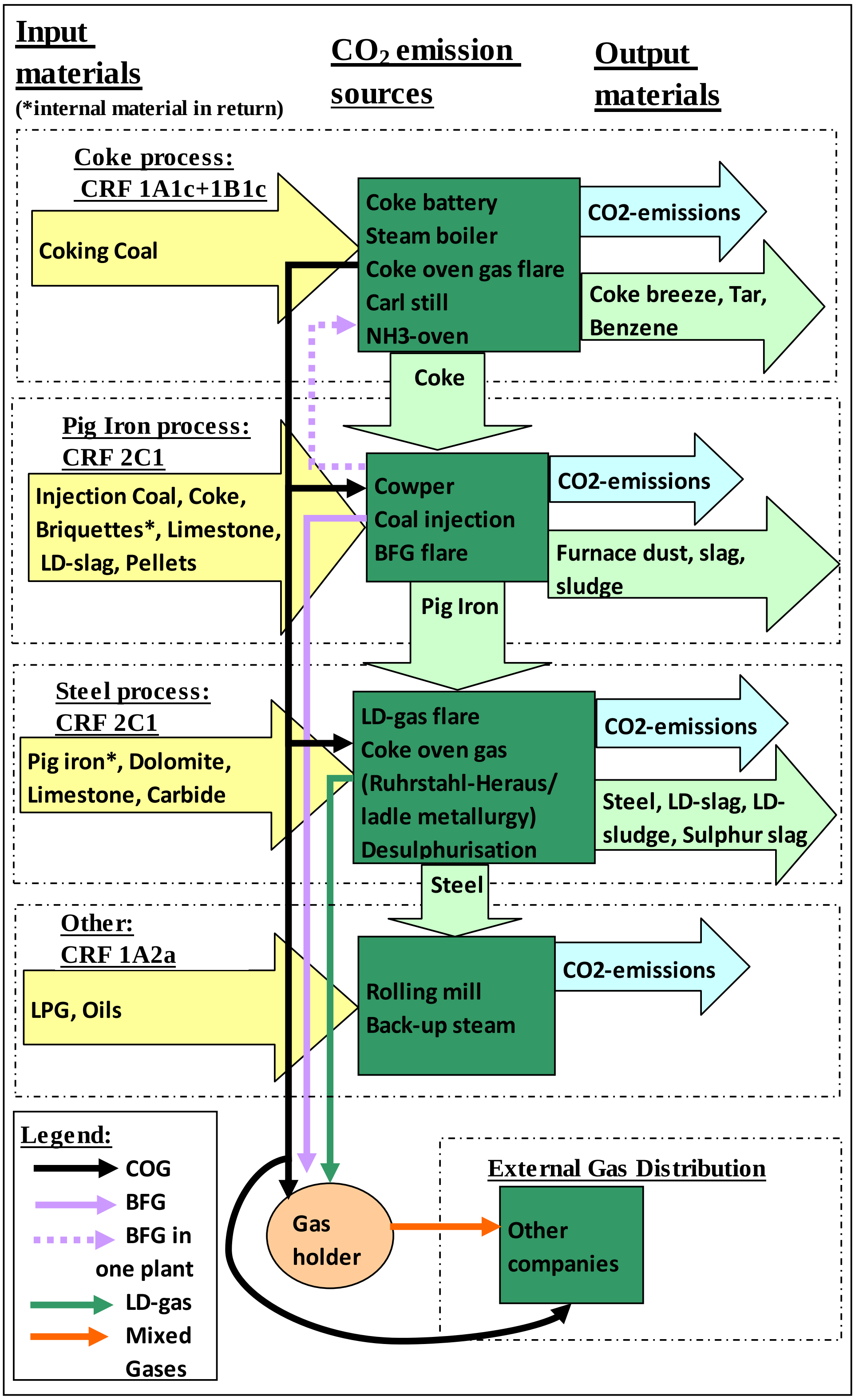

Figure 4.4.1. Carbon flow chart of integrated primary iron and steel plants in Sweden.

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. In addition to pig iron, dolomite, 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 CRT 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[201] 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 CRT sub-sectors is based on measured fuel consumption and associated CO_2 emissions (see Tables 4.4.2 and 4.4.3 and the describing text below). Note that energy consumption (TJ) cannot be reported in CRT-reporter for 2.C.1.b.

Table 4.4.2. 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	1 373	300	833	5	2 094	**4 606**
1995	1 537	341	944	6	2 383	**5 212**
2000	1 582	335	1 048	6	2 270	**5 241**
2005	2 303	344	1 109	5	2 206	**5 968**
2010	2 004	313	880	5	2 317	**5 519**
2015	1 559	458	825	24	1 690	**4 556**
2020	1 879	360	559	7	1 708	**4 512**
2021	1 873	327	592	9	1 911	**4 711**
2022	1 591	372	620	12	2 126	**4 722**
2023	1 589	373	565	6	2 026	**4 557**

*Excluding external fuels – gasoil, diesel, natural gas and oils, only combustion of internal gases included

[201] See 2006 IPCC Guidelines: Volume 3: Industrial Processes and Product Use, Box 1.1 (page 1.8)

Table 4.4.3. 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	4 424	3 886	115	9 208	29 524	**52 435**
1995	5 683	5 038	4 404	132	10 479	31 324	**57 060**
2000	7 990	4 636	4 890	120	9 910	29 406	**56 953**
2005	8 879	4 834	5 224	115	10 624	38 969	**68 644**
2010	7 384	4 069	4 237	109	8 529	40 307	**64 634**
2015	6 271	4 601	3 902	510	7 383	34 153	**57 083**
2020	7 272	4 256	2 925	140	7 483	31 795	**53 871**
2021	7 063	3 679	3 062	177	7 708	32 005	**53 694**
2022	6 278	4 312	3 047	202	9 237	36 738	**59 814**
2023	6 565	4 163	2 877	111	8 290	31 368	**53 374**

*Excluding external fuels – gasoil, diesel, natural gas and oils, only combustion of internal gases included.

Main data sources used for allocation of emissions and energy flows in 2003-2023 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 (CRT 1.A.1.c) and flaring (CRT 1.B.1.c) – emissions from flaring are calculated with national CO_2 emission factors, and the remaining emissions are allocated to CRT 1.A.1.c. Emissions from sold energy gases CRT 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 (CRT 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 CRT Reporter in CRT 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[202],[203]. Examples of material inputs for certain years, as well as their calorific values, are given in Tables 4.4.4 and 4.4.5, respectively.

[202] Gustafsson et al. 2011. Emissions from integrated iron and steel industry in Sweden: Model for estimation and allocation of energy consumption and CO_2 emissions for reporting to the UNFCCC, SMED report 97/2011

[203] Yaramenka, K, Jönsson, M, 2018, Förbättringar av inventeringar av utsläpp från SSAB, SMED PM

Table 4.4.4. Material input in the Swedish iron and steel production processes, ton.

Plant	Year	Coking coal	External coke	Injection coal	Source
1	1990	937 000	60 000	100 000	Personal communication
1	1995	920 000	70 400	102 000	Personal communication
1	2000	920 700	56 300	146 700	Personal communication
1	2005	946 100	39 300	314 000	Environmental report
1	2010	895 800	117 900	286 500	Environmental report
1	2015	892 000	0	182 700	Environmental report
1	2020	851 000	47 000	244 000	Environmental report
2	2005	623 972	136 901	170 217	Environmental report
2	2010	583 274	127 310	94 754	Environmental report
2	2015	543 590	60 434	116 390	Environmental report
2	2020	436 005	32 691	85 990	Environmental report

Table 4.4.5. Calorific values by input material in the Swedish iron and steel production processes, GJ/ton.

Plant	Coking coal	External coke	Injection coal	Source
1	32.23	29.67	30.6	Personal communication
2	32.23	27.5	30.6	Personal communication

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 the 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[204], 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 contribution to the carbon inputs. Carbon content of the coking coal was summarized and the relevant time-series for both facilities were compiled within a development project

204 If put in stock or sold externally

during the fall of 2018[205]. Due to data confidentiality, these time series cannot be displayed here but can be provided for reviewers upon request.

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 CRT 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 (CRT 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 CRT 2.C.1.b. Emissions of NO_X and SO_2 are based on detailed plant information from the environmental reports.

4.3.1.2.3 Direct reduced iron (CRT 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 onwards, EU 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 output 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 CRT 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 (CRT 1.A.2.a). Limestone used in the production is included in the emissions from the production of iron powder in CRT 2.C.1.c. Reported activity data is produced amount of direct reduced iron (iron sponge).

In submission 2024, CH_4 emissions from direct reduced iron is reported for the first time. In the calculations, default Tier 1 emission factors from the 2006 IPCC Guidelines together with activity data was used (natural gas used for production of reduction gas).

[205] Yaramenka, K, Jönsson, M, 2018, Förbättringar av inventeringar av utsläpp från SSAB, SMED PM

4.3.1.2.4 Sinter (CRT 2.C.1.d)

No plant-specific or national emission factors are available. Thus, in accordance with the 2019 Refinement, emissions are estimated using production data and default emissions factors (0.21 t CO_2/t sinter produced and 0.07 kg CH_4/ t sinter produced). Production data has been collected from "Statistics of the Swedish Mining Industry"[206] produced by the Geological Survey of Sweden (SGU).

4.3.1.2.5 Pellet (CRT 2.C.1.e)

Production data (iron pellets) are collected from the facilities' annual 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, organic binder olivine and quartzite 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. Emissions of CO_2 from the use of limestone and dolomite are from 2005 and onwards collected from the EU ETS. Before 2005, 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. Emission factor intervals for carbon containing raw materials and carbon content bound in pellets are presented in Table 4.4.6.

Table 4.4.6. Emission factor intervals for carbon containing raw materials (ton CO_2/ton) and carbon content bound in pellets (kg CO_2/ton).

	Average	Minimum	Maximum
Limestone, ton CO_2/ton	**0.42**	**0.41**	**0.43**
Dolomite, ton CO_2/ton	**0.45**	**0.43**	**0.46**
Bentonite, ton CO_2/ton	**0.040**	**0.020**	**0.075**
Organic binder, ton CO_2/ton	**1.4**	**0.5**	**2.1**
Olivin, ton CO_2/ton	**0.0014**	**0.0010**	**0.0022**
Quartzite, ton CO_2/ton	**0.004**	**0.002**	**0.005**
Pellets, kg CO_2/ton	**0.49**	**0.13**	**1.67**

Apart from raw materials that give rise to process related CO_2 emissions, reported in CRT 2.C.1.e, fuels are also used that give rise to CO_2 emissions and which, in accordance with the 2006 IPPC Guidelines, are to be reported as energy related emissions and reported in CRT 1. These fuels are light and heavy fuel oil and hard coal, and the emissions are reported in CRT 1.A.2.g. In addition to these fuels, bio-oil is also used. The raw material, the iron ore, mainly consists of magnetite. Magnetite requires less external energy input during enrichment and pellet production.

No data concerning the CO emissions is available and the time series is thus reported NE.

[206] Geological Survey of Sweden. http://www.sgu.se.

Emission factor for CO_2 in 2006 IPCC Guidelines
The CO_2 emission factor for iron ore pellet production, 0.03 ton CO_2/ton pellets produced, refers to Best Available Techniques Reference Document for Iron and Steel Production. As the Swedish iron ore pellet producer is the main contributor to data for the BREF, the implied emission factor should be consistent with the 2006 IPCC Guidelines. The information in the Best Available Techniques Reference Document for Iron and Steel Production (Remus et al., 2013) indicates that the CO_2 emissions are between 17 and 193 kg/t of pellets produced. With CO_2 data from the EU ETS as a basis and produced quantities of pellets from the company's environmental reports, an IEF of between 26 and 31 kg/t is obtained for the Swedish producer (including energy as well as process related emissions), which is within the interval of the information in the BAT document and on level with the IPCC default value. In CRT 2.C.1.e, only process-related CO_2 is reported, while energy-related emissions are reported in CRT 1.A.2.g (NID section 3.2.15). The emission factor indicates, as mentioned above, that the CO_2 emissions (both energy and process related) are between 17 and 193 kg/t of pellets produced.

As described in 2006 IPCC Guidelines the default emission factor should be used if the inventory compiler does not know anything about the fuels or raw materials used.

Pellet production process – overview
The iron ore is mainly extracted in underground mines, but there is also one open pit. The processing of the ore takes place in the vicinity of the mines and consists of sorting and fine-crushing plants, concentrators and pelletizing plants.

Sorting and crushing: The ore is roughly sorted and residual waste rock removed. After that, the iron ore is crushed into smaller fractions. This increases the iron concentration from approximately 45 to more than 60 percent.

Concentration: The ore is then finely ground and further purified to remove silicon, sodium, potassium, phosphorus, apatite etc. Additives like olivine, quartzite, limestone and dolomite are then mixed into the resulting slurry (a mix of ground iron ore and water).

Pelletisation: In the pelletising plants, binders are added, and the slurry is rolled in large rotating drums, into small balls called pellets. The iron ore pellets are then dried and preheated before finally being heated at 1 250°C to a point where the iron ore particles partially fuse together. Before delivery, the pellets are cooled down.

There are currently six pelletising plants producing iron ore pellets in Sweden. Four of the pellet plants are of the Grate-Kiln type, while the other two are of the Straight-grate (or traveling grate) type.

The pelletisation process requires high temperatures and coal, oil (including bio-oil) and electrical energy are used as energy carriers.

The emissions of CO_2 originating from coal and fossil oil are allocated to CRT 1.A.2.g, while CO_2 originating from raw materials, additives and binders are allocated to CRT 2.C.1.e.

4.3.1.2.6 Other (CRT 2.C.1.f)

The data on emitted amounts of NMVOCs have been taken from the facilities' annual environmental reports. For the years where data is missing for individual facilities, extrapolation has been used to make the time series complete.

4.3.1.3 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 the EU ETS, i.e., including any intermediate stock change of produced coke in the carbon 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.[207]

Figure 4.4.2 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 2025. It is obvious that the Swedish CO_2 IEF (0.53-0.80 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.

[207] Skårman, T. and Gustafsson, T. 2013. Revision of estimated greenhouse gas emissions for integrated iron and steel production. SMED Report No 126 2013.

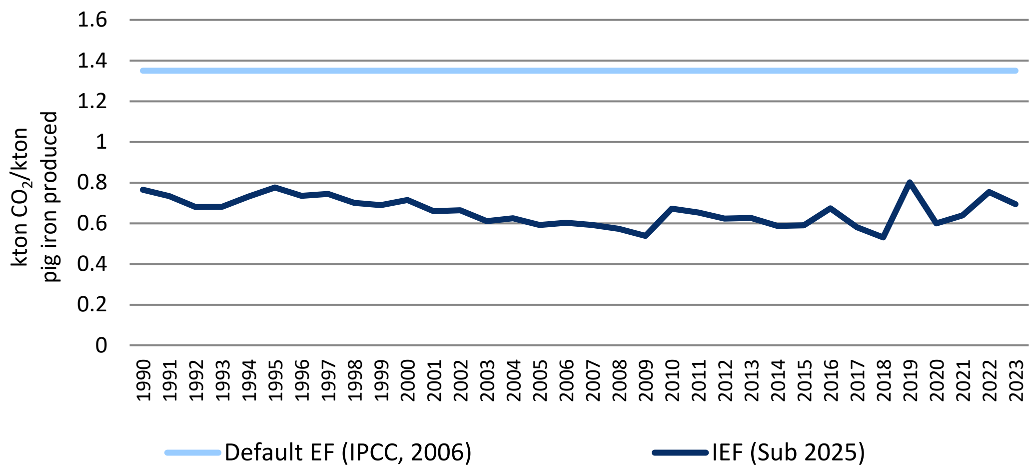

Figure 4.4.2 Default 2006 IPCC CO_2 EF for pig iron production and the CO_2 IEF for primary pig iron production in Sweden for submission 2025.

As the different process gases are allocated to different source categories according to an allocation model, the implied emission factor for CRT 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[208], 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.

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 require extra fuel. Still in 2014, only one out of two blast furnaces were in use, due to the overall weak economy. These activities or events may have contributed to the higher CO_2 IEF for 2010-2016.

In 2019, the CO_2 emissions in CRT 2.C.1.b increased significantly more than production. This increase is explained by disturbances in the production process at one of the facilities, which hindered possibilities to sell energy-rich process gases to external consumers for heat and power generation. Emissions from sold gases are included in the reporting within the energy sector (CRT 1.A.1.a). In 2019, however, the major part of surplus gases was flared at the iron-and-steel facility instead, which resulted in increased CO_2 emissions from the category CRT 2.C.1.b, and increased the ratio *CO_2 emissions / production volumes*. In 2020, no such process disturbances occurred, so both CO_2 emissions and the ratio *CO_2 emissions / production volumes* decreased. In 2021, CO_2 emissions were at roughly the same level as in 2020. Increase of CO_2 IEF in 2022 was largely due to that more carbon-containing internal gases. In 2023, CO_2 emissions and the ratio *CO_2 emissions / production volumes* decreased to the level of 2021.

[208] ENET-Steel, 2007.

The largest implication on the national total uncertainties from this category stems from uncertainties in CO_2 emissions in primary iron and steel production (CRT 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.

4.3.1.4 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 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 4.4.3). However, this is because 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.

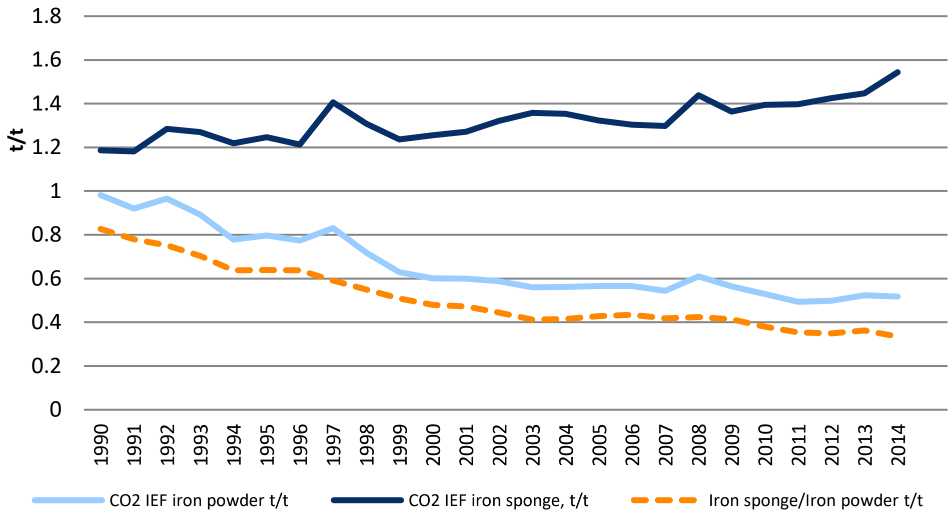

Figure 4.4.3. CO_2 implied emission factors in relation to iron sponge production and total iron powder production, as well as the production ratio of iron sponge to iron powder. Due to data confidentiality, data for the years after 2014 cannot be displayed.

Since the main part of process-related CO_2 emissions stem from iron sponge production, this has been chosen as reported activity data. Figure 4.10 illustrates the different IEFs as well as the trend of the production ratio of iron sponge to iron powder production.

The emission factor given for pellet production in 2006 IPCC Guidelines (0.03 ton CO_2/ton pellet) refers to Best Available Techniques Reference, Document on the Production of Iron and Steel, from December 2001 (15.6 – 31.8 kg CO_2/ton pellet). This emission factor represents emissions of CO_2 both from raw material, additives, binders and coal and fossil oil and can not be used to calculate the process related CO_2 emissions reported in CRT 2.C.1.e. In 2006 IPPC Guidelines, this text can be found: “If the inventory compiler knows the inputs used, CO_2 emissions should be calculated using the Tier 2 method, accounting for the fuel consumption, heating value and carbon content of the fuel.”. The EU ETS data is accredited and verified by an approved controller and considered to be of high quality.

With CO_2 data from the EU ETS (both process and energy related) as a basis and produced quantities of pellets from the company’s environmental reports, an IEF of between 26 and 31 kg/t is obtained for the Swedish producer, which is at the same level as the information in the BAT document. Only the process related CO_2 emissions (CRT 2.C.1.e) have EU ETS as data source, while the energy related emissions (CRT 1.A.2.g) are based on fuel statistics.

4.3.1.5 SOURCE-SPECIFIC RECALCULATIONS

2.C.1.a: No source-specific recalculations have been performed in submission 2025.

2.C.1.b: Value of combusted BFG in 2022 was corrected, resulting in 11% decrease of CH_4 emissions in submission 2025.

2.C.1.c: No source-specific recalculations have been performed in submission 2025.

2.C.1.d: No source-specific recalculations have been performed in submission 2025.

2.C.1.e: No source-specific recalculations have been performed ing submission 2025.

2.C.1.f: No source-specific recalculations have been performed in submission 2025.

4.3.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.3.2 Ferroalloy production (CRT 2.C.2)

4.3.2.1 SOURCE CATEGORY DESCRIPTION

Due to data confidentiality, data for 2015-2020 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 CRT 2.C.1. The production of ferrosilicon has decreased sharply since 2005, and between 2008 and 2011 and again from 2014 there has not been any ferrosilicon production at all. As CH_4 emissions within CRT 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. From 2008 are the SO_2 emissions at a fairly stable level with a few exceptions. 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. Higher sulfur concentrations in the raw materials used have resulted in increased emissions of SO_2 in 2012, 2018 and 2020.

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 4.4.7.

Table 4.4.7. Summary of source category description, CRT 2.C.2, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.C.2	CO_2	X	X		T3	PS	Yes
	CH_4	NA	NA		NA	NA	NA
	N_2O	NA	NA		NA	NA	NA

T3 Tier 3. PS Plant-specific.

4.3.2.2 METHODOLOGICAL ISSUES

The estimation of CO_2 emissions due to the production of ferroalloys are plant specific (in line with Tier 3). CO_2 emissions reported by the plant are calculated based on consumed amounts of reducing agents, i.e. electrodes and coke (and in 2003 coal), crome ore and other input agents, together with their specific carbon contents, and the amount of carbon bound in produced ferroalloys, slag and in dust. The general carbon balance, calculated as averages for 2013 – 2020, is:

$$\frac{Coke}{94\%}+\frac{Electrodes}{5\%}+\frac{Chrome\ ore}{<1\%}+\frac{Other\ agents}{<1\%}\rightarrow\frac{Ferroalloys}{13\%}+\frac{Emissions}{86\%}+\frac{Particles/slag}{1\%}$$

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 around 90% carbon.
- IPCC default factors for coal, coke and electrodes[209].

The following formula is used:

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

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.

The total amounts of carbon in the produced ferroalloys are presented in Table 4.4.8, and are calculated based on the carbon content in coke, coal, electrodes and dust. The amount

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

of carbon in the produced ferroalloys varies between 0.1% and 7%. This carbon is stored in the product and is reported under CRT 1.AD.10 (Non-energy use of fuels and feedstocks) - coke and coal.

Table 4.4.8. Total emissions of CO_2 based on plant specific data (reported in the CRT), data based on Swedish EF and thermal values, and based on 1996 IPCC Guidelines default values. Due to data confidentiality, data for the years 2015-2020 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	232
2010	107	96	104
2011	117	121	130
2012	101	99	107
2013	88	75	81
2014	110	100	107
2021	163	140	151
2022	197	173	187
2023	141	123	133

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 4.4.9), 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.

Table 4.4.9. Total amount of carbon bound in produced ferroalloys and production data. Due to data confidentiality, data for the years 2015-2020 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
2021	7.2	0	110	0
2022	7.8	0	129	0
2023	5.9	0	95	0

CH_4 emissions from production of ferrosilicon alloys are reported from submission 2010 and calculated based on ferrosillicon alloy production (Tier 2[210]). 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.

4.3.2.3 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 is considered to be consistent.

4.3.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

As presented in Table 4.4.7 verification of CO_2 emissions reported by the plant is obtained as calculated Swedish default values give similar results.

4.3.2.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed during submission 2025.

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 Aluminium production (CRT 2.C.3)

4.3.3.1 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. From 2008, when all Söderberg cells were shut down, these potlines have gradually been replaced by closed Prebake cells. In 2012, 56 closed Prebake cells in plant 1 and 242 closed Prebake cells in plant 2 (all CWPB) were in operation. 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.

Process related emissions from one producer of secondary aluminum are also included in CRT 2.C.3. The time series of emissions compiled for secondary aluminum production includes emissions of CO, NO_X and SO_2. Also, small amounts of NMVOC from one aluminum foundry are included in CRT 2.C.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

[210] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Table 4.8

Table 4.4.10. An overview of the rationale for data sources used for key categories in the industrial processes sector is presented in Annex 3.5.

Table 4.4.10. Summary of source category description, CRT 2.C.3, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.C.3	CO_2	X	-		T3	PS	Yes
	CH_4	NA	NA		NA	NA	NA
	PFCs	-	X		T2	D	Yes

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

4.3.3.2 METHODOLOGICAL ISSUES

4.3.3.2.1 Primary aluminium production

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 - 2022 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 0.171 and 0.297.

For the years 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 4.4.11). For 2023, the quantity of production as well as the IEF are classified.

Table 4.4.11. Implied emission factor for CO_2 for the production of primary aluminium. Production quantity and IEF are confidential for 2023.

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
2015	119	180	1.5
2016	124	190	1.5
2017	126	206	1.6
2018	125	188	1.5
2019	117	177	1.5
2020	115	172	1.5
2021	116	174	1.5
2022	117	175	1.5
2023	C	171	C

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 4.4.12.

Table 4.4.12. Activity data, emissions of C_2F_8, CF_4 and calculated IEF for primary aluminium production. Production quantity and IEF are confidential for 2023.

Year	Al production, CWPB, kt	Al production, VSS, kt	Total emissions, C_2F_6 t	Total emissions, CF_4 t	Calculated IEF 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	-
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	-
2018	124.8	-	0.84	6.94	0.0067	-	0.0557	-
2019	116.8	-	0.67	5.56	0.0058	-	0.0476	-
2020	114.9	-	0.89	7.36	0.0077	-	0.0640	-
2021	115.9	-	0.68	5.61	0.0059	-	0.0484	-

					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
2022	116.6	-	0.52	4.32	0.0045	-	0.0370	-
2023	C	-	0.48	3.93	C	-	C	-

Reported emissions of NO_X are calculated from production statistics using emission factors defined by Swedish EPA[211]. NMVOC emissions are calculated from reported emissions of tar, assuming that 70% of the tar is emitted as NMVOC[212]. Closing down the Söderberg ovens also eliminated the need for anode production in late 2008.

The shutdown of the anode production ended the tar emissions which meant that the NMVOC emissions also 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 - 2021 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 - 2021. 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.

4.3.3.2.2 Secondary aluminium production and aluminium foundries

Reported emissions data are based on information in the facilities' environmental reports. For the years where data is missing for individual facilities, extrapolation has been used to make the time series complete.

4.3.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

4.3.3.3.1 Primary aluminium production

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. Uncertainty for PFCs is ± 30% for 1990 and ± 5% for the latest year.

As can be seen in Table 4.4.11 the IEFs show a downward trend from 1990, especially so for CF_4. This reflects the company's on-going work aiming to reduce the time and

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

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

frequency of the anode minutes. Between 2008 and 2011 the Söderberg potlines were gradually 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 led 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 4.4.4). 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. In 2018 emissions of PFC increased compared to recent years. This is due to the sanctions introduced from the US aimed at Russian oligarks, of which one controlled the mother company that owns the Swedish facility. The sanctions resulted in cancelled deliveries of necessary raw-materials and spare parts from other companies trying to avoid effects of the sanctions. After the sanctions were introduced, the production process at the facility was instable due to lack of rawmaterials and spare parts for maintenance. The sanctions were removed on January 27, 2019, after changes in the company- and owner structure. During 2019, after the removal of the sanctions, the production has become more stable again, but some activities were delayed due to the sanctions in 2018. The company reports that they were catching up on these activites in 2019. In 2020, there have been a number of power outages which was disturbing the process, resulting in a higher frequency of anode minutes and higher emissions of PFCs.

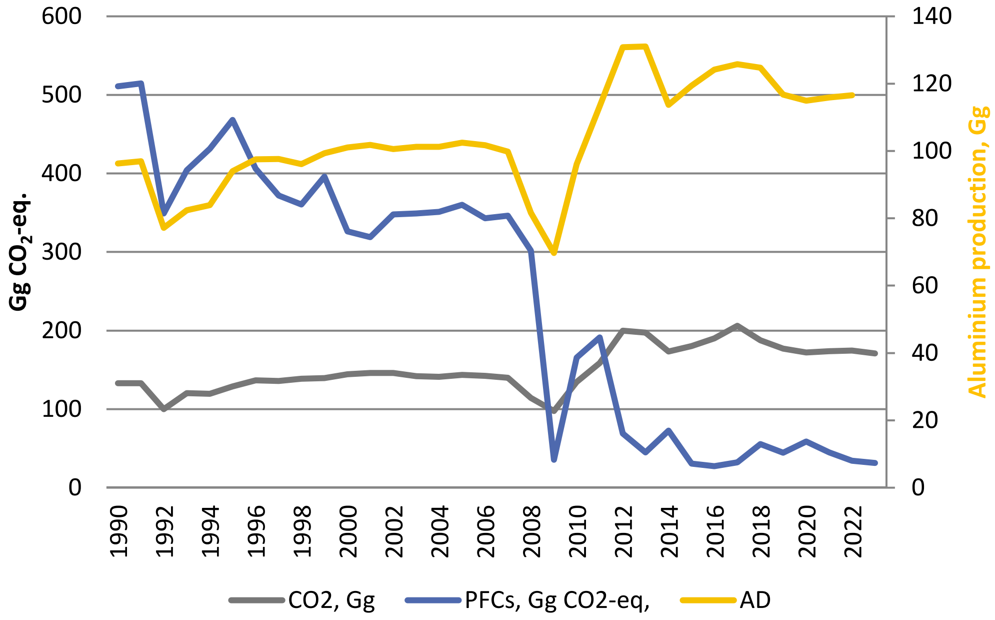

Figure 4.4.4. Time series for CO_2 and PCF emissions and produced amounts of primary aluminium in CRT 2.C.3. AD for 2023 is confidential.

The reported time series are considered to be consistent.

4.3.3.3.2 Secondary aluminium production and aluminium foudries

Uncertainties for CO, SO_2, NO_X and NMVOC are ± 100%, ± 30%, ± 50%, ± 100%, respectively.

4.3.3.4 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.

4.3.3.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed during submission 2025.

4.3.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.3.4 Magnesium production (CRT 2.C.4)

4.3.4.1 SOURCE CATEGORY DESCRIPTION

There is 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 CRT tables. However, there are four magnesium foundries in Sweden that have used SF_6 as a cover gas. In 2012 – 2013 and 2017 - 2022, small amounts of HFC-134a were also used as a cover gas.

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 4.4.13.

Table 4.4.13. Summary of source category description, CRT 2.C.4, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.C.4	SF_6	-	-		T2	D	Yes
2.C.4	HFC-134a	-	-		T2	D	Yes

D Default. T2 Tier 2

4.3.4.2 METHODOLOGICAL ISSUES

The total amounts of SF_6 and HFC-134a used annually in the magnesium foundries (CRT 2.C.4) are reported as emissions, according to the 2006 IPCC Guidelines. Data is obtained from companies using SF_6 and HFC-134a as a cover gas. From 1 January 2018, the use of SF_6 as a cover gas is prohibited and this gas has primarily been replaced by SO_2.

4.3.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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 CRT 2.C.4 to ± 20%. Time series are considered to be consistent.

4.3.4.4 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 CRT 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 4.4.5, below, implied emission factors (ton SF_6/kton magnesium casted) for the largest of the magnesium foundries are presented, from 2009 to 2017. Between 2009 and 2011, the implied emission factor decreases much while it remained at about the same level after 2011.

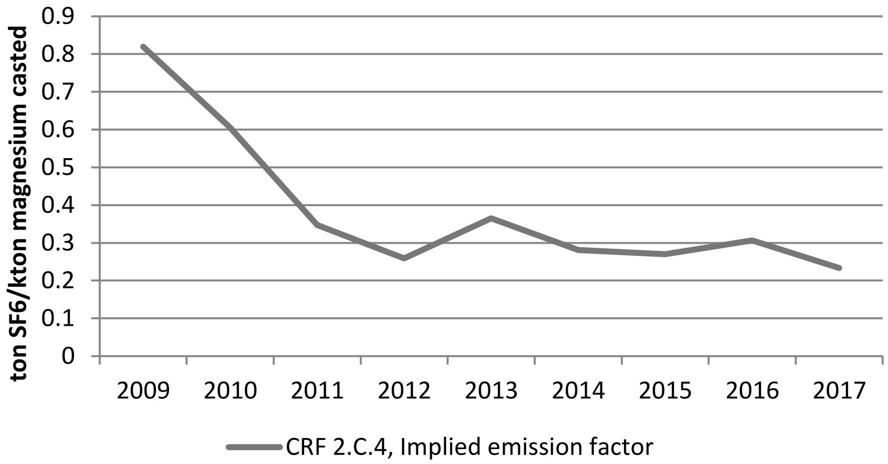

Figure 4.4.5. SF_6 implied emission factors for the largets Swedish magnesium foundry, 2009 – 2017.

4.3.4.5 SOURCE-SPECIFIC RECALCULATIONS

Due to updated activity data, recalculations have been performed for 2020-2022 during submission 2025, resulting in increased emissions of between 0.15-0.33 kt CO_2-eq.

4.3.4.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.3.5 Lead production (CRT 2.C.5)

4.3.5.1 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 CRT 2.C.7.c Other metal production. Thus, IE is reported in CRT 2.C.5.

4.3.6 Zinc production (CRT 2.C.6)

4.3.6.1 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 CRT 2.C.7.c Other metal production. Thus, IE is reported in CRT 2.C.6.

4.3.7 Other metal production (CRT 2.C.7)

4.3.7.1 SOURCE CATEGORY DESCRIPTION

Due to data confidentiality, CO_2 emissions for 2015 -2020 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 4.4.14.

Table 4.4.14. Summary of source category description, CRT 2.C.7, according to approach 1.

CRT	Gas	Key Category Assessment, 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

T3 Tier 3. PS Plant-Specific.

4.3.7.2 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[213]). 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 4.4.15.

Table 4.4.15. 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

[213] Yaramenka, K., Mawdsley, I. 2015

The metal recycling plant emits CO_2 from the melting of lead batteries composed of carbon containing plastics (polypropylene). 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 by the company also include energy related emissions, which are subsequently subtracted from the energy sector. From 2005 onwards, the amount of plastics, their carbon content, as well as the CO_2 emissions from plastics are known from the EU ETS. This information for 2005 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 4.4.6 below, metal production does not show the same trend as CO_2 emissions. The metal production 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 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. The sharp decline in metal production (copper) in year 2023 is due to a major fire in an electrolysis plant. However, the decline in copper production did not affect the total yearly CO_2 emission since the process in the electrolysis plant is driven by electrical energy.

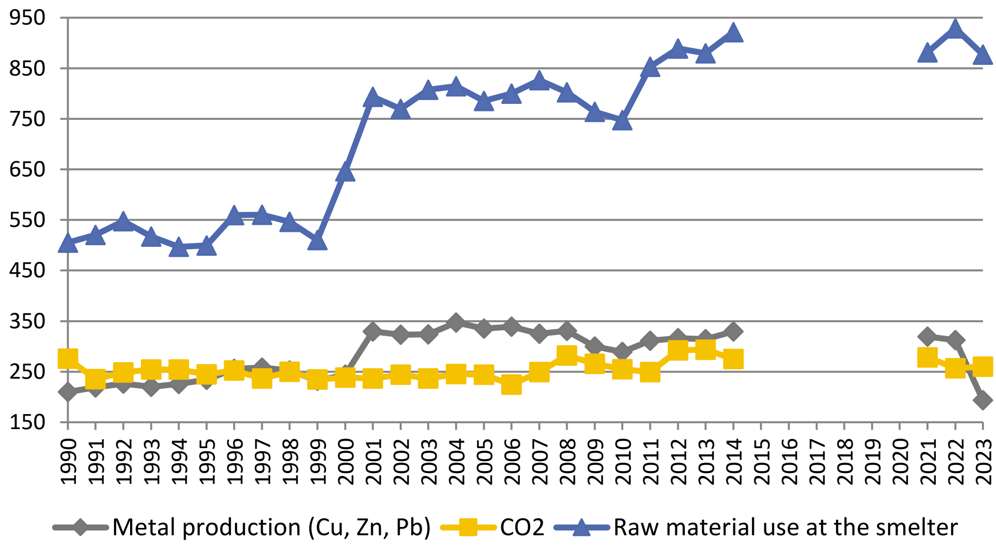

Figure 4.4.6. CO_2 emissions and activity data trends in CRT 2.C.7.c, kt. Due to data confidentiality, data for the years 2015-2020 cannot be displayed.

Figure 4.15 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 4.4.7; this is because materials with low emission factors are excluded.

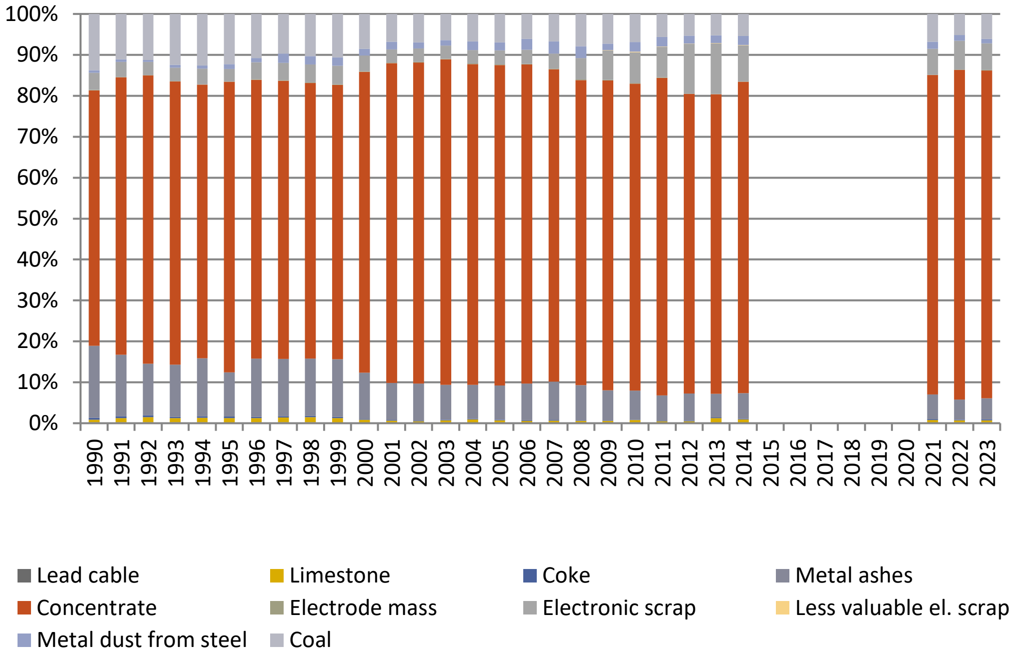

Figure 4.4.7. Consumption of raw materials with high carbon content and CO_2 emissions at the smelter, Gg. Due to data confidentiality, data for the years 2015-2020 cannot be displayed.

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 4.4.7 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 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.

4.3.7.3 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.

4.3.7.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

In submission 2016, the method for calculating emissions from the smelter has been updated since the previously applied method resulted in substantial underestimations. The new method is described in detail in Yaramenka & Mawdsley[214]. 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 emissions in annual environmental reports. The reported activity data and emissions are analysed and compared to EU ETS data. More information on QC activities related to the 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 2025 and suggests that summed emissions reported in CRT 1 and CRT 2 match total emissions reported in the respective environmental reports or to the EU ETS in a sufficient manner.

4.3.7.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed in submission 2025.

4.3.7.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.4 Non-energy products from fuels and solvent use (CRT 2.D)

4.4.1 Lubricant use (CRT 2.D.1)

4.4.1.1 SOURCE CATEGORY DESCRIPTION

In CRT 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 4.5.1.

Table 4.5.1. Summary of source category description, CRT 2.D.1, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.D.1	CO_2	X	-		T1	D	Yes

D Default. T1 Tier 1.

[214] Yaramenka, K., Mawdsley, I. 2015

4.4.1.2 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 no data is available for the current year, this is considered to be the best available method. Data for 2023 is thus preliminary and will be updated in submission 2026.

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 CRT 2.D.3 Other Solvent use. Therefore, these CO_2 emissions are subtracted from the amounts reported in CRT 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
$CO_{2_{2D3}}$ = CO_2 emissions included in CRT 2.D.3_Other_Solvent_use

Factors used for CO_2 estimates are presented in Table 4.5.2.

Table 4.5.2. Parameters used when calculating emission from oxidation of lubricants.

Parameter	Factor	Unit	References
CC_{SM}	20	Ton C/TJ	IPCC 2006, page 5.9
ODU_{SM}	20	%	IPCC 2006, page 5.9

The time series for CO_2 emissions and used amounts of lubricants in CRT 2.D.1 for 1990-2019 is presented in Figure 4.5.1. The amount of lubricant consumed varies relatively large between different years. During 2016-2019 the CO_2-emissions and the used amounts of lubricants were declining. Unfortunately, no specific explanation for this decline has been found by the Swedish Energy Agency and Statistics Sweden. Data for 2021-2023 showed an increase of the CO_2-emissions and the used amounts of lubricants which means that the declining trend is broken. However, data for 2020, 2021, 2022 and 2023 can not be shown due to confidentiality reasons.

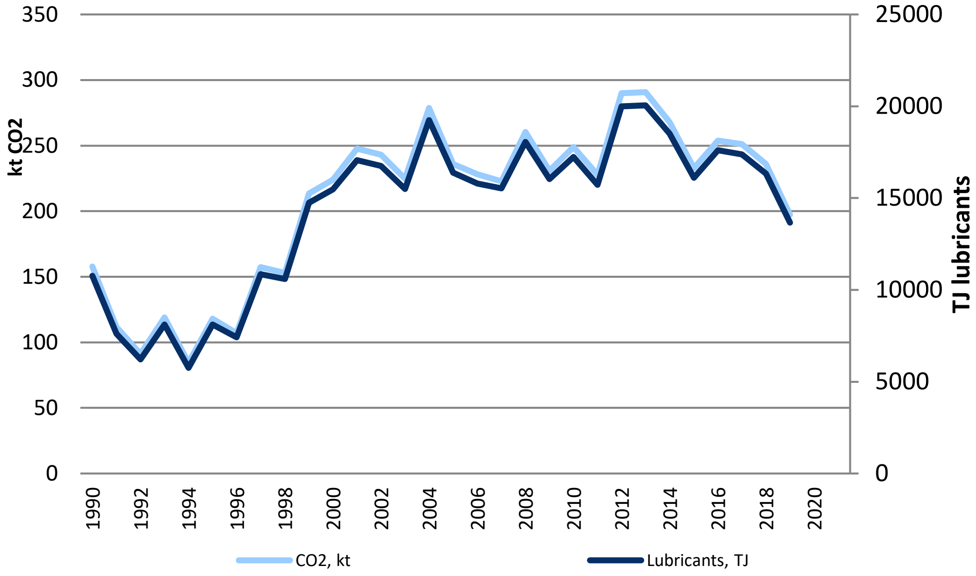

Figure 4.5.1. Time series for CO_2 (kt) and used amounts of lubricants (TJ) in CRT 2.D.1.

4.4.1.3 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 – 2022) and from Statistics Sweden (1990 – 2004). Data for 2022 is preliminary and will be updated in submission 2025.

Uncertainties for CRT 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%.

4.4.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.4.1.5 SOURCE-SPECIFIC RECALCULATIONS

As data from the Swedish Energy Agency was not available in time in submission 2025, input data for 2023 was estimated based on data for 2022. In Submission 2025, activity data for 2022 has been retrieved from the Swedish Energy Agency and were updated accordingly in the calculations. However, the amounts of lubricants consumed in 2022 is confidential.

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 Paraffin wax use (CRT 2.D.2)

4.4.2.1 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 CRT 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 reported in the energy sector (CRT 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 4.5.3.

Table 4.5.3. Summary of source category description, CRT 2.D.2, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.D.2	CO_2	-	-		T1	D	Yes

D Default. T1 Tier 1.

4.4.2.2 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.

Due to the delay of the data delivered by the Swedish Chemical Agency, data for the latest reporting year is set equal to the previous year. Since no obvious trend can be discerned and no data is available for the current year, this is considered to be the best available method. Data for 2023 is thus preliminary and will be updated in submission 2026.

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 4.5.4.

Table 4.5.4. Parameters used when calculating emissions.

Parameter	Factor	Unit	References
$PF_{\%}$	66	%	National Inventory Report, Norway[215]
VV_{Wax}	0.0402	TJ/t	Statistics Sweden
CC_L	20	Ton C/TJ	IPCC 2006, page 5.12
ODU_{Wax}	20	%	IPCC 2006, page 5,12

The time series for CO_2 emissions in CRT 2.D.2 is presented in Figure 4.5.2. The IEF is the same for the whole time series, 0.073 kt/TJ. Data for 2020-2023 can not be shown due to confidentially reasons.

215 http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8108.php

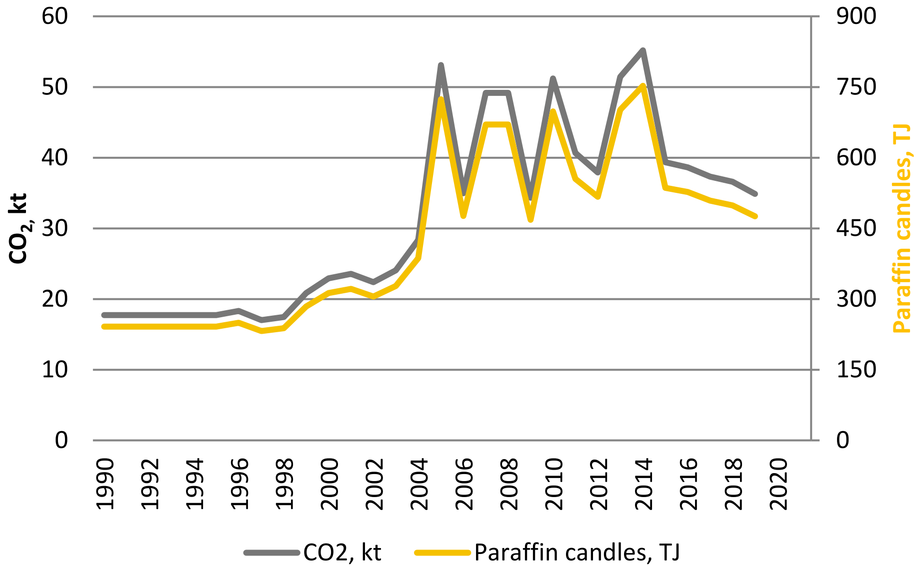

Figure 4.5.2. Time series for CO_2 (kt) and used amounts of paraffin candles (TJ) in CRT 2.D.2.

4.4.2.3 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 2022 is preliminary and may be updated in submission 2025.

Uncertainties for CRT 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 CRT 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 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%.

4.4.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.4.2.5 SOURCE-SPECIFIC RECALCULATIONS

Data from Statistics Sweden regarding import and export of candles for 2022 have been updated, resulting in a decrease of about 0.01 kt of CO_2 emissions.

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 Other (CRT 2.D.3)

4.4.3.1 SOURCE CATEGORY DESCRIPTION

In this source category urea used as a catalyst are included. In previous submissions, indirect CO_2 emissions from solvent use was also reported in CRT 2.D.3. However, these emissions have been removed in submission 2025.

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 4.5.5.

Table 4.5.5. Summary of source category description, CRT 2.D.3, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.D.3	CO_2	-	-		T1, T3*	CS, D*	Yes

D Default. CS Country Specific. T1 Tier 1. T3 Tier 3.

* Urea used as a catalyst

** Solvent and product use

Urea is used as a reducing agent in some types of NO_X reducing catalysts. These kinds 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 until 2017 are mainly a consequence of increased use in heavy duty road vehicles since catalysts have been more or less necessary in order 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 in the urea molecule will result in CO_2 emissions.

4.4.3.2 METHODOLOGICAL ISSUES

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 are 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 to 1995 and therefore, the CO_2 emissions for 1990-1994 is estimated from the average CO_2 emission from 1995-1999.

Due to the delay of the data delivered by the Swedish Chemical Agency, data for the latest reporting year is set equal to the previous year. Since no obvious trend can be discerned and no data is available for the current year, this is considered to be the best available method. Data for 2023 is thus preliminary and will be updated in submission 2026.

CO_2 from the urea use is calculated in accordance with 2006 IPCC Guidelines. See Table 4.5.6 for activity data and calculated emissions.

Table 4.5.6. 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
2015	51.6	37.9
2020	50.1	36.7
2021	50.1	36.7
2022	50.2	36.8
2023	50.2	36.8

4.4.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The total uncertainty of the EF used is set to ± 5%, and the uncertainty of activity data is set to ± 40%.

4.4.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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 2006 IPCC guidelines 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.

4.4.3.5 SOURCE-SPECIFIC RECALCULATIONS

4.4.3.5.1 Urea used as a catalyst

No recalculations in submission 2025.

4.4.3.5.2 Solvent use

Previously reported CO_2 from solvent use was excluded for the whole time series in submission 2025 as these emissions are indirect CO_2 emissions formed from oxidation of emitted NMVOC. As of submission 2025 the previously reported CO_2 in 2.D.3 is not allocated elsewhere in the inventory. The excluded CO_2 emissions amounts to approximately 100-150 kt per year and a total of 3 670 kt over the time series 1995-2023.

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.

4.5 Electronics industry (CRT 2.E)

4.5.1 Integrated circuit or semiconductor (CRT 2.E.1)

4.5.1.1 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 4.6.1.

Table 4.6.1. Summary of source category description, CRT 2.E.1, according to approach 1.

CRT	Gas	Key Category Assessment, 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

4.5.1.2 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 using the 2006 IPCC Guidelines Tier 1 method using an average expected lifetime of one year.

4.5.1.3 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 uncertainty for activity data is judged to be ± 2% and the uncertainty of the emission factor for HFCs, PFCs and SF_6 are judged to be ± 20%.
The time series are calculated using the same methodology for all years and are thus consistent.

4.5.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Cross-references with the Products Register at the Swedish Chemicals Agency could not be made for the entire reported time series, since the level of detail in the Products Register was insufficient.

4.5.1.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

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 TFT Flat panel display (CRT 2.E.2)

4.5.2.1 SOURCE CATEGORY DESCRIPTION

No production of TFT flat panel displays is currently known to occur in Sweden, thus NO is reported for CRT 2.E.2.

4.5.3 Photovoltaics (CRT 2.E.3)

4.5.3.1 SOURCE CATEGORY DESCRIPTION

No production of photovoltaics occurs in Sweden, thus NO is reported for CRT 2.E.3.

4.5.4 Heat transfer liquid (CRT 2.E.4)

4.5.4.1 SOURCE CATEGORY DESCRIPTION

There are no electronic industries using FCs in Sweden, thus NO is reported for CRT 2.E.4

4.5.5 Other (CRT 2.E.5)

4.5.5.1 SOURCE CATEGORY DESCRIPTION

NO is reported for CRT 2.E.5.

4.6 Product uses as substitutes for ODS (CRT 2.F)

Use and emissions of halocarbons have increased since 1990, especially in refrigeration and air-conditioning equipment (CRT 2.F.1), which is the main source of halocarbon emissions in Sweden.

The largest emission source in 2023 is refrigeration and air conditioning (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 available information, solvents containing HFCs or PFCs are not used in Sweden. An overview of reported emissions in CRT 2.F are shown in Table 4.6.1. The decreasing emission trend in the last few years is mainly due to the use of more efficient equiment and the transition towards lower GWP refrigerants (e.g., HFO (R1234yf) in vehicle air-conditioning, propane (R290) in heat pumps and CO_2 (R744) in supermarket refrigeration).

Due to issues with CRT Reporter, notation keys are missing for many F-gases. The notation key for HFC-23, HFC-245fa, HFC-365, HFC 43-10mee, HFC-134 and NF3 is IE while that of other HFCs and PFCs is NO.

Table 4.6.1. Overview of submitted emission data in CRT 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	4.6	NO	NO	1.3	NO	NO
1995	122	NO	NO	6.7	NO	NO
2000	592	111	5.5	22	NO	NO
2005	929	87	6.0	29	NO	NO
2010	1005	32	5.1	25	NO	NO
2011	982	36	2.1	21	NO	NO
2012	970	35	1.9	18	NO	NO
2013	959	37	1.2	18	NO	NO
2014	984	35	1.0	20	NO	NO
2015	1005	34	0.8	20	NO	NO
2016	1023	33	0.8	20	NO	NO
2017	985	32	3.4	21	NO	NO
2018	932	31	1.5	21	NO	NO
2019	892	27	1.3	16	NO	NO
2020	849	26	0.6	13	NO	NO
2021	821	16	0.2	14	NO	NO
2022	791	10	0.2	15	NO	NO
2023	733	9	0.2	15	NO	NO

The Swedish F-gas model
A national model corresponding to the IPCC Tier 2 approach has been used to estimate emissions in all subcategories, as far as possible. The basis for the emission estimates is 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 filled in products imported to or exported from Sweden (e.g., air-air heat pumps, metered dose inhalers, refrigerated 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 into 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 4.6.1 below. In submission 2022, 2023 and 2024 data from the SPIN database (Substances in Preparations in the Nordic Countries[216]) has also been used.

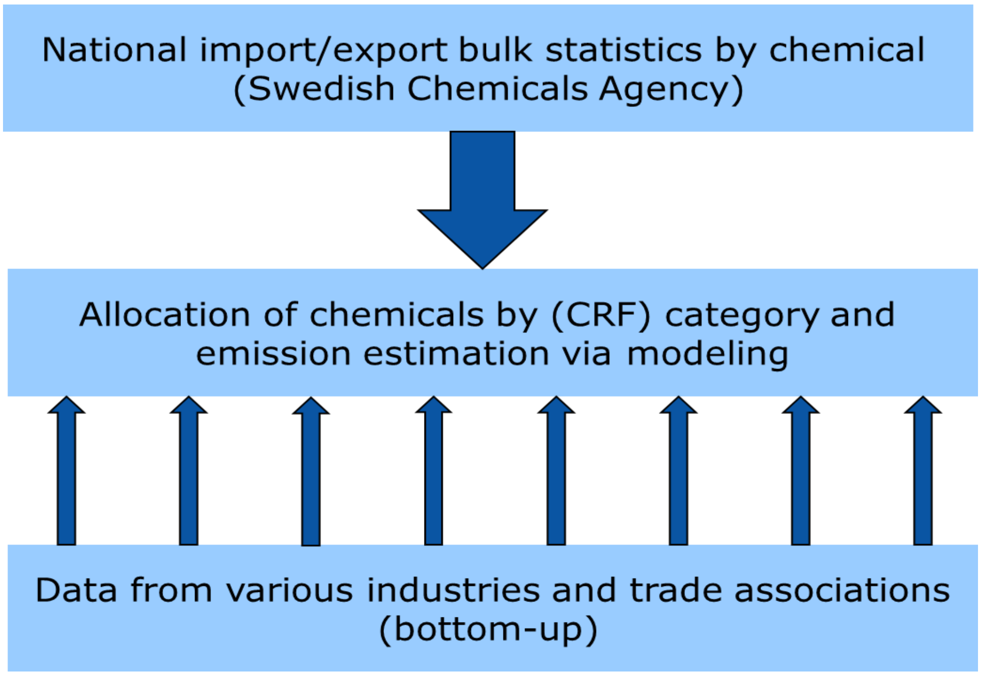

Figure 4.6.1. Schematic illustration of the Swedish national model used for estimation of emissions of fluorinated greenhouse gases.

As of submission 2015, the reporting is in accordance with the 2006 IPCC Guidelines. This means, for example, that the reporting includes 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. HFC-23, HFC-245fa, HFC-365, HFC-43-10mee, HFC-236fa and HFC-134 are used in small amounts in Sweden. Consumption data is classified as confidential. After correction of the amounts using the GWP values of the substances, HFC-134, HFC-245fa and HFC-43-10mee have been summed up with HFC-134a, HFC-365 with HFC-32 and HFC-23 and HFC-236fa with HFC-143a.

The model is described in more detail in Annex 3:1.

[216] http://spin2000.net/

4.6.1 Refrigeration and air conditioning (CRT 2.F.1)

4.6.1.1 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.

Emissions from HFCs and PFCs in 2.F.1. have increased largely between 1990 (5 kt CO_2 eq.) to 2016 (1023 kt CO_2 eq.). From 2017 onwards, however, the trend has reversed, and emissions have continuously declined (733 kt CO_2 eq., 2023). From 2005 to 2017, the most important source of greenhouse gases in this category has been the F-gas emissions from air-conditioning in mobile air-conditioning (MAC, CRT 2.F.1.e). As of 2017, the emissions from MAC have decreased while emissions from commercial refrigeration (CRT 2.F.1.a) and industrial refrigeration (2.F.1.c) have become dominant (Figure 4.6.2).

Due to the EU F-Gas Regulation (EU 517/2014), the use of high GWP HFCs as refrigerants are gradually being phased out in several areas, such as air-conditioning in vehicles, heat pumps, as well as supermarket fridges and freezers. Efforts are ongoing to replace these with other alternatives. Examples of alternative refrigerants include HFOs, propane, NH_3 and CO_2, as well as other HFCs with lower GWP.

The decreasing emissions from MAC are also a result from steadily improving equipment in vehicles, leading to declining leakages. Thus, the introduction of HFO-1234yf as a substitute for HFC-134a in passanger cars and light-duty vehicles, has also contributed to the decline in emissions. Similarly, the overall decreasing trend in CRT 2.F.1 over the last few years is a result of the more efficient equipment, and the transition to lower GWP refrigerants.

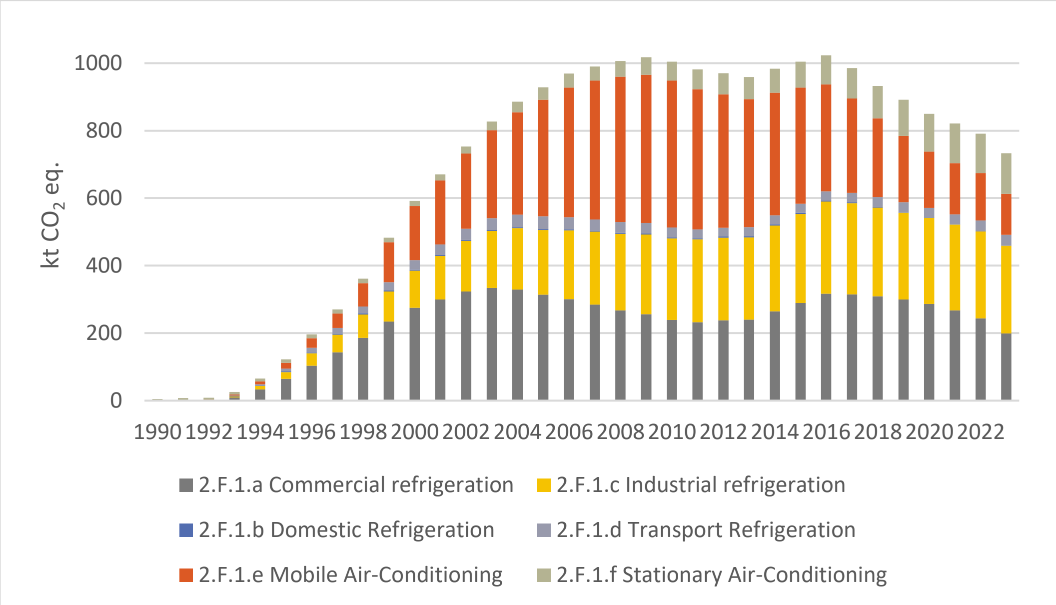

Figure 4.6.2. Overview of submitted emission data in CRT 2.F, separated in subsectors, kt CO_2 eq.

Starting as early as in the 1980s Sweden has had strict regulation regarding F-gases through legislation, (SNFS 1988:3, later amended by SNFS 1992:16). The Swedish Refrigeration Code of Best Practice (Svensk Kylnorm) include directives concerning annual supervision of refrigeration and heat pump equipment, which includes leakage control, but also requirements for preventive measures. In addition, starting in the late 1980s, companies operating with installations, service, maintenance or execution of the mandatory supervision, have professional permits from the Swedish Environmental Protection Agency, later transferred to requirements for accreditation with SWEDAC (Sweden's national accreditation body). The early national regulation and directive have, in many cases, lead to comparatively low leakage rates 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 4.6.2.

Table 4.6.2. Summary of source category description, CRT 2.F.1, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.F.1	HFCs	X	X		T2a	CS, D	Yes
	PFCs	-	-		T2	CS	Yes
	SF_6	NA	NA		NO	NO	NO

CS Country Specific. D Default. T2a Tier 2a.

4.6.1.2 METHODOLOGICAL ISSUES

Input data for the calculation of emissions consists of information from various sources; the Swedish Chemicals Agency, the SPIN database, equipment producers and importers. Table 4.6.3 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)[217] and from the Finnish inventory[218].

Given intervals indicate changes between 1990 and the last inventory year used in the calculations.

[217] Described in Annex 2

[218] Tommi Forsberg, SYKE, Finland, personal communication 2018-08-29

Table 4.6.3. 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. Given intervals 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, A-tractor cars (modified passenger cars registered as tractors) (2.F.1.e)	HFCs	11	0.8 - 0.7	1 – 0.5	15 - 5	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

2.F.1.a, 2.F.1.c, 2.F.1.f

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 chemicals 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 gives that 100% of all air-to-air heat pumps, 5% of all liquid water heat pumps 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. All exhaust air-to-air heat pumps are manufactured in Sweden.

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 up to emission year 2016 while it is decreasing in Germany. After 2016, the use of HFC-143a has decreased in Sweden.

According to Germany's NID, the calculations for these three CRT categories 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 judgement". 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 – 2021 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, if possible, to find new leakage factors relevant to Sweden. As mentioned previously, there are currently no national statistics that can be used to find new national emission factors in CRT 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 – 2024, 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.f, are however calculated using national emission factors. In the 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 2016-2023, the distribution for 2015.

The model has been updated due to the shift from commonly used high GWP HFCs to alternative refrigerants, and from 2021 onwards, a new refrigerant, R290 (propane), was introduced for heat pumps in Sweden.

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).

2.F.1.b
Activity data for household refrigerators for the 1990s have been obtained from EHL (Elektric Household appliances) which is a trade association that has aggregated information on the sale of refrigerators and freezers. For the years after 1999, a constant number has been assumed (450,000 units/year). 75% of the total number is assumed to have been manufactured in Sweden and 25% is imported (Kindbom et al., 2001).

Between 1990 and 1993, CFC:s were used as refrigerants in household refrigerators and freezers, for 1991 and 1992 together with HFC-134a. From 1994 onwards, propane has gradually replaced HFC-134a and had completely replaced HFC-134a by 2008 (Kindbom et al., 2001).

2.F.1.d
Data on the number of refrigerated trucks and trailers has been retrieved from the Traffic Register at the Swedish Road Administration and from Transport Analysis.

Until 1992, CFCs and HCFCs were used as refrigerants. From 1993 and 1994, it was assumed that 30% of new registered refrigerated trucks and trailers used R404a (44% HFC-125, 4% HFC-134a, 52% HFC-143a) as refrigerant. From 1995 onwards only R404a has been used. However, as of year 2018, a new refrigerant, R452A, has been introduced onto the market.

As the model assumes that the lifetime for refrigerated trucks and trailers is ten years, disposal in CRT 2.F.1.d is reported for the first time in 2003. Notation key NO (Not occurring) is reported for emissions from manufacturing and from stock for the years 1990, 1991 and 1992 and for disposal for the years 1990-2002.

Used emission factors have been developed through contact with the industry (Kindbom et al., 2001).

2.F.1.e
During the period from 1990 onwards, the product life factor (leakage from installed quantities) has decreased from 15% in the 1990s to 5% from 2011 onwards. 15% in the 1990s corresponds to the mid-range of the default emission factors in 2006 IPCC Guidelines. In the early 2000s, a study was conducted (Kindbom et al., 2001) in which contact was made with the industry to investigate, among other things, whether the

leakage factors used in the Swedish F-gas model were relevant. The industry then announced that they had improved and reduced the operational leakage. Therefore, a leakage factor of 10% has been applied between 2001 and 2009. In the 2006 IPCC Guidelines, Schwarz and Harnisch (2003) estimates operation emission factor to be between 5.3% to 10.6% for second generation mobile air conditioners installed in European models in 1996 and beyond. This corresponds well with the Swedish emission factor for leakage from installed amounts. The leakage factor for the year 2000 is interpolated between 1999 and 2001.

In 2011, another survey was published in which, among other things, leakage factors for MAC were studied (Gustafsson, T., 2011). In the study, Volvo Cars, the largest passenger car producer in Sweden, was contacted. According to Volvo Cars, the range for annual leakage is approximately 7-20 g. This corresponds to annual leakage of approximately 1-3%. Based on the information from Volvo Cars it was suggested that the yearly operation emission factor in Sweden to be lowered to 7.5% in 2010 and to 5% in 2011 and beyond. The leakage factor is higher than the information from Volvo Cars indicates, in order to avoid an underestimation of the emissions leakage because of accidents and increased wear due to age.

The model assumes that the leakage factors used can be applied to all manufacturers' passenger cars in Sweden.

As of 2021 onwards, a shift in refrigerants, from R134a to R1234yf, is introduced for vechicles produced in Sweden.

The amount of HFC filled into new manufactured products is based on data on the number of vehicles built in Sweden. Installed quantities in operating systems are based on the annual number of newly registered vehicles, regardless of whether the vehicles are produced in Sweden or imported.

Factors used in 2.F.1
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 presented in detail in Table 4.6.4.

Table 4.6.4. Emission factors used for emission estimates in CRT 2.F.1.

CRT	Year	Lifetime, years	Charge, kg	EF Initial Emission, %	EF Operation Emission, %/year	Emissions at disposal,%	Initial Charge Remaining,%
2.F.1.a Stand alone	1990-2023	10		0.5	1	5	90
2.F.1.a Medium & Large	1990-2023	7		0.5	10	5	90
2.F.1.b	1990-2023	20	0.1	2	1	5	90
2.F.1.c	1990-2023	15		0.5	7	5	90
2.F.1.d	1990	NO	NO	NO	NO	NO	NO
	1991	NO	NO	NO	NO	NO	NO
	1992	NO	NO	NO	NO	NO	NO
	1993	10	8.5	4.5	20	NO	NO
	1994	10	8	4.5	20	NO	NO
	1995	10	8	4.5	15	NO	NO
	1996	10	7.5	4.5	14	NO	NO
	1997	10	7	4.5	13	NO	NO
	1998	10	6.5	4.5	11.5	NO	NO
	1999	10	6	4.5	10	NO	NO
	2000	10	6	4.5	10	NO	NO
	2001	10	6	4.5	10	NO	NO
	2002	10	6	4.5	9	NO	NO
	2003	10	6	4.5	9	15	90
	2004	10	6	4.5	8	15	90
	2005-2023	10	6	4.5	7	15	90
2.F.1.f Heat pumps	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
	2004-2023	15	1	1	1	5	90
2.F.1.f other stationary air-conditioning	1990-2023	10		0.2	1	5	90

4.6.1.3 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. All uncertainties are documented and are based on expert judgement made in collaboration between inventory experts and experts at the Swedish Chemicals Agency. Prior to each submission, the uncertainties are reviewed.

AD and EF uncertainty are ±10% and ±40% for mobile air conditioning (2.F.1.e), ±25% and ±50% for domestic refrigeration (2.F.1.b) and ±20% and ±40% for 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 when reported together 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 CRT 2.F.1.a, 2.F.1.c and 2.F.1.f are higher compared to Finlands emission factor uncertainty (±40%). For CRT 2.F.1.d and 2.F.1.e the uncertainties are at the same level (±40%), For CRT 2.F.1.b Swedens emissions factor uncertainty is slightly higer compared to Finlands (±50% for Sweden and ±40% for Finland).

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.

4.6.1.4 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)[219], with experts at the Swedish EPA[220] and with the Swedish Car Recyclers Association[221]. 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[222], 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 4.6.5.

Sweden, together with the other Nordic countries, has in recent years compared the similarities and differences between the countries' F-gas inventories. In the study, we have compared, for example, which data sources and which emission factors are used for the emission calculations. In 2020, 2021 and 2022, the focus has been on the end-of-life factors, with focus on heat pumps in 2022.

[219] Per Jonasson, Managing Director, Swedish Refrigeration & Heat Pump Association. Personal communication

[220] Swedish EPA . Ujfalusi, Bernekorn, and Björsell. Personal communication.

[221] Michael Abraham, Managing Director, Swedish Car Recyclers Association. Personal communication

[222] 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 4.6.5. Emission factors used (1990 – 2023) 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, passenger 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,%
1990-1999	6	1	1	15	15	90	11	1	1	15	15	90	11	1	1	15	15	90	12	7	1	10	15	90
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
2001-2009	6	1	1	10	15	90	11	1	1	10	15	90	11	1	1	10	15	90	12	7	1	10	15	90
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
2011-2023	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 passenger cars is one of the most influential sub-sources in the category, its underlying factors are compared to IPCC default values and differences are analysed (Table 4.6.6). 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 4.6.6. 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 CRT 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 3:5) support 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.

4.6.1.5 SOURCE-SPECIFIC RECALCULATIONS

General: Due to the recurring one-year lag from data from the Products Register, preliminary data for 2022 used in submission 2024 has been updated for HFC-32, HFC-125, HFC-134a and HFC-140a. Beside this a few changes of emission estimates have been done for submission 2025. Recalculations in 2.F.1.a, c, and f are due to updated activity data in 2.F.1.e and is a consequence of the combined top-down and bottom-up approach of the Swedish F-gas model. The reason for recalculations and effect on the reported emissions are presented in Table 4.6.7 below.

Table 4.6.7. Recalculations in CRT 2.F.1, submission 2025.

CRT	Reason for recalculation	Year	Recalculation*, kton CO_2 eq.
2.F.1.a	Increased emissions influenced by updated activity data in 2.F.1.e	2015–2022	2015: +0.07 2016: +0.06 2017: +0.06 2018: +0.15 2019: +0.49 2020: +0.76 2021: +3.00 2022: +5.97
	Updated activity data for HFC-32, HFC-125, HFC-134a and HFC-140a from the Products Register from the Swedish Chemicals Agency	2022	
2.F.1.c	Increased emissions influenced by updated activity data in 2.F.1.e	2015–2022	2015: +0.04 2016: +0.04 2017: +0.03 2018: +0.09 2019: +0.30 2020: +0.47 2021: +1.50 2022: +2.63
	Updated activity data for HFC-32, HFC-125, HFC-134a and HFC-140a from the Products Register from the Swedish Chemicals Agency	2022	
2.F.1.d	Decreased emissions due to the model introduction of refrigerants with lower-GWP	2018–2022	2018: -0.13 2019: -0.36 2020: -0.57 2021: -0.88 2022: -0.12
2.F.1.e	Updated activity data for heavy duty trucks	2015–2022	2021: -1.24 2022: -2.25
	Decreased emissions due to the model introduction of refrigerants with lower-GWP	2021–2022	

CRT	Reason for recalculation	Year	Recalculation*, kton CO_2 eq.
2.F.1.f	Increased emissions influenced by updated activity data in 2.F.1.e	2015–2022	2015: +0.0004 2016: +0.0003 2017: +0.0003 2018: +0.01 2019: +0.02 2020: +0.02 2021: -2.19 2022: -3.98
	Emissions influenced by the model introduction of lower-GWP refrigerants	2021–2022	
	Updated activity data for HFC-32, HFC-125, HFC-134a and HFC-140a from the Products Register from the Swedish Chemicals Agency	2022	

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 Foam blowing agents (CRT 2.F.2)

4.6.2.1 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 2008 and have since then decreased due to reduced leakage during manufacturing, according to data from the only Swedish 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 4.6.8.

Table 4.6.8. Summary of source category description, CRT 2.F.2, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.F.2	HFCs	-	-		T2a	PS	Yes
	PFCs	NA	NA		NO	NO	NO
	SF_6	NA	NA		NO	NO	NO

PS Plant Specific. T2a Tier 2a.

4.6.2.2 METHODOLOGICAL ISSUES

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 4.6.9). 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 12 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 and from 2020 only from stocks.

In the model, it is assumed that 20% of the XPS products have a lifetime of 12 years. The remaining 80% have a significantly longer lifetime, over 50 years. So, for 80% of the XPS produced using HFC-134a there is still leakage from stock and will be so for a long time.

There is no specific regulation and legislation concerning the HFCs from XPS at disposal, but XPS containing HFCs is classified as hazardous waste and the management of such waste is covered by the waste regulation. This includes requirements that hazardous waste must be sorted out and handled separately from other waste. Since 2015, there is a requirement for foam to be labelled as containing F-gas, according to Article 12(5) of EU 517/2014.

Table 4.6.9. 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. Given intervals 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.

Data 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, has been obtained from the producer, 1996 - 2017. For the years 2018 – 2021, the corresponding information has not been received from the company. There is a clearly declining trend for used and emitted amounts of HFC-152a between 2013 and 2017. This trend is used to estimate used and emitted amounts of HFC-152a for 2018. The result of estimated quantity for this year has been verified with the data in The Swedish Chemicals Agency's Product Register and show good agreement. However, the information on HFC-152a in the Product Register is confidential and can therefore not be used for the emission calculations. In submission 2022 and 2023, data on the quantities of HFC-152a used in 2019 and 2020 has been retrieved from the SPIN database. For 2021, data from The Swedish Chemicals Agency's Product Register has been used, as this data is not confidential for the year. A sharp reduction in the amounts of HFC-152a used can be seen between 2020 and 2021. Information in the environmental report for 2021 states that the company has worked to reduce the use of HFC-152a and that already in 2020 it began testing the use of propellant gases without HFC-152a. New tests were carried out in production in 2021, and in June 2021 the last amount of HFC-152a was consumed. After 2021, no HFCs have been used as blowing agents.

Data that could be used to calculate emissions from imported quantities of foam is not available. An increasing proportion of produced quantities of XPS currently use blowing agents other than HFCs, such as CO_2 and HFO. When compared to other comparable countries, in kg CO_2 eq per capita, Sweden's emissions are in the same order of magnitude as in, for example, Norway. They report in their NID (submission 2020) that emissions of HFC-134a per capita are between 0-1.9 kg CO_2 eq (AR4 GWP) for the years before 2008 and 2.0-3.9 kg of CO_2 eq (AR4 GWP) for 2008-2012, while emissions of HFC-152a are 0-1.74 kg of CO_2 eq (AR4 GWP) for the years 1990-2012. A corresponding calculation for Sweden shows emissions of HFC-134a between 0.65 and 7.2 kg of CO_2 eq (AR4 GWP) per capita for the years prior to 2008 and between 1 and 11 kg of CO_2 eq (AR4 GWP) for the period 2008-2012. Emissions of HFC-152a calculated per capita in Sweden are between 0.7 and 3.5 kg CO_2 eq (AR4 GWP) 1990-2012. The comparison with the Norwegian figures indicates that any underestimation of the emissions would be small and below the threshold of significance. Sweden therefore considers that it is not Good Practice to make large efforts to find out if there are ways to collect data on imported quantities of foam, including which blowing agents has been used in the production.

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 CRT 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.

4.6.2.3 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 uncertainty for activity data is judged to be ± 2% and the uncertainty of the emission factor for HFCs is judged to be ± 20%.

The time series are calculated using the same methodology for all years and are thus consistent.

4.6.2.4 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 (see Table 4.6.10).

Table 4.6.10. Leakage factor used for the first 15 years in the national method compared to 2006 IPCC Guidelines Table 7.6.

Year	National method		2006 IPCC Guidelines, Table 7.6	
	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 the 2006 IPCC Guidelines are presented in Table 4.6.11. The product lifetime of XPS-foam is very long, several decades, and the total amounts of emitted chemical are in the long run comparable.

Table 4.6.11. Emissions of HFC-134a and HFC-152a 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 CO_2 eq.)	Emissions of HFC-134a and HFC-152a according to 2006 IPCC Guidelines (kt CO_2 eq.)
1996	12	12
1997	77	83
1998	83	92
1999	99	110
2000	111	116
2001	109	113
2002	104	106
2003	97	96
2004	106	103
2005	87	83
2006	74	66
2007	54	44
2008	51	39
2009	39	30
2010	32	25
2011	36	28
2012	35	27
2013	37	29
2014	35	28
2015	34	27

Year	Emissions of HFC-134a and HFC-152a according to the national method (kt CO_2 eq.)	Emissions of HFC-134a and HFC-152a according to 2006 IPCC Guidelines (kt CO_2 eq.)
2016	33	27
2017	32	27
2018	31	27
2019	27	23
2020	26	23
2021	16	14
2022	10	9
2023	9	8
SUM 1996 - 2023	1496	1416

4.6.2.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed in submission 2025.

4.6.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.6.3 Fire protection (CRT 2.F.3)

4.6.3.1 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 4.6.12.

Table 4.6.12. Summary of source category description, CRT 2.F.3, according to approach 1.

CRT	Gas	Key Category Assessment, 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

4.6.3.2 METHODOLOGICAL ISSUES

All imports of HFCs to be installed in fire extinguishers are registered at the Swedish Chemicals Agency. In 2001, the use of HFC-227ea in fire extinguishers was introduced in Sweden. Data has been obtained from the companies supplying such systems (Table 4.6.13).

Table 4.6.13. 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%.

For 2017 and 2018, one of the companies reported unusual high emissions of HFC-227ea from stock (1.8 and 0.34 kton CO_2 eq, respectively).

4.6.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties are mainly associated with the exported amounts, which are relatively large. The uncertainty for activity data is judged to be ± 5% and the uncertainty of the emission factor for HFCs is judged to be ± 20%. The time series are calculated using the same methodology for all years and are thus consistent.

4.6.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

HFCs 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[223]. 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%.

4.6.3.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed in submission 2025.

4.6.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

[223] 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.

4.6.4 Aerosols (CRT 2.F.4)

4.6.4.1 SOURCE CATEGORY DESCRIPTION

HFC may be used as propellant gas in aerosols, but also as a component in 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 4.6.14.

Table 4.6.14. Summary of source category description, CRT 2.F.4, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.F.4	HFCs	-	-		T2a	D	Yes
	PFCs	NA	NA		NO	NO	NO
	SF_6	NA	NA		NO	NO	NO

D Default. T2a Tier 2a.

4.6.4.2 METHODOLOGICAL ISSUES

Emission estimates cover technical aerosols as well as metered dose inhalers. The estimates consist of emissions from the use of imported technical aerosols and metered dose inhalers containing HFCs. The contribution from metered dose inhalers was relatively small in the beginning of the time series but has increased over time. For 2020, 2021 and 2022, the contribution from metered dose inhalers was over 97% of totally reported emissions in CRT 2.F.4.

The technical aerosol importer provided information on the imported and exported amounts of HFC-134a in products. Table 4.6.15 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 CRT reporter, annual emissions from disposal are reported together with emissions from the use of aerosols. The HFC-134a emissions from technical aerosols decreased strongly from 2018 to 2019. The reason to this is that in 2019, no technical aerosols with HFC-134a were imported, therefore the emissions reported in 2019 only represent emissions from disposal of amounts imported in 2018. From 2020 no emissions of HFC-134a occur in CRT 2.F.4.b, only minor emissions of HFC-152a.

Table 4.6.15. 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,%	NO
Emissions per year X during use,%	50
Emissions per year X+1 during use,%	50

* Lifetime means the average expected lifetime of a product, not the designed technical lifetime from its first commissioning.
** Top-down calculations

For metered dose inhalers, statistics on the numbers of sold inhalers were, 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.

4.6.4.3 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 uncertainty for activity data is judged to be ± 5% and the uncertainty of the emission factor for HFCs is judged to be ± 20% for CRT 2.F.4.a. The corresponding figures for CRT 2.F.4.b are ± 50% and ± 20%, respectively. The time series are calculated using the same methodology for all years and are thus consistent.

4.6.4.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The emissions reported in CRT 2.F.4 are from products imported to Sweden. Data and information from the Products Register, hosted by the Swedish Chemicals Agency, could not be used for validation or reporting purposes since the information in the Product Pegister only contains information on imports in bulk.

4.6.4.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed in submission 2025.

4.6.4.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.6.5 Solvents (CRT 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.

4.6.6 Other applications (CRT 2.F.6)

No other applications are covered in the Swedish inventory.

4.7 Other product manufacture and use (CRT 2.G)

4.7.1 Electrical equipment (CRT 2.G.1)

4.7.1.1 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[224]. The end-of-life factor of 35 years indicates that SF_6 containing equipment started to be replaced in 2010. 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[225].

In submission 2017, amounts of gases recovered at decommissioning are reported for the first time in the CRT tables for CRT 2.G. Recovered amounts are calculated as amount in products at decommissioning minus emissions from disposal.

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 4.7.1.

[224] Matz Tapper, Swedenergy. Personal communication.

[225] 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.

Table 4.7.1. Summary of source category description, CRT 2.G.1, according to approach 1.

CRT	Gas	Key Category Assessment, 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	-	-		T2, T3	CS, PS	Yes

CS Country Specific. PS Plant-specific. T2 Tier 2. T3 Tier 3

* Distribution

** Production

4.7.1.2 METHODOLOGICAL ISSUES

The larger part of annual SF_6 emissions in earlier years originated from the manufacture of GIS (Table 4.7.2), where emissions in 1995 and 1997 peak due to a leaking valve in 1995 and to rebuilding and accidental leakages in 1997. The SF_6 emissions from production have decreased in later years due to measures taken at the production facility. These estimates, obtained from the industry, are of medium to high quality, with better quality in later years.

Table 4.7.2. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of SF6, 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.

For the early 1990s, assumptions on the emitted amounts of SF_6 from GIS manufacture were made in cooperation with the industry. The industry has also provided information concerning the used amount of SF_6 for GIS manufacture (Table 4.8.3), as well as the share of products that are exported from the country, which often exceeds 90% of the production.

In Table 4.7.3 the calculated emissions and accumulated stock of SF_6 for electrical equipment is presented.

Table 4.7.3. 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	3.00	NO	3.4
1995	70	0.42	3.50	NO	3.9
2000	101	0.61	0.68	NO	1.3
2005	136	0.68	0.47	NO	1.1
2010	184	0.92	0.30	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	237	1.2	0.13	0.086	1.4
2018	241	1.2	0.11	0.086	1.4
2019	250	1.2	0.13	0.086	1.5
2020	253	1.3	0.05	0.086	1.4
2021	248	1.2	0.10	0.118	1.5
2022	250	1.2	0.09	0.118	1.5
2023	255	1.3	0.04	0.118	1.4

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 for most years (between 9 and 34%). 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 are not 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 or the SPIN database 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 could not be unambiguously solved, the unaccounted SF_6 from the Products Register was allocated to be used as electrical insulation (accumulated stock).

4.7.1.3 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 uncertainty for activity data is judged to be ± 10% and the uncertainty of the emission factor for SF_6 is judged to be ± 20%.

The time series are calculated using the same methodology for all years and are thus consistent.

4.7.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.7.1.5 SOURCE-SPECIFIC RECALCULATIONS

Recalculations have been performed for 2018-2022 due to minor updates to activity data in submission 2025, resulting in decreased emissions by 0.0007-0.03 kt CO_2-eq.

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 SF_6 and PFCs from other product use (CRT 2.G.2)

4.7.2.1 SOURCE CATEGORY DESCRIPTION

The estimated emissions from the use of SF_6 and PFC-218 in running shoes and SF_6 in sound-proof windows are reported in CRT 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.

Sweden has no specific information on military applications/systems using SF_6 or heat transfer fluids in high-powered electronic applications using PFCs. The national military aircraft manufacture company has been contacted, but as of yet, no answer has been received regarding the use of SF_6. Sweden has also searched for information on the Internet and in the environmental reports of aircraft manufacturers and manufacturers of associated equipment, but no data was found to be available. Neither has Sweden data on the total number and types of accelerators in the country. But data from the largest accelerator in Sweden, MAX IV, indicate that the emission of SF_6 is very small, less than one kg per year. This source could thus be considered 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 4.7.4.

Table 4.7.4. Summary of source category description, CRT 2.G.2, according to approach 1.

CRT	Gas	Key Category Assessment, 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.

* Running shoes

** Sound-proof windows, manufacturing

*** Sound-proof windows, stock

4.7.2.2 METHODOLOGICAL ISSUES

For running 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.[226] According to the results from a study performed in early 2004[227] 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 4.64).

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 4.7.5, given intervals 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 have to be estimated from emission year 2020. The emissions of SF_6 for 2019 were less than 1 kton CO_2 eq. and has by 2020 increased to over 5 kton CO_2 eq. due to the fact that emissions from disposal is reported for 2020. Also, in 2021 the total SF_6 emissions were just over 5 kton CO_2 eq. In 2022 the total SF_6 emissions were just below 4.5 kton CO_2 eq. Similarly, to 2022, in 2023 the total SF_6 emissions were around 4.5 kton CO_2 eq.

[226] Weholt, Ø. 1999. Materialstrømsanalyse av SF_6. Beregning av potensielt og faktisk utslipp over tid

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

Table 4.7.5. 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,%	74	100
Emissions at disposal,%	100	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.

4.7.2.3 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 uncertainty for activity data is judged to be ± 50% for jogging shoes and ± 5% for barrier gas windows. Uncertainty of the emission factor for PFCs and SF_6 are judged to be ± 50%. The time series are calculated using the same methodology for all years and are thus consistent.

4.7.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.7.2.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed in submission 2025.

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 N_2O from product use (CRT 2.G.3)

4.7.3.1 SOURCE CATEGORY DESCRIPTION

In CRT 2.G.3, sold amounts and use of N_2O from product use 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 does not occur in Sweden and thus reported as not occuring (NO). N_2O for use as a propellant in aerosol products, primarily in food industry, is included.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), are presented in Table 4.7.6.

Table 4.7.6. Summary of source category description, CRT 2.G.3, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.G.3	N_2O	-	-		T1	CS	Yes

CS Country Specific. T1 Tier 1

4.7.3.2 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 – 2018). The time series for use of N_2O in Sweden is reported in CRT 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 in the Products Register at the Swedish Chemicals Agency show a large change between 2018 and 2019. It must be investigated what the reason is for this major change, and in submission 2025, instead, the trend from 2003 to 2018 has been used to estimate used amounts of N_2O for 2019-2023.

4.7.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Reported time series are considered to be consistent, except for the last four years (2019-2022) where the trend from 2003 to 2018 has been used to estimate used amounts of N_2O. Uncertainties for CRT 2.G.3 is based on expert judgement. The uncertainty for the N_2O emission is set to ± 10%, and the uncertainty of activity data is set to ± 10%.

4.7.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.7.3.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed in submission 2025.

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 Tobacco smoking and use of fireworks (CRT 2.G.4)

No greenhouse gas emissions are reported from tobacco smoking and use of fireworks.

4.8 Other product manufacture and use (CRT 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). CRT 2.H.3 includes battery production, mineral wool production and quarrying and mining of minerals other than coal.

Sweden reports emissions of CO_2, CH_4 and N_2O from pulp and paper industry, CO_2 from use of solid coke in the sugar industry and CO_2 from mineral wool production. These emissions were previously allocated to the energy sector.

4.8.1 Pulp and paper (CRT 2.H.1)

4.8.1.1 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 CRT 1.A.2.D. Of the facilites with process-related emissions reported in CRT 2.H.1, one shut down in 2004, two in 2008 and one in 2012. For 2023, emissions from 33 individual pulp and paper facilities are included in reported emissions in CRT 2.H.1. The Kraft process (sulphate) dominates in Sweden, but the source category also includes emissions from sulphite facilities and facilities that are mainly CTMP (Chemo Thermo Mechanical Pulp) or TMP (Thermo Mechanical Pulp) facilities.

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 4.9.1.

Table 4.9.1. Summary of source category description, CRT 2.H.1, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.H.1	CO_2	-	-		T1	CS	Yes
	CH_4	-	-		T2	CS	Yes
	N_2O	X	-		T2	CS	Yes

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

4.8.1.2 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 following emissions are reported from the pulp and paper industry: CH_4, CO, CO_2, N_2O, NMVOC, NO_x and SO_2).

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 (and biogenic CO_2 emissions). The black liquor contains organic compounds and chemicals and is combusted to recover sodium (Na) and sulphur (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 amount of combusted black liquor and related CO_2 emissions are reported in CRT 1.A.2.d in order to account for the biogenic CO_2 emissions in the memo item "CO_2 emissions from biomass".

The estimated CO_2 process emissions that arise as a result of the use of limestone as make-up lime are allocated in CRT 2.A.2. Minor emissions of fossil CO_2 from use of soda ash and from use of limestone for flue gas cleaning were reported for the first time in CRT 2.H.1 in submission 2019.

The reported emissions of NMVOC do not include terpenes.

Activity data is presented in Figure 4.9.1 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.

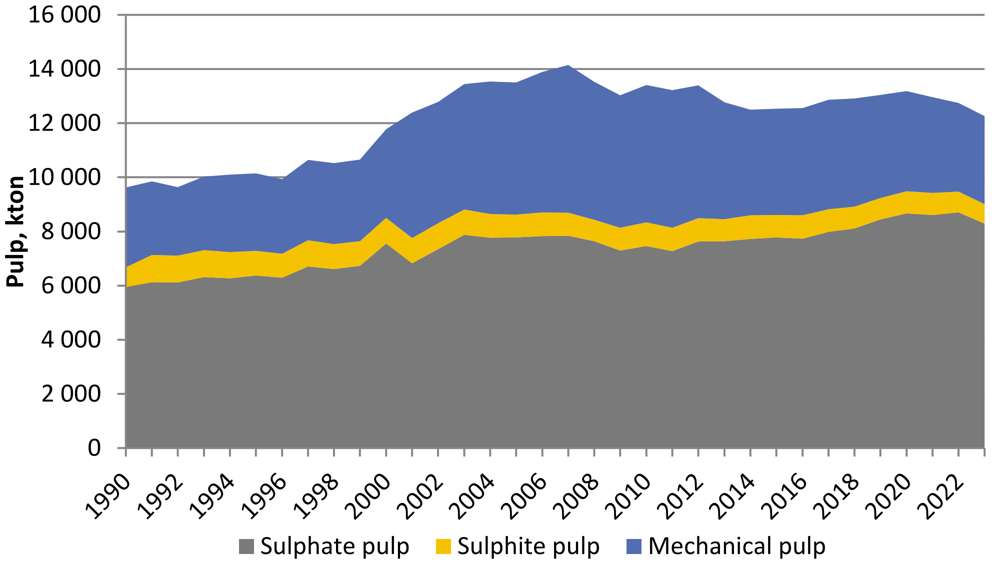

Figure 4.9.1. Production of pulp in Sweden 1990-2023.

4.8.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainty in activity data is ± 7% and uncertainty in emission factors are:
CH_4 ± 21%, N_2O ± 22%, CO ± 54%, CO_2 ± 5%, NMVOC ± 116%, NO_x ± 11% and SO_2 ± 24%

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

Update of the amount of flared LPG during 2022 at one of the facilities resulted in the decrease of emissions of CO_2 (by 0.015 kt), CH_4 (by 0.0000002 kt), and N_2O (by 0.00000002 kt).

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 Food and drink (CRT 2.H.2)

4.8.2.1 SOURCE CATEGORY DESCRIPTION

The food and drink industry is a moderate source of NMVOC and CO_2 emissions 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. In addition, CO_2 emissions from the use of coke for process purposes in one sugar refinery is reported.

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 4.9.2.

Table 4.9.2. Summary of source category description, CRT 2.H.2, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.H.2	CO_2				T3	PS	Yes
	CH_4	NA	NA		NA	NA	NA
	N_2O	NA	NA		NA	NA	NA

4.8.2.2 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[228] together with figures on import and export[229]. NMVOC emissions from beer production are based on the Swedish annual total production of beer[230]. 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 from Statistics Sweden. For the NMVOC emission estimates, emission factors presented in Table 4.9.3 are used. Emission factors used in 2.H.2 are mainly from the EMEP/EEA Emission Inventory Guidebook 2023. Sweden assumes that abatement equipment reduces the emissions by 90%.

In submission 2025, CO_2 emissions from the use of coke for process purposes at one sugar producer are reported for the first time in 2.H.2. These emissions were previously reported in 1.A.2.e. Emissions are based on data reported to the EU ETS and the quarterly fuel statistics.

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

[229] Statistics Sweden. http://www.scb.se/

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

Table 4.9.3. NMVOC emission factors for the reported production activities in CRT 2.H.2 - Food and drink. Sweden assumes that abatement equipment reduces the emissions by 90%.

Production activity	Emission factor	Unit	Reference EF (see footnotes)
Liquors	0.6	kg/1000 litres	231
Wine	0.08	kg/1000 litres	EMEP/EEA Guidebook 2019
Beer	0.035	kg/1000 litres	EMEP/EEA Guidebook 2019
Bread (typical Europe)	0.45	kg/Mg	EMEP/EEA Guidebook 2019
Cakes	0.1	kg/Mg	EMEP/EEA Guidebook 2019
Biscuits	0.1	kg/Mg	EMEP/EEA Guidebook 2019
Breakfast cereals	0.1	kg/Mg	EMEP/EEA Guidebook 2019
Sugar	1	kg/Mg	EMEP/EEA Guidebook 2019
Yeast	1.8	kg/Mg	232
Margarine and solid cooking fats	1	kg/Mg	EMEP/EEA Guidebook 2019
Coffee roasting	0.055	kg/Mg	EMEP/EEA Guidebook 2019
Animal feed	0.1	kg/Mg	EMEP/EEA Guidebook 2019

4.8.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The time series is consistent. The uncertainties are calculated according to Guidebook 2023. The uncertainty for NMVOC is ± 200%.

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

CO_2 emissions 1990-2022 (0.19-22 kt) from the use of coke in sugar production have been re-allocated from CRT 1.A.2.e to CRT 2.H.3 in submission 2025.

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 Other (CRT 2.H.3)

4.8.3.1 SOURCE CATEGORY DESCRIPTION

In CRT 2.H.3 CO_2 emissions from mineral wool production are reported.

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 4.9.4.

[231] Based on information from one producer, 2001

[232] Based on information from Finland

Table 4.9.4. Summary of source category description, CRT 2.H.3, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.H.3	CO_2	-	-	-	T2	D	No, see Annex 5
	CH_4	NA	NA	NA	NA	NA	NA
	N_2O	NA	NA	NA	NA	NA	NA

D Default. T2 Tier 2.

Mineral wool production occurs at two facilities run by two companies. Before 2004 there were three facilities, but one closed down during 2003.

4.8.3.2 METHODOLOGICAL ISSUES

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 the fact that 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.

4.8.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainties for emissions in 2.H.3 are based on expert judgement (CO_2). The uncertainty of direct CO_2 emissions in 2.H.3 is set to ± 6% and the time series is consistent.

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

No source-specific recalculations have been made in submission 2025.

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.

5 Agriculture (CRT 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.[233] 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. The share of agricultural land used in organic farming has increased, on the other hand.[234]

Total greenhouse gas (GHG) emissions from the agricultural sector have decreased by 13 % since 1990, from 7 294 kt CO_2-eq to 6 318 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.

[233] Ministry of the Environment, 2001.

[234] Swedish Board of Agriculture, www.jordbruksverket.se

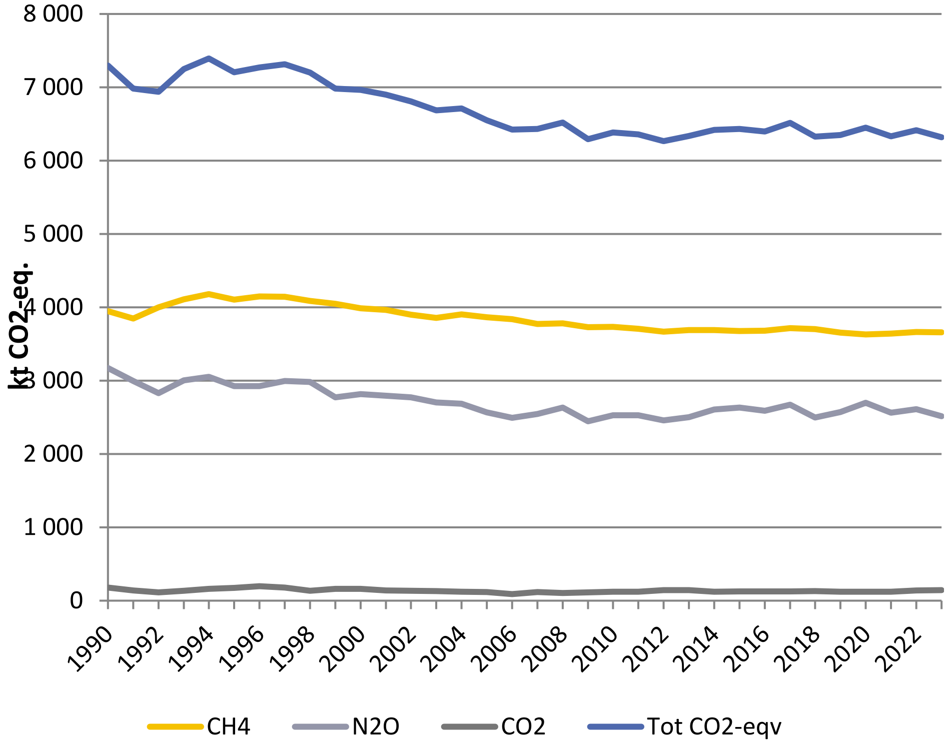

Figure 5.1. Total emissions of all greenhouse gases 1990-2023 calculated as CO_2-eq. from CRT 3, agriculture.

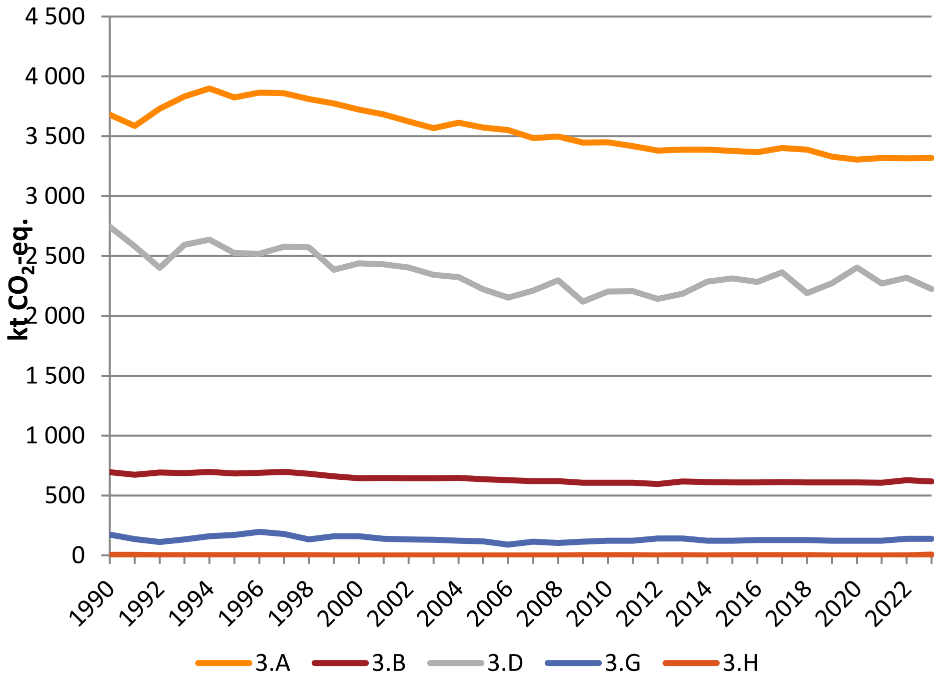

Figure 5.2. Total emissions of all greenhouse gases 1990-2023 calculated as CO_2-eq. from the different agricultural sub-sectors. There are no emissions from 3.C, 3.E-F and 3.I-J.

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[235]. 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 or younger than 6 months) is model-assisted: 60% are assumed younger than 6 months and the rest are assumed older than 6 months. Swine living shorter than one year, piglets and fattening pigs, are estimated from slaughter statistics. Concerning horses, the Farm Register underestimates the number of horses because only horses on farms are included (i.e. not horses for private leisure activities). However, three separate surveys[236] 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.

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[1]	Dairy cows	Dairy cows	Dairy cows
Non-Dairy Cattle[1]	Suckler cows	Suckler cows	Suckler cows
	Heifers	Heifers	Heifers
	Bulls and steers	Bulls and steers	Bulls and steers
	Calves	Calves < 6 months[3] Calves > 6 months[3]	Calves
Swine[1]	Swine	Sows	NO
		Boars	
		Pigs for meat production[2]	
		Piglets[2]	
Sheep[1]	Sheep	Sheep	Sheep
Goats[1]	Goats	Goats	Goats
Horses[1]	Horses	Horses	Horses
Poultry[1]	NE	Laying hens	NO
		Chickens	
		Slaughter Chickens[2]	
		Turkeys[2]	
Fur-bearing animals	NE	Minks[4]	NO
		Foxes[5]	
Other	Reindeer[6]	NO	Reindeer

(1) Swedish board of agriculture. (2) Estimated from slaughter statistics. (3) The age distribution of calves is estimated by using standard values. (4) Svensk mink (The trade organization Swedish mink). (5) Statistics Sweden (foxes exists only before 2001). (6) Sametinget (The Sami Parliament of Sweden).

[235] Swedish Board of Agriculture, JO 20-series.

[236] Swedish Board of Agriculture, JO 24-series.

5.2 Enteric Fermentation (CRT 3.A)

5.2.1 Source category description

Enteric fermentation from cattle is the major source of methane emissions in CRT 3.A. The total number of livestock in Sweden 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, CRT 3.A, according to approach 1.

CRT	Gas	Key Category Assessment, 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	-		T1	D	Yes
3.A.4 Goats	CH_4	-	-		T1	D	Yes
3.A.4 Horses	CH_4	X	-		T1	D	Yes
3.A.4 Reindeer	CH_4	X	-		T1	D	Yes
3.A.4 Swine	CH_4	-	-		T1	D	Yes

CS - Country Specific. T1 - tier 1. D - Default.

5.2.2 Methodological issues

5.2.2.1 EMISSION FACTORS, METHANE

The livestock population (table 5.5) 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 breeds and three months for other breeds. Since 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[237]. 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) [238]. The methods and the activity data used are to a large extent developed within

[237] Statistik rennäring - Sametinget

[238] Bertilsson, 2016.

the NorFor[239] 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) and the previous system used 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[240] 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[241], 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 (kg/year), MilkYield = total milk delivered to Swedish dairies (kg/year), 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 cow and 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.

$$ME\_Feed = Frac_{Conc} \times Conc + (1- Frac_{Conc}) \times Silage$$

239 http://www.norfor.info

240 http://www.agriwise.org

241 Data from The Swedish Board of Agriculture (jordbruksverket.se) Mejeriproduktion efter Variabel och År. PxWeb (sjv.se)

Metabolisable energy content in the feed (MJ/kg). $Frac_{Conc}$ = fraction of concentrates in the feed, Conc = energy content in concentrates (13.4 MJ/kg DM), Silage = energy content in silage (see table 5.6).

$$FA = Frac_{Conc} \times Conc\_F + (1- Frac_{Conc}) \times Silage\_F$$

Fatty acids content in the feed. Conc_F = fatty acids content in concentrates (43 g/kg DM), Silage_F = fatty acids 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[242].

$$EF\_Dairy = (CH_4\_MJ / 55.65) \times 365$$

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).

$$GE = DMI \times GE\_Feed$$

Gross Energy intake (GE) is calculated by multiplying DMI with the gross energy content of silage and concentrate, 20.0 and 18.4 MJ/kg ts respectively[243] (GE_Feed). Sweden does not use GE activity data in the model for calculating EF_Dairy but it is being calculated efterwards to be reported in the CRT tables.

$$\mathrm{Ym} = CH_4\_MJ / GE$$

The average methane conversion rate (Y_m) for dairy cattle is calculated by dividing the energy content in the emitted methane with the gross energy intake.

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). Due to slightly lower quality of feed compared to dairy cows, the energy content in silage is estimated to be 9.5 MJ/kg DM for the complete time series. (v) $Frac_{Conc}$ is zero, i.e. only silage feeding is assumed.

5.2.2.1.3 Calves, Heifers, bulls and steers

The estimation of the emission factors for calves, heifers and bulls and steers differ slightly from the method used for dairy cattle and suckler cows. Especially a reduced

[242] Nielsen et al. 2013

[243] McDonald et al. 2011

amount of activity data is 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.

Table 5.3. Activity data used to estimate the emissions factors for enteric fermentation[244].

	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	67.5	101.2	102.1
Metabolisable energy in feed (MJ/kg DM)	11.5	10.1	10.1	12.3	11.7	10.4
$Frac_{Conc}$	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,

$$CH_4\ MJ\ (fraction\ of\ GE) = -0.046 \times Frac_{Conc} + 0.071379$$

Where $Frac_{Conc}$ is the fraction of concentrates in the feed. This equation is used in the NorFor and is based on Danish trials[245]. 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 to get the annual emissions.

For the heifers and bulls and steers categories, the emission factors in table 5.7 are aggregated to take into account different age groups. Calves are defined as cattle younger than one year and the calf category is assumed to consist of 50% heifer calves and 50% bull calves. The heifer category is assumed to consist of 70 % individuals between one and two years and 30 % above two years. The corresponding numbers in the bulls and steers category is assumed to be 85 % between one and two years and 15 % above two years.

[244] Bertilsson 2016 och Spörndly 2003

[245] Nielsen 2013

Table 5.5. Population size of different animal groups (1000s heads).

Year	Dairy cows	Non-Dairy Cattle				Swine				Sheep	
		Suckler cows	Heifers	Bulls and steers	Calves	Sow	Pig for meat production	Piglet	Boar	Sheep	Lamb
1990	576	75	337	206	524	221	1 286	844	8.6	162	244
1995	482	157	370	226	542	237	1 310	855	7.6	195	266
2000	428	167	365	224	500	202	1 155	630	4.2	198	234
2005	393	177	327	200	508	185	1 093	599	2.7	222	249
2010	348	197	322	191	479	154	977	487	2.3	273	292
2015	340	184	311	178	467	140	852	425	1.5	289	306
2020	303	207	301	179	462	130	867	433	1.4	263	238
2021	302	210	298	178	465	128	874	436	1.5	272	252
2022	297	213	302	180	458	126	880	439	1.6	264	245
2023	296	210	300	180	459	111	848	423	1.6	264	222

Table 5.5 (continued).

Year	Horses	Goats		Other		Poultry			
	Horse	Goat	Kid	Reindeer	Fur-bearing animals	Laying hen	Turkey	Chicken	Slaughter Chicken
1990	316	2.8	2.8	253	297	6 400	122	2 200	4 476
1995	316	2.8	2.8	221	254	6 100	122	1 800	7 055
2000	316	2.8	2.8	261	276	5 700	122	1 700	7 896
2005	323	3.7	3.7	250	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	240	210	7 571	156	1 842	11 044
2020	356	7.5	7.5	240	200	8 403	130	2 420	12 696
2021	356	7.9	7.9	240	125	6 363	132	2 390	13 305
2022	356	8	8	240	135	7 919	133	1 722	12 986
2023	356	7.8	7.8	240	100	7 717	131	2 700	12 586

Table 5.6. Activity data used for estimating the emissions from enteric fermentation for dairy cattle.

Year	Total milk delivered* (kt)	Average fat content (%)	Average protein content (%)	Yield per cow, kg ECM/yr	Energy in silage (MJ ME/kg TS)	$Frac_{Conc}$	CH_4 EF for Dairy Cattle (kg CH_4/head/year)
1990	3 432	4.31	3.36	6 503	9.5	0.5	112.2
1995	3 243	4.33	3.34	7 352	9.6	0.5	121.9
2000	3 297	4.18	3.28	8 240	9.8	0.51	130.6
2005	3 163	4.25	3.38	8 734	9.9	0.52	135.2
2010	2 862	4.23	3.41	8 928	10	0.54	135.7
2015	2 933	4.25	3.42	9 401	10.1	0.55	140.0
2020	2 773	4.23	3.51	9 997	10.1	0.55	146.9
2021	2 782	4.26	3.51	10 118	10.1	0.55	148.3
2022	2 765	4.25	3.5	10 216	10.1	0.55	149.4
2023	2 819	4.26	3.53	10 485	10.1	0.55	152.6

* Including on-farm consumption.

Table 5.7. Methane from animals, emission factors used.

Livestock subgroups	kg CH_4/head/year	Method
Dairy cows	See table 5.6	1
Suckler cows	91.5	1
Heifers	63.7	1
Bulls and steers	57.8	1
Calves	25.5	1
Swine	1.5	2
Sheep	9	2
Goats	9	2
Horses	18	2
Poultry	No fermentation assumed	
Reindeer	12.5	3

(1) Bertilsson, 2016. (2) 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories table 10.10. (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 the increase is that as from this year also uncovered gilts was included in this group. Concerning horses, 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 determine whether all annual changes are reasonable. We compare the times series for the emission with the time series for the activity data to confirm that they are in agreement. We regularly conduct crosschecks of country-specific factors against the IPCC default factors. 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

No recalculations have been made in this category since last submission.

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 (CRT 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, CRT 3.B, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
3.B.1 Dairy cattle	CH_4	X	-		T2	CS	Yes
	N_2O	-	X		CS, T2	CS, D	Yes
3.B.1 Non-dairy cattle	CH_4	X	-		T2	CS	Yes
	N_2O	X	-		CS, T2	CS, D	Yes
3.B.2 Sheep	CH_4	-	-		T1	D	Yes
	N_2O	-	-		T2	D	Yes
3.B.3 Swine	CH_4	-	-		T2	CS	Yes
	N_2O	-	-		CS, T2	CS, D	Yes
3.B.4 Fur-bearing animals	CH_4	-	-		T1	D	Yes
	N_2O	-	-		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	-	-		T2	D	Yes
3.B.4 Reindeer	CH_4	-	-		T1	D	Yes
	N_2O	-	-		T2	D	Yes
3.B.5 Indirect	N_2O	-	-		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[246]. Data on stable periods (Table 5.9) and the manure management systems, liquid (Table 5.10), solid (Table 5.11) and deep bedding (Table 5.12) originate from this survey. Data on manure treated in on-farm anaerobic digesters (Table 5.13) are derived from the report series "Production and use of biogas and digestate", produced by the Swedish Gas Association for the Swedish Energy Agency[247]. This report series has been produced since 2005. Between 1997 (when the first pilot plants started to produce small amounts of biogas) and 2005, we assume a linear increase in amount of manure used as substrate. Emissions from

[246] Statistics Sweden, MI 30-series.

[247] Swedish Energy Agency. Produktion och användning av biogas och rötrester.

on-farm digesters are accounted for in the agricultural sector, while emissions during manure management from co-digesters (Table 5.14) 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 generally used as fertiliser. Data on composting (Table 5.13) originate from the report "Horse keeping in Sweden 2016"[248]. Only manure from horses is systematically composted in significant amounts in Sweden. National estimates of stable periods have been available since 1997. Before this, the data is 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. Annual average population for swine categories with shorter life span than one year, piglets and fattening pigs, is calculated from slaughter statistics. For other swine categories, the farm registry is used. 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 5.15). 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 5.16 and Table 5.17. The data are estimated values per head and year. That is, for animals who is in a animal category shorter than one year, for example pigs for meat production, the excretion if one hypothetical animal of a specific animal category would excrete during one 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 statistics from the Swedish Board of Agriculture 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. The Nex value for reindeer is calculated using the metod and data from the 2006 IPCC Refinement from 2019, Chapter 10, table 19 and equation 10.30 with the assumption (from the Sami parliament) that the slaughter weight represents half the live weight, the average reindeer weight was estimated to 64 kg. All emission factors used in the calculations are presented in Table 5.18.

[248] Swedish Board of Agriculture. Hästhållning i Sverige 2016.

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
2020	7.1	5.1	5.7	9.1	7.7	6	0	12
2021	7.1	5.1	5.7	9.1	7.7	6	0	12
2022	7.2	5.2	5.8	9.0	7.9	6	0	12
2023	7.2	5.2	5.8	9.0	7.9	6	0	12

Table 5.10. Percentage of manure from different animals handled in liquid storage systems

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	22.6	15.5	16.3	19.0	19.5	44.0	44.0	0.0	25.0	0.0
1995	30.6	21.0	22.0	25.8	26.5	63.0	63.0	0.0	25.0	0.0
2000	39.0	12.5	13.2	16.4	16.4	80.5	25.8	0.0	25.0	0.0
2005	50.8	5.9	19.6	22.5	18.9	91.3	31.8	0.0	20.8	0.0
2010	57.1	11.2	22.3	28.6	16.8	91.3	60.4	0.0	12.0	0.0
2015	60.4	10.0	24.9	31.4	16.1	81.4	49.7	0.0	30.1	0.0
2020	63.8	9.8	24.0	36.6	16.9	78.3	45.6	0.0	5.6	3.2
2021	63.7	9.7	24.0	36.5	16.8	77.8	45.4	0.0	5.6	3.2
2022	64.2	9.8	23.4	35.8	18.3	75.3	49.4	0.0	9.9	0.0
2023	63.6	9.7	23.2	35.5	18.1	72.3	47.4	0.0	9.9	0.0

Table 5.11. Percentage of manure from different animals handled in solid storage systems

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	51.9	28.9	30.3	35.5	36.4	54.0	45.0	50.0	0.0	100.0	33.0	55.0	87.3
1995	43.8	23.4	24.5	28.7	29.4	35.0	26.0	50.0	0.0	100.0	33.0	55.0	87.3
2000	35.3	28.0	29.5	36.7	36.7	18.0	67.0	50.0	0.0	100.0	33.0	55.0	87.3
2005	22.4	19.0	16.7	27.2	22.8	6.2	45.6	50.0	0.0	100.0	33.0	72.6	87.3
2010	16.4	20.1	15.2	25.8	22.0	5.2	30.4	50.0	0.0	100.0	33.0	88.0	87.3
2015	10.8	19.9	11.9	25.3	16.1	3.4	36.0	50.0	0.0	100.0	33.0	64.6	87.3
2020	5.1	10.3	7.9	10.6	11.9	2.3	23.8	50.0	0.0	100.0	33.0	90.9	69.6
2021	5.1	10.3	7.9	10.6	11.9	2.3	23.8	50.0	0.0	100.0	33.0	90.9	69.6
2022	4.7	11.0	7.7	11.8	10.6	3.0	13.5	50.0	0.0	100.0	33.0	86.0	61.0
2023	4.7	11.0	7.7	11.7	10.6	3.0	13.5	50.0	0.0	100.0	33.0	86.0	61.0

Table 5.12. Percentage of manure from different animals handled as deep bedding

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	0.8	7.2	7.6	8.9	9.1	2.0	11.0	0.0	2.0	20.0	13
1995	0.8	7.2	7.6	8.9	9.1	2.0	11.0	0.0	2.0	20.0	13
2000	0.8	7.7	8.1	10.1	10.1	1.0	7.0	0.0	2.0	20.0	13
2005	0.4	16.0	9.8	19.9	21.6	1.3	22.1	0.0	2.0	6.6	13
2010	0.8	14.5	10.5	18.8	29.5	0.9	7.4	0.0	2.0	0.0	13
2015	0.9	17.1	11.9	22.4	34.5	1.5	6.0	0.0	2.0	5.3	13
2020	1.0	21.3	13.3	25.6	33.5	1.0	19.8	0.0	2.0	3.6	27
2021	1.0	21.2	13.3	25.6	33.5	1.0	19.8	0.0	2.0	3.6	27
2022	0.9	21.1	14.7	24.0	34.6	1.9	24.1	0.0	2.0	4.1	39
2023	0.9	21.1	14.7	23.9	34.5	1.9	24.1	0.0	2.0	4.1	39

Table 5.13. Percentage of manure from different animals handled in on-farm anaerobic digestion treatment and composting systems. Affects only cattle, swine and horses. MCF for the entire digester process is given for different years

	Anaerobic digestion in on-farm digesters										Composting
Year	**Dairy cattle**	Suckler cows	Heifers	Bulls and steers	Calves	**Non-Dairy cattle**	Pigs for meat production	Other swine	**Swine**	**MCF for digesters**	**Horses**
1990	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	15.0
1995	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	15.0
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.1	5.7	15.0
2005	0.1	0.0	0.0	0.1	0.1	0.0	0.4	0.1	0.3	5.6	15.0
2010	0.2	0.1	0.1	0.1	0.1	0.1	0.8	0.6	0.8	5.5	15.0
2015	1.2	0.3	0.6	0.8	0.5	0.5	4.7	2.9	4.2	5.7	15.0
2020	1.7	0.5	0.8	1.2	0.7	0.7	6.6	3.8	5.9	5.7	15.0
2021	2.0	0.5	0.9	1.4	0.9	0.9	7.6	4.5	6.8	5.9	15.0
2022	2.7	0.7	1.2	1.8	1.2	1.1	9.9	6.5	9.1	5.6	15.0
2023	3.0	0.8	1.3	2.1	1.4	1.3	11.9	7.8	10.9	5.6	15.0

Table 5.14. Manure handled in anaerobic digestion treatment in co-digesters, percentage for different animals. These fractions of the manure are during manure management accounted for in the waste sector

	Anaerobic digestion in co-digesters								
Year	**Dairy cattle**	Suckler cows	Heifers	Bulls and steers	Calves	**Non-Dairy cattle**	Pigs for meat production	Other swine	**Swine**
1990	NO	NO	NO	NO	NO	NO	NO	NO	NO
1995	NO	NO	NO	NO	NO	NO	NO	NO	NO
2000	0.1	0.0	0.0	0.1	0.1	0.0	0.4	0.1	0.3
2005	0.2	0.1	0.1	0.1	0.1	0.1	0.9	0.3	0.7
2010	0.5	0.1	0.2	0.3	0.2	0.2	1.8	1.2	1.6
2015	2.2	0.6	1.1	1.5	1.0	1.0	8.9	5.5	8.0
2020	3.0	0.8	1.4	2.1	1.3	1.3	11.9	6.9	10.6
2021	2.9	0.8	1.3	2.0	1.3	1.3	11.3	6.6	10.1
2022	2.6	0.7	1.2	1.8	1.2	1.1	9.8	6.4	9.0
2023	2.8	0.8	1.2	1.9	1.3	1.2	10.9	7.2	10.0

Table 5.15. Manure 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
2020	5.39	137.0
2021	5.39	138.2
2022	5.40	139.2
2023	5.41	141.9

Table 5.16. Manure excretion 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 5.17. 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	5.4	2019 refinement, typical animal mass 64 kg		

Data from the Swedish Board of Agriculture except the value for reindeer.

5.3.2.1 EMISSIONS OF METHANE (INCLUDING EXCRETION FROM GRAZING ANIMALS) (CRT 3.B(A))

The IPCC tier 2 methodology is used for estimating methane from manure management for all animal groups, including excretions from grazing animals. The formula to calculate the emission factors for each livestock group, *i*, according to IPCC guideline's tier 2 methodology is:

$$EF_i = VS_i \times 365 \times B_{0i} \times 0.67 \times \sum_j MCF_j \times MS_{ij}$$

Where VS_i is the volatile substance excreted, 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.

For cattle and swine country specific values of VS are used whereas default values from 2019 Refinement are used for all other animal groups. The B_{0i} and MCF factors used are the default values from the 2006 IPCC guidelines table 10A-4 to 10A-9 and table 10.17

respectively, except for B_0 for swine and for the country-specific MCF for liquid manure and digesters. For swine the B_0 value 0.268 from the substrate handbook[249] is used.

For liquid manure the MCF 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 2019 Refinement of the 2006 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 for the entire digester process from storage of substrate to storage of digestate, are from a studies relevant to Swedish conditions. Rodhe et al. (2015)[250] investigated the greenhouse gas emissions from storage of digested and non-digested cattle slurry. From this study the $MCF_{storage,digestate}$ of 25% was obtained. The B_0 for digestate is 30% out of B_0 for untreated manure and the estimation that 35% of the total VS is consumed during the digestion process [251]. From Lantz & Björnsson[252] 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 remaining from cattle; the methane leaked 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[253] and the flare efficiency for the methane flared is estimated to be 90%.

The reported emissions in the CRT 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. This is to some extent counteracted by an increased use of deep litter systems for non-dairy cattle, and by an increased use of liquid systems for dairy cattle.

[249] Carlsson M & Uldal M. 2009

[250] Rodhe et al. (2015)

[251] Berglund, M. & Mjöfors, K. 2024.

[252] Lantz, M. & Björnsson, L. 2016

[253] Ahlberg-Eliasson et al. 2017

Table 5.18. Emission factors for manure management.

Manure Management System		MCF (% of B_0)		Note
Solid manure		2		1
Liquid manure		3.5		2
Deep litter		21		1
Digesters		See table 5.13		4
Composting		1		1
Pasture/Range/Paddock		0.47		1
B_0 Pasture/Range/Paddock		0.19 m^3 CH_4/kg VS		1
Animal category	**TAM (kg)**	**VS**	**B_0 (m^3 CH_4 / kg VS)**	
Dairy Cattle	-	87% of manure production (DM)	0.24	3, 1
Non-Dairy Cattle		87% of manure production (DM)	0.18	3, 1
Swine		87% of manure production (DM)	0.268	3, 5
Horse	377	5.65 kg VS / 1000 kg animal mass and day	0.30	1
Goat	40	9 kg VS / 1000 kg animal mass and day	0.18	1
Sheep	40	8.2 kg VS / 1000 kg animal mass and day	0.19	1
Turkeys	6.8	10.3 kg VS / 1000 kg animal mass and day	0.36	1
Laying hens	1.9	8.6 kg VS / 1000 kg animal mass and day	0.39	1
Chickens	1.4	5.3 kg VS / 1000 kg animal mass and day	0.36	1
Slaughter Chickens	1.2	16.1 kg VS / 1000 kg animal mass and day	0.36	1
Reindeer	64	0.39 kg VS / day	0.19	4, 1, 1
Fur-bearing animals	-	0.14 kg VS / day	0.25	1
Manure Management System		**Emission factors for N_2O (% N_2O-N of total N)**		
Liquid manure		0.5%		1
Solid manure		1.0%		1
Solid manure, hourses		0.5%		1
Solid manure, poultry		0.1%		1
Deep litter		1%		1
Deep litter, poultry		0.1%		1
Digesters		0.006%		1
Composting		0.5%		1
Pasture/Range/Paddock (Cattle) (Aggregated)		0.4%		1
Pasture/Range/Paddock (Sheep & other animals)		0.3%		1

MCF=Methane Conversion Factor. B_0=maximum methane producing capacity for manure. TAM=Total Animal Mass. VS= Volatile Substance. (1) 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. (2) Rodhe et al. 2009. (3) Dustan 2002. (4) National. (5) Carlsson M & Uldal M. 2009.

5.3.2.2 DIRECT EMISSIONS OF NITROUS OXIDE FROM MANURE MANAGEMENT (EXCLUDING EXCRETION FROM GRAZING ANIMALS) (CRT 3.B(B))

N_2O from manure management is estimated with the 2019 Refinement to the IPCC Guidelines, tier 2 methodology. Default emission factors from the 2019 Refinement to the 2006 IPCC Guidelines which are based on more recent literature are used in combination with national activity data. The emission of N_2O from manure management is calculated as:

$$N_2O = \sum_S \left(\sum_T N_T \times Nex_T \times MS_{(T,S)} \times EF_{(T,S)} \right) \times {}^{44}/_{28}$$

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 5.13). The emission factors are described in table 5.18. In the CRT 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. $N_{volatilization\text{-}MMS}$). 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 is considered to be low, because Swedish law regulates that the storage must be designed to minimize the leaching and runoff from manure into the environment. However, the model used to estimate nitrogen loss from leaching and runoff (see sector 5.4.2.2.2) will also capture this part, and the complete emissions are 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 NO_x and N_2 have to be taken into account. To estimate the fraction of nitrogen lost as NO_x, 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 estimated using the difference between the fractions in Table 10.22 and Table 10.23 in the 2006 guidelines (Table 5.19).

Table 5.19. 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	Not occuring
Dairy cattle	Solid storage	0.10
Dairy cattle	Deep bedding	0.10
Other cattle	Liquid/Slurry	Not occuring
Other cattle	Solid storage	0.05
Other cattle	Deep bedding	0.10
Swine	Liquid/Slurry	Not occuring
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 is mainly built on data collected through Statistics Sweden's survey on use of fertilisers and animal manure in agriculture [254]. 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[255]. As from 2005, regional results are published at the website of Statistics Sweden[256]. 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)

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[257]

P = stable periods[258]

T = Proportion of ammoniacal nitrogen

F(v) = emission of nitrogen through stable ventilation,% of total nitrogen content in stable manure[259].

F(l) = emission of nitrogen during storing,% of total nitrogen content in stable manure after ventilation losses[260].

F(s) = emission of nitrogen during spreading,% of ammoniacal nitrogen content in stable manure after ventilation and storing losses[261].

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[262]. 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

[254] Statistics Sweden, MI 30-series.

[255] Swedish Environmental Protection Agency 1997

[256] Statistics Sweden, MI 37-series.

[257] Swedish Board of Agriculture 1995; Swedish Board of Agriculture 2000; Swedish Board of Agriculture 2001

[258] Statistics Sweden, MI 30-series.

[259] Swedish Board of Agriculture 2005

[260] Swedish Institute of Agricultural and Environmental Engineering 2002

[261] Swedish Institute of Agricultural and Environmental Engineering 2002

[262] Statistics Sweden, MI 30-series.

Report to the LRTAP Convention for a detailed description of the calculations and used emission factors[263].

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 until 2013 and after that every third year, 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 determine whether all annual changes are reasonable. We compare the times series for the emission with the time series for the activity data to confirm that they are in agreement. We regularly conduct crosschecks of country-specific factors against the IPCC default factors. 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.

5.3.5 Source-specific recalculations

- Updates in the methane emission calculation according to 2019 Refinement and updates in the country specific methane emission calculation from on-farm digesters in accordance with Berglund and Mjöfors (2024). For more information see section 5.3.2.1 EMISSIONS OF METHANE (INCLUDING EXCRETION FROM GRAZING ANIMALS) (CRT 3.B(A)).
- Updates of EF for N2O according to 2019 Refinement.

The total effect of the recalculations in 3.B for the two most recent recalculated years entailed an increase in the emissions corresponding to 3.0% and 4.4% for the year 2021 and 2022.

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.

[263] http://www.ceip.at/ms/ceip_home1/ceip_home/status_reporting/

5.4 Agricultural Soils (CRT 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 5.20 gives an overview of all emission factors used in this sector.

Table 5.20. Emission factors for N_2O emissions from soils.

Direct emissions from soils	**Emission factor** % N_2O-N of N-supply	**Note**
Mineral fertiliser (Aggregated)	1%	1
Manure (Aggregated)	1%	1
Crop residue (Aggregated)	1%	1
Mineralization	1%	1
Manure during Pasture/Range/Paddock	See table 5.18	1
Direct emission due to cultivation	**Kg N_2O-N/ha/yr**	
Cultivation of Histosols	10.3	2
Indirect emissions from soils	**% N_2O-N of N-supply**	
Atmospheric Deposition (Aggregated)	1% of emitted N	1
Nitrogen Leaching and run-off	0.75% of N lost from leaching	3

(1) 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. (2) Lundblad 2024. (3) 2006 IPCC Guidelines.

5.4.1 Direct Soil Emissions (CRT 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 5.21.

Table 5.21. Summary of source category description for the entire category CRT 3.D.a, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
3.D.a.1 Inorganic N fertilizers	N_2O	X	X		T2	CS	Yes
3.D.a.2.a Animal manure	N_2O	X	-		T2	CS	Yes
3.D.a.2.b Sewage sludge	N_2O	-	-		T1	D	Yes
3.D.a.2.c Other organic fertilizers	N_2O	-	-		T1	D	Yes
3.D.a.3 Urine and dung deposited by grazing animals	N_2O	-	-		T1	D	Yes
3.D.a.4 Crop residues	N_2O	X	X		T2	CS	Yes
3.D.a.5 Mineralization/ immobilization associated with loss/gain of soil organic matter	N_2O	-	-		T2	CS	Yes
3.D.a.6 Cultivation of organic soils (i.e. histosols)	N_2O	X	X		T2	CS	Yes

CS - Country Specific. T1 - tier 1. T2 - tier 2. D - Default.

5.4.1.2 METHODOLOGICAL ISSUES

5.4.1.2.1 Nitrous oxide emissions from inorganic N fertilisers (CRT 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 5.22).

Table 5.22. Activity data used to estimate the direct soil emissions from inorganic and organic fertilisers.

Year	Inorganic fertilizers (t N)	Animal manure applied to soils (t N)	Fraction of N volatilised as NH_3 during storage of animal manure	Fraction of N volatilised as N_2O, NO_x, N_2 and lost through leaching and run-off during storage of animal manure	Fraction of N treated in co-digesters
1990	224 500	77 459	0.2021	0.0541	0.0000
1995	198 300	80 740	0.1893	0.0450	0.0000
2000	189 400	76 345	0.1899	0.0432	0.0012
2005	161 568	74 927	0.1872	0.0361	0.0029
2010	168 000	73 634	0.1844	0.0326	0.0060
2015	190 200	72 599	0.1853	0.0310	0.0261
2020	215 171	69 288	0.1855	0.0296	0.0356
2021	195 036	68 594	0.1844	0.0295	0.0345
2022	184 852	69 572	0.1845	0.0297	0.0307
2023	184 027	69 118	0.1837	0.0296	0.0329

Statistics on fertilisers and sludge are from Swedish Board of Agriculture and Statistics Sweden.

Table 5.22. (continued).

Year	Sewage sludge applied to soils (t N)	Other organic fertilizers applied to soils (excluding digestate from animal manure) (t N)	Animal manure digestate from co-digester applied to soils (t N)	Fraction of N volatilised as NH_3 during digestae of animal manure in co-digester	Fraction of N volatilised as N_2O, NO_x, N_2 and lost through leaching and run-off during storage of animal manure in co-digester
1990	1 180	1 700	0	0.0	0.0
1995	2 304	1 700	0	0.0	0.0
2000	1 758	1 800	105	0.1031	0.00006
2005	1 053	1 834	249	0.1050	0.00006
2010	2 224	2 921	506	0.1045	0.00006
2015	2 802	5 966	2 225	0.1053	0.00006
2020	4 799	6 974	2 911	0.1067	0.00006
2021	4 966	6 900	2 786	0.1067	0.00006
2022	5 285	8 066	2 508	0.1066	0.00006
2023	4 831	8 195	2673	0.1065	0.00006

Statistics on fertilisers and sludge are from Swedish Board of Agriculture and Statistics Sweden.

5.4.1.2.2 Nitrous oxide from organic N fertilisers (CRT 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 5.22), $Frac_{PRP}$ 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. To complete the annual amount of nitrogen applied to soils in 3.D.a.2, this value is complemented with N content in the smaller sources, sewage sludge, other organic fertilizers applied to soils and digestate from animal manure treated in co-digesters (which is part of other organic fertilisers but calculated separately). 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 5.22). 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 5.22) and "Production and use of biogas and digestate" produced by the Swedish Energy Agency, where data on digestate from co-digesters used as fertiliser is presented. For the years preceding 2009 there are no data on co-digester digestate as fertiliser. For these years, data are extrapolated as an average of the available data points. The N_2O emissions are then estimated as:

$$N_2O\ \text{emissions} = F_{ON} \times EF_1 \times 44/28$$

5.4.1.2.3 Urine and dung deposited by grazing animals (CRT 3.D.a.3)

To estimate the N_2O emissions from urine and dung deposited by grazing animals, the default emission factor of 0.4% is used for cattle and the default emission factor of 0.3% 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 5.23), 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 5.15 and Table 5.17.

Table 5.23. Manure management systems, percent 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	24.8	48.3	45.8	36.7	35.0	NO	50.0	100	50.0	NO	29.2
1995	24.8	48.3	45.8	36.7	35.0	NO	50.0	100	50.0	NO	30.1
2000	24.8	51.7	49.2	36.7	36.7	NO	50.0	100	50.0	NO	31.5
2005	26.1	58.9	53.7	30.2	36.6	NO	50.0	100	50.0	NO	32.4
2010	25.1	54.1	51.7	26.4	31.4	NO	50.0	100	50.0	NO	31.8
2015	24.5	52.1	49.7	18.6	31.7	NO	50.0	100	50.0	NO	30.6
2020	25.3	57.4	52.7	23.9	35.6	NO	50.0	100	50.0	NO	32.4
2021	25.3	57.4	52.7	23.9	35.6	NO	50.0	100	50.0	NO	32.7
2022	25.0	56.7	51.8	24.9	34.1	NO	50.0	100	50.0	NO	32.2
2023	25.0	56.7	51.8	24.9	34.1	NO	50.0	100	50.0	NO	32.4

Data from Statistics Sweden's survey "Use of fertilisers and animal manure in agriculture".

5.4.1.2.4 Crop residues (CRT 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[264] on how straw and tops from different crops are used.

264 Statistics Sweden, 2013.

$$Above\text{-}ground\ N_{(T)} = Crop_{(T)} \times\ Area_{(T)} \times R_{AG(T)} \times N_{AG(T)} \times Frac_{Renew(T)}\ \times \left(1 - Frac_{Remove(T)}\right)$$

$$Below\text{-}ground\ N_{(T)} = Crop_{(T)} \times\ Area_{(T)} \times R_{BG(T)} \times N_{BG(T)} \times Frac_{Renew(T)}$$

Where $R_{AG(T)}$ is the ratio of above-ground residues dry matter to harvested yield (i.e. $AG_{DM(T)}/Crop_{(T)}$), and $R_{BG(T)}$ the corresponding value for below-ground residues. $Crop_{(T)}$ is the annual yield of crop *T*, $N_{AG(T)}$ and $N_{BG(T)}$ are the fractions of nitrogen 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 5.24 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[265]. For other crops, a combination of national factors and IPCC default values are used[266]. The estimated activity data used as input to the emission calculations are presented in Table 5.25.

[265] Mattson, 2005.

[266] Andrist Rangel et al. 2016 and IPCC Guidelines 2006.

Table 5.24. 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

Table 5.25. 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	12 081 657	7 455 762	3 720 547	53 865	42 762
1995	9 391 580	5 584 360	2 780 341	41 084	32 989
2000	9 759 244	6 013 982	3 033 322	42 432	34 610
2005	9 228 332	5 645 238	2 880 763	40 523	33 225
2010	9 640 200	5 414 751	2 817 735	38 122	32 840
2015	11 678 122	7 031 373	3 652 365	46 280	41 321
2020	11 474 440	6 864 004	3 620 178	46 951	40 931
2021	10 660 052	6 131 355	3 250 860	42 230	36 843
2022	11 080 162	6 795 223	3 538 104	46 845	39 657
2023	9 636 005	5 402 100	2 953 499	37 319	33 455

Data on total crop yields are from the Swedish Board of Agriculture. Report series JO16.

5.4.1.2.5 Mineralization/immobilization associated with loss/gain of soil organic matter (CRT 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 section 6. The N2O 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 (see equation below), where *i* is the eight different agricultural production areas in Sweden. Mineralisation is generally a slow process, to compensate for that we apply a three years moving average on the emission estimate.

$$N_2O = \sum_{LU_i} [\Delta C_{Mineral,LU_i} \times 0.1] \times EF_1 \times {}^{44}/_{28}$$

5.4.1.2.6 Cultivation of organic soils (CRT 3.D.a.6)

The emission factor used to estimate emissions from cultivated histosols has been updated due to a recent literature review (Lundblad 2024). A value of 10.3 kg N_2O -N/ha is now used in the inventory. The area of organic soils on cropland 2008 and 2015 was re-assessed in a recent study[267]. The relationship between organic soil and total cropland area for intermediate years and the years from 1990 to 2007 is interpolated or extrapolated using the 2008-2015 trend in the relationship organic soils vs. total cropland area.

$$N_2O = Area_{Histosols} \times EF \times {}^{44}/_{28}$$

[267] Lindahl and Lundblad. 2022

5.4.1.2.7 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 every second or third year 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 has been created through interpolation and extrapolation. Gradually the quality of the data has increased and is now of adequate quality.

5.4.1.2.8 Source-specific QA/QC and verification

Annual increase or decrease is verified for the whole time series for all sub-sources to determine whether all annual changes are reasonable. We compare the times series for the emission with the time series for the activity data to confirm that they are in agreement. We regularly conduct crosschecks of country-specific factors against the IPCC default factors. 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.

5.4.1.2.9 Source-specific recalculations

- Changes in amount of N from animal manure as a consequence of updates in 3.B
- Area of histosols has been updated for the years 1990-2022 which affects N_2O emissions.
- The emission factor for histosols has been updated which affects N_2O emissions.
- The soil organic carbon stock on mineral soils has been updated for the years 1990-2022 which affects N_2O emissions.

The total effect of the recalculations in 3.D.a for the two most recent recalculated years was a decrease of the estimated emissions with -6.1% for both 2021 and 2022, respectively.

5.4.1.2.10 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 (CRT 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 (3.D.b.1) 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. To estimate the emissions from nitrogen leaching and run-off (3.D.b.2) we use a country-specific methodology. The summary of the latest key category assessment, methods and EF used, and information on completeness, are presented in Table 5.26.

Table 5.26. Summary of source category description for the entire category CRT 3.D.b, according to approach 1.

CRT	Gas	Key Category Assessment, 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	-		CS	D	Yes

CS - Country Specific. 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:

$$(N_2O - N = [(F_{SN} \times Frac_{GASF}) + (F_{ON} \times Frac_{GASM}) + (F_{PRP} \times Frac_{GASG}) + (F_{CoD} \times Frac_{GASCoD})] \times EF_4$$

Where F_{SN} is the annual amount of inorganic N fertiliser applied to soils (table 5.28). $Frac_{GASF}$ is the fractions of N that volatilises from inorganic fertilisers, the amount that volatilises differs between different types of fertilisers[268] which means that $Frac_{GASF}$ differ between different years (table 5.27 and table 5.28). F_{ON} is the annual amount of managed animal manure, sewage sludge and other organic N fertiliser applied to soil. $Frac_{GASM}$ describe the amount of nitrogen that volatilises from application of organic N fertilisers (table 5.29) and $Frac_{GASG}$ describe the fractions of N excreted on pastures that volatilises (table 5.30). F_{CoD} and $Frac_{GASCoD}$ refer to the annual amount of digestate from animal manure from co-digesters applied to soil and fraction of volatilised N from the

[268] EMEP/EEA air pollutant emission inventory guidebook 2023

digestate (table 5.29). These fractions are estimated by the model used for the national ammonia emission inventory.

Table 5.27. Emissions of ammonia from different fertiliser types.

Fertiliser	Volatilised as ammonia (g NH_3/kg N)
Anhydrous ammonia	20
Ammonium nitrate (AN)	24
Ammonium phosphate	84
Ammonium sulphate (AS)	84
Calcium ammonium nitrate (CAN)	24
Ammonium solutions (AN)	87
NK mixtures	24
NP mixtures	84
NPK mixtures	84
Other straight N compounds	84
Urea	195

Table 5.28. Amount of nitrogen in inorganic fertilisers (N t)

Year	Amount of nitrogen in inorganic fertilizers (t N)	Proportion of emitted fertiliser-N ($Frac_{GASF}$)
1990	224 500	0.0491
1995	198 300	0.0484
2000	189 400	0.0487
2005	161 568	0.0433
2010	168 000	0.0384
2015	190 200	0.0378
2020	215 171	0.0395
2021	195 036	0.0395
2022	184 852	0.0361
2023	184 027	0.0394

Statistics on fertilisers are from Swedish Board of Agriculture.

Table 5.29. Amount of nitrogen in organic N fertilisers

Year	Amount of nitrogen in animal manure applied to soils (t N)	Amount of nitrogen in sewage sludge applied to soils (t N)	Amount of nitrogen in other organic fertilisers applied to soils (excluding nitrogen in digestate from animal manure) (t N)	Fraction of applied organic N fertilisers that volatilises ($Frac_{GASM}$)	Amount of nitrogen in digestate from animal manure in co-digester (t N)	Fraction of applied organic N fertilisers that volatilises ($Frac_{GASCoD}$)
1990	77 459	1 180	1 700	0.1695	0	0.000
1995	80 740	2 304	1 700	0.1704	0	0.000
2000	76 345	1 758	1 800	0.1698	105	0.1827
2005	74 927	1 053	1 834	0.1659	249	0.1883
2010	73 634	2 224	2 921	0.1603	506	0.1863
2015	72 599	2 802	5 966	0.1609	2 225	0.1985
2020	69 288	4 799	6 974	0.1519	2 911	0.1826
2021	68 594	4 966	6 900	0.1504	2 786	0.1821
2022	69 572	5 285	8 066	0.1522	2 508	0.1771
2023	69 118	4 831	8 195	0.1522	2673	0.1776

Table 5.30. Amount of nitrogen excreted on pasture by grazing animals and digestate from aimal manure from co-digester

Year	Amount of nitrogen in urine and dung deposited by grazing animals (N t)	Fraction of nitrogen from grazing animals that volatilises ($Frac_{GASG}$)
1990	42 901	0.0777
1995	45 323	0.0777
2000	45 921	0.0775
2005	46 313	0.0775
2010	44 107	0.0770
2015	42 002	0.0768
2020	43 811	0.0771
2021	43 963	0.0770
2022	43 470	0.0771
2023	43 494	0.0771

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[269], which is a part of the SOIL/SOILN model. 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[270]. Since then the model has been elaborated and tested on data from controlled leaching experiments. These tests show that the model

[269] Johnsson, 1990; Swedish EPA, 2002.

[270] Johnsson et al., 1987.

estimates the leaching from soil with good precision[271]. 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 5.31). The SOILNDB 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. 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 cropland used in the LULUCF sector. The SOILNDB model has continuously been updated during the years. This means that the nitrogen leaching from different years have been computed in different versions of the model and were not fully comparable. In Johnsson et al. (2024) the average nitrogen leaching per hectare is recalculated for 1995, 2005, 2013 and 2019 in the same version of the model and these nitrogen leaching values are used from submission 2025. The years before 1995 and after 2019 are assumed to have the same nitrogen leaching as 1995 and 2019 respectively and for the intermediate years linearly interpolated values are used.

Table 5.31. 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	19.9	61 145	0.1376
1995	19.9	60 486	0.1499
2000	18.3	55 187	0.1387
2005	16.7	49 922	0.1378
2010	17.14	50 366	0.1372
2015	17.03	49 114	0.1218
2020	16.3	46 131	0.1069
2021	16.3	45 995	0.1145
2022	16.3	45 836	0.1107
2023	16.3	45 674	0.1167

* Estimated with the SOIL/SOILN model.

To estimate the implied $Frac_{LEACH}$, which is reported as additional information in the CRT 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 managed animal manure, also the part treated in co-digesters, 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 0.16 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).

[271] 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 reason for the continuous decrease between 1995 and 2005 is believed to mainly be dependent on changes in the crops used in Sweden, there after increased yield of fertilization/harvest, an increase in the area of catch crops, change in manured area and increased spring spreading of manure. The reason for the continuous decrease between 2005 and 2019 were increased fertilizer/harvest yield, crop mix change, change in manured area and increased spring spreading of manure.

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,[272] it is not possible to update the average leaching more frequently than that and 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 determine whether all annual changes are reasonable. We compare the times series for the emission with the time series for the activity data to confirm that they are in agreement. We regularly conduct crosschecks of country-specific factors against the IPCC default factors. 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

- Changes in amount of N because of updates in 3.B and 3.D.
- Updated country specific nitrogen leaching factors.

  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 -3.4% and -4.2% for 2021 and 2022, 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.

5.4.3 CO_2 emissions from liming (CRT 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[273]. The statistics on use of lime is produced

[272] Statistics Sweden, MI 30-series.

[273] Statistics Sweden, MI30 series. (www.scb.se/mi1001)

by Statistics Sweden every second year. 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[274].

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 5.32.

Table 5.32. Summary of source category description for the entire category CRT 3.G, according to approach 1.

CRT	Gas	Key Category Assessment (excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
3.G	CO_2	X	-		T1	D	Yes

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 emissions from liming is minor and do not motivate the time and resources to develop a tier 2 method with country-specific emission factors. A tier 2 method would give emissions that “are likely to be less than assumed using the Tier 1 approach” (2006 IPCC, section 11.3.1). Liming would then no longer be a key category. 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 5.33). 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 5.33. 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
2020	213 231	60 038
2021	213 231	60 038
2022	255 340	56 158
2023	255 340	56 158

[274] Statistics Sweden, MI30 series. (www.scb.se/mi1001)

5.4.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

In 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 determine whether all annual changes are reasonable. We compare the times series for the emission with the time series for the activity data to confirm that they are in agreement. We regularly conduct crosschecks of country-specific factors against the IPCC default factors. 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

- Updated activity data for year 2022 corresponding to increased emissions of 12% for this year.

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 (CRT 3.H)

5.4.4.1 SOURCE CATEGORY DESCRIPTION

During urea manufacture, 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..

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 5.34.

Table 5.34. Summary of source category description for the entire category CRT 3.H, according to approach 1.

CRT	Gas	Key Category Assessment (excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
3.H	CO_2	-	-		T1	D	Yes

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. 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 determine whether all annual changes are reasonable. We compare the times series for the emission with the time series for the activity data to confirm that they are in agreement. We regularly conduct crosschecks of country-specific factors against the IPCC default factors. 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 recalculations have 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 (CRT sector 4)

6.1 Overview of LULUCF

Sweden reports carbon stock changes in Living biomass, Dead wood, Litter and Soil organic carbon for Forest land, Cropland, Grassland, Settlements and Wetlands. Except for peat production areas, Wetlands and Other land are considered unmanaged[275].

The reporting also includes emissions and removals from:

- Harvested wood products (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) from drained organic soils,
- N_2O emissions due to mineralisation caused by land-use conversions or management change (4[III])
- Indirect N_2O emissions (4[IV])
- N_2O and CH_4 emissions from biomass burning (4[V])[276]

The extent of reporting of carbon pools, emissions, methodological tiers and result from the key category assessment for the LULUCF sector is summarized in Table 6.1.a and 6.1.b.

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, CRT 4.

6.1.a	Carbon pools				Other emissions				
	Living biomass	Litter	Dead wood	Soil carbon mineral/organic*	4(I)	4(II)**	4(III)	4(IV)	4(V)
4. LULUCF	-	-	-	-	-	-	-	T2	-
4.A.1 (Forest Land remaining Forest Land)	T3	T3	T3	T3/T2	T1	T2	T2	-	T2
4.A.2 (Land converted to Forest Land)	T3	T2	T3	T2	NO	T2	T2	-	NO

[275] On a request from the ERT, emissions/ removals from changes in living biomass and mineral soils are now reported for Land converted to Other land – even though such land is considered unmanaged.

[276] 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*	4(I)	4(II)**	4(III)	4(IV)	4(V)
4.B.1 (Cropland remaining Cropland)	T3	T3	T3	T3/ T2	IE***	T2	IE***	-	IE****
4.B.2 (Land converted to Cropland)	T3	T2	T3	T2	IE***	T2	T2	-	IE****
4.C.1 (Grassland remaining Grassland)	T3	T3	T3	T3/ T2	NO	T2	T2	-	T2
4.C.2 (Land converted to Grassland)	T3	T2	T3	T2	NO	T2	T2	-	IE****
4.D.1 (Wetlands remaining Wetlands)	NA	NA	NA	NA/T2,T3	NA	T2	NA	-	NA
4.D.2 (Land converted to Wetlands)	NA	NA	NA	NA	NA	NA	NA	-	NA
4.E.1 (Settlements remaining Settlements)	T3	NE	NE	T2	NO	NE	NE	-	IE****
4.E.2 (Land converted to Settlements)	T3	T2	T3	T2	NO	NE	T2	-	IE****
4.F.1 (Other land emaining other land)	NA	NA	NA	NA	NA	NA	NA	-	NA
4.F.2 (Land converted to Other land)	T3	T2	T3	T2	NA	NA	NA	-	NA
4.G HWP	T3	-	-	-	-	-	-	-	-

* Includes DOC for organic soils, ** Includes N_2O and CH_4 from drained organic soils and CH_4 from ditches, *** Reported in the Agricultural sector, **** Reported under Grassland

6.1.b	Key category assessment		
	Gas	Level	Trend
4 A 1 Forest land remaining forest land	CO_2	X	X
4 A 1 Forest land remaining forest land	CH_4	-	-
4 A 1 Forest land remaining forest land	N_2O	-	-
4 A 2 1 Cropland converted to forest land	CO_2	X	-
4 A 2 1 Cropland converted to forest land	N_2O	-	-
4 A 2 2 Grassland converted to forest land	CO_2	-	-
4 A 2 2 Grassland converted to forest land	N_2O	-	-
4 A 2 3 Wetlands 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	-
4 A Drained organic soils	N_2O	X	-
4 B 1 Cropland remaining cropland	CO_2	X	X
4 B 2 1 Forest land converted to cropland	CO_2	X	X
4 B Drained organic soils	CH_4	X	-
4 B 2 2 Grassland converted to cropland	CO_2	-	-
4 B 2 4 Settlements converted to cropland	CO_2	-	-
4 C 1 Grassland remaining grassland	CO_2	X	-
4 C 1 Grassland remaining grassland	CH_4	-	-
4 C 1 Grassland remaining grassland	N_2O	-	-
4 C 2 1 Forest land converted to grassland	CO_2	X	X
4 C Drained organic soils	CH_4	-	-
4 C 2 2 Cropland converted to grassland	CO_2	-	X
4 C 2 3 Wetlands converted to grassland	CO_2	-	-
4 C 2 4 Settlements converted to grassland	CO_2	-	-
4 C 2 5 Other land converted to grassland	CO_2	-	-
4 D 1 Wetlands remaining wetlands	CH_4	-	-
4 D 1 Wetlands remaining wetlands	N_2O	-	-
4 D 1 1 Peat extraction remaining peat extraction	CO_2	X	X
4 D 2 3 1 Forest converted to wetlands	CO_2	-	X
4 E 1 Settlements remaining settlements	CO_2	X	X
4 E 2 1 Forest land converted to settlements	CO_2	X	X
4 E 2 1 Forest land converted to settlements	N_2O	-	-
4 E 2 2 Cropland converted to settlements	CO_2	X	X
4 E 2 2 Cropland converted to settlements	N_2O	-	-
4 E 2 3 Grassland converted to settlements	CO_2	-	-
4 E 2 3 Grassland converted to settlements	N_2O	-	-
4 E 2 5 Other land converted to settlements	CO_2	-	-
4 E 2 5 Other land converted to settlements	N_2O	-	-
4 F Other land	N_2O	-	-
4 F 2 Land converted to other land	CO_2	-	X
4 Nitrogen leaching and run-off	N_2O	-	-
4 G Total HWP from domestic harvest	CO_2	X	-

6.1.1 Emissions/removals in LULUCF 1990-2023

In 2023, the net removal from the Land Use, Land-Use Change and Forestry sector (LULUCF) was estimated to -31 224 kt CO_2 -eq. including net removals in harvested wood products and to -26 237 kt CO_2 -eq.when excluding net removals in harvested wood products. The net removal decreased from 2022 to 2023 by 2 390 kt CO_2 -eq. As can be seen in figure 6.1 there was no clear long term trend for many years in the LULUCF-sector as a whole. Due to a decline in forest growth, a long-term increase in harvest rate (except for the last years) and an increase in mortality, the net removal in living biomass has decreased. This can be seen in figure 6.1 for forest land, and the total net removal has declined the last 10 years. There are also some 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.

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 forest, i.e., where annual stem wood production per hectare and year is larger than 1 m^3 and where forestry is considered is 23 Mha[277]. About 1.4 Mha of the productive forest is formally protected and 1.3 Mha is voluntarily protected resulting in 21 Mha used for wood supply[278].

Harvest of trees is more or less restricted to productive forests. There has been a continuous increase in felling during the reported period. A severe storm in 2005 created a temporary peak. Harvest fluctuates between years due to changes in demand for forest products. In 2023, the gross stemwood harvest was approximately 90[279] Mm^3 which was about 5 Mm^3 lower than 2022. For many decades, the gross removals of CO_2 (growth) have increased and been higher than harvests (including mortality). However, around 2012 the growth started to decline although still being on a stable high level. In 2018 growth slowed considerable to around 118[280] Mm^3 stemwood (approx. 162 Mt CO_2 whole tree biomass per year). The reduced growth may be explained by drought (especially in 2018), followed by bark-beetle attacks. Reduced growth and gradually increased felling rates can be seen in the reported net removal in living biomass which has gradually decreased since 2018 due to resampling of permanent sample plots in the five year period after 2018.

The largest carbon pools are living biomass and soil organic carbon on Forest land. The largest annual stock change has traditionally been the change in the living biomass pool but since 2017 the net change in mineral soils is larger (Figure 6.1 and 6.2). In the living biomass pool a net removal ranging between 1 (2022) and 38 (1991) Mt CO_2 $year^{-1}$ is reported for Forest land during the period whereas the net change in minerals soils has been stable between 20 and 23 Mt CO_2 $year^{-1}$.

The dead organic matter pool is a net sink, due to a continuous increase in dead wood, including stumps, and recently also a small increase in the fine litter (humus layer) of Forest land. This category has previously been reported as a source but due to gradually increasing litter amounts measured in the SFSI inventory the fine litter sub-pool is now a sink. The soil organic carbon pool resulted in net removals during the whole reported

[277] Swedish University of Agricultural Sciences, 2023

[278] Grundberg et al., 2022

[279] Gross harvest data from the Forest agency: https://www.skogsstyrelsen.se/statistik/statistik-efter-amne/bruttoavverkning/

[280] Average of 2019-2023. Based on data from the NFI

period. Note that some soils are sources (mainly drained organic soils) whereas others are sinks.

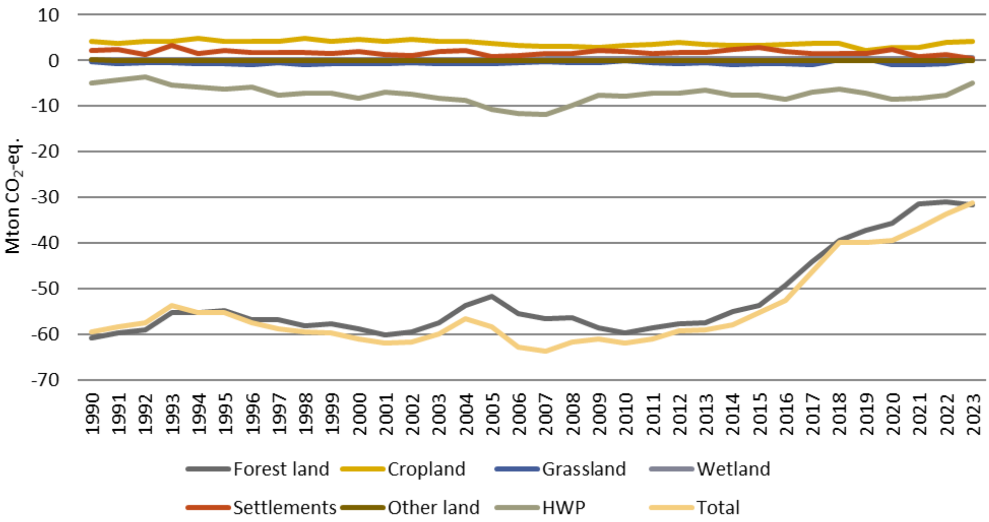

Figure 6.1. Net emissions/removals of GHG in the LULUCF sector from different land-use categories, harvested wood products (HWP) and the total for the sector.

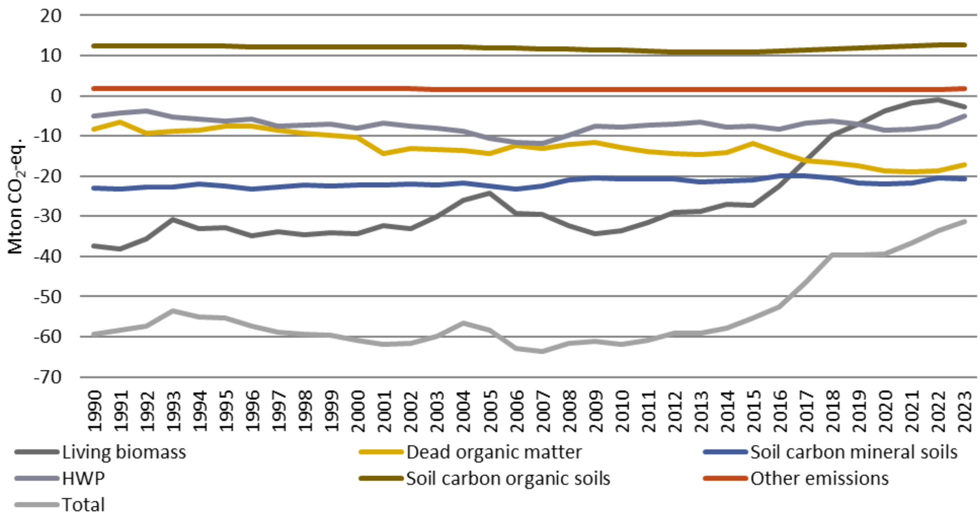

Figure 6.2. Net removals/emissions of GHG in the LULUCF sector from different carbon pools, other emissions (including CH_4 and N_2O from different sources), HWP and the total for the sector.

The HWP pool is a sink and has an inverse relationship with the 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 Mha of the Forest land is classified as Histosols and around 1 Mha of the Histosols are drained. The Cropland area on Histosols is estimated to approx. 114 kha (2023) and all of that area is drained. Drained Histosols on Forest land is currently the most important net source of green house gases in the Swedish LULUCF sector.

Emissions from Wetlands includes soil emissions from peat extraction areas and losses of carbon from the use of horticultural peat. It increases slightly over the entire reported period due to a slightly increasing long-term trend in the production area and a steady increase in the production of horticultural peat but levels off during some years, mainly due to a decrease in the area used for energy peat production. However, an increase in production area was observed in 2022 which persisted 2023 which indicates that the area for the previous three years may have been underestimated.

There have 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 soil carbon pool on Forest land is equivalent to more than 5 000 kt CO_2. The variation between years is reduced due to a method for interpolation and extrapolation of data that was introduced in submission 2023. 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 soil inventory results from 2021 and 2022 are added to the data. This means that the results reported in this submission are based on three completed soil inventories (1993-2002, 2003-2012 and 2013-2022).

A summary of emissions/ removals is found in Tables 6.2a and 6.2b.

A summary of recalculations compared to previous submissions is found in section 6.4.5.

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 to a fairly stable level, due to a decrease in the use of fertilisers in forestry. A dramatic drop was observed in 2022 and 2023, most likely due to the increased costs for fertilizers.

Emissions of N_2O and CH_4 from Histosols show no clear trend, but the emissions slightly decrease until 2012 whereafter they increase. This is due to variations in the estimate of the area of drained organic forest soils. The reasons for the decrease and following increase in area are under investigation. Emissions of non-CO_2 gases from drained organic 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 1 638 kt CO_2 eq. in 2023, which is a slight decrease from 1 677 kt CO_2 eq. in 1990, in line with the development in area of drained organic soils on Forest land. Note that N_2O emissions from Cropland are reported in the agricultural sector.

Emissions of CO_2 from DOC reported from drained 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 and land-use change categories (except Cropland remaining cropland) shows a slightly increasing trend until 2007 due to the accumulation 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 category.

The burnt area, which strongly drives the emissions from biomass burning, shows no trend. Except for 2014 and 2018 when large forest fires occured, the emissions from these categories correspond to less than 0.2 Mt CO_2-eq. per year on average. The CO_2 emissions are reported as IE under 4(V), as the CO_2 emissions are included in net removals in the living biomass pool.

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 $year^{-1}$]																					
	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	DOM	Min	
1990	-39.6	-4.4	-3.3	-21.7	6.9	0.0	0.0	-1.0	4.9	0.1	-0.5	-0.3	0.3	0.1	2.0	0.0	-0.1	0.3	0.2	0.0	0.0	-5.0
1995	-34.4	-4.6	-2.5	-21.6	6.9	-0.1	0.0	-0.6	4.7	-0.3	-0.5	-0.3	0.4	0.1	1.9	0.0	0.0	0.3	0.0	0.0	0.0	-6.3
2000	-35.4	-7.6	-2.5	-21.7	7.0	-0.2	0.0	0.0	4.4	-0.3	-0.4	-0.5	0.4	0.2	1.7	0.1	0.0	0.3	0.0	0.0	0.0	-8.2
2005	-24.2	-11.6	-2.5	-21.5	6.9	-0.2	0.0	-0.5	4.2	-0.1	-0.4	-0.6	0.3	0.2	0.3	0.1	0.0	0.3	0.0	0.0	0.0	-10.6
2010	-35.7	-9.3	-3.2	-19.3	6.6	-0.2	0.0	-0.7	3.9	0.7	-0.4	-0.7	0.4	0.3	1.5	0.1	0.0	0.3	0.0	0.0	0.0	-7.7
2011	-32.8	-10.7	-3.2	-19.3	6.3	0.0	0.0	-0.7	3.9	0.0	-0.1	-0.7	0.3	0.3	1.2	0.1	0.0	0.3	0.0	0.0	0.0	-7.3
2012	-30.6	-10.8	-3.6	-19.9	6.1	0.1	0.0	-0.1	3.8	0.0	-0.1	-0.8	0.3	0.3	1.4	0.1	0.0	0.3	0.0	0.0	0.0	-7.1
2013	-29.9	-10.6	-4.1	-20.3	6.2	-0.2	0.0	-0.4	3.7	0.1	-0.1	-0.8	0.2	0.3	1.3	0.1	0.0	0.3	0.0	0.0	0.0	-6.4
2014	-28.5	-10.3	-3.8	-20.0	6.3	-0.3	0.0	-0.4	3.7	-0.3	-0.2	-0.8	0.2	0.4	1.9	0.1	0.0	0.3	0.0	0.0	0.0	-7.7
2015	-29.8	-8.6	-3.2	-19.6	6.5	0.1	0.0	-0.6	3.6	0.1	-0.2	-0.8	0.2	0.4	2.4	0.1	0.0	0.3	0.0	0.0	0.0	-7.6
2016	-23.8	-9.6	-4.5	-19.1	6.5	-0.2	0.0	-0.1	3.6	0.0	-0.2	-0.8	0.2	0.4	1.6	0.1	0.0	0.3	0.0	0.0	0.0	-8.4
2017	-16.8	-11.0	-5.0	-19.4	6.8	-0.2	0.0	0.1	3.5	-0.2	-0.2	-0.8	0.2	0.4	1.0	0.1	0.0	0.3	0.0	0.0	0.0	-6.9
2018	-11.4	-11.9	-4.7	-19.8	7.1	-0.2	0.0	0.1	3.5	0.9	-0.2	-0.8	0.3	0.4	1.0	0.1	0.1	0.3	0.0	0.0	0.0	-6.2
2019	-9.0	-12.0	-5.3	-19.5	7.3	-0.1	0.0	-1.4	3.5	1.1	-0.2	-0.9	0.3	0.4	1.0	0.1	0.1	0.3	0.0	0.0	0.0	-7.1
2020	-5.4	-13.1	-5.6	-20.2	7.4	-0.1	0.0	-0.9	3.5	-0.2	-0.2	-0.9	0.4	0.4	1.9	0.1	0.1	0.3	0.0	0.0	0.0	-8.5
2021	-1.6	-13.1	-5.7	-20.1	7.7	0.0	0.0	-0.9	3.5	-0.2	-0.2	-0.8	0.4	0.4	0.2	0.1	0.1	0.3	0.0	0.0	0.0	-8.4
2022	-1.5	-12.6	-6.1	-20.0	7.9	-0.1	0.0	0.3	3.4	-0.1	-0.2	-0.9	0.4	0.5	0.7	0.1	0.1	0.3	0.0	0.0	0.0	-7.7
2023	-3.9	-10.8	-6.3	-20.0	8.0	0.5	0.0	0.1	3.4	0.7	-0.2	-0.9	0.4	0.5	-0.1	0.1	0.1	0.4	0.0	0.0	0.0	-5.0

Table 6.2.b. Summary of other emissions. The total LULUCF removal is expressed as CO2-eq. and includes both carbon stock changes and other emissions.

6.2b	Other emissions [kt substance year^{-1}]								Total LULUCF Mt CO_2-eq year^{-1}
	Fert. 4 (I)	Drainage 4(II)		Min. 4(III)	Ind. 4(IV)	Biomass burning 4 (V)			
Year	N_2O	CH_4	N_2O	N_2O	N_2O	CO_2	CH_4	N_2O	
1990	0.16	21.91	4.01	0.02	0.026	IE	0.08	0.00	-59.3
1995	0.16	21.91	4.01	0.02	0.026	IE	0.08	0.00	-59.3
2000	0.16	21.91	4.01	0.02	0.026	IE	0.08	0.00	-59.3
2005	0.16	21.91	4.01	0.02	0.026	IE	0.08	0.00	-59.3
2010	0.19	19.05	3.68	0.07	0.030	IE	0.03	0.00	-61.8
2011	0.12	18.68	3.56	0.07	0.020	IE	0.10	0.00	-60.9
2012	0.11	18.23	3.43	0.07	0.017	IE	0.05	0.00	-59.1
2013	0.06	18.19	3.48	0.07	0.009	IE	0.12	0.00	-59.0
2014	0.05	18.10	3.55	0.07	0.008	IE	1.21	0.01	-57.8
2015	0.08	18.01	3.60	0.07	0.012	IE	0.07	0.00	-55.3
2016	0.07	18.06	3.64	0.07	0.011	IE	0.12	0.00	-52.4
2017	0.06	18.10	3.72	0.07	0.009	IE	0.09	0.00	-46.4
2018	0.07	18.49	3.83	0.07	0.011	IE	2.07	0.01	-39.8
2019	0.08	18.47	3.90	0.07	0.013	IE	0.12	0.00	-39.8
2020	0.10	18.52	3.93	0.07	0.016	IE	0.06	0.00	-39.4
2021	0.10	18.64	4.01	0.07	0.016	IE	0.09	0.00	-36.7
2022	0.02	19.07	4.17	0.07	0.004	IE	0.07	0.00	-33.6
2023	0.04	19.01	4.17	0.07	0.006	IE	0.11	0.00	-31.2

6.2 Land-use definitions, 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[281]. 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*.

Forest land can temporary be unstocked due to human intervention such as final felling. Normally such land is replanted 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, grazing land may fulfil the forest criteria except for the predominant land use and is thereby not considered Forest land but classified as Grassland. Tree-rows narrower than 10 m are not considered Forest land. Roads and power-line routes within forests are considered Forest land 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 which implies that carbon stock changes in living biomass may be reported under any land use category.

The definition of Forest land is consistent with former reporting to other international bodies like 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 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 state of the Swedish forests to other bodies. In both cases the expected values of estimates are the same but estimates are subject to the random variation of the sample.

All Forest land is assumed managed. The underlying data are consistent for the whole reporting period.

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. Grassland is agricultural land that due topography, stoniness, coarse and/or shallow soils or high groundwater table are unsuitable for cropland cultivation. It often has a diverse field layer vegetation of grasses and herbs and a sparse or medium dense shrub and tree vegetation.

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

6.2.4 Wetlands

Generally, Wetlands are assumed unmanaged and are defined as mires and areas saturated by freshwater. However, an area of approx. 10 000 ha that is used for peat extraction is included under Wetlands and therefore assumed managed. Since this submission carbon stock changes of land converted to Wetland is also reported.

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 categories above. It includes most of the mountain area in northwest Sweden. Other land is assumed unmanaged although carbon stock changes of land converted to Other land is reported. The reported land-use categories are based on 12 national land-use categories (Table 6.3) monitored by the Swedish National Forest Inventory (NFI).

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 2019-2023 which implies that the total area is not exactly the same as in CRT table 4.1.

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).
Productive Forest land	23473				**23473**	Land which hosts a potential yield of stem-wood exceeding one cubic metre per hectare and year. **Forest land.**
Grazing Land				529	**529**	Not regularly cultivated, **Grassland.**
Arable Land				2819	**2819**	Regularly cultivated, **Cropland.**
Mire	2027	1213	1815		**5055**	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).**
Rock Surface	656	122	148		**926**	Rocky or stony areas, **Forest land (if forest according to FAO)** or **Other land***.
Sub alpine Coniferous Woodland	924	124	17		**1066**	Land-zone usually located between 1 and 7. **Forest land (if forest according to FAO) or Other land*.**

High Mountain		818	821	3309		**4947**	Usually unstocked or sparsely stocked, **Forest land (if forest according to FAO) or Other land*.**
Road and Railroad					522	**522**	For permanent use. Not only roadway and rail but also other connected areas as embankments, **Settlements**
Power line Within Forest					154	**154**	Minimum width 5 m, **Settlements**
Urban Land					1193	**1193**	Various kind of Settlements, **Settlements**
Other land*					57	**57**	Different kinds of land that is not covered by Other land-use categories. Examples: gravel pits, halting places and slalom slopes, **Settlements**
Freshwater					4427	**4427**	Lakes, rivers, streams, canals and ponds. Minimum width of 2 m, **Wetlands.**
UNFCCC-categories	*FL*	*27898*				***27898***	
	CL				*2819*	***2819***	
	GL				*522*	***522***	
	WL		*1213*	*1815*	*4427*	***7454***	
	S				*1926*	***1926***	
	OL		*1067*	*3474*		***4541***	
Total		**27898**	**2280**	**5289**	**9700**	**45168**	

* Note that the national land use category Other land in the NFI of Sweden do not correspond to the UNFCCC land use category Other land.

The national 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. Observe that the example in table 6.4 is based on both temporary and permanent sample plots in the NFI representing an average for 2019-2023. Thus, the total land area in Table 6.4 is not exactly the same as the total reported area in the CRT-tables.

6.2.7 Consistency in reporting land-use categories

The NFI has monitored land-use categories in a reasonably consistent way since 1983 (no appropriate data exists 1970-1982). Based on permanent sample plots, it is possible to trace both gross and net land-use transfers from 1983 to 2019. After 2019, only net changes in land use can be estimated since 2019 is currently the last year with a complete sample plot record (see section 6.2.8).

All land areas are included in the field inventory except urban land. Urban land is inventoried by remote sensing to be able to correctly determine areas. It is assumed that its relative importance for the Swedish carbon budget is negligible except when land is transferred to settlement due to land exploitation (emissions from such conversions to urban land are reported).

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 these 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. 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. 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.

Sweden has adopted Approach 3: Geographically-explicit land-use conversion data in accordance with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (and with the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories). In the Swedish context, a permanent sampling design (30 000 plots are revisited in the field) on all types of land is a prerequisite for Approach 3. In addition, the inventory began before the base year 1990 and follows the IPCC's recommended five-year inventory cycle. It is probably quite unique that not only land use and land use change but also important carbon pool changes (e.g. living biomass, dead wood, mineral soil) are measured using Approach 3.

6.2.8 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 30 000 permanent sample plots in the inventory (1990-2019). 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 28141.62 kha in 2019. This implies that, given the sample, the land-use matrix is consistent with reported areas[282]. Due to a five-year inventory cycle, we can only provide a full record of data for the years 1990-2019. Therefore, land use for recent years (2020-2023) is extrapolated 1, 2, 3 or 4 years depending on the inventory cycle, respectively. In the CRT Table 4.1, land use and land-use change matrices for recent years (2020-2023) are based on measured net land use per year and assumptions about land use conversions. It may be logical that the accumulated area in CRT tables 4.A-F is linked to table 4.1. However, it is not possible to convert extrapolated and accumulated areas of land-use change reported in CRT tables 4.A-F to annual values. This is due to the fact that the information on land areas leaving and entering the reported categories would be lost in the extrapolation of the years 2020-2023. Interpolating and extrapolating inventory data to expand the sample is a better way to estimate area changes compared to only use annual data (see annex 3:2 section 3.2.1.2). The IPCC acknowledge extrapolated data to improve the inventory but there are no guidelines on how to report CRT table 4.1 using extrapolated data.

282 Observe that Table 4.1 describes annual transitions between Land Use Categories while tables 4.A – 4.F describe the current area within each land use category. The total of e.g. Forest land in 4.1 is always the same as in 4.A. Given the 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.

Table 6.4. Land Use Categories 2018, 2019 and gross and net land use transfers 2018-2019 (based on about 30 000 permanent sample plots inventoried 1983-).

Area [kha]	From Year 2018	To Year 2019					
		Forest Land	Crop-Land	Grass-Land	Wet-Land	Settle-Ments	Other Land
F	28134.05	28111.61	0.00	3.83	9.53	9.08	0.00
C	2853.74	9.45	2837.25	1.83	0.00	5.20	0.00
G	498.99	5.46	2.20	489.83	0.00	0.41	1.09
W	7426.49	10.48	0.00	0.00	7416.01	0.00	0.00
S	1910.41	1.06	0.00	0.49	0.00	1908.85	0.00
O	4308.82	3.15	0.00	0.00	0.00	0.00	4305.66
Sum		**28141.20**	**2839.45**	**495.99**	**7425.55**	**1923.55**	**4306.75**

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[283]) and the Swedish Forest Soil Inventory (SFSI[284]) are integrated in the same sample design, using the same permanent sample plots. The main objective of the NFI/SFSI is monitoring of forest production and environmental status.

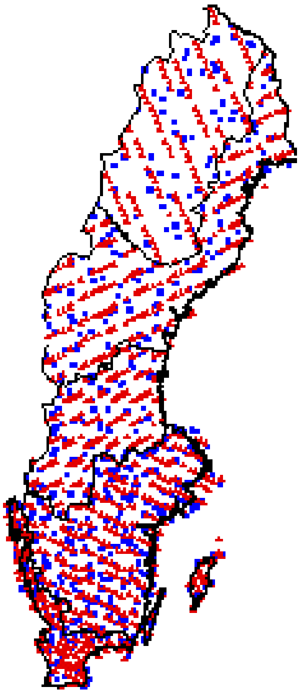
The NFI plots are re-inventoried every fifth year and the SFSI plots are re-inventoried every tenth year since changes in the soil are expected to be slower than changes in living biomass. Topsoil cores are taken at every second sample plot and deeper soil horizons are sampled on every fourth sample 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 6.3a and 6.3b). 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. The clusters, referred to as 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

[283] Ranneby et al., 1987

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

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.



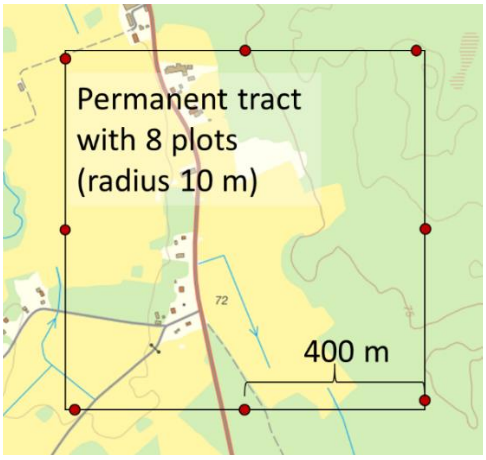


Figure 6.3a. Each year a permanent sample grid covering the whole country of Sweden, (red) is re-inventoried and a temporary sample grid (blue) is inventoried. Observe that the size and number of tracts differs by county. To be able to trace both gross and net land-use transfers, only permanent sample plots are used in the reporting. When estimating changes of e.g. C, the accuracy is higher using permanent then when using both temporary and permanent sampling plots. Each red dot in the map represents a cluster of sample plots (tract).

Figure 6.3b. The sample plots (red) are covering all relevant land uses. In the example above, plots are mainly located on Forest land and Cropland and some plots are divided into more than one land-use category. On the plots, measurements are made to estimate standing biomass of trees. Volume of dead wood per decay class is 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.

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 laboratory analysis. The O, H or A horizon[285] 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 European soil monitoring efforts, e.g. Biosoil[286] and soil samples are taken at fixed depths form the top of the mineral soil surface.

[285] O and H are organic soil layers and A refers to a humus rich, top mineral soil layer.

[286] http://biosoil.jrc.it/

6.3.1.1 SAMPLE BASED ESTIMATIONS

The sample frame consists of a sampling grid covering the entire land and freshwater area of Sweden (Figure 6.4). 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 or parts of counties) and a specific number of sample units are sampled per stratum. Each tract 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 approx. 30,000 randomly distributed sample plots represent an unbiased sample of carbon pool changes and areas per land use category in Sweden. The position of these plots is confidential in order to avoid special management of the plots.

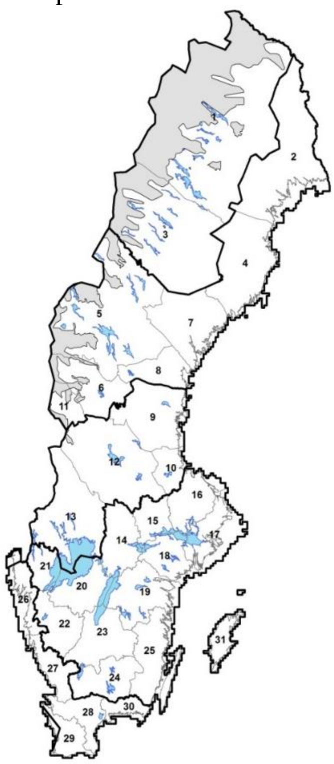


Figure 6.4. The country is divided into five regions, each with a different sample design and 31 strata used for stratification.

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[287]. Finally, the reported value on national level is estimated as the sum of the county values (for further information, see Annex to the NID section 3.2.1.1).

A five-year inventory cycle is used in the NFI and five different samples were randomly distributed using systematic grids 1983, 1984, 1985, 1986 and 1987, respectively. Each of these samples consists of around 6000 sample plots. The expected value of an estimator is

[287] Thompson, 1992

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 2019 and consequently only 24000, 18000, 12000 and 6000 sample plots are available for the estimates of 2020, 2021, 2022 and 2023 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 recalculated for the biomass carbon pool and revised in each submission. Note that the soil carbon pool is inventoried every ten years. This is because processes in the ground are considered slower. The changes in litter and soil pools are interpolated and extrapolated over the whole time series based on average measured change (see Annex Section 3.2.1.6).

Since the random variation in the estimates of areas is larger for the four most recent years (as also noted in the annual review reports), Sweden 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 of the total area are illustrated. The effect of the extrapolation levels out "strange" area and carbon stock variations evolving from the randomness of the sampling[288].

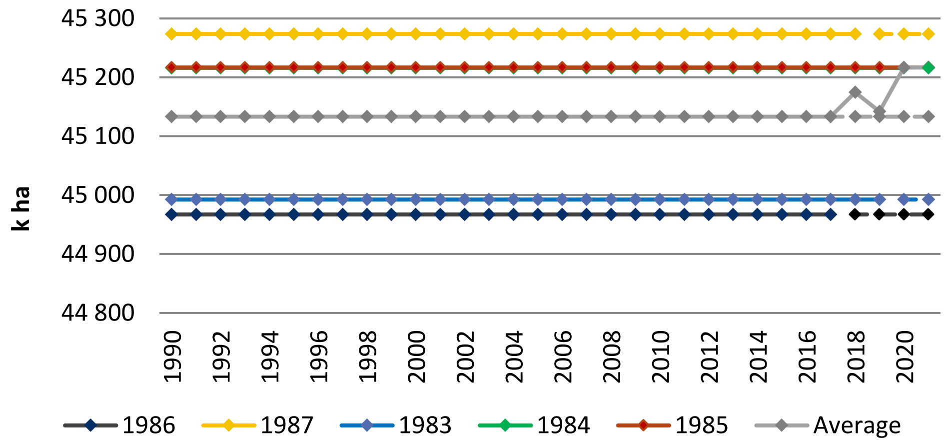


Figure 6.5. The total area of Sweden represented by five sub-samples (established in 1983, 1984, 1985, 1986 and 1987). Solid lines represent measured and dashed lines represent extrapolated values. The average solid line 1990-2021 represents average without extrapolated values and the average dashed line (2019-2021) represents the average with extrapolated values.

From submission 2025 the method to extrapolate net removals in living biomass for the four most recent years without a full record using the trend for the previous five year period has been exchanged to a new method. In this submission, growth is predicted using artificial intelligence technology (AI). The AI models for growth are trained based on historical growth using data from NFI plots, weather statistics and seasonal development on tree ring bore cores from temporary NFI-plots. Ingrowth (trees that become 100 mm in dbh) and mortality are considered. Harvest is modelled based on detection of changes in satellite images. The projections are made for the inventory cycles not inventoried to date. When the sample plot/cycle has been re-inventoried, the predicted value is discarded and replaced with the measured value (see Appendix 3.1.1.2). In the

[288] This improvement and the information provided is a response to reviewers (ARR 2011)

past, trend extrapolation has been used for living biomass but it was recognised that there was a lage risk of over or underestimation of net removals using past trends. The idea of replacing trend extrapolation with AI technology and remote sensing is to get a projected value that better matches the final measurement and thus to reduce the effect of recalculations.

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. All carbon stock changes on land converted to managed land are reported. Forest land (Forest land dedicated to conservation purposes included) may sometimes be converted to unmanaged land, i.e. to Other land or Wetlands by natural degradation without harvest. Such conversions are considered non-human induced. Previously carbon stock changes related to these conversions were not reported but, due to a recommendation from the UNFCCC ERT, emissions/removals from managed land categories (Forest land, Cropland, Grassland, Settlements and Wetlands) to Wetland and Other land are now reported since methods are available in the 2006 IPCC Guidelines.

6.3.1.2 THE LULUCF REPORTING DATABASE

All of the permanent sample plots of the NFI (around 30 000) are used for the area based sampling (design based). 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. Each plot has one value each year between inventories. This value is measured or interpolated. 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 during the inventory, the year of change in land use is randomly set (see 6.3.1.3 and Table A.3.2.1 in Annex 3:2) to any year between the previous and the present inventory.

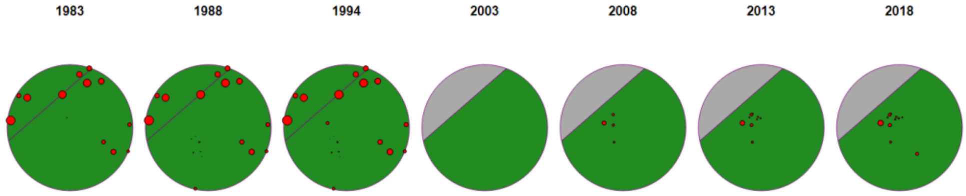


Figure 6.6. The figure shows measured data for a specific sample plot in the Swedish LULUCF database. The individual tree biomass on approximately 30 000 permanent sample plots is matched to land use and traced back to before the base year in a consistent way. Applying area-based sampling all 30 000 permanent sample plots represent the whole land and freshwater area in Sweden and carbon stock changes are estimated using the stock change method on these plots. Part of this specific plot was deforested (grey areas) between 1994 and 2003. The positioning of trees (red dots) is central when matching carbon stock changes in living biomass to land-use change (about 75% of deforested plots are divided into more than one land-use category). The position and biomass of the marked trees are identified at all inventories and demonstrate the possibility to match individual trees to land use over time.

6.3.1.3 LAND-USE TRANSFERS

The main requirement to detect land-use change is that the definition of the former land use is no longer met. For instance, if the definition of Forest land (6.2.1) does no longer hold, the land is considered converted to another land-use category. This rule is used regardless whether the land is considered managed or unmanaged, which means that land can be transferred from managed land to unmanaged and vice versa. For instance, the growing conditions on tree covered unmanaged Wetlands or Other land may change so that the forest definition is met. Then such Wetlands and Other land will be reported as converted to Forest land. A transfer in the opposite direction may be when sparsely tree covered Forest land is degrading and the forest definition does no longer hold.

Land-use conversions are assumed to occur at a random year between consecutive re-measurements. If a land-use conversion is also related to a loss of living biomass (Forest land converted to another land category) between consecutive inventories, the biomass is assumed to drop to the new level or zero the anticipated year of land-use conversion (i.e. the year of land use change).

Every plot that is converted to another land-use category is reported for 20 years in the corresponding land-use change category. After 20 years the plot will be reported in the new land-use category (a remaining 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 within the NFI, 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 and 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 a national definition[289] of Forest land. Therefore, land-use categories need re-assessment for the period 1983-1997. There are two main cases of re-assessments which are handled as follows:

1. If the land-use category for a sample plot was registered as Forest land according to the FAO definition 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 is assumed to have always belonged to the land-use category Forest land.
2. If the land-use category was registered as Forest land according to the FAO definition 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 is assumed to remain until the year of conversion. If at consecutive inventories after that, the land-use category remain as Forest land, 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.

[289] 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.

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 in the first inventory, as Wetland at the next inventory and then again as Forest land at the third inventory without any indications of human activities. A case like this is corrected in the post-data process so that the land-use category is assumed to be Forest land on all three occasions. This automatic correction has been used on data collected before 2003. After this year, a land-use category could only be changed during the inventory if indications of human activities are actually identified in the field, reducing the need for post-data processing. 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 but unsubstantiated 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”, a category where tree biomass is not measured) to Forest land and the new land-use category consists of old trees. This has been corrected so the land use is assumed to be Forest land at both occasions.

One example of the second type is when the delineation of a divided plot, i.e. a plot representing more than one land-use category, has been changed during the re-inventory due to personal judgments by the inventory team rather than due to actual changes. These land-use changes should not be registered as land-use changes and have been corrected in the post-data process by keeping the newer delineation. This is the case 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 related to land use

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.

6.3.3 Summary of sources for area estimation and stratification of areas for calculation of emissions and removals

In addition to the NFI and the SFSI, complementary data sources are required in order to estimate areas of certain combinations of land use categories and different soil types (Figure 6.7 and 6.8). For example, peat extraction areas are both small and rare in relative terms. The uncertainty in estimating peat extraction areas based on NFI plots would therefore be considerable. Additionally, to expand the rather limited data base on organic soils within the SFSI, it is supplemented with data on organic soils on NFI plots according to geographic information on soil types.

Figure 6.7. The figure shows a summary of sources for area estimation and stratification of areas for calculation of emissisons and removals in the LULUCF-sector. Further explanations are provided in Figure 6.8.

Source(s) of area calculations	Source application
NFI	The National Forest Inventory determines the total area by sampling statistics based on an unbiased sample of plots of the entire land area using a 5-yr inventory cycle.
NFI	The National Forest Inventory determines the total area of organic soils by sampling statistics based on an unbiased sample of plots using a 5-yr inventory cycle.
NFI / SFSI	The Swedish Forest Soil Inventory provide the proportions of mineral and organic soils, the proportions of drained and undrained organic soils, and the distribution of soil fertility indicators and climate categories for drained organic soils based on an unbiased sample of plots using a 10-yr inventory cycle.
NFI / SGS survey	The National Forest Inventory determines the total area of Wetland by sampling statistics based on an unbiased sample of plots. The area of peat extraction gained from the SEP is assumed to be included in the total area of Wetland remaining Wetland.
NFI / SGS survey	The National Forest Inventory determines the total area of Settlements by sampling statistics based on an unbiased sample of plots.
SEP	Areas of peat extraction and production of peat for horticultural use is taken from The Swedish Environmental Reporting Portal.
NFI / SGS soil type map	The proportions of mineral and organic soils are calculated from NFI sample plots based on their soil type according to the soil type map of the Swedish Geological Survey.
NFI / SFSI	All settlements remaining settlements, except power-line routes in productive forests on organic soils, are assumed to be mineral soils. The proportions of mineral and organic soils, the proportions of drained and undrained organic soils, and the distributions of soil fertiliy and climate variations within drained organic soils on power-line routes in productive forests are assumed to be the same as that of the Forest land remaining Forest land category.
NFI / SBA / SGS soil type map	The proportions of mineral and organic soils are calculated for all cropland found in the block database of the Swedish Board of Agriculture based on their soil type according to the soil type map of the Swedish Geological Survey. All organic soils on Cropland are assumed to be drained.
Dependent on the source of the remaining category of the new land use	The proportions of mineral soils and organic soils are assumed to be the same as that of the remaining category of the new land use.
Dependent on the source of the remaining category of the new land use	The proportions of mineral and organic soils, the proportions of drained and undrained organic soils, and the distributions of soil fertility and climate variations within drained organic soils are assumed to be the same as for the corresponding remaining category of the new land use, with the exception of former cropland for which all organic soils are assumed to be drained.
	Categories are either not observed (NO) or, for some unmanaged land use change categories, not estimated (NE).

Figure 6.8. Key to figure 6.7 explaining abbreviations and assumptions.

6.4 Description of categories (CRT 4A, 4B, 4C, 4D, 4E, 4F and 4G)

6.4.1 Definition of carbon pools and other sources

6.4.1.1 LIVING BIOMASS (CRT 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 biomass 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[290]. Other broad-leaved species constitute most of the remaining 8%. Below-ground biomass is defined as living biomass below stump height (1% of tree height) down to a root diameter of 2 mm while 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 land converted to Other land. The latter is due to natural transition from managed land to unmanaged land.

6.4.1.2 DEAD ORGANIC MATTER CRT-TABLES (CRT 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 (CRT 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, while fallen dead wood and snags are reported for all relevant land-use categories.

6.4.1.2.2 Litter (CRT 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 of the O horizon. Living 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.

6.4.1.3 SOIL ORGANIC CARBON (CRT 4A, 4B, 4C, 4D, 4E AND 4F)

Mineral soils

[290] Swedish University of Agricultural Sciences, 2023

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. The carbon pool considered is soil organic carbon down to a depth of 0.5 m measured from the top of the mineral soil. In cropland mineral soils, only the topsoil down to a depth of 0.25 m is considered for carbon stock change calculations.

Organic soils
For forest land, cropland and grassland, organic soils classified as Histosols[291] are included in the reporting and the entire depth of the soil profile is considered. Even if soil carbon is measured when the soil is classified as a Histosol, the carbon stock changes for these soils are based on emission factors (see below).

6.4.1.4 HWP (CRT 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 69 Mt 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 86% of the produced amount of the three product categories are consumed abroad and 14% domestically.

6.4.1.5 DIRECT N_2O EMISSIONS FROM N FERTILIZATION (CRT 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[292]. Thereafter, the annual fertilized area decreased for some years. Over time, this area has varied a lot and peaked in 2010 (80 200 ha). The fertilized area was about 22 500 ha in 2014 and increased steadily to 42 700 ha in 2021 but dropped to 9 900 ha in 2022. In 2023 the area was 14 900 ha. The activity data (fertilized 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 forest owners, defined as forest owners with more than 5000 ha of forest, contributes approximately 90% of fertilizer related emissions of N_2O and small-scale forest owners the remaining 10% of the emissions. To estimate the total annual emission, area figures are multiplied with a 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 (CRT 4(II))

N_2O emissions 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

[291] IUSS Working Group WRB. 2015.

[292] Swedish Forest Agency, 2012

of organic matter and a subsequent nitrification or denitrification of mineralized nitrogen which leads to N_2O emissions. Drainage was commonly used during the early part of the 20th century to increase productivity and to expand areas used for agriculture and forestry. The practice has more or less stopped due to a prohibition of new draining projects in the south and central parts of Sweden. Exceptions are made in two cases: (1) so called "protective drainage" that is done after clear cutting as a temporary measure to avoid a higher ground water table and (2) the drainage of peatland for peat extraction.

Emissions of CH_4 from these soils are mostly occurring from open ditches. On the drained soil itself, emissions of CH_4 are typically lower than it would be if the soil was not drained.

6.4.1.6.1 Rewetting in Sweden in 2021 and 2022

In recent years, the Swedish government have prioritized resources to restore wetlands and rewet drained organic soils through different funding programs to establish, rewet or restore wetlands[293]. However, rewetting of organic soils is still not reported under specific land use categories. This is due to lack of information on the land use after rewetting in the available data set of performed rewetting activities. In relation to the emissions and removals from soils, the effect of the current rewetting activities are marginal.

In 2021, an area of 1 800 ha was rewetted of which 830 ha was assessed as organic soils. The effect of the activity in 2021 was estimated to entail a decrease in emissions of 2.5 kt CO_2-equivalents using the same emission factors as for drained organic soils in Submission 2022 and emissions from rewetted soil according to the Swedish forestry board. In 2022 area of 2 100 ha was rewetted of which 1 500 ha was assessed as organic soils. The effect of the activity in 2022 was estimated to a decrease in emissions of 3.9 kt CO_2-equivalents using the same emission factors as for drained organic soils in Submission 2023. This means that in total rewetting activities 2021-2022 resulted in a decrease in annual emissions by 6.4 kt CO_2-equivalents.

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 (CRT 4(III))

A conversion in land use can be associated with a temporary increase in the mineralization of organic matter. A change in management of land causing loss of carbon can also contribute to 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 estimated net carbon loss from the soil. Emissions of N_2O from cropland remaining cropland is reported in the agricultural sector.

[293] https://www.naturvardsverket.se/amnesomraden/vatmark/bidrag-som-stod-for-att-anlagga-atervata-eller-restaurera-vatmarker/

6.4.1.8 INDIRECT NITROUS OXIDE (N_2O) EMISSIONS FROM MANAGED SOILS (CRT 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 (CRT 4(V))

Forest fires are rare in Sweden. Wildfires have been monitored by the Swedish Civil Contingencies Agency since 1996[294] and the area of wildfires on forest land has varied between 200 and 22 000 ha year^{-1}. Controlled burning to improve regeneration of trees after clear-cutting is monitored and there is a complete record from 1990 and onwards held by the Swedish Forest Agency. Controlled burning as part of nature conservation measures is monitored from 2006. In recent years, an area of approximately 60-400 ha is burnt annually after clear cutting and 100-400 ha is now annually burnt for nature conservation on forest land. 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 in parks. “No tree cover” is land with no trees such as agricultural land, open areas but also some mires. The assumed former stock on burned areas is based on estimates of 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 slightly underestimated since the reported numbers only include actual turnouts by the fire brigade. The accuracy of the estimated amount of carbon emitted as a result of fire per land category is probably low. This is due to a lack of knowledge about the burned stock in typically burned forests and a huge variation in fire intensity.

6.4.2 Methodological issues

6.4.2.1 BASE METHODOLOGY (CRT 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[295]) has monitored the living biomass pool since 1983 and the dead wood pool since the mid-1990s. The Swedish Forest Soil Inventory (SFSI) has inventoried the soil organic and litter pools since 1993 using a ten-year inventory cycle. 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 to the NID section 3.2.1.1). The SFSI uses the same permanent sample plots as the NFI but soil

[294] Swedish Rescue Services Agency, 2004

[295] Swedish University of Agricultural Sciences, 2023

sampling is only made on Forest land and Grassland and only on a sub-set of the sample plots.

6.4.2.2 METHODOLOGY LIVING BIOMASS (CRT 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[296] biomass functions to trees on permanent sample plots of the NFI[297]. The belowground biomass is estimated by using Peterssons and Ståhl's[298] biomass functions on biomass data from the same trees as for the aboveground biomass. A conversion factor of 0.50 is used to convert biomass to carbon[299]. Estimates of the change in the carbon pools are based on repeated measurements. Data for years between the repeated measurements are interpolated and for three of five inventory cycles, data for the most recent reporting years are projected using AI-techniques. 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. See the Annex to the NID, section 3.2.1.1. for further details.

6.4.2.3 DEAD ORGANIC MATTER CRT-TABLES (CRT 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.

6.4.2.3.1 Methodology dead wood CRT-tables (CRT 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[300]. The volume is measured by the NFI. The methodology is further described in the Annex to the NID, chapter 3.2.1.4.1.

Carbon stock changes in 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 change based on measurements of increment bore cores of sample trees) converted to CO_2 minus the estimated net change in the living biomass carbon pool (see 6.4.2.2). The harvest of stems is converted to stump and root biomass by conversion factors. The conversion factors are based on estimates of stem volume[301] and stump and root biomass[302] applied to sample trees representing the standing stock of Swedish forests. The decay of stumps is

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[296] Marklund, 1987 and 1988

[297] Ranneby et al., 1987

[298] Petersson and Ståhl, 2006

[299] Mensah, A.A., and Petersson, H. (2024) Carbon concentration of living tree biomass of Pinus sylvestris, Picea abies, Betula pendula and Betula pubescens in Sweden. Scandinavian Journal of Forest Research, DOI10.1080/02827581.2024.2332439

[300] Sandström et al., 2007

[301] Näslund,1947

[302] Petersson and Ståhl, 2006

modelled[303] 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. The methodology is further described in the Annex to the NID, section 3.2.1.4.1.

6.4.2.3.2 Methodology litter CRT-tables (CRT 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. Annual litter resulting from harvests is considered covered in the dead wood or coarse litter fraction described above. Litter fall from standing biomass 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 or the top of the mineral soil 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 to the NID, section 3.2.1.4.2).

6.4.2.4 METHODOLOGY SOIL ORGANIC CARBON (CRT 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, 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[304,305] 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 (CRT 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 the Annex to the NID, chapter 3.2.1.5).

6.4.2.4.2 Forest land and Grassland on organic soils (CRT 4.A.1 and 4.C.1)

The method is a Tier 2 method. Changes in the soil organic carbon pool on organic soils are calculated using emission factors. The emission factors rely on estimates of emissions

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303 Melin et al., 2009

304 the Introductory Carbon Balance Model

305 Andrén & Kätterer, 2001

divided into different classes of nutrient status and two different climate regimes. The nutrient status is determined by using the C:N-ratio in the soil while climate is divided geographically into a temperate and a boreal region. Emission factors was recently taken from the IPCC 2013 supplement for Wetlands[306] but from this submission updated emission factors based on a literature study are used. Emission factors for dissolved organic carbon (DOC) are based on a national survey (for further details, see the Annex to the NID, chapter 3.2.1.6). 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 are the same as for Forest land. Swedish Grasslands included in the reporting are defined as natural pastures which have soils that are more similar in character to Forest land soils than Cropland soils (for further details, see the Annex to the NID, chapter 3.2.1.6).

6.4.2.4.3 Cropland on mineral soils (CRT 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 model is described in Andrén & Kätterer[307]. 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[308](for further details see the Annex to the NID, chapter 3.2.1.7).

6.4.2.4.4 Cropland on organic soils (CRT 4B)

The method to estimate the carbon balance of organic cropland 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 a national survey[309]. The area of organic soil in these studies has been linked to the changes in total cropland area so that a decreasing cropland area proportionally affects the area of cropland on organic soils (for further details see the Annex to the NID, chapter 3.2.1.8).

6.4.2.5 METHODOLOGY FOR DEAD WOOD, LITTER AND SOIL ORGANIC CARBON FOR CONVERSION BETWEEN LAND-USE CLASSES CRT-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. 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 the Annex to the NID, chapter 3.2.1.10.

6.4.2.6 HWP (CRT 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.

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[306] IPCC 2014

[307] Andrén & Kätterer, 2001.

[308] Eriksson, 1997 and1999

[309] Lindahl and Lundblad, 2022

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 carbon stock changes for the three categories sawn wood, wood-based panels and paper products are calculated. Separate calculations are undertaken for products consumed abroad and products consumed domestically.

The carbon 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 collected 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 each product category. The general form of the equations is

$$p_{dh}=p*[(c_{rm}-i_{rm})/c_{rm}]$$

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 RP of domestic origin used abroad to produce new paper, the quota [production of RP/consumption of paper] in the EU + UK (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 from wood.

The conversion factors applied are 0.62 t per m^3 for wood-based panels, 0.42 t per m^3 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. The densities of the different panel categories came from Swedish Forest Industries association[310]. A corresponding methodology was applied to sawn wood, i.e., a weighted mean value of wood densities for the harvested wood

[310] https://www.traguiden.se/om-tra/materialet-tra/traets-egenskaper-och-kvalitet/densitet1/definitioner/ (In Swedish)

species, mainly Scots pine and Norway spruce, was calculated. Densities were calculated using stem biomass and volume from the Swedish NFI, supporting data were taken from Swedish Forest Industries association, and oral information from experts. 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 factor 0.9 came from from the spread sheet model provided by the IPCC[311] .

The amount of HWP put into landfills[312] is assumed to be 0.

Historical emissions differ somewhat compared to emissions reported in earlier years. In some cases data on production and trade are preliminary and have undergone slight changes following years.

6.4.2.7 CO_2 EMISSION FROM PEAT EXTRACTION (CRT 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 the extraction is stopped and site restoration begins (for further details see the Annex to the NID, section 3.2.1.9).

6.4.2.8 DIRECT N_2O EMISSIONS FROM N FERTILIZATION (CRT 4(I))

A Tier 1 methodology is used. All fertilization is assumed to occur on Forest land remaining Forest land[313]. In year 1990, calcium nitrate ($Ca(NO_3)_2$) was the dominant fertilizer but thereafter the fertilizer used has been ammonium nitrate (NH_4NO_3) 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 the Annex to the NID, section 3.2.2.1).

6.4.2.9 N_2O AND CH_4 EMISSIONS FROM DRAINAGE OF SOILS AND CH_4 FROM DITCHES (CRT 4(II))

A Tier 2 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 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

[311] IPCC_HWP_Tier_1_extend_FODWOOD v1 20 March06 Sept07 MODIF 22 10 08 KP

[312] 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)

[313] 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.

emission factors. For further information and the emission factors used, see the Annex to the NID, section 3.2.2.2.

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 (CRT 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[314]) using partially country-specific parameters (for further details the Annex to the NID, section 3.2.2.3).

6.4.2.11 INDIRECT NITROUS OXIDE (N_2O) EMISSIONS FROM MANAGED SOILS (CRT 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 (for further details, see the Annex to the NID, section 3.2.2.4).

6.4.2.12 EMISSIONS FROM BIOMASS BURNING (CRT 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 location of the burned areas is registered by the Civil Contingencies Agency (see section 6.4.1.8) and the fires in tree covered areas are matching areas defined as Forest land. The NFI registers 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, burnt area and emission factors. To avoid double-counting, CO_2 emissions from wildfires and controlled burning are included in 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. The IPCC 2006 GPG suggest emission factors that are slightly higher. However, Sweden finds a combusted proportion of 25% more realistic for Swedish conditions. 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 6.9.

[314] Intergovernmental Panel on Climate Change, 2006

Figure 6.9. 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 NID, table A.3.2.16.

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 either assumed through expert judgement or using the default error values according to IPCC [315].

6.4.3.1 LIVING BIOMASS (CRT 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. Research by Ståhl et al. (2014)[316] and Breidenbach et al. (2014)[317] indicate that the influence of model errors could be expected to be less than 1% of the total error budget. Estimates for reporting years 1990-2019 are based on approximately 30 000 sample plots and with a corresponding estimated standard error of 3 Mt CO_2/year. The estimate of uncertainty is quite stable between years but the relative estimates vary due to changes in net removals. Estimates for reporting years 2020, 2021, 2022 and 2023 are based on measurements on approximately 24000, 18000, 12000 and 6000 sample plots, respectively, combined with projected data. To avoid a potential risk of systematic errors we gradually update projected data using data from re-measured sample plots (see Annex 3:2 for further details).

[315] Intergovernmental Panel on Climate Change, 2006

[316]Ståhl et al., 2014.

[317]Breidenbach et al., 2014.

6.4.3.2 DEAD WOOD AND LITTER (CRT 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 SFSI. 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.

The accuracy of the litter estimations is continuously improved since the reported figures can be 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 - 2022 (the third inventory). Changes are interpolated for each plot between inventories. Litter pool changes for 2023 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 change in the fine litter fraction on mineral soils is estimated to be 0.32 t C ha^{-1} (n=7246) for changes occurring between the first and second inventory and 0.34 t C ha^{-1} (n=7180) for changes between the second and the third inventory. Note that this is the sample error of the carbon stock change over 10 years. The dead wood measurements are from the period 1995 to 2023. 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 (CRT 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 the carbon stock change in soil carbon on mineral soils is estimated to be 0.82 t C ha^{-1} (n=3134) for changes occurring between the first and second inventory and 0.94 t C ha^{-1} (n=2952) for changes between the second and the third inventory. Note that this is the sample error of the carbon stock change over 10 years. A problem associated with the used 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 the first inventory in order to avoid subjective judgments in sampling, e.g. regarding determination of soil horizon boundaries. This might give rise to problems of comparability between inventories, but should improve the quality of the data by reducing future risks of systematic errors.

Significant efforts are made to check data and to remove possible sources of error in the field data collection. The uncertainty in activity data (area) for CO_2 emission from drained organic soils on Forest land is judged to be 25% and errors in the emission factor to 40%. The uncertainty in emission factors (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 be 60%.

One of the major difficulties in reporting changes in DOM and SOC is that the pools are very large and the changes small in comparison to the pools. As seen in Figure 6.10, 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 are difficult to detect and the system is sensitive to systematic errors like small changes in data collection between inventories.

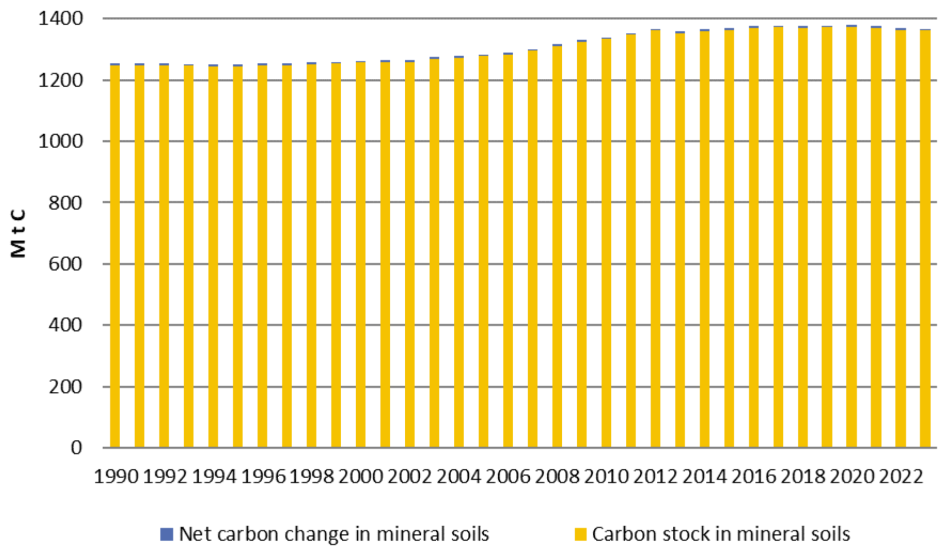

Figure 6.10. The reported change in soil carbon on mineral soils (blue bar) and the corresponding stock (yellow bar) for Forest land remaining Forest land.

6.4.3.4 HWP (CRT 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. In submission 2021 and 2022 the density 0.4 t m^{-3} was used. It was calculated using functions for all trees in the NFI. In the actual submission a corresponding analysis was made using sub sample trees for which height was registered, which ensures a more robust estimate for both volume and biomass, resulting in the density 0.42 t m^{-3}. Neither sawn wood, nor 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 wood 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-lives used for the different product categories is by far the most uncertain component in the calculations. Therefore, the uncertainty was estimated using varying half-lives. The half-lives were increased and decreased by 20%, and the uncertainty was estimated as the difference between the calculations using adjusted half-lives and the calculations using the default half-lives. A Monte Carlo analysis was used to estimate a mean standard deviation for the total emission which was converted to the uncertainty.

6.4.3.5 OTHER EMISSIONS (CRT 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 associated with 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 from the IPCC is that the emission factor should be in the range 0.25% to 6% and the interpretation is that a poorly chosen emission factor could lead to an emission factor uncertainty that is much larger than 25%.

4(II): For emissions from drainage, the error in activity data (areas) is judged to 25%. The uncertainty in the emission factors is mainly based on the confidence intervals calculated from the data in the litterature used to estimate the emission factors. The uncertainty in the emission factors for N_2O and for CH_4 are 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 considering 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 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%.

Table 6.5. Estimated and assumed uncertainty for LULUCF (Uncertainty=2•relative "standard error"). *=the absolute SE is around 3 Mton CO2/year and a relative uncertainty does not make sense

	2·Relative Standard Error,%		
Carbon pool / category	**CO_2**	**N_2O**	**CH_4**
Living biomass (permanent land use)	20	-	-
Living biomass (land use change)	15-390*		
Dead wood	50	-	-
Litter	50	-	-
Mineral soils (4.A.1, 4.B.1, 4.C.1)	35	-	-
Mineral soils (land use change)	50	-	-
Drained organic soils (4.A.1, 4.C.1)	35	-	-
Drained organic soils (4.B.1)	35		
Fertilization (4[I])	-	50	-
Drainage (4[II])	-	100	100
Mineralisation (4[III])	-	100	100
Indirect N2O (4[IV])		100	
Biomass burning (4[V])		100	100
HWP, 4G	25	-	-

6.4.3.6 COMPLETENESS

Each source/sink category has been reported only once. This is 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 reducing 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 all managed land converted to Other land, i.e. categories for which methods are provided in the 2006 IPCC Guidelines. The notation key "NO" is used when there is no observed occurrence for a certain category (e.g. 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-1990s. 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 2019, 2020, 2021, 2022 and 2023, respectively. When based on a five-year running average, the data is fixed for future reporting and should represent the reported year. The dead wood pool including stumps constitutes a relatively large 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. After 2018, large attacks of bark beetles have occurred on spruce. This has likely increased the net removal of standing and lying dead wood. Another reason may be that the inflow of new dead wood has increased from gradually more frequent windstorms, wildfires and other patho attacks, but no proper validation exists. The increased net removal of stumps is partially due to the harvest gradually increasing.

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 6.11).

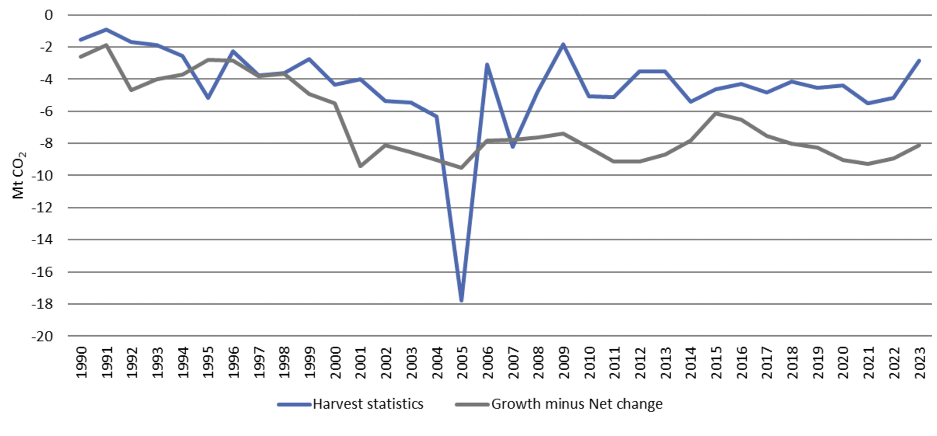

Figure 6.11. The reported net-removal from stumps (part of dead wood) is indirectly calculated from growth minus net-removal from living biomass (inflow) minus modelled decomposition (outflow). The validating net-removal from stumps is based on harvest statistics (inflow) minus modelled decomposition (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 were small differences with respect to the rate of change between the models and the measurements[318].

6.4.4.2 QUALITY ASSURANCE (QA)

The quality assurance system of the data collection within NFI used for the UNFCCC reporting has been described by the Swedish University of Agricultural Sciences[319]. 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 documentation of methodologies used is archived by the SLU.

6.4.5 Source-specific recalculations

Recalculations can be separated into several categories of which the two first ones can be considered “ordinary” recalculations in the Swedish inventory due to the applied methodology using random sampling.

The first category is recalculations due to updated NFI data which 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 SFSI. Beginning from Submission 2023, a new system for interpolating this data was introduced. It is described in section 3.2.1.6 in the Annex. In essence, the new interpolation system averages the calculated change in litter and soil carbon pools over the entire time series. Quantitatively important recalculations are expected for each submission because of phasing in new data on carbon stock change each year. It should be noted that these recalculations are very small, relative changes in carbon stocks that become quantitatively important emissions or uptake of CO_2 due to the size of the carbon pool. An annual change of 1 ‰ in the soil carbon pool, i.e., 1% between inventories (10 years), in Forest remaining Forest represents an annual emission/uptake of around 5 Mton CO_2. After introduction of the new interpolation, any variation in the time series within the same submission is due to varying sample plot numbers for individual years. This variation is in turn due to sample plots leaving or joining the land-use category due to

[318] Ortiz *et al.* 2009.

[319] Karltun *et al*., 2005.

land-use change or that a 20-year period in a land-use change transfer class is coming to an end. For some land-use categories the proportion of plots that do change classification making them either to leave or join a certain land-use category during the reporting period is relatively high. In an assessment of the Grassland remaining Grassland category, it was found that 25% of plots classified as Grassland remaining Grassland at any time, had changed classification during the reporting period.

The third category is when new activity data (not related to NFI or SFSI) 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 calculations 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 (6.2.9). This re-calculation is considered ordinary.

6.4.5.2 LIVING BIOMASS

To improve the accuracy of estimates, the living biomass pool and areas have been recalculated for the years 2019-2023 in the current submission. Each estimate for these years is now based on 6 000 more sample plots and incomplete inventory cycles have been projected to 2023, see section 6.3.1.1 and Appendix Table A3:2.2. This is from now on considered an ordinary re-calculation. This has resulted in a reduction in net removals 2019-2022.

Small trees (dbh<100 mm) were previously estimated with regression to -3.99 Mton CO_2 $year^{-1}$ for all years 1990 and onwards. The same number was used in the accounting reference, which means that the effects of small trees were offset in the accounting. Now the net removal of change in living biomass is estimated using the permanent NFI-plots, which means that the re-calculated net removal for recent years has decreased. This will require that also the accounting reference (FRL) needs to be corrected (see Appendix Table A3:2.4.).

The total effect of the recalculation on Living biomass on Forest land remaining forest land is illustrated in Table 6.6a and Figure 6.12.

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 2023 due to the introduction of more re-inventoried sample plots from the SFSI but recalculation changes are mainly affecting the data from 2003 and onwards. Measured data up to 2022 was available for this submission. That means that changes are calculated based on three separate measurements and that the reporting of litter and soil organic carbon is based on three complete SFSI cycles spanning 30 years.

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). A major investigation was also made to provide updated emission factors for CO_2, CH_4 and N_2O from drained organic soils. The new emission factors are based on a literature review including a large number of representative studies (for further details, see Annex 3:2).

Some of the carbon stock change factors for land use change categories have been reassessed regarding which factor to apply on the land area undergoing conversion. After discussion with the ERT, different assumptions are made to estimate the CSC factors in relation to whether the target land use reports CSC or whether it is assumed to be in equilibrium. See Annex 3:2 for further details.

6.4.5.4 NON-CARBON EMISSIONS

No recalculations have been made for N_2O emissions from nitrogen fertilization (4I). Recalculations have been made for non-carbon emissions (4II) from drained organic soils due to adjustments in activity data and emission factors (see above). Due to recalculations of the carbon stock changes, 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 major change in underlying activity data for wildfires (4V) has been made.

The recalculations are summarized in Table 6.6.a. and Table 6.6.b.

6.4.5.5 HWP

Recalculations have been made due to an error in activity data in previous submission.

Table 6.6a. and Table 6.6.b. Recalculations of carbon stock changes and other emissions between submission 2024 and submission 2025 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. Note that a value of 0.00 in table 6.6.a means that the estimate is below 0.005 and that a value of 0.0 in table 6.6.b. that the estimate is below 0.05.

6.6 a	Difference in carbon stock changes between Submission 2024 and 2025 [Mt CO_2]																					
	Forest land					Cropland				Grassland				Wet-land	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	DOM	SOC	
1990	-1.41	0.41	-7.21	-1.52	0.63	0.00	0.00	0.00	1.19	-0.01	-0.06	-0.14	0.00	-0.01	0.00	-0.06	-0.27	0.23	0.00	0.00	0.00	0.00
1995	-1.24	0.37	-6.37	-1.52	0.61	0.00	0.00	0.01	1.14	-0.01	-0.06	-0.14	0.02	-0.01	0.00	-0.09	-0.50	0.21	0.00	0.00	0.00	0.00
2000	-0.94	0.36	-6.38	-1.52	0.58	0.00	0.00	0.02	1.07	-0.01	-0.06	-0.14	0.04	0.00	0.00	-0.10	-0.67	0.25	0.00	0.00	0.00	0.00
2005	-0.60	0.35	-6.13	-1.52	0.62	0.00	0.00	0.03	1.02	0.00	-0.05	-0.14	0.04	0.05	0.00	-0.09	-0.80	0.23	0.00	0.00	0.00	0.00
2010	3.27	-0.52	-6.53	-1.39	0.75	-0.01	0.00	0.03	0.96	-0.02	-0.05	-0.16	0.05	0.10	0.00	-0.10	-0.77	0.10	0.00	0.00	-0.01	0.00
2015	4.69	-0.62	-6.12	-1.50	0.86	-0.01	0.00	0.04	0.87	0.20	-0.13	-0.30	0.03	0.14	-0.01	-0.09	-0.74	0.01	0.02	0.00	-0.01	0.00
2016	7.79	-1.32	-6.76	-1.50	0.93	-0.01	0.00	0.04	0.87	-0.01	-0.13	-0.31	0.03	0.15	0.18	-0.09	-0.73	0.04	0.02	0.00	-0.01	0.00
2017	7.97	-1.32	-7.51	-1.50	1.01	-0.01	0.00	0.04	0.87	-0.01	-0.13	-0.31	0.03	0.16	-0.01	-0.09	-0.73	0.04	0.02	0.00	-0.01	0.00
2018	5.97	-0.31	-6.63	-1.53	1.05	-0.01	0.00	0.04	0.86	-0.01	-0.13	-0.30	0.05	0.16	0.13	-0.09	-0.74	0.00	-0.01	0.00	-0.01	0.29
2019	8.80	-0.62	-6.95	-1.52	1.16	0.11	0.00	0.04	0.86	0.04	-0.13	-0.30	0.02	0.17	-0.06	-0.09	-0.74	-0.11	0.02	0.00	-0.01	0.20
2020	12.47	-1.60	-6.97	-1.48	1.36	-0.17	-0.01	0.04	0.88	-0.10	-0.13	-0.29	0.02	0.20	0.50	-0.09	-0.74	-0.18	0.03	0.00	-0.01	-0.09
2021	15.88	-1.93	-7.15	-1.34	1.56	0.11	-0.01	0.04	0.85	-0.10	-0.13	-0.28	-0.02	0.21	-0.56	-0.09	-0.74	-0.16	0.02	0.00	-0.01	0.47
2022	15.80	-1.38	-7.49	-1.22	1.80	0.09	-0.02	-0.07	0.90	-0.61	-0.12	-0.29	0.00	0.22	0.02	-0.09	-0.73	-0.31	0.02	0.00	-0.01	0.74

6.6 b	Other emissions [kt substance]								Total	
	Fert. 4 (I)	Drainage 4(II)		Mineralisation 4 (III)	Indirect 4 (IV)	Biomass burning 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	2.7	0.2	-0.1	0.0	IE	0.0	0.0	-8.0	-15
1995	0.0	2.6	0.1	-0.1	0.0	IE	0.0	0.0	-7.5	-16
2000	0.0	2.3	0.1	-0.2	0.0	IE	0.0	0.0	-7.7	-14
2005	0.0	2.5	0.1	-0.2	0.0	IE	0.0	0.0	-7.6	-15
2010	0.0	2.4	0.1	-0.2	0.0	IE	0.0	0.0	-5.0	-9
2013	0.0	2.5	0.2	-0.2	0.0	IE	0.0	0.0	-2.4	-4
2014	0.0	2.4	0.2	-0.2	0.0	IE	0.0	0.0	-2.8	-5
2015	0.0	2.2	0.2	-0.2	0.0	IE	0.0	0.0	-3.0	-6
2016	0.0	2.4	0.2	-0.2	0.0	IE	0.0	0.0	-1.2	-2
2017	0.0	2.3	0.2	-0.2	0.0	IE	0.0	0.0	-1.7	-4
2018	0.0	2.1	0.1	-0.2	0.0	IE	0.0	0.0	-1.2	-3
2019	0.0	2.1	0.1	-0.2	0.0	IE	0.0	0.0	0.7	2
2020	0.0	2.4	0.2	-0.2	0.0	IE	0.0	0.0	3.7	9
2021	0.0	2.4	0.2	-0.2	0.0	IE	0.0	0.0	6.9	16
2022	0.0	2.5	0.3	-0.2	0.0	IE	0.0	0.0	7.6	18

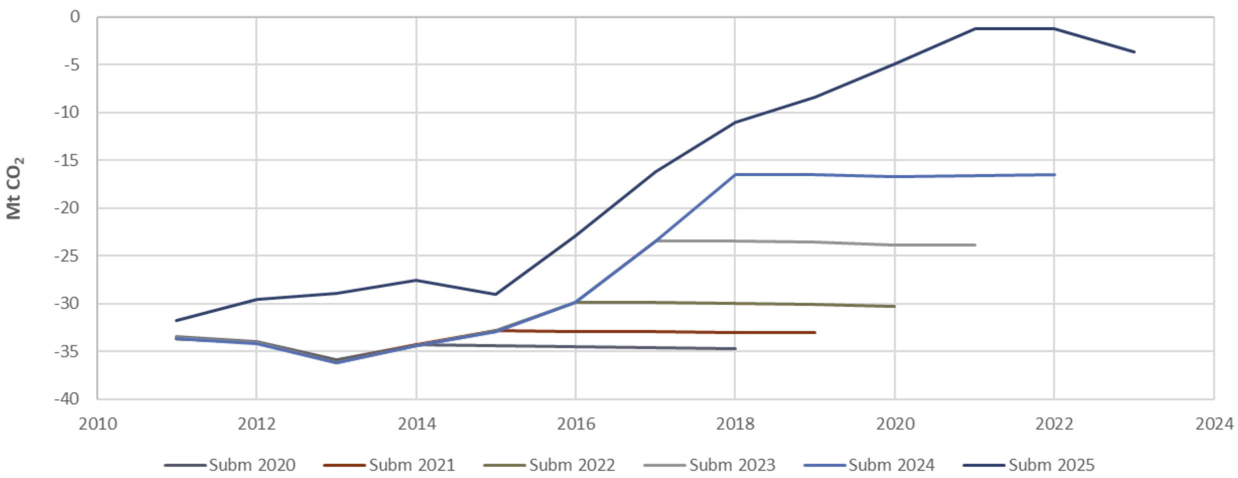

Figure 6.12. Reported living biomass on Forest land remaining forest land (4A1) according to different submissions. The values (the five latest reported years) are continuously recalculated. This year the difference between submissions relates both to the new method for extrapolation of the last four years and the recalcuation of small trees.

6.4.6 Planned improvements

Due to a recomendation from the ERT we have initiated a project for validation and potential improvement of the empirical models used to calculate annual litterfall. The project is on-going. If the project leads to improved models they will be included in submission 2026.

New research and successive development of methods as well as adapting the reporting to any new requirements under the UNFCCC in relation to the Paris agreement and the new LULUCF-regulation within the EU (EU 2018/841) and (EU 2023/839) may result in improvements in future Submissions.

7 Waste (CRT 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, CRT 5.A. Other sources of greenhouse gases are Biological treatment of solid waste, CRT 5.B and Wastewater treatment and discharge, CRT 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, CRT 5.C. Waste incineration with energy recovery is included in the Energy sector, Public electricity and heat production (CRT 1.A.1.a).

Greenhouse gas emissions in CO_2-eq. from the waste sector have 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.

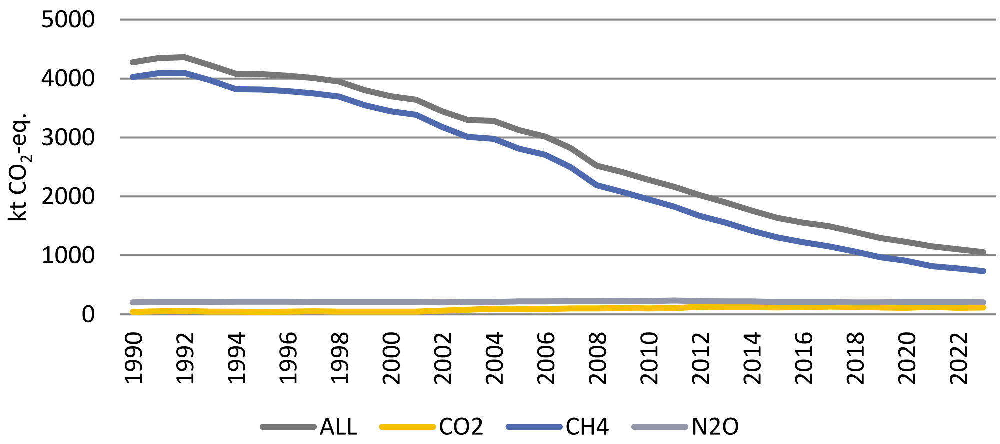

Figure 7.1. Total emissions of all greenhouse gases calculated as CO_2-eq. from CRT 5 Waste.

Biological treatment of solid waste (CRT 5.B) is the only subsector that shows an increasing trend for 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 organic solid waste to landfills.

For nitrous oxide, there has been a reduction of 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 7.2 shows that greenhouse gas emissions from the Waste sector (CRT 5) largely come from solid waste disposal (CRT 5.A). Methane in sub-sector 5.A represents between 90.0% and 44.6% of the total reported greenhouse gases in the Waste sector during the period 1990 – 2023. Emissions of greenhouse gases from waste incineration are 11.3% of the emissions of CRT 5 in 2023.

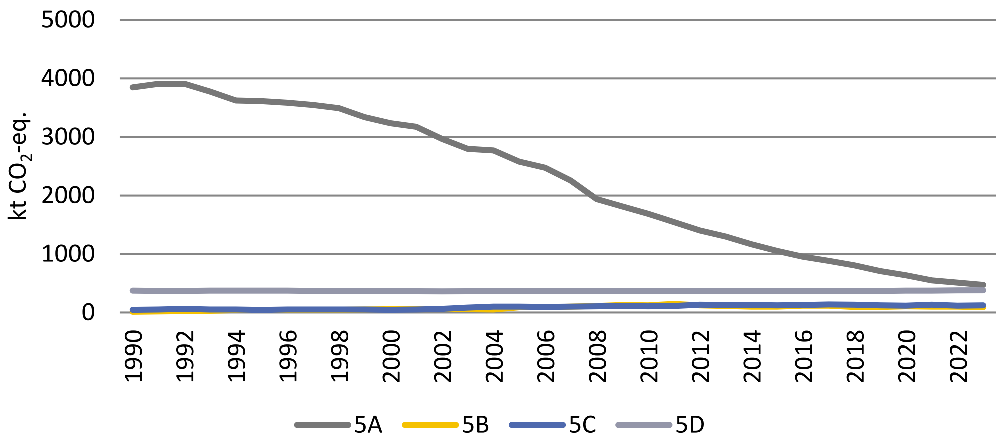

Figure 7.2. Total emissions of all greenhouse gases calculated as CO_2-eq. from the different waste sub-sectors (5A – Solid waste disposal, 5B – Biological treatment of solid waste, 5C – Incineration and open burning of waste, 5D Wastewater treatment and discharge).

7.1.1 Biogas production in Sweden

Most of the biogas is produced within the Waste sector (CRT 5). See further below in the CRT 5.A, CRT 5.B and CRT 5.D sections. According to a survey[320] by the Swedish Energy Agency completed by Avfall Sverige & SMED on biogas production and utilization, the production of biogas (including landfill gas extraction) in Sweden in 2023 was 2 283 GWh which is equivalent to 163.8 kt of methane. The corresponding amount in 2005 was 1 285 GWh (equivalent to 92.2 kt of methane)[321].

7.2 Solid waste disposal (CRT 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 2020, 91.9%[322] of the landfilled waste). An overview of waste streams in Sweden in year 2022 (excluding major mineral waste) is presented in Figure 7.3.

[320] Swedish Energy Agency, 2023

[321] Swedish Energy Agency, 2007

[322] Swedish EPA, 2022

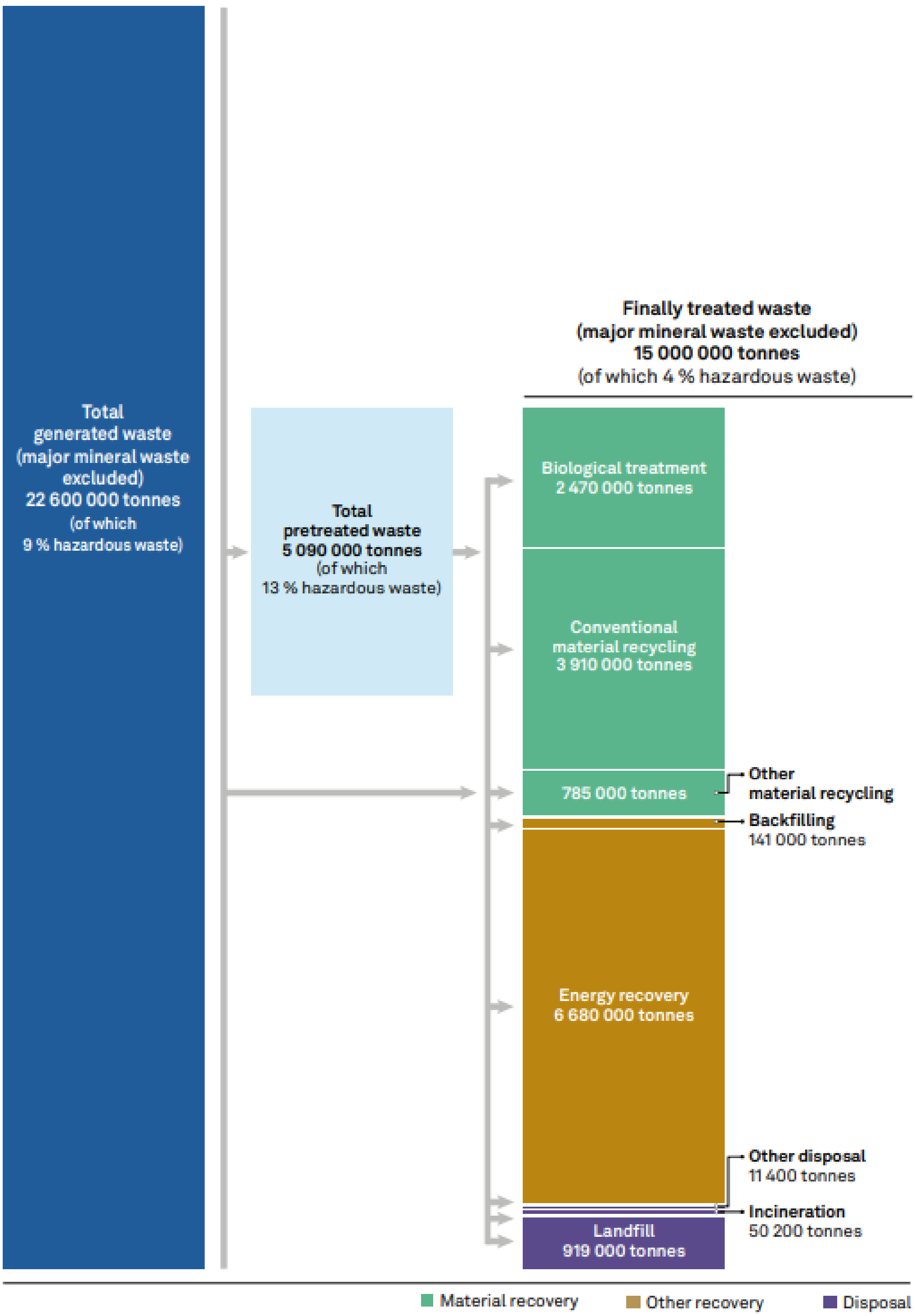

Figure 7.3. Waste streams in Sweden 2022 according to the Swedish EPA[323]. Major mineral waste is excluded.

[323] Swedish EPA, 2024

In the 1990s, the amount of deposited waste (other than mining waste) decreased significantly. This is especially notable for household waste, which is a large part of municipal solid waste (MSW). Only 1.5% of the treated household waste was deposited in 2023[324], which can be compared to 43.8% of the MSW in 1990 (data on the current definition of household waste is unavailable for year 1990). The remaining part of the treated household waste in 2023 was either incinerated (56.0%), recycled (24.3%), treated biologically (15.1%) or used as construction material (3.1%).

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 50[325] sites in 2023.

7.2.1 Legislation and policies

7.2.1.1 LANDFILLING

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 the waste that enters landfills, currently 725 SEK[326] per tonne 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 the landfills for municipal waste were taken out of operation, according to the trade association Avfall Sverige – Swedish Waste Management.

7.2.1.2 LITTERING

In Sweden, there are some problems with unmanaged waste. *Littering* is occurring, in particular around recycling stations. Garden waste from households is sometimes disposed in the nearby nature instead of being treated properly. Animal carcasses and similar waste and by-products are sometimes disposed in situ and when so, shall be buried in accordance with the law.
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.

[324] Swedish Waste Management 2024

[325] Swedish Waste Management 2024

[326] The Swedish Tax Agency 2024

7.2.2 Managed waste disposal sites (CRT 5.A.1)

7.2.2.1 SOURCE CATEGORY DESCRIPTION

Sweden is reporting data on emissions of methane (CH_4) from CRT 5.A.1.a Managed waste disposal sites: Anaerobic.
For methane from CRT 5.A.1.b Managed waste disposal sites: Semi-aerobic and CRT 5.A.2 Unmanaged waste disposal sites, Sweden is reporting NO (not occurring), since there are no known semi-aerobic[327] or unmanaged waste disposal sites for organic waste or municipal solid waste in use[328] 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, CRT 5.A.1, according to approach 1.

CRT	Gas	Key Category Assessment, 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 have 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

[327] IVL Svenska Miljöinstitutet AB (Sundqvist), 2014

[328] Nygren, 2010

calculation. The quality of data on household waste is high since 1980, but data on organic industrial waste were scarce at that time. 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 2023.

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 currently used in Sweden.

Table 7.2 Methane emission from Swedish landfills according to IPCC FOD method, deposited MSW*, sludges (containing DOC) and total (also reported as “Annual waste at the SWDS in CRT Table 5.A), 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** in kt
1990	137	2 323	1 400	3 723
1991	139	2 223	1 262	3 485
1992	140	2 203	1 174	3 377
1993	135	2 199	1 086	3 285
1994	129	2 166	860	3 026
1995	129	1 974	850	2 824
1996	128	1 857	880	2 737
1997	127	1 843	975	2 818
1998	125	1 678	700	2 378
1999	119	1 756	620	2 376
2000	115	1 529	587	2 116
2001	113	1 488	514	2 002
2002	106	1 338	341	1 679
2003	100	1 034	223	1 257
2004	99	811	113	923
2005	92	541	58	598

* 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 fractions), construction and demolition waste (organic fraction), sludge from wastewater handling and pulp industry containing DOC (wet weight).

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.

Table 7.3. Methane emission from Swedish landfills according to IPCC FOD method, deposited solid waste (containing DOC), deposited sludges (containing DOC) and total (also reported as "Annual waste at the SWDS in CRT Table 5.A), 2006-2023.

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, (wet weight)	Total in kt*
2006	88	1 249	180	1 429
2007	80	1 144	144	1 288
2008	69	1 039	108	1 147
2009	65	871	141	1 012
2010	60	648	164	813
2011	55	656	132	788
2012	50	664	99	763
2013	46	609	110	720
2014	42	555	121	677
2015	38	595	92	687
2016	34	635	63	698
2017	31	598	93	691
2018	29	562	123	685
2019	25	560	72	632
2020	23	558	22	580
2021	20	534	34	568
2022	18	510	45	555
2023	16	510	45	555

* Activity data and statistics for 2006, 2008, 2010, 2012, 2014, 2016, 2018, 2020 and 2022 are from Sweden's reporting to the Commission according to the Waste Statistic Regulation. Activity data and statistics for 2007, 2009, 2011, 2013, 2015, 2017, 2019, 2021 and 2023 are interpolated/extrapolated values.

Landfill gas extraction

Methane recovery at landfills 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, the first plant started to extract landfill gas in 1983. The activity increased until year 2003 when gas was recovered in 72 plants. Information on recovered gas (in energy units, MWh) is provided by Avfall Sverige and converted to quantity (t) methane by Statistics Sweden (see Table 7.4).

Table 7.4. Recovered and flared methane from landfill gas.

Year	Recovered and flared gas (t)	Year (cont.)	Recovered and flared gas (t)
1982	0[1]	2006	24 567[6]
1983	NE[2]	2007	24 553[6]
1990	12 000[3]	2008	28 444[7]
1991	13 500[3]	2009	25 248[7]
1992	16 000 [3]	2010	22 409[7]
1993	23 000[4]	2011	21 046[7]
1994	30 000[4]	2012	19 924[7]
1995	30 000[4]	2013	17 839[7]
1996	30 000[5]	2014	17 023[7]
1997	30 000[5]	2015	16 115[7]
1998	30 000[5]	2016	15 154[7]
1999	33 000[5]	2017	13 389[7]
2000	34 000[5]	2018	12 126[7]
2001	32 400[5]	2019	12 137[7]
2002	35 947[5]	2020	11 219[7]
2003	36 449[5]	2021	11 432[7]
2004	30 135[5]	2022	10 148[7]
2005	29 418[5]	2023	9 204[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, 2015-2024.

The recovered and flared methane from landfill gas in Table 7.4 is calculated on the basis of the energy production in MWh using the lower heating value for methane.

In year 2023, 5.6% of the produced biogas in Sweden was produced at landfills. The biogas production (extracted gas) on landfills decreased from 457 GWh to 128 GWh between 2005 and 2023, since the amounts of deposited organic waste has decreased significantly the past years, due to the implementation of waste treatment policies. About 38% of the biogas produced[329] (collected gas) at landfills was flared in 2023 (see Table 7.5). Landfill gas was extracted at 68 active or closed landfills[330].

Biogas from landfills is mainly used for heating but also for production of electricity. In year 2023, no[331] landfill gas was used as vehicle fuel.

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 CRT 1.

[329] Swedish Waste Management & SMED 2024

[330] Swedish Waste Management & SMED 2024

[331] Swedish Waste Management & SMED 2024

Table 7.5. Energy recovery and flaring at landfills in Sweden, MWh[332].

Year	2005	2010[1]	2015[1]	2020[1]	2021[1]	2022[1]	2023[1]
Energy recovery	340 000	273 029	157 682	100 493	95 694	90 165	79 162
Whereof prod. of electricity	20 000	25 484	17 017	3 537	3 349	2 822	2 120
Flaring	70 000	39 293	63 858	55 865	63 641	51 264	49 121
Total	**410 000**	**312 322**	**221 539**	**156 358**	**159 335**	**141 429**	**128 282**

1) Avfall Sverige (Swedish Waste Management) & SMED, 2015-2024. The information from Avfall Sverige is supplemented by SMED on additional landfills in operation and all closed landfills, which are excluded by Avfall Sverige.

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.

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.

The oxidation factor is estimated to be 10%, and the half-life of the methanogenesis is 7.5 years.[333] 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.

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.[334] An assumption is therefore made that before 1976, 37% of all deposited household waste was burned.

[332] Swedish Waste Management & SMED 2023

[333] Börjesson, 2000

[334] Swedish EPA, 1983.

7.2.2.2.2 WASTE STATISTICS IN SWEDEN, 1980 - 2005

The Swedish EPA made the first national survey on deposited waste in Sweden in 1980 (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 most well-documented waste category, with high quality data available since 1980. Household waste is also the most important category for methane production in landfills. Statistics on deposited sludge from households and park and garden waste are available since 1990. Standard values on fractions of deposited household waste from 1970 and 1975 are also available at the Swedish Waste Management.

Statistics on organic waste from industries are much scarcer. There is information on industrial waste from the 1980s but organic fractions were not specified. The official statistics from 1993 and 1998 on waste from manufacturing do not emphasize generation and treatment of organic waste. Dedicated studies on quantities and treatment of biological waste from industry were carried out in 1993 and 1996 by the Swedish EPA. According to these studies, deposited sludge from the pulp industry has previously been the most important organic deposited industrial waste category. This waste category is also documented by surveys, carried out regularly until 2000 by the Swedish EPA and later by Swedish Forest Industries Federation. Today, sludge from the pulp industry is incinerated or composted.

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.

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.

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”) that 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, CRT 5A”.

The Swedish EPA is responsible for the reporting in accordance with the regulation. So far, waste data have been reported for the reference years 2004, 2006, 2008, 2010, 2012, 2014, 2016, 2018, 2020 and 2022. No waste statistics on landfilling are compiled by the Swedish EPA for the intermediate years.

Background to the implementation of WStatR-data
The advantages of WStatR-data in relation to waste statistics for 1980-2005 (see above) 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 have per definition 100% coverage (completeness).

In 2010, a study[335] was carried out in order to analyse possibilities to use the reported waste data to WStatR for the calculations of methane from solid waste landfills.

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. The study recommended implementation of WStatR-data from reference year 2006 and onwards.

Estimation of DOC content
The national statistical waste database, which is used for storage of microdata for production of official waste statistics, is the source of information when estimating the DOC-values of the EWC Stat-codes.

In Sweden, the official waste statistics are produced by collecting microdata by using “LoW” codes. Since “LoW” is very detailed, it is also suitable for accurately estimating the DOC content (fraction of DOC) to the waste data aggregates of EWC Stat. Relevant waste categories are chosen (those which are containing Degradable Organic Carbon), and the DOC content of the chosen waste categories is investigated by analysing the microdata.

For each EWC Stat code, information on the identification of landfills, LoW codes and quantities of waste are gathered. The DOC content for each LoW code is 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 is set for all LoW codes within each EWC Stat code, the DOC content for the EWC Stat code is estimated by weighting the DOC content of the LoW codes. This is done by using the information on the waste quantity for each LoW code. The quantification of uncertainty associated with the DOC values is also 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 five times 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 redefined EWC-Stat codes was necessary. The second time was for the statistical reference year 2016 to update the estimations of the DOC-content. The third time was for the reference years 2012 and 2014 (in

[335] SMED (Edborg, Stenmarck, Sundquist & Szudy), 2010

submission 2021). The fourth time was for the reference year 2018 (in submission 2022). The fifth and most recent time was for the reference year 2020 (in submission 2024).

Interpolations and extrapolations are made for the intermediate years.

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]	0.20[19]	900[5]	0.07[20]
1994	1 380[6]	..	80[6]	0.20[19]	610[6]	0.07[20]
1995	1 200[7]	0.19[17]	60[7]	0.20[19]	540[7]	0.07[20]
1996	1 110[8]	..	70[8]	0.20[19]	470[8]	0.07[20]
1997	1 150[8]	0.18[18]	50[8]	0.20[19]	455[8]	0.07[20]
1998	1 020[9]	..	45[9]	0.20[19]	490[9]	0.07[20]
1999	972.5[10]	..	45[10]	0.20[19]	490[10]	0.07[20]
2000	869.5[11]	0.18[18]	53[11]	0.20[19]	345[11]	..
2001	880[12]	..	44[12]	0.20[19]	330[12]	..
2002	820[13]	..	40[13]	0.20[19]	215[13]	..
2003	575[14]	..	33[14]	0.20[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) 2006 IPCC Guidelines. 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[336] presents a historic overview of Swedish investigations, the first of

[336] Ohlsson, 1998 and REFORSK, 1998

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[337] 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.[338] Different fractions of household waste from southern Sweden have been analysed with the same methodology in 3 different years (1997, 2000 and 2004), see further in Table 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%.[339] The gas potential of the sludge is reduced by 50% because it is treated.[340] By using formulas for L_0 (methane generation potential) given 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.[341]

[337] Ohlsson, 1998

[338] RVF, 2005

[339] Recounted from RVF, 1996.

[340] Sweco Viak, 2000.

[341] Swedish EPA, 1993.

Industrial waste

As noted above, statistics on deposited industrial waste are not divided up 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.[342] The estimates have been made with the help of the information from many different sources such as national statistics, screening inspections of waste content, information on capacity of energy recovery from waste and extrapolation back in time using the industries part of Gross National Product (GNP). The study shows that great amounts of paper and wood have been deposited in construction and demolition waste, as well as in the category of "non-specific" industrial waste.

The first study on "specific" organic industrial waste was published in 1993;[343] 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.

[342] Profu, 2004.

[343] 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 are 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 are 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[344]. 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 slaughterhouses	22.5	0.88
Waste from potato and vegetable industries	11.5	0.64
Total:	**34**	**1.52**

Swedish EPA, 1996

The final gas potential is used as gas potentials in the methane calculations for 1996 and later. 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.[345] 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.

[344] Swedish EPA, 1996

[345] 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, 1952-2023

Landfilled quantities of DOC, 1952-2023

Table 7.13 below shows the calculated quantities of deposited DOC over the time period 1952-2023. These data are used as activity data when when caclulating the methane emissions by using the emissions with the FOD model. The data sources are the waste statistics described in the NID.

Table 7.13. Deposited quantities of Degradable Organic Carbon (DOC) 1952-2023, kt.

Year	DOC	Year	DOC	Year	DOC	Year	DOC
1952	472	1970	557	1988	588	2006	88
1953	475	1971	559	1989	623	2007	70
1954	479	1972	562	1990	655	2008	52
1955	482	1973	538	1991	611	2009	38
1956	486	1974	543	1992	591	2010	40
1957	489	1975	545	1993	575	2011	32
1958	492	1976	586	1994	536	2012	24
1959	495	1977	621	1995	498	2013	18
1960	500	1978	626	1996	476	2014	14
1961	506	1979	672	1997	479	2015	15
1962	511	1980	664	1998	407	2016	15
1963	516	1981	656	1999	422	2017	15
1964	524	1982	635	2000	375	2018	14
1965	530	1983	588	2001	350	2019	15
1966	535	1984	576	2002	296	2020	16
1967	540	1985	569	2003	224	2021	19
1968	546	1986	568	2004	173	2022	22
1969	550	1987	578	2005	115	2023	22

Used statistics 1952-2005

Tables 7.14 and Table 7.15 show the activity data 1952-2005 used in the calculations of methane emissions from solid waste disposal on land.

Table 7.14. Overview over used statistics on deposited waste and interpolated/-extrapolated values: Solid waste.

Year	Standard value: Household waste/ citizen (kg)	Fraction deposited household waste	Fraction of burned household waste on landfills	Deposited household waste and similar, (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 7.15. Overview over used statistics on deposited waste and interpolated/extrapolated values: Sludge, kt 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(*)

(*) Taken from statistical sources. Other values are interpolated or extrapolated.

Used statistics and DOC values 2006-2009

Table 7.16 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 values[346] for each waste category.

[346] SMED (Edborg, Stenmarck, Sundquist & Szudy), 2010

Table 7.16. Overview of 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	176.95	2
03.2	Industrial effluent sludges: Dry matter	11.91	10.58	9
05.	Health care and biological wastes: Hazardous	C	0.00	8
05.	Health care and biological wastes	C	0.01	8
07.2	Paper and cardboard wastes	38.98	2.30	36
07.5	Wood wastes	C	1.84	40
07.6	Textile wastes	0.23	0.97	24
09A	Animal and vegetal wastes *(excl. 09.11 & 09.3)*	11.55	6.06	15
09.11	Animal waste of food preparation and products	0.30	0.34	15
09.3	Animal faeces, urine and manure	0.37	0.08	9
10.1	Household and similar wastes	203.82	119.99	18
10.2	Mixed and undifferentiated materials	482.74	222.44	3.1
10.3	Sorting residues	311.48	507.60	2.5
11A	Common sludges *(excl. dredging spoils)*: Dry matter	26.38	13.14	28
	Total	**1 428.88**	**1 146.60**	

* 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 and DOC values 2010-2023

The EWC-Stat codes in Table 7.17 and Table 7.18 differs somewhat compared to those in Table 7.16. This is due to changes in the EWC-Stat code nomenclature implemented in the 2010 year data. The used statistics and DOC values for 2010-2023 are presented in separate tables below.

Waste statistics

Table 7.17 shows waste statistics for 2010, 2012, 2014, 2016, 2018, 2020 and 2022 used in the calculations of methane emissions from solid waste disposal. Waste statistics for 2011, 2013, 2015, 2017, 2019, 2021 and 2023 are interpolated/extrapolated.

Table 7.17. Overview of used statistics* 2010-2022 on deposited waste, kt.

EWC-Stat code	Description of waste categories	2010(*)	2012(*)	2014(*)	2016(*)	2018(*)	2020(*)	2022(*)
02A	Chemical wastes	85.30	93.60	126.00	158.00	159.00	151.00	128.60
03.2	Industrial effluent sludges: Dry matter	1.28	7.78	19.10	5.60	1.54	1.68	4.68
03.2	Industrial effluent sludges: Dry matter Hazardous	7.00	10.40	9.59	7.78	26.60	3.72	6.23
03.3	Sludges and liquid wastes from waste treatment: Dry matter	0.09	0.20	0.02	0.58	0.01	0.02	C
05.	Health care and biological wastes: Hazardous	0	0	0	-	-	-	-
05.	Health care and biological wastes	0	-	-	-	-	-	-
07.2	Paper and cardboard wastes	0.56	-	-	-	-	-	C
07.5	Wood wastes	0.06	6.46	4.39	-	0.72	0.20	C
07.6	Textile wastes	0	-	0.58	0.04	-	-	-
09.1	Animal and mixed food waste	1.18	0.40	0.25	0.06	0.08	0.01	C
09.2	Vegetal wastes	2.30	0.24	0.07	0	0	0	C
09.3	Animal faeces, urine and manure	0	-	-	-	-	-	0.28
10.1	Household and similar wastes	17.00	26.80	21.90	26.70	7.23	46.7	158.60
10.2	Mixed and undifferentiated materials	262.00	289.00	116.00	206.00	231.00	199.00	C
10.3	Sorting residues	280.00	247.00	286.00	244.00	164.00	161.00	C
11A	Common sludges *(excl. dredging spoils)*: Dry matter	26.20	5.31	1.56	1.87	2.05	0.15	0.26
	Total	**682.97**	**687.19**	**585.25**	**650.63**	**592.23**	**563.43**	**C**

* Waste statistics for 2010, 2012, 2014, 2016, 2018, 2020 and 2022 are from Sweden's reporting to the Commission in accordance with the Waste Statistic Regulation. (C: Confidential)

DOC values

Table 7.18 shows DOC values for 2010[347], 2012[348], 2014[349], 2016[350], 2018[351] and 2020[352] used in the calculations of methane emissions from solid waste disposal. DOC values for 2011, 2013, 2015, 2017, 2019, 2021 and 2023 are interpolated/extrapolated.

347 SMED (Sundqvist & Szudy), 2012

348 SMED (Sundqvist & Szudy), 2020

349 SMED (Sundqvist & Szudy), 2020

350 SMED (Sundqvist & Szudy), 2018

351 SMED (Sundqvist & Szudy), 2021

352 SMED (Sundqvist & Szudy), 2024

Table 7.18. Overview of used DOC values estimations, %.

EWC-Stat code	Description of waste categories	2010(*)	2012(**)	2014(**)	2016(**)	2018(**)	2020(**)
02A	Chemical wastes	0.5	1.00	0.993	0.99	1,00	1,00
03.2	Industrial effluent sludges: Dry matter	12.5	0.03	0	0.17	0.59	11
03.2	Industrial effluent sludges: Dry matter Hazardous	2	0	0	0	0	0
03.3	Sludges and liquid wastes from waste treatment: Dry matter	0	0	0	0	9.24	0
05.	Health care and biological wastes: Hazardous	8	9	9	-	-	-
05.	Health care and biological wastes	8	-	-	-	-	-
07.2	Paper and cardboard wastes	36	-	-	-	-	-
07.5	Wood wastes	40	40	40	-	40	40
07.6	Textile wastes	24	-	15	15	-	-
09.1	Animal and mixed food waste	13	9	3.77	14.1	9	9
09.2	Vegetal wastes	20	20	20	20	20	-
09.3	Animal faeces, urine and manure	9	-	-	-	-	-
10.1	Household and similar wastes	18	3.4	3.8	3.4	9.11	8.71
10.2	Mixed and undifferentiated materials	8.5	4.25	3.04	3.1	3.05	3.23
10.3	Sorting residues	2.5	2.17	2.23	2.3	2.41	1.99
11A	Common sludges *(excl. dredging spoils)*: Dry matter	28	28	28	28	28	28

* DOC content estimations are based on waste data from year 2008 and 2010.

** DOC content estimations are based on year specific waste data.

The variation of the DOC values for EWC-Stat categories with small quantities and few entries is sometimes high, since a single entry or a few entries of waste data can have a large impact on the composition of a particular EWC-Stat code for a single year. This is the case for the EWC-Stat categories: 03.2 ”Industrial effluent sludges”, 07.6 ”Textile wastes” and 10.1 “Household and similar wastes”. The DOC value for the EWC-Stat category 10.1 “Household and similar wastes” in year 2010 origins from year 2008, when some landfills were granted exemption from the national ban on landfilling organic waste.

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 data source has led to lower uncertainties since the data on DOC can be estimated with better precision. The uncertainty for emission year 1990 for AD is 40%, compared to 25% for 2023, while the uncertainty of EF remains at 50%. This means that the uncertainty has decreased from the base year (1990) to the most recent year (2023), 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 IPCC 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 IVL Swedish Environmental Research Institute has on behalf of the Swedish EPA scrutinized the activity data (quantities of deposited; household waste, park and garden waste, sludge from wastewater treatment) used for calculations. The accuracy in these activity data is judged to be good.

7.2.2.5 SOURCE-SPECIFIC RECALCULATIONS

Recalculations have been done for methane from CRT 5.A.1 Managed waste disposal sites for the years 2011-2013 and 2018-2022. The reasons for the recalculations were:
-implementation of newly published[353] activity data on landfilled waste for the year 2022,
-implementation of newly available[354] estimates on DOC values for year 2020,
-interpolations of the activity data and DOC values above,
-revision of data on collection of landfill gas for some landfills for the years 2011-2013, 2018 and 2020-2022. The emission estimates changed by between -0.41% and 0.30%.

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.

[353] Swedish EPA, 2024

[354] SMED (Sundqvist & Szudy), 2020

7.3 Biological treatment of solid waste (CRT 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 had 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 is 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, such 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 became more and more important during the 1990’s and several new plants were put in operation. The growth of composting was also 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 of organic waste from 2005.

The issue of the standards of the composting plants was raised when the problems of emissions of methane (CH_4) and nitrous oxide (N_2O) rose. 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 quantities of waste treated by composting have varied between 350 000 – 700 000 t/year. The trend is decreasing from year 2011, as quantities of waste treated by anaerobic digestion are increasing[355].

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 into operation in the fall of 1994, though co-digestion of *manure, waste from food production* and

[355] Swedish Waste Management 2010-2024

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 2023[356] the amount of waste to anaerobic digestion was 1809 kt and is forecasted to continue to increase for 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%[357] 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 2023, 50.6% of the produced biogas in Sweden was produced at anaerobic treatment plants for solid waste. The biogas production at these plants is equivalent to 82.9 kt of methane (or 1155 GWh). 3.3% of the biogas produced at anaerobic treatment plants for solid waste was flared in 2023, and 90.5% was upgraded into fuel for vehicles. Emissions from flaring and the utilization of the biogas is reported in CRT 1.

7.3.1 Composting (CRT 5.B.1) and anaerobic digestion at biogas facilities (CRT 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 CRT 5.B.1 Composting, and methane from CRT 5.B.2 Anaerobic digestion at biogas facilities.

Emissions from home composting of food waste and garden waste are not estimated due to the lack of data on composted garden waste. However, by using the available data on home composted food waste year 2023 (38 000 tonnes wet weight), the total emissions (methane and nitrous oxide) amounts to 6.67 kilotonnes CO_2-eq. Sweden's greenhouse gas emissions year 2023 (Total (without LULUCF)) in submission 2025 was 44 385.97 kt CO_2-equivalents. 6.67 kilotonnes CO_2-eq. equals 0.015% of the national total GHG emissions, which is below the threshold of significance (0.05%). The trend for home composting of food waste is slightly descending in Sweden over the past ten years. For the sampe period, separate collection of food waste in households has expanded.

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 7.19.

[356] Swedish Waste Management 2024

[357] Swedish Waste Management 2010

Table 7.19. Summary of source category description, CRT 5.B, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
5.B.1	CO_2	NA	NA		NA	NA	NA
	CH_4	-	-		T1	D	Yes
	N_2O	-	-		T1	D	Yes
	CO_2	NA	NA		NA	NA	NA
5.B.2	CH_4	-	-		T2	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 IPCC Guidelines (according to the changes in 9th Corrigenda for the 2006 IPCC Guidelines, July 2015) are used in the calculations (see Table 7.20) with the exception of the country-specific emission factors[358] used from year 2005 when calculating methane emissions from anaerobic digestion (see Table 7.21).

Table 7.20. 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 1990-2004)	Assumed negligible

The emissions of nitrous oxide from CRT 5.B.2 Anaerobic digestion at biogas facilities are reported as NA (not applicable) since the 2006 IPCC Guidelines assumes that the emissions are negligible.

Table 7.21. Country-specific emission factors used; CRT 5.B.2 Anaerobic digestion at biogas facilities.

Year	CH_4 Emission Factors (g CH_4/kg waste treated) on a wet weight basis.
2005	1.0[1]
2006	1.1[2]
2007	0.9[3]
2008	1.1[4]
2009	1.2[5]
2010	1.3[6]
2011	1.6[7]
2012	1.3[8]
2013	0.7[9]
2014	0.6[10]
2015	0.6[11]
2016	0.7[12]
2017	0.8[13]
2018	0.7[14]
2019	0.7[15]
2020	0.8[16]
2021	0.8[17]
2022	0.8[18]
2023	0.8[18]

1-17) are calculated with measurement data), 18) is extrapolated from year 2021.

For the earlier years, the country-specific emission factors are higher than the default factor. The emission factors cover the additional emissions that come with upgrading the generated methane into fuel for vehicles. With time, the technical improvements

[358] SMED (Sundqvist & Szudy), 2023

(chemical scrubber and regenerative thermal oxidizers) have decreased the emissions related to upgrading. In this sector, the upgrading of methane into fuel for vehicles has increased from 4.92 kt to 74.98 kt (or 1424%) from year 2005 to year 2023[359].

7.3.1.2.3 Statistics used as activity data

The statistics used as activity data (Table 7.22) are produced by Swedish Waste Management (Avfall Sverige former RVF). The data are judged to be of high quality. The data on waste quantities are in wet weight and have an estimated water content of 65%. Data on "Annual waste amount treated" reported in the CRT Table 5.B are based on these quantities but are converted to into quantities in dry matter by using the factor 0.35.

Table 7.22. Composted waste and waste to anaerobic digestion.

Year	Composted waste (t, wet weight)	Waste to anaerobic digestion, (t, 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[28]
2015	418 340[19]	1 616 110[29]
2016	476 138[20]	1 614 920[30]
2017	450 362[21]	1 562 210[31]

[359] Swedish Energy Agency, 2024

Year	Composted waste (t, wet weight)	Waste to anaerobic digestion, (t, wet weight)
2018	351 755[22]	1 631 400[32]
2019	354 830[23]	1 710 000[33]
2020	373 800[24]	1 763 010[34]
2021	343 692[25]	1 733 520[35]
2022	330 841[26]	1 789 800[36]
2023	276 080[27]	1 808 590[37]

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, 14-17) Svensk Avfallshantering 2011-2014, 18-27) Avfall Sverige / Swedish Waste Management (including oral communication), 28-37) Svensk Avfallshantering 2015-2024.

The past decade, some municipalities have changed treatment method for biological waste from composting to anaerobic digestion. Waste to anaerobic digestion increased by 226% from 2011 to 2023. The number of anaerobic digestion plants increased from 16 to 32 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 "Methane 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 "Methane 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 "Nitrous Oxide 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 IPCC 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

No source-specific recalculations have been done for CRT 5.B.1 Composting or CRT 5.B.2 Anaerobic digestion at biogas facilities.

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 (CRT 5.C)

7.4.1 Waste incineration (CRT 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 CRT 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 CRT 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 7.23.

Table 7.23. Summary of source category description, CRT 5.C.1, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources Estimated
		Level	Trend	Qualitative			
5.C	CO_2	X	-		T3	PS	Yes
	CH_4	-	-		T2	PS	Yes
	N_2O	-	-		T2	PS	Yes

PS Plant Specific. T2 Tier 2. T3 Tier 3.

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 CRT 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. NMVOC are until 2007 as reported by the facility. For 2007 – 2015, the NMVOC emissions are calculated based on IEF for 2007 and yearly incinerated amounts of waste. From 2016 NMVOC emissions, also based on continious measurements, 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 7.24, emissions of CO_2 from incineration of biogenic waste are reported in CRT 5.C.1.1.b and CO_2 from incineration of non-biogenic waste are reported in CRT 5.C.1.2.b. Emissions of CH_4 and N_2O from incineration of biogenic and non-biogenic waste are reported in CRT 5.C.1.2.b.

Table 7.24. Notation keys for emissions reported in CRT 5.C.

CRT	Greenhouse gas source and sink categories	CO_2		CH_4 and N_2O	
		Notation key	Emissions included in CRT	Notation key	Emissions included in CRT
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 CRT 1.

Emissions reported are CO_2, CH_4, N_2O, NO_X, SO_2, NMVOC and CO.

For the period before 2003 the company considers reported CO_2 emissions to be almost 100% fossil[360]. For the years from 2003 onwards, it is assumed that the share of biogenic material in the combusted MSW is 50 – 63% – this is according to the study performed by the facility in 2008, the study by Swedish Waste Management[361] from 2012, and the revision of CO_2 emissions before submission 2020. MSW constitutes about one third of the total combusted waste, which means that the share of biogenic CO_2 emissions in the total facility CO_2 emissions is currently about 17%.

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 CRT 5C. From 2008 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 – 2022. For 1990 until 2002 the volumes are not known and for these years the flue gas volumes have been estimated using the average of the ratios between volumes and incinerated amounts of waste for 2003 to 2008. Activity data and implied emission factors/emission factors used for the CH_4 and N_2O estimates are presented in Table 7.25.

[360] Personal communication, Hanna Eriksen, Hanna.Eriksen@sakab.se, 2012-08-23

[361] Swedish Waste Management. RAPPORT U2012:05. Determination of the fossil carbon content in combustible municipal solid waste in Sweden.

Table 7.25. Activity data and implied emission factors/emission factors used for estimations of CH_4 and N_2O emissions in CRT 5.C.

Year	Total amounts of incinerated waste	Flue gas volume	CH_4	N_2O
	kt	1000 m^3	IEF, kg/kt	EF, g/1000 m^3
1990	30	220 674*	7.73**	15.00
1995	33	240 637*	7.73**	15.00
2000	28	205 778*	7.73**	15.00
2005	126	1 099 338	7.73**	15.00
2010	156	1 007 061	5.79	15.00
2011	163	1 229 605	6.09	15.00
2012	158	1 194 418	7.81	15.00
2013	153	1 128 670	7.73	15.00
2014	153	1 201 632	5.27	15.00
2015	155	1 162 650	3.58	15.00
2016	148	1 133 767	4.78	15.00
2017	150	1 158 546	6.67	15.00
2018	153	1 183 838	9.38	15.00
2019	155	1 167 810	8.26	15.00
2020	151	819 965	9.48	15.00
2021	146	1 159 047	5.16	15.00
2022	135	1 204 523	1.82	15.00
2023	135	926 619	4.70	15.00
2015	155	1 162 650	3.58	15.00
2020	151	819 965	9.48	15.00
2021	146	1 159 047	5.16	15.00
2022	135	1 204 523	1.82	15.00
2023	135	926 619	4.70	15.00

* = 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 7.25 the implied emission factor (IEF) for CH_4 varies. Reported emissions for 2008 – 2022 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

During submission 2025, share of hazardous waste and consequently share of biogenic waste in the total was corrected for the year 2021, resulting in reallocation of 0.68 kt CO_2 from fossil to biogenic emissions.

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 (CRT 5.C.2)

7.4.2.1 SOURCE CATEGORY DESCRIPTION

In Sweden, accidental fires in 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[362]. 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 2019.

7.4.2.2 METHODOLOGICAL ISSUES

Emission factors for open burning of waste from EMEP Guidebook 2019 were used to estimate emissions of CO, SO_2, NO_x and NMVOC.

As there are no national statistics regarding the extent of garden burning and bonfires, instead statistics on number of small houses have been used. The data should be considered as indicative levels of emissions from these sources.

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[362] Bränder i avfall vid deponier och förbränningsanläggningar (2003) RVF rapport 2003:11, ISSN 1103-4092

7.4.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The time series is consistent. The uncertainties are calculated according to EMEP Guidebook 2019. The uncertainties are: CO ± 200%, NMVOC ± 201%, NO_x ± 200% and SO_2 ± 191%

7.4.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

7.4.2.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed for landfill fires during submission 2025.

7.4.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

7.5 Wastewater treatment and discharge (CRT 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. Most of the wastewater treatment facilities (municipal and industrial) in Sweden are using *aerobic* processes, where smaller amounts of methane are generated because of the use of aeration in the wastewater treatment process.

Municipal wastewater treatment facilities

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, biologically and chemically. In some larger plants, or plants with sensitive recipients, special nitrogen treatment is performed. Some of these wastewater treatment plants also receive wastewater from industries without internal wastewater treatment. There are also several smaller plants or private plants (WWTPs < 2,000 personal equivalents) of varying standard.[363]In year 2023, anaerobic digestion of sludge and biogas production was performed at 132[364] municipal wastewater treatment plants in Sweden (for more information, see below on biogas production).

Uncollected wastewater treatment

In addition, there are also approximately 1.3 million people in Sweden that are not connected to any wastewater treatment plant. Instead, this population is connected to on-site wastewater treatment. A wide range of technologies are used for on-site treatment of wastewater in Sweden, but it is most common that the technologies involve a septic tank followed by a leach field or similar. The sludge in the septic tank is pumped and transported to a municipal wastewater treatment plant and co-digested with the sludge generated at the wastewater treatment plant. The methane emissions due to co-digestion of sludge from septic tanks are included in the inventory as well as on-site emissions from septic tanks.

Industrial wastewater treatment facilities

The industrial wastewater is treated both internally and in municipal wastewater treatment plants. *Aerobic* processes are the most common kind, but there are a few exceptions. In 2023 there were eight (8) facilities using *anaerobic* wastewater treatment processes in Sweden, all of them are in the food industry and in the pulp and paper industry. Biogas is produced at these eight facilities (for more information, see below on biogas production).

There are no activities[365] in Sweden such as *anaerobic digestion of sludge* at industrial plants with internal wastewater treatment. The pulp and paper industry incinerates most of the sludge generated from treatment of the wastewater, in their boilers or chemical recovery systems. Some of the sludge is used to cover landfills or is treated by composting and sold as soil improvement.

[363] Swedish EPA & SMED, 2003

[364] Swedish Energy Agency, 2024

[365] Memo "*Occurrence of treatment of sludge by anaerobic digestion in Swedish industries", Statistics Sweden, 2011* "

In a more recent study[366], the food industry was scrutinized in order to find facilities within the food industry with internal wastewater treatment that practices anaerobic digestion of sludge. No such activities were found. The conclusion in the study is that sludge from these kinds of plants is either transported to external biogas facilities or used untreated as fertilizer on nearby farms.

Biogas production at municipal and industrial wastewater treatment facilities
Considerable quantities of heat and bioenergy are recovered from sewage and wastewater.[367] 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. Emissions from flaring and the utilization of the biogas is reported in CRT 1.

Municipal wastewater treatment facilities
In 2023, 31.3%[368] of the produced biogas in Sweden was produced at municipal wastewater treatment plants. The biogas production (by anaerobic digestion of sludge) at wastewater treatment plants increased by 27.9% from 2005 to 2023. 10.5% of this biogas was flared and 60.1% was upgraded into fuel for vehicles in 2023.

Industrial wastewater treatment facilities
In year 2023, four (4) facilities in the food industry and four (4) facilities in the pulp and paper industry practiced anaerobic wastewater treatment with energy recovery. 6.7% of the produced biogas in Sweden was produced in these industries. The biogas production at these industries increased by 141.3% from 1990 to 2023. 26.3% of the biogas produced was flared. 19.1% of the produced methane was upgraded.

7.5.1 Domestic wastewater (CRT 5.D.1) and Industrial wastewater (CRT 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 CRT 5.D.1 Domestic wastewater and CRT 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 7.26.

[366] SMED (Karlsson & Szudy), 2021

[367] Ministry of the Environment, 2001

[368] Swedish Energy Agency, 2024

Table 7.26. Summary of source category description, CRT 5.D, according to approach 1.

CRT	Gas	Key Category Assessment, excluding LULUCF			Method	EF	All sources Estimated
		Level	Trend	Qualitative			
5.D.1	CO_2	NA	NA		NA	NA	NA
	CH_4	X			T2, T3	CS	Yes
	N_2O	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), T3 (Tier 3).

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 (vol. 5, chap. 6) are used when calculating methane emissions (see below).

Domestic wastewater (CRT 5.D.1)

Emissions from the wastewater treatment ponds and sludge treatment are estimated separately.

EQUATION 6.1
TOTAL CH_4 EMISSIONS FROM DOMESTIC WASTEWATER

$$CH_4\ Emissions = \left[\sum_{i,j}\left(U_i \bullet T_{i,j} \bullet EF_j\right)\right]\left(TOW - S\right) - R$$

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

<u>Methane emissions from the wastewater treatment train</u>

Swedish WWTPs can be assumed to be well managed and according to 2006 IPCC Guidelines, emissions the wastewater treatment train, i.e. sedimentations tanks and biological treatment, then can be considered negligable. However, national measurements[369] shows that methane emissions do occur, and an emission factor of 2.7 g

[369] Swedish Water & Wastewater Association, 2014

methane/incoming kg COD is suggested. Recalculated to a methane correction factor (MCF), this factor corresponds to 0.036. Note that the default value of B_o is used. The application of equation 6.1 from the 2006 IPCC Guidelines on the wastewater treatment train nationally results in emissions around 1,300 tonnes methane.

Methane emissions from sludge treatment (anaerobic digestion of sewage sludge)
Methane emissions from on-site sludge treatment located at municipal WWTPs is estimated on the basis of total organics in wastewater removed, the amount of sludge generated and the methane potential of the sludge. The total amount of BOD within the sludge going to sludge treatment is calculated based on Oonk[370]. In total, 70% of the BOD in incoming wastewater is estimated to end up as undigested sludge. Of this, 90% is assumed to be digested (expert judgement).
Apart from this load, WWTPs anaerobic digesters in Sweden receives external additions of organic material that is not included in incoming wastewater. This part is assumed to add another 15% of organic material to the anaerobic digesters.

These calculations give an estimate of the organic load on digersters, i.e. TOW to be used in Equation 6.1. S, i.e. sludge removed from the process, is calculated based on the assumption that 55% of the organic material is degraded in a well functioning digestion process. The value of MCF for the process has been adjusted to 0.95. With these estimations, Equation 6.1 returns a national gas production in the same order as the amount given in national statistics[371].

When estimating the emissions, the national production of methane from the sector is used together with emission factors from national measurements[372] at WWTPs of methane emissions from the sludge digestion process. The emissions are in between 2% – 3% of the total biogas production.

Methane emissions from other sludge treatment methods are considerd negligable.

Methane emissions from uncollected wastewater treatment
Methane emissions from uncollected wastewater treatment, i.e. domestic wastewater that is not treated in a municipal WWTP, is calculated with Equation 6.1, but with an adjusted value for MCF. The load on these facilities is calculated[373] with the estimate that 1 300 000 people use such facilities to 100%. It is assumed that these facilities all look similar and are equipped with a septic tank followed by some kind of aerobic treatment step such as a drainage field. The default value of 0.5 for MCF is considered *to high* for Swedish conditions, as less than 50% of incoming organic load is degraded in the anaerobic septic tanks[374]. In Sweden, between 20% and 30% of incoming organic load is removed and degraded in septic tanks[375] under conditions that can be assumed to be

[370] Oonk, 2020

[371] Swedish Energy Agency, 2007–2024

[372] Swedish Waste Management, 2023

[373] SMED, 2015 (Olshammar, Ek, Rosenquist, Ejhed, Sidvall & Svanström)

[374] SMED, 2015 (Olshammar, Ek, Rosenquist, Ejhed, Sidvall & Svanström)

[375] SMED, 2015 (Olshammar, Ek, Rosenquist, Ejhed, Sidvall & Svanström)

anaerobic. Therefore, the MCF-value of 0.22 from Diaz-Valbuena[376] and Leverenz[377] describes the Swedish conditions better than the 2006 IPCC Guidelines default value of 0.5.

None of the produced methane is considered recovered.

Industrial wastewater (CRT 5.D.2)
Emissions from aerobic wastewater treatment ponds, on-site treatment of sludge generated in those aerobic ponds, and anaerobic digestion of wastewater are estimated separately.

EQUATION 6.4
TOTAL CH_4 EMISSIONS FROM INDUSTRIAL WASTEWATER

$$CH_4\ Emissions = \sum_i \left[\left(TOW_i - S_i \right) EF_i - R_i \right]$$

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

All aerobic wastewater treatment plants are well managed, and the methane correction factor is assumed to be 0. For these installations, the application of equation 6.4 of the 2006 IPCC Guidelines results in negligible methane emissions.

Sweden has chosen a *country-specific method* to estimate the emissions from anaerobic wastewater treatment. Energy statistics from the annual statistical report “Production of biogas and digestate year YYYY”[378] are used to quantify methane generation from anaerobic wastewater treatment. By using statistical information on produced quantity of biogas for flaring and energy recovery (in GWh), the produced quantity of methane in kilotonnes is calculated by using the lower heating value for methane. The following assumptions and parameters are used:

376 Diaz-Valbuena et al., 2011

377 Leverenz et al., 2010

378 Swedish Energy Agency, 2023

a. Energy content: 9,95 MWh/1000 Nm^3 methane
b. 1 Nm^3 methane = 0,714 kg methane
which results in 1 GWh = 0.07175 kilotonne methane.

According to wastewater treatment expertise[379], the loss of methane in the biogas production process should be between 2% and 5%, assuming 5% of methane being emitted in 1990–2000; a gradual decrease from 5% to 2% in 2001–2009; and 2% from 2010 onwards. The EF (from 5% to 2%) it is based on expert judgment on the effect of an increased awareness of methane leakages at biogas facilities and efforts to minimize methane leakages from those facilities.

7.5.1.2.2 Emission factors used (CH_4)

Domestic wastewater (CRT 5.D.1)
B_O: The maximum methane producing capacity (B_O) is set to 0. 6 kg CH_4/kg BOD (equals to 0.25 kg CH_4/kg COD).

Methane is emitted from three processes:
-the wastewater treatment train,
-the digestion process of municipal sludge, and
-septic tanks.

MCF (Methane correction factors):
The MCF for the wastewater treatment train, i.e. primary sedimentation, biological treatment and chemical treatment, is determined to 0.036 based on national measurements.
The MCF for digestion, i.e. “anaerobic stabilisation” is estimated to 0.95. This value is higher than the default value in 2006 IPCC Guidelines. This higher value is used to fit calculated production of biogas at Swedish WWTP with national statistics of the production.
The MCF for septic tanks and thus for uncollected WWT is set to 0.22 as the default MCF value of 0.5 is too high for Swedish conditions, as less than 50% of the organic load on these facilities is degraded/removed in the septic tank.

Industrial wastewater (CRT 5.D.2)
For the country-specific method, the estimate of the loss of methane in the biogas production process is[380]:
-5% for year 1990-2000,
-descending for year 2001-2009,
-2% from year 2010 and onwards.
Example: In year 2023, 152 GWh[381] biogas (or 10.76 kt methane) was produced (including flared quantities). By using the value 2% as the leakage factor, the emission of methane is calculated to 0.22 kt for year 2023.

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379 SMED (Szudy, Ek, Linné, Olshammar), 2017

380 SMED (Szudy, Ek, Linné, Olshammar), 2017

381 Swedish Energy Agency, 2024

7.5.1.2.3 Statistics used as activity data (CH_4)

Domestic wastewater (CRT 5.D.1)

TOW (total organics in wastewater) is calculated by using the value of BOD (60 g BOD/person). In Sweden, BOD_7 rather than BOD_5 is used, but according to Swedish statistics, a specific load of 60 g BOD_7/person/day is reasonable[382].

The activity data P (population) is calculated for the following two categories (A and B):
(A) population connected to municipal wastewater treatment facilities and
(B) population with uncollected WWT, i.e. local wastewater treatment facilities, often at household level.

(A) is calculated by using the total population in Sweden minus (B). The population not connected to municipal wastewater discharge system (B), 1 300 000 people, is an estimate[383].

An additional industrial load is added to (A). In year 1990 we assume the industrial load is 25% but reducing to 15% from year 2020 and onward. This is an expert judgement based on that the organic load on WWTP per connected person has decreased the past decades. A reasonable explanation for this that the industrial load has decreased, rather than that people discharge less organic material to the sewer net. This approach differs somewhat from the calculations of the nitrogen load (see further in section 7.5.1.2.6 Statistics used as activity data (N_2O)).

Swedish WWTP also receives external organic material (food waste, grease etc) that is fed directly into the digesters. When calculating the load on the digesters another 15% is added on top of the load from undigested sludge. This load is assumed to increase linearly from 0% in year 2000 to 15% in year 2010.

No industrial load is assumed for on-site treatment facilities, i.e. uncollected WWT.

Industrial wastewater (CRT 5.D.2)

Activity data for the country-specific method are statistical data on energy recovery from anaerobic wastewater treatment processes (see Table 7.27 below). Data published by the Swedish Energy Agency are available for year 2005-2023. For the years 1990, 1995 and 2000, data on biogas production at wastewater treatment facilities have been compiled within a project[384] for investigating historical data on biogas production. See further in section “Biogas production at wastewater treatment facilities”.

[382] Swedish Water & Wastewater Association, 2016

[383] SMED, 2018 (Olshammar)

[384] SMED (Szudy, Ek, Linné, Olshammar), 2017

Table 7.27. Biogas production on facilities in the pulp and paper industry and the food industry with anaerobic wastewater treatment, GWh.

Year	Flaring	Energy recovery	Total
1990	3[1]	60[1]	63[1]
1995	3[1]	90[1]	93[1]
2000	3[1]	96[1]	99[1]
2005	0[2]	94[2]	95[2]
2006	1[2]	91[2]	91[2]
2007	0[2]	123[2]	123[2]
2008	3[2]	127[2]	130[2]
2009	10[2]	93[2]	103[2]
2010	7[2]	106[2]	113[2]
2011	10[2]	114[2]	124[2]
2012	10[2]	108[2]	118[2]
2013	16[2]	102[2]	118[2]
2014	21[2]	105[2]	126[2]
2015	29[2]	88[2]	117[2]
2016	34[2]	94[2]	128[2]
2017	29[2]	96[2]	125[2]
2018	34[2]	109[2]	143[2]
2019	43[2]	100[2]	143[2]
2020	39[2]	95[2]	134[2]
2021	37[2]	112[2]	149[2]
2022	67[2]	132[2]	199[2]
2023	40[2]	112[2]	152[2]

1) SMED (Szudy, Ek, Linné, Olshammar), 2017, 2) Swedish Energy Agency, 2007-2024

7.5.1.2.4 Methodologies used (N_2O)

The direct and indirect nitrous oxide emissions are quantified on the basis of available statistics of N in both the influent and the effluent of wastewater treatment plants.

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.

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).

7.5.1.2.5 Emission factors used (N_2O)

For direct (or internal) emissions from biological nitrogen removal, a country-specific emission factor (0.0074 N_2O-N/kg N) is used for in WWTPs >2000 pe. The national value[385] is based on six annual environmental reports from two WWTPs > 2000 pe, where the amount of nitrogen in inlet converted to nitrous oxide was reported.

The default emission factor from vol. 5, chap. 6.3.1.2 of the 2006 IPCC Guidelines (0.005 N_2O-N/kg N) is used for indirect emissions from:
-effluent from WWTPs > 2000 pe
-effluent from WWTPs < 2000 pe
-effluent from industrial wastewater

7.5.1.2.6 Statistics used as activity data (N_2O)

National statistics on N in both the influent and the effluent (or discharge) of municipal wastewater treatment plants and industries are used as activity data.
Available statistics on N in the influent of large wastewater treatment plants are used for estimations of direct emissions at large wastewater treatment plants.
Available statistics on N in the effluent of large wastewater treatment plants are used as AD for indirect emissions.

For the part of the population not connected to large wastewater treatment plants, an estimate is made of N discharge on open waters on the basis of the amount of N per capita in the influent of wastewater treatment plants.

Domestic wastewater (CRT 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 (Table 7.28) are compiled and national statistics are published every second year by the Swedish EPA.[386]. The production time for these publications varies, and sometimes the statistics is not available until two years after the reference year.

[385] IVL Svenska Miljöinstitutet AB (Westling, Tjus & Ek), 2014

[386] Statistics Sweden, MI 22 SM, Swedish EPA and SMED.

Table 7.28. Influent and discharge of nitrogen, removal efficency: Large municipal wastewater treatment plants (from treatment of domestic, commercial and industrial waste water).

Year	Influent of nitrogen (t)	Discharge of nitrogen (t)	Removal efficiency (%)
1990	..	26 200	..
1992	..	25 310	..
1995	..	25 940	..
1998	40 086	21 376	47
2000	41 269	18 977	54
2002	40 999	18 036	56
2004	41 417	17 779	57
2006	42 956	18 347	57
2008	42 360	18 433	56
2010	42 292	17 419	59
2012	41 967	17 120	59
2014	41 340	15 743	62
2016	41 049	15 414	62
2018	41 294	14 982	64
2020	41 737	14 779	65
2022	..	..	..

Source: MI 22 SM, Swedish EPA and SMED

The statistics on influent and discharge 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. 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 nitrogen 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 connected to WWTPs < 2000 is estimated by subtracting total population in Sweden with the number of people connected to WWTPs > 2000 pe.

Industrial wastewater (CRT 5.D.2)

Data from environmental reports from industrial wastewater handling (Table 7.29) are 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 7.29. 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.)	Chem. (inl.)	Chem. (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	..	..	..	..	..	..	..	..	..	..
2018	2 123	32	54.	91	443	93	91	17	0	0	561
2019	1 699	..	..	..	..	..	..	..	..	..	..
2020	2 012	29	153	74	432	65	100	8	0	0	620
2021	2 071	..	..	..	..	..	..	..	..	..	..
2022	1 859	..	..	..	..	..	..	..	..	..	..
2023	1 732	..	..	..	..	..	..	..	..	..	..

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
Activity data:
"Human population": ± 5% (Default)
"BOD per person": ± 15% (Expert judgement)
Population served by unsewered sanition: ± 15% (Expert judgement)
"Correction factor for additional industrial BOD discharged into sewers": ± 20% (Default)
Correction factor for external organic matter into digesters: ± 20%.

Emission factors and methane correction factors:
"Maximum methane producing capacity (B_O)": ± 30% (Default)
MCF-wastewater treatment: -50% to + 100% (Expert judgement)
MCF-sludge treatment: not relevant as this is not determining emissions. The part leaking to the atmosphere is determining the quantity of the methane emissions from the sludge treatment.
MCF-uncollected WWT: ± 50% (Expert judgement)
EF-methane leakage: -50% to +100%. This is a nationally derived factor from measurements of methane leakages at sludge treatment at WWTP. This factor tells how much of the total produced biogas that is emitted ot the atmosphere.

Industrial wastewater
Emission factor "The loss of methane in the energy recovery process": ± 25% (Expert judgement)
Activity data "Energy recovery from anaerobic wastewater treatment processes (MWh)": ± 5% (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 are considered to have a margin of inaccuracy of well under 10% at national level.
2006 IPCC Guidelines states that "Large uncertainties are associated with the IPCC default emission factors for nitrous oxide from effluent. Currently insufficient field data exist to improve this factor. Also, the nitrous oxide 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 nitrous oxide". 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 industrial wastewater treatment facilities 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 are considered to have a margin of inaccuracy of well under 10% at national level.
2006 IPCC Guidelines states that “Large uncertainties are associated with the IPCC default emission factors for nitrous oxide from effluent. Currently insufficient field data exist to improve this factor. Also, the nitrous oxide 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 nitrous oxide”. It is referred as an expert judgement.

The time series in the waste sector are calculated consistently and in line with the 2006 IPCC 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

In submission 2025, recalculations of methane emissions from Domestic wastewater (CRT 5.D.1) were made for the years 1990-2022 due to the implementation of the IPCC default value of Bo and other improvements. Emissions from wastewater treatment trains has been added to the calculations, and the emissions from digestion processes reviewed and recalulated. Also, emissions from uncollected WWT (on-site wastewater treatment) has been included. The emissions of methane increased by between 366% and 599% year 1990-2022.

Recalculation was made for the emission of nitrous oxide from CRT 5.D.2 Industrial wastewater for the year 2022 due to availability of new data on nitrogen discharges from the pulp- and paper industry. The emissions of nitrous oxide decreased by 5.98%.

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 Indirect CO_2 and nitrous oxide emissions

Sweden does not calculate and report indirect emissions of CO_2.

9.1 Indirect N_2O emissions from atmospheric deposition of nitrogen in NO_X and NH_3

9.1.1 Source category description

Sweden calculates and reports indirect emissions of N_2O from other sectors than agricultural and LULUCF.

9.1.2 Methodological issues

Indirect emissions of N_2O, from sectors other than agriculture and LULUCF, are calculated using Equation 7.1 from 2006 IPCC Guidelines, Volume 1 and default emission factor EF_4 (0.010) given in Table 11.3 of Volume 4. The method assumes that N_2O emissions from atmospheric deposition are reported by the country that produced the original NO_X and NH_3 emissions.

Equation 7.1. Calculation of indirect N_2O emissions, from 2006 IPCC Guidelines, Volume 1.

EQUATION 7.1
N_2O EMISSIONS FROM ATMOSPHERIC DEPOSITION OF NO_X AND NH_3

$$N_2O_{(i)} = \left[\left(NO_x\text{-}N_{(i)}\right) + \left(NH_3\text{-}N_{(i)}\right)\right] \bullet EF_4 \bullet 44/28$$

Data regarding NO_X and NH_3 emissions have been obtained from the present submission for UNFCCC and CLRTAP, respectively. Emissions from international transportation have been excluded from the calculations since these are not included in the national total emissions. It has been considered that emissions from aviation are reported differently in the CRT- and NFR-tables, and the CRT format has been followed in this regard. Activity data for the CRT / NFR codes 3B, 3D and 4 have been excluded as indirect emissions are already reported in the inventory for these codes.

9.1.3 Uncertainties and time-series consistency

No formal uncertainty analysis has been performed as the uncertainty for activity data (in this case NO_X and NH_3 emissions in the relevant CRT / NFR codes) do not exist at the aggregated level. The emission factor uncertainty is ± 80% according to the range given in Table 11.3 of Chapter 7.3 of Volume 1 of IPCC, 2006.

9.1.4 Source-specific QA/QC and verification

Emissions of NO_X reported under UNFCCC have been cross-checked with emissions reported under CLRTAP.

9.1.5 Source-specific recalculations

No recalculations were performed during submission 2025.

9.1.6 Source-specific planned improvements

No major improvements are currently planned for next submission.

10 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 sections.

Below, a summary description of the most significant revisions of methods and data are described by sector.

10.1 Explanations and justifications for recalculations

10.1.1 Energy, CRT 1

10.1.1.1 STATIONARY COMBUSTION

In submission 2025 the following main revisions were made:

• Revision of emission factor (CO_2) for natural gas in 2019 was due to an updated emission factor became available for that year.
• Minor correction for one plant in waste incineration for 2015 to 2023. The correction occurred due to administrative variables were updated and corrected.
• Revision of 1.AA.2.d due to a company informed energy statistics that their use of solid fuels are for industrial processes and not for energy production. This led to reallocation of the emissions to the IPPU sector.
• Revision of AD in 1A2g and 1a4 for 2022 due to the final energy balances were not available for year 2022 during data collection in submission 2024.

10.1.1.2 MOBILE COMBUSTION

10.1.1.2.1 Aviation

- During 2024, Statistics Sweden performed a project aiming to investigate the validity of net calorific values and emission factors in the mobile energy subsector. As a result, the net calorific value for fossil jet kerosene has been updated from 35.28 to 34.85 GJ/m^3, the emission factor for CO_2 from fossil and biogenic jet kerosene was updated from 78.5 to 73.45 ton/TJ and emission factor for SO_2 from fossil and biogenic jet kerosene was updated from 0.0236 to 0.0232 ton/TJ. This update was performed in order to align the emission factors of SMED with those used by the Swedish Defence Research Agency (FOI) in their emission model for aviation.

- In submission 2025, the monthly fuel deliveries indicated that the amount of delivered jet kerosene had decreased compared to 2022. Since most other indicators, such as number of flights and passengers indicated increasing air traffic, it was decided that the monthly fuel deliveries can't be relied on for the year 2023. As a result, the fuel consumption for aviation was extrapolated from year 2022 to 2023 with the same percentual increase as the fuel consumption estimated by FOI.

- The fuel consumed by the armed forces between 1990 and 2017 has by mistake been included twice in previous emission estimations and this was corrected in submission 2025.

10.1.1.2.2 Road traffic

In submission 2025, the following changes have been made to the HBEFA road model:

- Calibration of fuel consumption by LCV, gas-fueled passenger cars and gasoline-fueled plug-in hybrids, which entails an increased fuel consumption for all three vehicle categories.
- The method for allocation of the number of kilometres driven between different fuels for passenger cars has been updated for the years 2000-2022. The update resulted in an increased energy consumption from gasoline between 2007 and 2012 but a decrease between 2014 and 2020. The opposite is true for diesel cars. Furthermore, the energy consumption from gas-fueled cars increased throughout the updated period.
- Age dependent number of kilometres driven for passenger cars and LCV for the years 2016-2022. In short, this project entails a re-allocation of driven kilometres from newer to older euro classes. As a result, CH_4 emissions from passenger cars and LCV increase, mainly because of more kilometres driven by older gasoline vehicles. Gasoline consumption increases for 1-1.5% during the period.

In addition to the changes made in the road model HBEFA, the following changes have been made:

- For the years 2020-2022, the net calorific value for biogasoline has been updated. Before, the update the value was 31.71 GJ/m^3 for these years, after the update it's 32.15, 31.57, 31.71 and 31.96 respectively, for the years 2020, 2021, 2022 and 2023.
- The emissions from diesel- and gasoline vehicles estimated in the road emission model HBEFA were previously only allocated to the fossil component of the fuel mix. The emissions have now been proportionally allocated to both the fossil and biogenic fuels used by these vehicles. This means that the emissions from the fossil diesel and gasoline used by diesel- and gasoline vehicles decrease and the emissions from biofuels increase for all years with a consumption of low-blended biofuels.
- FAME and HVO used in road traffic (and by working machinery) were in previous submissions aggregated into FAME in the emission calculations. From submission 2025 they are separated. As FAME and HVO have slightly different calorific values and emission factors for CO_2, the emission estimation of biogenic was CO_2 affected. Overall, the effect of this change on emissions is very small.

- The CO_2 emission factor for natural gas has been updated for the years 2019, 2021 and 2022. Where the CO_2 emission factor was 56.89, 55.52 and 55.52 kg/GJ for the years 2019, 2021 and 2022 respectively, they are now 56.54, 55.47 and 56.38 kg/GJ.
- Changes have been made to the model for working machinery, which have reduced the consumption of diesel and, to some extent gasoline. A reduced consumption by working machinery entails an increase in the amount of fuel that is allocated to road traffic.
- The fuel consumed by the armed forces in 1990-2017 has by mistake been included twice in the emission estimations in previous submissions. This has been corrected in submission 2025.

10.1.1.2.3 Navigation

- Data on the consumption of LNG by domestic and international navigation has been collected through a survey to shipping companies in 2020-2024. In 2024, the survey failed to return satisfactory results for the year 2023, because several shipping companies failed to respond to the survey. An alternative method was therefore employed for domestic navigation for the years 2021-2023. The energy consumption for each dual fuel LNG ship is taken from the model Shipair. The method then applies the ratio of LNG/MGO used by one of the biggest LNG users to all other shipping companies using LNG. Back testing for previous years has revealed that the results differ by less than 5% from the results in the survey. Unfortunately, this method does not work for international navigation since Shipair currently only covers domestic navigation. For international navigation the results from the LNG survey are still used. For 2021-2022, consumption of the companies that failed to respond was extrapolated with the percentual change of other shipping companies. For 2023, those companies used for extrapolation also failed to respond and the consumption was instead assumed to be the same as for 2022.
- Due to updates of the monthly fuel deliveries, the total amount of marine gasoil and residual fuel oil have decreased somewhat for the year 2022. Since Fuel consumption in domestic navigation is calculated by the model Shipair while fuel use in international navigation is calculated as the total deliveries minus the amounts used in domestic navigation, this change only affects international navigation.

10.1.1.2.4 Non-road mobile machinery

A development project regarding annual machine operating hours was conducted during 2023. The project was conduced based on testing and inspection data from the certified organisation Swedish machine testing. The project involved testing data from year 2019-2023 for construction machinery. Included in the same project was also a study on operating hours of tractors. The study analysed the registered operating hours between change in ownership. The project resulted in adjusted machine hours for most of the machinery included in the non-road mobile machinery model. In general, the previous machine hours were overestimated and thus the recalculations resulted in decreased emissions throughout most of the time series. An example of a significant finding was that the annual average operating hours for machine year 0 (the year a machine was brought into operation) was notably overestimated.

10.1.1.2.5 Fishing

The energy consumption of the fishing fleet is estimated by adjusting the fuel consumption from a survey in 2005 with the total installed effect in the fleet. In 2018, a new survey from the Swedish Energy Agency showed that the actual fuel consumption was somewhat lower than the consumption as estimated using this method. In 2023, yet another survey from the Swedish energy agency confirmed this[387].

Thus, in 2024 a study was performed in order to update the fuel consumption for the fishing fleet based on the two surveys from 2018 and 2023. This study introduces a correction factor, consumption per installed effect for each of the years for which there is data (2005, 2017 and 2022). The correction factor is then interpolated for the years in between. The introduction of the correction factor lowers the fuel consumption of the fishing fleet for all years after 2005. The difference becomes gradually bigger through the time series and for 2022 the fuel consumption is 32% lower in submission 2025 than in submission 2024 (Fig 3.18).

10.1.1.3 FUGITIVE EMISSIONS

Several emission sources have been estimated for the first time in submission 2025:

- Emissions from charcoal production (CRT 1.B.1.B)
- Fugitive emissions from LNG terminals (CRT 1.B.2.B)
- Fugitive emissions from post-meter natural gas consumption (industry, gas vehicles and appliances in residential and commercial sector) (CRT 1.B.2.B.6)

In addition, CH_4 emissions from coke production have been estimated for the first time in submission 2025 (CRT 1.B.1.B).

10.1.2 Industrial processes and product use, CRT 2

CO_2 emissions previously reported in CRT 2.D.3 were in fact indirect CO_2 emissions and have therefore been removed from CRT 2.D.3 in submission 2025.

CO_2 emissions from the use of coke in the sugar industry have been re-allocated from CRT 1.A.2.E to CRT 2.H.2 since the coke is used for process purposes as opposed to energy combustion.

2.D.3: Solvent use: Activity data from the Swedish Chemicals Agency is only available with a one-year-delay. In submission 2025 activity data for 2022 is updated.

For a complete list and more detailed information on recalculations: see the sections “Source-specific recalculations” in section “Industrial processes and product use (CRT sector 2)”.

[387] https://www.energimyndigheten.se/statistik/officiell-energistatistik/tillforsel-och-anvandning/energianvandningen-inom-fiskesektorn/?currentTab=2

10.1.3 Agriculture, CRT 3

Since last submission there are major recalculations due to updates according to 2019 Refinement in the calculation of methane and nitrous oxide in manure management. There are also updates in the ammonia calculation in inorganic fertilizers according to Guidebook 2023 which affects the indirect nitrous oxide emissions. See under the paragraphs, source-specific recalculations, in the agriculture chapter for a complete list of all recalculations.

10.1.4 LULUCF, CRT 4

An important part of the difference between the two latest submissions for the LULUCF-sector is due to the ordinary update according to the methodology used, i.e. the continuous update of the statistics from the NFI and the soil inventory.

This year a major revision of the method to extrapolate the net removals in living biomass for inventory plots not yet re-inventpried was performed, see section 6.3.1.1 and Appendix Table A3:2.2. In addition, the method to estimate net removals in small trees was revised. Small trees (dbh<100 mm) were previously estimated with regression to -3.99 Mton CO2 year-1 for all years 1990 and onwards. Now the net removal of change in living biomass is estimated using the permanent NFI-plots, which means that the re-calculated net removal for recent years has decreased (see Appendix Table A3:2.4.).

The total effect of the recalculation on Living biomass on Forest land remaining forest land is illustrated in Table 6.6a and Figure 6.12.

As for the previous submission, the approach to estimating carbon stock changes in dead wood, litter and mineral soil for several land – use change categories has been revised. For further details, see NID Annex 3:2.

10.1.5 Waste, CRT 5

Recalculations have been done for:
-methane from CRT 5.A.1 Managed waste disposal sites for the years 2011-2013 and 2018-2022,
-methane emissions from CRT 5.D.1 Domestic wastewater for the years 1990-2022, and
-nitrous oxide emissions from CRT 5.D.2 Industrial wastewater for the year 2022.

For more detailed information on recalculations: see the sections "Source-specific recalculations" in section "Waste (CRT sector 5)".

10.2 Implications for emission levels

As can be seen in Table 10.1 below, the recalculations carried out in the 2025 submission (compared to the 2024 submission) are below one percent on the national total emissions (excluding LULUCF, expressed as CO_2-eq.) for all years. The table also displays recalculations by CRT sector and year. Most significant revisions can be seen for the LULUCF sector.

Table 10.1. Recalculations of GHG emissions between submission 2024 and submission 2025 by CRT sector and total.

Year	Total (excl. LULUCF)		Total (incl. LULUCF)		CRT 1		CRT 2		CRT 3		CRT 4		CRT 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	**-60**	-0.08%	**-8010**	-40.31%	**136**	0.26%	**-212**	-2.86%	**-113**	-1.52%	**-7950**	15.47%	**129**	3.1%
1991	**-38**	-0.05%	**-7239**	-35.79%	**136**	0.26%	**-194**	-2.69%	**-109**	-1.53%	**-7202**	14.08%	**129**	3.06%
1992	**-8**	-0.01%	**-7278**	-34.89%	**140**	0.26%	**-177**	-2.64%	**-100**	-1.42%	**-7270**	14.49%	**130**	3.07%
1993	**-2**	0,0%	**-7360**	-29.45%	**136**	0.26%	**-160**	-2.34%	**-108**	-1.47%	**-7358**	15.91%	**130**	3.18%
1994	**31**	0.04%	**-7368**	-28.38%	**147**	0.27%	**-145**	-1.98%	**-103**	-1.37%	**-7399**	15.49%	**131**	3.32%
1995	**34**	0.05%	**-7429**	-29.38%	**145**	0.27%	**-139**	-1.8%	**-104**	-1.42%	**-7463**	15.61%	**132**	3.34%
1996	**25**	0.03%	**-7485**	-27.62%	**132**	0.23%	**-133**	-1.78%	**-106**	-1.44%	**-7510**	15.05%	**132**	3.38%
1997	**34**	0.05%	**-7547**	-36.07%	**128**	0.24%	**-126**	-1.68%	**-100**	-1.35%	**-7581**	14.81%	**133**	3.42%
1998	**25**	0.04%	**-7595**	-36.65%	**115**	0.21%	**-120**	-1.56%	**-103**	-1.41%	**-7620**	14.72%	**133**	3.49%
1999	**6**	0.01%	**-7610**	-44.03%	**107**	0.21%	**-122**	-1.59%	**-113**	-1.59%	**-7616**	14.62%	**134**	3.64%
2000	**19**	0.03%	**-7644**	-51.72%	**113**	0.23%	**-123**	-1.52%	**-106**	-1.49%	**-7663**	14.37%	**134**	3.76%
2001	**-5**	-0.01%	**-7700**	-52.48%	**94**	0.19%	**-120**	-1.46%	**-114**	-1.62%	**-7695**	14.19%	**135**	3.85%
2002	**2**	0,0%	**-7674**	-49.18%	**99**	0.19%	**-120**	-1.43%	**-113**	-1.63%	**-7676**	14.24%	**136**	4.11%
2003	**-22**	-0.03%	**-8046**	-44.74%	**81**	0.16%	**-123**	-1.52%	**-117**	-1.73%	**-8024**	15.47%	**137**	4.34%
2004	**-41**	-0.06%	**-7655**	-37.89%	**80**	0.16%	**-141**	-1.63%	**-119**	-1.74%	**-7614**	15.55%	**138**	4.39%
2005	**-53**	-0.08%	**-7608**	-48.7%	**90**	0.19%	**-148**	-1.72%	**-135**	-2.02%	**-7554**	14.91%	**139**	4.66%
2006	**-48**	-0.07%	**-7773**	-71.7%	**71**	0.15%	**-129**	-1.52%	**-130**	-1.99%	**-7726**	14.02%	**142**	4.92%
2007	**-71**	-0.11%	**-8943**	-89.82%	**66**	0.14%	**-150**	-1.76%	**-130**	-1.99%	**-8873**	16.17%	**143**	5.35%
2008	**-62**	-0.1%	**-7096**	-91.29%	**64**	0.14%	**-136**	-1.67%	**-134**	-2.02%	**-7035**	12.88%	**145**	6.09%
2009	**-52**	-0.09%	**-7551**	-164.88%	**63**	0.14%	**-120**	-1.94%	**-141**	-2.19%	**-7500**	13.99%	**147**	6.47%
2010	**-34**	-0.05%	**-5021**	-68.38%	**69**	0.15%	**-117**	-1.43%	**-134**	-2.06%	**-4987**	8.78%	**149**	6.98%
2011	**-58**	-0.1%	**-5086**	-130.43%	**66**	0.15%	**-127**	-1.65%	**-140**	-2.15%	**-5028**	9,0%	**143**	7.07%
2012	**-70**	-0.12%	**-3644**	-270.24%	**50**	0.12%	**-125**	-1.7%	**-140**	-2.19%	**-3574**	6.43%	**145**	7.72%
2013	**-64**	-0.12%	**-2470**	184.59%	**47**	0.12%	**-113**	-1.53%	**-138**	-2.13%	**-2406**	4.25%	**139**	7.91%
2014	**-37**	-0.07%	**-2832**	192.99%	**53**	0.14%	**-113**	-1.55%	**-128**	-1.95%	**-2795**	5.08%	**151**	9.35%
2015	**-56**	-0.1%	**-3031**	-303.67%	**37**	0.1%	**-120**	-1.66%	**-124**	-1.89%	**-2975**	5.68%	**151**	10.16%
2016	**-45**	-0.08%	**-1214**	-61.6%	**22**	0.06%	**-97**	-1.24%	**-125**	-1.92%	**-1169**	2.28%	**155**	11.06%
2017	**-24**	-0.05%	**-1693**	-22.23%	**37**	0.1%	**-93**	-1.23%	**-124**	-1.86%	**-1669**	3.73%	**156**	11.61%
2018	**-129**	-0.25%	**-1299**	-10.03%	**-63**	-0.17%	**-94**	-1.31%	**-127**	-1.96%	**-1171**	3.03%	**155**	12.5%
2019	**-5**	-0.01%	**741**	7.65%	**61**	0.18%	**-96**	-1.22%	**-127**	-1.96%	**746**	-1.84%	**157**	13.76%
2020	**-18**	-0.04%	**3674**	124.24%	**42**	0.13%	**-98**	-1.54%	**-118**	-1.8%	**3691**	-8.58%	**157**	14.54%
2021	**-1**	0,0%	**6923**	167.55%	**51**	0.15%	**-86**	-1.23%	**-123**	-1.91%	**6924**	-15.89%	**157**	15.7%
2022	**-34**	-0.07%	**7570**	187.76%	**-24**	-0.08%	**-67**	-0.97%	**-101**	-1.55%	**7604**	-18.45%	**159**	16.8%

10.3 Implications for emission trends

The national total emissions of GHG have changed for all inventory years due to the recalculations. As can be seen in Table 10.1 above, national total emissions (excluding LULUCF) in 1990 were changed by +59.89 kton CO_2-eq between the 2024 submission and the 2025 submission. National total emissions (excluding LULUCF) in 2022 were changed by +33.86 kton CO_2-eq between the 2024 submission and the 2025 submission.

10.4 Recalculations and other changes made in response to the UNFCCC review process

In Table 10.2 and Table 10.3, the findings of the latest UNFCCC review (ERT’s provisional main findings) are presented together with the status of implementation in Sweden and references to sections in this NID.

Information on responses and implementation of UNFCCC review report recommendations included in the previous Swedish submissions are available in previous Swedish NID’s.
https://unfccc.int/ghg-inventories-annex-i-parties/2023

Table 10.2 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 NID.

ID#	*Issue/problem classification*[a, b]	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
General					
G.1	Notation keys (G.6, 2022). Convention reporting adherence.	(a) Include justification for the insignificance of emissions for category 2.G; (b) Report HFC-125 and HFC-143a emissions for subcategory 2.F.1.d as “NO” for 2000–2002 if emissions did not occur in those years.	(a) Addressing. See ID# I.8 below. (b) Resolved. Sweden reported HFC-125 and HFC-143a emissions for category 2.F.1.d transport refrigeration (disposal) for 1990–2002 as “NO” in CRT table 2(II).B-H (sheet 2). During the review, Sweden explained that no refrigerated trailers and refrigerated trucks were equipped with the R404a cooling systems (i.e. with HFC-125 and HFC-143a as refrigerant fluids) from 1990 to 1992, 30 per cent of refrigerated trucks and refrigerated trailers had R404a in their cooling systems in 1993–1994, and 100 per cent of refrigerated trucks and refrigerated trailers had R404a in their cooling systems from 1995 onward. This means that emissions from disposal did not occur for 1990–2002 and increased significantly between 2004 and 2005 since the lifespan of the equipment is 10 years (see ID# I.13 in table 5).		

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
G.2	Other (G.3, 2022) (G.5, 2020) Comparability	(a) Complete the empty cells of CRT table 6 by including either the indirect CO_2 and N_2O emissions or the correct notation keys in accordance with paragraph 37 of the UNFCCC Annex I inventory reporting guidelines; (b) Include in the NID information about indirect CO2 and N2O emissions in order to improve transparency.	(a) Not resolved. Sweden continued to report blank cells for indirect CO_2 emissions from the IPPU, agriculture, LULUCF and waste sectors and for the sector "other" in CRT table 6, as well as for indirect N_2O emissions for the sector "other". The ERT considers that the recommendation has not yet been addressed because the Party did not use notation keys or include the required information in CRT table 6 for the cases mentioned above. During the review, the Party clarified that this information will be reported in the 2024 inventory submission. (b) Resolved. The Party provided information on the reporting of indirect CO2 and N2O emissions in its NID (section 9, p.438).	Values or notation keys were included for indirect CO2 and N2O for all categories except indirect CO2 emissions from the energy sector in submission 2024. Notation key for indirect CO2 emissions from the energy sector will be included in the 2025 submission.	
G.3	Uncertainty analysis (G.2, 2022) (G.4, 2020) Convention reporting adherence	Include in the NID an uncertainty analysis for 1990 (the base year under the Convention).	Resolved. The Party provided a summary of the results of the uncertainty analysis for 1990 and 2021 in its NID (section 1.7.1, pp.56–58), with more detail provided in annex 7 to the NID. The overall uncertainty for 1990 emissions is reported to be ±14.2 per cent excluding LULUCF. When including LULUCF, the uncertainty increases to ±53 per cent for 1990.		
Energy					

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
E.1	Fuel combustion – reference approach – CO_2 – liquid fuels (E.7, 2022) Transparency	Include in the NID the results of continued efforts to address the discrepancies between the reference and sectoral approaches for liquid fuels and the challenges in using data from the new questionnaires used with data providers along with the outcomes of work on resolving quality issues in the data sources used for estimating GHG emissions.	Addressing. The Party reported in its NID (annex 4, section 4.5.3, p.186) that the projects aimed at reducing the differences between the reference and the sectoral approaches were not prioritized, but that it will pursue projects aimed at reducing the differences and improve the description of the remaining differences in the 2024 inventory submission (NID, annex 4, section 4.7, p.194). The Party provided in its NID (annex 4, section 4.4.1.2) an analysis of the differences between the approaches for liquid fuels and stated in the NID (section 3.2.1, p.112) that the fuel consumption according to the sectoral approach is consistent with the official energy statistics for fuel consumption. The ERT noted that the differences in CO_2 emissions between the approaches for liquid fuels reported in the NID (annex 4, section 4.4.1.2) and CRT table 1.A(c) were not identical. For example, in NID figure A4.2 (annex 4, p.174), the relative difference between the approaches for 1990 is approximately –1 per cent, whereas in CRT table 1.A(c) it is –9 per cent, or for 2002 the value in NID figure A4.2 is approximately +1 per cent, whereas in CRT table 1.A(c) it is –1.4 per cent. During the review, the Party clarified that the EFs used to calculate stored carbon in the reference approach as presented in the NID (figure A4.2) were not identical to those used for the reporting of stored carbon in the reference approach as presented in CRT table 1.A(c), but that it will use the same EFs for the reporting in the NID and CRT table 1.A(c) for its 2024 inventory submission. The Party stated that it will review the process for preparing the documentation in the NID and correct it for the next inventory submission. The ERT considers that the recommendation has not yet been fully addressed because the Party did not include in the NID the results of the ongoing efforts to reduce the discrepancies between the reference and sectoral approaches for liquid fuels.	We corrected the used emission factors in the NID so it corresponds to the EFs in the CRT tables.	Annex 4, section 4.4.1.2

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
E.2	International navigation – residual fuel oil – CO_2 (E.6, 2022) (E.5, 2020) (E.8, 2019) Convention reporting adherence	Correct the erroneous values of residual fuel oil consumption reported in CRT table 1.A(b) for the entire time series; and improve QC to ensure that data used in the CRT tables are consistent throughout.	Resolved. The ERT noted that the error in the value of residual fuel oil consumption for 2017 – the original cause of this recommendation – has been corrected by the Party. In its 2020 inventory submission, the Party, together with the national agency providing the Swedish energy balance, improved the methodology for estimating residual fuel oil for marine bunkers. The ERT notes that, since the improvement, the values of residual fuel oil consumption for 2019–2021 have been identical in CRT table 1.D.2 (sectoral approach) and table 1.A(b) (reference approach). On the other hand, the ERT notes that inconsistencies between CRT table 1.D.2 and table 1.A(b) regarding residual fuel oil consumption from 1990 to 2018 remain (see ID# E.4 in table 5).		

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
E.3	International navigation – CO_2, CH_4 and N_2O – all fuels (E.8, 2022) Transparency	Include in the NID information explaining that data harmonization work was carried out after the 2010 study mentioned in NID section 3.2.2, that fuel use by navigation is based on sales statistics and split into domestic and international navigation, and that the NCVs for fuels have been harmonized so that the GHG inventory contains the same values as those reported to the International Energy Agency.	Resolved. The ERT commends the Party for describing the methodology used for splitting fuel consumption between domestic and international navigation in the NID (section 3.2.19.2, p.162, and annex 2, section 2.1.14, p.50). The data harmonization work for NCVs for liquid fuels after the 2010 study (in order that the GHG inventory contains the same values as those reported to the International Energy Agency) is also described in annex 4 to the NID in the analysis of differences between the reference and sectoral approaches (NID section 4.4.1.2, p.176).		
IPPU					
I.1	2.A.3 Glass production – CO2 (I.7, 2022) Convention reporting adherence	Report the AD available in CRT table 2(I).A- H (sheet 1) and explain in the documentation box and in the NID why the AD are not complete.	Addressing. The Party did not include the requested AD in CRT table 2(I).A-H (sheet 1), nor did it provide any explanation in the documentation box. It reported the AD as “NA”. In the NID (p.214), the Party explained that the amounts of container glass, flat glass, manual glass and glass wool produced are attributed to different processes, and hence it is not appropriate to sum up and report these data as AD in the CRT tables. However, AD are presented in the NID (table 4.2.7, p.215). During the review, the Party stated that it will include the sum of the different AD in the CRT tables in the 2024 inventory submission.	AD for CRT 2.A.3 were included in the CRT tables in submission 2024.	NID chapter 4.2.3.1

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
I.2	2.B.5 Carbide production – CO2 (I.8, 2022) Transparency	Explain in more detail the methodology used to estimate CO_2 emissions from carbide production (category 2.B.5) in the NID.	Resolved. The Party explained in detail the methodology used in its NID, namely that a tier 1 methodology using the IPCC default EF is applied (see NID table 4.3.3). The Party also stated in its NID (p.225) that emissions associated with calcium carbide are now allocated in accordance with the 2006 IPCC Guidelines: emissions from lime calcination are reported in category 2.A.2 lime production, while CO_2 emissions from calcium carbide production (where CO_2 emissions arise as a result of combusting carbide furnace gas generated during the calcium carbide production process) and emissions from using calcium carbide (acetylene production and use) are reported in the IPPU sector under category 2.B.5.b. The NID also explains that CO2 emissions from carbide production and their allocation had been revised for the 2021 annual submission (section 4.3.5.3, p.228). The information provided by the Party during the 2022 review to explain why the recalculated CO2 emissions for this category increased differently for different years was included in the 2023 NID. The ERT considers that the information provided in the NID is complete and transparent and thus that the recommendation has been resolved.		
I.3	2.B.5 Carbide production – CO2 (I.9, 2022) Transparency	Report AD as a sum of produced carbide and carbide used for acetylene production in CRT table 2(I).A-H (sheet 1) and explain this way of reporting AD in the documentation box and in the NID.	Resolved. The Party reported AD for carbide production under category 2.B.5.b in CRT table 2(I).A-H (sheet 1) and it explained in its NID (p.228) that the AD were the sum of the carbide produced and the carbide used for acetylene production.		

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
I.4	2.C.1 Iron and steel production – CO_2 (I.4, 2022) (I.7, 2020)(I.17, 2019) (I.17, 2017) Convention reporting adherence	Report on any recalculations to emissions and AD across the time series for sources in the energy and IPPU sectors affected by the integrated steelworks (i.e. subcategories 1.A.1.a, 1.A.1.c, 1.A.2.a, 1.B.1.c and 2.C.1.b) (as a result of harmonization of the data).	Not resolved. The Party provided a detailed explanation of the differences between the sectoral and reference approach in its NID (section 3.2.1, p.113) and noted that, in general, the differences observed between the reference approach and the sectoral approach have decreased since the last submission. In the NID (annex 4, section 4.4.2, p.179), the Party stated that it is continuously making efforts to reduce the discrepancies for solid fuels through cooperation with the Swedish Energy Agency and the steelworks operators. During the review, the Party clarified that it would revise the NID chapter on the reference and sectoral approaches in the future, focusing on the comparability of the different sources of AD, and referred to the NID (section 3.2.1 and annex 4) on what has been done to address the issue. The ERT considers that the recommendation has not yet been addressed because the Party did not report recalculations of emissions and AD across the time series for categories in the energy and IPPU sectors affected by the harmonization of data in the integrated steelworks.	Reported emissions and AD in CRT are correctly estimated. The differences between RA-SA found in CRT 1Ac can be allocated to differences in data collection and data sources used. See NID Annex 4 for further explanations.	NID Annex 4

I.5	2.C.1 Iron and steel production – CO_2 (I.10, 2022) Transparency	(a) Provide information in the NID on the mass-balance approach applied, including the list of raw materials taken into account for the estimation of CO_2 emissions from iron ore pellet production; (b) Transparently report a description of the pellet production process indicating the allocation of energy-related emissions; (c) Collect information on the carbon content both in raw materials and in pellet production, reporting them as national totals if necessary to protect confidential information, in order to explain the low value of the IEF reported in CRT table 2(I).A-H (sheet 2) for estimating CO2 emissions from pellet production for 2020 under subcategory 2.C.1.e.	(a) Resolved. The Party reported in its NID (section 4.4.1.2.5, p.244) that the amounts of bentonite, organic binder, olivine, quartzite, limestone and dolomite used for the production of iron ore pellets and the corresponding CO_2 emissions are collected from the EU ETS and are reported by companies and facilities. The Party described in its NID (p.242) the detailed mass-balance approach used to verify the data on emissions reported to the EU ETS for the production of pig iron (category 2.C.1.b). During the review, the Party clarified that it does not make an equivalent mass balance for pellet production (category 2.C.1.e) as made for pig iron. Process-related emissions are estimated from the EU ETS data. Only process-related CO_2 emissions have the EU ETS as a data source, while energy-related emissions (CO_2, CH_4 and N_2O, all reported in the energy sector) are based on fuel statistics. The ERT noted that this information is also included in the NID (p.244) and considered that this recommendation has been fully addressed. (b) Not resolved. The Party did not include a description of the pellet production process in the NID. During the review, the Party provided information on the allocation of energy-related emissions (emissions from the use of light and heavy fuel oil and hard coal are reported in category 1.A.2.g of the energy sector). During the review, the Party clarified that only CO2 process-related emissions are sourced from the EU ETS, while energy-related emissions are based on fuel statistics. The ERT considers that the recommendation has not yet been addressed because a description of the pellet production process was not included in the NID. (c) Addressing. The Party reported in its NID (table 4.4.6, p.244) a list of all inputs and outputs (pellets), with their average, minimum and maximum carbon content. However, the Party did not explicitly explain in the NID why the IEF (0.004 kt/kt) reported in CRT table 2(I).A-H (sheet 2) is lower than the default EF of 0.03 in the 2006 IPCC Guidelines (vol. 3, chap. 4, table 4.1, p.4.25). During the review, the Party explained that it suspects that the default EF in the 2006 IPCC Guidelines corresponds to total CO2 emissions (i.e. both process- and energy-related CO2 emissions) and if this EF is used it would lead to a large overestimation of the process-related emissions in category 2.C.1.e. The Party also provided data that demonstrate that the IEFs, when including both process- and energy-related emissions, are closer to the defaults in the 2006 IPCC Guidelines. The ERT considers that this recommendation has not yet been fully addressed, as Sweden did not include in the NID information that explains the low	Resolved in NID **submission 2024**. In NID **submission 2025**, in the section 4.3.1.2.5. the pellet production is explained in detail and the Emission factor intervals for carbon containing rawmaterials are listed in Table 4.4.6.	4.3.2.1.5

			value of the IEF reported in CRT table 2(I).A-H (sheet 2)		

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
I.6	2.C.1 Iron and steel production – CO_2 (I.11, 2022) Transparency	Provide in the NID information explaining that the high CO_2 IEF for 2019 (0.80 t/t) was due to the extensive use of carbon-rich residues (i.e. with a high carbon content) instead of the iron ore pellets used in pig iron production in 2018 and 2020 (IEFs of 0.53 and 0.60 t/t respectively).	Resolved. The Party reported in its NID (section 4.4.1.1.2, p.237) that the significant increase in the IEF is explained by a disturbance in the production process at one of the facilities in 2019, which hindered the possibility of selling energy-rich process gases to external consumers and led to the gases being flared. Additionally, the Party explained that there was no process disturbance in 2020 to cause a low CO_2 IEF that year. The ERT considers that the recommendation has been fully addressed.		
I.7	2.D.1 Lubricant use – CO2 (I.12, 2022) Transparency	Provide in the NID information on the causes of the declining trend in lubricant use in the country since 2013.	Not resolved. The Party reported in its NID (section 4.5.1, p.264) that the amount of lubricant used has declined in recent years and that no specific explanation for the trend has been found. During the review, the Party explained that it had not yet found an explanation for the trend but that since AD for the last year of the time series (2021 in the 2023 inventory submission) are not available, the actual AD for 2021 will be used for the next inventory submission, and will show an increase to approximately the 2019 level, indicating a break in the decline. The ERT considers that the recommendation has not yet been addressed because the Party did not include a description in the NID of the investigation to explain the decline.	The investigation included contacts with Swedish Energy Agency and Statistics Sweden that didn't find specific explanations for the declining trend 2016-2020. The trend is broken, and during 2021-2023 the amount of lubricants increases.	4.5.1.2

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
I.8	2.G.2 SF_6 and PFCs from other product use – SF_6 and PFCs (I.13, 2022) Completeness	(a) Investigate the occurrence of SF_6 or PFC emissions from military applications (subcategory 2.G.2.a) and report its findings in the NID, and estimate and report SF_6 and PFC emissions if applicable, for the entire time series; (b) Estimate and report SF6 emissions from accelerators (subcategory 2.G.2.b) or, if it considers these emissions insignificant, demonstrate that the likely level of emissions is below the significance threshold established in paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines.	(a) Addressing. The Party reported in its NID (section 4.8.2.1, p.300) that it has no specific information on military applications or systems using SF_6 or heat transfer fluids in high-powered electronics applications using PFCs. During the review, the Party explained that it had searched for information by contacting the company that manufactures military aircraft in the country but had not received answers regarding the use of SF_6. The Party also looked for information on the Internet and in the environmental reports of aircraft manufacturers and manufacturers of associated equipment, but no data were found to be available. The ERT considers that the recommendation has not yet been fully addressed because the Party did not report the findings of its investigation in the NID. (b) Addressing. The Party reported in its NID (section 4.8.2.1, p.300) that it has no data on the total number and type of accelerators in the country. The Party also indicated in the NID that emissions of SF6 are very small (less than 1 kg per year for the biggest accelerator in the country). The ERT considers that the recommendation has not been fully addressed because the Party did not demonstrate in its NID that the likely level of SF6 emissions from all accelerators is below the significance threshold established in paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines and below 500 kt CO2 eq.	This has been addressed for submission 2025.	In NID: Chapter 4.8.2.1.
Agriculture					

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
A.1	3.A.1 Cattle – CH_4 (A.10, 2022) Transparency	(a) Correct the equation for GE in the NID; (b) Provide information on gross energy in silage and concentrate respectively.	(a) Resolved. The Party corrected the equation for GE in the NID (section 5.2.2.1.1, p.316). (b) Not resolved. The Party did not provide information on GE in silage and concentrate respectively in its NID. During the review, the ERT observed that information on GE in silage and concentrate is available in Bertilsson (2016) but that this information was not included in the NID.	(b) This has been addressed.	In NID: Chapter 5.2.2.1.1
A.2	3.A.1 Cattle – CH_4 (A.11, 2022) Transparency	Correct in the NID (section 5.2.2.1.1) the description of the unit of Conc_F and Silage_F in the equation for fatty acid content in feed.	Resolved. The Party corrected the description of the unit of Conc_F and Silage_F in the equation for fatty acid content in feed in the NID (section 5.2.2.1.1, p.315).		
A.3	3.A.1 Cattle – CH_4 (A.12, 2022) Transparency	Report the population of heifers, bulls and steers by age used to derive the CH_4 EFs in order to improve the transparency of the calculations.	Addressing. During the review, the Party noted that a clarification on the assumptions of the population composition for heifers, bulls and steers was reported in the NID (section 5.2.2.1.3, p.317). The Party reported in its NID (p.317) that the assumed age composition for bulls and steers is 85 per cent between one and two years and 15 per cent above two years; for heifers, the corresponding figures are 70 and 30 per cent respectively. During the review, the Party also clarified how the proportion of calves raised for meat aged <3 months that are assumed not to be emitting enteric methane is calculated. The NID (table 5.5, p.318) presents aggregate data on the population of calves, but not on the number of calves used to calculate enteric emissions. However, the ERT considers that this recommendation has not yet been fully addressed because the population of male and female calves used to calculate enteric emissions is not reported in the NID and it is not possible to reconstruct the emissions reported in the CRT tables using the information provided in the NID (in NID tables 5.5 (population data) and 5.3 and 5.4 (EFs)). Table 5.5 does report populations of calves, heifers and steers but does not report the populations in different age classes in a way that enables the emissions to be accurately reconstructed.	The proportion of calves has been addressed	In NID: Chapter 5.2.2.1.3

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
A.4	3.B Manure management – N2O (A.4, 2022) (A.9, 2020) Transparency	Explain that manure used in co-digestion is omitted from CRT table 3.B(b) and provide the fraction of manure co-digested for the aggregate categories of dairy cattle, non- dairy cattle and swine along with the disaggregated values currently provided in NID table 5.14.	Resolved. The Party reported the fraction of manure co-digested for the aggregate categories of dairy cattle, non-dairy cattle and swine in its NID (table 5.14, p.324). Sweden also explained in its NID (p.322) that manure emissions from on-farm digesters are accounted for in the agriculture sector, while emissions from co-digesters are excluded from the agriculture sector and are therefore not reported in CRT table 3.B(b) but are accounted for in the waste sector instead. The ERT therefore considers this issue as resolved.		
A.5	3.B.4 Other livestock – N2O (A.6, 2022) (A.11, 2020) Transparency	Justify that the Nex rate applied for reindeer is appropriate to national circumstances compared with the default value and the higher value previously used in the NID.	Resolved. The Party reported in its NID (table 5.17, p.326) that a Nex value of 5.4 kg N/head/year was used and noted as a comment: “2019 refinement, typical animal mass 64 kg”. The NID (section 5.3.2, p.322) states that the Nex value for reindeer is calculated using the methodology and data from the *2019 Refinement to the 2006 IPCC* Guidelines for National Greenhouse Gas Inventories (chap. 10, table 19, equation 10.30) with the assumption (from the Sami parliament) that the slaughter weight represents half the live weight, hence the average reindeer weight was estimated to be 64 kg. During the review, the Party clarified that the figure of the typical animal mass of 64 kg was calculated using statistics on the distribution of the different types of reindeer in the herd, slaughter statistics provided by the Sami parliament (available at https://www.sametinget.se/statistik/renslakt/detaljer and https://www.sametinget.se/statistik/renhjorden) and the assumption confirmed by the Sami parliament that the slaughter weight represents half the live weight. The ERT considers that the recommendation has been addressed since the related information provided in the NID reflects the national circumstances, as explained in the NID.		

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
A.6	3.D.a.2.c Other organic fertilizers applied to soils – N2O (A.13, 2022) Convention reporting adherence	Report the N in other organic fertilizers applied to soils consistently between the NID and CRT tables.	Resolved. The Party reported the N in other organic fertilizers applied to soils consistently between the NID and CRT tables. For example, for 2020, the Party reported in its NID (table 5.22, p.335) "Other organic fertilizers applied to soils (excluding digestate from animal manure)" as 6,974 t N and "Animal manure digestate from co- digester applied to soils" as 2,911 t N, which sum (accounting for rounding) to the 9,885,388 kg N reported in CRT table 3.D for category 3.D.a.2.c.		
A.7	3.D.b Indirect N_2O emissions from managed soils – N_2O (A.14, 2022) Transparency	(a) Explain, in NID sections 5.4.2.2.1 and 5.4.2.2.2, that the digestate from co-digesters is included in the calculation of indirect N_2O emissions for categories 3.D.b.1 and 3.D.b.2; (b) Correct the equation reported in the NID for estimating N2O emissions from atmospheric deposition to: N2O-N = [(FSN × FracGASF) + (FON × FracGASM) + (FCOD × FracGASCOD) + (FPRP × FracGASG)] × EF4.	(a) Addressing. The Party reported in its NID (section 5.4.2.2.1, p.341) that "the annual amount of digestate from animal manure from co-digester applied to soil" is included in the calculation of volatilized N from agricultural inputs of N and included the amount of N in digestate from animal manure co-digesters as shown in NID table 5.30 (p.343). However, no information on the inclusion or exclusion of digestate from co-digesters was included in the NID (section 5.4.2.2.2, p.343) to address nitrogen leaching and run- off. During the review, the Party clarified that "nitrogen in digestate from animal manure in co-digester is included in the calculation of $Frac_{LEACH-(H)}$". The Party further stated that the text will be updated in the 2024 NID. (b) Resolved. The Party corrected the equation reported in its NID (p.341) for estimating N2O emissions from atmospheric deposition.	(a) Information about digestate from co-digesters has been addressed in the NID.	In NID: Chapter 5.4.2.2.2

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
A.8	3.G Liming – CO_2 - (A.9, 2022) (A.15, 2020) Accuracy	Estimate CO_2 emissions from liming by applying the recommended method from figure 11.4 in the 2006 IPCC Guidelines (vol. 4). If the Party continues to use the tier 1 method, explain in the NID why a recommended method from the 2006 IPCC Guidelines has not been followed as required by paragraph 11 of the UNFCCC Annex I inventory reporting guidelines.	Resolved. The Party reported in its NID (pp.345–346) that it used the tier 1 method from the 2006 IPCC Guidelines together with default EFs to estimate emissions for this category and that emissions from liming are minor and do not justify the time and resources needed to estimate them using a tier 2 method with country-specific EFs. Furthermore, it was stated that a tier 2 method would calculate emissions that are likely to be less than emissions estimated using the tier 1 method (2006 IPCC Guidelines, vol. 4, chap. 11, section 11.3.1, p.11.27) and liming would then no longer be a key category. During the review, the Party clarified that since its emissions from liming are just above the threshold for being a key category, it has chosen to follow the text in the 2006 IPCC Guidelines, which states that actual CO2 emissions from liming are expected to be less than the emissions estimated using the tier 1 approach (which assumes that all C in applied lime is emitted as CO2 in the year of application) because the amount of CO2 emitted after liming depends on site-specific influences and the transportation of dissolved inorganic C through rivers and lakes to the ocean. The Party noted that the potential advantages of developing tier 2 EFs are too small to warrant a diversion of resources that could be better used elsewhere. The ERT considers that the recommendation has been addressed as required by paragraph 11 of the UNFCCC Annex I inventory reporting guidelines.		
A.9	3.G Liming – CO_2 (A.15, 2022) Convention reporting adherence	Correct the equation for calculating CO_2 emissions from limestone and dolomite reported in the NID by adding opening and closing brackets around the parameters for limestone and dolomite before multiplying them by the CO_2/C conversion factor.	Resolved. The Party reported in its NID (section 5.4.3.2, p.346) the correct equation for calculating CO_2 emissions from limestone and dolomite.		

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
LULUCF					
L.1	4. General (LULUCF) – CO2 (L.1, 2022) (L.8, 2020) Accuracy	Justify the use of the country-specific EF of 0.12 CO2-C/ha/year for DOC emissions from drained organic soils for forest land, cropland and grassland for the temperate region on the basis of national circumstances or, alternatively, apply the default EF for DOC from the Wetlands Supplement (table 2.2) for the temperate region while collecting new information.	Not resolved. The Party reported in its NID (annex 3, pp.129–132) that country-specific EFs (t CO_2-C/ha/year) developed from a model (Wallin et al., 2021) were used for forest land and grassland to estimate off-site CO_2 emissions of DOC from drained organic soils in forest land (0.07 t CO_2-C/ha/year for boreal, 0.08 t CO_2-C/ha/year for temperate) and grassland (0.04 t CO_2-C/ha/year for boreal, 0.09 t CO_2-C/ha/year for temperate), while the IPCC default value of 0.12 t CO_2-C/ha/year for boreal from the Wetlands Supplement (table 2.2) was used for cropland and land-use conversions. The ERT noted that the Party did not modify the Wallin et al. (2021) model or provide adequate documentation in the NID, nor did it justify in the NID why the selected default EF for cropland for the boreal zone of 0.12 t CO_2-C/ha/year is representative when Sweden has both temperate and boreal climate zones. The ERT considers that the recommendation has not yet been resolved because the Party did not provide justification as to why the Wallin et al. (2021) model is representative of national circumstances for forest land and grassland or, alternatively, did not use the default EFs exclusively in accordance with the appropriate climate zone. During the review, the Party clarified that it plans to resolve the issue for the 2024 inventory submission by firstly revisiting the Wallin et al. (2021) study and justifying why the country-specific EFs are representative of forest land and grassland, and secondly by improving the justification for using default EFs for the boreal zone despite Sweden having both temperate and boreal climate zones. The Party also clarified that according to Lindgren and Lundblad (2014, p.34) the EF for boreal drained organic soils is more appropriate for Swedish conditions than the default for the temperate zone.	The EF:s for DOC has been assessed and compared with the IPCC default factors. Reasons for the choise of EF:s are included in the NID Annex. (response from NID 2024)	See NID annex 3:2 section 3.2.1.8

L.2	4. General (LULUCF) (L.2, 2022) (L.9, 2020) Convention reporting adherence	Report comparable information on areas of land conversion across CRT table 4.1 and CRT tables 4.A–4.F. If there are remaining inconsistencies, provide a detailed explanation for the difference in the areas reported in CRT table 4.1 and background CRT tables 4.A–4.F.	Addressing. The Party reported in its NID (section 6.2.8, p.360) that land use in CRT table 4.1 is based on the extrapolation of complete NFI sampling plots from 1990–2017 and that there is no IPCC guidance on the extrapolation of these areas into annual values for CRT tables 4.A–4. F. As a result, the Party reported in its NID (p.488) that inconsistencies between CRT table 4.1 and CRT tables 4.A–4.F persist. The ERT noted the Party's explanation and the inconsistencies among CRT tables. For example, CRT table 4.D reported the area of forest land conversion to other wetlands in 2020 as 67.22 kha and in 2021 as 71.53 kha, but CRT table 4.1 reported annual land conversion from forest land to wetlands as "NO". During the review, the Party acknowledged the inconsistencies between CRT table 4.1 and CRT tables 4.A–4.F. However, the Party noted that the land areas reported in CRT tables 4.A–4.F describe areas converted to other uses for up to 20 years per land-use category, but the areas reported in CRT table 4.1 describe annual transferred areas between land-use categories. Thus, the areas reported in CRT tables 4.A–4.F (e.g. forest land converted to wetlands) are not the same as the areas reported in CRT table 4.1, but the total area is the same in all tables (in the previous example, the sum of wetlands remaining wetlands and all the conversions to wetlands from forest land, cropland, grazing land, settlements and other land). The Party acknowledged that the actual transfers to be reported in CRT table 4.1 for the last four years of the time series cannot be directly estimated from a multiannual periodic survey, but that it is aware of this issue and has tried to solve it by trial and error, and that it will explain this approach in its next inventory submission. The Party also noted that the IPCC recommends periodic surveys using a five-year inventory cycle but gives no guidance on how to report the land-use matrix. The Party also indicated that it will review the use of notation keys in CRT table 4.1 for its next inventory submission. The ERT notes the challenge faced by the Party to report the four most recent years of land conversions and suggests that the Party explore the use of alternative methods of extrapolation, such as the Food and Agriculture Organization of the United Nations' Global Forest Resources Assessment 2020: Guidelines and Specifications for the years in the time series for which complete NFI data are unavailable. During the review, the Party stated that it would explore different options for improving the reporting of the four most recent years of land conversions but that the use of the Global Forest Resources Assessment 2020: Guidelines and Specifications may not result in more accurate estimates. The ERT considers that the recommendation has not yet been	Observe that Table 4.1 describes annual transitions between Land Use Categories while tables 4.A – 4.F describe the area within each Land Use Category. The total of e.g. F in 4.1 is always the same as in 4.A. (response from NID 2024)	New text footnote 6.2.8:

			addressed because the Party did not provide consistent information on land conversions across CRT table 4.1 and CRT tables 4.A–4.F or provide in its NID a detailed explanation of the difference in land areas reported in CRT table 4.1 and CRT tables 4.A–4.F.			

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
L.3	4. General (LULUCF) – CO_2, CH_4 and N_2O (L.19, 2022) Transparency	Improve the transparency of estimators used for upscaling plot data on page 120 of annex 3 to the NID.	Not resolved. The Party did not improve the transparency of the estimators used for upscaling plot data in its NID (annex 3, pp.113–114). The Party indicated in its NID (p.558) that the recommendation from the previous review was not considered as it had not received the final annual review report for the 2022 annual submission at the time of the preparation of the GHG inventory. During the review, the Party clarified that the first estimator (area weight) weights the sample in the design-based approach, explaining what area each sample unit represents. The ratio estimator, however, is used to upscale plot data to estimate either CSCs or land-use change area. The ERT considers that the recommendation has not yet been addressed because the Party did not improve the transparency of the estimators used for upscaling plot data, for example by incorporating in the NID the clarifications that the Party provided during the review.	A sentence is added.	NID Annex 3.2.1.1

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
L.4	4. General (LULUCF) – CO2 (L.20, 2022) Accuracy	Explain in the NID for forest land and grassland why double counting of emissions or removals from mineral soils between land conversion categories and land remaining land categories is negligible despite the combination of tier 1 or tier 2 methods for land conversion categories and tier 3 methods for land remaining land categories or revise the estimates in order to avoid double counting of emissions or removals between the "land converted to" categories in the early years of the reporting period and the "land remaining land" categories in the later years of the reporting period.	Not resolved. The Party did not report in its NID why double counting of emissions or removals from mineral soils is negligible despite the combination of tier 1 or tier 2 methods. The Party reported in its NID (annex 3, section 3.2.1.10, pp.137–140) that country-specific EFs and removal factors were used for calculating the SOC stock change in mineral soils associated with land-use changes. The ERT noted that the Party is using a tier 2 method where for most conversions the factors were based on average SOC stocks in forest land (45 t C/ha), forest on former agricultural soils (87 t C/ha), cropland (100 t C/ha) and grassland (110 t C/ha), with transition periods or assumptions of SOC gains or losses for certain land uses (e.g. forest land converted to cropland increases by 20 per cent over 20 years). However, for conversions from cropland to grassland, and from settlements or other land to either cropland or grassland, the factors were based on the tier 3 estimated average net emissions or removals for 1990–2021 for cropland remaining cropland (for settlement or other land converted to cropland and cropland converted to grassland) and for grassland remaining grassland (for settlement or other land converted to grassland). The ERT noted that no explanation was provided and that estimates were not revised because the potential double counting appears to be negligible. During the review, the Party clarified that it is planning to address the issue in the 2024 inventory submission by improving the explanation of the method but will not revise the methodology. In addition, the Party clarified that NFI plots for land remaining land and converted land are considered separately and a land conversion effect in the soil C stock 21 years after the land-use change is covered in the measurement of the plots of the land remaining land and is reflected in the estimation of CSC for the land remaining land. The ERT agrees with this rationale. However, the ERT considers that the recommendation has not yet been addressed because the Party did not provide in the NID information explaining why double counting of CSC from mineral soils in the land remaining land and land converted to other land-use categories is negligible, nor has the Party revised the estimates in order to avoid the potential double counting.	The approach to estimate CSC for LUC categories has been assessed and partly changed. The approach is described in the NID annex including how double counting is avoided. (explained already in NID 2024)	See NID annex 3:2 sections 3.2.1.11, 3.2.1.11.1, 3.2.1.11.2

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	**Section in NID**
L.5	Land representation – CO_2, CH_4 and N_2O (L.21, 2022) Transparency	Better describe the assumptions used for land-use changes between 1970 and 1990 in the NID, for example by providing one representative land-transition matrix for that period.	Not resolved. The Party did not provide a better description of the assumptions used for land-use changes between 1970 and 1990 in its NID. The Party reported in its NID (p.551) that the recommendation from the previous review report was not considered as it had not received the final annual review report for the 2022 annual submission at the time of the preparation of the GHG inventory. During the review, the Party clarified that it plans to describe the assumptions used for land-use changes between 1970 and 1990 transparently in the 2024 inventory submission.	Sentence added (explained already in NID 2024)	NID 6.2.7
L.6	4.A Forest land – CO_2 (L.22, 2022) Transparency	(a) Better explain why the Party reports small trees <100 mm in DBH as constant net removals in the NID (the ERT notes that, according to the good practice guidance in the 2006 IPCC Guidelines (vol. 4, chap.4, p.4.72), Parties can choose to report the removals associated with small trees (understory) as zero); (b) Explain how the Party avoids double counting when small trees reach 100 mm DBH.	(a) Not resolved. The Party did not explain the rationale behind the assumption of constant carbon net removals from small trees (i.e. trees <100 mm in DBH) for every reported year. The Party also indicated in its NID (p.556) that the recommendation from the previous review report was not considered as it had not received the final annual review report for the 2022 annual submission at the time of the preparation of the GHG inventory. During the review, the Party clarified that CSCs in small trees are estimated using regression. The Party also noted that it is planning to improve the transparency of the reporting. (b) Not resolved. The Party did not explain in its NID how the double counting of net removals from small trees is avoided when they reach 100 mm DBH. The Party also indicated in its NID (p.556) that the recommendation from the previous review report was not considered as it had not received the final annual review report for the 2022 annual submission at the time of the preparation of the GHG inventory. During the review, the Party clarified that sample trees are measured individually and included in the estimation of living biomass only after they reach 100 mm. The ERT notes that the potential concern of double counting net removals in the estimation is not resolved by the fact that small trees are excluded from the accounting procedure, as explained by the Party during the review. The ERT considers that the recommendation has not yet been addressed because the Party did not provide in its NID additional information on the assumption that the annual net removals from small trees remain constant over the entire time series, regardless of the age structure and management practice.	The method has been updated in Submission 2025.	NID Annex 3.2.1.2.2

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
L.7	4.A Forest land – CO_2 (L.23, 2022) Accuracy	(a) Provide in the NID the time series for each deadwood and litter subcomponent separately so that the model estimates can be transparently distinguished from the measurements; (b) Reconsider its litterfall models, either verifying them against independent measurements or reverting to a simpler tier 1 or tier 2 approach (the ERT notes that litterfall estimates are likely to result in minor CSCs and that a higher-tier approach is therefore probably not mandatory because the contribution in emissions and removals could be considered not substantial).	(a) Not resolved. The Party did not include the time series for the different deadwood and litter subcomponents in its NID. The Party indicated in its NID (pp.554–555) that the recommendation from the previous review report was not considered as it had not received the final annual review report for the 2022 annual submission at the time of the preparation of the GHG inventory. During the review, the Party clarified that the time series for the different deadwood and litter subcomponents will be included in the 2024 inventory submission. (b) Not resolved. The Party did not provide additional information in its NID on the reconsideration of the models applied to estimate litterfall, either by verifying them against independent measurements or by reverting to a simpler tier 1 or tier 2 approach. The ERT noted that the Party reported in its NID (pp.375–376 and annex 3, pp.121–122) the same information as in its 2022 NID. The Party also indicated in its NID (pp.554–555) that the recommendation from the previous review report was not considered as it had not received the final annual review report for the 2022 annual submission at the time of the preparation of the GHG inventory. During the review, the Party clarified that a review of the regression models used for the annual litter fall component is under way, together with a consultation on their validity from a statistical point of view.	Time series for litter subcomponents have been included in the NID Annex 3:2. (updated in NID 2024)	Time series for litter subcomponents have been included in the NID Annex 3:2.

ID#	*Issue/problem classification*[a, b]	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
L.8	4.A.1 Forest land remaining forest land – CO2 (L.24, 2022) Transparency	Categorize the Party's method for estimating deadwood and coarse litter in land conversions as tier 3 and describe how the estimates at the category level are distributed to subcategories and the exceptions (for stumps and litter) to this general rule.	Not resolved. The Party did not provide information in its NID to address the recommendation from the previous review report. The Party reported in its NID (pp.349–350) the method for estimating deadwood and coarse litter in land conversions as tier 2, which is the same as reported in the 2022 NID (p.360). The Party indicated in its 2023 NID (p.544) that the recommendation was addressed in annex 3.2 to the NID (pp.118–121). However, no additional information was provided on how the estimates at the category level are distributed to categories and the exceptions (for stumps and litter) in relation to the IPCC land-use categories (forest land and cropland). During the review, the Party clarified that it is working on this issue and it will evaluate the tier levels and the estimation methods to resolve this issue for the 2024 inventory submission.	The approach to distribute the estimate of dead wood on LU and LUC categories has been re-assesed. (first time in submission 2024)	See NID annex 3:2 section 3.2.1.11.1
L.9	4.A.1 Forest land remaining forest land – CO2 (L.25, 2022) Transparency	Improve the documentation of the Party's interpolation and extrapolation procedure of CSCs in the NID.	Resolved. The Party explained that the estimation of CSCs in living biomass for the last four years of the time series was made using trend extrapolation for the 36 land-use categories, including forest land remaining forest land (NID, p.375, and annex 3, pp.114–115). Moreover, the Party provided additional information on the interpolation of the plot data between consecutive inventories (NID, p.366, and annex 3, p.116). The ERT considers that the recommendation has been fully addressed.	A new method was implemented in this Submission.	NID Annex: 3.2.1.2 and NID 6.2.8 and 6.4.2.2

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
L.10	4.A.1 Forest land remaining forest land – CO_2 (L.26, 2022) Accuracy	(a) Examine the reason for the systematic overestimation of "projected" net removals (reported values for years y–4 to y) compared with "actual" net removals when the NFI is complete; (b) Investigate whether the extrapolation of not yet remeasured plots can be improved; (c) Report the findings in the NID.	(a) Not resolved. The Party did not report in its NID information regarding the reason for the systematic overestimation of "projected" net removals compared with "actual" net removals when the NFI is complete. The Party indicated in its NID (p.550) that the recommendation from the previous review report was not considered as it had not received the final annual review report for the 2022 annual submission at the time of the preparation of the GHG inventory. During the review, the Party clarified that it plans to improve its reporting so that extrapolated data will better match the final measured data. The Party noted that the projected (trend extrapolated) method suggested in the 2006 IPCC Guidelines may produce either overestimates or underestimates if the real trend changes. (b, c) Not resolved. The Party did not report in its NID whether the extrapolation of plots that had yet to be remeasured can be improved. The Party indicated in its NID (p.550) that the recommendation from the previous review report was not considered as it had not received the final annual review report for the 2022 annual submission at the time of the preparation of the GHG inventory. During the review, the Party clarified that it is looking into potential ways to improve the accuracy of its reporting by either visiting all 30,000 sample plots in key years (e.g. 2025), which would result in a significant additional cost, or by simulating growth for the 24,000 sample plots remeasured between years one and four with the help of the Heureka simulation model. The Party is planning a pilot study to address this issue. As for (a) above, the Party noted that the projected (trend extrapolated) method suggested in the 2006 IPCC Guidelines may produce either overestimates or underestimates if the real trend changes.	A new method was implemented in this Submission.	NID Annex: 3.2.1.2 and NID 6.2.8 and 6.4.2.2

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
L.11	4.A.1 Forest land remaining forest land – CO_2 (L.27, 2022) Transparency	(a) Report harvest statistics in the NID, for example using the same figure as NID figure 2.38 (displaying total emissions/removals for, inter alia, living biomass); (b) Validate reported numbers of changes in living biomass by, for example, using the default biomass gain–loss method from the 2006 IPCC Guidelines (vol. 4, chap. 4.2.1.1).	(a) Not resolved. The Party did not report in its NID any harvest statistics. The Party reported in its NID (pp.552–553) that the recommendation from the previous review report was not considered as it had not received the final annual review report for the 2022 annual submission at the time of the preparation of the GHG inventory. The ERT noted that the Party included a link to the national harvest statistics in its NID (footnote 284, p.351). However, the information could not be retrieved from that link, but was found at another one (https://www.skogsstyrelsen.se/statistik/statistik-efter-amne/avverkning/). This information shows an increasing trend in felling, consistent with the FAOSTAT data. The ERT considers that the recommendation has not yet been addressed because the Party did not include harvest statistics in its NID in accordance, for example, with NID figure 2.38 (p.95). (b) Not resolved. The Party did not report in its NID the validation results for the reported CSC values in living biomass. The Party indicated in its NID (pp.552–553) that the recommendation from the previous review report was not considered as it had not received the final annual review report for the 2022 annual submission at the time of the preparation of the GHG inventory. During the review, the Party clarified that it plans to validate the reporting of CSC values in living biomass using the default biomass gain– loss method in the 2006 IPCC Guidelines. The Party noted that a comparison should also include growth estimated as a running average.	Comprehensive validation is now added in the Annex (Response presented in NID 2024)	NID Annex 3.2.1.1

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
L.12	4.A.1 Forest land remaining forest land – CO_2 (L.28, 2022) Transparency	(a) Clarify in the NID that the NFI cycle is five years for living biomass but 10 years for the other pools; (b) Clarify the reason for the recalculations for deadwood and litter in forest land performed between the 2020 and 2022 annual submissions in its NID; (c) Demonstrate that recategorized land-use changes are the reason for the recalculations in grassland, e.g. by reporting the share of "requalified" grassland plots between two annual submissions when substantial recalculations are performed for years of the time series that are more than 12 years before the respective submission year.	(a) Resolved. The Party explained in its NID (p.362) that the data reported in the inventory for the living biomass and deadwood pools are based on the NFI cycle (five years), but that the data for the litter and SOC pools are based on the Swedish Forest Soil Inventory cycle (10 years). (b) Resolved. The Party explained in its NID (p.388) that recalculations for deadwood and litter in forest land performed over the entire time series were due to the incorporation of information from reinventoried sample plots from the Swedish Forest Soil Inventory. (c) Not resolved. The Party did not report in its NID additional information to explain the substantial recalculations in the grassland category or to demonstrate that recategorized land-use changes are the reason for the recalculations in this category. The Party indicated in its NID (pp.553–554) that the recommendation from the previous review report was not considered as it had not received the final annual review report for the 2022 annual submission at the time of the preparation of the GHG inventory. During the review, the Party reiterated that the issues could not be addressed for the 2023 inventory submission.	During submission 2023 Sweden change the interpolation method for litter and soil carbon stocks over the whole reporting period. Since the comment by the ERT was made in relation to submission 2022 some of the observations are no longer relevant. Further explanations on the substantial recalculations has been addid in the NID. Information on the difference in inventory rotation between the NFI and the SFSI are now found in several	6.4.5 Source-specific recalculations

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
				sections of the NID. Information of the share of requalified plots for Grassland are now found in 6.4.5 Source-specific recalculations (Response presented in NID 2024)	

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	**Section in NID**
L.13	4.A.2 Land converted to forest land (L.8, 2022) (L.12, 2020) Transparency	When reporting in the NID on CSC due to the conversion of wetlands and other land to forest land, distinguish between conversion due to natural causes and conversion due to human activities, and include the information provided during the review.	Not resolved. The ERT noted that the Party reported CSCs resulting from the conversion of wetlands and other land to forest land. The Party used NFI sampling data for land representation and explained in its NID (pp.367–368) that only land conversion due to human activities is identified as land converted to new land use in the GHG inventory. The ERT considers that the recommendation has not yet been fully addressed because the Party did not provide information in the NID on CSC due to the conversion of wetlands and other land to forest land, nor did it distinguish between conversion due to natural causes and conversion due to human activities. During the review, the Party clarified that it is working on the issue and is planning to resolve it for the 2024 inventory submission.	The reason to not report land converted to flooded land is that no flooding (i.e. building of larger dams or reservoirs) have been observed. Text now included in the NID annex. (Response presented in NID 2024)	See NID annex 3:2 section 3.2.1.11

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
L.14	4.A.2 Cropland converted to forest land – CO_2 (L.29, 2022) Accuracy	Either reconsider the EFs used for litter and soils on cropland converted to forest land and cropland converted to grassland or transparently document a plausible reason for the deviation from the default values in the 2006 IPCC Guidelines.	Not resolved. The Party reported in its NID (annex 3, table A3:2.13, p.140) that the CSC factors for cropland converted to forest land are –0.26 t C/ha/year (mineral soils) and 0.3 t C/ha/year (litter), which are the same values as reported in its 2022 annual submission. For cropland converted to grassland, the Party updated the CSC factor to 0.053 t C/ha/year for mineral soils, with a reference indicating that this corresponds to the estimated average net emissions from mineral soils on cropland remaining cropland for 1990–2021. The ERT did not identify new information in the NID providing transparent documentation of a plausible reason for the deviation compared with the CSC factors resulting from the default carbon reference stocks and/or soil stock change factors in the 2006 IPCC Guidelines. During the review, the Party confirmed that it is working on the issue and plans to resolve it in the 2024 inventory submission by adding more information in the NID. The ERT considers that the recommendation has not yet been addressed because the Party did not reconsider the EFs used for litter and soils on cropland converted to forest land and cropland converted to grassland or provide in a transparent manner the necessary documentation (e.g. extracted summarized results from scientific papers) in the NID that justifies the EFs used for litter and mineral soils on cropland converted to forest land and cropland converted to grassland.	The approach has been better described and motivated in the NID Annex. (Response presented in NID 2024)	See NID annex 3:2 section 3.2.1.11.2

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
L.15	4.B.1 Cropland remaining cropland – CO_2 (L.30, 2022) Transparency	Demonstrate in the NID that the ICBM model has been verified against independent measurements of CSCs in cropland over a sufficient number of sites and is representative of the heterogeneity in soils, climatic conditions and cropping practices in the Party (the ERT notes that one of several options that could consider to address this recommendation is including in the NID several graphs (e.g. measured versus simulated CSCs) or figures containing numerical data in order to support this verification).	Addressing. The Party reported in its NID (annex 3, p.130) that the new ICBM version and parameter values used were derived using more than two decades of new data from the original calibration site, and that the new version considers more accurately the higher humification rate (2.6 times) of below-ground crop residues than above-ground crop residues, which is also in accordance with the results of Swedish long-term field experiments. Furthermore, the Party also noted that two adjustments had been made in the AD, as well as in the implementation of new allometric functions for leys, and in improvements in the time series of manure input to the model. The ERT welcomes the above-mentioned improvements but notes that documentation verifying the current version of the ICBM and its ability to represent the heterogeneity in soils, climatic conditions and cropping practices in the Party is still missing from the NID. During the review, the Party clarified that it is working on the issue and plans to resolve it in the 2024 inventory submission by adding more information in the NID. The ERT considers that the recommendation has not yet been fully addressed because the Party did not provide explicit information on how the ICBM has been verified against independent measurements of CSCs in cropland and whether it is representative of the heterogeneity in soils, climatic conditions and cropping practices in the Party, which may be illustrated by including in the NID graphics of representative areas with measured versus simulated CSC together, or as a minimum including numerical data that supports the verification of the ICBM.	A section describing the validation of the ICBM-model has now been included in the NID annex. (Response presented in NID 2024)	See NID annex 3:2

ID#	*Issue/problem classification*[a, b]	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
L.16	4.B.2 Grassland converted to cropland – CO2 (L.31, 2022) Accuracy	Justify how differences in national averages for different land categories to estimate the soil CSCs in land conversions compares plots with similar characteristics as recommended by the 2006 IPCC Guidelines (vol. 4, chap. 2, p.2.38), or update CSCs for land conversions, in particular if any substantial differences compared with the default EFs (e.g. land-use factor parameters; vol. 4, chap. 5, p.5.17) cannot be adequately justified.	Not resolved. The Party reported in its NID (annex 3, table A3:2.13, p.140) the CSC factors used to calculate changes in carbon pools on land in conversion. CSCs in mineral soils on grassland converted to cropland are estimated by using a CSC factor of –0.5 t C/ha/year based on country-specific soil carbon reference stocks of 110 t/C/ha for grassland and 100 t/C/ha for cropland and a default transition period of 20 years. The soil carbon reference stocks are based on national averages of measured soil carbon stock from the NFI and the Swedish National Soil Inventory for cropland and grassland. In the previous review, the ERT questioned whether the national averages are truly representative of the areas undergoing conversion between cropland and grassland and noted that the 2006 IPCC Guidelines (vol. 4, chap. 2, p.2.38) recommend comparing plots with similar characteristics, such as histories and management, as well as similar topographic position, soil physical properties and geographical proximity, when deriving soil carbon stocks. The previous ERT therefore recommended the Party either to justify the use of the CSC factors or to update the factors used for these conversions. During the review, the Party clarified that it is working on addressing these issues and plans to resolve them in the 2024 inventory submission by adding more information in the NID that justifies the country-specific CSC factors. The ERT considers that the recommendation has not yet been addressed because the Party did not provide any further information in the NID that substantiates the use of national averages of soil carbon reference stocks for different land categories based on comparison of plots with similar characteristics as recommended by the 2006 IPCC Guidelines, nor has the Party updated the CSC factors for land conversions used in the estimates.	The approach has been better described and motivated in the NID Annex. (Response presented in NID 2024)	See NID annex 3:2 section 1.2.1.11.2

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
L.17	4.C.2 Cropland converted to grassland – CO_2 (L.32, 2022) Accuracy	Reconsider the EF used for CSCs in mineral soils in cropland converted to grassland and revise the information in the NID that the EF used to estimate CSCs in mineral soils in cropland converted to grassland is the same as the EF for cropland remaining cropland or transparently justify in its NID why the EF for cropland remaining cropland is appropriate.	Not resolved. The Party reported in its NID (annex 3, table A3:2.13, p.140) the CSC factor (0.053 t/C/ha) used to calculate CSCs in mineral soils in cropland converted to grassland, which is based on the national average CSC factor for mineral soils in cropland remaining cropland estimated by the ICBM model for 1990–2021. During the review, the Party clarified that, in accordance with the extensive study published in Karltun et al. (2015) (which was mistakenly referred to as Karltun et al. (2017) in the NID), very small changes can be expected in the soil carbon stocks on these land-use conversions (i.e. cropland to grassland), and that the Party therefore considers the CSC factors representative and credible. The ERT considers that the recommendation has not yet been addressed because the Party neither provided adequate information in the NID that justifies using the same EF for estimating CSCs in mineral soils in cropland converted to grassland as the average CSC factor for mineral soils in cropland remaining cropland nor revised the methodology used.	The approach has been better described and motivated in the NID Annex. (Response presented in NID 2024)	See NID annex 3:2 section 1.2.1.11.2

L.18	4.E.2 Land converted to settlements – CO_2 (L.33, 2022) Transparency	(a) Explain in the NID that the percentage losses for SOC on cropland or grassland converted to settlements reported in the NID (annex 3, p.143) were not related to an intrinsic feature of the initial land use, but rather that had been able to quantify the share of the converted area that had severely been disturbed (e.g. with roads and car parks representing severe disturbances, and gardens representing minor disturbances) on the basis of satellite images; (b) Provide information on the share of the area that has been severely disturbed for each subcategory under land converted to settlements.	(a) Not resolved. The Party reported in its NID (annex 3, p.139) that, based on the study published in Karltun et al. (2015), 30 and 90 per cent of carbon stock is assumed to be lost over a 20-year transition period when cropland or grassland is converted to settlements respectively. These numbers were reported as the land area affected by the land-use change; however, the Party did not note that the above-mentioned percentage losses were the share of the converted land area that had been severely disturbed, based on satellite images. Furthermore, the Party reported in its NID (pp.548–549) that the issue was not considered in the 2023 inventory submission. The ERT considers that it is not clear why the percentage of the share of the converted land was used as the percentage of the loss of carbon stock. The ERT notes that Karltun et al. (2015) contains an analysis of how much carbon loss occurs for the different types of conversion to settlements. The ERT considers that information about the share of converted land that has been severely disturbed; the ratio of carbon loss in each land conversion to certain subcategories of settlements that have been severely disturbed, such as roads, power lines and actual settlements; and the share of land converted to certain subcategories of settlements that have been severely disturbed is missing from the NID. During the review, the Party clarified that it is working on these issues and is planning to resolve them by improving transparency in the 2024 inventory submission. (b) Addressing. The Party reported in its NID (annex 3, p.139) that Karltun et al. (2015) was the basis of the applied methodology. It also reported that 30 and 90 per cent of carbon stock is assumed to be lost over a 20-year transition period when cropland or grassland is converted to settlements respectively. However, Karltun et al. (2015) provides no information on the percentage of cropland and grassland converted to settlements that results in carbon stock loss nor on what percentage of carbon stock is lost upon conversion. The ERT noted that Karltun et al. (2015) only provides a ratio of forest land converted into different categories of settlements (roads (45 per cent), power lines (14 per cent) and actual settlements (41 per cent)), with varying percentages given for loss of litter and carbon stock on forest land converted to different categories of settlements. The ratio of settlement types for cropland or grassland converted to settlements is not provided in Karltun et al. (2015). During the review, the Party clarified that it is working on these issues and is planning to resolve them in its 2024 inventory submission. The ERT considers that the recommendation has not yet been addressed because the Party did not report in the NID information on	The approach has been better described and motivated in the NID Annex. (Response presented in NID 2024)	See NID annex 3:2 section 1.2.1.11.2

			the share of the area that has been severely disturbed for cropland or grassland converted to settlements.		

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
L.19	4.F.2 Land converted to other land – CO_2 (L.34, 2022) Transparency	(a) Document in the NID the method used to derive the EFs for the subcategories under land converted to other land; (b) In particular, because under “other land” as defined by the Party, subcategories with heterogeneous carbon stocks (e.g. “high mountains with grass”, “bare rock”, “ice” and “quarries”) are aggregated, document the different types of conversions from “other land” to other land-use categories and how the EFs accurately reflect those conversions.	(a) Not resolved. The Party provided the CSC factors used to calculate changes in the SOC of mineral soils associated with land converted to other land from forest land, grassland, wetlands and settlements in its NID (annex 3, table A3:2.13, p.140). However, the Party did not provide information on the methods used to derive these factors in the relevant section of its NID (annex 3, section 3.2.1.10, pp.137–140). During the review, the Party clarified the above-mentioned CSC factors for mineral soils as follows: the –0.04 t C/ha/year EF for forest land converted to other land is based on the assumption that the initial carbon stock of forest land is 45 t C/ha, that 3 per cent of the plots that experience a land-use change experienced SOC loss associated with land-use change and that the affected plots lose SOC at the same level as the average for forest land converted to settlements. The 0.21 t C/ha/year EF for grassland converted to other land is assumed to be the same as the EF for grassland remaining grassland; the footnote in NID table A3:2.13 is incorrect. The use of 0 for EFs for wetlands and settlements converted to other land is on the basis of the assumption in Karltun et al. (2015) that the soil for these conversions is unchanged. The ERT considers that the inclusion of the above-mentioned information in its NID would resolve this issue. (b) Not resolved. The Party did not report in its NID information on how the different types of “other land” were considered when estimating the CSC factors for mineral soils for land conversions from “other land” to other land-use categories. During the review, the Party clarified that some land conversions, such as conversions between forest land and the other land subcategory “high mountains with grass”, do not cause significant change in the SOC.	The approach has been better described and motivated in the NID Annex. As there is a difference between the national category Other land and the UNFCCC category Other land a footnote has been included to table 6.3 in the NID. (Response presented in NID 2024)	See NID annex 3:2 section 1.2.1.11.2 Also see table 6.3 in the NID

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
L.20	4.G.2 Paper and paperboard – CO_2 (L.35, 2022) Comparability	Investigate the possibilities for adjusting the two-year IPCC default half-life for paper instead of including recycling in the inflow (the ERT notes that the effect on the net estimate is, however, likely to be minor).	Not resolved. The Party reported in its NID (p.378) that the inflow of carbon to the paper products pool includes paper from recovered paper and that the default half-life of two years is used. The Party also indicated in its NID (p.558) that the recommendation from the previous review report was not considered as it had not received the final annual review report for the 2022 annual submission at the time of the preparation of the GHG inventory. During the review, the Party informed the ERT that it acknowledged this matter and it plans to resolve the issue in the 2024 inventory submission.	The possibilities of adjusting the half-life of paper is currently investigated and the outcome of the process will be evaluated during next year. (Response presented in NID 2024)	
Waste					
W.1	5.B Biological treatment of solid waste – CH_4 and N_2O (W.11, 2022) Transparency	(a) Include in the NID information on the value of moisture content (65 per cent); (b) Correct NID table 7.21 so that the values reported and amounts indicated in the column headings are in the same units (kt or t).	(a) Resolved. The Party updated the information on the moisture content in the NID (section 7.3.1.2.3, p.419), which was defined to be 65 per cent. The ERT commends the Party for its effort to increase the transparency of the NID. (b) Resolved. The Party revised its NID table 7.21 (p.419) and included the same units (t) in the column headings for the values reported.		

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	**Section in NID**
W.2	5.D Wastewater treatment and discharge – N2O (W.4, 2022) (W.3, 2020) (W.4, 2019) Transparency	Describe more transparently in the NID the methodologies used for the estimation of N_2O emissions from wastewater, along with the AD and EFs used. Specifically, explain that direct emissions are estimated on the basis of available statistics on N in the influent of large wastewater treatment plants and a country-specific EF of 0.0074 kg N2O- N/kg N in the influent.	Resolved. The Party included information on the available data on the measured amount of N in the influent to large wastewater treatment plants in the NID (section 7.5.1.2.6, p.432), which includes referenced N influent and discharge of N from large wastewater treatment plants. In the NID (section 7.5.1.2.5, p.432), the Party included information on a country-specific EF of 0.0074 kg N_2O-N/kg N in the influent, which was based on studies from six wastewater treatment plants. The Party described how these statistics were used to estimate the N influent to small wastewater treatment plants in the NID (p.433). The ERT considers that the recommendation has been fully addressed.		
W.3	5.D.1 Domestic wastewater – CH_4 (W.6, 2022) (W.5, 2020) (W.5 2019) Transparency	Explain that CH_4 generation from anaerobic digestion of sludge treatment is estimated on the basis of total organics in wastewater removed, the amount of sludge generated and the CH_4 potential of the sludge, and that 4 per cent of CH_4 generation is assumed to be emitted.	Resolved. The 2023 NID includes a description stating that CH_4 from anaerobic digestion is calculated on the basis of the rate of BOD removed as sludge and that 62 per cent of the five-day BOD is removed as sludge in larger facilities and 50 per cent is removed as sludge in on-site treatment facilities (section 7.5.1.2.1, p.429). The NID also reports that the emissions are estimated to be between 4 and 7 per cent of the CH_4 generated from sludge treatment. The ERT considers that the recommendation from the previous ERT has been addressed.		

W.4	5.D.1 Domestic wastewater – CH_4 (W.12, 2022) Transparency	(a) Include the parameters used for estimating BOD in the NID, especially the values for per capita BOD and additional industrial load, and provide justification in cases where those values differ from the default values in the 2006 IPCC Guidelines; (b) Justify the use of different EFs for industrial load for organic matter and N.	(a) Not resolved. The NID does not include the parameters used for estimating BOD in wastewater. During the review, the Party provided an internal document (Comments on Table 4D1 Domestic Wastewater Treatment and Discharge (methane).docx) that details the parameters and calculations used for domestic wastewater treatment. The document states that 70 g BOD/person/day was used in 1990 and that 60 g BOD/person/day was used in all subsequent years. The document further states that 15 per cent of the wastewater in [centralized] municipal wastewater treatment plants was added by industry. The document also describes the rationale behind the above-mentioned estimates that 62 per cent and 50 per cent of BOD is removed as sludge. The Party explained that it will make efforts to improve the transparency of the information in its 2024 inventory submission. (b) Addressing. The previous ERT identified that the parameters (EFs) for the industrial load to domestic wastewater (I), for organic matter (BOD) and for FIND-COM (2006 IPCC Guidelines, vol. 5, chap. 6, equations 6.3 and 6.8) had different values in the 2022 NID (1.15 and 1.25). In the 2006 IPCC Guidelines, the default value for both I and FIND-COM is 1.25. The current ERT identified that, in the 2023 NID (p.433), the Party stated that the parameter for the industrial load of N to domestic wastewater is the equivalent of FIND-COM, and that this factor has a default value of 1.25 (which matches the default value for FIND-COM in the 2006 IPCC Guidelines (vol. 5, chap. 6, p.6.25)). The 2023 NID does not include the parameter I for industrial inputs of BOD to domestic wastewater or a justification for the value used. During the review, the Party provided an internal document (Comments on Table 4D1 Domestic Wastewater Treatment and Discharge (methane).docx) that includes the parameter I for additional industrial organic (BOD) inputs, which in that document is estimated to be 15 per cent (or 1.15). This value differs from the default value of 25 per cent (1.25) found in the 2006 IPCC Guidelines (vol. 5, chap. 6, p.6.14). No details or justification for the value of the parameter were provided in the NID or in the document shared during the review. The ERT notes that this parameter is still different from the EF FIND-COM for industrial inputs of N in the 2023 NID. The Party recognized the need for further investigation of the parameters for the additional industrial load. The Party explained that it will make efforts to improve the transparency of the information in its 2024 inventory submission.	a) Resolved in NID **submission 2024**. In NID **submission 2025**, the section 7.5.1.2.1. is completely rewritten, to reflect the extensive improvements on Sweden's implementation of the 2006 IPCC Guidelines methodologies. b) A decreasing country-specific value of the correction factor (parameter I) for additional industrial load of BOD has been	a) 7.5.1.2.1 b) 7.5.1.2.3

				introduced in **submission 2025** due to the extensive improvements on Sweden's implementation of the 2006 IPCC Guidelines methodologies. The approach to the correction factor I is explained in the NID **submission 2025**, as well as the difference to the default correction factor (FIND-COM) used in the calculations of industrial nitrogen load.	

ID#	*Issue/problem classification[a, b]*	*Recommendation from previous review report*	*ERT assessment and rationale*	***Response /Status of implementation***	***Section in NID***
W.5	5.D.1 Domestic wastewater – CH_4 (W.13, 2022) Accuracy	Revise the country-specific B_o value using either a new country-specific value that corresponds to the observed CH_4 generation or the IPCC default value and recalculate its emission estimates accordingly.	Not resolved. The Party did not revise the country-specific B_o value by using a new country-specific value or by using the IPCC default value. During the review, the Party provided an internal document (*Comments on Table 4D1 Domestic Wastewater Treatment and Discharge (methane).docx*) that summarizes in detail the methods employed for calculating CH_4 emissions from domestic wastewater. The document, however, does not include further elaboration on how the national parameter for B_o was obtained. The internal document includes a statement, as does the NID, that the B_o in the 2006 IPCC Guidelines is incorrect and that "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". However, the document provided does not include a reference citation or a rationale for this theoretical value. During the review, the Party noted that it is investigating its country-specific value of B_o. The ERT notes that the unit values used in the NID and in the provided document (0.35 m^3/kg BOD) differ from the units presented in other published values, such as 0.35 kg CH_4/kg five-day BOD (Lexmond and Zeeman, 1995) or 0.25 kg CH_4/kg COD (Doorn et al., 1997).	Resolved. The 2006 IPCC Guidelines default value of Bo has been implemented in the calculations among several other changes, due to the extensive work to improve the Swedish implementation of the 2006 IPCC Guidelines methodologies in **submission 2025**.	7.5.1.2.3 7.5.1.5

Table 10.3 Additional findings made during the individual review of the 2023 annual inventory submission

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
General					
G.3	Inventory management	The ERT noted that during the review Sweden took a while to respond to some questions raised by the ERT. The ERT considered that this could be in part due to the Party not having multiple accounts with access to the online system for questions and answers. During the review, Sweden explained that it has implemented an internal quality check process in which answers to questions from the ERT are initially compiled by national experts within SMED and these responses then undergo internal review by the Swedish Environmental Protection Agency. The Party suggested that its arrangements for responding to questions from the ERT may result in a slightly longer response time, but it believes that these arrangements are an important step for ensuring accurate responses. Given that multiple experts from different agencies are involved in the process of preparing draft answers and their review, the Party considers that setting up numerous accounts in the virtual team room could pose logistical challenges. The Party suggested that it will explore ways to enhance the efficiency of its internal quality checks in order to improve the response times during the review and noted that some questions arrived later than expected before the start of the review week. The ERT encourages Sweden to enhance the speed at which it responds to questions from the ERT during the review week.	Not an issue/problem		

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
G.4	QA/QC and verification	The Party reported in its NID (section 1.3.1, p.39) that it is the responsibility of SMED to maintain and develop an internal quality system, as described in the framework contract between the Swedish Environmental Protection Agency and the experts doing the work. The SMED quality system is described in a detailed manual. The manual is updated annually and lists all QC steps that must be undertaken during inventory work (for tier 1 and, where appropriate, tier 2 methodologies). It also includes descriptions of roles and responsibilities, databases and models, work manuals for each CRT category and documented procedures for uncertainty and key source analyses, and procedures for handling and responding to the UNFCCC review of the Swedish inventory. During the review, Sweden clarified that tier 2 methodologies and source-specific QA procedures for tier 3 methodologies are described in the QC checklists (appendix 5 to the manual) and in the work documentation (appendix 4 to the manual). The ERT encourages Sweden to make clear reference to the tier 3 QA/QC procedures provided in the manual for each sector where appropriate in its NID.	Not an issue/problem		
Energy					

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
E.4	International navigation – residual fuel oil and gas/diesel oil – fuel consumption	The ERT noted that the reported residual fuel oil consumption of marine bunkers is different in CRT table 1.D.2 (sectoral approach) and CRT table 1.A(b) (reference approach) for 1990–2018. For example, residual fuel oil consumption for 2005 and 2018 is 78,032 TJ and 55,044 TJ in CRT table 1.A(b) but 78,530 TJ and 54,604 TJ in CRT table 1.D.2. During the review, the Party explained that after the methodological change in 2018, the data suppliers of the Swedish energy balance (which is the basis for the estimates reported in CRT table 1.A(b)) did not revise the whole time series of residual fuel oil consumption backwards, as was done for the GHG inventory, owing to the less strict QC requirements regarding time-series consistency. The Party noted that it will explain clearly in the NID of its next inventory submission why the data reported cannot be fully harmonized. The ERT also noted inconsistencies between CRT table 1.D.2 and CRT table 1.A(b) for gas/diesel oil consumption for 1990–2015. For example, gas/diesel oil consumption for 2005 and 2015 is 7,755.88 TJ and 31,352.04 TJ in CRT table 1.A(b) but 7,224.49 TJ and 32,810.15 TJ in CRT table 1.D.2. During the review, the Party explained that the methodological change in 2018 not only affected residual fuel oil but also gas/diesel oil. In contrast to the GHG inventory, the data suppliers of the Swedish energy balance did not revise the whole time series of gas/diesel oil consumption backwards owing to the less strict QC requirements regarding time- series consistency. The ERT understands that harmonizing input data with third-party data suppliers, such as national statistical agencies, that provide energy balances is a difficult process, especially given the limited capacity of inventory compilers to change statistics prepared by independent national agencies. The ERT recommends that the Party either harmonize the data for 1990–2018 regarding marine bunker fuels (residual fuel oil and gas/diesel oil) reported in the reference approach (CRT table 1.A(b)) with the sectoral approach (CRT table 1.D.2) or include a detailed explanation in the NID on why the data cannot be harmonized.	Yes. Convention reporting adherence	Sweden will strive to better explain recalculations in future NIDs.	

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
E.5	1.A.2.c Chemicals – all fuels – CO_2, CH_4, N_2O	The Party reported in its NID (p.134) that there was a reallocation of emissions from carbide furnace gas from category 2.B.5 carbide production to category 1.A.2.c chemicals owing to the results of a project that investigated the allocation of emissions to stationary combustion or process emissions. The Party also reported in its NID (p.136) that some of the recalculations were the result of revising the CO_2 EFs for several fuels and reallocating emissions from IPPU to category 1.A.2.c owing to the split of stationary and process emissions from one company. The ERT noted that the recalculation led to an increase in emissions in category 1.A.2.c of around 80 kt CO_2 for most years (with a minimum of –7 kt CO_2 in 2019 and a maximum of 217 kt CO_2 in 2000). However, according to the NID (section 4.3.5.5, p.229), no recalculation occurred in category 2.B.5. The ERT noted that there was no recalculation of emissions for category 2.B.5, although the AD were revised for all years of the time series (from "NA" in the 2022 annual submission to values in the 2023 inventory submission). During the review, the Party clarified that there was a reallocation of emissions from category 2.B.10 other (chemical industry) to category 1.A.2.c. However, the study forming the basis for the reallocation was considered to be confidential and could not be shared with the ERT. The Party explained that the reallocation was due to more detailed information becoming available from one plant that allowed a split between energy- related and process-related emissions. Previously, all emissions were allocated to category 2.B.10 owing to a lack of information on the emissions. The Party also explained that it aims to explain the reallocation of emissions between IPPU and category 1.A.2 and to clarify which information is confidential as transparently as possible in the NID of its 2024 inventory submission. The ERT noted that the increase in CO2 emissions reported in category 1.A.2.c approximately matched the corresponding decreases in CO2 emissions in category 2.B.10 for 1990–1999. However, there is no such correspondence for later years. For example, in 2000 CO2 emissions increased in category 1.A.2.c by 216.5 kt, while in category 2.B.10 they only decreased by 111.2 kt; in 2018 CO2 emissions decreased by 1.7 kt in category 1.A.2.c but decreased by 34.9 kt in category 2.B.10. During the review, the Party explained that some of	Yes. Transparency	Sweden will aim to explain the recalculation of emissions. Sweden, as done during the review, acknowledges that the explanation did not cover all changes. Sweden will work for better explanations in the coming NID for recalculations. As the NID for the previous submission is closed how can Sweden resolve this issue? Does the ERT need any more clarification about this issue?	

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
		the recalculations were the result of the revision of the CO2 EFs and explained the remaining differences. The ERT also noted that recalculations for category 1.A.2.c predominantly affected emissions from liquid fuels; however, according to annex 2 to the NID (p.70) and the corresponding reference (Josefsson Ortiz et al. (2022)), the CO2 EF of liquid fuels has not significantly changed. The ERT recommends that the Party provide detailed information in the NID on the recalculations made between the 2022 and 2023 inventory submissions for category 1.A.2.c for liquid fuels to allow an understanding of the reallocation of emissions from IPPU to category 1.A.2.c and the accuracy of this reallocation. If the information is considered to be confidential, the ERT recommends that the Party clearly state which information is confidential and cannot be provided but explain the recalculation as transparently as possible given the circumstances.			

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
E.6	1.A.2.d Pulp, paper, print – all fuels – CO_2, CH_4, N_2O	The Party reported in its NID (p.138) that a major revision of EFs for several fuel types and the split of liquefied natural gas from natural gas resulted in recalculations in category 1.A.2.d, with a total decrease in emissions for the two most recent recalculated years of 0.25 kt CO_2 eq for 2019 and 0.17 kt CO_2 eq for 2020. However, the ERT noted that the recalculations for 1990–2020 resulted in an average decrease in emission estimates of 35 kt CO_2 eq for 1990–2020, with a maximum decrease of 132.66 kt CO_2 eq in 1991 and a minimum decrease of 0.09 kt CO_2 eq in 2018. During the review, the Party clarified that the change in EFs for other fossil fuels was the main reason for the recalculation for the years prior to 2013. There was also a reallocation of fuels from other fossil fuels to biomass. This contributed to the observed changes, in particular from 2013 onward. In addition, there was a reallocation of methanol from biomass to other fossil fuels for 2018–2020 since it was discovered that the methanol was not of biogenic origin. The Party explained that it will work to improve the explanations for the recalculations in the NIDs of its next inventory submissions. The ERT recommends that the Party explain and provide detailed information in the NID on the recalculations made between the 2022 and 2023 inventory submissions for this category, specifically information on the change in EFs for other fossil fuels for the years prior to 2013; the reallocation of fuels from other fossil fuels to biomass, in particular from 2013 onward; and the reallocation of methanol from biomass to other fossil fuels for 2018–2020 based on the discovery that the methanol was not of biogenic origin.	Yes. Transparency	Sweden will strive to better explain recalculations in future NIDs.	

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
E.7	1.A.3.b Road transportation – biomass – CH4 and N2O	During the review, the Party explained that CH_4 and N_2O emissions (but not CO_2 emissions) from biofuels, estimated with the model for road transport, are reported under fossil fuels (e.g. diesel oil, gasoline and natural gas) and that this approach is applied for all vehicle types under category 1.A.3.b road transportation. Noting that the 2006 IPCC Guidelines (vol. 2, chap. 3.2.1.1, p.3.13) state that the combustion of biofuels generates anthropogenic CH4 and N2O that should be calculated and verified in emission estimates, and that without the separation of emission estimates of biofuels such emission estimates cannot be compared across Parties and transparency is reduced (even though total emissions are accounted for), the ERT recommends that the Party report CH4 and N2O emissions from the use of biofuels separately under biomass for all vehicle types (i.e. cars, light-duty trucks, heavy-duty trucks and buses, and motorcycles) under category 1.A.3.b road transportation.	Yes. Comparability	This issue has been corrected in submission 2025.	3.2.17.5

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
E.8	1.A.3.b.ii Light-duty trucks – biomass – CH_4 and N_2O	According to the AD values reported for category 1.A.3.b.ii light-duty trucks in CRT table 1.A(a) (sheet 3), biomass was consumed from 1998 onward (e.g. 7,271.26 TJ (NCV) in 2021). The Party reported CO_2 emissions from biomass in this vehicle category from 1998 onward, but reported CH_4 and N_2O emissions from biomass for 1998–2015 as “IE, NO” and CH_4 and N_2O emission estimates for 2016 onward. During the review, the Party explained that the notation key “NO” for 1998–2015 represents that no biogas was used in those years and that light-duty trucks started using biogas in 2016. For “IE”, the Party explained that ethanol and biodiesel have been blended into fossil gasoline and fossil diesel oil respectively since 1998 and that the CH4 and N2O emissions from blended biofuels are reported under gasoline and diesel oil, as appropriate, hence “IE” is reported for biomass. The Party also explained that this approach is applied for all vehicle types under category 1.A.3.b road transportation. The Party indicated that it will delete the notation key “NO” for 1998–2015 for CH4 and N2O emissions from category 1.A.3.b.ii light-duty trucks and will explain in the NID that biogas was not used in category 1.A.3.b.ii light-duty trucks in those years, and that it will aim to report CH4 and N2O from biomass separately for all vehicle categories under category 1.A.3.b road transportation in its 2025 inventory submission. The ERT recommends that the Party explain in the NID that biogas was not used for light-duty trucks in 1998–2015. Noting that the Party reports CH4 and N2O emissions from biomass for categories 1.A.3.b.i cars and 1.A.3.b.iii heavy-duty trucks and buses from the combustion of biomass other than the blending of liquid fuels with biofuels (e.g. the combustion of biogas), the ERT also recommends that the Party add a table with AD of the different types of biofuel per vehicle category and year in the NID in order to clarify the consumption of different types of biomass in road transportation.	Yes. Transparency	It has been clarified in the text that consumption of biogas did not start at the same time for all vehicle types. Furthermore, the figures have been re-made so that in each diagram there is only one fuel which is shown by vehicle type, further clarifying this discrepancy.	3.2.17.1
IPPU					

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
I.9	2.A.2 Lime production – CO_2	The Party reported in its NID (p.213) that in 2015 a review of category 2.A.2 lime production was made, in which two data sources (the EU ETS and the Swedish Lime Association) were compared, and it was determined that the best available data source for this category is the EU ETS. Sweden also reported in its NID (p.213) that the main reason for concluding that the EU ETS is the best available data source is that data from the Swedish Lime Association often arrives too late to be used in the compilation and reporting of the GHG inventory. Additionally, the ERT noted that the NID (figure 4.2.3, p.213) shows a divergence in the values of the three data sources used (the EU ETS, the Swedish Lime Association and Statistics Sweden), which has been increasing over the past few years. For example, for 2020 there is a difference of approximately 300 kt of lime production between Statistics Sweden and the Swedish Lime Association and a difference of 100 kt between the EU ETS and the Swedish Lime Association. During the review, the Party stated that it trusts the reliability of the reported values from the EU ETS since the data are verified. The Party also stated that it believes that Statistics Sweden includes calcium hydroxide in its data set, which does not result in CO2 emissions, and that using this data for category 2.A.2 lime production would lead to an overestimation of emissions. The Party stated that it will assess the option of using the data from Statistics Sweden and the Swedish Lime Association in future inventory submissions. The ERT recommends that the Party investigate the data differences between the EU ETS, the Swedish Lime Association and Statistics Sweden and include in the NID information on the results of this investigation and the reason for the increasing divergence of the three data sources.	Yes. Transparency	Explanation provided in NID	NID chapter 4.2.2.4

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
I.10	2.A.3 Glass production – SO2 and NOX	The Party reported in its NID (section 4.2.3.1, p.214) that the total emissions of SO_2 and NO_X from the float glass production furnace that ceased operations in 2013 are allocated to category 2.A.3 glass production, since a separation into energy-related and process-related emissions is not possible. However, the ERT could not locate the indicated emissions of SO_2 and NO_X in CRT table 2(I) (sheet 1). During the review, the Party clarified that since the CRT tables do not allow SO2 and NOX emissions to be reported in category 2.A.3, these emissions are reported in category 2.A.4, and that NOX and SO2 emissions from float glass production have not been reported since 2013, when the facility emitting NOX shut down, and this will be clarified in the NID of the Party's next inventory submission. Additionally, in 2012 emissions of NOX and SO2 from float glass production comprised about 2 per cent of emissions in category 1.A.2 and a majority of emissions in category 2.A.3. The allocation of emissions to the IPPU sector may affect comparability; however, this allocation was necessary in order to ensure that the total emissions were correctly reported. The ERT encourages the Party to indicate in the NID the category in which the NOX and SO2 emissions from float glass production are included and to provide clear information on the effect of not separating the energy- related and process-related NOX and SO2 emissions, as this raises comparability issues across the energy and IPPU sectors.	Not an issue/problem	Question resolved/explained in NID	Chapter 4.2.3.1

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
I.11	2.B.10 Other (chemical industry) – CO_2	The Party stated in its NID (section 4.3.10.1, p.231) that, according to the 2006 IPCC Guidelines (vol. 3, chap. 3, section 3.9.1, p.3.57), emissions from the combustion of fuels produced within a facility (internal make-up gases) and emissions from feedstock fuels should be allocated to the source category in the IPPU sector, except when the fuels are used in another source category (e.g. district heating). Sweden also stated that it followed the recommendations of the 2006 IPCC Guidelines as far as possible, but that exceptions were made for some facilities since the CO_2 process emissions are difficult to separate from the combustion emissions reported in the energy sector. In those cases, all emissions are reported in the energy sector. The ERT noted that the use of "IE" does not make it clear which categories of the IPPU sector are impacted by "specific plants" and that no assessment of the comparability across categories due to the impact of allocating these emissions to the energy sector was carried out. During the review, the Party clarified that some process emissions were allocated to the energy sector (category 1.A.2.c chemicals) owing to difficulties with separating energy-related emissions from process-related emissions, and this may affect comparability across categories to some extent, but that this allocation is necessary in order to ensure that total emissions are correctly reported. The Party also explained that, while data confidentiality prevents a quantification of the effect on comparability in the NID, it can clarify that the allocation affects comparability. The ERT recommends that the Party clarify which CRT categories include specific plants' emissions that are identified with notation key "IE". The ERT also recommends that the Party include in its NID an explanation as to how confidentiality prevents the effect on comparability of emissions across category 2.B.10 and category 1.A.2.c chemicals from being quantified.	Yes. Transparency	Question resolved/explained in NID	Chapter 4.3.10.2

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
I.12	2.C.3 Aluminium production – PFCs	The ERT noted that the production of aluminium reported for 2021 in CRT table 2(I).A-H (sheet 2) for category 2.C.3 aluminium production is 115.86 kt and the production of aluminium reported in table 2(II).B-H (sheet 1) for by-product emissions of CF4 and of C2F6 is 115.86 t (i.e. 1,000 times lower). As a result, the IEFs calculated in CRT table 2(II).B-H (sheet 1) (45.12 kg CF4/t and 5.46 kg C2F6/t) are two orders of magnitude greater than expected (the IPCC default for the centre-worked prebake process is 0.4 kg CF4/t and 0.04 kg C2F6/t (2006 IPCC Guidelines, vol. 3, chap. 4, table 4.15)). The same issue occurs for all years in the time series. During the review, the Party clarified that information on the amount of aluminium produced should be reported in table 2(I).A-H (sheet 2) in kt, while in table 2(II).B-H (sheet 1) the information should be reported in t. Confusion over the use of units for the amount of aluminium produced led to the errors in table 2(II).B-H (sheet 1). The Party stated that it will rectify the issue in its 2024 inventory submission. The ERT recommends that the Party correct the amount of aluminium produced associated with PFC emissions reported in CRT table 2(II).B-H (sheet 1) to the required unit (t) so that the reported IEFs reflect the correct units.	Yes. Convention reporting adherence	Production of primary aluminium is reported in the right unit CRT table 2(II).B-H (sheet 1) in submission 2025, however the error still remains in the 2024 submission.	

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
I.13	2.F.1 Refrigeration and air conditioning – HFCs	The ERT noted that the 2022 review report included a recommendation for the Party to report HFC-125 and HFC-143a emissions for category 2.F.1.d transport refrigeration (disposal) as "NO" for 2000–2002 if emissions did not occur in those years (see ID# G.1 in table 3). In accordance with this, Sweden reported HFC-125 and HFC-143a emissions for category 2.F.1.d transport refrigeration (disposal) for 1990–2002 as "NO" in CRT table 2(II).B-H (sheet 2). During the review, Sweden explained that no refrigerated trailers and refrigerated trucks were equipped with the R404a cooling systems (i.e. with HFC-125 and HFC-143a as refrigerants) during 1990–1992, 30 per cent of refrigerated trucks and refrigerated trailers had R404a in their cooling systems during 1993 and 1994, and 100 per cent had R404a in their cooling systems from 1995 onward. This means that emissions from disposal did not occur for 1990–2002 and increased significantly between 2004 and 2005 since the lifespan of the equipment is 10 years. The ERT recommends that the Party explain in its NID the use of HFC-125 and HFC-143a in the estimates reported for the time series, including for 1990–1992, 1993–1994 and 1995 onward, and provide justification for the use of notation key "NO" for reporting these emissions for 1990–2002 for category 2.F.1.d transport refrigeration (disposal).	Yes. Transparency	Question resolved/explained in NID	Chapter 4.7.1.2

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
I.14	2.F.1 Refrigeration and air conditioning – HFCs and PFCs	The Party reported in its NID (table 4.7.4, p.285) that for category 2.F.1.d transport refrigeration the EF for emissions from stocks is 20 per cent for 1993–1994, and 7 per cent for 2005–2021. For heat pumps reported under category 2.F.1.f, the EF for emissions from stocks decreased from 10 per cent in 1990 to 1 per cent in 1999 onward. For the other categories under 2.F.1, the PLF is assumed constant (e.g. for category 2.F.1.a commercial refrigeration, the applied PLF for all years is 10 per cent, while for category 2.F.1.c industrial refrigeration it is 7 per cent for all years). The Party explained in the NID (p.281) that Sweden had legal measures in place as early as the 1980s to limit and prevent HFC and PFC leakage, which explains the comparatively low PLF. As the legal framework was already in place in 1990 and most probably affects all categories, it was not clear to the ERT why the PLF should show a further decline from 1990 onward, and why only the categories 2.F.1.d transport refrigeration and 2.F.1.f heat pumps are showing a decline, whereas the PLF for the other categories is constant. During the review, the Party clarified that for categories other than transport refrigeration and heat pumps there are no country-specific EFs available and therefore the default EF in the 2006 IPCC Guidelines is used throughout the time series. The Party indicated that the information source used to estimate the EF for transport refrigeration and heat pumps is most likely expert judgment made in collaboration with relevant trade associations and manufacturers; however, the underlying documentation is not available. The ERT recommends that the Party include information in the NID on references and underlying assumptions for the EFs for all categories, in particular on how the legal framework put in place since the 1980s affected the EFs for emissions from stocks for transport refrigeration and heat pumps. If the applied EF for emissions from stocks and their decline cannot be substantiated, the ERT recommends that the Party apply the default EFs for emissions from stocks provided in the 2006 IPCC Guidelines (vol. 3, chap. 7, table 7.9) for all years.	Yes. Transparency	Question resolved/explained in NID	Chapter 4.7.1.2

I.15	2.F.1 Refrigeration and air conditioning – HFCs and PFCs	The Party listed in its NID (section 4.7.1) all categories of category 2.F.1 but did not list separately the specific sources of AD for calculating emissions for the different applications reported under this category. The ERT noted that the source of AD (fluorinated gases in imported equipment and in nationally produced equipment) used for estimating emissions from domestic refrigeration is not clearly referenced in the NID and no information is provided regarding the assumptions made for the AD (e.g. if actual data are used or if data were extrapolated to cover all relevant amounts). By comparing the reported amounts filled into newly manufactured products and the total annual stock increase, it can be deduced that about 25 per cent of the new stock is imported, and that 75 per cent of new equipment is produced nationally, but the distinction between what comprises actual data and what comprises interpolated data is not clear. Also, the ERT noted that the data reported for the average annual stock of HFC-134a in CRT table 2(II).B-H(sheet 2) are not fully consistent with the PLF factor of 1 per cent referenced in the NID; it seems that for the calculation of stock for 2003 onward a PLF of <1 per cent (ranging from 0.1–0.9 per cent) was applied. However, emissions were calculated correctly from stocks applying a PLF of 1 per cent. During the review, the Party explained that AD for household refrigerators for the 1990s were obtained from the trade association responsible for compiling aggregated information on the sale of refrigerators and freezers in Sweden. For the years after 1999, a constant number was assumed (450,000 units/year). The assumption that 75 per cent of the total number was manufactured in Sweden is based on expert judgment. The Party also explained that emissions from installed quantities are calculated with an EF (PLF) of 1 per cent for the entire time series, but HFC-134a was gradually replaced by propane until it was fully replaced in 2008. The ERT notes that the replacement of HFC-134a by a different gas is for new equipment and does not affect the existing stock. For 2009 no decommissioning is reported, thus the decrease in stock from 2009 to 2010 is solely due to emissions from existing stock. The Party reported 223.22 t HFC-134a as stock for 2009, and 222.83 t for 2010, which is a reduction of 0.1 per cent, whereas the Party noted that a 1 per cent reduction was applied. The ERT recommends that the Party review its calculation of emissions from stocks, particularly the application of the 1 per cent PLF, and include in the NID the additional information on AD used for estimating emissions from household refrigerators, including clarification that the AD for household refrigerators were obtained from the trade association and an explanation of the assumption made regarding the number of units sold.	Yes. Accuracy	Question resolved in CRT Table 2(II).B-H (sheet 2), and explained in NID	Chapter 4.7.1.2

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
I.16	2.F.1 Refrigeration and air conditioning – HFCs	The Party reported declining PLFs for light-duty vehicles and passenger cars under category 2.F.1.e mobile air conditioning from 15 per cent (from 1990 to 1999) to 5 per cent (from 2011 to 2021), in its NID (table 4.7.5, p.287). In its NID (p.286), the Party references a study as the source of the parameters for 2010 onward. However, no reference to the source of the values used for 1990–1999 was provided and the ERT did not find an explanation on the declining values of PLFs across the time series in the NID. During the review, the Party clarified that PLFs are based on information provided by a national car manufacturer that estimated the annual HFC leakage to be 7–20 g, which corresponds to an annual HFC leakage of approximately 1–3 per cent. Based on this information, which is from 2011, it was suggested that the yearly operation EF (i.e. PLF) in Sweden be lowered to 7.5 per cent for 2010 and to 5 per cent for 2011 onward, compared with a value of 15 per cent used for 1990–1999; for 2000, 12 per cent is suggested to be used, and 10 per cent is suggested to be used for 2001–2009. The leakage factor is assumed higher than the estimate by the national car manufacturer in order to avoid an underestimation of the leaked emissions because of accidents and increased wear due to age. The Party also explained that according to Kindbom et al. (2001), reference is made to the 2006 IPCC Guidelines for the selection of a leakage factor for the 1990s. For these years, the average of the specified range was selected: 15 per cent. Contact was made with the industry in preparing Kindbom et al. (2001) and it is stated in the report that the industry was working to reduce the operational leakage and that the operational leakage had been improved and reduced. Therefore, a leakage factor of 10 per cent was applied from 2001 to 2009. The leakage factor for 2000 is interpolated for 1999 to 2001. The model assumes that the leakage factors used can be applied to all passenger cars manufactured in Sweden. The ERT recommends that the Party review the option of decreasing PLFs from 15 per cent, which is the average of the IPCC default range, to 10 per cent, which is a PLF based on expert judgment, and review a potential additional decrease from 10 to 5 per cent, also based on expert judgment, and provide supporting documentation	Yes. Accuracy	Question resolved/explained in NID	Chapter 4.7.1.4

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
		on the applicability of the PLFs. The ERT also recommends that the Party include in the NID additional information on the selection of PLFs for the different periods in the time series.			
I.17	2.F.1 Refrigeration and air conditioning – HFCs	The Party reported the amounts of HFC-134a filled into newly manufactured cars and the average annual stocks for mobile air conditioning in CRT table 2(II).B-H (sheet 2). The ERT noted that reported stock for 2021 is lower than the sum of the stock for 2020 (the amounts filled into new vehicles in 2020 minus disposal for 2020, considering emissions from stocks, disposal and recovery). The ERT did not find in the NID a detailed explanation of the calculation of the stock, particularly on how the export of used cars affects the reported stock. During the review, the Party clarified that the sums of the stock in 2020 and the amount filled in 2021 and the subtracted emissions during manufacturing, from stock and disposal, as well as recovery for 2020, correspond to 99 per cent of stock for 2021, but not 100 per cent. The Party confirmed that the export of cars is not the reason for this deviation but did not provide an explanation for the deviation. The ERT recommends that the Party include in the NID detailed information on how the stock of HFC-134a in the air conditioning of cars is calculated, particularly by providing an explanation of the observed deviation.	Yes. Transparency	Question resolved/explained in NID	Chapter 4.7.1.2

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
I.18	2.F.2 Foam blowing agents – HFCs	The Party reported in CRT table 2(II).B-H (sheet 2) emissions from the production of closed cell foam (XPS) containing HFC-134a from 1996 to 2007 (for 2008 onward, the Party reported "NO") and disposal emissions from 2008 to 2019 (for the years prior to 2008 and for 2020 and 2021, the Party reported "NO"). DLFs applied in the estimates for HFC-134a range from 75 per cent for 2008 to 52 per cent for 2019 (for 2015 the DLF applied is 60 per cent). During the review, the Party clarified that the DLFs decreased because in recent years the requirements for recapture during disposal have become stricter. The Party also explained that, while there is no specific regulation or legislation concerning the disposal of XPS containing HFCs, XPS containing HFCs is classified as hazardous waste and the management of such waste is covered by the waste regulation. This includes requirements that hazardous waste must be sorted and handled separately from other waste. Since 2015, article 12(5) of the EU 517/2014 regulation on fluorinated greenhouse gases requires that foam be labelled as containing fluorinated gas. The ERT notes that the provided reference for the legal measure in place since 2015 does not imply a further decrease of the DLFs after 2015, but acknowledges that the applied factor of 60 per cent might be appropriate, as owing to the regulation all HFC-containing XPS has to be disposed of separately. To assume that the legal framework is not 100 per cent effective is reasonable, as there may be problems with the labelling of XPS that has been in stock for a long time. The ERT recommends that the Party include in its NID information on the DLFs used in the estimations for the entire series. The ERT also recommends that the Party provide supporting evidence or a rationale for the decreasing DLFs applied after 2015.	Yes. Transparency	Question resolved/explained in NID	Chapter 4.7.2.2

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
I.19	2.F.2 Foam blowing agents – HFCs	The Party reported in CRT table 2(II).B-H (sheet 2) emissions from the production of closed cell foam (XPS) containing HFC-134a from 1996 to 2007 (for 2008 onward, the Party reported “NO”) and disposal emissions from 2008 to 2019 (for the years prior to 2008 and for 2020 and 2021, the Party reported “NO”). Table 4.7.10 of the NID (pp.291–292) presents the annual leakage rates for HFC-134a used in XPS. The ERT noted that the last production of closed cell foam containing HFC-134a is reported for 2007, thus all XPS from this production is assumed to be disposed of after 12 years, and in 2019 the HFC-134a stocks should be zero. However, there are still stocks reported for 2020 and 2021 in CRT table 2(II).B-H (sheet 2) (e.g. for 2021 the reported average annual stocks amount to 348.51 t HFC-134a). In the NID (table 4.7.9, p.290), it is stated that the lifetime of the closed cell foam is more than 12 years. In the NID (p.292), it is stated that the lifetime of XPS is several decades, which is in line with the default value of 50 years provided in the 2006 IPCC Guidelines (vol. 3, chap. 7, table 7.6). Also, the ERT deduced from the data that after 12 years about 33 per cent (the sum of the leakage factors of years 1–12) of the HFC-134a initially contained in the foam is emitted, thus about 67 per cent should remain in products at decommissioning after 12 years. The ratio of the reported amounts of HFC-134a in disposed products to the initial amounts 12 years before ranges from 1 per cent for 2019 disposal to 38 per cent for 2009 disposal. The ERT understands that exports of XPS are considered, which is indicated in the NID (p.290), thus the amounts of HFC-134a reported as remaining in products at decommissioning in CRT table 2(II).B-H (sheet 2) (e.g. for 2009: 2.95 t HFC-134a) are related to the annual increase in stocks (e.g. the increase in stocks from 1996 to 1997 is 44 t: 48.52 t HFC-134a stock in 1997 minus 4.2 t stock in 1996). The ERT assumes that HFC-134a contained in exported foams is not added to the stock, and also that emissions from manufacture are not added to the stock, thus the calculated increase in average annual stocks should only refer to HFC-134a in new XPS used in the country. The resulting ratio of the amounts reported as remaining in products at decommissioning to the annual increase in stock ranges from 7 to 16 per cent, compared with 67 per cent deduced from the information in the NID; the Party did not provide further information on assumptions made	Yes. Transparency	Question resolved/explained in NID	Chapter 4.7.2.2

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
		concerning the lifetime to explain this deviation in its NID. During the review, the Party clarified that in the model it is assumed that 20 per cent of the XPS products have a lifetime of 12 years. The remaining 80 per cent have a significantly longer lifetime of more than 50 years. So, for 80 per cent of the XPS produced using HFC-134a there is still leakage from stock, and this will remain the case for a long time. The ERT recommends that the Party include in the NID the information on assumptions made for the lifetime of XPS foams (i.e. that in the model it is assumed that 20 per cent of the XPS products have a lifetime of 12 years, and that the remaining 80 per cent have a significantly longer lifetime of more than 50 years, so there will still be leakage from stock for a long time).			
Agriculture					
A.10	3. Agriculture	The Party reported in the agriculture chapter in its NID various tables providing data for the most recent three years instead of the most recent 10 years. The ERT noted that this is not in line with paragraph 48 of the UNFCCC Annex I inventory reporting guidelines, which request that the base year, the most recent 10 years and any previous years since the base year ending with 0 or 5 (1990, 1995, 2000, etc.) be reported. During the review, the Party clarified that it will make an effort to address this issue. However, the Party noted that the agriculture chapter in the NID includes 19 tables with time-series data and adding six more lines in every table will increase the NID by approximately three pages but may not improve its comprehensibility. The Party also noted that the data requested are also presented in the CRT tables. The ERT encourages the Party to update the tables of the NID with the time series of emissions to include the most recent 10 years instead of the most recent three years in line with paragraph 48 of the UNFCCC Annex I inventory reporting guidelines.	Not an issue/problem		

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
A.11	3.D.a.6. Cultivation of organic soils (i.e. histosols) – N_2O	The Party reported values on areas of organic soils in CRT tables 3.D, 4.B and 4.C. The ERT noted that the figure reported for organic soils in CRT table 3.D is not equal to the amount reported for organic soils in cropland in CRT table 4.B and grassland in CRT table 4.C. For example, for 2021 Sweden reported 113.84 kha (113,840.16 ha) for the area of cultivated organic soils under category 3.D.a.6, while also reporting area figures for organic soils in total cropland and total grassland as 115.69 kha and 49.64 kha respectively. The total of the latter two figures adds up to 165.33 kha, which is not equal to the amount reported for category 3.D.a.6 (113.84 kha). During the review, the Party clarified that the area of cropland reported in category 3.D.a.6 is cropland remaining cropland and land converted to cropland on organic soils (113.84 kha). The Party did note a mismatch in the total area of total drained organic soils on cropland in CRT table 4.B (115.69 kha), which was stated owing to a slightly different assessment of the area (i.e. due to rounding of the NFI data). The Party stated that it would correct this inconsistency in its next inventory submission. The area of drained organic grassland soils is not cultivated and is therefore not included under category 3.D.a.6. The ERT recommends that the Party provide detailed information in the NID on drained organic grassland soils that are stated as not being cultivated and as a result not included in the calculation. The ERT also recommends that the Party address the inconsistency in the areas of organic soils reported in CRT table 3.D and the areas reported in cropland in CRT table 4.B and grassland in CRT table 4.C (e.g. for 2021 Sweden reported 113,840.16 ha (113.84 kha) for the area of cultivated organic soils (category 3.D.a.6), while reporting area figures for organic soils in total cropland and total grassland as 115.69 kha and 49.64 kha respectively (i.e. a total of 165.33 kha)).	Yes. Transparency	Question resolved/explained in NID	In NID: chapter 5.4.1.2.6
LULUCF					

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
L.21	Land representation – CO_2, CH_4 and N_2O	The Party reported in its NID (p.358) that wetlands in Sweden were assumed to be unmanaged, except for areas of peat extraction. However, the Party reported in its CRT table 4.1 all wetlands remaining wetlands under unmanaged wetlands and used notation key “NA” for managed wetlands. The ERT noted that this is not in accordance with the UNFCCC Annex I inventory reporting guidelines because notation key “NA” is not applicable for land on which activities exist, such as the wetland areas of peat extraction. The ERT considered the proper notation key to be “IE” if disaggregated reporting of areas from a certain land use is not possible. During the review, the Party clarified that the area data for peat extraction originates from data from the peat industry. Although this area is properly reflected in CRT table 4.D, it is not possible to reflect this area in the calculation of the land-use matrix in CRT table 4.1, which is constructed based on the NFI. The Party also expressed the view that using notation key “IE” for managed wetlands remaining wetlands would be reasonable. The Party indicated that it will address this issue in its next inventory submission. The ERT recommends that the Party report consistent areas of peat extraction under managed wetlands remaining managed wetlands in CRT tables 4.1 and 4.D or, if this is not possible, use notation key “IE” for managed wetlands remaining wetlands in CRT table 4.1.	Yes. Convention reporting adherence	This issue has not yet been implemented	

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
L.22	Land representation – CO_2, CH_4 and N_2O	The Party reported different total national areas in the NIDs of its 2022 and 2023 inventory submissions. The Party reported 45,142 kha in the NID of its 2022 inventory submission (table 6.3, p.368) and 45,136 kha in the NID of its 2023 inventory submission (table 6.3, p.359). However, the total national area is reported as constant (45,133.18 kha) in CRT table 4.1 for all reporting years in the 2023 inventory submission. The Party did not provide an explanation of why the total national area is not consistent between NID table 6.3 and CRT table 4.1 nor the reasons why the total national area is not the same for each submission. During the review, the Party clarified that the total national area is estimated using both temporary and permanent sample plots from the NFI, while the official reporting is based on permanent plots, which is the basis for tracking the trend and generating the land-use change matrix. The Party also acknowledged that there is a small difference in the estimated total national area and the area reported in the NID but stated that all land areas are reported. In addition, the Party clarified that the change in the national area is the result of incorrect coordinates for some sample plots and land rise from the sea in the northern coastal zone. When a change in the land area is identified, the land area is recalculated for the entire time series in each submission to maintain the time-series consistency and the latest land area is reflected in its NID. The Party indicated that it would aim to improve the explanation in the NID of its next inventory submission. The ERT recommends that the Party explain in its NID the difference between the total national area and the area reported in CRT table 4.1 and how the total national area changed in response to the incorrect coordinates for some sample plots and land rise from the sea, and how the reported total national area changed in the inventory submissions from previous years.	Yes. Transparency	Differences in total area between submissions are less than 0.01% and are due to input data being adjusted. If e.g. a plot part in the field is identified to be outside the sample (e.g. to be located in Norway), the NFI corrects it. Sweden will consider describing this better in the NID.	
Waste					

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
W.6	5.A Solid waste disposal on land – CH_4	Tables 7.2–7.17 of the NID (pp.397–413) present the AD of waste disposed of in landfills (quantity and DOC). The NID describes discontinuities in the AD for types of waste between time periods owing to changing sources and waste category definitions over time. The ERT found that the consistency of the time series of solid waste disposal data was difficult to review because the AD for the solid waste disposed of in landfills are spread over 15 tables in the NID, with changes in format between the tables. Furthermore, the AD for solid waste disposed of in landfills could not be matched with corresponding values in the CRT tables (see ID# W.7 below). For example, the entire time series of total waste disposed of in landfill (1952–2021) could not easily be determined from the data presented in the NID, nor could the total or average DOC of waste landfilled. During the review, the Party shared with the ERT a table containing the amounts of all types of waste landfilled at SWDS, including the DOC of these types. The Party indicated that it will address this issue in its next inventory submission. The ERT recommends that the Party include a single comprehensive synthesis table in its NID, such as total solid waste or DOC disposed of in landfill by year. The ERT encourages the Party to include a synthesis figure showing the time series of solid waste disposal AD.	Yes. Transparency	Resolved. A table containing landfilled quantities of DOC for the time period 1952-2022 was included in Table 7.13: Deposited quantities of Degradable Organic Carbon (DOC) 1952-2022, kt, in the NID submission 2024.	7.2.2.2.5

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
W.7	5.A.1 Managed waste disposal sites – CH_4	Tables 7.2–7.17 of the NID (pp.397–413) present quantities of waste disposed of in landfills and the DOC of the waste types. The ERT noted that the waste quantities disposed of in landfills and the DOC presented in the NID do not match the values reported in CRT table 5.A. For example, the “Total deposited waste (excl. mining waste)” in table 7.2 of the NID (p.397) does not match the “Annual solid waste at SWDS” in CRT table 5.A; similarly for table 7.3 of the NID (p.398). Also, NID table 7.2 (p.397) reports that 5,563 kt total solid waste was disposed of in 1990, whereas CRT table 5.A reports that 3,723 kt was disposed of in SWDS in 1990. Table 7.3 (p.398) reports that 4,414 kt of solid waste (excluding mining waste) was disposed of in 2021, whereas CRT table 5.A reports that 580 kt was disposed of in 2021. During the review, the Party clarified that the annual waste disposed of at SWDS reported in CRT table 5.A for 1990–2005 is the sum of deposited municipal solid waste and deposited sludge from the wastewater handling and pulp industry containing DOC reported in the NID (table 7.2, p.397), and that the annual waste at SWDS reported in CRT table 5.A for 2006–2021 is based on data presented in the NID (table 7.3, p.398). The Party indicated that the reason the sum presented in table 7.3 in the NID does not equal the amount of annual waste at the SWDS reported in the CRT tables for 2006–2021 is because the sludge in table 7.3 is reported as dry matter, while the sludge reported in the CRT tables is in wet weight. Given the lack of transparency of the information in the NID, the ERT was unable to evaluate the accuracy of the values in CRT table 5.A based on the NID. The Party indicated that it would provide a better explanation in the NID of its next inventory submission as to which waste data are reported in CRT table 5.A. The ERT recommends that the Party include in the NID a clear description of the AD presented in the NID, and that tables showing annual solid waste disposal in the NID align with the data presented in the CRT tables, with enough detail provided to allow readers to replicate the AD reported in the CRT tables and to understand the data presented in the CRT tables with greater clarity and transparency.	Yes. Transparency	Resolved. Table 7.2 and 7.3 in the NID **submission 2024** have been improved, and now contains totals that are harmonized with corresponding data reported in the CRT/CRT: ”Annual waste at the SWDS”. Improved clarifications on the scope of these data are included in the NID.	7.2.2.2.1

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
W.8	5.A.1 Managed waste disposal sites – CH_4	The ERT noted that the DOC value for garden waste (0.17) reported in the NID (table 7.7, p.403) is based on the Revised 1996 IPCC Guidelines (vol. 3, chap. 6, table 6.3). The 2006 IPCC Guidelines (vol. 5, chap. 2, table 2.4) present an updated default DOC estimate for yard and garden waste (0.20, wet weight). During the review, the Party indicated that it will update the DOC value for garden waste from 0.17 (from the Revised 1996 IPCC Guidelines) to 0.20 (from the 2006 IPCC Guidelines) in its 2024 inventory submission. The ERT recommends that the Party either use in its estimates the DOC for garden waste (0.20, wet weight) from the 2006 IPCC Guidelines (vol. 5, chap. 2, table 2.4) instead of DOC = 0.17 from the Revised 1996 IPCC Guidelines and explain the recalculation made in the NID or, if using the latter, justify why DOC = 0.17 better reflects its national circumstances.	Yes. Accuracy	Resolved. In **submission 2024**, the DOC value for garden waste has been updated to the default DOC estimate for yard and garden waste (0.20, wet weight) from 2006 IPCC Guidelines. Table 7.7 in the NID has been updated as well as the emission calculations.	7.2.2.2.4

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
W.9	5.A.1 Managed waste disposal sites – CH_4	The NID (p.400) includes some details on the burning of waste at landfills before 1976. It indicates that no information is available on the fraction of waste that was burned; however, the NID indicates that 311 of the 847 landfills (36.7 per cent of landfills) practised open burning in 1975. This ratio of the number of landfills burning waste on site is extended to the total amount of waste burned at landfills, specifically: "An assumption is…made that before 1976, 37 per cent of all deposited household waste was burned" (NID, p.400). This assumption implies that 100 per cent of the waste disposed of at landfills that practised open burning was combusted. During the review, the Party indicated that, in general, the landfills only burned a fraction of the burnable waste, and that this practice was limited to only being used for waste that was easily burned. It further explained that historical data on the quantities of waste disposed of in landfills for 1952–1979 are based on assumptions and expert judgment that are difficult to verify since written sources are scarce. Sweden further clarified that further reassessment of this issue would also have to be made by expert judgment and would face the same verification issues. The ERT acknowledges that precise estimates of the fraction of waste burned (at sites that burned waste) may be challenging to estimate. Nonetheless, given the indication that only a portion of waste was combusted, the currently applied assumption that 100 per cent of waste was burned (at sites that did burn waste) is inaccurate. It is the opinion of the ERT that effort should be made to provide a best estimate or a new expert judgment of the proportion combusted at these sites and that this would contribute to the transparency and accuracy of the NID. The ERT recommends that the Party revise the assumed fraction of waste burned at SWDS that did burn waste before 1976 (100 per cent), revise the historical estimates of waste burned at landfills, recalculate emissions accordingly and explain the recalculation in its NID.	Yes. Accuracy	No new data or findings are yet available.	

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
W.10	5.B.1 Composting – CH_4 and N_2O	The Party reported in its NID (p.416) that emissions from home composting are not estimated. The ERT found in publicly available publications (Ermolaev et al., 2014) that home composting is widely used for biological household waste in Sweden, with more than 10 per cent of all biologically treated food waste home composted. During the review, the Party provided additional information, including preliminary estimates of home composting of food waste for 2021 (31,120 t wet weight), showing that total emissions (CH4 and N2O) were 5.46 kt CO2 eq, which is equal to 0.01 per cent of the national total GHG emissions of Sweden (without LULUCF), which totalled 47,816.70 kt CO2 eq in 2021. However, the ERT noted that paragraph 18(b)(i) of the conclusions and recommendations from the 19th meeting of GHG inventory lead reviewersb indicates that the significance threshold defined in paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines applies at the category/subcategory level where the notation key “NE” may be used in the CRT tables. The ERT concluded that the significance threshold cannot be applied to just home composting, since home composting is part of category 5.B.1 and not a category in the CRT tables. The ERT recommends that the Party estimate and report CH4 and N2O emissions from home composting under category 5.B.1 composting for all applicable years of the time series.	Yes. Completeness	No new data or findings are yet available.	

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
W.11	5.D Wastewater treatment and discharge – CH4	The NID (p.430) indicates that the method for estimating CH_4 generation from anaerobic wastewater treatment is based on energy production. However, information about the data source for biogas production was missing from the NID, cited only as “statistical information on generated energy”. The NID (p.430) also indicates that emissions are estimated based on a percentage loss from the energy recovery process. However, it is unclear whether flared biogas was included in the estimation of CH_4 generation, and whether emissions from biogas flaring were included in the estimates. During the review, the Party clarified that the energy production data are from the Swedish Energy Agency’s annual statistical report and provided a table with data and calculations of biogas energy production, including flaring and energy recovery. The Party shared a spreadsheet with the ERT that demonstrated that flared biogas (reported as GWh from the data source) was considered in the estimates of CH_4 generation. The Party also clarified that the CH_4 from flaring and recovery is calculated based on the energy production and uses the NCV. The Party indicated that it would include this information in its next inventory submission. The ERT recommends that the Party improve the transparency of the NID by including a citation to the data source of the biogas production energy AD and providing a synthesis of the AD that were shared with the ERT during the review, showing the time series of biogas production and including a description of how the CH4 generation was determined and the conversion equation or parameters (from GWh to mass CH4) used.	Yes. Transparency	Resolved. In the NID **submission 2024**, the new Table 7.27 has been introduced, which contains data on biogas production on facilities with anaerobic wastewater treatment (in GWh). The Table 7.27 is including citations to the data sources. A description on how the CH_4 generation was determined and	7.5.1.2.3 7.5.1.2.1

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
				the parameters used when converting from GWh to mass CH_4 is also presented in the NID **submission 2024**.	

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
W.12	5.D.1 Domestic wastewater – CH_4	In the NID (section 7.5, p.427), it is stated that CH_4 emissions from septic tanks were omitted from the inventory, based on an assumption that CH_4 generation in septic tanks is unlikely to occur below 15 °C because methanogens are not active, and because the annual average air temperature in Sweden is 4.8 °C. The ERT notes that the discussion presented in the 2006 IPCC Guidelines (vol. 5, chap. 5, p.6.7) on the impact of temperature on methanogenesis refers to the effect of temperature on methanogenesis in lagoons, not in septic tanks. According to the 2006 IPCC Guidelines, for lagoons, “Below 15°C, significant CH_4 production is unlikely because methanogens are not active and the lagoon will serve principally as a sedimentation tank”. The 2006 IPCC Guidelines (vol. 5, chap. 6.2.2, table 6.3) do not include specific provision for the impact of temperature on methanogenesis in septic tanks; the CH_4 conversion factor (agriculture) for septic tanks is 0.5 (vol. 5, chap. 6.2.2, table 6.3). The ERT considers that omitting emissions from septic tanks results in an underestimation of the emissions reported in the inventory. During the review, the Party provided additional information and example calculations, citing two documents (JTI, 2008; Leverenz et al., 2010). The ERT reviewed the documents cited by the Party and noted that JTI (2008) mentioned that CH4 production from sludge is limited to depressed temperatures (between 5 and 20 °C), though it did not provide further evidence on the subject. Leverenz et al. (2010) states that the temperature inside a septic tank depends on water use in the house as well as seasonal temperature variations, that septic tanks do experience seasonal temperature variations and that, even in cold months, CH4 generation does occur, albeit at lower rates. Leverenz et al. (2010) notes that the reduced degradation in colder months can be offset by higher decomposition during warmer months. The ERT concluded that the references shared by the Party, notably Leverenz et al. (2010), seem to indicate that methanogenesis remains possible in septic systems (albeit potentially at lower rates) if septic tank temperatures are low. The references refute what the Party reported in the NID, which is that CH4 emissions from septic tanks can be omitted based on an assumption that CH4 generation in septic tanks is unlikely to occur if mean annual temperatures are below 15 °C. Furthermore, the ERT	Yes. Completeness	Resolved. Methane emissions from septic tanks (category 5.D.1) has been included in the calculations in **submission 2025** as well as explanations in the NID to the recalculations. This change has been done in an effort to improve the Swedish implementation of the 2006 IPCC Guidelines methodologies.	7.5 7.5.1.2.1 7.5.1.2.2 7.5.1.5

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?	Response /status s of implementation	Section in the NID
		notes that while the annual average temperature in Sweden might be 4.8 °C, regional differences may exist and temperatures during summer rise above 15 °C, at which times emissions may occur. The ERT commends the Party for the effort to provide additional references but still considers that the additional information does not specifically provide evidence that there is no methanogenesis occurring in septic tanks due to cool ambient air temperatures. The ERT recommends that the Party improve the completeness of the GHG inventory by including in the calculations for category 5.D.1 the CH4 emissions for septic tanks taking into consideration the 2006 IPCC Guidelines and explain the recalculation in the NID or provide evidence in the NID that demonstrates that CH4 emissions from septic tanks do not occur in the country.			

PART 2: SUPPLEMENTARY INFORMATION REQUIRED UNDER ARTICLE 7, PARAGRAPH 1

11 Information on changes in national system

Since we are entering a new reporting and accounting period in 2021 Sweden has made a review of the national system to be in line with the reporting requirements under EU legislation (Governance regulation 2018/1999) and reporting requirements under the climate convention and the Paris Agreement.

Sweden has updated the climate reporting ordinance and the agreements following by the ordinance. We have added two more agencies for delivering of data – Swedish eHealth Agency and Swedish Medical Products Agency. Data from Geological Survey of Sweden aren't needed anymore since the responsibility for peat production now is regulated in the Environmental code and Swedish Environmental Protection Agency is responsible for this reporting.

12 Information on changes in national registry

The following changes to the national registry of Sweden have occurred in 2023. Note that the 2023 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 changes.**
15/CMP.1 annex II.E paragraph 32.(c) Change to database structure or the capacity of national registry	**There have been five new EUCR releases in production (versions 13.10, 13.10.2, 13.10.3, 13.10.4 and 13.11.2) after version 13.8.2 (the production version at the time of the last Chapter 14 submission). No changes were applied to the database, whose model is provided in Annex A. No change was required to the application backup plan or to the disaster recovery plan. 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	**The changes that have been introduced with versions 13.10, 13.10.2, 13.10.3, 13.10.4 and 13.11.2 compared with version 13.8.2 of the national registry are presented in Annex B. It is to be noted that 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 are 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 were introduced.**
15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information	**No change to the list of publicly available information occurred during the reported period.**
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	**No change to the registry internet address during the reported period.**
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	**No change during the reported period.**

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14 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
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
CMP	Meeting of the Parties to the Kyoto Protocol
CO	Carbon monoxide
CO_2	Carbon dioxide
COP	Conference Of the Parties
CORINAIR	EMEP/CORINAIR Emission Inventory Guidebook
CRT	Common Reporting Table
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
NID	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
TCCCA	transparency, consistency, completeness, comparability and accuracy
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