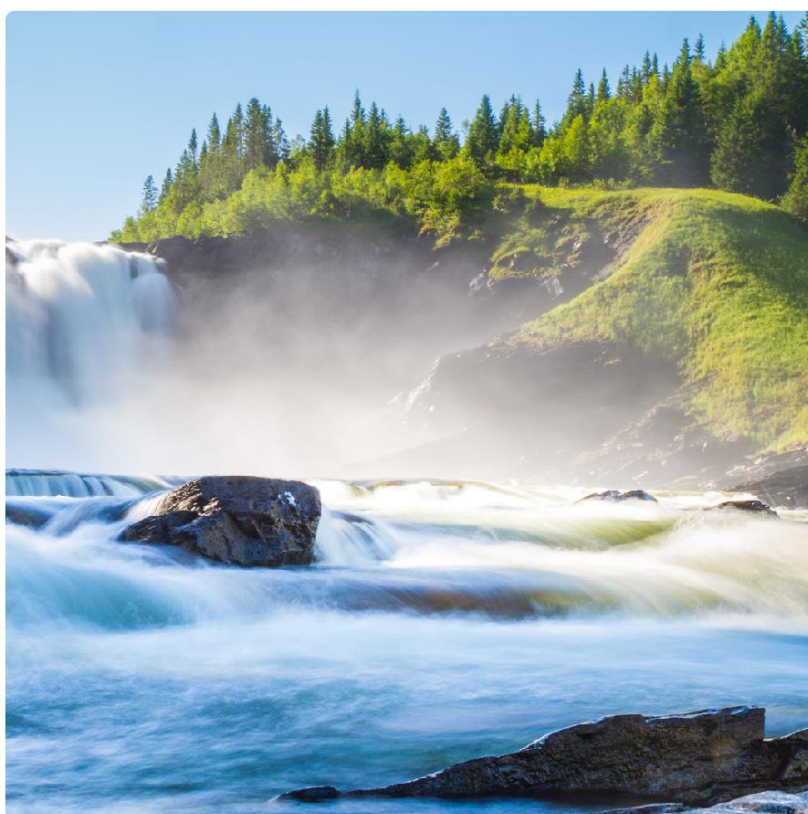
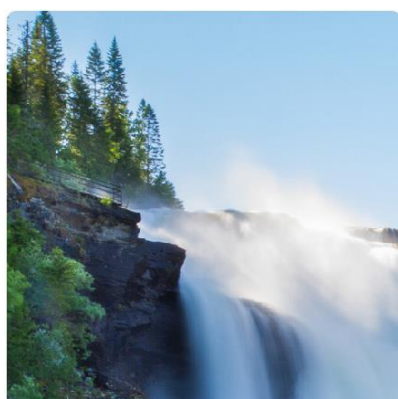


National Inventory Report Sweden 2018

Greenhouse Gas Emission Inventories 1990-2016

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



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Preface

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

The National Inventory Report (NIR) for the year 2018 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 2016, and descriptions of methods used to produce the estimates. The methods used to calculate emissions and removals are in accordance with the IPCC 2006 Guidelines for National Greenhouse Gas Inventories, IPCC supplementary guidelines for KP LULUCF, and the IPCC supplementary guidelines for Wetlands (*2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*).

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

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Contents

PREFACE	1
CONTENTS	4
SAMMANFATTNING	14
S 1. Bakgrund	14
S 2. Översikt av utsläpps- och upptagstrender, inklusive KP-LULUCF, per gas	16
S 3. Översikt av utsläppstrender per sektor	18
S 4. Översikt av utsläppstrender för indirekta växthusgaser och SO ₂	21
EXECUTIVE SUMMARY	23
ES 1. Background Information	23
ES 2. Summary of national emissions and removal trends	25
ES 3. Overview of Source and Sink Category Emission Estimates and Trends	27
ES 4. Overview of Emission Estimates and Trends of Indirect GHGs and SO ₂	30
SUMMARY IN ARABIC	32
SUMMARY IN FRENCH	37
1 INTRODUCTION	41
1.1 Background Information	41
1.1.1 Climate change	41
1.1.2 Greenhouse gas inventories	43
1.1.3 Supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol	43
1.1.4 Sweden's commitment under the first commitment period of the Kyoto Protocol and the EU Burden Sharing decision	44
1.1.5 Sweden's commitment under the second commitment period of the Kyoto Protocol and the EU Effort Sharing decision	44
1.1.6 National emission targets	45
1.2 Institutional arrangements	46
1.2.1 Legal arrangements	47
1.2.2 Institutional arrangements	47
1.3 Inventory planning, preparation and management	51
1.3.1 Quality system	51
1.3.2 Training, awareness and skills	54

1.3.3	Inventory planning (PLAN)	54
1.3.4	Inventory preparation (DO)	55
1.3.5	QA/QC procedures and extensive review of GHG inventory and KP-LULUCF inventory	57
1.4	Brief general description of methodologies and data sources used	63
1.4.1	GHG inventory	63
1.4.2	KP-LULUCF inventory	64
1.5	Brief description of key categories, including for UNFCCC/KP-LULUCF key categories	65
1.5.1	GHG inventory (including and excluding LULUCF)	65
1.5.2	KP-LULUCF inventory	68
1.6	Information on QA/QC	68
1.6.1	QA/QC Procedures	68
1.6.2	Verification activities	68
1.6.3	Treatment of confidentiality issues	68
1.7	General uncertainty evaluation	69
1.7.1	GHG inventory	69
1.7.2	KP-LULUCF activities	72
1.8	General assessment of completeness	72
1.8.1	GHG inventory	72
1.8.2	Energy	72
1.8.3	Industrial Processes and Product Use	72
1.8.4	Agriculture	73
1.8.5	Land Use, Land Use Change and Forestry	73
1.8.6	Waste	73
1.8.7	KP-LULUCF	73
2	TRENDS IN GREENHOUSE GAS EMISSIONS	74
2.1	Total greenhouse gas emissions and removals	74
2.1.1	Overview of emissions by sector	75
2.2	Description and interpretation of emission trends by gas	77
2.2.1	Carbon dioxide (CO ₂)	78
2.2.2	Methane (CH ₄)	78
2.2.3	Nitrous oxide (N ₂ O)	78
2.2.4	Fluorinated greenhouse gases	80
2.3	Emissions by CRF sectors	81
2.3.1	Energy (CRF sector 1)	81
2.3.2	Industrial processes and product use (CRF sector 2)	95

2.3.3	Agriculture Sector (CRF 3)	101
2.3.4	Land Use, Land Use Change and Forestry – LULUCF (CRF sector 4)	106
2.3.5	Waste (CRF sector 5)	111
2.3.6	International shipping and aviation	115
2.4	Precursors and indirect emissions	116
2.4.1	Non-methane volatile organic compounds (NMVOCs)	116
2.4.2	Nitrogen oxides (NO _x)	118
2.4.3	Carbon monoxide (CO)	119
2.4.4	Sulphur dioxide (SO ₂)	121
3	ENERGY (CRF SECTOR 1)	123
3.1	Overview of sector	123
3.2	Fuel combustion (CRF 1.A)	125
3.2.1	Comparison of the sectoral approach with the reference approach	126
3.2.2	International bunker fuels	127
3.2.3	Feedstocks and non-energy use of fuels	130
3.2.4	CO ₂ capture from flue gases and subsequent CO ₂ storage	131
3.2.5	Country-specific issues	131
3.2.6	Public electricity and heat production (CRF 1.A.1.a)	131
3.2.7	Petroleum refining (CRF 1.A.1.b)	137
3.2.8	Manufacture of solid fuels and other energy industries (CRF 1.A.1.c)	140
3.2.9	Iron and steel (CRF 1.A.2.a)	142
3.2.10	Non-Ferrous Metals (CRF 1.A.2.b)	146
3.2.11	Chemicals (CRF 1.A.2.c)	148
3.2.12	Pulp, Paper and Print (CRF 1.A.2.d)	151
3.2.13	Food Processing, Beverages and Tobacco (CRF 1.A.2.e)	153
3.2.14	Non-metallic minerals (CRF 1.A.2.f)	155
3.2.15	Other Industries (CRF 1.A.2.g)	157
3.2.16	Civil Aviation (CRF 1.A.3.a)	162
3.2.17	Road transport (CRF 1.A.3.b)	165
3.2.18	Railways (CRF 1.A.3.c)	175
3.2.19	Navigation (CRF 1.A.3.d)	177
3.2.20	Other transportation (CRF 1.A.3.e)	183
3.2.21	Commercial/institutional (CRF 1.A.4.a)	186
3.2.22	Residential (CRF 1.A.4.b)	190
3.2.23	Agriculture/forestry/fisheries (CRF 1.A.4.c)	193

3.2.24	Other stationary (CRF 1.A.5.a)	197
3.2.25	Other mobile (CRF 1.A.5.b)	197
3.3	Fugitive emissions from solid fuels and oil and natural gas (CRF 1.B)	199
3.3.1	Fugitive emissions from solid fuels (CRF 1.B.1)	199
3.3.2	Oil and natural gas (CRF 1.B.2)	201
4	INDUSTRIAL PROCESSES AND PRODUCT USE (CRF SECTOR 2)	216
4.1	Overview of sector	216
4.2	Mineral industry (CRF 2.A)	218
4.2.1	Cement production (CRF 2.A.1)	218
4.2.2	Lime production (CRF 2.A.2)	224
4.2.3	Glass production (CRF 2.A.3)	229
4.2.4	Other process uses of carbonates (CRF 2.A.4)	231
4.3	Chemical industry (CRF 2.B)	235
4.3.1	Ammonia production (CRF 2.B.1)	235
4.3.2	Nitric acid production (CRF 2.B.2)	236
4.3.3	Adipic acid production (CRF 2.B.3)	239
4.3.4	Caprolactam, glyoxal and glyoxylic acid production (CRF 2.B.4)	239
4.3.5	Carbide production (CRF 2.B.5)	239
4.3.6	Titanium dioxide production (CRF 2.B.6)	244
4.3.7	Soda ash production (CRF 2.B.7)	244
4.3.8	Petrochemical and carbon black production (CRF 2.B.8)	244
4.3.9	Fluorochemical production (CRF 2.B.9)	244
4.3.10	Other (CRF 2.B.10)	245
4.4	Metal industry (CRF 2.C)	250
4.4.1	Iron and steel production (CRF 2.C.1)	250
4.4.2	Ferroalloy production (CRF 2.C.2)	263
4.4.3	Aluminium production (CRF 2.C.3)	267
4.4.4	Magnesium production (CRF 2.C.4)	271
4.4.5	Lead production (CRF 2.C.5)	273
4.4.6	Zinc production (CRF 2.C.6)	273
4.4.7	Other metal production (CRF 2.C.7)	274
4.5	Non-energy products from fuels and solvent use (CRF 2.D)	278
4.5.1	Lubricant use (CRF 2.D.1)	278
4.5.2	Paraffin wax use (CRF 2.D.2)	281
4.5.3	Other (CRF 2.D.3)	284

4.6	Electronics industry (CRF 2.E)	293
4.6.1	Integrated circuit or semiconductor (CRF 2.E.1)	293
4.6.2	TFT Flat panel display (CRF 2.E.2)	294
4.6.3	Photovoltaics (CRF 2.E.3)	294
4.6.4	Heat transfer liquid (CRF 2.E.4)	294
4.6.5	Other (CRF 2.E.5)	294
4.7	Product uses as substitutes for ODS (CRF 2.F)	295
4.7.1	Refrigeration and air conditioning (CRF 2.F.1)	297
4.7.2	Foam blowing agents (CRF 2.F.2)	306
4.7.3	Fire protection (CRF 2.F.3)	309
4.7.4	Aerosols (CRF 2.F.4)	311
4.7.5	Solvents (CRF 2.F.5)	313
4.7.6	Other applications (CRF 2.F.6)	313
4.8	Other product manufacture and use (CRF 2.G)	313
4.8.1	Electrical equipment (CRF 2.G.1)	313
4.8.2	SF ₆ and PFCs from other product use (CRF 2.G.2)	317
4.8.3	N ₂ O from product use (CRF 2.G.3)	318
4.8.4	Tobacco smoking and use of fireworks (CRF 2.G.4)	319
4.9	Other product manufacture and use (CRF 2.H)	320
4.9.1	Pulp and paper (CRF 2.H.1)	320
4.9.2	Food and drink (CRF 2.H.2)	322
4.9.3	Other (CRF 2.H.3)	324
5	AGRICULTURE (CRF SECTOR 3)	327
5.1	Overview of sector	327
5.2	Enteric Fermentation (CRF 3.A)	329
5.2.1	Source category description	329
5.2.2	Methodological issues	330
5.2.3	Uncertainties and time-series consistency	335
5.2.4	Source-specific QA/QC and verification	335
5.2.5	Source-specific recalculations	335
5.2.6	Source-specific planned improvements	335
5.3	Manure Management (CRF 3.B)	335
5.3.1	Source category description	335
5.3.2	Methodological issues	336
5.3.3	Uncertainties and time-series consistency	344
5.3.4	Source-specific QA/QC and verification	344
5.3.5	Source-specific recalculations	345

5.3.6	Source-specific planned improvements	345
5.4	Agricultural Soils (CRF 3.D)	345
5.4.1	Direct Soil Emissions (CRF 3.D.a)	346
5.4.2	Indirect Emissions (CRF 3.D.b)	352
5.4.3	CO ₂ emissions from liming (CRF 3.G)	356
5.4.4	CO ₂ emissions from urea application (CRF 3.H)	358
6	LAND USE, LAND-USE CHANGE AND FORESTRY (CRF SECTOR 4)	360
6.1	Overview of LULUCF	360
6.1.1	Emission/removals in LULUCF 1990-2016	361
6.2	Land-use definitions and the classification systems used and their correspondence to the land use, land-use change and forestry categories	368
6.2.1	Forest land	368
6.2.2	Cropland	368
6.2.3	Grassland	368
6.2.4	Wetlands	368
6.2.5	Settlements	368
6.2.6	Other land	369
6.2.7	The connection between national and reported land use categories	369
6.2.8	Consistency in reporting land use categories	371
6.2.9	Land use and land-use change matrix	371
6.3	Information on approaches used for representing land areas and on land-use databases used for the inventory preparation	372
6.3.1	The Swedish National Forest Inventory (NFI) and the Swedish Forest Soil Inventory (SFSI).	372
6.3.2	Other sources of information for activity data	378
6.4	Description of categories (CRF 4A, 4B, 4C, 4D, 4E, 4F and 4G)	378
6.4.1	Definition of carbon pools and other sources	378
6.4.2	Methodological issues	382
6.4.3	Uncertainties and time series consistency	389
6.4.4	Category-specific time series consistency, verification and QA/QC	393
6.4.5	Source-specific Recalculations	395
6.4.6	Planned improvements	399
7	WASTE (CRF SECTOR 5)	400
7.1	Overview of sector	400
7.1.1	Biogas production in Sweden	401

7.2	Solid waste disposal (CRF 5.A)	401
7.2.1	Legislation and policies	403
7.2.2	Managed waste disposal sites (CRF 5.A.1)	403
7.3	Biological treatment of solid waste (CRF 5.B)	422
7.3.1	Composting (CRF 5.B.1) and anaerobic digestion at biogas facilities (CRF 5.B.2)	424
7.4	Incineration and open burning of waste (CRF 5.C)	429
7.4.1	Waste incineration (CRF 5.C.1)	429
7.4.2	Open burning of waste (CRF 5.C.2)	433
7.5	Wastewater treatment and discharge (CRF 5.D)	433
7.5.1	Domestic wastewater (CRF 5.D.1) and Industrial wastewater (CRF 5.D.2)	435
8	OTHER	444
9	RECALCULATIONS AND IMPROVEMENTS	445
9.1	Explanations and justifications for recalculations	445
9.1.1	Energy, CRF 1	445
9.1.2	Industrial processes and product use, CRF 2	446
9.1.3	Agriculture, CRF 3	446
9.1.4	LULUCF, CRF 4	447
9.1.5	Waste, CRF 5	447
9.2	Implications for emission levels	448
9.3	Implications for emission trends	450
9.4	Recalculations and other changes made in response to the UNFCCC review process	451
10	KP-LULUCF	489
10.1	General information	489
10.1.1	Emissions/removals from AR, D and FM	491
10.1.2	Definitions of forest and any other criteria	494
10.1.3	Elected activities under Article 3, paragraph 4, of the Kyoto Protocol	496
10.1.4	Description of how the definitions of each activity under Article 3.3 and each elected activity under Article 3.4 have been implemented and applied consistently over time	496
10.1.5	Descriptions of precedence conditions and/or hierarchy among Article 3.4 activities, and how they have been consistently applied in determining how land was classified.	498
10.2	Land-related information	498

10.2.1	Spatial assessment unit used for determining the area of the units of land under Article 3.3	498
10.2.2	Methodology used to develop the land use matrix	499
10.2.3	Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations	500
10.3	Activity-specific information	501
10.3.1	Methods for carbon stock change and GHG emission and removal estimates	501
10.4	Article 3.3	510
10.4.1	Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2020 and are direct human-induced	510
10.4.2	Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation	511
10.4.3	Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested	511
10.5	Article 3.4	512
10.5.1	Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human induced	512
10.5.2	For Parties included in Annex I that elect cropland management and/or grazing land management and/or revegetation and/or wetland drainage and rewetting, anthropogenic GHG emissions by sources and removals by sinks for each year of the commitment period and for the base year	512
10.5.3	Information that demonstrates that emissions by sources and removals by sinks resulting from forest management under Article 3, paragraph 4, and any elected activities under Article 3, paragraph 4, are not accounted for under activities under Article 3, paragraph 3;	512
10.5.4	Information on how all emissions arising from the conversion of natural forests to planted forests are accounted for in accordance with any supplementary methodological guidance developed by the IPCC and adopted by the CMP;	512
10.5.5	Information that demonstrates methodological consistency between the reference level and reporting for forest management during the second commitment period, including the area accounted for, the treatment of harvested wood products, and the accounting of any emissions from natural disturbances;	513
10.5.6	Any technical corrections made pursuant to decision 2/CMP.7, annex, paragraph 14, to ensure consistency between the reference	

	level and reporting for forest management during the second commitment period	514
10.6	Other information	516
10.6.1	Key category analysis for Article 3.3 activities and any elected activities under Article 3.4	516
10.7	Information relating to Article 6	516
10.8	Coming improvements	516
11	INFORMATION ON ACCOUNTING OF KYOTO UNITS	517
11.1	Background information	517
11.2	Summary of information reported in the SEF tables	517
11.3	Discrepancies and notifications	518
11.4	Publicly accessible information	519
11.5	Calculation of the commitment period reserve (CPR)	522
11.5.1	Assigned Amount	522
11.5.2	Commitment Period Reserve (CPR)	522
11.6	KP-LULUCF accounting	523
12	INFORMATION ON CHANGES IN NATIONAL SYSTEM	524
13	INFORMATION ON CHANGES IN NATIONAL REGISTRY	525
14	INFORMATION ON MINIMIZATION OF ADVERSE IMPACTS IN ACCORDANCE WITH ARTICLE 3, PARAGRAPH 14	527
14.1	Changes in information provided under Article 3, paragraph 14	527
14.2	Paragraph 23	527
14.3	Paragraph 24 (a)	529
14.4	Paragraph 24 (b)	529
14.5	Paragraph 24 (c)	529
14.6	Paragraph 24 (d)	529
14.7	Paragraph 24 (e)	530
14.8	Paragraph 24 (f)	531
15	REFERENCES	532
	Section 1	532
	Section 2	532
	Section 3	533
	Section 4	537
	Section 5	540
	Section 6	545
	Section 7	548

Section 9	554
Section 10	554
16	UNITS AND ABBREVIATIONS
	556

Sammanfattning

S 1. Bakgrund

Växthusgaser har alltid funnits i atmosfären, men på grund av mänsklig aktivitet har koncentrationen av många av dem ökat, vilket intensifierar växthuseffekten. 1988 bildades FN:s klimatpanel (Intergovernmental Panel on Climate Change – IPCC). Två år senare konstaterade panelen att antropogen klimatpåverkan utgör ett globalt hot och efterfrågade en internationell överenskommelse för att hantera problemet. FN:s generalförsamling inledde förhandlingar om en ramkonvention kring klimatförändringar (UNFCCC), vilken trädde i kraft 1994. Det långsiktiga målet är att stabilisera halterna av växthusgaser i atmosfären på en nivå som förhindrar skadliga antropogena klimatförändringar från att äga rum.

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

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

Kyotoprotokollets åtaganden gäller minskade utsläpp av växthusgaser från dessa parter om minst 5 % under åren 2008-2012 jämfört med basåret 1990. Under första åtagandeperioden under Kyotoprotokollet åtog sig EU att gemensamt minska utsläppen med 8 % i förhållande till 1990 (utom för fluorerade växthusgaser där basåret är 1995). 2012 beslutade parterna under Kyotoprotokollet om en andra åtagandeperiod (2013 till och med 2020) i enlighet med Dohaändringen av

Kyotoprotokollet 1/CMP.8. Under denna åtagandeperiod har EU tillsammans med Island åtagit sig att minska växthusgasutsläppen till 2020 med 20 % i förhållande till basåret 1990. Sveriges åtagande inom EU är att minska våra nationella utsläpp med 17 % till 2020 jämfört med 2005 inom de sektorer som inte ingår i EU:s system för handel med utsläppsrätter.

Enligt FN:s klimatkonventions fjärde och tolfte artiklar samt den sjunde artikeln under Kyotoprotokollet, måste Annex I-parterna årligen rapportera sina utsläpp från källor och upptag i sänkor för alla växthusgaser som inte omfattas av Montrealprotokollet. Sveriges nationella inventeringsrapport (National Inventory Report – NIR) för år 2018 utgör den årliga rapporteringen enligt både FN:s klimatkonvention och Kyotoprotokollet. Rapporten har förberetts utifrån de riktlinjer som FN:s klimatkonvention antog vid dess nittonde konferens (Conference of the Parties – COP 19) i Warszawa 2013 samt följande beslut tillsammans med motsvarande antagna riktlinjer under Kyotoprotokollet. Rapporten innehåller den nationella växthusgasutsläppsinventeringen för perioden 1990 till 2015 samt beskrivningar av metoderna som använts för att ta fram statistiken. Metoderna som använts följer FN:s klimatpanels riktlinjer för nationell växthusgasinventering från 2006, FN:s klimatpanels tilläggsriktlinjer för markanvändning, förändrad markanvändning och skogsbruk (Land Use, Land Use Change and Forestry – LULUCF) samt tilläggsriktlinjer för våtmarker (se *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*).

Rapporten omfattar utsläpp till luft av de direkta växthusgaserna CO₂, CH₄, N₂O, HFC, PFC, SF₆ och NF₃ samt de indirekta växthusgaserna NO_x, CO, NMVOC och SO₂. Rapporten innehåller information om Sveriges inventering av växthusgaser för alla år från 1990 till 2016, inklusive beskrivningar av metoder, datakällor, osäkerheter, utförd kvalitetssäkring och kvalitetsstyrning (QA/QC) samt en trendanalys.

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

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

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

De totala utsläppen av växthusgaser i Sverige exklusive LULUCF, uttryckt i koldioxidekvivalenter, var 52,9 miljoner ton år 2016 (Tabell S.1 och Tabell S.2). Av dessa var utsläppen som inte omfattas av EU:s system för handel med utsläppsrätter 33,6 miljoner ton, vilket är 64 % av de totala utsläppen. Jämfört med 2015 är det en minskning med ca 1,6 %. Utsläppen har minskat med 26 % mellan 1990 och 2016.

Nettoupptaget för sektorn markanvändning, förändrad markanvändning och skogsbruk (LULUCF) fortsatte att ligga på en hög nivå 2016. Uptaget har ökat med knappt 40 % sedan 1990, beroende på att tillväxten i skog och mark är större än avverkningen.

De totala utsläppen av koldioxid (CO₂) 2016 var 26 % lägre än 1990 och 1,9 % lägre än 2015. Koldioxid står för 43 miljoner ton vilket är cirka 80 % av de totala utsläppen av växthusgaser. Energisektorn, inklusive transporter, står för 86 % av de totala koldioxidutsläppen och är därmed den största källan till koldioxidutsläpp i Sverige.

Sedan 1990 har utsläppen av metan (CH₄) minskat med 38 %, vilket främst beror på åtgärder inom avfallssektorn. Även jordbrukssektorn visar minskade utsläpp. Mellan 2015 och 2016 har utsläppen minskat med 1,5 %. Metanutsläppen var 4,7 miljoner ton koldioxidekvivalenter år 2016 vilket motsvarar cirka 9 % av de totala utsläppen av växthusgaser. Metanutsläpp kommer framför allt från jordbruket, avfallsdeponier och från förbränning av fossila bränslen inom energisektorn.

De totala utsläppen av lustgas (N₂O) 2016 var 4,6 miljoner ton koldioxidekvivalenter, vilket är en minskning med cirka 20 % jämfört med 1990 och med 0,9 % jämfört med 2015. Detta förklaras framförallt av en minskad användning av mineralgödsel. År 2016 stod lustgas för cirka 9 % av de totala utsläppen av växthusgaser. Utsläpp av lustgas härrör huvudsakligen från jordbrukssektorn (cirka 76 %).

De totala utsläppen av fluorerade växthusgaser (PFCs, HFCs och SF₆) var närmare en miljon ton koldioxidekvivalenter år 2016 vilket är 43 % högre jämfört med 1990. Den högre nivån beror främst på att ozonförstörande ämnen ersatts av växthusgaser HFCs. Utsläppen av HFCs har dock minskat med närmare 19 % mellan 2009 och 2016 till följd av införandet av en ny EU-förordning 2006. Samtliga rapporterade fluorerade växthusgaser står för 1,8 % av de totala utsläppen av växthusgaser.

Tabell S.1. Utsläpp av växthusgaser per gas (kt CO₂ ekvivalenter)

UTSLÄPP AV VÄXTHUSGASER	1990	1995	2000	2005	2010	2014	2015	2016
CO ₂ inkl. LULUCF	19 833	25 017	14 961	19 075	6 528	1 245	-3 140	-2 052
CO ₂ exkl. LULUCF	57 506	59 276	54 725	53 843	52 927	43 226	43 386	42 568
CH ₄ inkl. CH ₄ från LULUCF	8 071	8 039	7 493	6 828	5 895	5 392	5 258	5 185
CH ₄ exkl. CH ₄ från LULUCF	7 602	7 568	7 018	6 354	5 441	4 923	4 818	4 746
N ₂ O inkl. N ₂ O från LULUCF	7 009	7 193	6 996	6 292	6 107	5 898	5 787	5 817
N ₂ O exkl. N ₂ O från LULUCF	5 730	5 905	5 691	4 962	4 803	4 680	4 566	4 606
HFCs	6	130	721	1 006	990	910	897	883
PFCs	569	532	376	406	188	82	35	31
SF ₆	102	135	119	152	63	46	53	59
NF ₃	NO	NO	NO	NO	NO	NO	NO	NO
Ospecificerade HFCs and PFCs	NO	NO	NO	NO	NO	NO	NO	NO
Total (inkl. LULUCF)	35 589	41 046	30 666	33 759	19 771	13 572	8 890	9 923
Total (exkl. LULUCF)	71 515	73 547	68 649	66 722	64 412	53 866	53 755	52 893

Tabell S.2. Utsläpp av växthusgaser per sektor (kt CO₂ ekvivalenter)

Källor till utsläpp & sänkor	1990	1995	2000	2005	2010	2014	2015	2016
1. Energy	53 023	54 763	50 006	48 982	48 126	38 838	38 980	37 790
2. Industrial Processes and Product Use	7 120	7 316	7 656	8 027	7 548	6 543	6 509	6 895
3. Agriculture	7 630	7 905	7 765	7 040	6 813	6 990	6 864	6 879
4. LULUCF	-35 926	-32 500	-37 983	-32 963	-44 641	-40 294	-44 865	-42 969
5. Waste	3 742	3 562	3 222	2 673	1 924	1 494	1 402	1 328
6. Other	NO	NO	NO	NO	NO	NO	NO	NO
Total (inklusive LULUCF)	35 589	41 046	30 666	33 759	19 771	13 572	8 890	9 923

S 3. Översikt av utsläppstrender per sektor

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

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

CRF	Sektor	Primär källa till aktivitetdata/utsläppsdata
1	Energi	
	-Stationär förbränning	Statistiska undersökningar av energiförbrukning
	-Transport	Transportmyndigheter
2	Industriprocesser och produktanvändning	Miljörapporter
		Statistiska undersökningar av energiförbrukning
		Direktkontakt med företag
		EU:s system för handel med utsläppsrätter
		Nationella data från produktregistret på
		Kemikalieinspektionen
		Nationella experter
3	Jordbruk	Officiella statistiska rapporter
		Organisationer och forskare
4	Markanvändning, förändrad markanvändning och skogsbruk	Sveriges lantbruksuniversitet
		Skogsstyrelsen
5	Avfall	Avfall Sverige (fd RVF)
		Skogsindustrierna
		Statistiska centralbyrån
		Naturvårdsverket
		Energimyndigheten/Energigas Sverige
		Miljörapporter

Utsläppen från energisektorn (CRF 1), inklusive transporter, var under 2016 cirka 38 miljoner ton koldioxidekvivalenter, vilket motsvarar 71 % av de totala utsläppen. Trenden för perioden 1990 till 2016 visar på minskade utsläpp om 29 %. Utsläppsminskningen beror huvudsakligen på minskad olje användning för uppvärmning av bostäder och lokaler som ingår i ”Övriga sektorer” (CRF 1A4). ”Övriga sektorer” har minskat utsläppen med 72 % till omkring 3,2 miljoner ton koldioxidekvivalenter 2016. Utsläppen i energisektorn var 3 % lägre 2016 jämfört med 2015, beroende på minskade utsläpp från transportsektorn.

Energiindustrins (CRF 1A1) totala utsläpp var 9,2 miljoner ton koldioxidekvivalenter 2016, vilket är 8 % lägre med jämfört med 1990. Energiindustrin domineras av el- och fjärrvärmeproduktionen (CRF 1A1a) som stod för 6,8 miljoner ton koldioxidekvivalenter 2016, vilket är 14 % lägre än 1990. Utsläppen från el- och värmeproduktionen varierar mellan åren, framförallt på grund av vädrets (temperatur och nederbörd) påverkan på utsläppen. Utsläppen från el- och fjärrvärmeproduktionen var 6 % högre 2016 än 2015, vilket beror främst på kallare väder. Utsläpp från förbränning i raffinaderier (CRF 1A1b) och koksverk (CRF 1A1c) var 2,4 miljoner ton koldioxidekvivalenter 2016.

Utsläpp från förbränning inom tillverkningsindustrin och byggsektorn (CRF 1A2) var oförändrade 2016 jämfört med 2015. Utsläppen har minskat sedan med motsvarande 33 % sedan 1990, men varierar mellan åren med förändrade produktionsvolymerna som är kopplade till konjunktursvängningar. Utsläppsminskningen beror till största delen på minskad olje användning, som delvis kan förklaras av en övergång till el och biobränslen.

Utsläppen från transportsektorn (CRF 1A3) står för en tredjedel av de nationella utsläppen av växthusgaser. Utsläppen från transportsektorn var 16,9 miljoner ton koldioxidekvivalenter under 2016, varav knappt 16 miljoner ton från vägtransporter. Utsläppen från transportsektorn minskade med 5 % från 2015 till 2016 och utsläppen var 12 % lägre 2016 jämfört med 1990. Den lägre utsläppsnivån beror på att andelen biobränsle som används inom vägtrafiken har ökat och energieffektivare tekniker. Utsläppsminskningen har dock dämpats av att trafikarbetet har ökat.

Utsläppen av växthusgaser från industriprocesser och produktanvändning (CRF 2) uppgick till 6,9 miljoner ton koldioxidekvivalenter år 2016, vilket motsvarar cirka 13 % av Sveriges totala utsläpp. Inom sektorn är koldioxid den dominerande växthusgasen (82 %), 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 6 % högre 2016 jämfört med 2015. Trenden för perioden 1990-2016 visar på minskade utsläpp om cirka 3 %. Utsläppen från produktanvändning var betydligt högre 2016 jämfört med 1990, men visar på en minskande trend sedan 2010.

Utsläppen inom jordbrukssektorn (CRF 3) har minskat med 0,75 miljoner ton CO₂-ekvivalenter, vilket motsvarar en minskning om knappt 10 % mellan 1990 och 2016. De främsta orsakerna till utsläppstrenden för jordbrukssektorn sedan 1990 är minskat antal djur, främst mjölkkor och svin, samt minskade lustgasutsläpp från odlingsmark till följd av en successiv minskning av användning av mineralgödsel. Under 2016 ökade de samlade utsläppen från jordbrukssektorn marginellt, med 0,2 %, jämfört med föregående år. Det förklaras främst av en ökad användning av organisk gödsel (CRF 3Da2c) samt gödsel från betesdjur (CRF 3Da3). Denna sektor är den största källan till utsläpp av lustgas och metan. År 2016 var de totala utsläppen från jordbrukssektorn 6,9 miljoner ton koldioxidekvivalenter eller 13 % av de nationella totala utsläppen. Av dessa utsläpp var ungefär hälften lustgas och hälften metan.

Nettoupptaget för sektorn markanvändning, förändrad markanvändning och skogsbruk (LULUCF - CRF 4) har under 2016 uppskattas till cirka 43 miljoner ton koldioxidekvivalenter. Större delen av nettoupptaget sker i kolpoolerna levande biomassa och mineraljord. Det är framförallt på skogsmark som det stora koldioxidupptaget sker. Skogsmark utgör 63 % av Sveriges landareal. Det totala upptaget för skogsmark ökade från cirka 37 miljoner ton till omkring 41 miljoner ton koldioxidekvivalenter mellan 1990 och 2016. Nettoupptaget påverkas av störningar i skördar samt naturliga störningar som stormer. Nettoutsläppen inom LULUCF-sektorn beror främst på dränerade torvjordar. Dessa nettoutsläpp har dock minskat något sedan 1990, från cirka 9 miljoner ton till cirka 8 miljoner ton koldioxidekvivalenter.

Utsläppen från avfallssektor (CRF 5) har minskat med ca 65 % jämfört med 1990. Från 2015 till 2016 minskar utsläppen med 5,2 % till följd av fortsatt minskade utsläpp från avfallsdeponier. Utsläppen från avfallssektorn domineras av metangas från avfallsdeponier. Metangasutsläpp står för 77 % av utsläppen, medan lustgasutsläpp från avloppsvattensbehandling samt biologisk behandling av fast avfall står för 18 % och koldioxidutsläpp från förbränning av avfall står för resten. Förbud har införts att deponera avfall och successivt har man övergått till framförallt förbränning av avfall för energiåtervinning. Utsläpp från förbränning av avfall för produktion av el och värme allokeras till energisektorn och inte till avfallssektorn. 2016 var de totala utsläppen från avfallssektorn 1,3 miljoner ton koldioxidekvivalenter, vilket motsvarar 2,4 % av de totala växthusgasutsläppen.

S 4. Översikt av utsläppstrender för indirekta växthusgaser och SO₂

De indirekta växthusgaserna NO_x, NMVOC, CO och SO₂ 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 SO₂ (tusentals ton)

Gas	1990	1995	2000	2005	2010	2014	2015	2016
NO_x	281	251	217	185	158	140	135	131
NMVOC	354	263	224	212	184	161	162	159
SO₂	104	69	43	36	29	20	18	19
CO	1 078	940	680	560	492	438	428	430

Utsläppen av kväveoxider (NO_x) var cirka 131 tusen ton 2016. Energisektorn står för 81 % av totalen. Utsläppen av kväveoxider har minskat med mer än hälften (53 %) sedan 1990 och med 3 % sedan 2015. Detta beror främst på skärpta utsläppskrav för bilar inom EU. Den ökade användningen av fjärrvärme och införandet av NO_x-avgiftssystemet under början av 1990-talet har också lett till en minskning av utsläppen.

Utsläppen av flyktiga organiska ämnen (NMVOC) var 159 tusen ton 2016. Industriprocesser och produktanvändning (framför allt från lösningsmedel och andra produkter) och energisektorn (framför allt vägtrafik och småskalig vedeldning för uppvärmning av bostäder) är de dominerande källorna till utsläppen, och bidrar med 47 % respektive 34 %. Utsläppen av flyktiga organiska ämnen har minskat kraftigt, med 55 %, sedan 1990. De totala utsläppen minskade marginellt jämfört med 2015. Den största reduktionen av utsläpp av NMVOC har skett inom transportsektorn där utsläppen 2016 minskade med 92 % sedan år 1990 och med 8 % jämfört med 2016. Utsläppen av NMVOC har även minskat med 63 % från oljeraffinaderier sedan 1990 och med 30 % inom produktanvändning. Huvudanledningen till den skarpa reduktionen av utsläppen sedan 1990 är ökat antal energieffektiva bilar, introduktion av nya avgasreningskrav för fordon samt minskade utsläpp från användning av lösningsmedel.

Utsläppen av svaveldioxid (SO₂) var 19 tusen ton år 1990 och har minskat med 82 % sedan 1990. Utsläppen har minskat med ca 6 % från 2015 till 2016, främst inom massa och pappersindustrin. Hälften av SO₂-utsläppen kommer från energisektorn (framför allt från el- och fjärrvärmeproduktion) och hälften från industriprocesser och produktanvändning, såsom metallproduktion och pappersmassaindustrin. Den långsiktiga reduktionen av utsläppen beror framförallt på en övergång till bränslen med lägre svavelhalt, framförallt inom inrikes sjöfart där utsläppen har minskar med hela 98 % sedan 1990.

Utsläppen av kolmonoxid (CO) har minskat med 60 % sedan 1990 och är cirka 0,43 miljoner ton år 2016. Utsläppen har dock varit relativt konstanta mellan 2015 och 2016. Cirka 93 % av kolmonoxidutsläppen härrör från energisektorn, varav 20 % kommer från transporter och 32 % från småskalig uppvärmning av bostäder.

Executive Summary

ES 1. Background Information

Greenhouse gases have always been present in the atmosphere, but now concentrations of several of them are rising as a result of human activity, which intensifies the greenhouse effect. The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 and two years later they concluded that anthropogenic climate change is a global threat, which needs to be addressed through an international agreement. The United Nations started negotiations on a framework convention on climate change (UNFCCC), which came into force in 1994. The long-term goal of the convention is to stabilize the amount of greenhouse gases in the atmosphere at a level where harmful anthropogenic climate changes are prevented.

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

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

The first commitment period of the Kyoto Protocol involves binding obligations for the parties that ratified the protocol (the Annex I parties) to decrease their emissions of greenhouse gases (GHG) with at least 5 % during 2008-2012

compared to the base year 1990. Under the first commitment period of the Kyoto Protocol the European Union, together with Iceland, agreed to reduce their emissions by 8 compared to the base year 1990 (for fluorinated greenhouse gases the base year is 1995). In 2012 the parties under the Kyoto Protocol decided on a second commitment period (2013 to 2020) according to the Doha Amendment to the Kyoto Protocol 1/CMP.8. Under this commitment period the EU has, together with Iceland, committed to reduce the emissions by 20 % by 2020 compared to the emissions of greenhouse gases in 1990. The Swedish commitment within the EU is to reduce national emissions by 17 % until 2020 compared to 2005 within sectors that are not part of the EU Emissions Trading System.

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

This report covers anthropogenic emissions of direct greenhouse gases CO₂, CH₄, N₂O, HFC, PFC, SF₆, NF₃ and indirect greenhouse gases NO_x, CO, NMVOC and SO₂. The report contains information on Sweden's inventories of greenhouse gases for all years from 1990 to 2016, including descriptions of methods, data sources, uncertainties, the quality assurance and quality control (QA/QC) activities carried out as well as a trend analysis.

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

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

ES 2. Summary of national emissions and removal trends

Total greenhouse gas emissions in Sweden excluding LULUCF, expressed in CO₂-equivalent, were about 52.9 million tonnes in 2016 (Table ES.1). The emissions that are not covered by the EU ETS amounted to 32.6 million tonnes, which is 64% of total emissions. Total emissions have decreased by approximately 1.6 % compared to 2015 and by about 26% compared to 1990. In 2016, the net uptake within the land use, land-use change and forestry (LULUCF) sector remained at a relatively high level. The net uptake has increased by nearly 40% since 1990 because growth in forests and land has been greater than harvests. Net removals are influenced by disturbances due to harvests and natural disturbances such as storms.

The national emissions of carbon dioxide (CO₂) were 26% lower in 2016 compared to 1990. CO₂ emissions accounted for approximately 43 Mt in 2016, which is about 80% of the overall GHG emissions in 2016. The energy sector, including transport, accounted for 86 % of the overall carbon dioxide emissions, which makes it the largest source of carbon dioxide in Sweden.

Since 1990, methane emissions (CH₄) have decreased by 38%, mainly due to measures in the waste sector. The agricultural sector also shows reduced emissions. Between 2015 and 2016, emissions have decreased by 1.5%. Methane emissions were 4.7 million tonnes of carbon dioxide equivalents by 2016, which corresponds to approximately 9% of total greenhouse gas emissions. Methane emissions are mainly from agriculture, landfills and fossil fuels burning in the energy sector.

Nitrous oxide emissions (N₂O) were 4.6 million tonnes of carbon dioxide equivalent in 2016, which is a decrease of about 20% compared to 1990 and 0.9% compared to 2015. This is mainly due to a reduction in mineral fertilizer use. In 2016, nitrous oxide about 9% of total greenhouse gas emissions. Emissions of nitrous oxide originate mainly from the agricultural sector (approximately 76%).

Emissions of fluorinated greenhouse gases (PFCs, HFCs and SF₆) were close to one million tonnes of carbon dioxide equivalents by 2016, which is 43% higher compared to 1990. This is mainly due to the replacement of ozone-depleting substances by greenhouse gases HFCs. However, emissions of HFCs have decreased by almost 19% between 2009 and 2016 due to the introduction of a new EU regulation in 2006. All reported fluorinated greenhouse gases account for 1.8% of total greenhouse gas emissions.

Table ES.1. Greenhouse gas emissions by gas (kt CO₂-eq.)

GREENHOUSE GAS EMISSIONS	1990	1995	2000	2005	2010	2014	2015	2016
CO ₂ inkl. netto CO ₂ from LULUCF	19 833	25 017	14 961	19 075	6 528	1 245	-3 140	-2 052
CO ₂ exkl. netto CO ₂ from LULUCF	57 506	59 276	54 725	53 843	52 927	43 226	43 386	42 568
CH ₄ inkl. CH ₄ from LULUCF	8 071	8 039	7 493	6 828	5 895	5 392	5 258	5 185
CH ₄ exkl. CH ₄ from LULUCF	7 602	7 568	7 018	6 354	5 441	4 923	4 818	4 746
N ₂ O inkl. N ₂ O from LULUCF	7 009	7 193	6 996	6 292	6 107	5 898	5 787	5 817
N ₂ O exkl. N ₂ O from LULUCF	5 730	5 905	5 691	4 962	4 803	4 680	4 566	4 606
HFCs	6	130	721	1 006	990	910	897	883
PFCs	569	532	376	406	188	82	35	31
SF ₆	102	135	119	152	63	46	53	59
NF ₃	NO	NO	NO	NO	NO	NO	NO	NO
Unspecified mix of HFCs and PFCs	NO	NO	NO	NO	NO	NO	NO	NO
Total (incl. LULUCF)	35 589	41 046	30 666	33 759	19 771	13 572	8 890	9 923
Total (exkl. LULUCF)	71 515	73 547	68 649	66 722	64 412	53 866	53 755	52 893

Table ES.2. Greenhouse gas emissions by sector (kt CO₂-eq.)

GHG SOURCE & SINK CATEGORIES	1990	1995	2000	2005	2010	2014	2015	2016
1. Energy	53 023	54 763	50 006	48 982	48 126	38 838	38 980	37 790
2. Industrial Processes and Product Use	7 120	7 316	7 656	8 027	7 548	6 543	6 509	6 895
3. Agriculture	7 630	7 905	7 765	7 040	6 813	6 990	6 864	6 879
4. LULUCF	-35 926	-32 500	-37 983	-32 963	-44 641	-40 294	-44 865	-42 969
5. Waste	3 742	3 562	3 222	2 673	1 924	1 494	1 402	1 328
6. Other	NO	NO	NO	NO	NO	NO	NO	NO
Total (including LULUCF)	35 589	41 046	30 666	33 759	19 771	13 572	8 890	9 923

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

The sectors included in the inventory and the main sources used for activity data and/or emission data are presented in Table ES.3. The emissions are collected directly from these data sources, or calculated based on activity data. Greenhouse gas emissions are shown by sector in Table ES.2.

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

CRF	Sector	Main source for activity/emission data
1	Energy	
	-Stationary combustion	Statistical survey on energy consumption
	-Transport	Transport authorities
2	Industrial processes and product use	Environmental reports Statistical survey on energy consumption 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 National experts
3	Agriculture	Official statistical reports Organisations and researchers
4	Land Use, Land Use Change and Forestry	Swedish University of Agricultural Sciences Swedish Forest Agency
5	Waste	Swedish Association of Waste Management The Swedish Forest Industries Federation Statistics Sweden Swedish Environmental Protection Agency Environmental reports

Emissions from the energy sector (CRF 1), including transport, were approximately 38 million tonnes of CO₂-equivalent in 2016, which corresponds to about 71% of the overall national greenhouse gas emissions. The trend for the period 1990-2016 show a general reduction in emissions of approximately 29%. This decrease is mainly due to a decrease in the use of oil for heating in residential, commercial and institutional buildings, included in “Other Sectors” (CRF 1A4). Emissions in “Other Sectors” have decreased by 72%, to approximately 3.2 million tonnes of CO₂-equivalent in 2016. Emissions decreased by 3% between 2015 and 2016 in the energy sector, primarily as a result of decreased emissions from transports.

Greenhouse gas emissions from energy industries (CRF 1A1) were approximately 9.2 million tonnes in 2016, which is 8% lower compared to 1990. The energy industries are dominated by electricity and district heating production (CRF 1A1a) with emissions of 6.8 million tonnes of CO₂-equivalent in 2016, which is 14% lower than in 1990. Emissions from electricity and district heating production fluctuate over the years mainly due to the influence of weather conditions (temperature and precipitation). The emissions from electricity and district heating production increased by 6% in 2016 compared to 2015, which was primarily due to colder weather. Emissions from Refineries (CRF 1A1b) and Manufacture of solid fuels (CRF 1A1c) amounted to 2.4 million tonnes in 2016.

Emissions from manufacturing industries and construction (CRF 1A2) were unchanged in 2016 compared to the previous year. These emissions decreased by 33% in 2016 compared to 1990, but generally fluctuate with production volumes that are closely related to the economic development. The decrease in emissions is mainly due to decreased use of oil products, which can partly be explained by a shift towards electricity and biofuels.

Emissions from the transport sector corresponds to one third of the national emissions of greenhouse gases. In 2016, emissions were approximately 16.9 million tonnes, of which close to 16 million tonnes were from road transportation. Emissions from the transport sector decreased by 5% from 2015 to 2016 and were 12% lower 2016 compared to 1990. The lower emissions level can be explained by an increased share of renewable fuels and more fuel-efficient vehicles. Nevertheless, the emissions reductions have been dampened by an increased trend in the amount of traffic.

Greenhouse gas emissions from the industrial processes and product use (CRF 2) were 6.9 million tonnes CO₂-equivalent in 2016 (Table ES.2), representing approximately 13% of the national emissions. Emissions from industrial processes and product use are predominantly carbon dioxide (82 %), 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 6% higher 2016 compared to 2015. The trend for the period 1990-2016 shows

decreasing emissions of 3%. Emissions from product use were significantly higher in 2016 compared to 1990, but show a decreasing trend since 2010.

Emissions in the agricultural sector (CRF 3) have decreased by 0.75 million tonnes of CO₂-equivalent, which represents a decrease of almost 10% between 1990 and 2016. The main causes of the emission trend for the agricultural sector since 1990 are reduced numbers of animals, mainly dairy cows and pigs, as well as reduced greenhouse gas emissions from cultivated land due to a gradual reduction of mineral fertilizer use. In 2016, total emissions from the agricultural sector increased marginally, by 0.2%, compared with the previous year. This is mainly due to increased use of organic fertilizer (CRF 3Da2c) and manure from grazing animals (CRF 3Da3). This sector is the largest source of nitrous oxide and methane emissions. By 2016, total emissions from the agricultural sector were 6.9 million tonnes of carbon dioxide equivalent or 13% of national total emissions. Of these emissions, about half were nitrous oxide and half methane.

In 2016, the net removal in the sector land use, land-use change and forestry (LULUCF) was estimated to circa 43 million tonnes CO₂-equivalent. The majority of the net removals place in living biomass and mineral soils. The largest carbon pool is forest land. Forest land accounts for 63% of Sweden's land area. The net removal in forest land increased from about 37 million tonnes to about 41 million tonnes of carbon dioxide equivalents between 1990 and 2016. The net removals are influenced by disturbances due to harvests and natural disturbances such as storms. The net emissions in the LULUCF sector mainly depend on drainage peat soils. However, these net emissions have decreased slightly since 1990, from about 9 million tonnes to about 8 million tonnes of carbon dioxide equivalents.

Emissions from the waste sector (CRF 5) have decreased by about 65% compared to 1990. From 2015 to 2016, emissions have been reduced by 5.2% due to continued reduced emissions from landfills. Emissions from the waste sector are dominated by methane gas from waste landfills. Methane emissions account for 77% of emissions, while nitrous oxide emissions from wastewater treatment and biological treatment of solid waste account for 18% and carbon dioxide emissions from waste incineration account for the rest. A ban has been introduced on landfill which has created a shift towards incineration of waste for energy recovery. Emissions from the incineration of waste for electricity and heat production are allocated to the energy sector and not to the waste sector. In 2016, emissions from the waste sector were 1.3 million tonnes of carbon dioxide equivalent, which corresponds to 2.4% of the total greenhouse gas emissions.

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

Indirect greenhouse gases are not included in the national total. They are shown in Table ES.4.

Table ES.4. Emissions of indirect greenhouse gases and SO₂ (kt)

Gas	1990	1995	2000	2005	2010	2014	2015	2016
NO_x	281	251	217	185	158	140	135	131
NM VOC	354	263	224	212	184	161	162	159
SO₂	104	69	43	36	29	20	18	19
CO	1 078	940	680	560	492	438	428	430

Emissions of nitrogen oxides (NO_x) were about 131 thousand tonnes in 2016. The energy sector accounts for 81% of the total. Emissions of nitrogen oxides have fallen by more than half (53%) since 1990 and by 3% since 2015. This is mainly due to the tightening of the EU road vehicle emission regulation standards. The increased use of district heating and the “NO_x charge” in the early 1990s have also resulted in a reduction of emissions.

In 2016, a total of 159 thousand tonnes of non-methane volatile organic compounds (NMVOCs) were emitted in Sweden. Industrial processes and product use (mainly solvents and product use) and the energy sector (mainly road transportation, wood combustion in the residential sector) are the predominant sources of emissions, contributing with 47% and 34%, respectively. Emissions of NMVOCs have declined sharply, by about 55%, since 1990, and decreased marginally compared to 2015. The largest decline has occurred in the transport sector where emissions have decreased by 92% compared to 1990 and by 8% compared to 2015. NMVOC emissions have also decreased by 63% from oil refineries since 1990 and by 30% in product use. The main reason behind the reduction of emissions is the introduction of stricter emission standards in the EU regulation for road vehicles and lower emissions from solvents.

Emissions of sulphur dioxide (SO₂) are 19 thousand tonnes in 2016, which corresponds to a reduction of 82% compared to 1990. The emissions in 2016 have decreased by 6% in 2016 compared to 2015. About half of the sulphur dioxide emissions derive from the energy sector (mainly electricity and district heating production) and half from industrial processes and product use, such as metal production and pulp and paper industry. The long-term reduction is mainly due to a transfer from fuels with high sulphur content to low-sulphur fuels, mainly in domestic shipping, where emissions have fallen by 98% since 1990.

Carbon monoxide (CO) emissions have decreased by 60% since 1990 and are around 0.43 million tons in 2016. Nevertheless, emissions have been relatively

constant between 2015 and 2016. More than 93% of the emissions arise from the energy sector, of which about 20% comes from transport sector and about 34% from residential heat production.

Summary in Arabic

مقدمة

إن التغيرات المناخية التي نشهدها في عصرنا الحالي يعود سببها إلى زيادة تراكيز غازات الدفيئة (CO_2 , CH_4 , N_2O , SF_6 , PFC , HF) في الغلاف الجوي. لقد كانت هذه الغازات موجودة دائماً وبشكل طبيعي في الغلاف الجوي ولكن بتركيز قليلة. أظهرت البيانات والتحليلات الكيميائية للغلاف الجوي في العقدين الماضيين إزدياداً مضطرباً لتركيز هذه الغازات مقارنةً عما كانت عليه في العقود الأخيرة. وبالرغم من وجود هذه الغازات دائماً وبشكل طبيعي في الغلاف الجوي، فإن تراكيز بعضها أخذت في الارتفاع نتيجة لإزدياد النشاط البشري متمثلاً في حرق المشتقات البترولية للحصول على الطاقة ومن خلال النشاطات الزراعية، والذي بدوره يفاقم من حدة ظاهرة الاحتباس الحراري.

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

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

يشكل هذا التقرير (NIR submission 2018) جرداً سنوياً لانبعاثات غازات الدفيئة المباشرة (CO_2 , CH_4 , N_2O , HFC , PFC , SF_6) وغير المباشرة (SO_2 , CO , NO_x , NMVOC) في الغلاف الجوي الناتجة من النشاطات البشرية في السويد لعام 2016 بالإضافة إلى معلومات عن قوائم الجرد لغازات الاحتباس الحراري لجميع السنوات من 1990 إلى 2016، بما في ذلك وصفا للطرق التحليل و معلومات أخرى متعلقة.

نظرة عامة على تقديرات انبعاثات غازات الدفيئة المباشرة واتجاهاتها

قوائم جرد غازات الدفيئة

تقديرات انبعاثات غازات الدفيئة واتجاهاتها ما بين الفترة 1990-2016 ملخصة في الرسم البياني أدناه. بلغ مجموع انبعاثات غازات الدفيئة في السويد لعام 2016 ما يقارب 53 مليون طن مكافئ محسوبة بما يعادلها من ثاني أكسيد الكربون، بإنخفاض بنحو 0.76 طن مقارنةً بعام 2015. وتراجعت الانبعاثات بنسبة حوالي 26% أو ما يزيد على 18 مليون طن بين عامي 1990 و 2016. وفي عام 2016، تم تقدير صافي امتصاص غاز ثاني أكسيد الكربون بواسطة الغابات والاراضي الحرجية بحوالي 42 مليون طن مكافئ ثاني أكسيد الكربون.

أنظر Figure 2.1 لمقادير الانبعاثات الصادرة من القطاعات المختلفة في السويد ما بين 1990-2016 مقدرة بمليون طن مكافئ ومحسوبة بما يعادلها من ثاني أكسيد الكربون. يمثل قطاع تغيير استخدام الأراضي والحراجة (LULUCF) بالمجمل قطاعاً لامتصاص غاز ثاني أكسيد الكربون.

غاز ثاني أكسيد الكربون (CO₂)

بلغت انبعاثات CO₂ حوالي 42,7 مليون طن في عام 2016، منخفضاً بما يقارب 26% مقارنةً بعام 1990. ويستحوذ قطاع الطاقة، بما في ذلك قطاع النقل، على أكثر من 86% من إجمالي الانبعاثات، لذا يعتبر هذا القطاع المصدر الأكبر لغاز ثاني أكسيد الكربون في السويد. ويمثل هذا الغاز حوالي 81 بالمئة من الانبعاثات الإجمالية لغازات الدفيئة.

غاز الميثان (CH₄)

ينبعث غاز الميثان (CH₄) بشكل أساسي من النشاطات الزراعية ومواقع مكبات النفايات حيث يتكون غاز الميثان خلال عمليات الهضم للحيوانات المجتررة وعمليات التخمر لروث هذه الحيوانات في المزارع. أما في قطاع النفايات فيتكون الميثان نتيجة تخمر النفايات العضوية. كان مجمل الإنبعاث في عام 2016 بحوالي 4.6 مليون طن مكافئ محسوبة بما يعادلها من ثاني أكسيد الكربون، منخفضاً حوالي 38% مقارنة مع عام 1990، ويرجع هذا الانخفاض في المقام الأول إلى التدابير المنفذة في قطاع النفايات والزراعة والتي تحد من تكون الميثان من هذين القطاعين.

غاز أكسيد النيتروز (N₂O)

في عام 2016، بلغت انبعاثات أكسيد النيتروز (N₂O) حوالي 4.6 مليون طن مكافئ محسوبة بما يعادلها من ثاني أكسيد الكربون، منخفضاً بنسبة 20% مقارنة مع عام 1990. ينشأ هذا الغاز أساساً من قطاع الزراعة وخصوصاً من تخمر روث حيوانات المزارع ومن خلال إنبعاث هذا الغاز من السماد العضوي وغير العضوي المستعمل لتحسين مستوى المحاصيل الزراعية. كما يتكون هذا الغاز خلال عمليات إحتراق الوقود المتعلقة في إنتاج الطاقة ومن خلال معالجة مياه الصرف الصحي والعمليات الصناعية. ويمثل القطاع الزراعي الجزء الأكبر من الانخفاض وذلك للتدابير المنفذة في القطاع للحد من إنبعاث هذا الغاز.

غازات الكربون المشبعة بالفلور

بلغ مجموع انبعاثات الغازات المفلورة (مركبات الكربون المشبعة بالفلور، ومركب سادس فلوريد الكبريت، SF_6) في عام 2016 ما يقارب من مليون طن مكافئ محسوبة بما يعادلها من ثاني أكسيد الكربون. القطاع الوحيد المسؤول عن هذه الانبعاثات هو قطاع الصناعة حيث تدخل مركبات الكربون المشبعة بالفلور في العديد من الصناعات مثل الاسفنج والمطاط الصناعي.

تقديرات الانبعاثات والإزالة لغازات الدفيئة من القطاعات المختلفة

قطاع الطاقة

تتأثر كميات الانبعاثات الناجمة من قطاع الطاقة بمعدل درجات الحرارة السنوية (شتاء بارد أو معتدل نسبياً) و معدل هطول الأمطار (وهذا يؤثر على معدل إنتاج الطاقة الكهرومائية) وحالة الاقتصاد (معدل الانتاج الصناعي وتأثره بالإنتعاش أو الركود). عموماً فإن اتجاه كميات الانبعاثات من قطاع الطاقة للفترة ما بين 1990-2016 يشير إلى انخفاض مستمر. في عام 2016 انخفضت انبعاثات الغازات المسببة للاحتباس الحراري بأكثر من الربع مقارنة بعام 1990 وذلك لانخفاض الانبعاثات الناجمة عن إنتاج الطاقة والنقل. لقد بلغ مجموع انبعاثات غازات الدفيئة من قطاع الطاقة بما في ذلك النقل لعام 2016 حوالي 38 مليون طن مكافئ محسوبة بما يعادلها من ثاني أكسيد الكربون. وهذا ما يعادل 71% من إجمالي الانبعاثات. وأصبحت كميات الانبعاثات الصادرة من قطاع المواصلات (حركة المرور على الطرق) عام 2016 تعادل تقريباً مستويات الانبعاثات الصادرة عن هذا القطاع لعام 1990.

انخفضت كميات ثاني أكسيد الكربون من إنتاج الكهرباء وطاقة التدفئة عام 2016 بمقدار 8% مقارنة مع عام 1990 بالرغم من إزدياد الحاجة للطاقة خلال هذه الفترة ويرجع هذا إلى الاعتماد بشكل أكبر على الطاقة الكهرومائية والطاقة النووية (نظراً لعدم إنتاج أية انبعاثات من هذه المصادر) وهذا أدى بدوره إلى انخفاض استخدام الوقود الأحفوري. في عام 2016 ارتفعت انبعاثات ثاني أكسيد الكربون من إنتاج الكهرباء وطاقة التدفئة بنحو 2% مقارنة مع عام 2015.

قطاع الصناعة

يعتبر ثاني أكسيد الكربون أبرز غازات الدفيئة الذي ينبعث من قطاع الصناعة تليه الغازات المفلورة، وأكسيد النيتروز وغاز الميثان بنسب ضئيلة.

معظم هذه الانبعاثات من هذا القطاع تصدر أساساً من العمليات الصناعية المتعلقة من إنتاج الحديد والصلب والمعادن في السويد. قدرت الانبعاثات الإجمالية من هذا القطاع في عام 2016 ما يقرب من 6.9 مليون طن مكافئ محسوبة بما يعادلها من ثاني أكسيد الكربون، مما يجعل هذا القطاع يمثل ما يقرب من 13% من إجمالي الانبعاثات الوطنية. لم تتخفض الانبعاثات الكلية من هذا القطاع بين عامي 2016 و 2015 بشكل ملحوظ. منذ عام 1990 وكميات الانبعاثات من قطاع الصناعة في تذبذب وذلك نتيجة لتذبذب حجم الإنتاج والذي يتأثر بحالة الاقتصاد العالمي لكنها انخفضت بشكل ضئيل (3) منذ عام 1990 (%).

قطاع الزراعة

يشكل قطاع الزراعة أكبر مصدر لانبعاثات غاز الميثان وغاز أكسيد النيتروز. في عام 2016، بلغ مجموع انبعاثات هذا القطاع حوالي 6.9 مليون طن مكافئ محسوبة بما يعادلها من ثاني أكسيد الكربون. ويشكل أكسيد النيتروز وغاز الميثان 51% و 47% على التوالي، بينما تبلغ حصة غاز

ثاني أكسيد الكربون حوالي 2% من هذا القطاع. لقد انخفضت الانبعاثات لعام 2016 بنسبة حوالي 10% مقارنة بعام 1990 وذلك يعود إلى انخفاض عدد المواشي في السويد وانخفاض استخدام الأسمدة الصناعية في الزراعة. يتكون غاز الميثان أساساً من خلال عمليات الهضم للحيوانات المجترة وكذلك من خلال عمليات التخمر لروث الماشية. أما انبعاثات أكسيد النيتروز فتتسبب من تبخر هذا الغاز من روث الحيوانات وكذلك نتيجة لاستخدام الأسمدة العضوية والصناعية وزراعة المحاصيل المثبتة للنيتروجين. وتأتي نصف هذه الانبعاثات من الأراضي الزراعية.

قطاع تغيير استخدام الأراضي والحراجة (LULUCF)

تتميز السويد باحتوائها على مساحات واسعة من الغابات والاحراج. في عام 2016 قدر صافي إزالة ثاني أكسيد الكربون (بواسطة امتصاص الأشجار لغاز ثاني أكسيد الكربون والتربة) من قطاع تغيير استخدام الأراضي والحراجة (LULUCF) بحوالي 43 مليون طن. وقد انخفض صافي الإزالة عام 2016 بشكل ملحوظ مقارنةً مع 2015.

قطاع النفايات

يهيمن غاز الميثان على الغازات الأخرى التي تصدر عن قطاع النفايات حيث بلغت انبعاثات الميثان في عام 2016 بنحو 78% من إجمالي انبعاثات هذا القطاع. في حين بلغت انبعاثات أكسيد النيتروز من معالجة مياه الصرف الصحي حوالي 18% وانبعاثات ثاني أكسيد الكربون الناتجة عن حرق النفايات نحو 4%. وفي عام 2016 كانت مجموع الانبعاثات من هذا قطاع ما يقرب من 1.3 مليون طن مكافئ محسوبة بما يعادلها من ثاني أكسيد الكربون. وتشكل هذه الكمية حوالي 3% من إجمالي انبعاثات غازات الدفيئة الوطنية. وبالمقارنة مع عام 1990 فقد انخفضت الانبعاثات بنحو 65% وذلك نتيجة لجمع غاز الميثان من مكبات النفايات حيث يتكون هذا الغاز خلال عمليات التخمر للنفايات العضوية. وقد لعبت مجموعة من القوانين المحلية دوراً بارزاً للحد من انبعاثات الميثان من النفايات، كفرض حظر على التخلص مباشرة من النفايات العضوية في المكبات. كما أن فرض ضريبة على طمر النفايات كان له دوراً رئيسياً في انخفاض الانبعاثات بشكل كبير انخفضت بنسبة الانبعاثات 5% عام 2016 مقارنةً بالعام 2015.

نظرة عامة على تقديرات انبعاثات غازات الدفيئة الغير المباشرة واتجاهاتها

لإلقاء نظرة على مقادير انبعاثات غازات الدفيئة الغير المباشرة واتجاهاتها ما بين الفترة 1990- 2016 (أنظر إلى 2.46, 2.48, 2.50, 2.52 Figure).

أكاسيد النيتروجين (NOx)

قدرت كميات انبعاثات أكاسيد النيتروجين في السويد عام بحوالي 131 كيلوطن منخفضاً بحوالي النصف مقارنة بعام 1990. كما انخفضت انبعاثات أكاسيد النيتروجين من حركة السير على الطرق بنسبة أكثر من 53% بين عامي 1990 و 2016. تعتبر كلاً من حركة السير على الطرق في المدن والمركبات النقل الكبيرة والنقل البحري وصناعة الكهرباء والتدفئة من أكبر مصادر انبعاثات أكاسيد النيتروجين. ونظراً لمساهمة حركة السير على الطرق الكبير لهذه الانبعاثات فقد أدخلت في أواخر الثمانينات من القرن الماضي الكثير من التعديلات التكنولوجية على المركبات وما رافقها من معايير أكثر صرامة للحد من هذه الانبعاثات حيث أسهمت هذه الإجراءات إلى خفض كبير لمستويات أكاسيد النيتروجين في السويد. وقد أدت زيادة استخدام التدفئة المركزية المعتمدة على الوقود في أوائل

تسعينات القرن الماضي إلى سن قانون يعرف "بضريبة انبعاثات أكاسيد النيتروجين" ونتيجة لهذا فقد إنخفضت انبعاثات أكاسيد النيتروجين من قطاع الطاقة بشكل كبير.

غاز أول أكسيد الكربون (CO)

يتكون غاز أول أكسيد الكربون من خلال عمليات حرق الوقود الاحفوري والعضوي في قطاع الطاقة مثل صناعة الطاقة والتدفئة وكذلك أثناء عملية الاحتراق في محركات المركبات. انخفضت انبعاثات أول أكسيد الكربون من 1.1 مليون طن في 1990 إلى 0.43 مليون طن في عام 2016 بمقدار 60%. ويصدر عن قطاع الصناعة معظم مجموع انبعاثات أول أكسيد الكربون، حيث ينتج من قطاع النقل والمواصلات، الذي ينضوي تحت قطاع الطاقة، بما قيمة الخمس من هذه الانبعاثات.

المركبات العضوية المتطايرة (NMVOC)

قدرت كميات انبعاثات المركبات العضوية المتطايرة عام 2016 بحوالي 159 كيلوطن، بانخفاض يزيد عن النصف مقارنة بعام 1990. تعتبر وسائل النقل على الطرق المساهم الرئيسي في انبعاثات المركبات العضوية المتطايرة. كما أن عمليات حرق الحطب للتدفئة المنزلية واستخدام المذيبات في المنتجات الصناعية كالدھانات تؤدي إلى انبعاث المركبات العضوية المتطايرة وبنسب متفاوتة. وقد أسهمت المعايير البيئية الغير إلزامية المتبعة في تقنيات مواقد الحطب الحديثة إلى خفض هذه الانبعاثات بشكل محسوس.

غاز ثاني أكسيد الكبريت (SO₂)

انخفضت انبعاثات ثاني أكسيد الكبريت من 104 كيلوطن في عام 1990 إلى ما يقرب من 19 كيلوطن في عام 2016 أي إنخفاضاً بنسبة 82% تقريباً. يأتي معظم ثاني أكسيد الكبريت من قطاعات الطاقة والنقل والصناعة. ويرجع الفضل لإنخفاض انبعاثات ثاني أكسيد الكبريت الكبيرة أساساً إلى الانتقال لإستخدام لأنواع الوقود المنخفض الكبريت بشكل عام كوقود المركبات أو وقود التدفئة. كما أن فرض ضريبة على الوقود الذي يحتوي على نسب عالية من الكبريت عام 1991 ساهم من الحد من هذه الانبعاثات.

Summary in French

Introduction

Les gaz à effet de serre ont toujours été présents dans l'atmosphère, mais la concentration de plusieurs d'entre eux a significativement augmenté en raison de l'activité humaine, ce qui a intensifié l'effet de serre. Dans ce rapport d'inventaire national sont présentées les émissions de gaz à effets de serre directes de CO₂, CH₄, N₂O, HFC, PFC, SF₆ et NF₃ ainsi que les émissions indirectes de NO_x, CO, COVNM et SO₂ pour la Suède sur la période 1990 à 2016. Les méthodes employées, les sources des données, les incertitudes, le contrôle qualité (QA/QC) et l'analyse de tendances sont décrites en accord avec les lignes directrices 2006 du GIEC ainsi que les compléments ultérieurs. Les données électroniques sur les émissions, sur les activités et sur les facteurs d'émission sont fournies dans le format d'inventaire commun (CRF) tel que demandé par la CCNUCC. La Suède suit par ailleurs des règles de confidentialité qui font que certaines données des catégories CRF1 et CRF2 ont été classées avec la clé de notation Classified (C). La Suède travaille pour limiter l'étendue de la confidentialité de ces données d'inventaire.

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

Résumé des émissions de gaz à effet de serre en Suède, par gas

Les émissions totales de gaz à effet de serre en Suède, hors secteur UTCATF (utilisation des terres, changement d'affectation des terres et foresterie), étaient de 52,9 millions de tonnes en 2016, ce qui est une baisse de 1,6% par rapport à 2015. Les émissions ont diminué de 26% entre 1990 et 2016.

En 2016, l'absorption nette au sein de l'utilisation des terres, changement d'affectation des terres et foresterie UTCATF est resté à un niveau relativement élevé (environ 50 millions de tonnes) et à environ 40% de plus par rapport à son niveau en 1990 car la croissance forestière a été supérieure à la récolte.

Les émissions de dioxyde de carbone (CO₂) étaient de 43 millions de tonnes ce qui représente 80% des émissions de GES en Suède. Par rapport à 1990 ces émissions ont baissées de 26%. Le secteur de l'énergie, y compris le transport, représente près de 86% des émissions totales de dioxyde de carbone.

Les émissions de méthane (CH₄) proviennent principalement de l'agriculture et des sites d'enfouissement, et se chiffraient à environ 4,7 millions de tonnes équivalent CO₂ en 2016, soit 9% du total. Depuis 1990, les émissions ont diminué d'environ 38%, principalement en raison des mesures mises en œuvre dans les secteurs des déchets et de l'agriculture.

En 2016, les émissions globales de protoxyde d'azote (N₂O) étaient d'environ 4,6 millions de tonnes exprimées en équivalent CO₂, soit 9% du total, en baisse d'environ 20% par rapport à 1990. Les émissions d'oxyde d'azote proviennent principalement de l'application d'engrais azotés dans le secteur agricole (environ 76%), mais aussi du domaine de l'énergie, le traitement des eaux usées et les procédés industriels et l'utilisation des produits. Les procédés industriels, l'usage de produits et le secteur agricole expliquent en grande partie la baisse de ces émissions.

Les émissions totales de gaz fluorés (PFC, HFC et SF₆) étaient en 2016 proches de 1 Mt exprimé en équivalent carbone, soit 1,8% du total. Ces émissions ont augmentées de 43% par rapport à 1990, principalement dû au remplacement des substances destructeurs de la couche d'ozone par les HFC. Cependant, les émissions de HFC ont depuis 2009 baissées de 19% à la suite d'une nouvelle directive européenne introduite en 2006.

Les émissions indirectes de gaz à effet de serre sont estimées à 1 millions de tonnes calculés en équivalent CO₂. Elles sont en baisse de 59% depuis 1990. Les émissions de CO représentent 58% du total.

Résumé des émissions de gaz à effet de serre en Suède, par secteur

Les émissions du secteur de l'énergie (CRF 1), y compris le transport, étaient d'environ 38 Mt ou équivalent CO₂ en 2016, ce qui correspond à environ 71% des émissions nationales totales de gaz à effet de serre. On observe une diminution de 29% sur la période 1990-2016, principalement due à une diminution de l'utilisation du pétrole pour le chauffage dans le secteur résidentiel, commercial et institutionnel, inclus dans les « autres secteurs » 1A4. Dans ce secteur, les émissions ont diminuées de 72% pour atteindre environ 3,2 millions de tonnes équivalent CO₂ en 2016. Entre 2015 et 2016, il y a eu une réduction de 3% des émissions dans le secteur de l'énergie, principalement en raison d'une réduction des émissions provenant des transports.

Les émissions de gaz à effet de serre du secteur des industries énergétiques (CRF 1A1) étaient d'environ 9,2 millions de tonnes en 2016, soit 8% de moins qu'en 1990. Les industries de l'énergie sont dominées par l'électricité et de chaleur (CRF 1A1A) avec des émissions de 6,8 millions de tonnes équivalent CO₂ en 2016, soit 14% de moins qu'en 1990. Les émissions provenant de l'électricité et la production de chaleur fluctuent au fil des années, principalement en raison de l'influence des conditions météorologiques (température et précipitations), mais ces émissions ont une tendance à la baisse. Les émissions de l'électricité et de la chaleur ont diminuées de 6% par rapport à 2015 dû à un hiver plus froid. Les émissions provenant des raffineries (CRF 1A1b) et de la fabrication de combustibles solides (CRF 1A1c) s'élevaient à 2,4 Mt en 2016.

Les émissions des industries manufacturières et de la construction (CRF 1A2) (un sous-secteur du secteur de l'énergie) sont demeurées inchangées en 2016 par rapport à l'année précédente. Ces émissions varient en fonction des volumes de production, qui sont eux-mêmes dépendants de la conjoncture économique. Cependant, la tendance générale montre une diminution de 33% par rapport à 1990, principalement du fait d'une diminution de l'utilisation des produits pétroliers, en partie expliquée par un transfert vers l'électricité et les biocarburants.

Les émissions du secteur des transports représentent environ un tiers des émissions nationales de gaz à effet de serre. En 2016, les émissions étaient environ 16,9 millions de tonne, 5% inférieur à celui de 2015 et 12% plus faibles par rapport au niveau de 1990. Une plus forte utilisation des carburants renouvelables et des véhicules économes ont compensé l'augmentation du trafic et contribué à cette tendance à la baisse.

En 2016, les émissions provenant des procédés industriels et de l'utilisation de produits (CRF 2) s'élevaient à 6,9 millions de tonnes équivalent CO₂, ce qui représente environ 13% des émissions nationales. Les émissions de ce secteur sont dominés par du dioxyde de carbone (82%), suivi par les gaz à effet de serre fluorés et de l'oxyde nitreux. Les industries des métaux (fer et acier) et des minéraux (ciment) sont les principales sources d'émissions. Les émissions du secteur CRF 2 ont augmenté de 6% en 2016 par rapport à 2015. La tendance pour la période de 1990 à 2016 montre une réduction des émissions de 3%. Les émissions provenant de l'utilisation des produits étaient significativement plus élevées en 2016 qu'en 1990, mais montrent une tendance à la baisse depuis 2010.

Le secteur de l'agriculture (CRF 3) est la plus grande source d'émissions d'oxyde nitreux et de méthane. En 2016, le secteur a contribué avec 6,9 millions de tonnes équivalent CO₂ ou 13% du total national, soit 51% était composé de N₂O, 47% ou CH₄ et environ 2% de CO₂. Les émissions du secteur ont diminué de 0,75 Mt équivalent CO₂ ou 10% par rapport à 1990. En 2016, les émissions globales du secteur agricole a légèrement augmenté de 0,2%.

En 2016, le stockage de carbone net dû à l'Utilisation des Terres, le Changement d'Affectation des Terres et la Foresterie (UTCATF) a été estimé à environ 43 millions de tonnes équivalent . 63 % de la superficie suédoise est couverte de forêts. La taille et la variabilité des absorptions nettes dans le secteur UTCATF est principalement dû à la variation des stocks de carbone dans les terres forestières, et les changements dans la biomasse vivante constituent la majeure partie de ces changements du fait du changement des stocks de carbone dans sols minéraux. Le stockage net est influencé par les récoltes et les perturbations naturelles telles que les tempêtes. La plus grande source d'émissions provient des terres cultivées des établissements humains.

PART 1: ANNUAL INVENTORY SUBMISSION 2018

1 Introduction

According to Articles 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC), Annex I Parties are required to annually submit national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol. The inventory submitted to the UNFCCC, through the secretariat, shall include emissions and removals in the Common Reporting Format (CRF) and a National Inventory Report (NIR). The submission is prepared in accordance with the reporting guidelines 24/CP.19 under the UNFCCC.

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

This report constitutes Sweden's NIR for submission 2018. The report contains information on Sweden's inventories for all years from 1990 to 2016 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 (QA/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 in 1997 in Kyoto, Japan. The Kyoto Protocol involved binding obligations for the Annex I countries (including all EU Member States and other industrialized countries).

1.1.2 Greenhouse gas inventories

The inventory covers anthropogenic emissions of direct greenhouse gases CO₂, CH₄, N₂O, HFCs, PFCs, SF₆, NF₃ and indirect greenhouse gases NO_x, CO, NMVOC and SO₂. 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 (O₃) is also a greenhouse gas, but it is not necessary to report on O₃ separately since it is formed by the chemical reactions of nitrogen oxides, hydrocarbons and/or carbon monoxide. The estimated emissions and removals of greenhouse gases are calculated according to the UNFCCC reporting guidelines (decision 24/CP.19).

The requirements of the Kyoto Protocol have led to an increased need for international supervision of the emissions reported by the Parties. The Kyoto Protocol therefore contains additional rules for how emissions and removals should be estimated, reported and reviewed. Emissions of the direct greenhouse gases CO₂, N₂O, CH₄, HFCs, PFCs, SF₆ and NF₃ are calculated as CO₂-eq. and aggregated to a national total. Emissions of the indirect greenhouse gases NO_x, CO, NMVOC and SO₂ are reported, but not included in the total.

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

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

Sweden provides supplementary information under Article 7 of the Kyoto Protocol for the Land Use, Land-Use Change and Forestry according to the requirements under the Kyoto Protocol. The inventory for Kyoto Protocol activities encompasses emissions and removals originating from the activities Afforestation and Reforestation (AR), Deforestation (D) and Forest Management (FM) under article 3.3 and 3.4 under the Kyoto Protocol, respectively. Forest Management covers a major part of the Swedish land area whereas Afforestation, Reforestation and Deforestation are quite uncommon relative to the total land area but important when it comes to reported emissions and removals.

Forest Management and Afforestation/Reforestation and Deforestation reporting under the Kyoto Protocol is to a large extent harmonized with the UNFCCC-reporting of Forest land and land converted to and from Forest land. Small discrepancies occur regarding the accumulation of reported land areas as described in section 10.

In addition to the reporting of carbon pool changes, direct N₂O emissions from N fertilization, non- CO₂ emissions from drained organic soils, emissions from mineralisation and emissions (N₂O and CH₄) from forest fires are reported under relevant activities. Forest fires – both natural and wildfires – are uncommon and, this far, has not been registered on afforestation land.

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

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

The Swedish commitment for the first commitment period of the Kyoto Protocol (2008–2012) was the same as the Swedish commitment under the EU burden sharing. The target was 104 % of the base year's emissions as an average for the years 2008–2012, excluding LULUCF. The base year was set to 1990 for all greenhouse gas emissions except fluorinated greenhouse gases for which 1995 was chosen. The emissions of the base year were 72.2 Mt CO₂-eq. when the assigned amount was determined.

Sweden's assigned amount for the first commitment period was set to 75 million units per year (one unit equals one t of CO₂-eq.), as an average for 2008–2012, amounting to 375 million units for the whole period.

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

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

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

The joint target under the Effort Sharing decision is split among the EU Member States and the Swedish target is a reduction of 17 % compared to 2005. For KP-LULUCF every member state has a commitment. Sweden has chosen to account

only for the mandatory activities under article 3.3, Afforestation/Reforestation and Deforestation and article 3.4, Forest Management.

1.1.6 National emission targets

1.1.6.1 THE SWEDISH TARGET FOR 2045

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

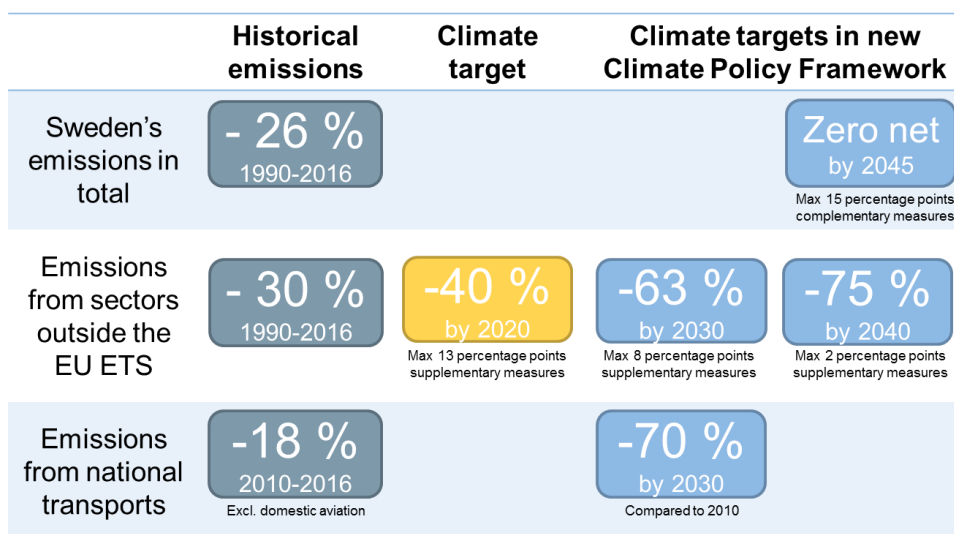


Figure 1.1 – Sweden's national targets

Targets

- By 2045, Sweden is to have no net emissions of greenhouse gases into the atmosphere and should thereafter achieve negative emissions. This means emissions from activities in Swedish territory are to be at least 85 % lower by 2045 compared with 1990.
- Emissions in Sweden outside of the EU ETS should, by 2030, be at least 63 % lower than emissions in 1990, and by 2040 at least 75 % lower. To achieve these targets by 2030 and 2040, no more than 8 and 2 percentage points, respectively, of the emissions reductions may be realised through supplementary measures.
- Emissions from domestic transport are to be reduced by at least 70 % by 2030 compared with 2010. Domestic aviation¹ is not included in the goal since this subsector is included in the EU ETS.

¹ The emissions only includes CO₂.

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

1.1.6.2 THE SWEDISH TARGET FOR 2020

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

1.2 Institutional arrangements

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

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

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

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

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

1.2.1 Legal arrangements

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

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

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

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

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

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

1.2.2 Institutional arrangements

Preparing the annual inventory and other reports is done in collaboration between the Ministry of the Environment and Energy, the Swedish Environmental Protection Agency and other government agencies and consultants. Sections 13-27

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

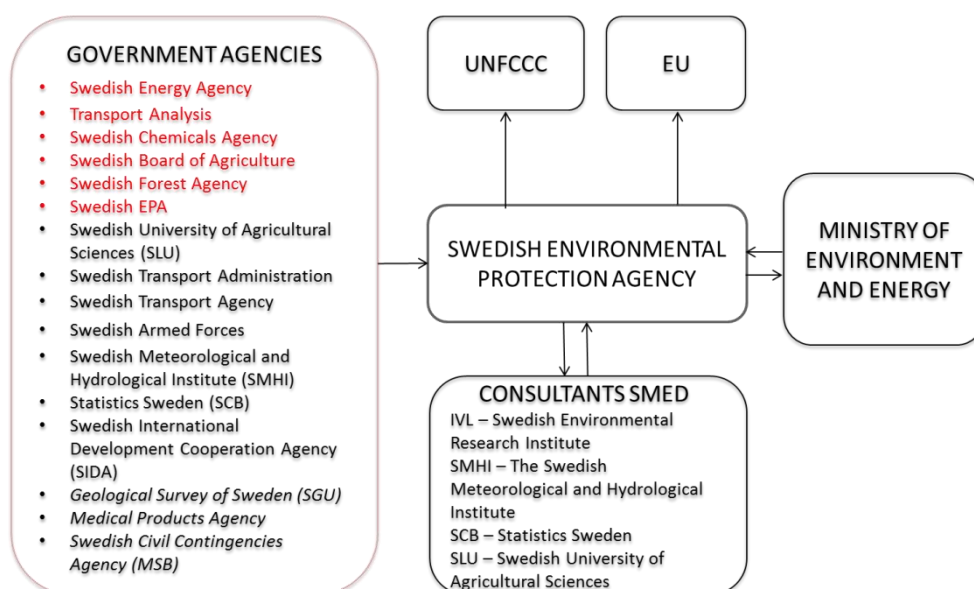


Figure 1.2. The Swedish national system on climate reporting

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

1.2.2.1 SINGLE NATIONAL ENTITY

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

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1.2.2.2 SWEDISH EPA RESPONSIBILITIES

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

The Swedish EPA sends the inventory to Ministry of the Environment and – on behalf of the Ministry of Environment – submits the inventory to the EU and to the UNFCCC. The Swedish EPA is also responsible for making the greenhouse gas inventory available to the public.

The National inventory compiler at the Swedish EPA is Ms. Frida Löfström.

1.2.2.3 AGENCIES RESPONSIBILITIES

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

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

Sector	Data and documentation provided by	Peer review conducted by
Energy	Swedish Energy Agency, the Swedish Transport Administration, the Swedish Transport Agency, Transport Analysis, the Swedish Armed Forces.	Swedish Energy Agency (energy sector excluding transports) Transport Analysis (transports)
Industrial Processes and Product Use	Swedish Chemicals Agency, Medical Products Agency.	The Swedish EPA (CO ₂ , CH ₄ and N ₂ O) Swedish Chemicals Agency
Agriculture	Swedish Board of Agriculture, Statistics Sweden (SCB).	The Swedish Board of Agriculture
Land Use, Land-Use Change And Forestry Sector	Swedish University of Agricultural Sciences (SLU), Statistics Sweden (SCB), the Swedish Forest Agency, the Swedish Meteorological and Hydrological Institute (SMHI), the Swedish Board of Agriculture, Swedish Civil Contingencies Agency (MSB), the Geological Survey of Sweden (SGU).	Swedish Forest Agency The Swedish Board of Agriculture (agriculture related parts)
Waste	The Swedish EPA	The Swedish EPA – another unit, not the one responsible for data.

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

1.2.2.4 THE SMED CONSORTIUM

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

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

SMED receives data and documentation from responsible authorities as described above (see Table 1.1) and produces the data and documentation in the Swedish inventory except for the trend section in the NIR (Swedish EPA) and the supplementary information under KP about the Registry and the KP flexible mechanisms (Swedish Energy Agency).

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

² <http://www.smed.se/>

1.3 Inventory planning, preparation and management

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

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

1.3.1 Quality system

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

The quality system includes several procedures such as training of staff, inventory planning and preparation, QA/QC procedures, publication, data storage, and follow-up and improvements. All QA/QC procedures are documented in a QA/QC plan³. The QA/QC plan also includes a scheduled time frame describing the different stages of the inventory from its initial development to final reporting. The quality system ensures that the inventory is systematically planned, prepared and followed up in accordance with specified quality requirements so that the inventory is continuously developed and improved.

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

Procedural Arrangements



Figure 1.3. Structure of the quality system

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

The responsibility of SMED to maintain and develop an internal quality system is described in the framework contract between the Swedish EPA and the consultants. The SMED quality system is described in a detailed manual⁴. The manual is updated annually and lists all quality control steps that must be undertaken during inventory work (Tier 1 and where appropriate Tier 2). It also includes descriptions of roles and responsibilities, of databases and models, work manuals for each CRF category and documented procedures for uncertainty and key source analyses, as well as procedures for handling and responding to UNFCCC's review of the Swedish inventory. It also handles follow-up and improvement by procedures of non-conformity reporting and collection of improvement needs from all stages of the annual inventory cycle. This results in a planning document, which is used as a basis for planning and selecting further actions to improve the inventory. Figure 1.4 below shows a process description of the annual Swedish inventory.

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

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2018

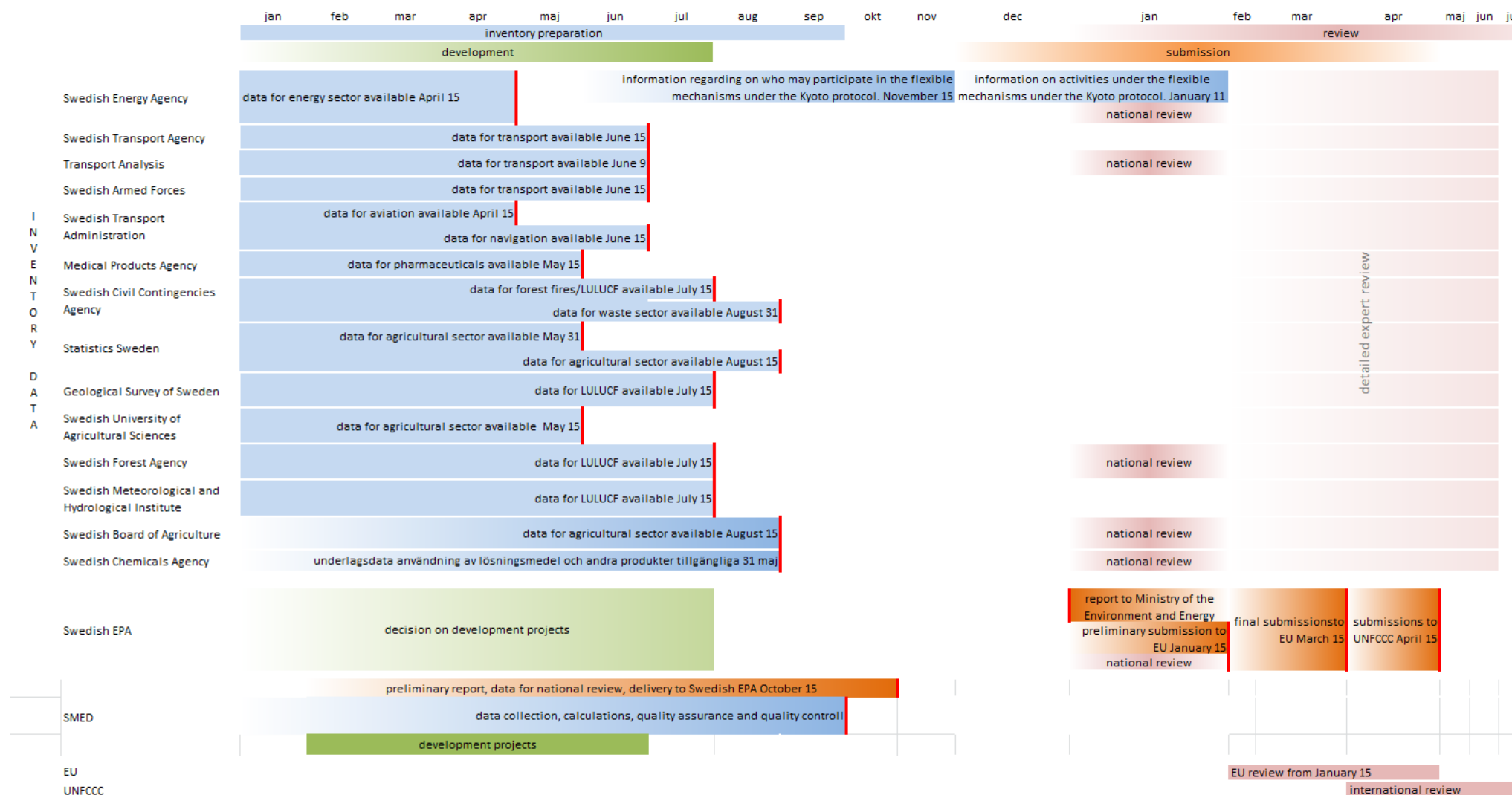


Figure 1.4. Overview of the Swedish GHG inventory planning, preparation and management.

1.3.2 Training, awareness and skills

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

1.3.3 Inventory planning (PLAN)

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

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

Based on the priorities and on detailed information in the updated list on suggestions for improvements, SMED compiles a gross list of development projects for the coming years. The gross list of development projects is discussed between SMED and the Swedish EPA. During December - February the Swedish EPA decides on 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 collect data and information for the greenhouse gas emissions calculations from various government agencies, organizations and companies over the period from April to August. The calculations are performed in models, statistics programs and calculation programs in April to September. Over the period from September to October, the material is put together in a reporting format. A short description of data collection and processing for each sector is provided below. See sections 3-8 for a detailed description. Preparation of the inventory is documented in detailed work documentation, which serves as instructions for inventory compilers to ensure quality and consistency, and also serves as information in the national peer review process.

1.3.4.1 ENERGY- STATIONARY COMBUSTION

Energy industries: Data from quarterly fuel statistics, a total survey conducted by Statistics Sweden at plant level and by fuel type. For some petroleum refining plants, data from the European Union Emission Trading Scheme (ETS) is used.

Manufacturing industries: Data mainly from the quarterly fuel statistics, a sample survey conducted by Statistics Sweden. In some cases data from the industrial energy statistics or ETS is used as a complement. All data is at plant level and by fuel type.

Other sectors: Data from official statistical reports prepared by Statistics Sweden at national level and by fuel type.

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

1.3.4.2 ENERGY- MOBILE COMBUSTION

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

1.3.4.3 ENERGY – FUGITIVE EMISSIONS

For flaring in refineries and chemical industries, activity data and CO₂ emissions from ETS are used for 2005 and later. In earlier years, data was collected through personal contacts with the facilities. Activity data and CO₂ emissions from hydrogen production in oil refineries are taken from ETS and reported under CRF 1.B.2.a.1 in line with 2006 IPCC Guidelines. For non-CO₂ emissions, regular emission factors for stationary combustion are used.

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

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

1.3.4.4 INDUSTRIAL PROCESSES AND PRODUCT USE

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

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

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

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

1.3.4.5 AGRICULTURE

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

1.3.4.6 LAND USE, LAND USE CHANGE AND FORESTRY

Estimates presented in the LULUCF sector are mainly based on data from the SLU and the Swedish EPA. The SLU provides data from the National Forest Inventory, and the Swedish EPA provides data from the Swedish Soil Inventory. The two inventories are integrated and use the same infra-structure for the field sampling. Apart from those two inventories data from the Swedish Forest Agency, the Swedish Meteorological and Hydrological Institute (SMHI), the Swedish Board of

Agriculture, Swedish Civil Contingencies Agency (MSB), the Geological Survey of Sweden (SGU) and Statistics Sweden (SCB) is used.

1.3.4.7 WASTE

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

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

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

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

1.3.5.1 QUALITY CONTROL

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

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

- Completeness check
- Trend and outlier analyses
- Review of internal documentation and archiving

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

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

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

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

CRF	Action
1.A, 1.B Energy amounts and emissions of parts of CO ₂	Analysis of differences between the sectoral and reference approach. In order to check activity data and EF, several quality control projects have been carried out over time comparing the inventory data with information from environmental reports and EU ETS data.
1.B Fugitive emissions and flaring of CO ₂ CH ₄ and N ₂ O	Measured emissions from flaring are checked to assure that the quality is sufficiently high. Trends for activity data and emissions are compared and analysed.
2.A.1 Cement production, process emissions of CO ₂	Emissions are calculated both using the bottom-up and the top-down method, the results have been compared and differences explained. It is also stated that emission factors and activity data used are in accordance with internationally accepted methods.
2.A.2 Lime production, process emissions of CO ₂	Emissions are calculated using both the bottom-up and the top-down method, the results have been compared and differences explained.
2.B.2 N ₂ O-emissions from Nitric Acid production	Bottom-up production data could not be compared to official data since official data for were not available in the statistical database. Only one company produces nitric acid. Calculation methods, abatement technique and production capacity is based on information achieved directly from the company.
2.C.1 Iron and steel production	Activity data are checked with fuel combustion data in order to avoid double counting of emissions or omissions. Activity data is also compared to trade statistics. IEF are compared to IPCC default values.
2.C.3 PFC emissions from aluminium production	Documented process information obtained directly from the company enable plant-specific data checks.
2.F Product uses as substitutes for ODS	Differences between country specific emission factors and default emission factors from IPCC Guidelines are documented.
5A Solid waste disposal (CH ₄)	Survey data collection methods are reviewed and data is cross-checked with the data for the previous years.
5B Biological treatment of solid waste (CH ₄ and N ₂ O)	Input parameters are reviewed by waste experts.
5D Wastewater treatment and discharge (CH ₄)	Country-specific value of B0 and the IPCC default value have been compared and differences analysed.
5D Wastewater treatment and discharge (CH ₄)	Agreement between the units used for degradable carbon in waste (TOW) and B0 is confirmed.

1.3.5.2 QUALITY ASSURANCE

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

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

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

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

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

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

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

1.3.5.3 FINALIZATION, PUBLICATION AND SUBMISSION OF THE INVENTORY

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

1.3.5.4 DATA STORAGE

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

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

1.3.5.5 FOLLOW-UP AND IMPROVEMENT (ACT)

Each year, all comments received from national and international reviews that are not already addressed and also ideas from SMED and the Swedish EPA are compiled into a list for suggestions on improvements. From this list, development projects are formed each year as describes in section 1.3.3. All suggestions not implemented one year is kept on the list for next year. In Table 1.3 below

⁵ <https://tps.naturvardsverket.se/>

implemented improvements in this submission due to major development projects are presented. Other corrections, emission estimation improvements and updates of various statistics are described under each source category in section 3-8 below. In addition, improvements related to transparency of the NIR are continuously addressed in response to questions raised by national experts during the national peer review, and in response to previous ERT recommendations.

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

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

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

Sector/CRF category	Implemented improvement	Quality criteria (TCCCA)	Need identified by	Reference to NIR section
IPPU/2.B.10	Addition of CO ₂ emissions from two chemical industries in 2.B.10.	Accuracy	SMED	4.3.10
IPPU/2.D.3	Revision of the calculation model for solvents (CRF 2.D.3) resulting in improved emission estimates and allocation.	Transparency, Accuracy	SMED	4.5.3 and Annex 3.3

1.4 Brief general description of methodologies and data sources used

1.4.1 GHG inventory

Emission estimates are mainly based on data from national or official Swedish statistics, e.g. energy statistics, European Union Emission Trading Scheme (EU ETS)⁶, environmental reports⁷, agricultural and forestry statistics, as well as data on production (e.g. cement) and consumption (e.g. fluorinated gases: F-gases) obtained directly from the major producers and consumers, respectively.

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

The methodologies used for Sweden's greenhouse gas emissions inventory are in accordance with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines)⁸. In some cases, the methodologies prescribed in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines)⁹ and the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (Good Practice Guidance)¹⁰, IPCC's supplementary guidelines for Wetlands and the Kyoto protocol (WL GL¹¹ and KP GL¹²) are also used. Some parts of the methodologies are taken directly from the EMEP/EEA air pollutant emission inventory guidebook (formerly called the EMEP CORINAIR emission inventory guidebook).¹³

In Table 1.4, all Tier methods used, which differ from Tier methods recommended in 2006 IPCC Guidelines, are presented. There is also a brief explanation of why the recommended methods have not been used. Note that for sectors where no specific recommendations are made in the 2006 IPCC Guidelines, these sectors are not included in Table 1.4. For an overview of the methods used in all sectors, see Summary 3 in the CRF tables and in each sector section, where a more detailed explanation on data sources and methodologies is given.

⁶ See Annex 8.1

⁷ See Annex 8.3

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

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

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

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

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

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

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

Sector	Used method Tier	2006 IPCC Guidelines method Tier	Explanation
Energy: Emissions of CH ₄ and N ₂ O from navigation	1	2	Reliable data required for Tier 2 is currently not available (various engine types etc.).

The combined effect of various greenhouse gases has been calculated using global warming potential factors (GWP) according to decision 4/CMP.7 and presented in Annex 8.4. These are developed by the IPCC and are used as a means of comparing the relative significance of various gases in terms of their greenhouse effect, expressed in CO₂-equivalent.

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

1.4.2 KP-LULUCF inventory

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

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

The carbon pool changes associated to the activities reported under the Kyoto protocol is estimated in exactly the same way as under the UNFCCC reporting, using the stock change method and area based sampling for most of the carbon pools. However, for the KP-reporting, the living biomass pool is reported separated into above-ground and below-ground biomass, respectively, and the dead organic matter pool is separated into litter and dead wood also for Deforestation and not only for Afforestation/Reforestation and Forest Management.

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

1.5.1 GHG inventory (including and excluding LULUCF)

According to 2006 IPCC Guidelines, key categories in a national inventory should be identified in order to prioritize the efforts in improving the quality of the inventory estimates. Key categories are defined as sources and/or sinks that have “a significant influence on a country’s total inventory of direct greenhouse gases in terms of the absolute level, the trend, or the uncertainty in emissions and removals”. The identification of level and trend key categories is done in two different approaches. The two approaches differ in the sense that approach 2 also includes information of uncertainties. According to the UNFCCC reporting guidelines, Annex I Parties shall identify their key categories for the base year and the latest reported inventory year, using approach 1, level and trend assessment, including and excluding LULUCF. Parties are encouraged to also use approach 2 and to add additional key categories to the result of approach 1. The resulting key categories from the two approaches are presented under each source category description of chapter 3-7, in CRF table 7 and in Table A1.1 – A1.8 in Annex 1. There the methodology is discussed in detail and the corresponding background tables, according to the 2006 IPCC Guidelines, are presented.

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

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

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

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

L=Level, T=Trend.

1.5.2 KP-LULUCF inventory

The key category assessment for KP-LULUCF is found in section 10.6.1.

Forest management, Afforestation/Reforestation and Deforestation were considered key-categories for CO₂, Forest management (fertilization and drained organic soils), Afforestation/Reforestation (mineralisation) and Deforestation (mineralisation) were considered key-categories for N₂O and Forest management (drained organic soils) was considered key-category for CH₄.

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

A thorough confidentiality analysis, using a P%-rule¹⁴, has been conducted for sectors using statistics from statistical surveys on fuel consumption and information collected for the EU Emissions Trading System. Results based on micro-data from Swedish Chemicals Agency and Swedish eHealth Agency are not classified in the CRF-tables since the aggregation level is high enough to protect company data. When the confidentiality analysis showed that a certain category should be classified to protect data of one or more companies, the companies have been asked to give consent to publish the data. If the company declined or a consent could be acquired, the data are considered confidential and marked using notation key 'C'.

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

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

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

1.7 General uncertainty evaluation

1.7.1 GHG inventory

An uncertainty analysis has been performed according to the approach 1 method described in volume 1, chapter 3 of the 2006 IPCC guidelines. See Annex 7 for the results and for a description of the method used. The analysis has been performed both including and excluding LULUCF. According to the IPCC Guidelines, uncertainty estimates are an essential part of an emission inventory. They should be derived for each variable used in the inventory (measured emissions, activity data and emission factors) and aggregated into uncertainty estimates in total national emissions and emission changes over time (trends). The 2006 IPCC Guidelines identify that: "An uncertainty analysis should be seen, first and foremost, as a means to help prioritise national efforts to reduce the uncertainty of inventories in the future, and guide decisions on methodological choice".

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

same activity data and therefore are correlated. The study is described briefly in Annex 7 and in detail in a SMED report¹⁵.

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

Uncertainty estimates have been performed for the base year 1990 and 2016 for direct greenhouse gases, e.g. CO₂, CH₄, N₂O and F-gases and are presented as 95 % confidence intervals.

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

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

1.7.1.1 RESULTS

The results of the uncertainty calculations according to the approach 1 are presented in Annex 7. The overall uncertainty for 2016 GHG emissions (in CO₂-eq.) in Sweden is calculated to be ± 5.0 %, excluding LULUCF (Figure 1.5). A considerable part of the overall uncertainty stems from uncertainty in the agricultural sector (CRF 3). When including LULUCF in national total emissions the uncertainty increases (± 76 %), this is due to the combination of large (and increasing) net removals in LULUCF in combination of the prominent decrease in fossil emissions (Figure 1.5). Table 1.6 shows the ten sources with the largest uncertainty contributions in the inventory for 2016, excluding LULUCF.

¹⁵ Gustafsson, 2005

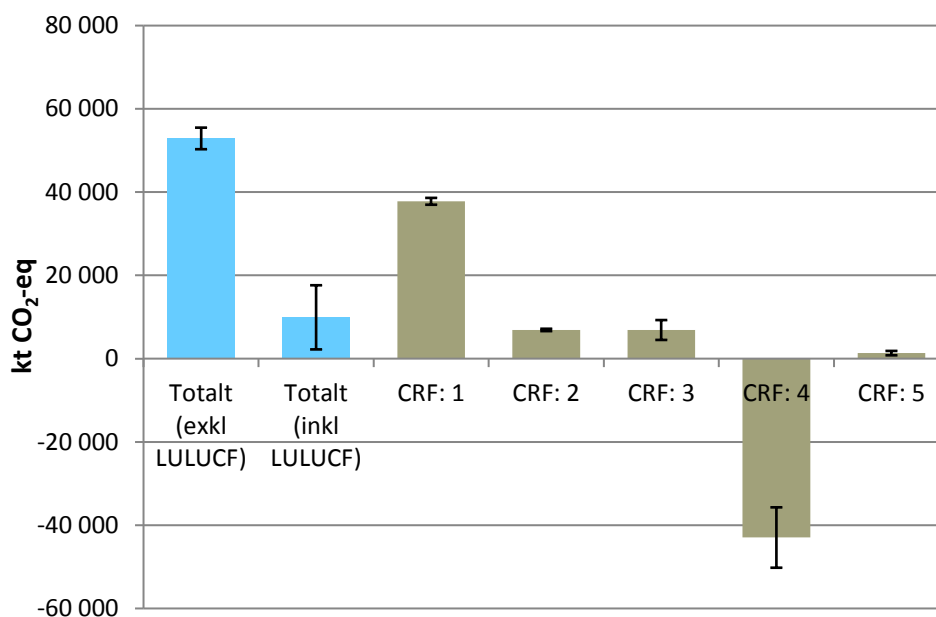


Figure 1.5. Uncertainty estimates, as 95 % confidence intervals, in national total emissions (excluding and including LULUCF) and by sector.

Table 1.6. The ten sources with the largest uncertainty contributions in the Swedish inventory for 2016, excluding LULUCF.

IPCC Source Category	GHG	Year 2016 emissions or removals (kt CO ₂ -eq.)	Combined uncertainty (%)	Relative contribution to variance in year 2016 (%)
3 D a 1 Inorganic N fertilizers	N ₂ O	871	203.0	14.9%
3 D a 4 Crop residues applied to soils	N ₂ O	379	203.0	6.5%
3 D a 6 Cultivation of organic soils (i.e. histosols)	N ₂ O	838	85.1	6.0%
3 D a 3 Urine and dung deposited by grazing animals	N ₂ O	351	203.0	6.0%
3 D a 2 a Animal manure applied to soils	N ₂ O	344	203.0	5.9%
5 A 1 Managed waste disposal sites	CH ₄	908	55.9	4.3%
1 A 1 a Public Electricity and Heat Production: Other Fuels	CO ₂	2316	19.8	3.9%
3 D b 1 Atmospheric deposition	N ₂ O	95	401.5	3.2%
3 B Indirect N ₂ O emissions	N ₂ O	83	401.5	2.8%
1 A 3 b i Road Transportation, Cars: Gasoline	CO ₂	6514	5	2.8%

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. I.e. there is a 95 % probability that the decrease in GHG emissions in Sweden between 1990 and 2016 is in the interval 24.1 % to 27.9 %.

1.7.2 KP-LULUCF activities

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

1.8 General assessment of completeness

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

1.8.1 GHG inventory

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

1.8.2 Energy

Emissions of CH₄ and N₂O from FAME used by military transportation (CRF 1A5b) in 1999-2001 and emissions of CH₄ and N₂O from ethanol used by military transportation in 2007-2012 are not estimated. Emissions are expected to be minor and there is no IPCC methodology available for estimating these emissions.

1.8.3 Industrial Processes and Product Use

For most sources, and particularly for the most important ones, the estimates are in accordance with the requirements concerning completeness as laid out in the 2006 IPCC Guidelines. However, some exceptions do exist. These are primarily in sub-sectors with a large number of smaller facilities with minor emissions and for which no IPCC default methodology exists. For CH₄ emissions from ethylene production, a default methodology is provided by the 2006 IPCC Guidelines. However, as the company's own estimate is below the result of the default method by about a factor of ten and is below the threshold of 0.05 % of national total emissions (about 30 kt CO₂-eq), Sweden has chosen to report NE for this source, as it is judged to be insignificant in relation to the amount of effort it would require to obtain a complete time series.

Data is complete for all greenhouse gases, possibly with the exception of CH₄ for a few non-mandatory sources, e.g. within the chemical industry.

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

1.8.4 Agriculture

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

1.8.5 Land Use, Land Use Change and Forestry

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

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

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

1.8.6 Waste

Accidental landfill fires occur in Sweden; however emissions of CO₂, CH₄ and N₂O are reported NE since there is no default method provided by the 2006 IPCC Guidelines that can be applied in this case, and is below the threshold of 0.05 % of national total emissions (about 30 kt CO₂ eq.). Emissions are estimated to be insignificant in relation to the amount of effort it would require to obtain activity and emission data. All other data are complete.

1.8.7 KP-LULUCF

Sweden reports all mandatory activities under Article 3.3 and Article 3.4 of the Kyoto Protocol (KP). All carbon pools (including HWP) as well as associated mandatory emissions (such as fertilization of forest land, non- CO₂ emissions and DOC from drained organic soils, indirect N₂O emissions, N₂O from mineralisation of N and biomass burning) are reported for Afforestation/Reforestation, Deforestation and Forest management.

2 Trends in greenhouse gas emissions

2.1 Total greenhouse gas emissions and removals

In 2016, total greenhouse gas emissions (excluding LULUCF) in Sweden amounted to 52.9 Mt CO₂-eq. (Figure 2.1). The emissions show a decreasing trend although there are some annual fluctuations in a few sectors that affect the total emissions. Total emissions have decreased by 18.6 Mt or 26 % between 1990 and 2016. Between 2015 and 2016, the total greenhouse gas emissions decreased by 1.6 %.

The land use, land-use change and forestry sector (LULUCF, CRF sector 4) has generated annual net removals during the whole inventory period (1990-2016). The removals show substantial annual fluctuations. The net removal level during the last decade is slightly higher compared to the earlier years in the time period starting with 1990.

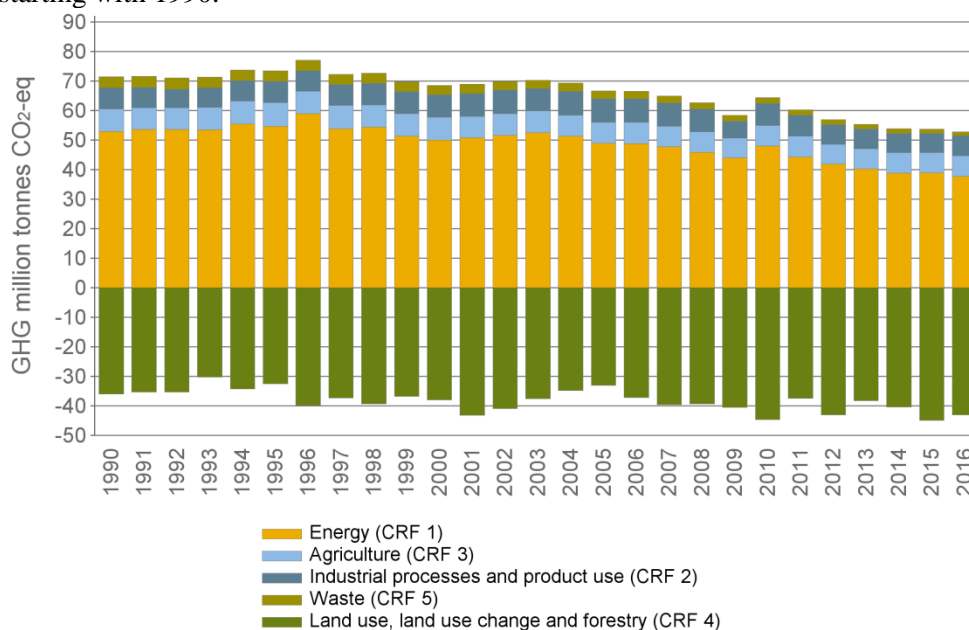


Figure 2.1. Total emissions and removals of greenhouse gases calculated as CO₂-eq. from Land use, land use change and forestry (LULUCF, CRF 4) and the other sectors (CRF 1.2.3 and 5), 1990-2016.

The energy sector contributed the most to the overall decrease in emissions, with 15.2 Mt of greenhouse gases between 1990 and 2016, primarily through reductions of 8.2 Mt in the residential, commercial/institutional and agriculture, forestry and fisheries subsectors (CRF 1.A.4), and of 3.8 Mt in manufacturing industries and construction (CRF 1.A.2). Other sectors also contributed significantly to the overall

decreased emissions during the period; waste (CRF 5) by 2.4 Mt, transport (CRF 1.A.3), by another 2.2 Mt, and agriculture (CRF 3) by 0.75 Mt.

2.1.1 Overview of emissions by sector

The energy sector (CRF 1) is comprised by emissions from transport (CRF 1.A.3), 32 % of the total emissions, energy industries (CRF 1.A.1), 17 % of total emissions, and combustion in manufacturing industries and construction (CRF 1.A.2), 14 % of total emissions. Emissions from military activities (CRF 1.A.5) accounted for 0.3 % of total emissions, fugitive emissions (CRF 1.B) for 1.4 % of total emissions, and other activities (CRF 1.A.4) for 6 % of total emissions, see Figure 2.2. Agriculture (CRF 3) accounted for 13 % of total greenhouse gas emissions in 2016, industrial processes and product use (CRF 2) accounted for 13 %, and waste (CRF 5) accounted for 2.5 %.

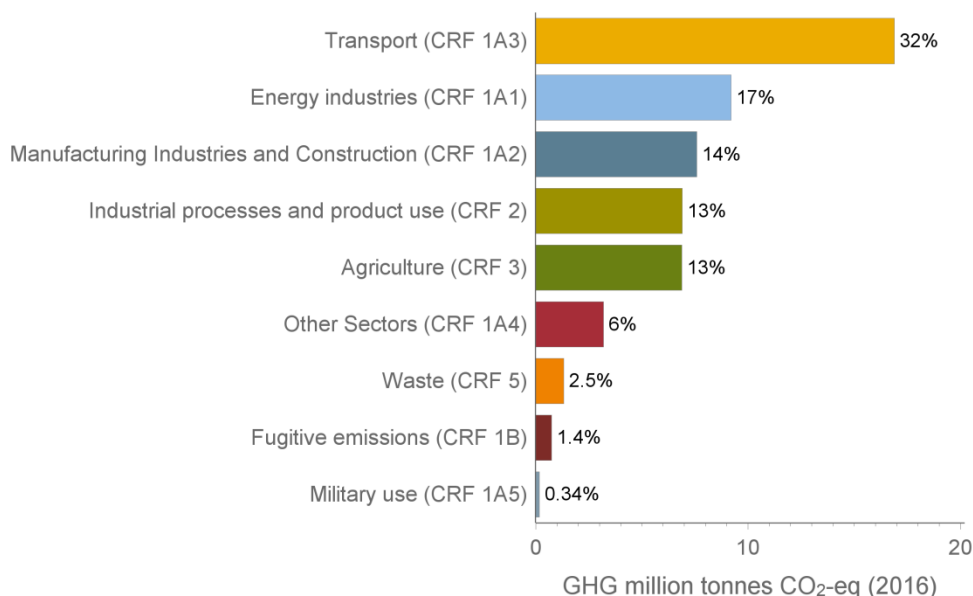


Figure 2.2. Greenhouse gas emissions by sector, 2016.

The historical trends (1990-2016) of the largest categories are shown in Figure 2.3. Emissions from transport are dominated by road transport. The emissions were lower in 2016 than in 1990. The decrease over the years is due to more energy efficient cars and an increased use of biofuels, but the impact of these measures on emissions reductions have been suppressed by an increased trend in the amount of traffic. Emissions from energy industries primarily come from the production of electricity and heat. The fluctuations in emissions between different years are large, due to the weather conditions' influence on the need for heating. Emissions from manufacturing industries and construction have decreased since the late 90's. They depend on the economic development but there is also a long-term decrease as a result of a switch from oil to biomass, especially in the pulp and paper industry. Emissions from agriculture have decreased slightly since 1990 due to less livestock and smaller amounts of fertilizers used. Emissions from IPPU (Industrial Processes

and Product Use) consist of emissions from industrial processes as well as emissions from product use, mainly fluorinated greenhouse gases in, for example, cooling systems. Emissions from IPPU emanate from industrial processes which fluctuate with the level of production. The chemical industry has decreased its emissions due to enhanced production technologies.

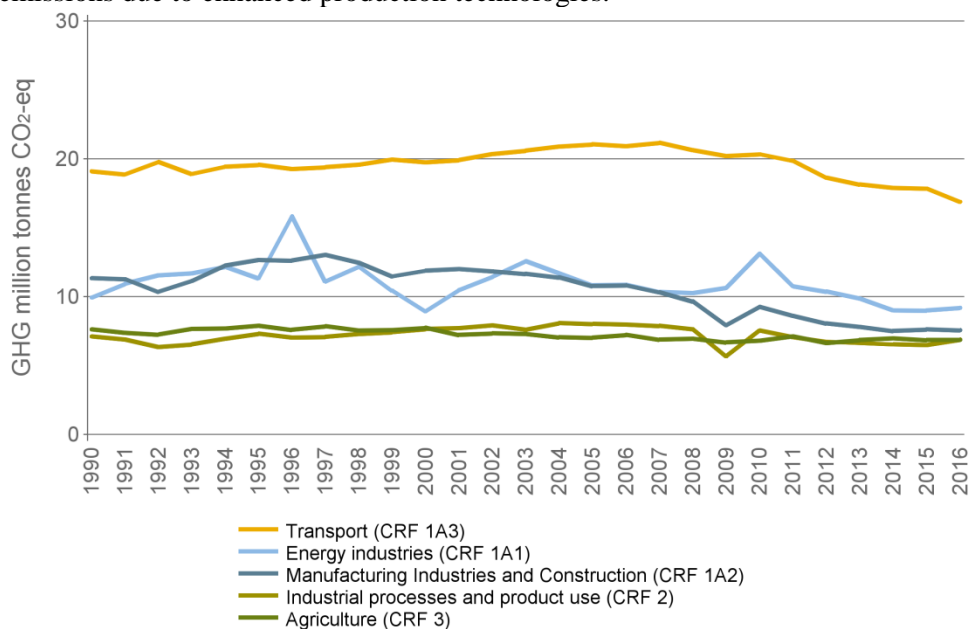


Figure 2.3. Total emissions of all greenhouse gases calculated as CO₂-eq. for agriculture (CRF 3), energy industries (CRF 1A1), Industrial processes and product use (CRF 2), manufacturing industries and construction (CRF 1A2) and transport (1A3), 1990-2016.

2.2 Description and interpretation of emission trends by gas

In 2016, emissions (excl. LULUCF) of carbon dioxide (CO₂) amounted to 42.6 Mt in total, which is equivalent to 80 % of total greenhouse gas emissions, calculated as CO₂-eq, see Figure 2.4. Emissions of methane (CH₄) accounted for 4.7 Mt of CO₂-eq. (about 9 % of total emissions), emissions of nitrous oxide (N₂O) 4.6 Mt (9 %), fluorinated greenhouse gases 0.9 Mt (1.8 %). The shares of the different greenhouses gases have remained stable over the period 1990 to 2016.

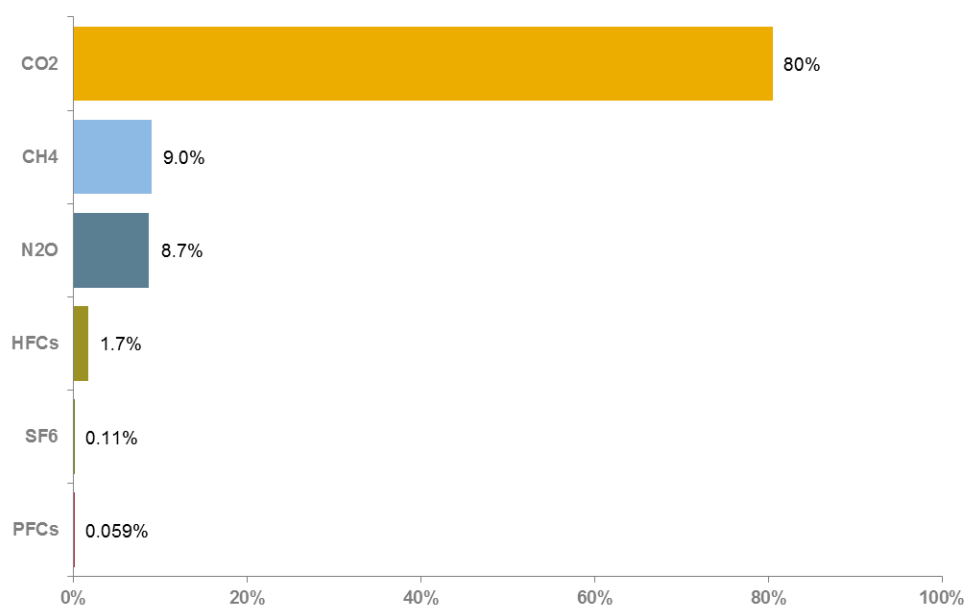


Figure 2.4. Share of greenhouse gases of total emissions in CO₂-eq, in 2016.

2.2.1 Carbon dioxide (CO₂)

In 2016, the carbon dioxide (CO₂) emissions in Sweden amounted to 42.6 Mt in total, excluding LULUCF (Figure 2.5). The main source for emissions of carbon dioxide is the combustion of fossil fuels, which mainly takes place in the energy sector (CRF 1). Another important source is the raw material used in the industry processes. Emissions of carbon dioxide were 26 % lower in 2016 than in 1990.

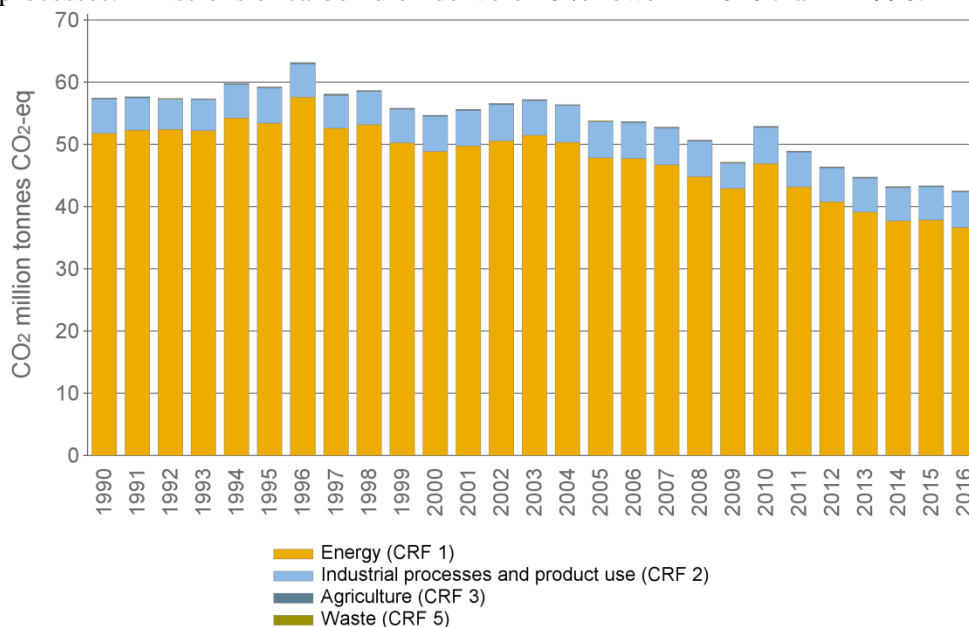


Figure 2.5. Total emissions of carbon dioxide 1990-2016 (excluding LULUCF).

2.2.2 Methane (CH₄)

The total emissions of methane (CH₄), excluding emissions from LULUCF, were 4.7 Mt calculated as CO₂-eq. in 2016, see Figure 2.6. The main sources of methane are agriculture (CRF 3) (69 %), the waste sector (CRF 5) (22 %) and the combustion of fossil fuels in the energy sector (CRF 1) (10 %). Emissions of methane have decreased by 38 % since 1990. The main reason for the decrease is mitigation measures undertaken in the waste sector, for example reduced deposition of organic waste in landfills and collection of landfill gas for combustion. The waste sector decreased its emissions of methane by 70 % between 1990 and 2016, while emissions in the agricultural sector dropped by 8 % during the same period.

2.2.3 Nitrous oxide (N₂O)

In 2016, emissions of nitrous oxide (N₂O) amounted to 4.6 Mt CO₂-eq. (excl. LULUCF), see Figure 2.7. The main source of nitrous oxide emissions is the agriculture sector (CRF 3), which accounted for 76 % of the emissions in 2016. Compared to 1990, the overall emissions of N₂O have decreased by 20 %, which is more than 1 Mt of CO₂-eq. The industrial processes and product use sector (CRF 2) accounts for the largest part of the decrease in emissions of nitrous oxide and have dropped by approximately 76 % during the period.

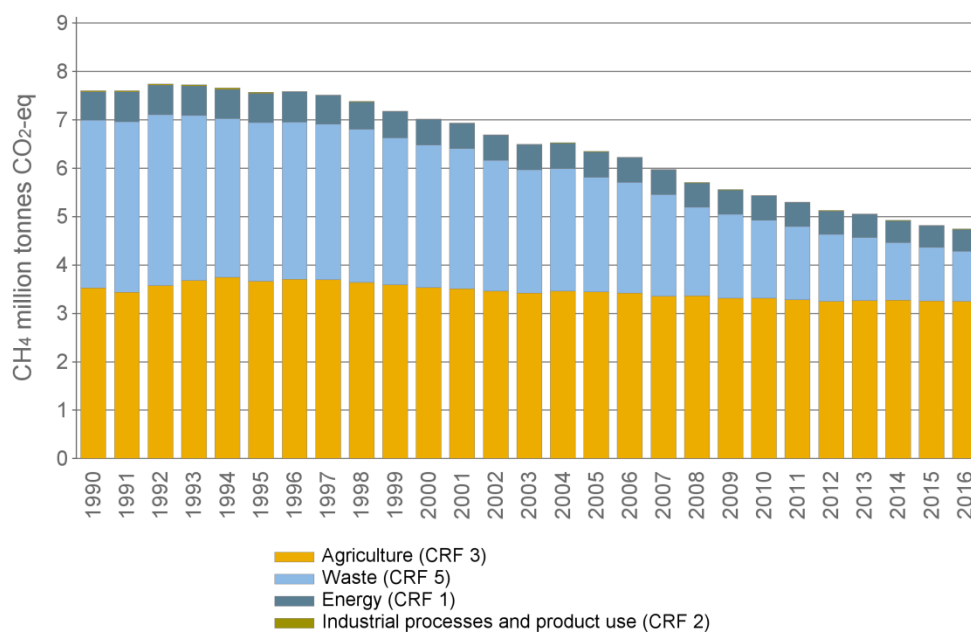


Figure 2.6. Total emissions of methane (CH₄) by sectors 1990-2016 (excluding LULUCF).

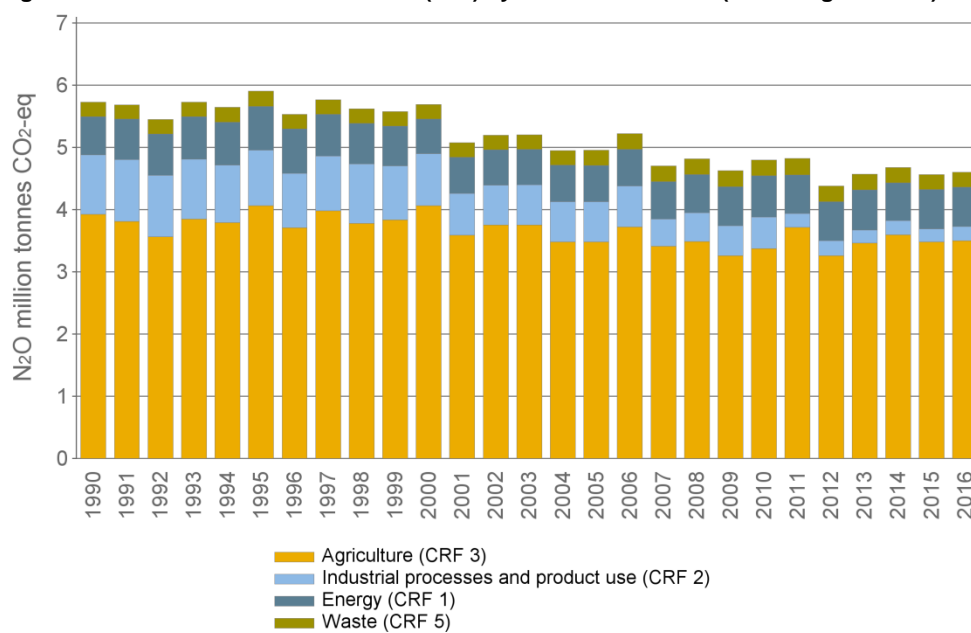


Figure 2.7. Total emissions of nitrous oxide (N₂O) by sectors 1990-2016 (excluding LULUCF).

2.2.4 Fluorinated greenhouse gases

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

Total emissions of fluorinated gases in 2016 amounted to 1.0 Mt CO₂-eq, see Figure 2.8, and accounted for almost 2 % of total greenhouse gas emissions. Emissions have increased by 44 % since 1990. They increased from around 0.7 Mt of CO₂-eq. in 1990 to almost 1.5 Mt in 2007, but have decreased to under 1 Mt in the last two years. The overall increase is mainly due to increased emissions of HFCs, which accounted for 91 % of the total fluorinated gases in 2016.

The emissions of HFCs increased by 0.9 Mt of CO₂-eq. between 1990 and 2016, 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 decreasing and emissions have dropped by 2 % between 2015 and 2016.

PFCs emissions, on the other hand, have decreased by 95 % during the period 1990 to 2016. Emissions of SF₆ decreased by 42 % between 1990 and 2016. However, there are inter-annual fluctuations throughout the period.

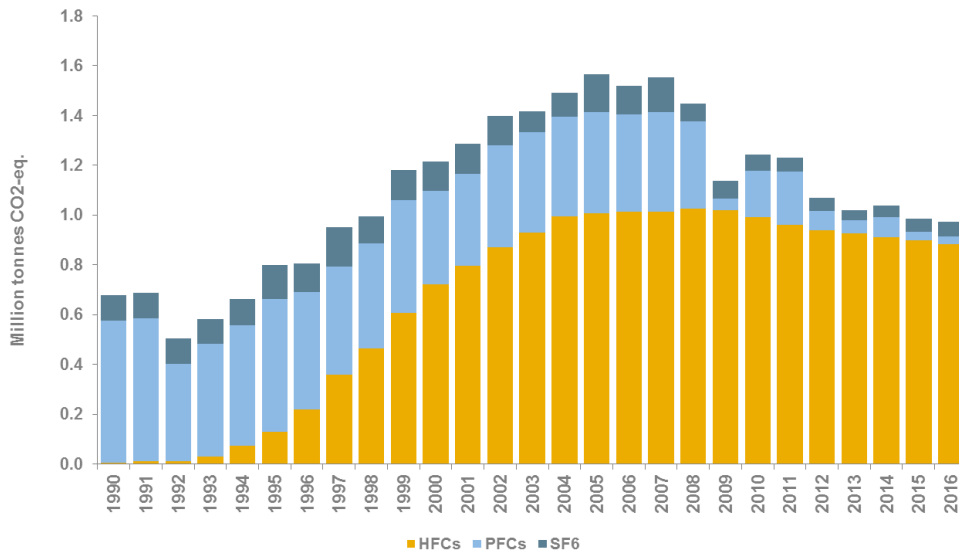


Figure 2.8. Total emissions of HFC, PFCs and SF₆, 1990-2016 (excluding LULUCF).

2.3 Emissions by CRF sectors

2.3.1 Energy (CRF sector 1)

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

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

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

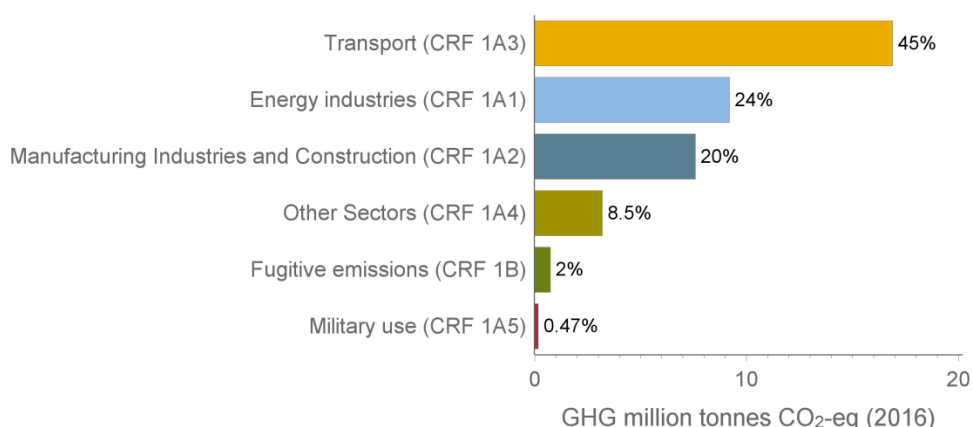


Figure 2.9. Share of emissions within the Energy sector, by subsector in 2016.

Total emissions in the energy sector have decreased over the period 1990-2015, from 53.0 to 37.8 Mt CO₂-eq. This is a decrease of 29 % which mainly depends on

a decreased use of fossil fuels in residential and commercial/institutional, included in “Other Sectors” (CRF 1A4), and manufacturing industries and construction (CRF 1A2). Between 2015 and 2016 there was 3 % decrease in emissions within the energy sector, mostly because of a decrease of emissions from transports.

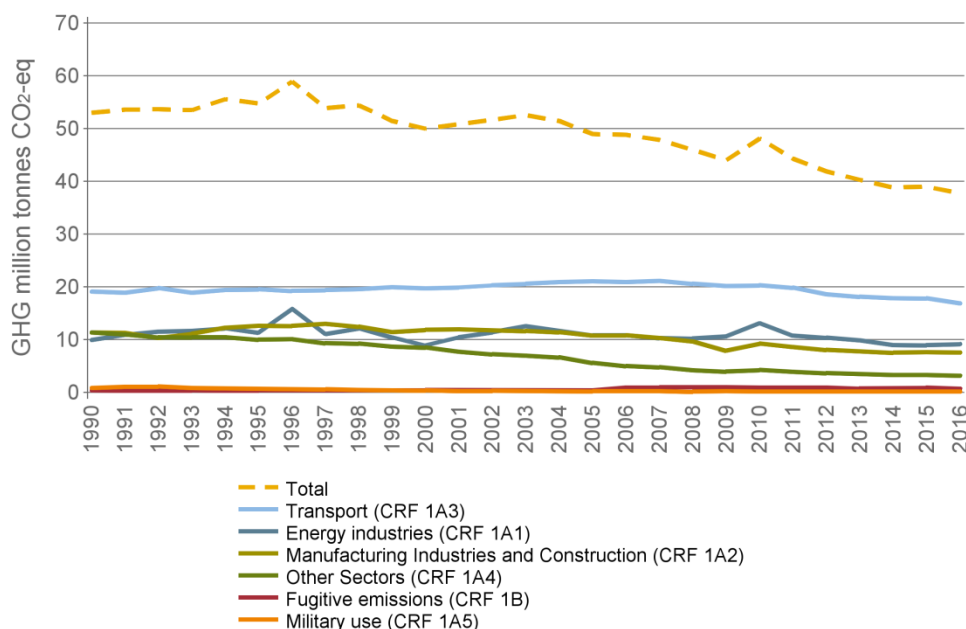


Figure 2.10. Emissions from the Energy sector, total and by subsector, in 2016.

2.3.1.1 ENERGY INDUSTRIES (CRF 1A1)

Energy industries are dominated by the electricity and heat production with by far the largest part of the emissions and also the only subsector where emissions fluctuate over the years. The fluctuations between different years are large, due to the weather conditions' influence on the electricity and heat production (CRF 1A1a). In 2016, there was an increase in emissions from the energy industries by 2 % compared to 2015. Sweden's electricity and heat production is to a large extent composed by renewable energy and district heating is mainly based on biofuels and waste. Therefore, the emissions are still around the same level as in 1990, even though the supply of district heating has increased with over 40 % in the same period.

Total emissions from energy industries (CRF 1A1) were 9.2 Mt CO₂-eq. in 2016 (Figure 2.11), which is 8 % lower than in 1990. Electricity and heat production (CRF 1A1a) account for the larger part of the emissions with 74 % (6.8 Mt) in 2016. Emissions from Refineries (1A1b) and Manufacture of solid fuels (CRF 1A1c) amounted to 2.4 Mt in 2016.

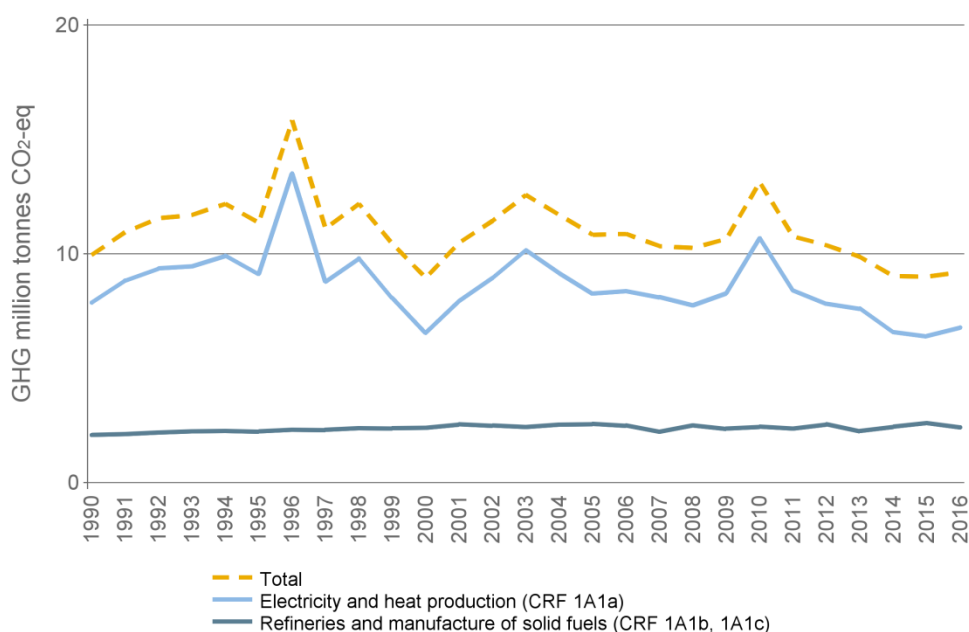


Figure 2.11. Emissions from Energy industries by subsector and total, 2016.

2.3.1.1.1 Electricity and heat production (CRF1A1a)

Emissions from production of electricity and heat production totalled to 6.8 Mt of CO₂-eq. in 2016, which is an increase by 6 % compared to 2015. The emissions from electricity and heat production vary over time but have a decreasing trend and have been reduced by 14 % between 1990 and 2016. Emissions in 2016 were higher than in 2015, mainly due to colder weather in 2016. The main reason behind the variations between years is the weather conditions' impact on the demand for electricity and heat.

The main reason behind the variations between years is the weather conditions' impact on the demand for electricity and heat. Sweden's electricity and heat production are based largely on hydropower, nuclear power and biofuels. Fossil fuels serve as a complement, especially by cold weather. Temperature and precipitation conditions, which vary between years, have an impact on hydropower production and heating needs, which leads to a variation in emissions between years. This is illustrated by the high emissions in 1996, which was a cold and dry year, and by the low emissions in 2000, which was a warm year with heavy precipitation and thus good availability of hydropower. Also 2010 was a very cold year, with increased emissions as a result.

In years with low hydropower production, the emissions depend on the kind of electricity production that offsets the hydropower shortage. As an example, the emissions were much lower in 2003 when the deficient production of hydropower primarily was offset by imports of electricity, compared to 1996 when the shortage of hydropower to a larger extent was offset by increased oil-fuelled condensing

power production. The increased possibilities to import electricity, primarily from other Nordic countries, make it possible to avoid emissions from fossil-fuelled electricity generation when other power supply is low.

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

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

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

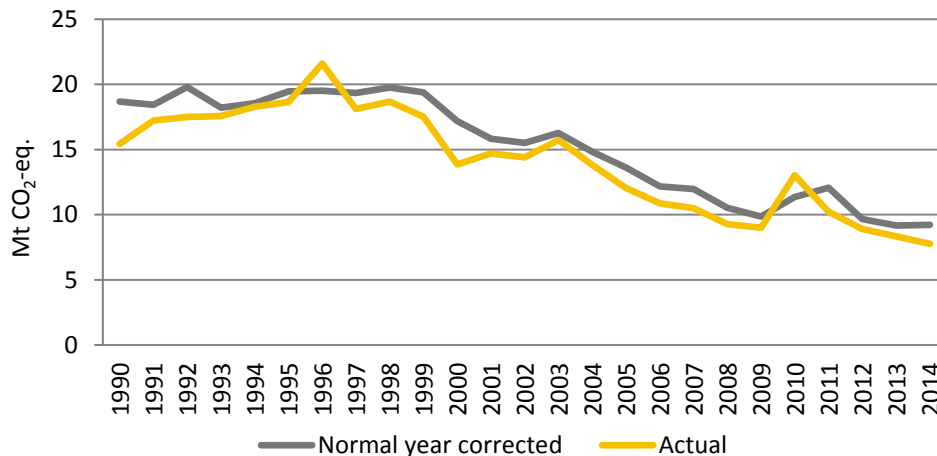


Figure 2.12. Actual and normal-year corrected fossil CO₂-emissions for heating of buildings and electricity generation in Sweden for the years 1990-2014. Included sectors are production of electricity and heat (1A1a) and residential and commercial/institutional (1A4a-b). Normal-year corrected emissions are only available until year 2014. For the year 2014 preliminary statistics on fossil fuel consumption is used.

2.3.1.2 MANUFACTURING INDUSTRIES AND CONSTRUCTION (CRF 1A2)

The mining, iron and steel as well as pulp and paper industries are examples of historically important industries for Sweden. Emissions from combustion in

manufacturing industries and construction were 7.6 Mt CO₂-eq. in 2016 (Figure 2.13). Emissions in 2016 were 33 % lower than in 1990 and close to unchanged compared to 2015. Although increasing slightly up until 1997, the emissions have a steady decreasing trend since then. The lower emissions in 2009 and higher emissions in 2010 were due to the financial crisis impact on production levels and their subsequent recovery. The decreasing trend is primarily related to a lower use of oil. Oil has been replaced by electricity or biofuels, partly depending on the difference in relative prices between electricity and oil.

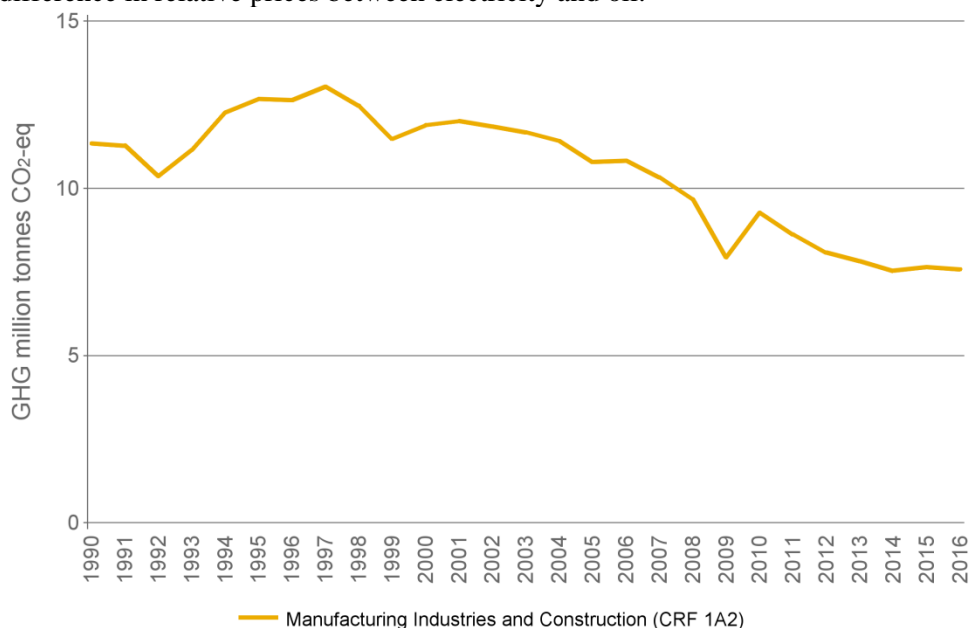


Figure 2.13. Total emissions from manufacturing industries and construction (CRF 1.A.2), 1990-2016.

A small number of energy-intensive industries account for a large share in the sector's greenhouse gas emissions. The iron and steel industry (CRF 1A2a), the non-metallic minerals industry (CRF 1A2f) and the chemical industry (CRF 1A2c) account for 16 %, 16 % and 17 % respectively of the emissions in 2016 (Figure 2.14).

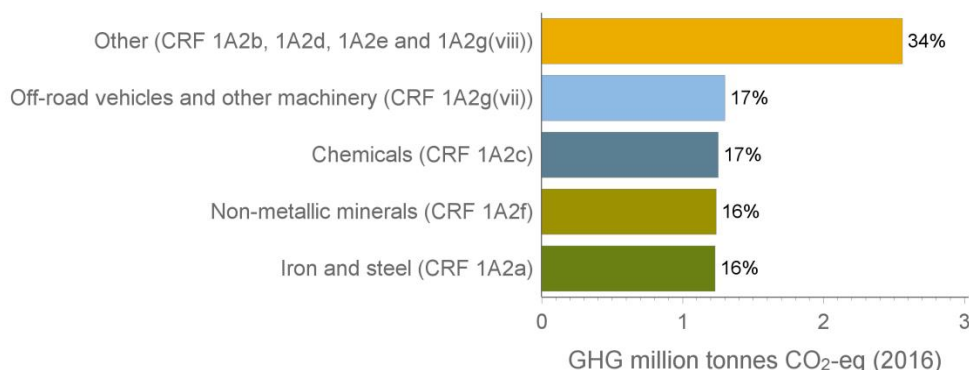


Figure 2.14. Emissions from the Energy sector; Manufacturing industries and construction in year 2016.

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

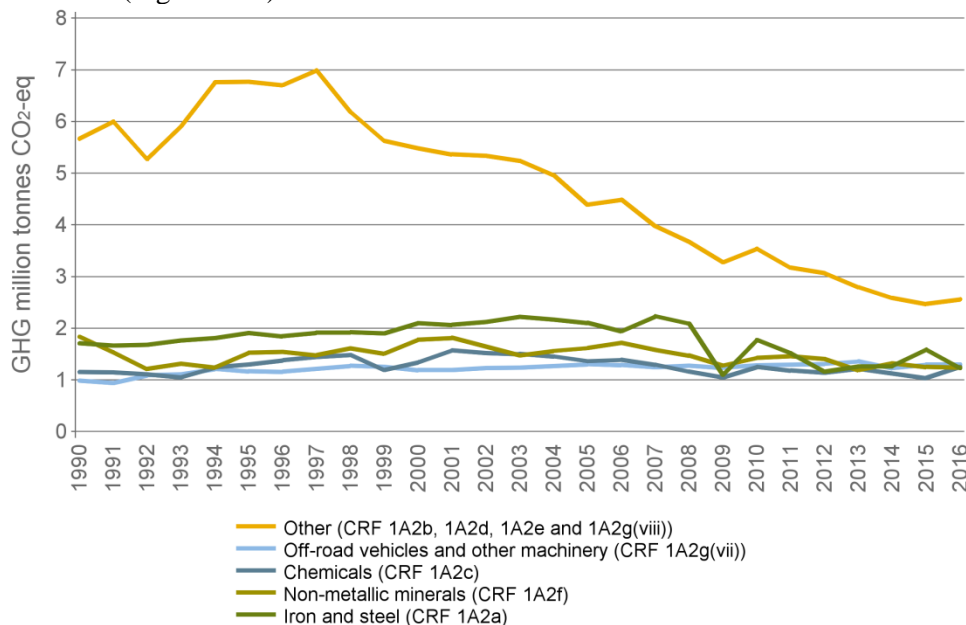


Figure 2.15. Emissions from combustion in manufacturing industries by subsectors, 1990-2016.

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

Emissions from chemicals (CRF 1A2c) and non-metallic minerals (CRF 1A2f) has yearly variations in response to market fluctuations but the long-term trend has remained relatively stable since 1990. The emissions level of non-metallic minerals is significantly lower in 2016 than in 1990 due to high emissions from use of coal in 1990-1991.

2.3.1.3 FUGITIVE EMISSIONS FROM FUELS (CRF1B)

Fugitive emissions come for example from processing, storage and use of fuels, flaring of gas, transmission and distribution of gas. Emissions were around 0.73 Mt of CO₂-eq. in 2016, which is a decrease of 20 % compared to 2015, see Figure 2.16. The increase of fugitive emissions from oil (CRF 1B2a), observed in the time series from 2006, is related to the establishment of hydrogen production facilities at

¹⁶ Jernkontoret, 2015

two oil refineries. In total, the emissions have increased with 90 % compared to 1990.

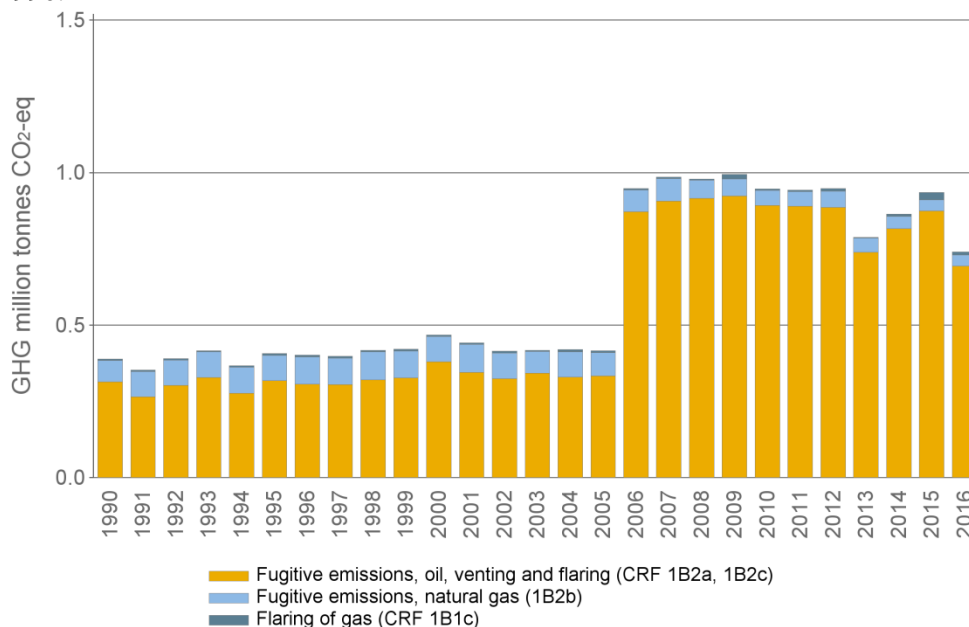


Figure 2.16. Emissions of greenhouse gases from fugitive emissions, total and by major subsectors, 1990-2016.

2.3.1.4 TRANSPORT (CRF 1.A.3)

The majority of the emissions in this subsector come from road traffic; mainly from cars and heavy duty vehicles. The total emissions from transport have decreased since 2010. Emissions from cars have decreased from 2007 to 2016, apart from a slight increase between 2014 and 2015. The decrease in emissions is largely due to increased use of biofuels and increased energy efficiency. The emissions have decreased although traffic in Sweden is increasing. Emissions from heavy duty vehicles follow the fluctuations of economic activity. They increased between 1990 and 2011 and subsequently started to decrease, a development that slowed down last year.

Emissions from transport include emissions from domestic aviation (CRF 1A3a), road transport (CRF 1A3b), railways (CRF 1A3c), national navigation (CRF 1A3d) and other working machinery and off-road equipment (CRF 1A3e). The subsectors' shares of the total emissions of the sector are shown in Figure 2.17. In 2016, the greenhouse gas emissions from road transport were 15.8 Mt, 0.5 Mt from domestic aviation, 0.3 Mt from domestic navigation and 0.2 Mt from working machinery. Emissions from railways were less than one tenth Mt in 2016.

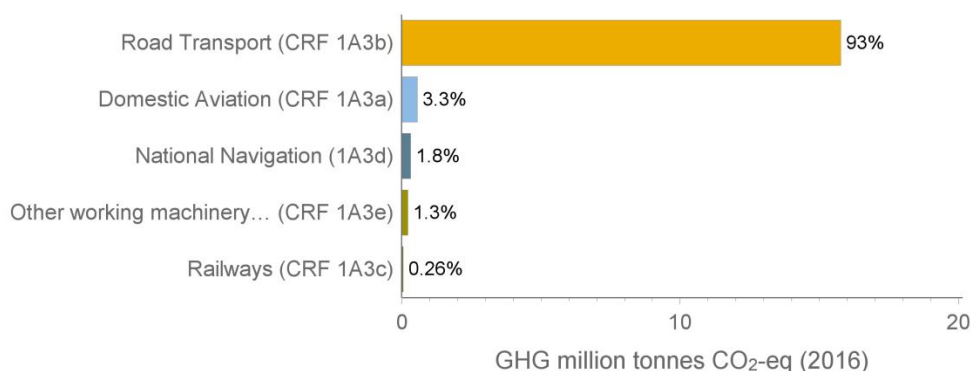


Figure 2.17. Share of emissions from sub sectors in the transport sector 2016.

Carbon dioxide accounts for the largest share of greenhouse gas emissions from the transport sector. Methane emissions were less than one tenth Mt CO₂ eq in 2016 and have fallen 88 % since 1990 as a result of better exhaust emissions control. Nitrous oxide emissions totalled 0.2 Mt of CO₂-eq. in 2016. Emissions of nitrous oxide increased from 1990 to 1997 due to the increased use of cars fitted with catalytic converters. Emissions decreased during the early 2000s following the introduction of enhanced exhaust treatment technology, but have started to increase again from 2007 and onwards but are still on a lower level than in 1990.

2.3.1.4.1 Road transport

Emissions from road transport includes emissions from passenger cars (CRF 1A3b i), light duty vehicles (CRF 1A3b ii), heavy goods vehicles (1A3b iii), buses (CRF 1A3b iii) and mopeds and motorcycles (CRF 1A3b iv). The emissions in 2016 and the share of the emissions from road traffic are shown in Figure 2.18.

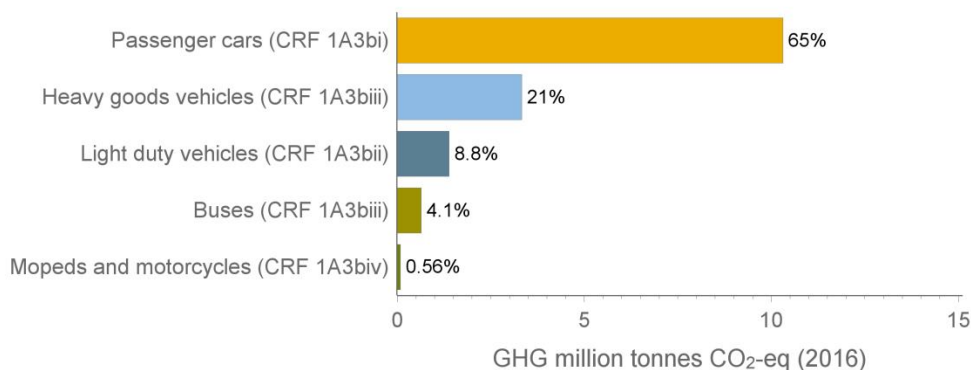


Figure 2.18. Share of emissions from subsectors of road transport in 2016.

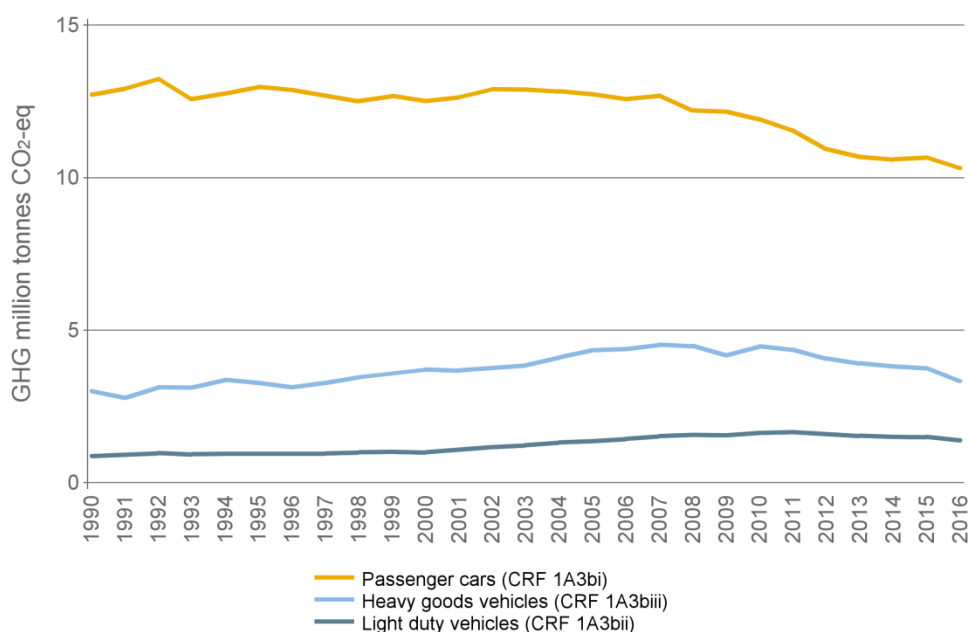


Figure 2.19. Emissions from road traffic by sub-sector, 1990-2016.

Emissions from passenger cars were 10.3 Mt CO₂-eq. in 2016, which is 19 % lower than in 1990. Emissions from passenger cars were on a fairly constant level until 2007 when they started to decrease. Besides a slight increase between 2014 and 2015 the emissions have decreased since 2007. Before 2008 the growth in transport activity was offset by a greater use of renewable fuels, more energy efficient vehicles and reduced fuel consumption which kept the level of emissions constant. The decrease that is seen in emissions after 2007 is much due to increased use of renewable fuels, more energy efficient vehicles and reduced fuel consumption in combination with the economic downturn which started in 2008.

Emissions from heavy duty vehicles were 3.3 Mt CO₂-eq. in 2016. Emissions from heavy-duty vehicles were overall increasing from the early 1990s up until 2008. Since 2010 the emissions are decreasing.

The switch from petrol-powered to diesel-powered cars is leading to a more energy efficient car fleet, which since the mid-2000s has been reinforced by a general improvement in energy efficiency for new cars. The average carbon dioxide emissions per km for new cars decreased since the early 2000th, shown in Figure 2.20, with the largest reduction between 2005 and 2012. Between 2012 and 2013 the energy efficiency rate has stagnated. The stagnation is due to the increased share of four wheel drive vehicles among new cars.¹⁷

¹⁷ Swedish Transport Administration, 2015

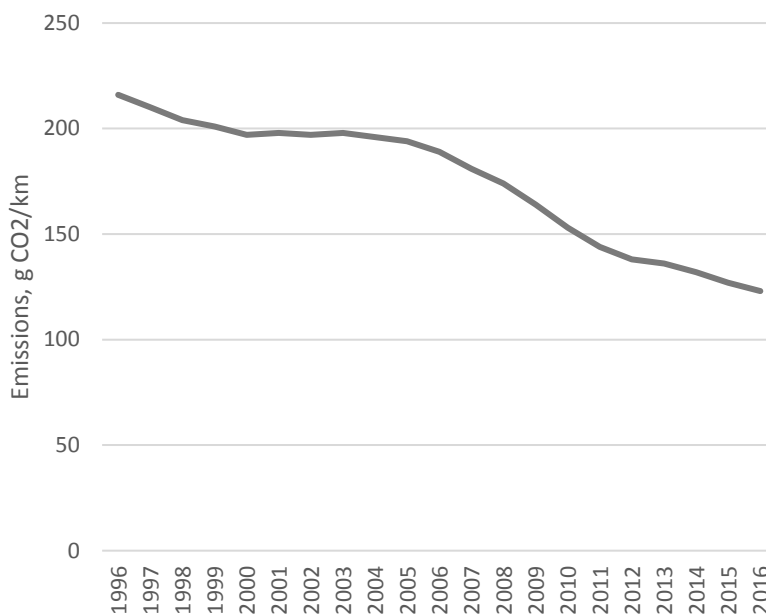


Figure 2.20. Average CO₂-emissions per km for new cars in Sweden, 1990 – 2016.
Source: Trafikverket.

There are several policy measures contributing to the trend for emissions from passenger cars: the EU-requirements limiting the carbon dioxide emissions from new cars, increased fuel taxes, tax exemption for transport biofuels, carbon dioxide-based vehicle tax, tax relief for green cars and green car rebates, together with rising market price for petrol and diesel. They have contributed to more fuel-efficient cars and an increased number of fuel-flexible cars. The use of renewable fuels has been principally boosted by the fact that since 2004 they have been exempt from carbon dioxide tax and energy tax, along with a law from 2006 requiring every major petrol station to provide a renewable fuel. Large-scale blending of ethanol into petrol began in 2003, with the result that almost all petrol sold in Sweden now contains 5 % ethanol. Blending of biodiesel, such as FAME and HVO, into diesel has also increased during recent years.

2.3.1.4.2 Domestic aviation, national navigation and railways

In 2016, emissions from domestic aviation totalled 0.6 Mt of CO₂-eq, see Figure 2.22, which is 20 % lower than the level in 1990. However, the emissions varied during the period. The emissions increased by 8 % from 2015 to 2016.

Emissions from national navigation were 0.3 Mt of CO₂-eq. in 2016, see Figure 2.22. This is 48 % lower than in 1990 and 17 % lower than in 2015, but emissions have varied over the period.

Sweden's railways are largely electrified, with only a few smaller lines served by diesel-hauled trains. Emissions from rail transport have been more than halved since 1990 and are now below 50 kt of CO₂-eq. (Figure 2.21).

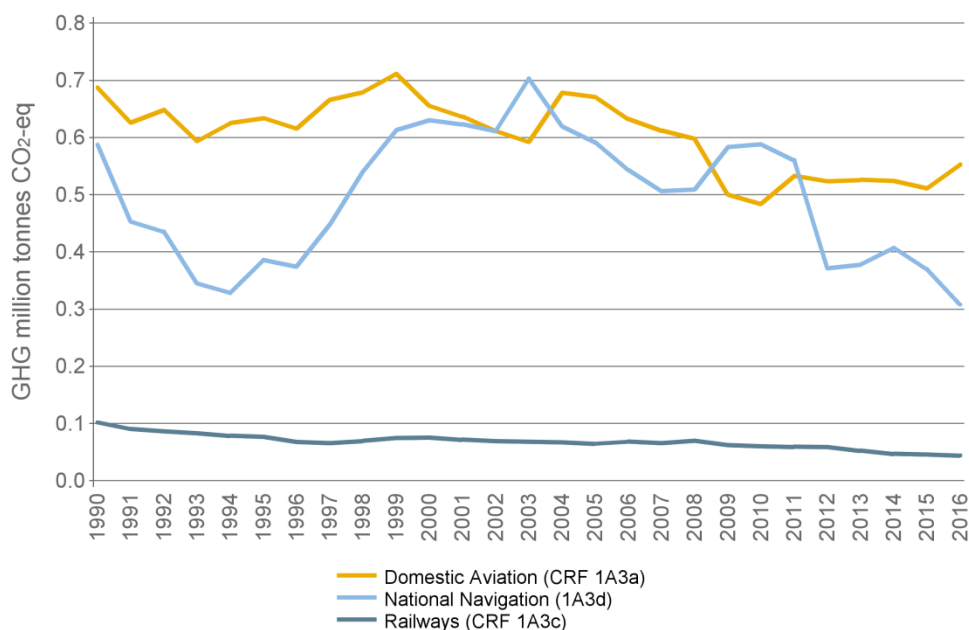


Figure 2.21. Emissions of CO₂ eq. from aviation, navigation and railways, 1990-2016.

2.3.1.5 OTHER SECTORS (CRF1A4)

In other sectors, emissions have decreased by 72 % during 1990-2016 due to a strong decrease in combustion of fossil fuels for heating in the residential and commercial/institutional sectors. Fossil fuels have been replaced by district heating, some biomass, and electricity, including increased usage of heat pumps in recent years. Since emissions from stationary combustion for heating purposes has decreased significantly, the main emissions within the sector now come from working machinery and off road vehicles. There has been a continued decrease in emissions between 2015 and 2016 with 4 %.

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

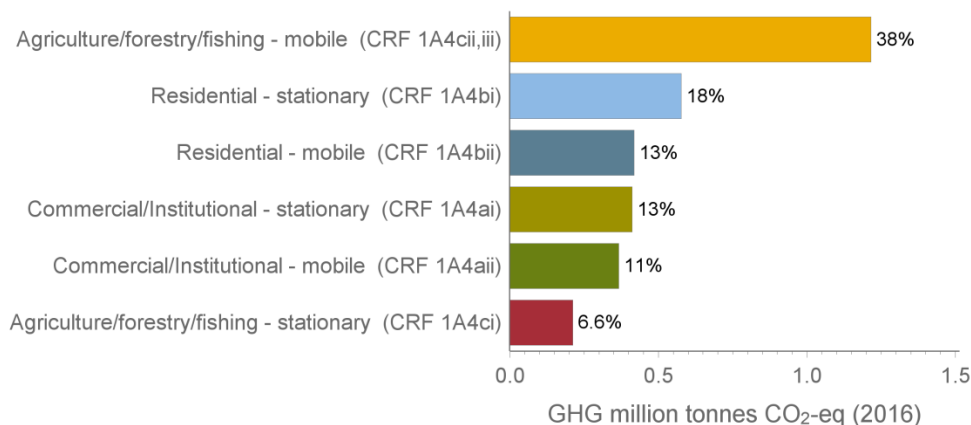


Figure 2.22. Share of emissions within Other sectors by subsector in 2016, with mobile and stationary combustion shown separately for each subsector.

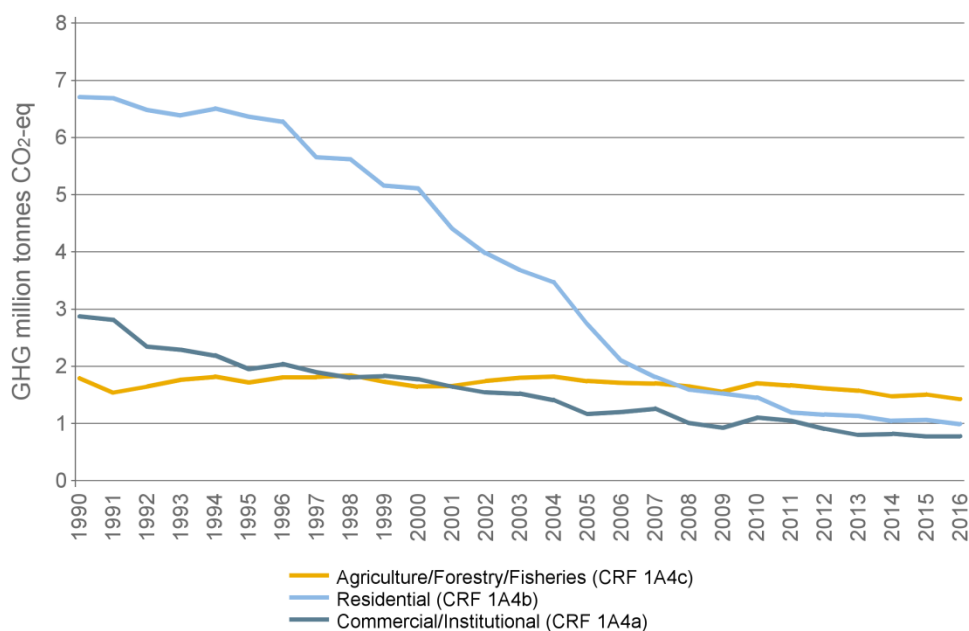


Figure 2.23. Emissions from Other sectors, total and by subsector, 1990-2016.

Emissions in Other sectors were approximately 3.2 Mt of CO₂-eq. in 2016. The reduction is due to a strong decrease in emissions from heating in the commercial/institutional and residential (CRF 1A4a and 1A4b) sectors between 1990 and 2016 (Figure 2.23) of 73 and 85 %, respectively. In comparison with 2015 the total emissions from the residential sector continued to decrease with 7 %. Emissions from the commercial/institutional sector, however, were at the same level as in 2015. The emissions from agriculture, forestry and fisheries (CRF 1A4c) were 1.4 Mt CO₂-eq. in 2016, which is 20 % less than in 1990.

Total emissions from off-road vehicles and other machinery within the sector were 2 Mt of -eq, which represents 62 % of the emissions from Other sectors. Distribution between stationary and mobile combustion sources, as well as total

emissions, is shown in Figure 2.24 below. Emissions from stationary combustion have decreased by 87 % in total from 1990 to 2016, while emissions from mobile combustion were 6 % higher in 2016 than in 1990 (Figure 2.24). Since emissions from stationary combustion have decreased substantially, the mobile combustion now is the largest source of emissions.

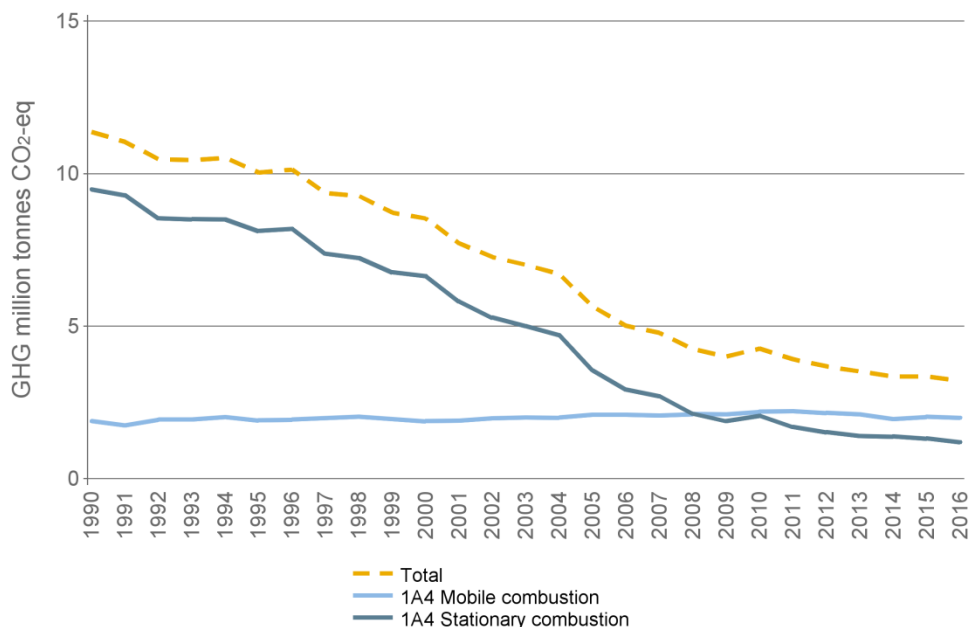


Figure 2.24. Emissions from mobile combustion, stationary combustion and emissions in total, 1990-2016.

Emissions from working machinery and off road vehicles (mobile combustion) have increased by 6 % in total since 1990. The residential sector (CRF 1A4b) has increased emissions from mobile combustion by about 50 % since 1990, yet these emissions are relatively low, 0.4 Mt of CO₂-eq. in 2016, see Figure 2.25. Emissions from mobile combustion in agriculture was 1 % higher in 2016 compared to emission levels in 1990. Emissions from mobile combustion in forestry (1A4c) have varied over the years and was around 7 % lower in 2016 compared to 1990, see Figure 2.25. In the commercial/institutional sector (CRF 1A4a) emissions from mobile combustion have varied during the period but were in around 20 % higher in 2016 compared to 1990. In fisheries (CRF 1A4c) the emissions have been declining during the past decades, following the trend with a shrinking fleet of fishing vessels in Sweden. It should be noted that the emissions from working machinery and off road vehicles are model-based and there is a high uncertainty connected to these emissions. More can be read about the used model in Annex 2.

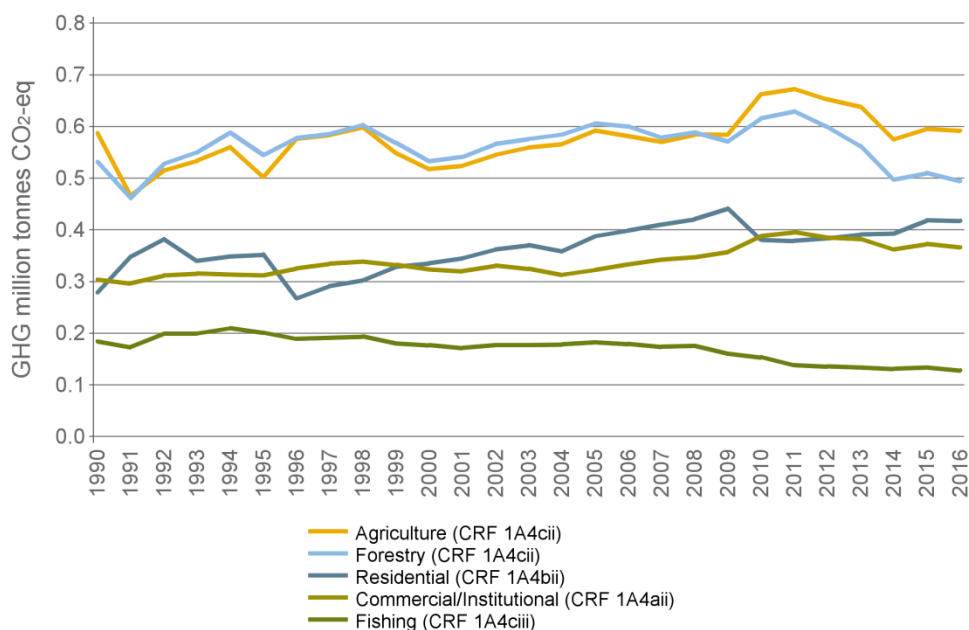


Figure 2.25. Emissions off-road vehicles and other machinery in each subsector, 1990-2016.

In the residential sector (CRF 1A4b), the emissions from stationary combustion have decreased by 91 % since 1990, and in the commercial/institutional sector (CRF 1A4a) emissions from stationary combustion have decreased by 84 %. Emissions from stationary combustion in agriculture, forestry and fisheries (CRF 1A4c) are small and have decreased, with 56 % compared to 1990. Emissions from stationary combustion within each subsector are shown in Figure 2.26.

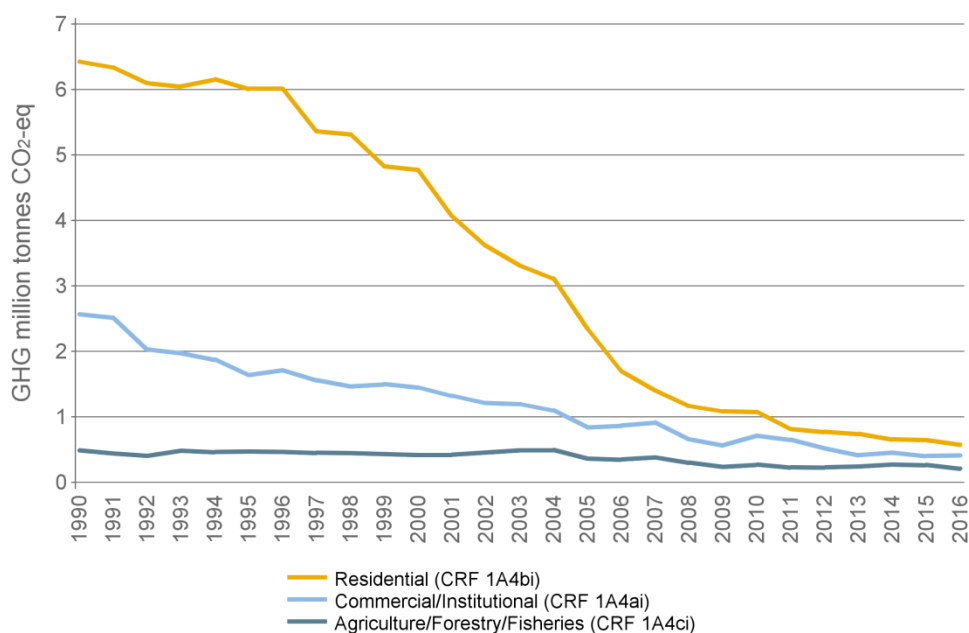


Figure 2.26. Emissions from stationary combustion in each subsector, 1990-2016.

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

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

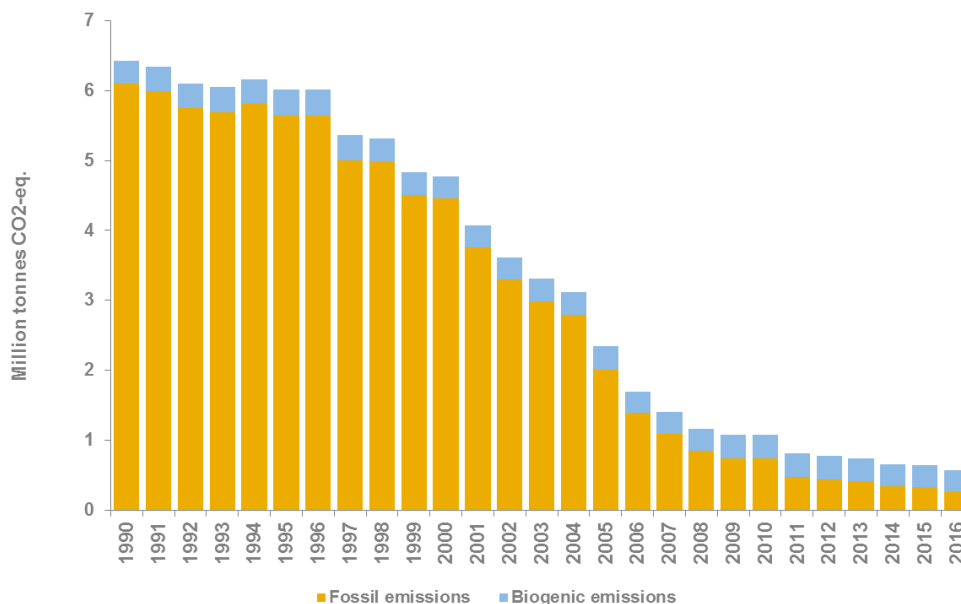


Figure 2.27. Emissions from Residential sector (1A4b) fossil and biogenic, stationary combustion, 1990-2016.

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.¹⁸

2.3.2 Industrial processes and product use (CRF sector 2)

Greenhouse gas emissions within the sector industrial processes and product use (CRF 2) stem from the materials used in industrial processes as well as the use of various products such as fluorinated gases, solvents, lubricants and paraffin waxes. Emissions of greenhouse gases from industrial processes and product use have been decreasing in recent years. Greenhouse gas emissions from industrial

¹⁸ Swedish Energy Agency, 2015b

processes are mainly affected by production levels in response to market fluctuations. Emissions from product use were significantly higher in 2016 compared to 1990.

Emissions from the industrial processes and products use sector represented 13 % of the total national emissions in 2016. The main sources of emissions in the industrial processes and product use sector is the production of iron and steel (included in metal industry; 2C) and the cement and lime industries (included in mineral industry; 2A), see Figure 2.28. Note that emissions from combustion in manufacturing industries and construction are allocated to CRF 1A2.

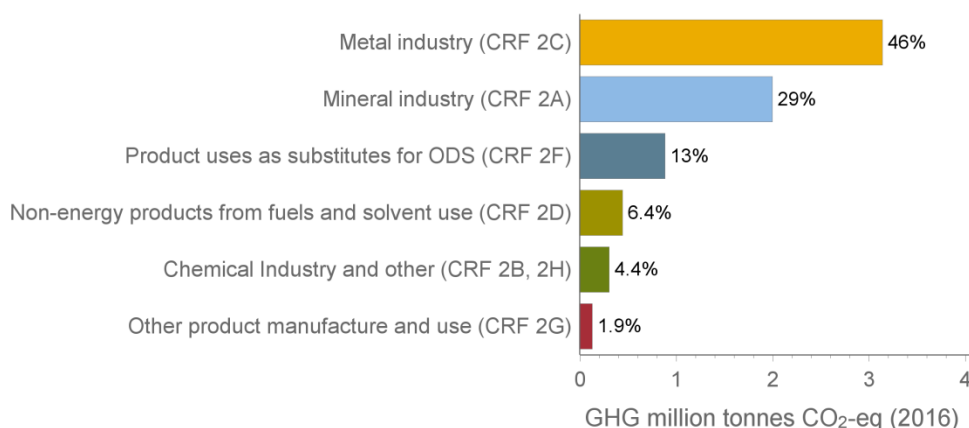


Figure 2.28. Emissions from the industrial processes and product use, 2016.

Greenhouse gas emissions from the industrial processes and product use sector were 3 % lower in 2016 compared to 1990, equivalent to 0.2 Mt of CO₂-eq, see Figure 2.29. After a few years of steady decrease, greenhouse gas emissions from the sector increased with 6 % between 2015 and 2016.

Greenhouse gas emissions from industrial processes (CRF 2A, 2B, 2C, 2E, 2H) show an overall decreasing trend since 1995, with the exception of 2009, and were 27 % lower in 2016 compared to 1990, see Figure 2.29. Greenhouse gas emissions from product use (CRF 2D, 2F, 2G) showed an increasing trend that culminated in 2004-2010 and has been decreasing since then. Nevertheless, greenhouse gas emissions from product use were 157 % higher in 2016 compared to 1990.

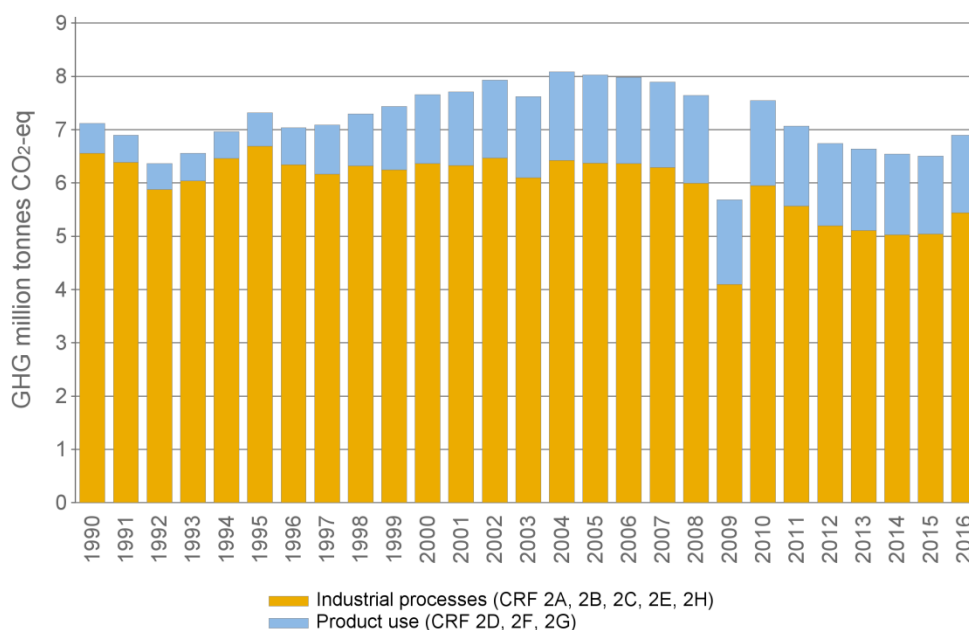


Figure 2.29. Emissions from the industrial processes (CRF 2A, 2B, 2C, 2E, 2H) and product use (CRF 2D, 2F, 2G), 1990-2016.

2.3.2.1 EMISSIONS PER GAS

Carbon dioxide (CO₂) dominates the emissions of this sector with 5.7 Mt of CO₂-eq. in 2016, representing 82 % of the sector's emissions, see Figure 2.30. CO₂ 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 (N₂O) and fluorinated gases (HFCs, PFCs and SF₆). N₂O emissions were 0.23 Mt of CO₂-eq. in 2016 and mainly come from the production of nitric acid. In 2016, the N₂O emissions have decreased by 76 % since 1990. Emissions of fluorinated gases were 0.97 Mt of CO₂-eq. in 2016 and have increased by 44 % 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 CO₂, 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 and the regulation is provided in section 2.2.4.

¹⁹ EU, 2014

²⁰ EU, 2012

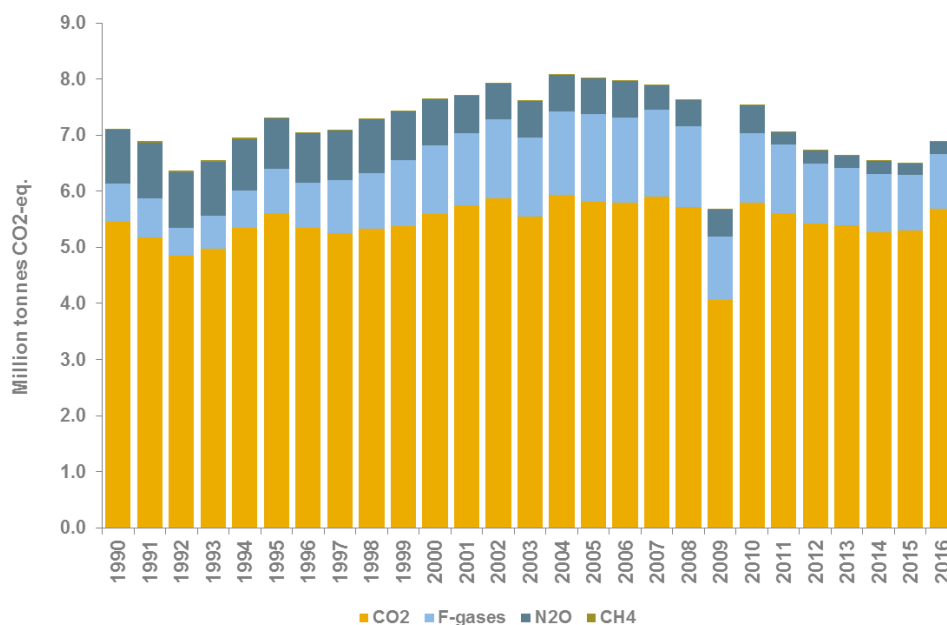


Figure 2.30. Emissions from the industrial processes and product use sector per gas, 1990-2016.

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

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

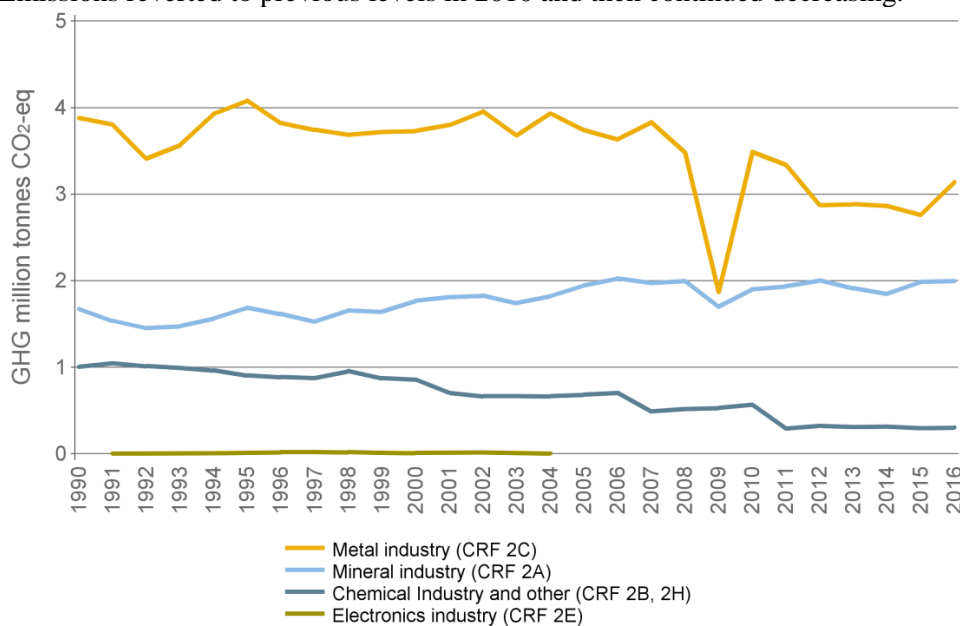


Figure 2.31. Emissions from industrial processes, per subsector, 1990-2016.

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 2016, see Figure 2.31. The emissions were fairly stable until 2008, with the exception of some inter-annual variations. In 2009, emissions decreased rapidly due to reduced production levels in response to the global economic recession. Although production levels – and emission levels – increased again in 2010, the metal industry has not fully reverted to the emission levels prior to the recession (Figure 2.31).

Production of aluminium (CRF 2C3) also causes emissions of perfluorocarbons (PFCs) under conditions where the amount of alumina falls below a critical level in the process (commonly referred to as “anode effects”). These emissions have decreased in recent years, primarily as a result of investments in new technology in primary aluminium production²¹ since 2007.

Mineral industry (2A) is the second largest subsector, accounting for 29 % of the sector's total emissions in 2016, see Figure 2.31. Cement production (2A1) accounts for more than 22 % of the sector's total emissions. The industry also includes production lime (2A2) and glass (2A3). The emissions from the mineral industry show an increasing trend, of 19 %, during the period from 1990 to 2016, mainly due to improving economic conditions in the building sector, both in Sweden and in other countries to which cement is exported. This resulted in an increased production of clinker that is used for the production of cement. Emissions decreased in 2009 as a result of a decline in production in response to the global economic recession. Emissions reverted to previous levels within two years.

Emissions from the chemical industry (2B) show a decreasing trend in emissions from 1990 to 2011 with few minor exceptions. The decrease since 2007 is primarily a result of a new treatment technology for nitric acid production²². The new technology has resulted in reduced emissions of nitrous oxide. The technology has been further developed resulting in additional emissions reductions in 2010. Together with other production (2H), that primarily includes process emissions from the pulp and paper industry and mineral wool production, the activities accounted for 4 % of the sector's total emissions in 2016.

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

²¹ Ny Teknik, 2014

²² Yara, 2007

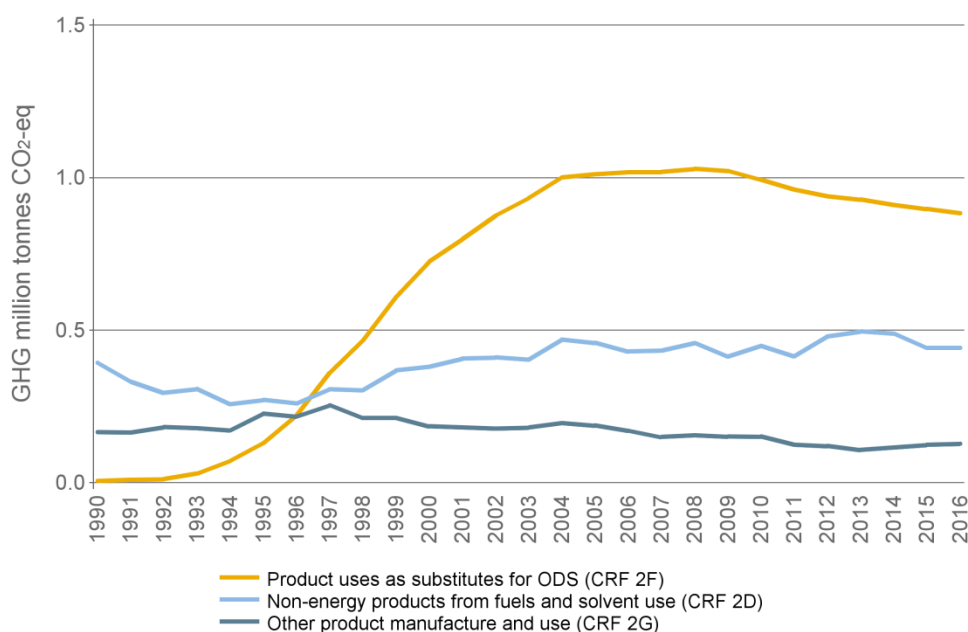


Figure 2.32. Emissions from product use, per subsector, 1990-2016.

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

Greenhouse gas emissions from product use (CRF 2D, 2F, 2G) represent 3 % of the national total emissions in 2016. 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 2016, the emissions in this subsector accounted for around 0.9 Mt of CO₂-eq, which represents 13 % of the total emissions from industrial processes and product use. The emissions have increased considerably since 1990, from almost 0 in 1990. The increase between 1990 and 2009 was almost 1 Mt of CO₂-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 years²³. 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

²³ Swedish Chemicals Agency, 2017

subsector represented 6 % of the industrial processes and product use sector in 2016, or 0.4 Mt of CO₂-eq. The emissions increased by 13 % during the period 1990 to 2016. The increase is mainly due to increased CO₂ emissions from use of lubricants.

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 N₂O from product use in medical applications. The greenhouse gas emissions in this subsector accounted for around 0.1 Mt of CO₂-eq. in 2016. The trend was increasing until 1995 but has since gradually decreased by nearly 50 %.

2.3.3 Agriculture Sector (CRF 3)

The main sources of greenhouse gas emissions from the agricultural sector are methane emission from cattle and nitrous oxide emissions from soil and manure, which are almost equal in size. In addition, there is small amount of carbon dioxide emissions from liming and urea application. In 2016, the emissions from agriculture were about 10 % lower compared with 1990. The decrease is due to a continuous decline in livestock number and a drop in emissions from agricultural soils in general. . The emissions in 2016 have increased slightly (0.2 %) compared to previous year due to an increased use of fertilizers.

Within the agriculture sector (CRF 3), agricultural soils (3D) and enteric fermentation (3A) are the largest emission sub-categories, accounting for 46 and 43%, respectively. The manure management (3B) and liming (3G) contribute with 9 % and 2 %, respectively. Emission from urea application (3H) is very limited (Figure 2.33).

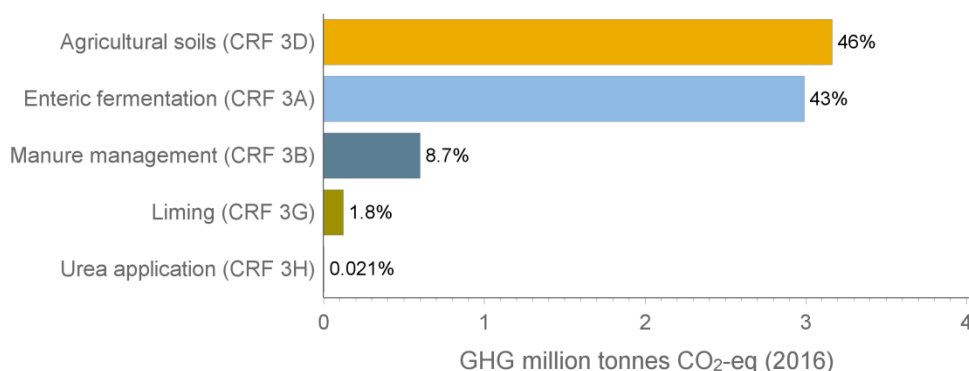


Figure 2.33. Emissions in the Agriculture sector in 2016 (Gg CO₂-eq)

Different activities within the agriculture sector contribute to emissions of greenhouse gases through a variety of processes in which carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O) are emitted. The main sources of CH₄ and N₂O emission in Sweden are animal husbandry and crop production which includes

for example, the use of synthetic fertilizer. Animal husbandry in Sweden is dominated by beef and dairy cattle, but also has significant swine, sheep and poultry components. Other livestock species farming include goats, horses, reindeer and fur-bearing animals. Agricultural farming includes predominantly the production of cereals, sugar beet and oilseeds.

In 2016, the emissions from the agriculture sector were about 6.9 Mt CO₂-eq. which equals 13 % of the total national greenhouse gas emissions (excluding LULUCF). About one-half (51 %) of the sector's emissions consisted of N₂O, 47 % CH₄ and the rest (less than 2 %) was CO₂. In 2016, emissions from the agriculture sector have decreased by 0.75 Mt CO₂-eq., or about 10 % lower compared to 1990 levels (Figure 2.34).

The main drivers of the long-term decreasing emission trend are a decline in the numbers livestock and a decrease in N₂O emissions from agricultural soils (3D), initiated by drop of synthetic fertilizer application. Emissions from liming and dolomite use (3G) and urea application (3H) have also decreased.

In 2016, the total emission of the sector slightly increased by about 0.2 % compared to the previous year, primarily due to increased use of organic fertilizer (CRF 3Da2c) and deposition of urine and dung from grazing animals (CRF 3Da3).

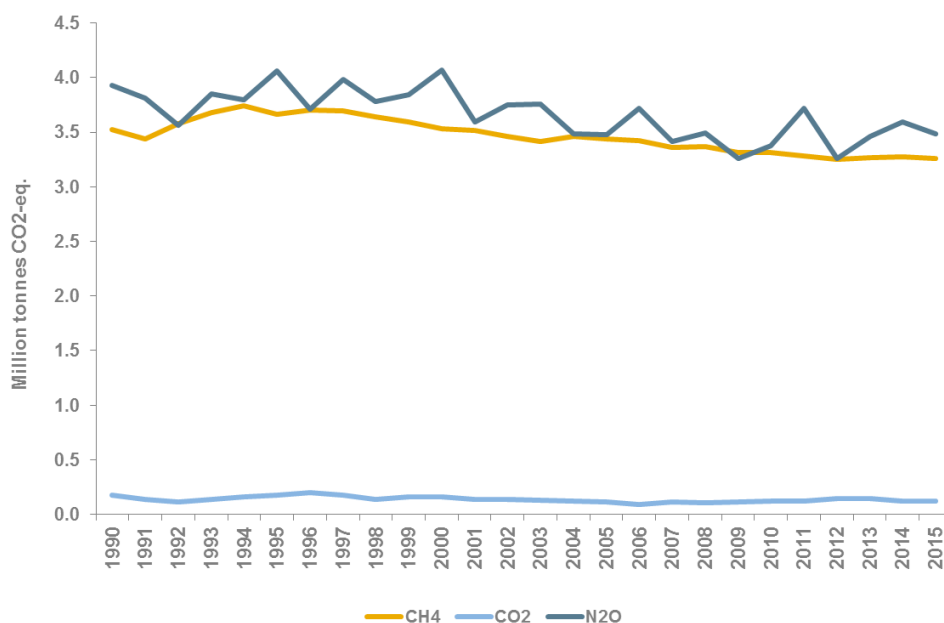


Figure 2.34. Emissions from agriculture sector per gas 1990-2016 (Gg CO₂-eq.).

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

The aggregated CH₄ emission from enteric fermentation (3A) were about 3 Mt - CO₂-eq. which equates to about 43 % of the sector's emission and representing the largest single source of CH₄ emission in the national inventory. The emission has decreased by about 9 % since 1990. In 2016, the emission dropped slightly by about 0.4 % compared to the previous year, see Figure 2.35.

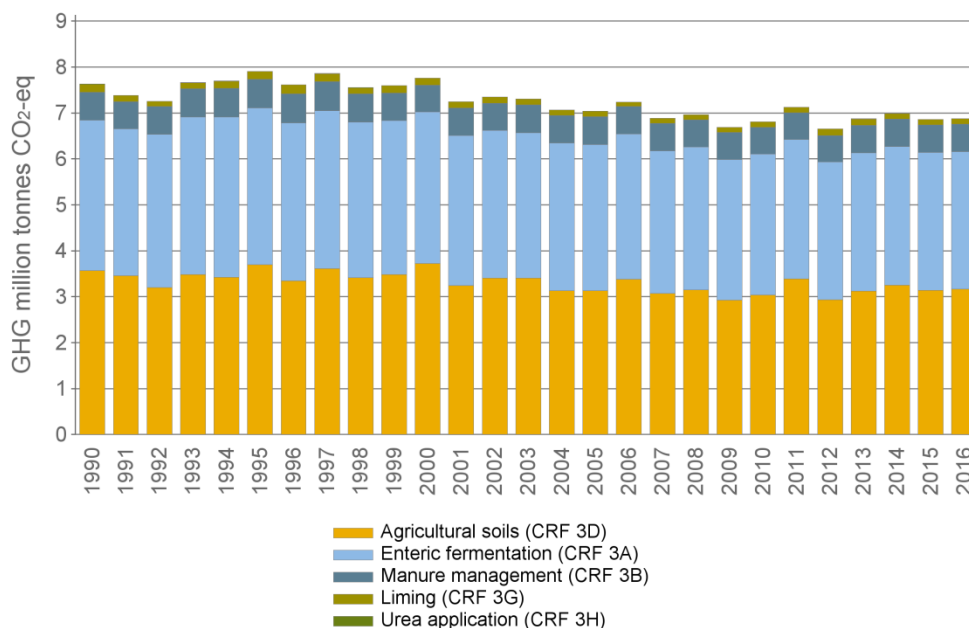


Figure 2.35. Emissions from agriculture subsector 1990-2016 (Gg CO₂-eq).

The key driver for CH₄ emission reduction since 1990 is a decline in livestock numbers, mainly dairy-cows and swine. The population of dairy-cows, for example, has decreased by about 43 % (from 576 000 to 331 000 heads between 1990 and 2016). Between 2015 and 2016, the population decreased by about 2.7 % or 9 000 heads. The numbers of swine have also decreased by almost the same magnitude during this period. The most important factor for dairy cows is the amount of milk produced. Higher milk production per dairy cow gives lower CH₄ emissions per kg of milk produced. The milk production per cow has increased by about 45 % between 1990 and 2016. The average milk yield per cow in 2016 was 9432 kg yr⁻¹ cow⁻¹. Productivity improvements in milk farms mean that each cow produces more milk, allowing farmers to reduce the number of milk cows.

A significant reduction in dairy cattle population (about 8 %) took place in 1990/1991, when a large number of farms abandoned milk production and shifted towards non-dairy cattle. Some of these farms changed to extensive meat production with the aid of government conversion grants, and the number of beef cattle therefore, increased by about 15 % during the first half of the 1990s.

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

The population of heifers, bulls and stouts in 2016 is very comparable to 1990 levels. The culmination of the number of heifers, bulls and stouts in 1996 was followed by a steep decline until 2003, which slowed down until 2016. Although there is a long-term trend for a successive decrease in dairy-cattle and swine population, the numbers of horses, goats, sheep and chickens for slaughter have increased. Overall, the changes have resulted in a decrease of CH₄ emissions from both livestock and N₂O from their manure.

In 2016, the aggregated emissions from manure management (3B) were about 9 % (or 0.6 Mt CO₂-eq.) of the sector's emission. The composition of the emissions was 44 % CH₄ and 56 % N₂O. The total emission from manure management in 2016 is slightly below the 1990 levels, even though the numbers of dairy cattle have decreased substantially. This can be explained by the increase in milk production per cow as cows that produce more milk also produce more manure.

2.3.3.2 AGRICULTURAL SOILS (CRF 3.D)

The sub-sector, agricultural soils (3D) is the largest single source of N₂O emission in the national inventory. In 2016, 3D was responsible for about 46 % (or about 3.2 Mt CO₂-eq.) of the sector's total (Figure 2.35). The emission has decreased by about 11 % since 1990, but increased by 1 % in 2016 compared to the previous year, mainly due to increased use of organic fertilizer and increased deposition of urine and dung from grazing animals.

The main sources of N₂O emission are the supply and conversion of nitrogen from use of synthetic fertilizers, cultivation of organic soils from drained histosols, crop residues applied to soils and animal waste. Other small sources include sewage sludge used as fertilizer in crop fields, emissions from organic soils as a result of mineralization and immobilization associated with loss/gain of soil organic matter, atmospheric deposition and conversion of the nitrogen that leaches to lakes and watercourses.

The emission trend of agricultural soils depends largely on the amount of inorganic nitrogen applied to soils, but also influenced by other sources such as mineralization and immobilization associated with loss/gain of soil organic matter, cultivation of organic soils and animal waste applied to soil. Emissions from agricultural soils have declined by about 11 % compared to 1990, due to decreased use of synthetic fertilizers and farmyard manure. For instance, the nitrogen input via application of synthetic fertilizers on agricultural soils declined from 225 kt to

about 186 kt between 1990 and 2016 (equivalent to a reduction of 17 %)²⁴ which corresponds to emissions reduction of about the same magnitude. Emissions of N₂O from application of N-fertilizers (CRF 3Da1) in 2016 have decreased by about 2% due to reduced sales compared to 2015.

Sales of other types of mineral fertilizer, i.e., phosphorus, potassium and sulfur fertilizers have also decreased over the same period. Sale and use of fertilizer can be affected by many factors, such as the area of arable land, fertilizer prices and crop types. Although there is a general downward trend of N₂O emission from the agricultural soils since 1990, the emission has increased over the past few years due to increased use of fertilizers. Sales of N-fertilizers in 2015/16 increased by more than 25 % compared with 2011/2012. This is due to increased areas of cereals which led to higher demand of fertilizers. As a result of these conditions, the production of cereals has increased during this period. In 2015, a combination of favourable weather conditions for the winter crops and large areas of winter wheat led to an increase use of N-fertilizers, which in turn led to that the grain harvest was the largest since 1997.

Deposition of urine and manure from grazing animals and atmospheric deposition and N-leaching and run-off have also decreased since 1990.

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

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

The estimated emissions from liming in 2016 were about 123 kt CO₂, compared to 173 kt CO₂ in 1990 (a decrease by 29 %). The total emissions of CO₂ account for less than 2% of the sector's emission (Figure 2.34).

Carbon dioxide is extracted from the atmosphere for urea manufacturing and then released again upon urea application to soils. The amount of urea used in Sweden is limited and relatively smaller than in the rest of Europe, which may be due to that urea is a slow release fertilizer, which does not fit well in areas with a short growing season (i.e., northern latitudes). In 2016, CO₂ emission from urea application amounted to about 1.4 kt, compared to 4.3 kt in 1990.

²⁴ Statistics Sweden, 2016

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

This sector consists of source and sink categories linked to land use, land use change and forestry. The total net removal was 43 Mt CO₂-eq. in 2016. Forest land covers more than half of the Swedish total land area, and is therefore the dominant category in this sector. The largest net removals occur in forest land and amounted to about 41 Mt CO₂-eq. in 2016, followed by harvested wood products with removals of about 8Mt CO₂-eq. The largest net emissions in this sector occur in settlements and in cropland. The net emissions in 2016 are about 4,6 Mt CO₂-eq. as a mean value in these two categories. Sources and sinks in the LULUCF sector as a whole have resulted in net removals since 1990.

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

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

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

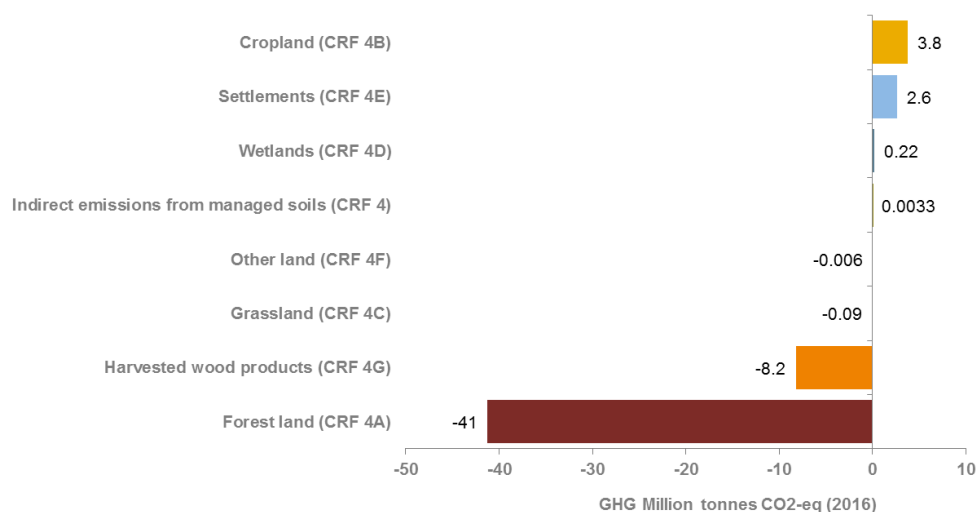


Figure 2.36. Emissions (+) and removals (-) in the LULUCF sector; for the categories, Forest land (CRF4A), Cropland (CRF 4B), Grassland (CRF 4C), Wetland (CRF 4D), Settlements (CRF4F) and HWP (CRF 4G) in 2016.

The LULUCF sector generated annual net removals in Sweden during the whole period 1990-2016 (Figure 2.37). In 2016 total net removal from the sector was estimated to about 43 Mt CO₂-eq. During the period net removals have varied between around 36 to 43 Mt of CO₂-eq. Between 2015 and 2016 the total net removals decreased by nearly 2 Mt CO₂-eq. The total size and variation of net removals in the LULUCF-sector is mainly affected by the carbon stock change in forest land, and changes in the carbon pool living biomass constitute the major part of these changes in net removals followed by carbon stock changes in mineral soils. Net removals in this sector are heavily influenced by harvests and natural disturbances such as storms on forest land.

Net removals in living biomass in forest land varied between approximately 23 (2005) and 37 (1996 and 2010) Mt of CO₂-eq. during the period 1990-until2016.. Between 2015 and 2016 the total net removal on forest land increased with 0,5 Mt CO₂-eq. There are two dips in the trend, in 2005 and 2007, because of two severe storms. According to the Swedish National Board of Forestry, the felling, including wood felled by storms, was estimated at 122 Mm³sk in 2005. However, the decrease in the living biomass in 2005, resulted in an increase in the HWP-pool in 2006.

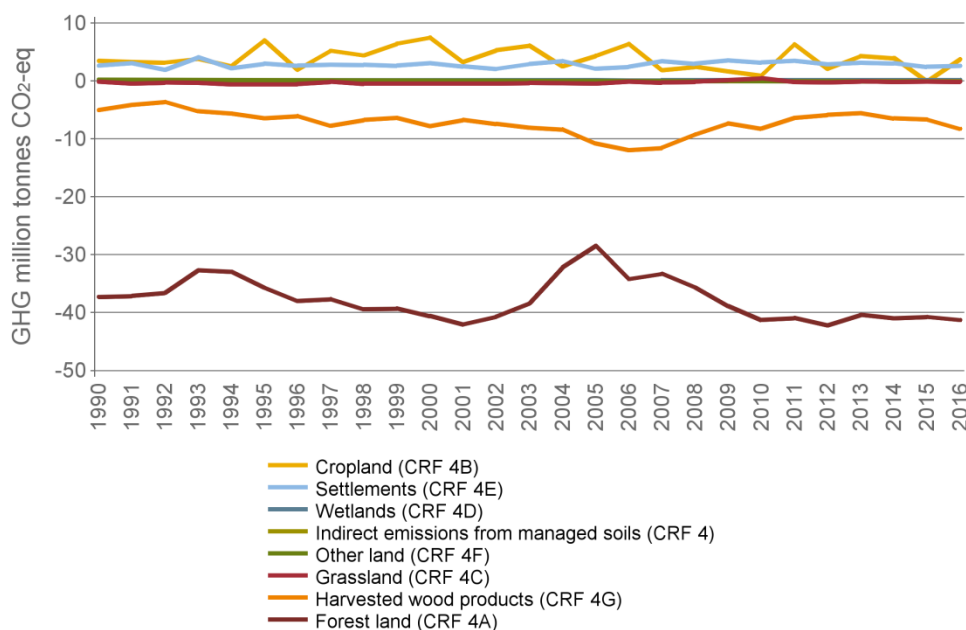


Figure 2.37. Net emissions (+) and removals (-) of greenhouse gases in the LULUCF sector from different land-use categories and total net removals for the LULUCF-sector, 1990-2016.

Although inter-annual fluctuations in harvest rates are quite large, the increase in harvest rates has stagnated in recent years. In 2016 the gross harvest was approximately 92Mm³sk²⁵. Gross removal (growth) in Sweden shows an increasing trend and is currently at around 120 Mm³sk (approx. 165 Mt CO₂-eq per year). Since harvest level is below growth, there is a steady carbon stock in living biomass which has prevailed since the beginning of the 21st century.

The categories grassland and wetlands account for very small areas and small net removals and net emissions compared to forest land. The carbon stock changes in grassland and wetlands were small during the period 1990 to 2016. The net removals in the category grassland have varied during the period. The variation in the net removal was due to the variation in harvest of trees (living biomass) in the grassland category. The trend goes from a small sink to a very small sink. The emissions from wetlands are due to drainage of organic soils for peat production. The emissions have varied between nearly 80 to 200 kt carbon dioxide.

The largest net emissions in this sector come from cropland and settlements. Net emissions from cropland has been about 4 Mt of CO₂-eq. as a mean value. The inter-annual variation in net emissions in cropland is connected to the variation in mineral soils. The annual variations depend on what are grown and how large areas of crops that are grown between years together with the climatic conditions (air temperature and precipitations). The total net emissions between 2015 and 2016

²⁵ SLU, 2017

varied with nearly 4 Mt CO₂-eq. The emissions of carbon dioxide in croplands originate from the cultivation of organic soils. Emissions from drained organic soils are the largest source in in this land use category.

Net emissions from settlements were in the range of 1,9 (1992) to 3,5 (2011) Mt of CO₂-eq. in the period 1990 to 2016. Emissions were higher in the period 2007 to 2011 but have decreased since then. The net emissions increased by about 140 kton CO₂-eq. between 2015 and 2016. Emissions are mainly caused by urbanisation and establishments of power lines and forest roads.

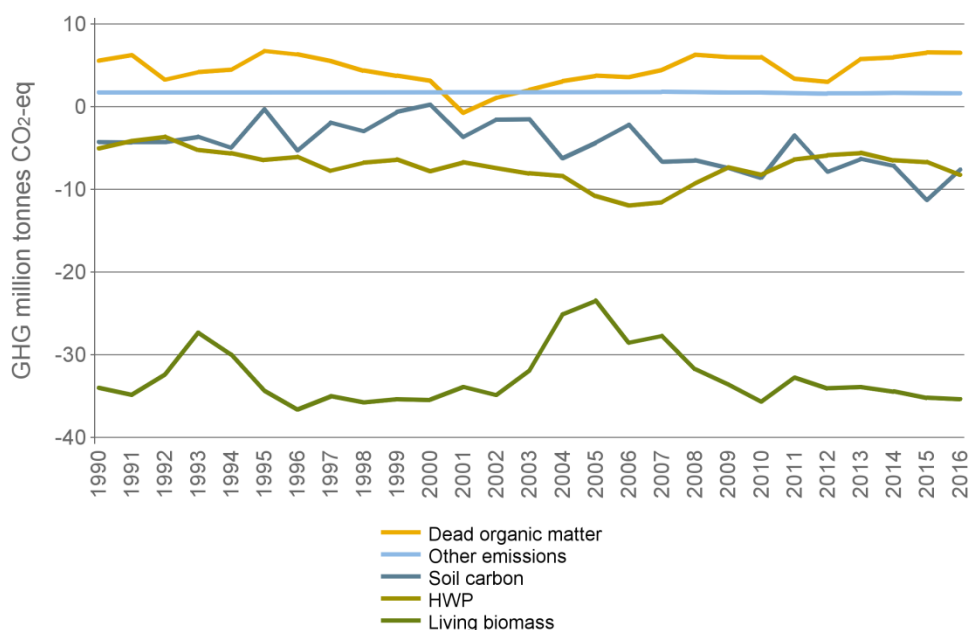


Figure 2.38. Emissions (+) and removals (-) of carbon dioxide from different carbon pools, 1990-2016.

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 N₂O, indirect (N₂O), mineralization (N₂O), biomass burning (N₂O and CH₄) and drainage (N₂O and CH₄) for different land use categories.

Net removals in living biomass are significant, as illustrated by the net removals on primarily forest land. The HWP pool stock change depends on the estimated difference between the inflow of carbon in terms of new products and the modelled outflow of discarded products. At present, the estimated pool therefore covariates with the Living biomass net removals in the category forest land. The largest net removals in the pool/category HWP, occurred after the big storm in 2005 resulting in increased felling (salvage logging) the year after the storm.

Since 2006 the pool/category is a slightly decreasing sink and removals have varied between 12 (2006) and 3.6 (1992) Mt CO₂-eq. The total removal increased by 1,6 Mt CO₂-eq. between 2015 and 2016.

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

2.3.5 Waste (CRF sector 5)

More than two thirds of the emissions from the waste sector come from solid waste disposal which generates methane. These emissions have decreased by almost 70 % since 1990 and several policy instruments – both legislative and economic – have had significant impact on this trend. The most important mitigation measures are an expansion of methane recovery from landfills, reduced landfill disposal of organic material, increased levels of recovery of materials and waste incineration with energy recovery.

Emissions from waste (CRF 5) include emissions from solid waste disposal (CRF 5A), wastewater treatment and discharge (CRF 5D), biological treatment of solid waste (CRF 5B) and incineration and open burning of waste (CRF 5C). The shares of the sub sectors of the total emissions of the sector are shown in Figure 2.39. Greenhouse gas emissions from the waste sector amounted to 1.3 Mt CO₂-eq. in 2016, or 2.4 % of the national total of greenhouse gas emissions. Out of this, 0.9 Mt CO₂-eq. came from solid waste disposal.

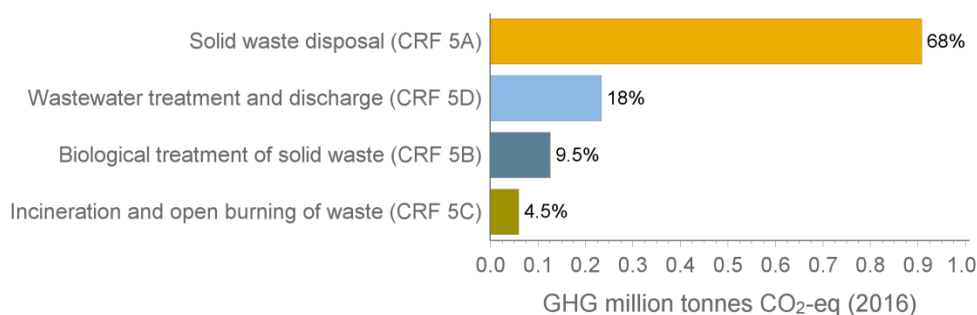


Figure 2.39. Share of emissions from sub sectors in the waste sector 2016.

Emissions in the sector are predominantly methane (CH₄), 77 % in 2016, as seen in Figure 2.40. Emissions of methane from the waste sector have decreased by 70 % in the period 1990 to 2016, due to an increased level of collection and management of methane gas from landfills and reduced amounts of organic material being deposited in landfills.

In 2016, nitrous oxide (N₂O) emissions amounted to 18 % of the emissions. There has been a reduction in the quantity of nitrogen discharged from municipal wastewater treatment plants from the mid-1990s, when nitrogen treatment in wastewater treatment plants in Sweden was developed. The waste sector also emits small amounts of carbon dioxide emissions (CO₂), 5 % of the emissions in 2016. These emissions come from the incineration of waste, of which a minor part is reported in the waste sector and the major part is reported in the energy sector.

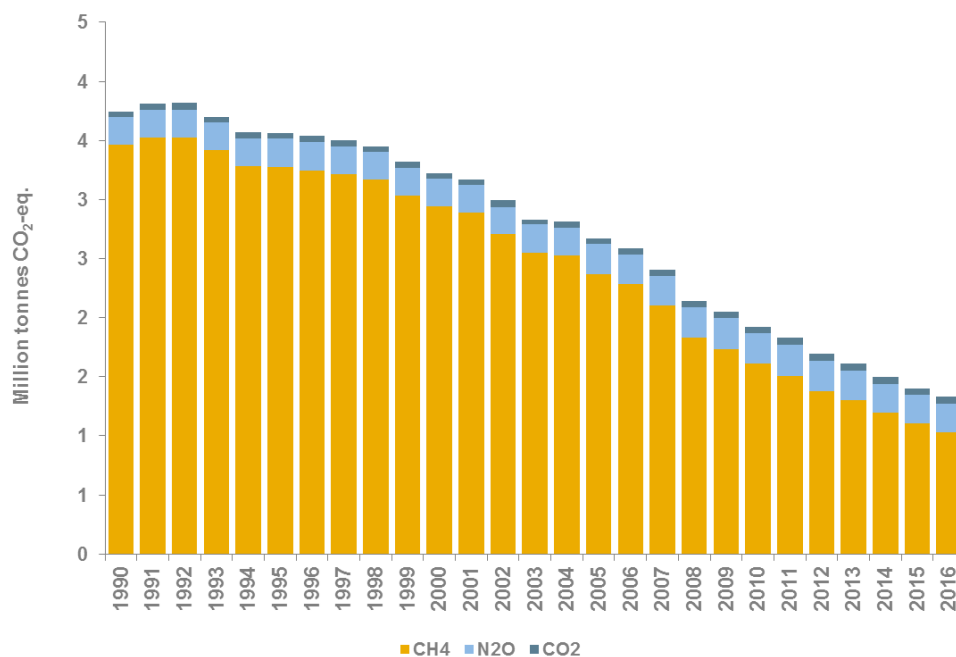


Figure 2.40. Emissions from the waste sector, per gas, 1990-2016.

Emissions from the waste sector have decreased by 65 % 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 the sector – a decrease of 73 % between 1990 and 2016.

While emissions from wastewater treatment and discharge decreased by 10 % from 1990 until 2016, emissions emanating from biological treatment of solid waste and incineration and open burning of waste both show increasing trends from 1990 to 2016, by 800 and 36 % respectively.

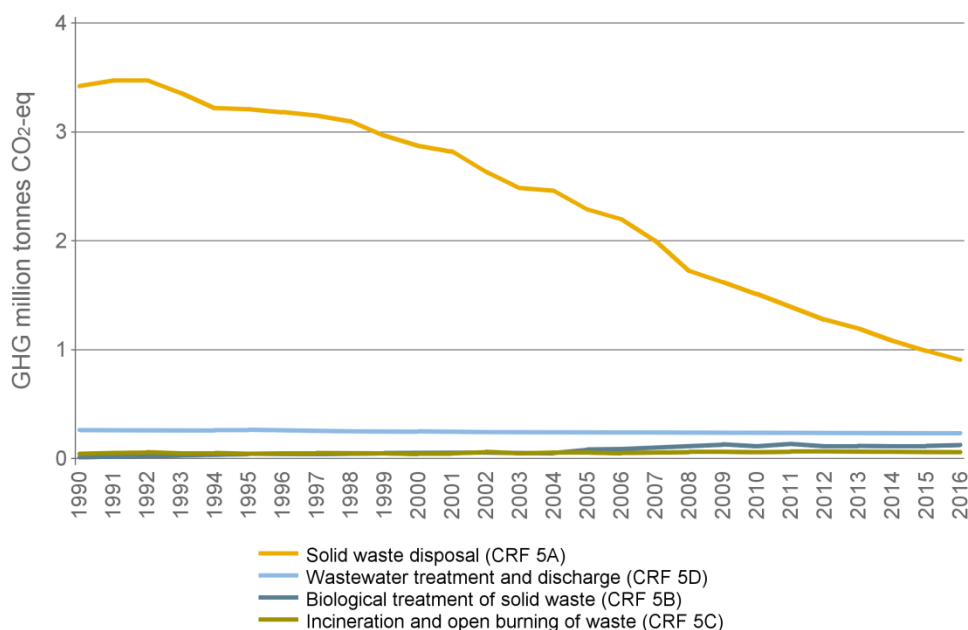


Figure 2.41. Emissions from the waste sector, per subsector, 1990-2016.

2.3.5.1 SOLID WASTE DISPOSAL (CRF 5A)

In 2016, 68 % of the emissions from the waste sector came from solid waste disposal (CRF 5A). Between 2015 and 2016 the emissions decreased by 8 %. Solid waste disposal covers managed, unmanaged and uncategorized waste that have been deposited in landfills. Landfills are the second largest source for emissions of methane gas in Sweden, after livestock farming (in agriculture, CRF 3). Methane is formed when organic waste deposited in landfills starts to decay. Increased collection levels and management of methane gas from landfills and reduced amounts of organic material being deposited in landfills have led to steadily declining methane emissions from Swedish landfills since the early 1990s.

Waste management has developed considerably over the past twenty years. Several policy instruments have had a significant impact on this trend. Producer responsibility was introduced for several groups of products in the 1990s and, today, eight groups of products are covered (i.e. batteries, cars, tires, electric and electronic products, packaging, paper, pharmaceuticals and radioactive products)²⁶. A tax on depositing waste in landfills was introduced in 2000²⁷. Bans on landfill disposal of combustible waste (in 2002) and organic material (in 2005) have also been introduced²⁸. These bans contributed to substantial shifts in Swedish waste management. The landfilling of other types of waste has also fallen sharply.

²⁶ Swedish EPA, 2017

²⁷ Avfall Sverige, 2017

²⁸ Swedish EPA, 2012

Finally, the obligation for municipal waste planning that was introduced in 1991²⁹ may also have contributed to the increased collection of methane from landfills as well as to the reduced deposits of degradable material.

2.3.5.1 WASTEWATER TREATMENT AND DISCHARGE (CRF 5D)

About 18 % of the emissions in the waste sector are emitted from wastewater treatment and discharge. The emissions were approximately 0.2 Mt CO₂-eq. in 2016. Wastewater treatment facilities have been continuously improved since the late 1960s³⁰. Emissions from Swedish wastewater treatment and discharge have decreased by approximately 11 % since 1990, which may be explained by the improvement of facilities during the period as well as increased biogas generation from sewage sludge (Figure 2.41).

2.3.5.2 BIOLOGICAL TREATMENT OF SOLID WASTE (CRF 5B)

Biological treatment of solid waste accounted for 9 % of the total emissions in the waste sector in 2016 (approximately 0.1 Mt CO₂-eq). Biological treatment of solid waste includes composting (aerobic digestion) and anaerobic digestion of organic waste as well as mechanical-biological treatment. Mechanical-biological treatment denotes mechanical treatments (e.g. separation, shredding and crushing) in combination with composting, anaerobic digestion, combustion or recycling. 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 were 9 % of the total emissions from the waste sector but have shown an increasing trend over the last two decades. In fact, the emissions have increased tenfold since 1990, especially in recent years when also production of biogas using anaerobic digestion was scaled up³¹. This may explain the increasing trend together with the fact that composting and digestion overall has become more important treatment methods of municipal waste during the time period (Figure 2.41).

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

In 2016, 5 % of the total emissions in the waste sector occurred in incineration and open burning of waste. Emissions have shown an increased trend since 1990, and in particular since 2003. The total generation of municipal waste has increased over the period and incineration has become the most important treatment option for municipal waste (Figure 2.41). However, the main incineration of municipal waste uses energy recovery and the emissions are therefore accounted for in the energy

²⁹ Swedish EPA, 1991

³⁰ Swedish EPA, 2009

³¹ Swedish Energy Agency, 2015

sector (CRF 1). Nevertheless, this has led to a higher incineration capacity which together with larger quantities of waste being categorized as hazardous may explain the trend also for incineration and open burning of waste in the waste sector.

2.3.6 International shipping and aviation

International bunkers include refuelling in Sweden by international shipping and aviation. These emissions are reported as memo items and are not included in the total Swedish emissions calculated in relation to the Convention and Kyoto Protocol commitments. Greenhouse gas emissions from international shipping and aviation, also known as international bunkers, are considerably larger than those from domestic shipping and aviation. In 2016, they amounted to 9.4 Mt of CO₂-eq, which is an increase of 12 % since 2015 (Figure 2.42).

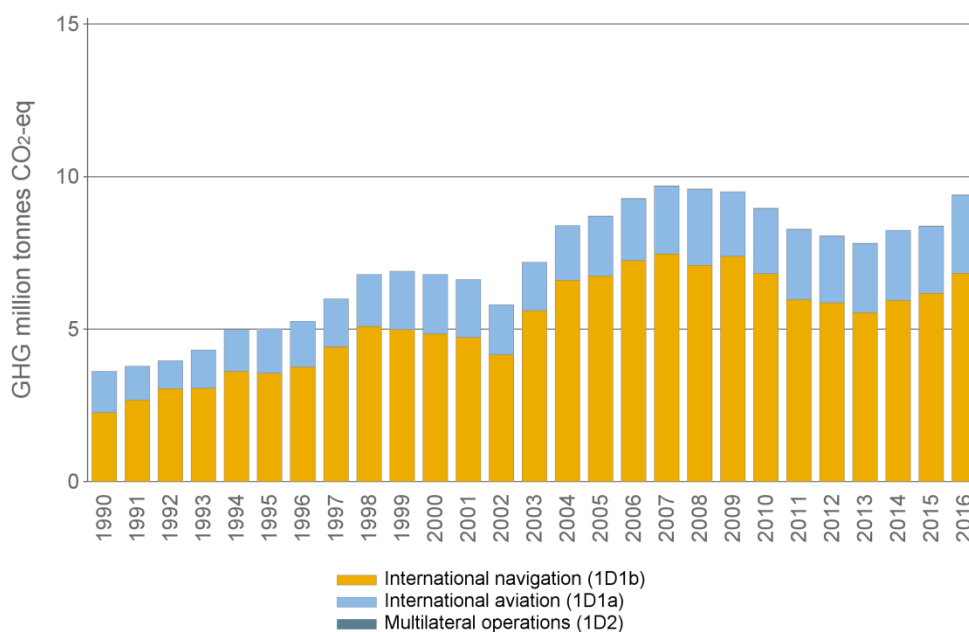


Figure 2.42. Emissions from international bunkers, total and per subsector, 1990-2016.

Emissions from international shipping reached a total of 6.8 Mt of CO₂-eq. in 2016. This is an increase of 11 % compared with 2015 and 202 % higher than in 1990.

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

- That Swedish bunker companies have gained market share in the bunkering market, partly because they were early on offering low-sulfur fuel and partly because a major competing Danish company went bankrupt in 2014.
- The production of residual oil (fuel oil nos. 2-5) has increased due to higher demand for low-sulfur fuel, where residual oil is a by-product from the production of low-sulfur fuel and then the residual fuel are sold as cheaper high-sulfur fuel.

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

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

Greenhouse gas emissions from international aviation bunkers were 2.6 Mt of CO₂-eq. in 2016. This is an increase of 17 % compared to 2015 and 89 % higher than in 1990. Emissions from international bunkering of aviation have varied over time. The trend points to a rise in these emissions, owing to growth in travel abroad.

2.4 Precursors and indirect emissions

The indirect greenhouse gases in Sweden include nitrogen oxides (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOC) and sulphur dioxide (SO₂). The first three gases influence the concentration of ozone in the lower troposphere and hence have influence on the radiative forcing. Sulphur dioxide contributes to aerosol formation in the atmosphere. Sulphate 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 SO₂ in Sweden as their emissions have declined significantly since 1990.

2.4.1 Non-methane volatile organic compounds (NMVOCs)

A total of 159 kt of non-methane volatile organic compounds (NMVOCs) were emitted in 2016. Less than a half (47 %) of the NMVOC emissions come from the industrial processes and product use sector (CRF 2). The energy sector (CRF 1) and the agriculture sector (CRF 3) contributed 31 and 19 % respectively. Remaining emissions (0.6 %) arise from the waste sector (Figure 2.43).

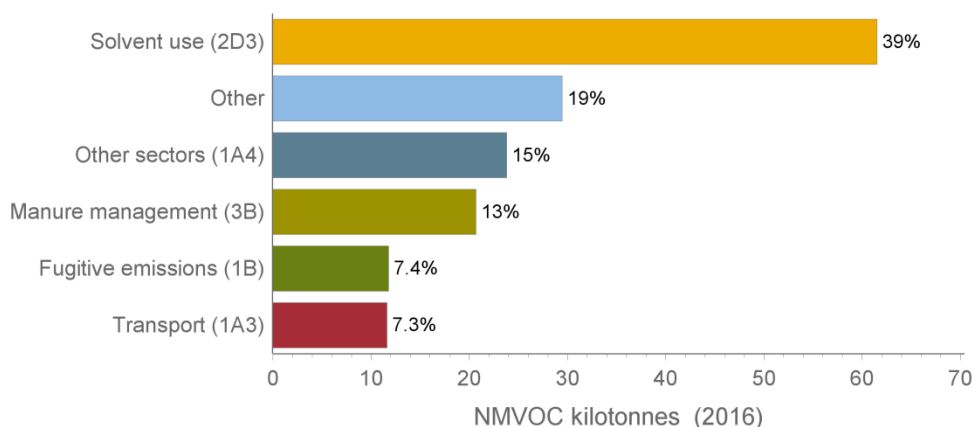


Figure 2.43. Emission sources of NMVOC in 2016 (kt).

Within CRF 2, most of NMVOC emissions (39 %) come from solvent use (2D), while emissions from CRF 1 come from Other sector (1A4) transport (1A3), which accounts for 45 and 22 %, respectively of the sector's total. Residential stationary combustion (1A4b) and fugitive emissions of oil and natural gas (1B) were responsible for 10 and 7 %, respectively of the aggregated NMVOC emissions in 2016. Emission from manure management (3B) and agricultural soils (3D) accounted for 13 and 6 %, respectively.

The total emissions of NMVOCs have declined by 55 % since 1990. The emission has marginally increased compared to 2015 (see Figure 2.44). The decline is sharp in the energy sector (CRF 1) and is clearly visible in the industrial processes and product use sector (CRF 2), amounting to about 74 and 30 %, respectively compared to 1990. In 2016, emissions of NMVOCs from the energy sector (CRF 1) decreased by 4 % compared to the previous year, while the emissions from (CRF 2) remained almost at the same level.

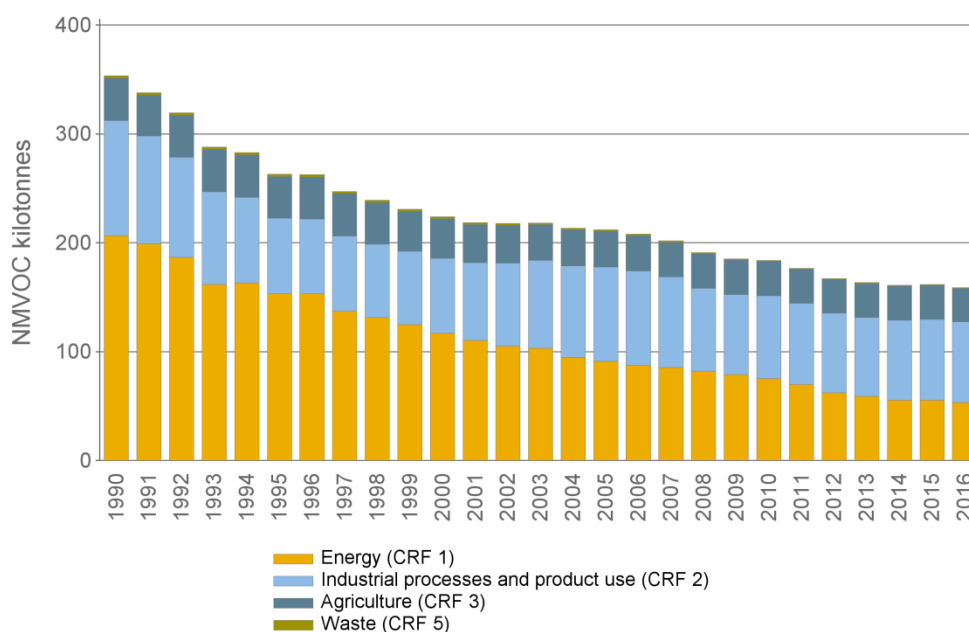


Figure 2.44. Emission trends of NMVOC 1990-2016 in kt.

The largest reduction in NMVOC emissions has occurred in the transport sector (1A3), primarily from road traffic (1A3b), where emissions declined by about 92 % since 1990. The main drivers for the sharp decrease in the energy sector in the last two decades are the increased energy efficiency in cars and the introduction of new exhaust systems and emission requirements. Fugitive emissions from fuels (1B) have declined by more than 63 % since 1990 due to technology improvements.

For the industrial processes sector and product use (CRF 2), the decrease of NMVOC emission is related to national abatement measures, such as the reduction

of solvents in paint and also due to the substitution of solvent-based paint for paint with less or no solvents. Emissions from the agriculture sector (CRF 3) declined by about 19 % mainly due to a decrease in the livestock population and a *reduction in the use* of animal manure applied to soils.

2.4.2 Nitrogen oxides (NO_x)

In 2016, the total emissions of NO_x were about 131 kt. The energy sector (CRF 1) accounted for most of the NO_x emission (81 %). The industrial processes and product use sector (CRF 2) and the agriculture sector (CRF 3) were responsible for about 9 and 10 %, respectively. NO_x-emissions from the waste sector (CRF 5) are very limited, see Figure 2.45.

In 2016, the transport sector (1A3) was responsible for 40 % and manufacturing industries and construction (1A2) accounted for 18 %, while other sector (1A4) and energy industries (1A1) accounted for about 11 % each of the national total.

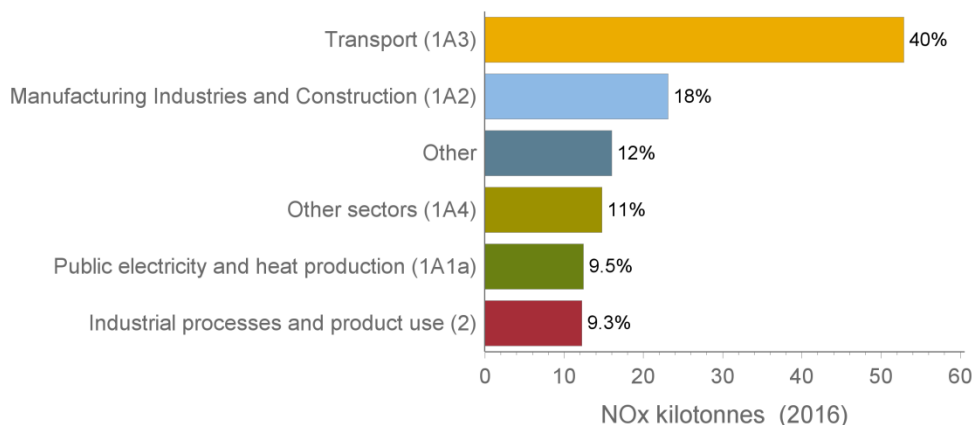


Figure 2.45. Emission sources of NO_x in 2016 (kt).

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

The total emissions of NO_x have declined by more than a half (53 %) since 1990 and had decreased by about 3 % compared to the previous year, see Figure 2.46. NO_x-emissions from the transport sector (1A3) have declined by about two thirds since 1990. Emissions from transport sector have significantly decreased by about 7 % compared to 2015. From 2015 to 2016, the emissions from diesel passenger cars increased by about 6 %, due to the increase in diesel-driven vehicles, but for the diesel powered heavy-duty vehicles the emissions declined by about 18 %. In urban areas, road traffic is the most significant contributor to emissions of NO_x, but the introduction of catalytic converters on cars in the late 1980's and the subsequent gradually more stringent emission standards have contributed to the reduction of nitrogen oxide levels in urban areas.

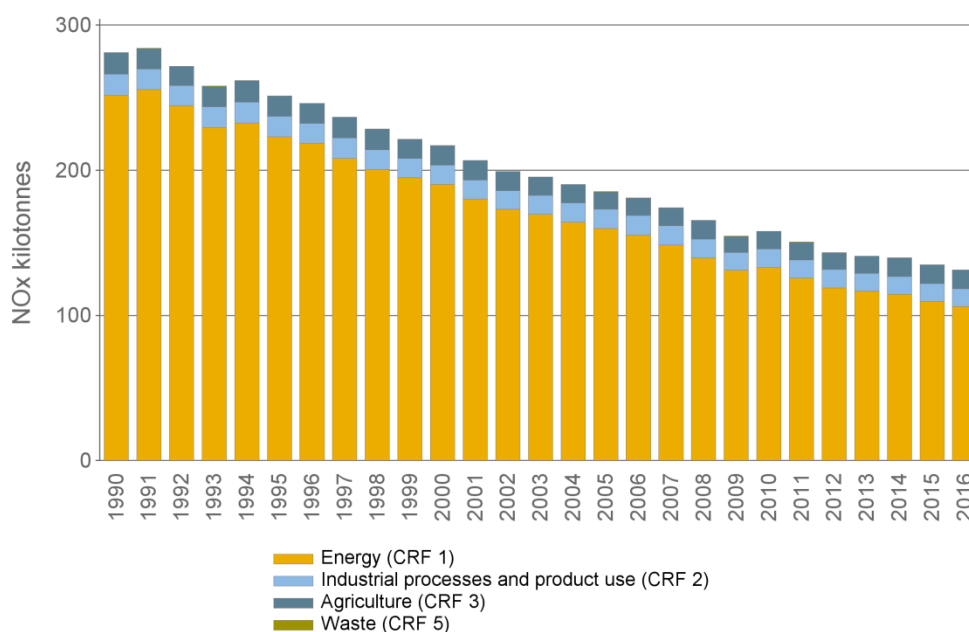


Figure 2.46. Emission trends of NO_x 1990-2016 (kt).

NO_x emissions from energy industries (1A1a), which accounts for about 11 % of the national total, have been reduced by 17 % since 1990. But the annual NO_x emissions from (1A1a) show significant fluctuations between 1990 and 2016. Weather influences the demand for heating of houses and buildings resulting in emission patterns that mirror the inter-annual variability of weather. For example, the unusually warm weather in 2014, relative to the average temperatures, resulted in lower emissions of NO_x than the previous year. The increased use of district heating and the "NO_x charge" of the early 1990s, contributed in emission reduction of NO_x.

Since 1990, emissions of NO_x from the agriculture sector show a significant decline (14 %), which is mainly related to a fall in synthetic fertilizer application. However, the emissions have relatively increased in the last few years as a result of the increased application of fertilizers.

2.4.3 Carbon monoxide (CO)

The aggregated emissions of carbon monoxide (CO) have decreased from 1.1 Mt in 1990 to about 0.4 Mt in 2016, a decline of 60 %.

In 2016, the energy sector (CRF 1) accounted for most of the CO emission (93 %). The rest come from the industrial processes and product use sector (CRF 2). Emission from the waste sector (CRF 5) is very limited, see Figure 2.47.

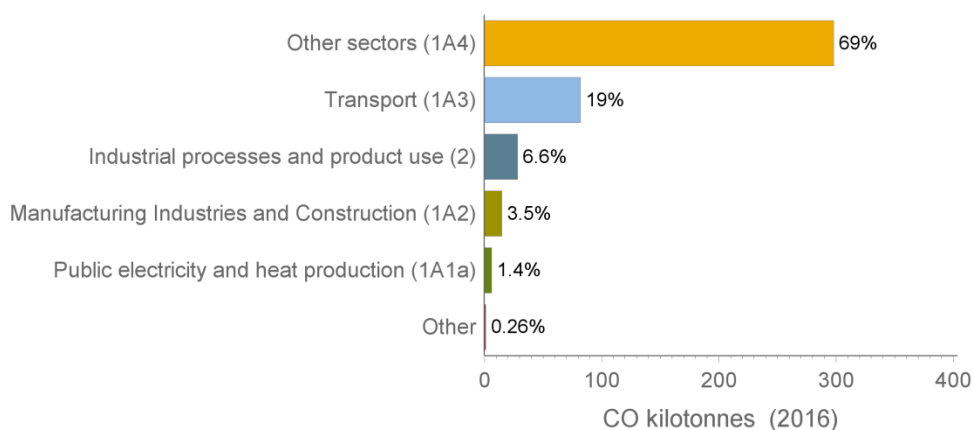


Figure 2.47. Emission sources of CO in 2016 (kt).

Within the energy sector in 2016, transport (1A3) was responsible for 19 % and other sectors (1A4) accounted for 65 % (mainly from residential heat production (1A4b) and commercial/institutional (1A4a)). Emissions from manufacturing industries and construction (1A2) and the industrial processes and product use sector (CRF 2) accounted for about 3 and 7 %, respectively.

Carbon monoxide emissions show a declining trend over the period, see Figure 2.48. The emissions have marginally increased between 2015 and 2016. Emissions from the whole energy sector have declined by two-third compared to 1990. The transport sector (1A3) is responsible for most of the reduction (90 %), due to the increased use of catalytic converters on cars. However, emissions from (CRF 2) have increased by 29 % compared to 1990, mainly from aluminum production (2C3) and pulp and paper industry (2H1).

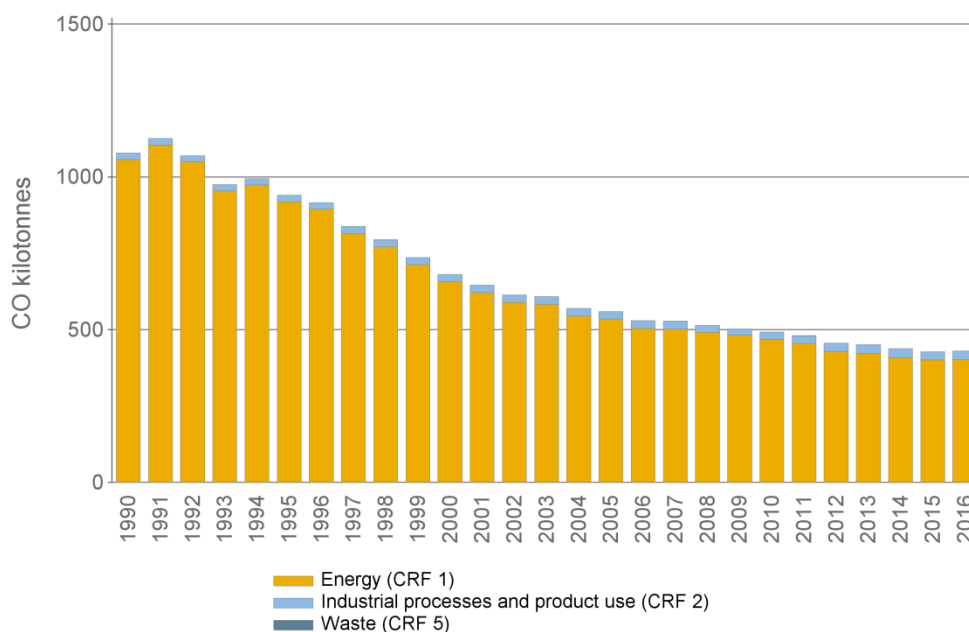


Figure 2.48. Emission trends of CO 1990-2016 (kt).

2.4.4 Sulphur dioxide (SO₂)

Emissions of SO₂ have decreased from about 104 kt in 1990 to less than 19 kt in 2016, a reduction of 82 %.

In 2016, about a half (49 %) of the total SO₂ emission comes from the energy sector (CRF 1). Remaining emissions (51 %) arise from the industrial processes and product use sector (CRF 2). SO₂-emission from the waste sector (CRF 5) is very limited.

Most of the emissions within the energy sector come from combustion of fuels in energy industries (1A1) and manufacturing industries and construction (1A2) which accounted for 17 and 20 %, respectively. Transport was responsible for 2 % of the total emission in 2016. The metal industry (2C) and pulp and paper industry (2H) are the main contributors for SO₂ emission and accounted for 23 and 22 %, respectively of the national total, see Figure 2.49.

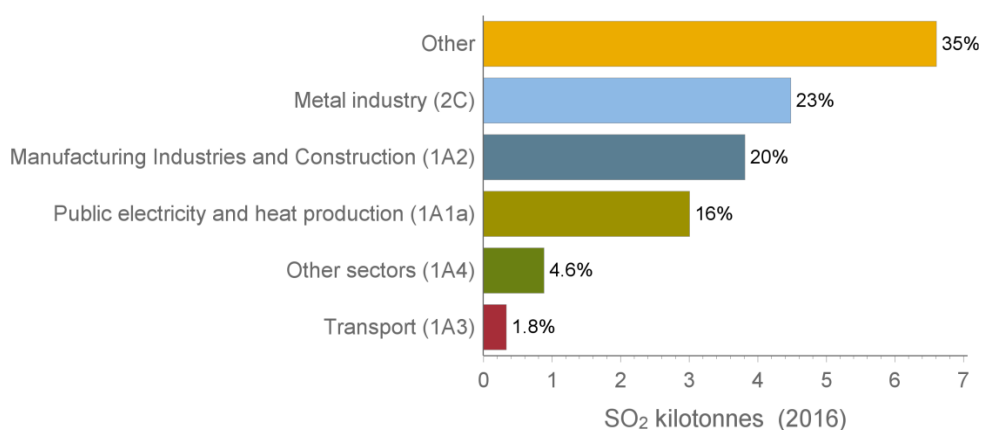


Figure 2.49. Emission sources of SO₂ in 2016 (kt).

Emissions from transport (1A3) in 2016 have declined by 97 % compared to 1990, see Figure 2.50. A similar trend with declining emissions can be seen in other subsectors within the energy sector, such as other (1A4) which declined by 94 %. The emissions have also declined by 71 % from the industrial processes and product use sector. The main reason for the large reduction in SO₂ emission was a transfer from fuels with high sulphur levels to low-sulphur fuels, for both transport (road traffic) and heating. A tax on sulphur, introduced in 1991, has been important in this transition.

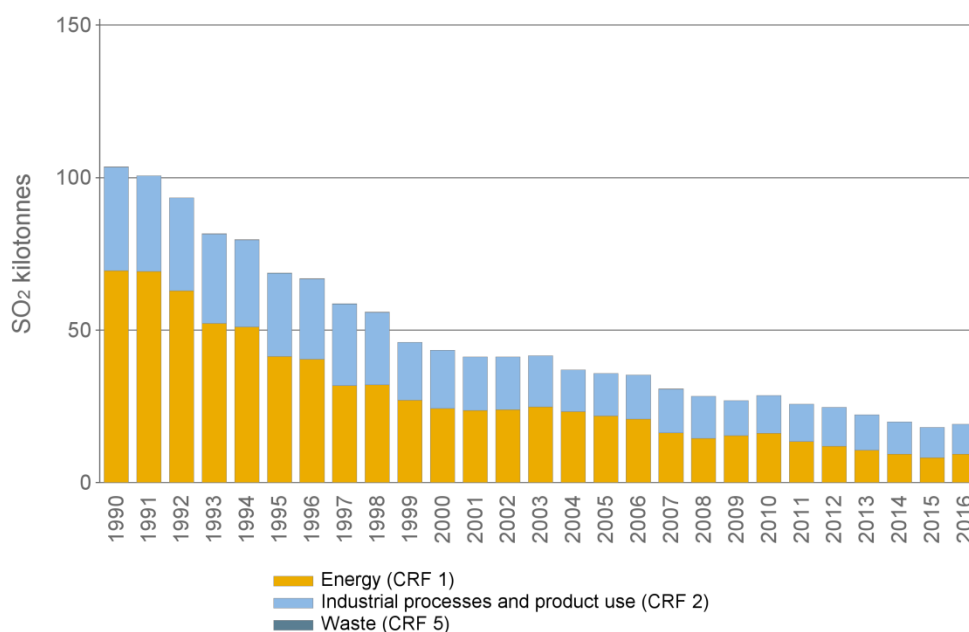


Figure 2.50. Emission trends of SO₂ 1990-2016 (kt).

SO₂-emissions in 2016 increased by 6 % relative to 2015 and the pulp and paper industry (1A2d) is the main contributor for this increase. Compared to previous year, emissions from 1A1 have increased by 8 %, due to increased energy production from district heating.

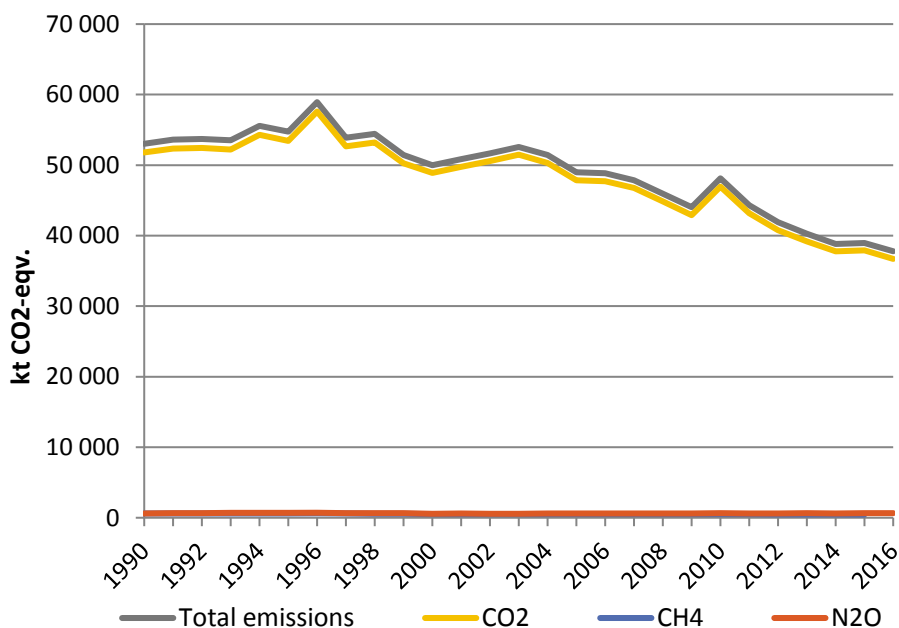
Domestic navigation contributed with less than 1 % of the total SO₂ emission in 2016. The emissions have decreased by 98 % compared to 1990, and are now less than 0.1 kt in total, due to a switch to oils with lower sulphur content. The emissions from combustion of hazardous waste in the waste sector are insignificant (about 13 t of SO₂).

3 Energy (CRF sector 1)

3.1 Overview of sector

The energy sector includes emissions from fuel combustion (CRF 1.A) and fugitive emissions from fuel production and handling (CRF 1.B). Energy consumption per capita is high in Sweden compared to other OECD countries. This is because of the availability of natural resources such as forests and hydropower, which led to the early and rapid expansion of energy-intensive industries. Sweden's geographical location, with low mean annual temperatures also explains the high demand for energy for heating. The energy sector, including transport, has long accounted for the major part of Swedish greenhouse gas emissions, and emissions of carbon dioxide dominate overwhelmingly in this sector. However, carbon dioxide emissions per capita from the energy sector are relatively low in Sweden compared with other industrialized nations. This is due to a relatively high use of hydropower and nuclear power and low use of fossil fuels, as well as the use of energy and carbon dioxide taxation for limiting the emissions of carbon dioxide³².

It can be seen in Figure 3.1 that in the energy sector, emissions of CO₂ contribute about 97 % of total greenhouse gas emissions (in CO₂-eq.) in 2016. Emissions of total greenhouse gases from the energy sector have decreased by 29 % from 51 821 kt CO₂-eq. in 1990 to 36 703 kt CO₂-eq. in 2016, mainly due to reduced fossil fuel consumption in the residential sector (CRF 1.A.4) (Figure 3.2).



³² Ministry of the Environment, 2001

Figure 3.1. Total emissions of all greenhouse gases calculated as Gg CO₂-eq. from CRF 1 Energy.

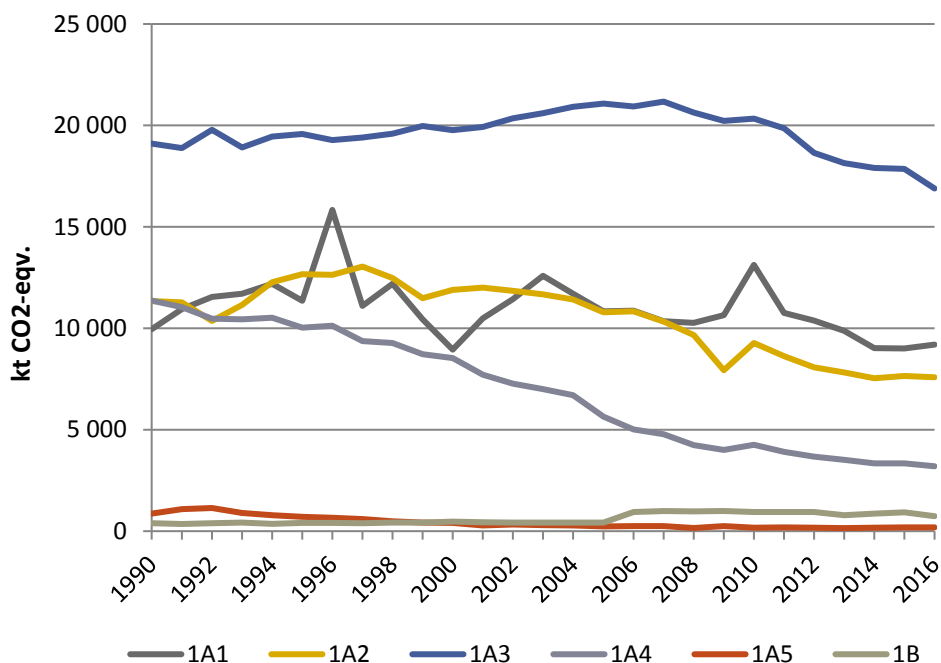


Figure 3.2. Total emissions of all greenhouse gases calculated as CO₂-eq. from the different sub-sectors within the Energy sector. 1A1 Energy industries. 1A2 Manufacturing industries and construction. 1A3 Transport. 1A4 Other sectors. 1A5 Other. 1B Fugitive emissions.

As shown in Figure 3.2, the transport sector (CRF 1.A.3) accounts for the largest part of the GHG emissions from the energy sector. Emissions from public electricity and heat production (CRF 1.A.1) varies mainly because of temperature variations between years. As mentioned earlier, the emissions from residential heating (CRF 1.A.4) are decreasing due to the a shift from usage of heating oils to district heating. In manufacturing industries and construction (CRF 1.A.2), the three largest industries in terms of fuel consumption are the pulp and paper industry, the chemical industry and the iron and steel industry. Despite rising industrial production, oil consumption has fallen sharply since 1970. This has been possible due to increased use of electricity and improved energy efficiency.

The large emissions from CRF 1.A.1 in 1996 and 2010 are mostly due to the cold winters that year and low production of nuclear energy, which meant that the demand of electricity and heat had to be met by combustion based energy. In 2011, conditions were less extreme and emissions especially from electricity and heat production decreased considerably. The dip in emissions from manufacturing industries and construction in 2009 reflects the economic conditions resulting in lower demand of e.g. iron and steel. The recent increase in fugitive emissions from oil and natural gas (CRF 1.B.2) is caused by hydrogen production facilities put into operation at two of the oil refineries in 2005 and 2006 respectively.

3.2 Fuel combustion (CRF 1.A)

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

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

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

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

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

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

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

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

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

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

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

3.2.1 Comparison of the sectoral approach with the reference approach

A detailed discussion on the reference approach and the differences compared to the sectoral approach is provided in Annex 4. Figure 3.3 shows the differences in fuel consumption and CO₂ emissions between the Reference and Sectoral Approach for the all fossil fuels 1990-2016.

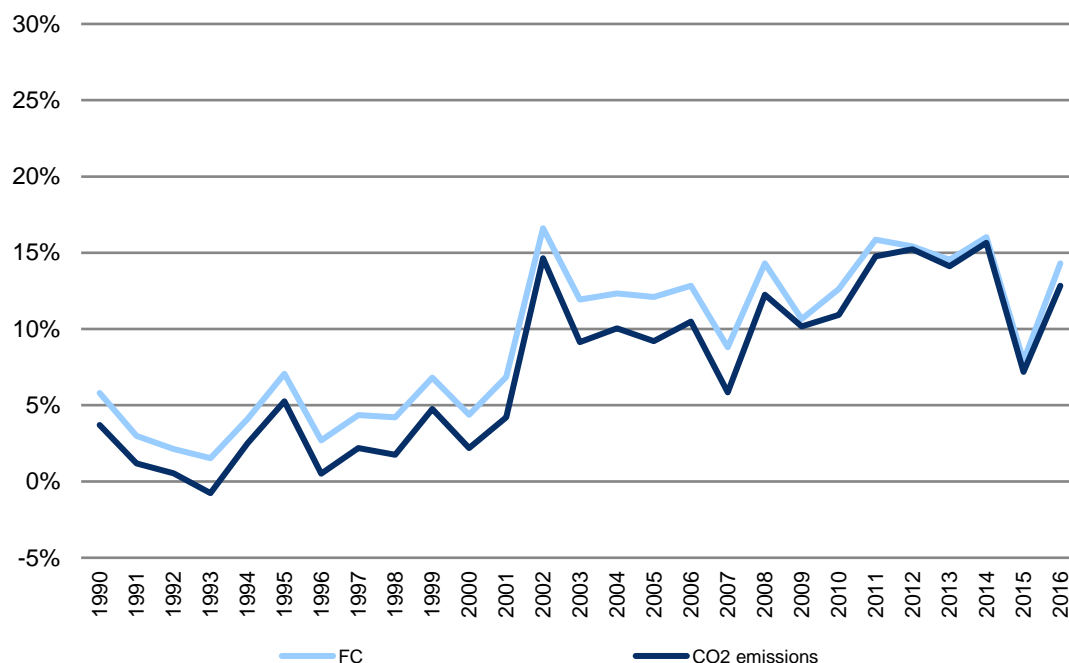


Figure 3.3. Differences between Reference Approach and Sectoral Approach (Reference minus Sectoral expressed as percent of sectoral approach).

Fuel consumption and CO₂ emissions according to the Sectoral Approach is both higher and lower than according to the Reference Approach between 1990 and 2016. For most years the difference is larger than 2 %. In response to recommendations in the in country review of Sweden in 2013, a cooperation between Swedish EPA, Swedish Energy Agency, SMED and Statistics Sweden has been initiated with the aim to find explanations to the differences.

The largest parts of the differences, in absolute numbers, are related to liquid and solid fuels. Consumption of liquid fuels according to sectoral approach is consistent with official energy statistics on fuel consumption, as described in Annex 4. The Swedish Energy agency has initiated efforts to improve the supply statistics, especially for liquid fuels, and hopefully, this will reduce statistical differences from 2017, submission year 2019.

The differences for solid fuels are very large. One important reason is that the different data sources used for reference and sectoral approaches have very different purposes. In sectoral approach, the main data sources for the iron and

steel industry are environmental reports and data reported to EU ETS and are considered as accurate. In reference approach, monthly fuel statistics, trade and delivery statistics are used. Data on stock change could be part of the problem and will be reviewed with in the cooperation mentioned above. For solid fuels, the difference in energy and emissions, respectively, is not consistent between years. This is related to solid fuels used in the iron and steel industry. Large amounts of energy are lost in coke ovens and blast furnaces when coking coal is transformed to coke and coke oven gas, and coke is transformed to blast furnace gas. This means that the reported amounts of coke oven gas, blast furnace gas and steel converter gas reported in the sectoral approach contains all the carbon but only parts of the energy reported as coal in the reference approach, which gives a large difference between the reference and sectoral approach for consumption of solid fuels. Using non-energy use from CRF2 instead of from the Energy balances in the comparison between SA and RA as means to explain the large differences lead to a decrease in difference, but could however not explain all the discrepancies (See Annex 2 for further details). Further investigations on possible reasons for the differences are needed.

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

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

3.2.2 International bunker fuels

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

Emissions from international bunkers for aviation and navigation are not included in the national total, but instead reported separately as a memo item in CRF 1.D. This is in accordance with the IPCC Guidelines. However, when the Swedish emissions are evaluated, international bunkers are important, as greenhouse gas (GHG) emissions from international bunkering are almost ten times higher than from domestic navigation and aviation and have increased significantly since 1990. The increase of GHG emissions can to some extent be explained by increased travel abroad by flight, an increase in freight transport by shipping and an increased market share for Swedish bunker companies; partly as they were early in offering low-sulfur fuel for navigation and partly because a major competing Danish company went bankrupt in 2014. For more information regarding the increase of GHG as a result of an increase in consumption of bunker fuels, see chapter 2.3.6. The UNFCCC expert review team (ERT) noticed that the data reported to the IEA (International Energy Agency) generally is higher than what is reported to the UNFCCC. A study in 2010 showed that the differences between the IEA and the UNFCCC reporting can, to some extent, be explained by revision policies of the

different reporting obligations. Since the UNFCCC has a high demand on consistency of time series, efforts are made to ensure high quality of times series³³.

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

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

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

The emissions from aviation reported to the UNFCCC are based on data from the monthly survey on supply and delivery of petroleum products from Statistics Sweden (see Annex 2) and 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 earlier years.

Greenhouse gas (GHG) emissions from international aviation bunkers were ~2 560 kt of CO₂-eq. in 2016. This is an increase by 17 % since 2015 and an increase of 89 % since 1990. Emissions from international bunkering of aviation have varied over time. The trend indicates a rise in the emissions of GHG, owing to growth in foreign travel.

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

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

A database with information regarding 200 different types of aircraft is also used. The emission data regarding different types of aircrafts in the database originates from “ICAO Engine Exhaust Emission Data Bank”. All this data is used to calculate emissions and amounts of burnt fuel for total flight time as well as for aircraft movements below 3000 feet at the airports, the so called LTO cycle. The

³³ Hedlund & Lidén, 2010.

FOI has in a published report, which described their method for estimating the emission from aviation³⁴.

Due to the fact that the Swedish airports generally are smaller than international airports in other countries; taxi times are much shorter for domestic flights and climb-out and take-off times are often shorter as well compared to the International Civil Aviation Organization (ICAO) standards that the IPCC guidelines follow³⁵. The traffic from Swedish airports consumes as a result less fuel and gives rise to less emission. The estimated fuel consumption and emissions are adjusted to match the statistics on delivered amount of aviation fuels from Statistics Sweden (see Annex 2).

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 aggregation is based on estimated emissions from the LTO cycle & Cruise reported by STAg *and* the national/international (bunker) fuel consumption from the monthly survey on supply and delivery of petroleum products from Statistics Sweden. This is in line with the IPCC guidelines and data of good quality exists from 1995 and onwards.

Emissions of CO₂ and SO₂ as from 1995 are based on emission data from STAg. Estimated fuel consumption is based on data from the monthly survey on supply and delivery of petroleum products from Statistics Sweden (see Annex 2), fuel data reported by the Swedish Transport Agency (STAg), thermal values from 2006 IPCC Guidelines and country specific emission factors. The emissions of HC, estimated by STAg, are split into NMVOC and CH₄ based on the ratio according to the EMEP/EEA Air Pollutant Emission Inventory Guidebook 2013. N₂O emissions from LTO are estimated by using the number of LTO cycles reported by FOI together with emission factors from EMEP/EEA Guidebook 2013. N₂O emissions from cruise are based on delivered amounts of fuel for cruise activities estimated by FOI, together with emission factors according to the EMEP/EEA Guidebook 2013. All emissions estimated by STAg are adjusted to be in line with the national fuel delivery statistics.

Emissions of CO₂ for 1990-1994 are based on fuel delivery statistics, thermal values from 2006 IPCC Guidelines, country specific emission factors and an assumed international share of the total air traffic. Emissions of SO₂ are estimated based on the fuel and energy consumption and emissions of CO₂ in 1990-1994. The number of LTO cycles in 1990-1994 was estimated by measuring the mean value for LTO cycles for domestic and international flights in 1995-2000. Emissions of CO for 1990-1994 were calculated by comparing the ratio between CO and CO₂ emissions in 1995. The same ratio was applied for 1990-1994. The calculation of

³⁴ Mårtensson, T. & Hasselrot, A., 2013.

³⁵ Gustafsson, 2005.

NO_x emissions was made in a similar way as for CO emissions. The emissions of HC in 1990-1994 were estimated by extrapolation.

3.2.2.2 INTERNATIONAL NAVIGATION, CRF 1 D1B

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

The emission of GHG from international shipping totalled in ~6840 kt of CO₂-eq. in 2016. This corresponds to an increase by 11 % compared to 2015, and an increase by 202 % since 1990. International freight transport activity has increased, as the volume of goods transported has grown and globalisation of trade and production systems has led to goods being transported over greater distances. Another factor for the increased emissions could be that Swedish refineries produce low-sulphur marine fuels (fuel oil nos. 2–5), meeting strict environmental standards and because a major competing Danish company went bankrupt in 2014. This has led to more shipping companies choosing to refuel in Sweden. Fluctuations in bunker volumes between years are also dependent on fuel prices in Sweden compared with ports in other countries. See chapter 2.3.6. for more information.

In 2011, the fuel consumption by national and international navigation was studied by SMED and the results were presented in the report “Emissions from navigation and fishing including international bunkers”³⁶. Fuel data in the survey “Monthly fuel, gas and inventory statistics” was analysed and found to be of good quality. As a consequence of that the VAT is applied on national fuel consumption, but not on international bunkers, all respondents to the survey are able to separate these fuel amounts accurately. Fuels used for domestic and international navigation have been separated in line IPCC Guidelines.

3.2.2.3 MULTILATERAL OPERATIONS, CRF 1.D.2

Emission from multilateral operations are not included in the national total but instead reported separately as a memo item in CRF 1.D.2, in accordance with 2006 IPCC Guidelines. These emissions are calculated based on information from the military on the amount of fuel purchased in Sweden but used abroad by Swedish forces participating in international operations.

3.2.3 Feedstocks and non-energy use of fuels

Activity data on feedstocks and non-energy use of fuels is collected from the environmental reports and the EU ETS statistics. Sweden uses the same data for

³⁶ Eklund et al. 2011.

CRF table 1.A.d, non-energy use (NEU) of fuels as for feedstocks and non-energy uses in the IPPPU sector (CRF 2) and Fugitive sector (CRF 1.B).

Net calorific values and carbon emission factors are the same as in CRF 1.A.b. The parameter “fraction of carbon stored” has been set to 1.00 for all fuels, which is in line with the 2006 IPCC Guidelines. Emissions from use of fuels reported in CRF 1.B or CRF 2 is reported as “CO₂ emissions from the NEU reported in the inventory” in the CRF-tables.

3.2.4 CO₂ capture from flue gases and subsequent CO₂ storage

So far, storage of CO₂ does not occur in Sweden³⁷. There are, however, several research projects going on where CO₂ is captured from flue gases at a pilot scale³⁸.

3.2.5 Country-specific issues

No country-specific issues are reported in this submission.

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

3.2.6.1 SOURCE CATEGORY DESCRIPTION

Swedish production of electricity is characterized by large proportions of hydropower and nuclear energy. Only a small share of electricity production is based on fuels used in conventional power plants. Public electricity and heat use vary between years, due to variations in ambient temperatures for instance. In addition, production of electricity based on fuels depends to a large extent on the actual weather conditions. Years with dry weather and cold winters have a significant effect on the use of fuel in electricity production since less electricity can be produced by means of hydropower and more electricity is needed for heating. The largest emissions from electricity production were thus in 1996, due to very dry and cold weather. The winters 2009/2010 and 2010/2011 were unusually cold, which lead to an increase in fuel consumption particularly in 2010. Liquid fuels and natural gas account for most of the increase, although the increase in natural gas use can to a large extent be explained by the fact that new gas fuelled facilities have been taken into operation. The use of solid fuels also increased substantially between 2009 and 2010, but in this case the explanation is the recovery from the dip in production in the iron and steel industry in 2009, which thus affected the amounts of energy gases sold to the public electricity and heat production plants.

In Sweden, electricity and district heating are used to a large extent to heat homes and commercial premises. Increased use of district heating since 1990 to heat homes and commercial/industrial premises has led to increased energy efficiency and thus lower emissions. Emissions of methane and nitrous oxide have increased

³⁷ Geological Survey of Sweden, 2010.

³⁸ E-on 2010-11-04, Fortum 2010-11-04.

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

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

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

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

Production of district heating is currently to a large extent based on biomass and waste. There has been a shift from fossil fuels towards biomass since 1990. In 1990, 25 % of fuels used were biomass including biogenic waste, and 6 % was fossil waste. In 2016, 73 % of all fuels used for district heating were biomass (including the biogenic fraction of waste), while waste (fossil fraction) accounted for 11 %³⁹. 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 176 PJ (2015)⁴⁰ but, due to the more frequent use of biomass, greenhouse gas emissions from district heating were lower in 2016 than in 1990.

The number and distribution of Swedish power stations in 2015 are presented in Table 3.1⁴¹. 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.

³⁹ 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.A.1.A.ii and 1.A.1.A.iii

⁴⁰ Statistics Sweden/Swedish Energy Agency EN11SM 1601 (Electricity supply, district heating and supply of natural and gasworks gas 2015.). Data for 2015 currently not available.

⁴¹ Data for 2016 currently not available. Statistics Sweden /Swedish Energy Agency EN11SM 1601 (Electricity supply, district heating and supply of natural and gasworks gas 2015).

Table 3.1. Number and distribution of Swedish energy stations 2015

Type of plants	Number of plants	Gross Production GWh	Gross Production TJ
Total power stations	4 332	161 959	583 052
Power generation not based on fuels	4 163	91 707	330 145
Wind power	3 174	16 268	58 565
Hydropower	989	75 439	271 580
Power generation based on fuels	169	70 252	252 907
Nuclear power	3	56 348	202 853
Conv. thermal power	166	13 906	50 062

A summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.2.

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

CRF	Gas	Key Category Assessment 2016, 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 ₂ O	X (Biomass)	X (Biomass)		T2	CS	Yes

CS Country Specific. T2 Tier 2.

* Shows key category (level) per fuel type

** Shows key category (trend) per fuel type

3.2.6.2 METHODOLOGICAL ISSUES

Plant specific activity data and country- and sector-specific emission factors are used, which is considered to be Tier 2 methodology. The activity data source for emissions in CRF 1.A.1.a is the quarterly fuel statistics, further described in Annex 2. Emission factors, also further described in Annex 2, are generally country specific, but in a few cases plant specific emission factors are used. For energy gases purchased from the iron and steel works and combusted by public electricity and heat production plants, CO₂ 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 CO₂ emissions from the plants using these fuels in CRF 1A1a.

The most important fuels in recent years are wooden fuels followed by solid waste. Greenhouse gas emission factors for wood are national⁴². In submission 2015, solid

⁴² Boström et al, 2004.

waste was for the first time split into a biogenic and a fossil fraction, and the emission factors for CO₂ were revised. This is further described in Annex 2. The fractions of the fossil and the biogenic part for the CO₂ emissions of solid waste is estimated by both a national average emission factor and plant specific emission factors for the seven largest plants in Sweden. Since 2015 the seven largest incineration plants report their emissions of CO₂ to the EU Emission Trading System (ETS). This reporting is considered of high quality and therefore the emission factors from this reporting are used for these plants. For the rest of the incineration plants, a national average emission factor is used. In submission 2018 the fractions of biogenic and fossil waste for the seven largest plants was 56.7 % and 37.5 % respectively. These fractions vary in time and are applied since year 2015. The proportions 64 % biogenic and 36 % fossil is applied for the emission years from 1990 to 2014 for all plants and also since 2015 for plants not included in the ETS⁴³. Since the quarterly fuel statistics do not contain information on fossil and biogenic fractions of the waste, these fractions are applied on the fuel consumption for the plants.

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

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

3.2.6.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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

The variations in IEFs (implied emission factors) between years are normally small. The IEFs for solid fuels, however, are considerably more variable than for 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 CO₂ EF than other solid fuels, the share of blast furnace gas has a very large influence on the aggregate CO₂ IEF for solid fuels. The production in the iron and steel industry was much lower in 2009 than in other recent years, the share of blast furnace gas in CRF 1.A.1.a dropped, which explains the drop in CO₂ IEF for solid fuels in 1.A.1.a in 2009. In submission 2012, the IEF for N₂O varies significantly. This is mainly because the

⁴³ Stripple et al, 2014.

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 CO₂ emission factor for this fuel is considerably lower than the emission factor for municipal waste. The emission factors are discussed in Annex 2. There is no reliable information about the composition of municipal waste in the 1990’s, so the composition calculated by Strippel et al from 2014 is used for all years as described above.

Emissions of NO_x and SO₂ and in relation to fuel consumption are also slightly variable between years due to variations in fuel mix. In the latest years, especially the SO₂ emissions in relation to fuel consumption have decreased due to a shift from residual fuel oils towards natural gas.

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. Wooden fuels are the most common fuels in this sector, but as CO₂ emissions from biomass are not included in the sectoral total of GHG emissions, CO₂ from combustion of peat, blast furnace gas and “other fuels” accounts for the largest contributions to the aggregate uncertainty of GHG emissions in CRF 1A1a. The activity data uncertainties are relatively low, 2 % for peat and blast furnace gas and 10 % for “other fuels”. The CO₂ emission factor uncertainties are 20 % for peat and blast furnace gas, and 100 % for “other fuels”. Thus EF uncertainties account for the greater part of the aggregate uncertainties. Activity data uncertainties are assigned by expert judgements made by staff at the energy statistics department of Statistics Sweden. Emission factor uncertainties have been assigned by national experts on emissions from stationary combustion.

Due to the final revision of emission factors for CRF 1A1a some IEF time series are in general lower and less variable in time than in submission 2017. These are in particular the indirect GHGs SO₂ and NO_x:

- Liquid fuels: lower, less variable in time for NO_x, SO₂
- Biomass fuels: lower less variable in time for NO_x, SO₂
- Peat; Lower, less variable in time for SO₂
- Other Fossil Fuels; less variable in time for SO₂

3.2.6.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

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

The time series for all revised data have been studied carefully in search for outliers and to make sure that levels are reasonable. Remarks in recent review reports from the UNFCCC have been carefully read and taken into account whenever time limits allow. The results are verified by calculating CO₂ emissions with the reference approach, and comparing results with the sectoral approach (see Annex 4).

During 2011, there was a study⁴⁴ comparing the currently used quarterly fuel statistics with two other data sources, and the conclusion was that the quarterly fuel statistics is of very good quality, and also the only data source that is ready in time for use for the last emission year.

3.2.6.5 SOURCE-SPECIFIC RECALCULATIONS

In submission 2017 a major revision of the emission factors was initiated and finished in submission 2018. The revision is described in more detail in Annex 2. Briefly, the revision includes several fuel types and recalculations are made for the whole time series for all the revised fuel types except for CO₂ emissions from solid waste, which was only revised for the emission year 2015⁴⁵. In submission 2018 the emission factors left to revise from submission 2017 were made.

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.

⁴⁴ Eklund et al 2011.

⁴⁵ Mawdsley, I., Wisell, T., Strippel, H., Ortiz, C. 2016. Revision of emission factors for electricity generation and district heating (CRF/NFR 1A1a). SMED Report No 194 2016. Agreement No 2250-16-003. Commissioned by the Swedish Environmental Protection Agency

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

3.2.7.1 SOURCE CATEGORY DESCRIPTION

Refineries process crude oil into a variety of hydrocarbon products such as gasoline and kerosene. During the refining process, dissolved gases are separated, some of which may be leaked or vented during processing and consequently reported under CRF 1.B.2. There are five refineries in Sweden. Three of these refineries produce fuel products such as gasoline, diesel and heating oils. The other two refineries mainly produce bitumen products and naphthenic special oils. One facility has a catalytic cracker; two facilities have hydrogen production plants and four of the facilities have sulphur recovery plants. The five refineries account for more than 99 % of the fuel consumption and emissions reported in CRF 1.A.1.b. In addition to the refineries, there are a few small manufacturers of e.g. lubricants which are also classified as ISIC 23200. The emissions from these plants are also reported in CRF 1.A.1b.

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

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

The implied emission factor for CO₂ for refinery gas is slightly lower for 2008 and later years when plant specific emission factors are used. However, since the national emission factor used for earlier years is based on information from the refineries, the decreasing IEF is considered to reflect changes in production conditions which in turn alter the composition of the refinery gas.

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

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

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1A1b	CO ₂	X (Liquid fuels)	X (Gaseous fuels, Liquid fuels)		T2	CS	Yes
	CH ₄				T2	CS	Yes
	N ₂ O				T2	CS	Yes

CS Country Specific. T2 Tier 2.

* Shows key category (level) per fuel type

** Shows key category (trend) per fuel type

3.2.7.2 METHODOLOGICAL ISSUES

Refineries are not included in the quarterly fuel statistics. As a result, activity data for the five refineries was collected directly from each company for 1990-1999, since the industrial energy statistics and quarterly fuel statistics did not account for all fuels produced within refineries during these years. The corresponding energy content of all fuels was also collected and individual thermal values were calculated for each operator and fuel. For 2000-2004, e.g. before the EU Emission Trading System (ETS) was established, energy statistics was used as the data quality was improved compared to the 1990's and is considered to be sufficient for these years.

Data from ETS are used for four refinery plants for 2005 and later years⁴⁶. For the fifth plant data from environmental reports were used due to lack of transparency in ETS data in the early years. In 2008 and later years, the quality of ETS data is considered to be very high for all five of the refineries, and thus this is the primary data source for the GHG inventory. However, one of the refineries reports refinery gas and natural gas aggregated in the ETS data, and for this facility, 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 CO₂ emission factors reported to the ETS⁴⁷ are used for 2008 and later, since they are considered to be more accurate than the older national emission factor. The CO₂ emission factors for refinery gas are generally quite stable for each of the refineries, but the differences between the refineries are large.

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

3.2.7.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The use of so many different sources for this sector could of course lead to consistency problems. Data used in the inventory is however analysed and no (significant) signs of inconsistency have been found. E.g. the slight dip in fuel consumption in 2007 is visible in all available data sources and is thus real and not caused by the shifting of data sources.

CO₂ from refinery gas is by far the largest source of uncertainty due to the fact that refinery gas accounts for about 90 % of the energy from fuel combustion in this sector. The assigned uncertainties are based on information directly from the facilities. These are updated regularly but not annually. The emission factor uncertainty and the activity data uncertainty is around 10 % for submission 2016.

⁴⁶ Backman & Gustafsson, 2006.

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

The uncertainty of the activity data is around 1.5 %, but the uncertainty of the NCV is unknown, so the total uncertainty for the activity data was judged to 10 %. Activity data uncertainty for the 1990's is also estimated to 10 %.

3.2.7.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

In submission 2018, a development project 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 and ippu sector are done on a more regular basis, for the same range of facilities, and using a unified procedure. In the tool, for each of the relevant facilities, emissions reported in the energy sector (CRF 1A) are summed up with the emissions reported in the CRF 2, 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. This work is ongoing, and feasible reallocations will be done in the submission 2019.

3.2.7.5 SOURCE-SPECIFIC RECALCULATIONS

During submission 2018 a major revision of emission factors for whole industry sector was implemented, including 1.A.1.b. The revision concerned various fuel types and for all emission factors except for CO₂. A more in depth description of the new emission factors used are found in Annex 2. In addition due to revision of allocation of fuel consumption between CRF 1 and 2 refinery gas was reallocated between the CRF codes 1.A.1.b. and 1.B. according to the results of the study⁴⁸.

⁴⁸ Mawdsley, I., Stripple, H. 2017.

3.2.7.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

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

3.2.8.1 SOURCE CATEGORY DESCRIPTION

This category includes emissions from two plants belonging to one company, producing coke to be used in blast furnaces for production of iron. The plants are integrated into the iron and steel production industry⁴⁹. The trend is related to the amounts of iron and steel produced, and hence there was a dip in 2009. Since 2009, the production and the emissions have increased gradually, and in 2012 the emissions were about the same level as in the early 2000's.

Charcoal production in Sweden and the related emissions from the activity is derived from small companies that are included in the emission estimates from small industries (CRF 1.A.2.g). Since the activity data for this sector is aggregated from the national energy balances, it is thereby not possible for Sweden to separate the emissions that are related to charcoal production from the aggregate. Hence, the fugitive CH₄ emissions from charcoal production are reported in CRF 1.A.2.g. In earlier submissions, the notation key for fugitive CH₄ emissions in 1.A.1.c was mistakenly reported as NO but is now reported as IE.

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

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

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1A1c	CO ₂	X (Solid fuels)	X (Solid fuels)		T2	CS	Yes
	CH ₄				T2	CS	Yes
	N ₂ O				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. CO₂ emissions are estimated based on carbon balances for the two integrated iron and

⁴⁹ Fuel combustion in manufacturing of nuclear fuels was included in CRF 1A1c in previous submissions, but for confidentiality reasons the very small emissions from these facilities have been included in CRF 1A1aiii instead.

steel production facilities and information on allocation on different categories from the facilities' environmental reports.

Emissions of N₂O, CH₄, NMVOC and CO are estimated with Tier 2 methodology with national emission factors. Estimates of emissions of SO₂ and NO_x are available from environmental reports on an aggregate level, and these emissions are distributed over the different CRF codes (1.A.1.c, 1.A.2.a, 1.B.1.c and 2.C.1, SO₂ also 2.B.5 and 1.B.1.b) according to the activity data distribution. The methodology is described in more detail in the section **Fel! Hittar inte referensälla.** (CRF 2.C.1.2.).

Due to confidentiality reasons the whole sector is reported as C.

3.2.8.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The time series is considered to be very consistent as all data on emissions from the coke producing plants has been collected directly from the facilities. The inter-annual variations in IEFs for solid fuels are caused by variations in the relative amounts of blast furnace gas and coke oven gas, respectively, between years. The composition of each gas is also quite variable, and this is another explanation to the fluctuating IEF's. Solid fuel consumption decreased considerably in 2009 due to lower production of coke caused by lower demand of primary iron and steel. In 2010, the demand increased and thus the fuel consumption increased to about the same level as before 2009.

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. CO₂ from blast furnace gas and coke oven gas are the dominating sources of uncertainty.

3.2.8.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

3.2.8.5 SOURCE-SPECIFIC RECALCULATIONS

In submission 2018 there were several recalculations for the sector. Emission factors for N₂O was updated accordingly to the major revision of emission factors for the industry sector⁵⁰. Emission factors for NO_x has been revised and updated for two of the largest plants for the year 2008 to 2015. In addition the whole time series for particle emissions has also been revised for these two plants.

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.

⁵⁰ Mawdsley, I., Strippel, H. 2017. Revision of emission factors for stationary combustion within the industrial sector, SMED Report No 7.

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

3.2.9.1 SOURCE CATEGORY DESCRIPTION

The iron and steel industry is, together with the pulp and paper industry and the chemical industry, one of the most energy intensive industrial branches in Sweden. In 2009, fuel consumption in the iron and steel industry fell sharply as a consequence of decreased production (2.8 Mt of steel) due to the global recession. In 2016, the production was 4.6 Mt⁵¹, an increase of almost 6 percent compared to 2015. Emissions from iron and steel companies with less than 10 employees are allocated to CRF 1.A.2.g because the model estimate of fuel consumption for these small companies is produced on an aggregate level and not separated by ISIC code.

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

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

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.2.a	CO ₂	X (Gaseous fuels, Liquid fuels, Solid fuels)	X (Gaseous fuels, Solid fuels)		T2,T3	CS, PS	Yes
	CH ₄				T2	CS	Yes
	N ₂ O				T2	CS	Yes

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

* Shows key category (level) per fuel type

** Shows key category (trend) per fuel type

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

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

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

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

⁵¹ The Swedish Steel Producers' Association, 2017-11-08.

1A2gviii for biomass and in CRF 1A2a solid for peat, also for confidentiality reasons.

Emissions reported from primary steel works and other iron and steel works are reported in both CRF 1A2a and in CRF 2.C.1 since some emission arises from fuel combustion and some from reducing agents in the process. The text in this section is hence closely connected to the text in the section CRF 2.C.1.1 (secondary steel) and CRF 2.C.1.2 (primary pig iron and steel).

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

3.2.9.2.1 Primary iron and steel works

In Sweden, there are two plants for integrated primary iron and steel production basing their production on iron ore pellets. The integrated iron and steel production consists of material flows between coke oven, blast furnace and steelworks, and in one plant, rolling mill (see Table 3.6). Emissions from fuel combustion (oils, LPG (Liquefied Petroleum Gas) and recovered energy gases, i.e. coke oven gas and blast furnace gas) used in the rolling mills and for in-house power and heat production is allocated to this sub-sector in accordance with the IPCC Guidelines. From one of the facilities, large amounts of recovered energy gases are sold to a public heat and power plant, and the emissions from combustion of these gases are hence reported in CRF 1.A.1.a.

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

The allocation of total CO₂ emissions and energy consumption (TJ) on plant stations and consequently CRF sub-sector is based on measured fuel consumption and associated C

Table 3.6. Allocation of fuel consumption and CO₂ emissions in 2016 from iron ore based iron and steel industry to different CRF codes.

CRF	Plant station	CO ₂ emissions (kt)	Energy consumption (TJ)
1.A.1.a	Power and Heat Production (sold amount of energy gases)	2012	6699
1.A.1.c	Coke Oven	294	4493
1.A.2.a	Combustion in Rolling Mills + Power and Heat Production	623	3772
1.B.1.c	Flare in Coke Oven (COG)	54	219
2.C.1.b	Blast Furnace + Steelworks (including Flaring of BFG and LD-gas)	1523	8984
NA	Products and losses	NA	16765
Total		4506	40932

3.2.9.2.2 Secondary iron and steel works

Except for the primary iron ore based iron and steel works, this sector includes emissions from for instance electric arc furnaces plants, iron ore pellet plants and iron powder plants. For these facilities, data on fuel consumption for energy purposes is from the quarterly fuel statistics. National NCVs and emission factors are used.

3.2.9.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

For the two largest facilities, the time series is considered to be very consistent since the time series developed in 2009 was compiled in close cooperation with the facilities. For CRF 1.A.2.a in total, the time series is also considered to be consistent, despite the fact that the quarterly fuel survey is used for most years and the annual industrial energy survey for some years. The quarterly fuel survey data is weighted to cover the same population as the yearly industrial energy survey. A discussion on the reasons for changing data sources can be found in Annex 2.

The CO₂ implied emission factors for solid fuels in CRF 1.A.2.a are higher than for solid fuels in other industries, since a large proportion of the fuel used is blast furnace gas which has a high carbon content compared to other solid fuels. This also implies that the IEF varies between years, and it is considerably lower in 2009 than recent years because of the drop in blast furnace gas consumption. This explains the fact aggregate CO₂ IEF for solid fuels in CRF 1.A.2.a is considerably lower in 2009 than in earlier and later years. See also section **Fel! Hittar inte referenskölla..** 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.

3.2.9.4 SOURCE SPECIFIC QA/QC AND VERIFICATION

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

In submission 2018, a development project 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 and ippu sector are done on a more regular basis, for the same range of facilities, and using a unified procedure. In the tool, for each of the relevant facilities, emissions reported in the energy sector (CRF 1A) are summed up with the emissions reported in the CRF 2, 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. This work is ongoing, and feasible reallocations will be done in the submission 2019.

3.2.9.5 SOURCE SPECIFIC RECALCULATIONS

In submission 2018 a major revision of the emission factors was made within the industrial sector. Briefly, the revision was to a large extent based on conclusions from the previous major emission factor revision that was made within the public electricity and heat production sector (CRF 1.A.1.a) in submission 2017⁵². This is due to the fact that many combustion processes in the industrial sector are similar to those in the heat and power sector⁵³. In conclusion, the revision includes several fuel types and recalculations were in general made for the whole time series for all the revised fuel types. The revision is described in more detail in Annex 2.

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.

⁵² Mawdsley, I., Wisell, T., Stripple, H., Ortiz, C. 2016.

⁵³ Mawdsley, I., Stripple, H. 2017.

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

3.2.10.1 SOURCE CATEGORY DESCRIPTION

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

As for all subcategories to CRF 1.A.2, for companies with less than 10 employees the Tier 1 method is used, since current data does not allow the Tier 2 methods to be used. Emissions from companies with less than 10 employees are allocated to CRF 1.A.2.g.

Fuel consumption shows a decreasing trend for the period 1990-2002, but from 2003 onwards, the inter-annual variations in fuel consumption for energy production are relatively small. In recent years, the copper producers account for 40-50 % of the fuel consumption in 1A2b and the aluminium producers account for 32-45 %. The most common fuel is LPG (45-61 % in recent years), followed by natural gas and heating oils.

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

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

CRF	Gas	Key Category Assessment 2016, excluding LULUCF			Method	EF	All sources estimated
		Level*	Trend*	Qualitative			
1.A.2.b	CO ₂				T2	CS	Yes
	CH ₄				T2	CS	Yes
	N ₂ O				T2	CS	Yes

CS Country Specific. T2 Tier 2.

* Shows key category (level) per fuel type

** Shows key category (trend) per fuel type

3.2.10.2 METHODOLOGICAL ISSUES

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

3.2.10.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. In 1990, the largest contribution to the aggregate uncertainty arises from CO₂ from “other solid fossil fuels” due to the fact that the emission factor uncertainty for this quite unspecified fuel is as high as 100 %. In later years, this fuel is not used in CRF 1.A.2.b, and CO₂ from LPG accounts for most of the uncertainty. The uncertainty is 5 %, both in activity data and in the CO₂ emission factor for this fuel. Activity data uncertainties are assigned by expert judgements by staff at the energy statistics department of Statistics Sweden. Emission factor uncertainties have been assigned by national experts on emissions from stationary combustion.

3.2.10.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The same QA/QC procedures are used for CRF 1.A.2.b as for 1.A.2.a described above. In addition to this, a detailed quality study of the non-ferrous metal industry was performed in 2010⁵⁴. In submission 2018, a development project 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 and ippu sector are done on a more regular basis, for the same range of facilities, and using a unified procedure. In the tool, for each of the relevant facilities, emissions reported in the energy sector (CRF 1A) are summed up with the emissions reported in the CRF 2, 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. This work is ongoing, and feasible reallocations will be done in the submission 2019.

3.2.10.5 SOURCE-SPECIFIC RECALCULATIONS

In submission 2018 a major revision of the emission factors was made within the industrial sector. Briefly, the revision was to a large extent based on conclusions from the previous major emission factor revision that was made within the public electricity and heat production sector (CRF 1.A.1.a) in submission 2017⁵⁵. This is due to the fact that many combustion processes in the industrial sector are similar to those in the heat and power sector⁵⁶. In conclusion, the revision includes several fuel types and recalculations were in general made for the whole time series for all the revised fuel types. The revision is described in more detail in Annex 2.

⁵⁴ Skårman et.al, 2008.

⁵⁵ Mawdsley, I., Wisell, T., Stripple, H., Ortiz, C. 2016.

⁵⁶ Mawdsley, I., Stripple, H. 2017.

3.2.10.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

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

3.2.11.1 SOURCE CATEGORY DESCRIPTION

The chemical industry produces a number of different products such as chemicals, plastics, solvents, petrochemical products etc. In total, around 50 plants are included, of which ten uses more than 90 % of the energy according to the activity data used for emission calculations for this sector. The fuel consumption trend is increasing since 1990, especially for liquid fuels, mainly due to increased use within the basic plastic industry. Throughout the time series, liquid fuels account for about 80 % of the energy and gaseous fuels for 10-15 %.

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

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

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

CRF	Gas	Key Category Assessment 2016, excluding LULUCF			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.2.c	CO ₂	X (Gaseous fuels, Liquid fuels)	X (Liquid fuels, Solid Fuels)		T2	CS	Yes
	CH ₄				T2	CS	Yes
	N ₂ O				T2	CS	Yes

CS Country Specific. T2 Tier 2.

* Shows key category (level) per fuel type

** Shows key category (trend) per fuel type

3.2.11.2 METHODOLOGICAL ISSUES

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

Generally, plants classified as ISIC Division 24 according to ISIC Rev.3⁵⁷ in the energy statistics are included in this sector, as recommended in IPCC 2006 Guidelines.

⁵⁷ United Nations Statistics Division, 2010

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

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

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

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

For the years 2007-2013, plant specific CO₂ emission factors for by product gases from the petrochemical industries are used. The emission factors are based on total emissions for each plant minus process emissions and emissions from combustion of fuels other than by product gases, i.e. they are in fact implied emission factors based on reliable information on total emissions from the environmental reports.

3.2.11.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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

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

As noted by the ERT, the implied emission factors for “other fuels” are variable, especially in the early years. This is explained by the fact that municipal waste has occasionally been combusted within the chemical industry, and most years also “other non-specified fuels”. As these fuels have quite different emission factors for CO₂, 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 CO₂ within CRF 1.A.2.c.

The ERT, submission 2012, also noted variable CH₄ 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 CH₄. The exact amounts of the different biomass fuels cannot be shown due to confidentiality reasons.

In 2011, a consistent time series of the CO₂ 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 CO₂/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 CO₂ emissions. The company also provided a time series of CO₂ 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- CO₂ emissions, emission factors for natural gas are used as no specific emission factors are available and both fuels consist mainly of methane.

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. CO₂ from methane-based gas mixtures accounts for most of the uncertainty. The uncertainty in activity data is 1.5 % (2012) and the emission factor uncertainty is assumed to be 10 % based on the variation in plant specific values. The Activity data uncertainty for this fuel 2012 is as reported to the EU ETS. For the other fuels used and for all fuels for 1990, uncertainties are assigned by expert judgements by staff at the energy statistics department of Statistics Sweden.

3.2.11.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

In general, the same QA/QC procedures are used for CRF 1.A.2.c as for 1.A.2.a and 1.A.2.b described above. For the largest plants in terms of emissions and fuel consumption, both environmental reports and ETS data are used for verification of the estimates based on energy statistics.

In the development project in 2010⁵⁸ mentioned above, the activity data time series 1990-2008 for all fuel types and all facilities within the chemical industry were thoroughly reviewed. In submission 2018, a development project 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 and ippu sector 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, missions reported in the energy sector (CRF 1A) are summed up with the emissions reported in the CRF 2, 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. This work is ongoing, and feasible reallocations will be done in the submission 2019.

3.2.11.5 SOURCE-SPECIFIC RECALCULATIONS

In submission 2018 a major revision of the emission factors was made within the industrial sector. Briefly, the revision was to a large extent based on conclusions from the previous major emission factor revision that was made within the public electricity and heat production sector (CRF 1.A.1.a) in submission 2017⁵⁹. This is due to the fact that many combustion processes in the industrial sector are similar to those in the heat and power sector⁶⁰. In conclusion, the revision includes several fuel types and recalculations were in general made for the whole time series for all the revised fuel types. The revision is described in more detail in Annex 2.

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.

⁵⁸ Gustafsson, Nyström & Gerner, 2010

⁵⁹ Mawdsley, I., Wisell, T., Strippel, H., Ortiz, C. 2016.

⁶⁰ Mawdsley, I., Strippel, H. 2017.

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

3.2.12.1 SOURCE CATEGORY DESCRIPTION

In 2016 there were 50 paper mill and pulp industry plants and 120 sawmills (production capacity >10 000 m³/year) in Sweden. In total, they were producing 10.1 Mt of paper, 17.8 Mm³ of sawn timber and 11.6 Mt of pulp⁶¹. Since 1990, production has had an increasing trend, but not in the latest few years. There is no apparent trend in total fuel consumption since 1990, but in recent years, the share of energy from biomass fuels has increased, from 68 % of fuel consumption in 2007 to 83 % in 2016. As for CRF 1.A.2 in general, emissions from companies with less than 10 employees are allocated to CRF 1A2g.

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

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

CRF	Gas	Key Category Assessment 2016, 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 ₂ O				T2	CS	Yes

CS Country Specific. T2 Tier 2.

* Shows key category (level) per fuel type

** Shows key category (trend) per fuel type

3.2.12.2 METHODOLOGICAL ISSUES

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

Emissions from combustion of spent cooking liquor are presently not reported in CRF 1A2d as this activity has been considered an industrial process, despite the fact that the process heat is used for heat and electricity production. Emissions of CH₄, N₂O and indirect greenhouse gases from the processes in which the cooking liquor is consumed, are reported in CRF 2.

⁶¹ The Swedish Forest Industries Federation, 2017-11-10
<http://www.skogsindustrierna.se/skogsindustrin/skogsindustrin-i-korthet/fakta--nyckeltal/>

3.2.12.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As for CRF 1A2 in general, time series consistency despite the changes in activity data source is discussed in Annex 2. The fluctuating IEFs for liquid fuels reflect variations in fuel mix. In the 1990s, petroleum coke was used in some facilities, and in the latest years, combustion of residual fuel oil has decreased a bit. Fuels classified as “other fuels” are scarcely occurring in this CRF category, and as in 1A2c, the large variations in IEFs are caused by occasional use of municipal waste.

In recent years, the relative amount of biomass has increased and the relative amounts of liquid fuels, especially residual fuel oil, have decreased. One effect of the increasing share of biomass is that emissions of fossil CO₂ 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. N₂O from wooden fuels and CO₂ from residual fuel oil are the greatest contributors to the aggregate uncertainty in this sector. The activity data uncertainty is 2 % for all years for both of these fuels. The N₂O emission factor uncertainty for wood is 40 % and the CO₂ emission factor for residual fuel oil is 1 %. Activity data uncertainties are assigned by expert judgements made by persons in the energy statistics department at Statistics Sweden. Emission factor uncertainties have been assigned by national experts on emissions from stationary combustion.

3.2.12.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

3.2.12.5 SOURCE-SPECIFIC RECALCULATIONS

In submission 2018 a major revision of the emission factors was made within the industrial sector. Briefly, the revision was to a large extent based on conclusions from the previous major emission factor revision that was made within the public electricity and heat production sector (CRF 1.A.1.a) in submission 2017⁶². This is due to the fact that many combustion processes in the industrial sector are similar to those in the heat and power sector⁶³. In conclusion, the revision includes several fuel types and recalculations were in general made for the whole time series for all the revised fuel types. The revision is described in more detail in Annex 2.

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.

⁶² Mawdsley, I., Wisell, T., Stripple, H., Ortiz, C. 2016.

⁶³ Mawdsley, I., Stripple, H. 2017.

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

3.2.13.1 SOURCE CATEGORY DESCRIPTION

The food and drink industry is the fourth largest branch of industry measured as production value and number of employees. There are about 3000 companies, of which only around 650 have more than 10 employees⁶⁴. The largest number of companies and employees are found in the bakery industry, but the most energy intensive branch is the sugar industry which accounts for about 25 % of the fuel consumption in 1.A.2.e. Dairies, breweries, producers of refined vegetable fats and potato products are other industries with significant fuel consumption (around 7-12 % each of the fuel consumption in 1.A.2.e). The fuel consumption varies between years. A slight decrease can be observed since 1990. In later years, gaseous fuels account for 45-49 % and liquid fuels account for about 38-40 % of the total fuel consumption. As for CRF 1.A.2 in general, emissions from companies with less than 10 employees are allocated to CRF 1.A.2.g.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.10.

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

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.2.e	CO ₂	X (Gaseous fuels, Liquid fuels)	X (Liquid fuels)		T2	CS	Yes
	CH ₄				T2	CS	Yes
	N ₂ O				T2	CS	Yes

CS Country Specific. T2 Tier 2.

* Shows key category (level) per fuel type

** Shows key category (trend) per fuel type

3.2.13.2 METHODOLOGICAL ISSUES

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

3.2.13.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As for CRF 1.A.2 in general, time series consistency despite the changes in activity data source is discussed in Annex 2. The IEFs are slightly variable between years

⁶⁴ The Swedish Food Federation 2013-10-02

due to variations in fuel mix. The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. In the early 1990's, CO₂ from residual fuel oil was the largest source of uncertainty, followed by CO₂ from natural gas. In recent years, CO₂ from natural gas accounts for most of the uncertainty. For both fuels, the activity data uncertainty is 5 %. CO₂ emission factor uncertainty is 1 % and 5 % for residual fuel oil and natural gas, respectively. Activity data uncertainties are assigned by expert judgements made by persons in the energy statistics department in Statistics Sweden. Emission factor uncertainties have been assigned by national experts on emissions from stationary combustion.

3.2.13.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

3.2.13.5 SOURCE-SPECIFIC RECALCULATIONS

In submission 2018 a major revision of the emission factors was made within the industrial sector. Briefly, the revision was to a large extent based on conclusions from the previous major emission factor revision that was made within the public electricity and heat production sector (CRF 1.A.1.a) in submission 2017⁶⁵. This is due to the fact that many combustion processes in the industrial sector are similar to those in the heat and power sector⁶⁶. In conclusion, the revision includes several fuel types and recalculations were in general made for the whole time series for all the revised fuel types. The revision is described in more detail in Annex 2.

3.2.13.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

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

3.2.14.1 SOURCE CATEGORY DESCRIPTION

This source category includes stationary combustion of fuels in non-metallic mineral industries (ISIC 26). Cement production accounts for the major part of the emissions. The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.11.

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

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			

⁶⁵ Mawdsley, I., Wisell, T., Stripple, H., Ortiz, C. 2016.

⁶⁶ Mawdsley, I., Stripple, H. 2017.

1.A.2.f	CO ₂	X (Gaseous fuels, Liquid fuels, Other fuels, Solid fuels)	X (Gaseous fuels, Liquid fuels, Other fuels, Solid fuels)	T2	CS	Yes
	CH ₄			T2	CS	Yes
	N ₂ O			T2	CS	Yes

CS Country Specific. T2 Tier 2

* Shows key category (level) per fuel type

** Shows key category (trend) per fuel type

3.2.14.2 METHODOLOGICAL ISSUES

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

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

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

For practical reasons, SO₂ and NO_x emission data available from environmental reports are reported in CRF 2.A.7. All other energy related emissions for this facility are reported in CRF 1.A.2.f.

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

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

3.2.14.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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

3.2.14.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Generally, the same QA/QC procedures are applied for 1.A.2.f as for other 1.A.2 categories described above. In some earlier submissions, extensive QA/QC and

verification efforts have been made for the other sectors including the construction industry. This is described in section 3.2.21.4.1 below.

3.2.14.5 SOURCE-SPECIFIC RECALCULATIONS

In submission 2018 a major revision of the emission factors was made within the industrial sector. Briefly, the revision was to a large extent based on conclusions from the previous major emission factor revision that was made within the public electricity and heat production sector (CRF 1.A.1.a) in submission 2017⁶⁷. This is due to the fact that many combustion processes in the industrial sector are similar to those in the heat and power sector⁶⁸. In conclusion, the revision includes several fuel types and recalculations were in general made for the whole time series for all the revised fuel types. The revision is described in more detail in Annex 2.

3.2.14.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

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

3.2.15.1 SOURCE CATEGORY DESCRIPTION

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

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

The mobile emission source included in this sector is combustion by off-road vehicles and other machinery (working machinery) used in the construction and manufacturing industry. The emissions of greenhouse gases from this sector represent ~ 38 % of all emissions of GHG from working machinery. These emissions are reported in 1A2gvii.

⁶⁷ Mawdsley, I., Wisell, T., Stripple, H., Ortiz, C. 2016.

⁶⁸ Mawdsley, I., Stripple, H. 2017.

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 CO₂ from this branch of industry are low. The construction industry also accounts for a significant share of fuel consumption and emissions. The fuel consumption varies between years, but for stationary combustion within 1.A.2.g in total, it has decreased slightly since 1990. Liquid and biomass fuels account for most of the decrease. For mobile combustion, i.e. working machinery, fuel consumption in 2014 was about 50 % higher than in 1990.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.12.

Table 3.12. Summary of source category description, CRF 1A2g, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.2.g Off-road vehicles and other machinery	CO ₂	X (Liquid fuels)	X (Liquid fuels)		T2	CS	Yes
	CH ₄				T3	CS	Yes
	N ₂ O				T3	CS	Yes
1.A.2.g Other (1.A.2.g i-vi reported as "C" or "IE" in 1.A.2.g Other)	CO ₂	X (Gaseous fuels, Liquid fuels, Solid fuels)	X (Liquid fuels, Solid fuels)		T2	CS	Yes
	CH ₄				T2	CS	Yes
	N ₂ O				T2	CS	Yes

CS Country Specific. T2 Tier 2 T3 Tier 3.

* Shows key category (level) per fuel type

** Shows key category (trend) per fuel type

3.2.15.2 METHODOLOGICAL ISSUES

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

Due to confidentiality reasons, solid, liquid and biomass fuels under stationary combustion are reported as C for energy consumption and for GHGs (CO₂, CH₄ and N₂O for liquid, CO₂, N₂O for solid and CH₄ and N₂O for biomass).

3.2.15.2.1 Stationary combustion

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

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

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

Year	LPG	Domestic heating oil	Residual fuel oil	Natural gas	Biomass
1990	46	5 051	420	39	-
2000	46	4 621	382	40	-
2005	145	1 352	291	-	40
2010	166	1 541	332	-	46
2011	170	1 581	341	-	48
2012	170	1 582	341	-	48
2013	175	1 631	352	-	49
2014	176	1 640	354	-	49
2015	183	1 705	368	-	51
2016	189	1 757	379	-	53

(Preliminary data for 2016)

Emissions from stationary combustion in mining and quarrying and in the manufacturing of various products such as textiles, wearing apparel, leather, wood and wood products, rubber and plastics products, fabricated metal products and manufacturing of different types of machinery, are calculated with activity data from the industrial energy statistics for 1990-1996 and 2000-2002, and from the quarterly fuel statistics for 1997-1999 and 2003 and later. For more details on these surveys see Annex 2.

Emissions from all companies in ISIC 10-37 with less than 10 employees are estimated and reported under CRF 1.A.2.g. Activity data is provided by the Swedish Energy Agency⁶⁹. 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 Agency⁷⁰. The methodology used for this sub-category is the same as for stationary combustion in the Other sector, see section 3.2.21.4.1. Activity data is basically from the annual energy balances. Data for the latest emission year is preliminary as the calculations have to be completed before the annual energy balances are published. However, the data in Table 3.13 differ slightly from the official energy balances due to use of slightly different calorific values especially for earlier years.

3.2.15.2.2 *Mobile combustion/Working machinery*

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

⁶⁹ Swedish Energy Agency: Annual Energy balances. See also Annex 2.

⁷⁰ Swedish Energy Agency: Annual Energy balances. See also Annex 2.

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 CO₂ and SO₂ which are estimated according to Tier 2. The model is further described in Annex 2.⁷¹

The consumption of gasoline and diesel, estimated by the model for off-road vehicles, is adjusted with regard to low-blended biofuel. The fuel consumption is also modified with a residual of gasoline and diesel. This residual arise as the volume of gasoline and diesel allocated to different sectors through a top-down approach is compared to the total volume of the gasoline and diesel consumed according to a bottom-up estimate. See Annex 2 for more information regarding the allocation of fuels for mobile combustion⁷².

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

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

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

3.2.15.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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

As for stationary combustion in CRF 1A2 in general, time series consistency despite the changes in activity data source is discussed in Annex 2. As for other categories in CRF 1.A.2, the IEFs vary slightly between years due to variations in fuel mix. In earlier submissions, the EC (European Commission) has asked for clarification of the drop in wood consumption in 2000 compared to earlier years.

⁷¹ Annex 2: 1.6 Methodology for off-road vehicles and working machinery

⁷² See Annex 2. chapter "1.4 Allocation of fuels for mobile combustion" for more information."

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 CO₂ from diesel (used by off-road vehicles and working machinery) and heating oils (used for stationary combustion) represent the largest sources of uncertainty in regard to GHG emissions within CRF 1.A.2.g. The activity data uncertainty for all heating oils within this sector is as high as 20 % on an aggregate level, due to the fact that emissions from the construction sector and small industries are estimated with the Tier 1 method. The activity data uncertainty for diesel combusted in off-road vehicles and working machinery is 5 % and for gasoline 3 % based on fuel sold.

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

3.2.15.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Generally, the same QA/QC procedures are applied for 1.A.2.g as for other 1.A.2 categories described above. In some earlier submissions, extensive QA/QC and verification efforts have been made for the other sectors including the construction industry. This is described in section 3.2.21.4.1 below.

3.2.15.5 SOURCE-SPECIFIC RECALCULATIONS

Activity data for stationary combustion in the construction sector and enterprises with less than 10 employees in all industrial branches have been revised for 2005-2013 following revisions of the annual energy balances.

In submission 2018 a major revision of the emission factors was made within the industrial sector for stationary combustion. Briefly, the revision was to a large extent based on conclusions from the previous major emission factor revision that was made within the public electricity and heat production sector (CRF 1.A.1.a) in

submission 2017⁷³. This is due to the fact that many combustion processes in the industrial sector are similar to those in the heat and power sector⁷⁴. In conclusion, the revision includes several fuel types and recalculations were in general made for the whole time series for all the revised fuel types. The revision is described in more detail in Annex 2.

The model for working machinery has been updated with sales data for off-road vehicles for 2005-2016 in submission 2018, which was provided by the Swedish trade association for suppliers of mobile machines. The allocation key in the model was also updated, as new information regarding the sector distribution was received from both the trade association and the vehicle register. The age of some of the oldest tractors in the model was adjusted as well, as they in previous submissions mistakenly were grouped together in the oldest age category⁷⁵.

The updated model has resulted in decreased emissions of greenhouse gases from off-road vehicles and other machinery used in the construction and manufacturing industry for most years in submission 2018 compared to submission 2017, except for 2004 and the last two years.

3.2.15.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

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

3.2.16.1 SOURCE CATEGORY DESCRIPTION

Activity data is presently provided for a total of 40 airports with regular and/or chartered air traffic in Sweden. The national government administers 13 of these airports, while the remaining 27 are private and/or administered by local governments.⁷⁶ The traffic routed through governmental airports account for about 90 % of the total fuel consumption within the civil aviation sector. The emission of greenhouse gases (GHG) from national aviation in 2016 was 553 kt CO₂-eq., which is an increase by 8 % since last year and a decrease by 20 % compared to 1990.

This can be compared to emissions from international aviation which have increased by 17 % since 2015 and by 89 % since 1990, to reach 2560 kt CO₂-eq. in 2016.

⁷³ Mawdsley, I., Wisell, T., Strippel, H., Ortiz, C. 2016.

⁷⁴ Mawdsley, I., Strippel, H. 2017.

⁷⁵ Eklund, V., Lidén, M., Jerksjö, M., 2017. Regelbunden indataförsörjning till beräkningsmodellen för arbetsmaskiner. SMED PM 2017.

⁷⁶ Transportstyrelsen, 2013.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.15.

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

CRF	Gas	Key Category Assessment 2016, 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, D	Yes
	N ₂ O				T3	D	Yes

T1 Tier 1. T3 Tier 3. CS Country Specific. D Default.

* Shows key category (level) per fuel type

** Shows key category (trend) per fuel type

3.2.16.2 METHODOLOGICAL ISSUES

Sweden uses Tier 2 to estimate emissions of CO₂ and SO₂ and Tier 3 to estimate CH₄, N₂O and the indirect greenhouse gases CO, NO_x and NMVOC. Emissions from aviation in agricultural and forestry activities are included in domestic aviation in line with IPCC Guidelines. Emissions from domestic military use of aviation fuels are reported under Other – mobile sources (CRF 1.A.5.b).

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

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

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

A database with information regarding 200 different types of aircraft is also used. The emission data regarding different types of aircrafts in the database originates from “ICAO Engine Exhaust Emission Data Bank”. All this data is used to calculate emissions and amounts of burnt fuel for the whole flight as well as for aircraft movements below 3000 feet at the airports, the so called LTO cycle

(landing and take-off). The FOI has in a published report described their method for estimating the emission from aviation⁷⁷.

Due to the fact that the Swedish airports generally are smaller than international airports in other countries; taxi times are much shorter for domestic flights and climb-out and take-off times are often shorter as well compared to the International Civil Aviation Organization (ICAO) standards that the IPCC guidelines follow⁷⁸. The traffic from Swedish airports consumes as a result less fuel and gives rise to less emission.

The emissions reported by STAg is aggregated into four groups; emissions from domestic landing and take-off (LTO), domestic cruise, international LTO and international cruise. The aggregation is based on estimated emissions from the LTO cycle & Cruise reported by STAg *and* statistics on aviation fuel for national and international aviation from Statistics Sweden.

The estimated fuel consumption and emissions reported by the Swedish Transport Agency (STAg) are adjusted to be on the same level as statistics on delivered amount of aviation fuels in Sweden⁷⁹. This is in line with the IPCC guidelines. Emissions of CO₂ and SO₂ are based on the adjusted fuel consumption, thermal values from 2006 IPCC Guidelines and country specific emission factors.

The estimated emissions of HC are split into NMVOC and CH₄, based on the ratio given in EMEP/EEA guidebook 2013⁸⁰. Emissions of N₂O from LTO are estimated by using the number of LTO cycles reported by STAg and with emission factors in EMEP/EEA guidebook 2013. Emissions of N₂O from cruise are based on the adjusted amount of fuel for cruise activities and emission factors from the EMEP/EEA 2013 Guidebook.

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

3.2.16.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

In order to maintain consistency with the time-series the estimation procedures have been developed as described above. However, due to the fact that some of the estimations are not based on activity data but on other factors as LTO cycles, a certain degree of uncertainty exists. The method for estimating emissions for 1990-1994 is also slightly different, due to lack of activity data.

⁷⁷ Mårtensson, T. & Hasselrot, A., 2013.

⁷⁸ Gustafsson, 2005.

⁷⁹ A monthly survey by Statistics Sweden on supply and delivery of petroleum products. See Annex 2 for more information.

⁸⁰ EMEP/EEA air pollutant emission inventory guidebook 2013.

Emissions of CO₂ and SO₂ for 1990-1994 are based on fuel delivery statistics, thermal values from 2006 IPCC Guidelines and country specific emission factors. The emissions are split into domestic and national aviation based on the mean value for LTO cycles for domestic and international flights in 1995-2000. Emissions of CO for the period 1990-1994 were calculated from the ratio between CO and CO₂ in 1995 (the same ratio was assumed for 1990-1994). The emissions of NO_x in 1990-1994 were estimated in a similar way as for CO, whereas the emissions of NMVOC in 1990-1994 were calculated by extrapolation.

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

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

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

3.2.16.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

3.2.16.5 SOURCE-SPECIFIC RECALCULATIONS

No source specific recalculations have been made in submission 2018.

3.2.16.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

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

3.2.17.1 SOURCE CATEGORY DESCRIPTION

Road transport is the single largest source category contributing to the national greenhouse gas emissions (GHG) in Sweden. The emissions of GHG from road transportation were 15.8 kt CO₂-eq. in 2016, which accounts for approximately 77.4 % of the total emissions of GHG from mobile combustion in Sweden and correspond to 39 % of the total emission of GHG from all sectors (excluding LULUCF). The emissions of GHG from road transportation has decreased 5.6 % since 2015 and decreased by 9.8 % since 1990.

Road transport includes five vehicle categories: Passenger cars, Buses, Heavy goods vehicles (HGV), Light commercial vehicles (LCV) and Mopeds & Motorcycles. Gasoline has previously been the most common fuel used for road transportation, but as from 2011 the amount of diesel used by road traffic as well as the emissions of GHG from diesel surpassed gasoline. The increasing consumption of diesel by road traffic is primarily explained by a shift from gasoline cars to diesel cars, but also by an increased consumption of diesel by HGV and LCV. The total consumption of diesel by HGV and LCV correspond to 52 % of the total consumption of diesel by road traffic in 2016, while passenger cars consume around 42 % of the total diesel for road traffic.

The consumption of diesel by HGV increased by 56 % between 1990 and 2007, from an already high level, and then started to decrease. The consumption of diesel by HGV was 13 % higher in 2016 than in 1990. The consumption of diesel by LCV has increased by 707 % since 1990, levelled out in 2011 and is still on a lower level than both passenger cars and HGV. The consumption of diesel by passenger cars has increased annually since 1995 but decreased by 2.8 % between 2015 and 2016.

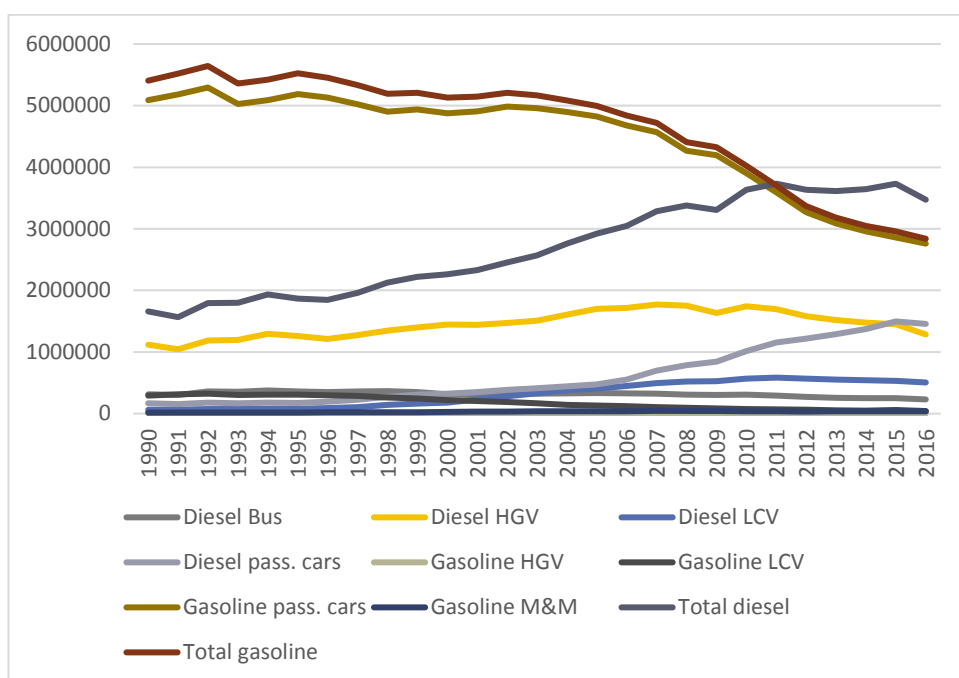


Figure 3.4. Consumption of diesel and gasoline by vehicle type 1990-2016 (m³).

The total use of liquid biofuels (FAME and ethanol) has increased by more than 850 % since 2003, when large-scale blending of ethanol into petrol began. The increasing production and use of biofuels was initiated by advantageous policy regulations and tax reliefs for biofuels⁸¹. The amount of biogas used by road traffic has also increased greatly since it was introduced on the market and has doubled every other to every third year between 1998 and 2008.

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

⁸¹ Swedish Energy Agency, 2013.

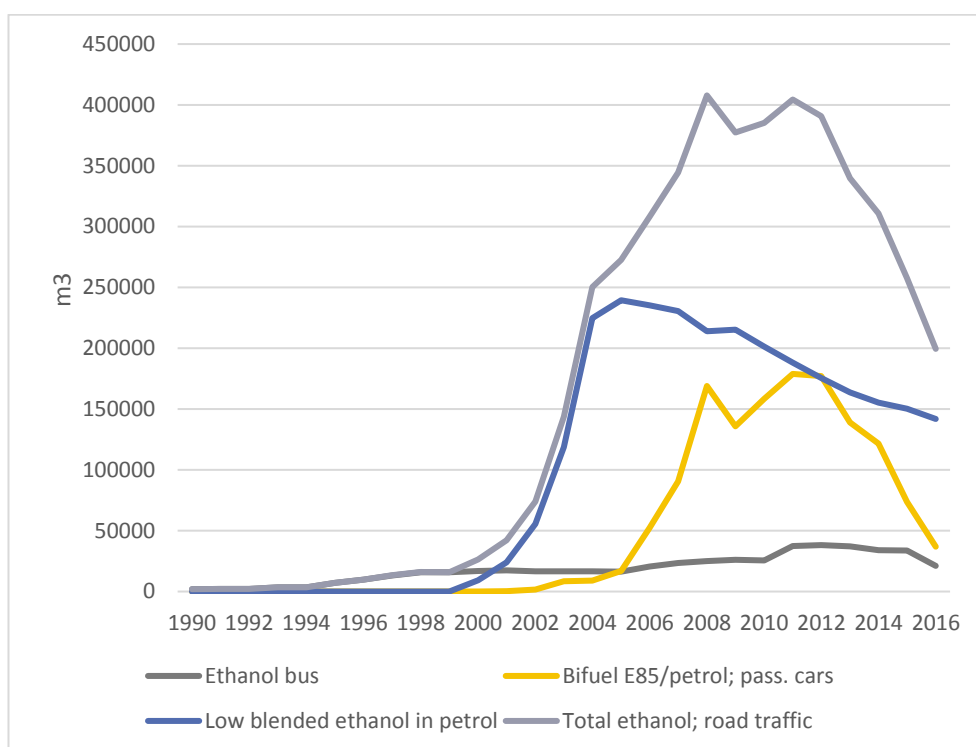


Figure 3.5 Consumption of ethanol by road traffic 1990-2016 (m³)

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

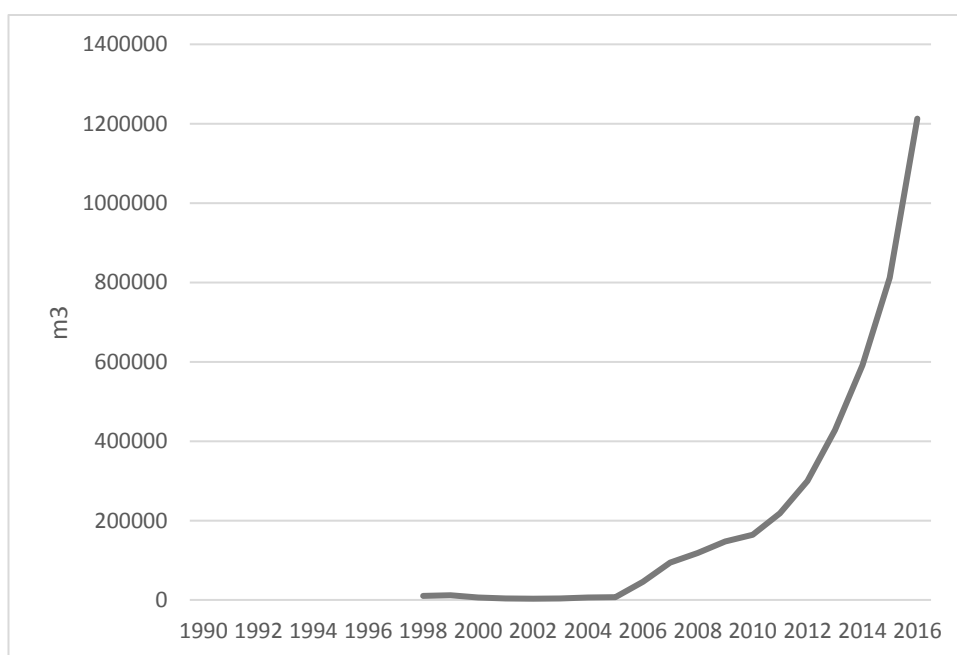


Figure 3.6 Consumption of FAME by road traffic 1990-2016 (m³).

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.16.

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

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.3.b Cars	CO ₂	X (Diesel oil, Gasoline)	X (Diesel oil, Gasoline)		T2	CS	Yes
	CH ₄		X (Gasoline)		T2, T3	CS	Yes
	N ₂ O		X (Gasoline)		T2, T3	CS	Yes
1.A.3.b Light duty trucks	CO ₂	X (Diesel oil, Gasoline)	X (Diesel oil, Gasoline)		T2	CS	Yes
	CH ₄				T2, T3	CS	Yes
	N ₂ O				T2, T3	CS	Yes
1.A.3.b Heavy duty trucks and buses	CO ₂	X (Biomass, Diesel oil)	X (Diesel oil)		T2	CS	Yes
	CH ₄				T2, T3	CS	Yes
	N ₂ O		X (Diesel oil)		T2, T3	CS	Yes
1.A.3.b Motorcycles	CO ₂	X (Gasoline)	X (Gasoline)		T2	CS	Yes
	CH ₄				T2, T3	CS	Yes
	N ₂ O				T2, T3	CS	Yes

CS Country Specific, T2 Tier 2, T3 Tier 3.

* Shows key category (level) per fuel type

** Shows key category (trend) per fuel type

3.2.17.2 METHODOLOGICAL ISSUES

The road emission model HBEFA version 3.3 is used by the Swedish Transport Administration (STA) to estimate the fuel consumption and emissions from road traffic. The fuel consumption is adjusted to be in line with national statistics on supply and delivery of petroleum products⁸². The fuel consumption and emissions are allocated by fuel type and five vehicle categories: Passenger cars, Light commercial vehicles (LCV), Heavy goods vehicles (HGV), Buses and Mopeds & Motorcycles. The road traffic emission model HBEFA is updated yearly with new information regarding emission factors, vehicle fleet, composition of the fuel and the current traffic work.

Emissions of CO₂ from combustion of gasoline and diesel are based on country-specific thermal values and emission factors provided by the Swedish Petroleum and Biofuel Institute (SPBI)⁸³ as shown in Annex 2. Emissions of SO₂ are based on the actual sulphur content for the different environmental classes of petrol and

⁸² Statistic Sweden. Data from Monthly fuel, gas and inventory statistics (www.scb.se). See Annex 2. chapter "1.4 Allocation of fuels for mobile combustion" for more information regarding the allocation of fuels for mobile combustion.

⁸³ Swedish petroleum and biofuel institute. www.spbi.se

diesel fuel. The data on actual sulphur content is provided by the Swedish Transport Administration (STA) and based on estimates made by the Swedish Road and Transport Research Institute (VTI) for the years 1990-2001 and on fuel analysis from SPBI from 2001 and onwards.

The activity data used to estimate the emissions of CO₂ and SO₂ from natural gas and biofuels are based on national statistics on supply and delivery of natural gas, biogas, ethanol and FAME (Fatty Acid Methyl Ester)⁸⁴. Emissions of CO₂ from combustion of ethanol and FAME are based on country-specific thermal values and emission factors⁸⁵. The thermal value and emission factor for CO₂ for natural gas is retrieved from the Danish Energinet for 1990-2005 and from Swedegas as from 2006. Emissions of CO₂ from biogas, ethanol and FAME are reported as biomass and not included in the national totals.

Emissions of CH₄, N₂O, CO, NMVOC and NO_x for most fuel and vehicle types are estimated by the road emission model HBEFA. Emissions of CH₄ and N₂O from low blended ethanol in gasoline and FAME are included in the estimated emissions from gasoline and diesel vehicles in HBEFA. The emissions of N₂O and CH₄ from E85 cars are also estimated by HBEFA, but the model does however not calculate the emissions of N₂O and CH₄ from ethanol buses. These emissions are estimated with default emission factors from 2006 IPCC Guidelines according to Tier 1.

Emissions of N₂O from natural gas and biogas from buses are also missing in HBEFA, but are estimated by using activity data on delivered amounts of natural gas and biogas for road transport and country specific emission factors⁸⁶.

Bottom-up estimations of the fuel consumption and CO₂ emissions provided by the Swedish Transport Administration (STA) using the HBEFA model differ from those reported to the UNFCCC (based on fuel delivery). The STA aims to describe what is emitted on Swedish roads, regardless of where the fuel was bought or the nationality of the vehicles. According to IPCC Guidelines, the inventory should only account for emissions from fuel purchased in Sweden. The fuel consumption and the CO₂ emissions of CO₂ reported to UNFCCC, are as a consequence adjusted to be in line with national statistics on supply and delivery of petroleum products.

An overview of the two different objectives is presented in Table 3.17.

⁸⁴ Monthly surveys from Statistics Sweden: "Deliveries of motor fuel gas" and "Monthly fuel, gas and inventory statistics"

⁸⁵ Paulrud, S., Fridell, E., Stripple, H., Gustafsson, T., 2010.

⁸⁶ Paulrud, S., Fridell, E., Stripple, H., Gustafsson, T., 2010.

Table 3.17. Emissions from road transport reported by the STA and in the CRF.

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

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

Emissions of greenhouse gases from the use of LPG by road traffic are estimated for the first time in submission 2017 and are based on national statistics on supply and delivery of LPG for road traffic. The emissions of CO₂ are estimated using country-specific thermal value and emission factor, while emission factors from IPCC 2006 guidebook are used to estimate the emissions of CH₄ and N₂O. The emissions are minor and only represent 0.02-0.03 % of emissions of CO₂-eq. from road transportation considering the whole time series.

The emissions of methane (CH₄) and nitrous oxides (N₂O) from E85 passenger cars is estimated by HBEFA as from submission 2017. The emissions were earlier estimated by using activity data (fuel consumption) and default emission factors from 2006 IPCC Guidelines (GL). The emissions of CH₄ and N₂O have decreased by 98 % respectively 100 % as an effect of change of method.

Military transport emissions are reported under CRF 1.A.5.b in accordance with the IPCC Guidelines. As Military road transport is included in HBEFA 3.3, the emissions for each vehicle type are reduced by proportional amount equal to the weight of the fuel consumption reported by the Swedish Armed Forces relative to the fuel consumption from national statistics allocated to civil road transport.

3.2.17.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Activity data for gasoline, diesel and natural gas is available from 1990, while reliable activity data for biogas exists from 1996, for ethanol from 1998 and for FAME from 1999.

One important basic parameter for the HBEFA model is vehicle-km, which is calculated through another model. This second model is based on the mileage driven by the vehicle noted at time of MOT (annual testing of the vehicle). A passenger car that goes through MOT in the beginning of 2015 has driven the most part during 2014. If the development of traffic is without interruption, this issue is not a problem for the calculations. However if a sudden event occurs, such as a drop in the economy, it will not be shown as clearly in the development of vehicle mileage as in statistics on fuel consumption.

The trend in the implied emission factor for CH₄ for gaseous fuels (Natural gas & Biogas) shows minor inter-annual fluctuations in submission 2018 compared to submission 2017. The reason is that the country-specific emission factors for CH₄ emissions are more harmonized between passenger cars (ca 1 kg/TJ) and buses (ca 20 kg/TJ). This is due to the implementation of CH₄ emissions from the HBEFA model in submission 2018, described in detail under source-specific recalculations. The implied emission factor is an average for both vehicle categories. The consumption of Natural gas and Biogas by buses and passenger cars is shown in Figure 3.7 and Figure 3.8 below.

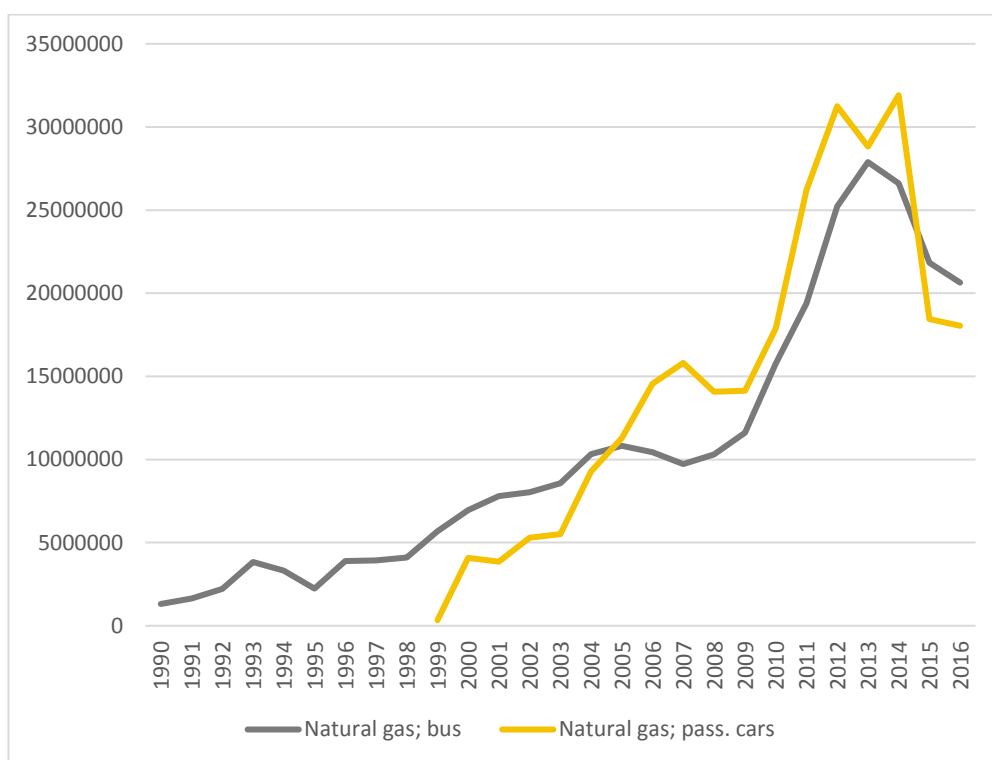


Figure 3.7 Consumption of natural gas by road traffic 1990-2016 (m³).

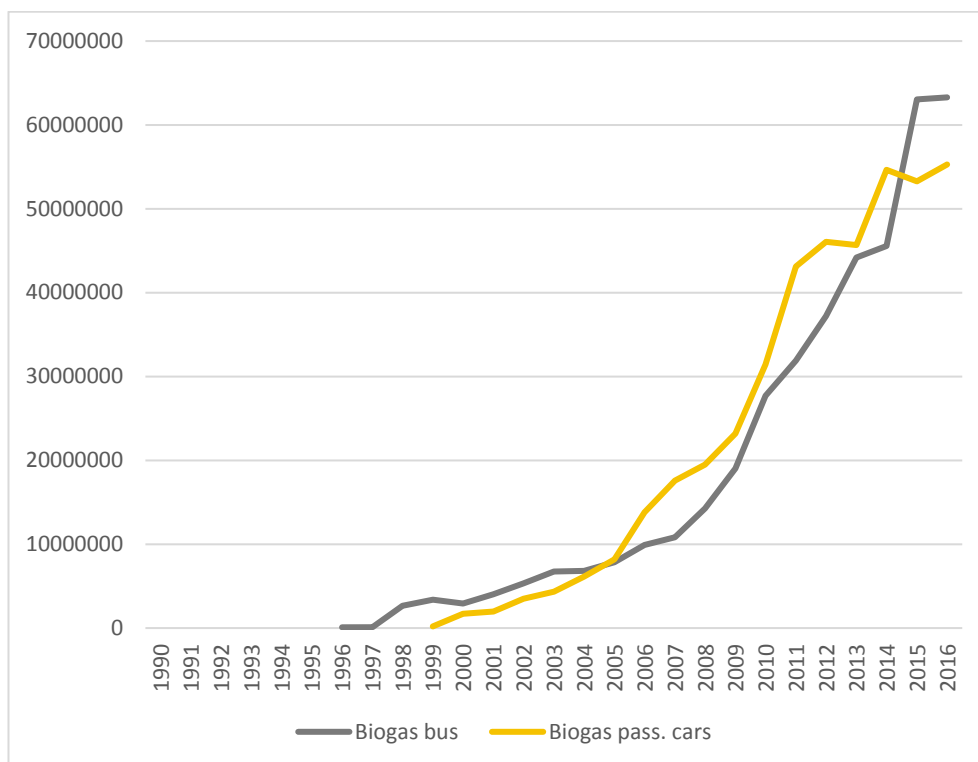


Figure 3.8. Consumption of biogas by road traffic 1990-2016 (m³).

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

Time series are checked for consistency and recalculations are verified.

3.2.17.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

3.2.17.5 SOURCE-SPECIFIC RECALCULATIONS

The road traffic emission model HBEFA is updated yearly with new information regarding emission factors, vehicle fleet, composition of the fuel and the current traffic work.

In submission 2018, the HBEFA model version 3.3 has implemented updated emission factors for NO_x regarding Euro IV and Euro VI passenger cars. The transition to the new model with updated emission factors for Euro 4-6 passenger cars leads to higher emissions of nitrogen oxides and the difference is increasing

with time. Emissions of NMVOC from gas buses is also included in the HBEFA 3.3 model in submission 2018.

Moreover, a reallocation of both biogas and natural gas from passenger cars to buses has been implemented in HBEFA in submission 2018. This applies to year 1995, 1999 and onwards and leads to decreased emissions for gas fueled passenger cars and increased emissions for gas fueled buses. Emissions of CH₄ from buses, estimated by HBEFA for the entire time series, is also implemented in submission 2018. Since the method used in submission 2017 applied older and higher emission factors, there is a decrease in CH₄ emissions from gas buses in submission 2018.

As for the gas fueled passenger cars, data on biogas and natural gas consumption has been revised. There is in submission 2018 data on consumption for the years 1995, 1999 and onwards, whereas submission 2017 showed consumption for the years 1997-2015. Emissions of CH₄ from natural gas and biogas from passenger cars is in submission 2018 estimated by HBEFA for the years 2005-2016.

Regarding 1995-2004, CH₄ emissions are estimated using the HBEFA model's 2005 implied emission factor. In submission 2017, emission factors from the 2006 IPCC Guidelines were used. Emissions of N₂O from biogas and natural gas from passenger cars are in submission 2018 recalculated using the same method as for CH₄.

Besides the above mentioned, the effect of the HBEFA updates on the emissions from road traffic in submission 2018 is marginal compared to the emissions in submission 2017.

In order for the CO₂ emission factors for natural gas to better comply with the thermal values collected from Swedegas, data on emission factors were updated with Swedegas data for the years 2006-2015 in submission 2018. The 2015 thermal value for natural gas was also revised.

Moreover, the delivered quantities of natural gas and biogas were also revised for the year 2015 in submission 2018.

The estimated consumption of gasoline and diesel by HBEFA was modified for all years by a residual of gasoline and diesel. The residual is the difference in the gasoline respectively the diesel consumption when comparing the national statistics on supply and delivery of petroleum products⁸⁷ (top-down approach) to the bottom-up estimated fuel consumption. The residual is proportionally redistributed to the following sectors: to 1A3b (road transportation), 1A3d (domestic navigation), 1A2g vii, 1A3e, 1A4b and 1A4c (off-road vehicles and working machinery) and 1A4c (fishing).

⁸⁷ Statistic Sweden. Data from Monthly fuel, gas and inventory statistics (www.scb.se). See Annex 2. chapter "1.4 Allocation of fuels for mobile combustion" for more information regarding the allocation of fuels for mobile combustion.

3.2.17.6 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 (CRF 1.A.3.c)

3.2.18.1 SOURCE CATEGORY DESCRIPTION

The majority of all railway traffic in Sweden runs on electricity. Only a small part runs on diesel fuel. Emissions related to the use of electricity for railway should not be included in this sector according to IPCC's guidelines. Production of electricity is accounted for in CRF 1A1A, regardless of where it's consumed.

The consumption of diesel oil for railways has steadily decreased since 1990. As a consequence, the emissions of CO₂-eq. have declined by 57 % from 1990 (102 kt) to 2016 (44 kt).

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.18.

Table 3.18. Summary of source category description, CRF 1.A.3.c, according to approach 1.

CRF	Gas	Key Category Assessment 2016, 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 ₂ O				T1	D	Yes

CS: Country Specific. D: Default. T1: Tier 1. T2: Tier 2.

* Shows key category (level) per fuel type

** Shows key category (trend) per fuel type

3.2.18.2 METHODOLOGICAL ISSUES

Both Tier 1 and Tier 2 methods are used. Information on emissions from railways is provided by the Swedish Transport Administration (STA). STA estimates the emissions of CO₂, SO₂, NO_x, NMVOC, CH₄, CO, HC and N₂O based on the amount of diesel consumed by the railways⁸⁸ and various emission factors.

Country specific emission factors used for calculating CO₂ and SO₂ emissions are supplied by SPBI⁸⁹.

⁸⁸ The Swedish Energy Agency took over the responsibility for publication of data regarding consumption of fuel by Railways in 2017; previously published by the governmental agency Traffic Analysis.

⁸⁹ Swedish Petroleum and Biofuel Institute. www.spbi.se

Emissions of CH₄ and N₂O are estimated with emission factors from EMEP/EEA Guidebook 2013 for all engines, since these emissions are not regulated by EU directives. The threshold limits for CO and NO_x is used as emission factors for all emissions from engines that comply with the EU emission standards Stage IIIA and Stage IIIB.⁹⁰ For engines introduced before the implementation of EU emissions standards, the emission factors from EMEP/EEA guidebook 2013 are used to estimate emissions of CO and NO_x.

The conversion of g/kWh to g/litre is based on the fuel consumption factors in Table 3-5 in the EMEP/EEA Guidebook 2013 and a diesel density of 816 g / litre. The same density is used for all years.

3.2.18.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Overall, the emissions for CRF 1.A.3.c are consistent over time and associated with low uncertainties. The estimate of diesel consumption is based on fees paid by the rail operators and is considered to be of very high quality.

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

3.2.18.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

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

3.2.18.5 SOURCE-SPECIFIC RECALCULATIONS

No source specific procedures have been made.

3.2.18.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

⁹⁰ <http://www.dieselnet.com/standards/eu/nonroad.php#rail>

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

3.2.19.1 SOURCE CATEGORY DESCRIPTION

The source category covers emissions of greenhouse gases from domestic navigation and leisure boats. Emissions from diesel oil, domestic heating oil and residual fuel oil purchased in Sweden but used abroad are reported separately as international bunker emissions (CRF 1.D). CO₂ emissions from navigation do not show any particular trend, but fluctuates over time.

The allocation of emissions from navigation is summarized in Table 3.19.

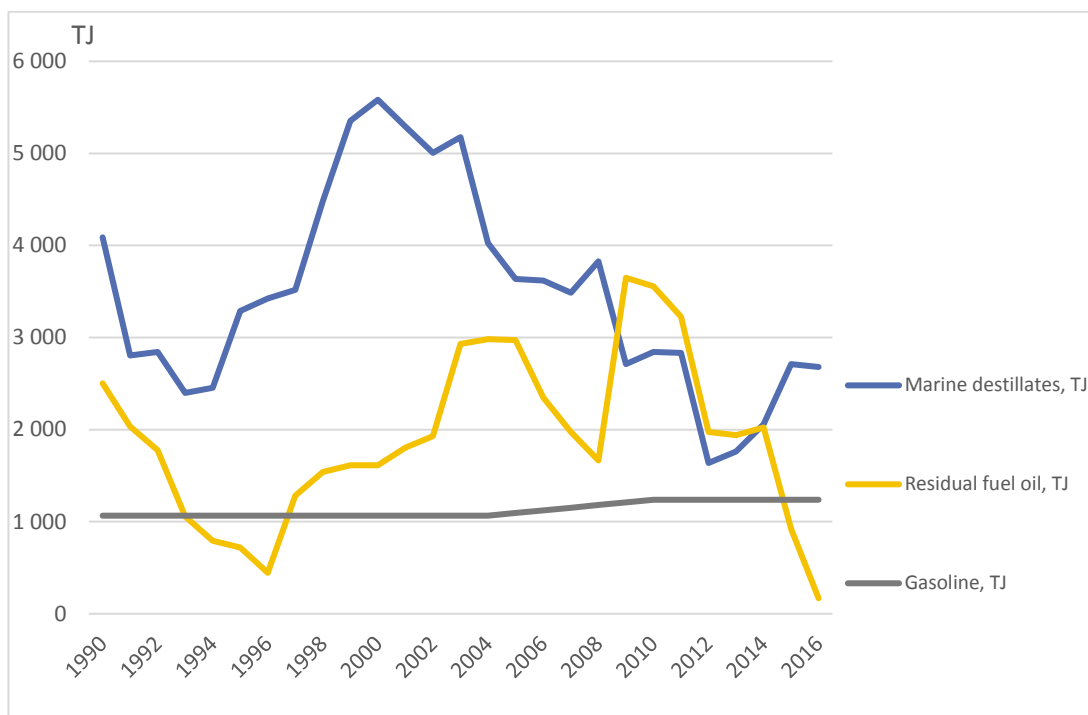
Table 3.19. Reporting of emissions from navigation, according to 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Journey type between two ports	Domestic	International
Departs and arrives in same country	Yes (1A3d)	No,
Departs from one country and arrives in another	No	Yes (1 D)

In the last year the emissions of greenhouse gases from domestic navigation have decreased by 17 %, comparing 2015 to 2016. The emission of greenhouse gases were 308 kt CO₂-eq. in 2016, which is a decline by 48 % since 1990.

This can be compared to emissions of greenhouse gases from international navigation, which have tripled since 1990 and increased by 11 % since 2015, to reach 6 837 kt CO₂-eq. in 2016.

In 2012 the fuel consumption by domestic navigation shifted from residual fuel oil to marine distillates. This was most likely the result of stricter rules regarding the sulphur content in marine fuels, which were decided on in 2012 and enforced in January 2015, and with a continuing downward trend for heavy fuel oils.



Figur 3.9. Fuel consumption of residual oil and marine distillate by domestic navigation (including leisure boats) 1990-2016 (TJ)

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.20.

Table 3.20. Summary of source category description, CRF 1A3d, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.3.d	CO ₂	X (Gas/Diesel oil)	X (Residual Oil)		T2	CS	Yes
	CH ₄				T2	CS, D	Yes
	N ₂ O				T2	CS, D	Yes

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

* Shows key category (level) per fuel type

** Shows key category (trend) per fuel type

3.2.19.2 METHODOLOGICAL ISSUES

The emissions from domestic navigation are estimated applying Tier 2. The fuel consumption⁹¹ is based on the monthly survey on supply and delivery of petroleum

⁹¹ Except for leisure boats.

products⁹². The emissions factors for CO₂ are based on a SMED study conducted in 2004⁹³ while the emission factors for CH₄, N₂O and NMVOC are provided by the Swedish Maritime Administration (SMA) for 2005-2015 and by the Swedish Transport Agency (STA) as from 2016 in accordance with the Swedish climate legislation.

The fuel consumption by leisure boats was reviewed in 2014, which resulted in an increase in the consumption of gasoline by leisure boats for 2005-2013 and an inclusion of diesel consumption by leisure boats for the whole time series⁹⁴.

The gasoline and diesel consumption by leisure boats in Sweden 1990-2004 is based on a survey regarding leisure boat from 2004 and a study carried out by SMED in 2005⁹⁵. The gasoline consumption by leisure boats was estimated to 32,500 m³/year⁹⁶ and the diesel consumption to 12,000 m³/year for the years 1990-2004 as a result of these studies.

The gasoline and diesel consumption by leisure boats in 2005-2015 is based on a leisure boat survey from 2010⁹⁷ and an assessment of the survey carried out by SMED in 2014⁹⁸. The gasoline and the diesel consumption by leisure boats, for 2010 and onwards, was estimated to 37,768 m³/year respectively 18,172 m³/year as a result of these studies. The consumption of both gasoline and diesel has been estimated by interpolation for the years 2005-2009.

Emissions of CO₂ and SO₂ from leisure boats are based on the estimated consumption of gasoline and diesel and the same thermal values and the same emission factors as for gasoline and diesel used by road traffic.

Emissions of CH₄ and N₂O from *gasoline leisure boats* are based on the fuel consumption and emission factors from EMEP Corinair, while the emission factors for NO_x, NMVOC and CO were updated in submission 2018 by the Swedish Environmental Research Institute (IVL) for the whole time period⁹⁹. The emissions from leisure boats also depend on the ratio between 2-stroke and 4-stroke engines and the ratio used is based on a study by Statistics Sweden from

⁹² Statistic Sweden. Monthly fuel, gas and inventory statistics. See annex 2 for more information regarding different surveys.

⁹³ Cooper and Gustafsson, 2004.

⁹⁴ Eklund V. 2014.

⁹⁵ Gustafsson, 2005.

⁹⁶ Statistics Sweden, 2005a.

⁹⁷ Transportstyrelsen, 2010.

⁹⁸ Eklund V. 2014.

⁹⁹ Fridell, E., Mawdsley, I., Wisell T. 2017.

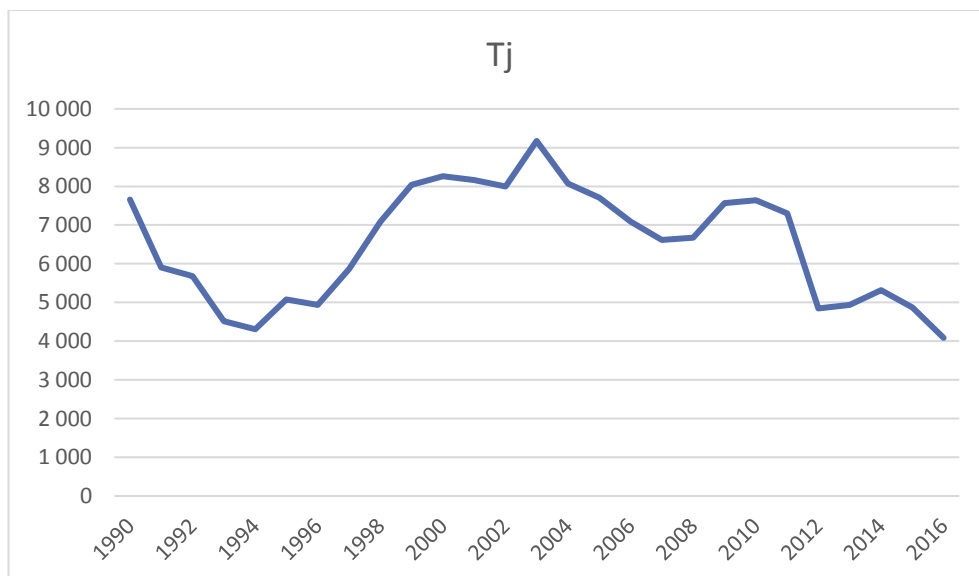
2005¹⁰⁰. The study indicates that there is a larger share of 4-stroke engines in 2004 than in 1990. Based on the assumption that the move towards a larger number of 4-stroke engines has been gradual between since 1990, the ratio for each year between 1990 and 2004 has been estimated by interpolation. From 2005 and onwards, the ratio between 2- and 4-stroke engines is assumed to be the same as for 2004.

Emissions of CH₄ and N₂O from the consumption of *diesel by leisure boats* are based on the fuel consumption and emission factors provided by the Swedish Maritime Administration up to 2015 and from the Swedish Transport Agency as from 2016. The emissions of NO_x, NMVOC and CO from diesel leisure boats were updated in submission 2018 by the Swedish Environmental Research Institute (IVL) for the whole time period¹⁰¹.

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

3.2.19.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The fuel consumption by domestic navigation is based on the amount of fuels that are purchased and consumed in Sweden according to the monthly survey on supply and delivery of petroleum products from Statistics Sweden (see Annex 2)¹⁰². This statistics shows fluctuations for which it has been difficult to find natural explanations. See Figure 3.10.



¹⁰⁰ Statistics Sweden, 2005a.

¹⁰¹ Fridell E., Mawdsley I., Wisell T. 2017.

¹⁰² Statistic Sweden. Monthly fuel, gas and inventory statistics. EN31SM.

Figure 3.10 Fuel consumption by national navigation (including leisure boats) 1990-2016

In 2011, the fuel consumption by national and international navigation was studied and the result was presented in the report “Emissions from navigation and fishing including international bunkers”¹⁰³. Fuel data in the survey “Monthly fuel, gas and inventory statistics” was analysed and in general found to be of good quality.

Fuels used for international navigation and purchased by business corporations are exempt from VAT, as opposed to fuels sold to boats/ships sailing within the Swedish borders. This serves as the base for splitting liquid fuels between domestic navigation and international navigation. As a consequence of that VAT is applied on national fuel consumption, but not on international bunkers, the respondents to the survey are able to separate fuels used for domestic and international navigation correctly and in line with IPCC Guidelines.

The Swedish Energy Agency (STEM) has for the last 2.5 years worked to improve the survey “Monthly fuel, gas and inventory statistics”¹⁰⁴ which is the source for activity data (fuel consumption), for both domestic and international navigation, in the Swedish inventory. STEM will implement the new version of the survey in January 2018. The results from the new survey will be implemented in submission 2020.

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

3.2.19.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

In 2011 an attempt was made to verify the emissions for domestic shipping by comparison with an alternative, independent bottom-up calculation. The bottom-up calculation includes all ship movements in the waters around Sweden. Ship positioning data is gathered using the AIS (Automatic Identification System), which is a complement to radar that provides positions and some static information

¹⁰³ Eklund et al. 2011.

¹⁰⁴ 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/>

for almost all ships found in the Baltic and the North Sea. The calculations distinguish domestic shipping from international shipping by tracking each ship from its origin to its destination harbour. A route is classified as domestic if origin and destination is within the same country. Where the ship refuels is not possible to distinguish using this method, which causes a slight difference to the reporting guidelines. However, for the purpose of verification this difference is considered to be of little importance. Emission factors are assigned individually for each ship depending on its technical properties. The power output, fuel consumption and emissions are estimated with 5 minute resolution for all ships carrying an AIS transponder. For the years 2009-2011, about 40 000 unique transponder IDs are registered by AIS.

The results from the bottom-up calculation show higher emissions than reported emissions from domestic navigation. This could be related to fishing vessels (reported under CRF 1A4c) and military ships (1A5b). Further studies should also include fishing and military ships to get the whole picture. The data needs to be further analysed.

In 2016-2017 another project was carried out by The Swedish Meteorological and Hydrological Institute regarding AIS data and navigation¹⁰⁵ on behalf of the the Swedish Energy Agency (STEM). This project investigated the possibility to use AIS data as a base, to separate sales statistics into domestic respectively international shipping. To do this, the Shipair model system was used to estimate the fuel consumption by domestic navigation for 2013-2015.

The results showed that the model complies with seasonal variations in sales statistics, with an increase during the warm season as shipping increases in intensity. At the same time, there are major differences between the result in the model and sales statistics. Accumulated throughout the year, the modeled fuel consumption is double as high as the sales statistics for domestic navigation. The STEM will look into the possibility to implement this result in their work to improve the survey “Monthly fuel, gas and inventory statistics”.

3.2.19.5 SOURCE-SPECIFIC RECALCULATIONS

The amount of diesel for national navigation was slightly modified for all years with regard to the distribution of the residual of diesel to 1A3b (road transportation), 1A3d (domestic navigation), 1A2g vii, 1A3e, 1A4b and 1A4c (off-road vehicles and working machinery) and 1A4c (fishing).

This resulted in slightly decreased emissions of CO₂ equivalents in the beginning of the time series and slightly increased emissions oin the end of the time series.

¹⁰⁵ Jakobsson M., Segersson D., Windmark F. 2017.

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.

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

3.2.20.1 SOURCE CATEGORY DESCRIPTION

Emissions reported under CRF 1.A.3.e refer to emissions from combustion of natural gas for pipeline transport (1.A.3.e.i) as well as emissions from off-road vehicles and other machinery (1.A.3.e.ii) including for example lift trucks, tractors and some other mobile machinery. The emissions of greenhouse gases from working machinery in 1A3eii represent only ~ 6 % of all emissions of GHG from working machinery.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.21.

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

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1.A.3.e	CO ₂	X (Diesel oil)			T2	CS	Yes
	CH ₄				T1,T2,T3	D,CS	Yes
	N ₂ O				T1,T2,T3	D,CS	Yes

D Default, T2 Tier 2, T3 Tier 3. CS Country Specific.

* Shows key category (level) per fuel type

** Shows key category (trend) per fuel type

3.2.20.2 METHODOLOGICAL ISSUES

3.2.20.2.1 Pipeline Transport (1.A.3.e.i)

Annual amounts of total natural gas in pipeline transport in Sweden are known for the whole reporting period 1990-2015. Combustion of natural gas for pipeline transport of natural gas in Sweden is only known for 2013 and for the following years, but not for 1990-2012. According to the national expert at Swedegas (Anders Hellström), 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.

Annual national calorific values and CO₂ EFs were applied together with tier 1 default CH₄ and N₂O EFs from the 2006 IPCC Guidelines.

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 CO₂ and SO₂ which are estimated according to Tier 2. The model is further explained in Annex 2.¹⁰⁶

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 combustion¹⁰⁷.

Emissions from off-road vehicles and other machinery are also reported under CRF 1.A.2.g vii, 1.A.4.A, 1.A.4.b and 1.A.4.c, in line with IPCC Guidelines, see Table 3.22.

Table 3.22. Distribution of emissions from off-road vehicles and other machinery.

Category	CRF	Definition IPCC Guidelines
Industry	1.A.2.g vii	Mobile machineries in industry that run on petroleum fuels, as for example tractors, dumpers, cranes, excavators, generators, wheel loaders, sorting works, pump units etc.
Other	1.A.3.e ii	Combustion emissions from all remaining transport activities including ground activities in airports and harbours, and off-road activities not otherwise reported under 1.A.4.c or 1.A.2.g vii.
Commercial/ Institutional	1.A.4.a.ii	Garden machinery, eg lawn mowers and clearing saws, not used by private users, Also tractors not used in 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.

¹⁰⁶ Annex 2: 1.6 Methodology for off-road vehicles and working machinery

¹⁰⁷ See Annex 2. chapter “1.4 Allocation of fuels for mobile combustion” for more information.”

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

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

3.2.20.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The model was implemented the first time in submission 2009. During 2010 the model underwent a second verification. Activity data and emissions factors were reviewed in 2012 and 2013. Time series are checked for consistency and recalculations are verified every year.

3.2.20.5 SOURCE-SPECIFIC RECALCULATIONS

model for working machinery has been updated with sales data for off-road vehicles for 2005-2016 in submission 2018, which was provided by the Swedish trade association for suppliers of mobile machines. The allocation key in the model was also updated, as new information regarding the sector distribution was received from both the trade association and the vehicle register. The age of some of the oldest tractors in the model was adjusted as well, as they in previous submissions mistakenly were grouped together in the oldest age category¹⁰⁸.

The updated model has resulted in decreased emissions of greenhouse gases from off-road vehicles and other machinery for most years in submission 2018 compared to submission 2017.

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.

¹⁰⁸ Eklund, V., Lidén, M., Jerksjö, M., 2017. Regelbunden indataförsörjning till beräkningsmodellen för arbetsmaskiner. SMED PM 2017.

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

3.2.21.1 SOURCE CATEGORY DESCRIPTION

This category includes stationary combustion for heating of premises used for commercial and institutional activities and emissions from working machinery used in these activities. The emissions of greenhouse gases (GHG) from working machinery in 1A4a represent around 11 % of all emissions of GHG from working machinery.

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 2015 it was around 7000 TJ. Liquid fuels account for most of the decrease. The share of liquid fuels in 1990 was about 95 % and the corresponding share in 2016 was 32%.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.23.

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

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.4.a	CO ₂	X (Diesel Oil, Gaseous fuels, Liquid fuels, Gasoline)	X (Diesel Oil, Gaseous fuels, Liquid fuels, Gasoline)		T2	CS	Yes
	CH ₄				T2, T3	CS	Yes
	N ₂ O				T2, T3	CS	Yes

CS Country Specific. T2 Tier 2, T3 Tier 3

* Shows key category (level) per fuel type

** Shows key category (trend) per fuel type

3.2.21.2 METHODOLOGICAL ISSUES

3.2.21.2.1 Stationary combustion

For stationary combustion within CRF 1.A.4.a, all activity data and emission factors are on national level by fuel type and estimated emissions are therefore considered to correspond to Tier 2. The data source for activity data is the annual energy balance, which for this sector is mainly based on premises statistics that is further described in section 3.2.21.4.1 and in Annex 2. Activity data for the latest emission year is preliminary as the annual energy balances are not published at the time when the emission calculations have to be finalized.

3.2.21.2.2 *Mobile combustion/Working machinery*

Emissions from mobile combustion in CRF 1.A.4.a refer mainly to gardening machines for professional use and tractors that are not used in industry, farming, or forestry. A national model is used to estimate emissions from all working machinery used in Sweden and it is considered to correspond to Tier 3 for all emissions, except for CO₂ and SO₂ which are estimated according to Tier 2. The model is further explained in Annex 2.¹⁰⁹

The consumption of gasoline and diesel, estimated by the model for off-road vehicles, is adjusted with regard to low-blended biofuel. The fuel consumption is also modified with a residual of gasoline and diesel. This residual arise as the volume of gasoline and diesel allocated to different sectors through a top-down approach is compared to the total volume of the gasoline and diesel consumed according to a bottom-up estimate. See Annex 2 for more information regarding the allocation of fuels for mobile combustion¹¹⁰.

Emissions from working machinery are also reported under CRF 1.A.3.e, 1.A.4.A, 1.A.4.b and 1.A.4.c, in line with IPCC Guidelines, see Table 3.24.

Table 3.24. Distribution of emissions from off-road vehicles and other machinery

Category	CRF	Definition IPCC Guidelines
Industry	1.A.2.g vii	Mobile machineries in industry that run on petroleum fuels, as for example tractors, dumpers, cranes, excavators, generators, wheel loaders, sorting works, pump units etc.
Other	1.A.3.e ii	Combustion emissions from all remaining transport activities including ground activities in airports and harbours, and off-road activities not otherwise reported under 1.A.4.c or 1.A.2.g vii.
Commercial/ Institutional	1.A.4.a.ii	Garden machinery, eg lawn mowers and clearing saws, not used by private users, Also tractors not used in 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.

3.2.21.3 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. CO₂ from domestic heating oil is the largest uncertainty source. The activity data and emission factor uncertainties are 20 % and 1 % respectively. The large activity data uncertainty is due to the use of data from the annual energy balances.

¹⁰⁹ Annex 2: 1.6 Methodology for off-road vehicles and working machinery

¹¹⁰ See Annex 2. chapter "1.4 Allocation of fuels for mobile combustion" for more information."

The implied emission factor for CO₂ for liquid fuels in CRF 1.A.4.a fluctuates according to the relative proportions of LPG, domestic heating oil and residual fuel oils (the latter not used in the latest years). The IEF is below 70 in the years 2007-2011 due to extensive use of LPG. In 2012, the share of LPG decreased somewhat, resulting in a CO₂ IEF of 71.9 kg/GJ.

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

3.2.21.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

In submission 2005 and earlier, there were large uncertainties in estimation models and allocation methods for fuel in the other sectors. In 2005, a study was performed by SMED, aiming at identifying and analysing the methods and models applied for each sub-sector and determine whether they were in line with the IPCC guideline recommendations¹¹¹. In addition, each fuel was traced back to its original source in order to determine whether it had been correctly allocated on stationary and mobile combustion.

The results from the study show good agreement with IPCC guideline recommendations. All fuels but biomass had little or no changes in methodologies, and where changes occurred, no significant inconsistencies in fuel consumption time series were detected. However, for biomass, several significant inconsistencies were identified leading to recalculations of activity data and emissions in CRF 1.A.4.a and 1.A.4.b¹¹². Due to these recalculations there are obvious inconsistencies between the national energy balances and the national emission inventory data for years before 2005. Furthermore, all fuels proved to be correctly allocated on stationary and mobile combustion. All diesel oil and gasoline

¹¹¹ Gustafsson, et al. 2005.

¹¹² Paulrud et al. 2005.

reported under Other sectors in the energy balances is allocated to mobile combustion, while all the other fuels are related to stationary combustion.

3.2.21.4.1 Activity data for stationary combustion in other sectors

For stationary combustion within the Other sectors the activity data source is the energy balance. The Swedish Energy Agency provides preliminary data for the latest emission year, which are quite coherent with the final data, although minor revisions of data for the most recent years will still be made in subsequent submissions, when final annual energy balances are available.

Since 2002, and in particular since 2004, the consumption of biomass fuels has increased in this sector. This is partly explained by the general shift from liquid to biomass fuels in recent years. However, a data check performed in 2009 showed that the data for biomass use in the commercial/institutional sector in the energy balances might not be complete. Further investigations were planned to submission 2011, but this issue was not prioritised since no suitable alternative or complementary data sources were found.

In submission 2010 it was noted that the consumption of biomass, liquid fuels and gaseous fuels within this sector was higher in 2007 than in 2006 and 2008. In 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

In submission 2018 activity data for use of oils in forestry sector was revised for years 2005 to 2015. The revision resulted in very large relative changes within the in the sector.

In addition activity data for all categories in this sector has been revised between for year 2015 due to revision of the annual energy balances.

The model for working machinery has been updated with sales data for off-road vehicles for 2005-2016 in submission 2018, which was provided by the Swedish trade association for suppliers of mobile machines. The allocation key in the model was also updated, as new information regarding the sector distribution was received from both the trade association and the vehicle register. The age of some

of the oldest tractors in the model was adjusted as well, as they in previous submissions mistakenly were grouped together in the oldest age category¹¹³.

The updated model has resulted in both increased and decreased emissions of greenhouse gases, comparing submission 2018 to submission 2017. But the increase of greenhouse gas emissions between 2010 and 2015 represent the greatest difference between the submissions.

3.2.21.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan. Activity data for 2005-2012 will be reviewed and possibly revised in submission 2016 due to recent revisions of the annual energy balances.

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

3.2.22.1 SOURCE CATEGORY DESCRIPTION

In this category both stationary and mobile combustion occur. Stationary combustion of fuels within residential decreased by 62 % between 1990 and 2016, mainly due to a continuous increase in district heating use¹¹⁴. In recent years, the use of heat pumps has also increased significantly¹¹⁵. Most of this change occurred before 2006; however, the use of heating oils is still decreasing while combustion of wood, wood chips and pellets has increased in recent years. In 2009-2010, fuel consumption increased due to the cold winters these years, especially in 2010. Despite this, the consumption of heating oil continued to decrease while consumption of wooden fuels and natural gas increased quite considerably. Emissions of CO₂, CH₄ and N₂O from the use of charcoal are included in this source category.

Mobile combustion in 1.A.4.b refer to gardening machines used in households e.g. lawn mowers, hedged cutters, clearing saws and more. Also snow mobiles and four wheelers not used for professional purposes are allocated to 1.A.4.b. The emissions of greenhouse gases (GHG) from working machinery in 1.A.4.b represent around 12 % of all emissions of GHG from working machinery.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.25.

¹¹³ Eklund, V., Lidén, M., Jerksjö, M., 2017. Regelbunden indataförsörjning till beräkningsmodellen för arbetsmaskiner. SMED PM 2017.

¹¹⁴ Swedish Energy Agency 2014a

¹¹⁵ Swedish Energy Agency 2014b

Table 3.25. Summary of source category description, CRF 1A4b, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.4.b	CO ₂	X (Liquid fuels)	X (Liquid fuels)		T2	CS	Yes
	CH ₄	X (Biomass)			T2,T3	CS	Yes
	N ₂ O				T2,T3	CS	Yes

CS Country Specific. T2 Tier 2, T3 Tier 3.

* Shows key category (level) per fuel type

** Shows key category (trend) per fuel type

3.2.22.2 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 on the three most common combustion technologies: boiler, stoves and open fire places. Since 1998 biomass activity data is separated on wood logs, pellets/briquettes and wood chips/saw dust. Historical biomass data has been estimated by inter- and extrapolation.

Estimation models and allocation methods for fuel in the Other sectors, and use of preliminary data for stationary combustion in other sectors as discussed in section 3.2.21.4.1, also applies to CRF 1.A.4.b.

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

3.2.22.2.2 *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 CO₂ and SO₂ which are estimated according to Tier 2. The model is further explained in Annex 2.¹¹⁶

The consumption of gasoline and diesel, estimated by the model for off-road vehicles, is adjusted with regard to low-blended biofuel. The fuel consumption is also modified with a residual of gasoline and diesel. This residual arise as the

¹¹⁶ Annex 2: 1.6 Methodology for off-road vehicles and working machinery

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 combustion¹¹⁷.

Emissions from off-road vehicles and other machinery are also reported under CRF 1.A.2.g vii, 1.A.3.e, 1.A.4.A and 1.A.4.c in line with IPCC Guidelines, see Table 3.26.

Table 3.26. Distribution of emissions from off-road vehicles and other machinery

Category	CRF	Definition IPCC Guidelines
Industry	1.A.2.g vii	Mobile machineries in industry that run on petroleum fuels, as for example tractors, dumpers, cranes, excavators, generators, wheel loaders, sorting works, pump units etc.
Other	1.A.3.e ii	Combustion emissions from all remaining transport activities including ground activities in airports and harbours, and off-road activities not otherwise reported under 1.A.4.c or 1.A.2.g vii.
Commercial/ Institutional	1.A.4.a.ii	Garden machinery, eg lawn mowers and clearing saws, not used by private users, Also tractors not used in 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.

3.2.22.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. CO₂ from domestic heating oil is the largest uncertainty source. The activity data and emission factor uncertainties are 20 % and 1 % respectively. The large activity data uncertainty is due to the use of Tier 1 methodology with input data from the annual energy balances.

The time series for 1.A.4.b is considered to be consistent as there haven't been any major changes in methodology or input data to the energy balances that affect this category. The estimates for the last year, however, are somewhat inconsistent due to the issues described in section 3.2.21.4.1. The CO₂ IEF for liquid fuels shows a decreasing trend because the share of residual fuel oil is decreasing. The CH₄ IEF for biomass is slightly fluctuating between years due to variations in type of biomass and technology.

In 2004 the consumption of gasoline by working machinery drops as a result of a large increase in the total consumption of low-blended ethanol, which is allocated to road traffic and off-road vehicles and working machinery. The amount of low-blended gasoline allocated to road traffic is given by the road emission model

¹¹⁷ See Annex 2. chapter "1.4 Allocation of fuels for mobile combustion" for more information."

HBEFA in combination with national fuel statistics. The rest of the ethanol is allocated to working machinery. The consumption of gasoline drops noticeably when the gasoline consumption by working machinery is decreased by a larger amount of low-blended ethanol in 2004.

3.2.22.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

See section 3.2.21.4

3.2.22.5 SOURCE-SPECIFIC RECALCULATIONS

Following revisions of the energy balances, the activity data for stationary combustion within 1.A.4.b was revised for all fuels for the year 2014.

The model for working machinery has been updated with sales data for off-road vehicles for 2005-2016 in submission 2018, which was provided by the Swedish trade association for suppliers of mobile machines. The allocation key in the model was also updated, as new information regarding the sector distribution was received from both the trade association and the vehicle register. The age of some of the oldest tractors in the model was adjusted as well, as they in previous submissions mistakenly were grouped together in the oldest age category¹¹⁸

The updated model has resulted in increased emissions of greenhouse gases from off-road vehicles and other machinery for all years in submission 2018 compared to submission 2017.

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. In submission 2019 Sweden will implement new updated emission factors for combustion of biomass fuels in domestic combustion.

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

3.2.23.1 SOURCE CATEGORY DESCRIPTION

This category includes emissions from stationary combustion for heating purposes and mobile combustion in working machinery within agriculture and forestry, and fishing vessels. The emissions of greenhouse gases (GHG) from working machinery in 1.A.4.c represent around 32 % of all emissions of GHG from working machinery. The structure of the agricultural sector in Sweden is described in chapter 6.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.27.

¹¹⁸ Eklund, V., Lidén, M., Jerksjö, M., 2017. Regelbunden indataförsörjning till beräkningsmodellen för arbetsmaskiner. SMED PM 2017.

Table 3.27. Summary of source category description, CRF 1A4c, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.4.c	CO ₂	X (Liquid fuels)	X (Liquid fuels, Solid fuels)		T2	CS	Yes
	CH ₄				T2,T3	CS	Yes
	N ₂ O				T2,T3	CS	Yes

CS Country Specific. T2 Tier 2, T3 Tier 3.

* Shows key category (level) per fuel type

** Shows key category (trend) per fuel type

3.2.23.2 METHODOLOGICAL ISSUES

3.2.23.2.1 *Stationary combustion*

For stationary combustion, all activity data and emission factors are on national level by fuel type and estimated emissions are therefore considered to correspond to Tier 2 for agriculture and forestry (stationary combustion is not occurring for fisheries). Activity data is taken from the annual energy balances, which for this sector are based on models and results from a survey from 1985 and repeated in 2007 (see Other statistics from Statistics Sweden in Annex 2).

Estimation models and allocation methods for fuel in the Other sectors as discussed in section 3.2.21, and use of preliminary data for stationary combustion in other sectors as discussed in section 3.2.21.4.1 also applies to CRF 1.A.4.c.

3.2.23.2.2 *Mobile combustion*

The estimated fuel consumption for fisheries is based on a survey on energy consumption within the fishing industry by Statistics Sweden¹¹⁹ together with data on the Swedish fishing fleets' total installed effect in kW from the Swedish Agency for Marine and Water Management (SwAM). The estimate on fuel consumption provided by Statistics Sweden refer to 2005, and for the previous and following years the fuel consumption is estimated by adjusting the 2005 value according to the development in total installed effect.

The emissions factors used to estimate emissions from Fisheries are based on a SMED study from 2005¹²⁰, producing emission factors for CO₂, SO₂, NO_x, NMVOC, CH₄ and N₂O for 1990-2004. From 2005 estimates are based on the same consumption estimate and emission factors as for 2004. However, from 2007 and onwards the emission factors for SO₂ from fisheries are assumed to be the same as for domestic navigation, which are updated every year.

¹¹⁹ Statistics Sweden, 2006 ENFT0601.

¹²⁰ Cooper et al., 2005a.

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

Mobile combustion in CRF 1.A.4.c refers more than the fishing industry also 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 CO₂ and SO₂ which are estimated according to Tier 2. The model is further explained in Annex 2.¹²¹

The consumption of gasoline and diesel, estimated by the model for off-road vehicles, is adjusted with regard to low-blended biofuel. The fuel consumption is also modified with a residual of gasoline and diesel. This residual 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 combustion¹²².

Emissions from off-road vehicles and other machinery are also reported under CRF 1.A.2.g vii, 1.A.3.e ii, 1.A.4.a.ii and 1.A.4.b in line with IPCC Guidelines, see Table 3.28.

Table 3.28. Distribution of emissions from off-road vehicles and other machinery

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

3.2.23.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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

¹²¹ Annex 2: 1.6 Methodology for off-road vehicles and working machinery

¹²² See Annex 2. chapter "1.4 Allocation of fuels for mobile combustion" for more information."

The sharp increase in use of biomass in 2003 is due to a revision in submission 2009, where improved data was used for 2003 and later years. There is no information available to improve data from 2002 and earlier years. Emissions in 1990 are considered to be of a sufficient quality as they are based on the 1985 survey mentioned above, which was reasonably recent in 1990. The time series for liquid, solid and gaseous fuels are considered to be consistent. Solid fuels have not been used in this sector since 2000.

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

3.2.23.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

3.2.23.5 SOURCE-SPECIFIC RECALCULATIONS

Following revisions of the energy balances, the activity data for stationary combustion within 1A4c was revised for all fuels 2015. In addition revision of the energy consumption of oil fuels within the forestry sector was made for the years 2005-2015.

The model for working machinery has been updated with sales data for off-road vehicles for 2005-2016 in submission 2018, which was provided by the Swedish trade association for suppliers of mobile machines. The allocation key in the model was also updated, as new information regarding the sector distribution was received from both the trade association and the vehicle register. The age of some of the oldest tractors in the model was adjusted as well, as they in previous submissions mistakenly were grouped together in the oldest age category.¹²³

¹²³Eklund, V., Lidén, M., Jerksjö, M., 2017. Regelbunden indataförsörjning till beräkningsmodellen för arbetsmaskiner. SMED PM 2017.

The updated model has resulted in increased emissions of greenhouse gases from working machinery used by agriculture for all years while the emissions from working machinery used by the forest sector has decreased for all years. The emissions of greenhouse gases from all working machines in sector 1A4c increase in the beginning and in the end of the time series while decreasing in the middle of the time series.

3.2.23.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan. Activity data for stationary combustion 2005-2012 will be reviewed and possibly revised in submission 2016 due to recent revisions of the annual energy balances.

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

No emissions are reported in this sector.

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

3.2.25.1 SOURCE CATEGORY DESCRIPTION

CRF 1A5b includes emissions from military transports. Emissions from military transports have decreased over the years 1990-2008 due to a decrease in activity.

The consumption of jet kerosene is the largest contributor to GHG from military activities (1.A.5.b) in Sweden. The emissions of GHG from 1.A.5.b increased sharply 1990-1993, but have had a decreasing trend for the rest of the time series. The decrease slowed down in the last years, but has increased by 15 % since 2014. The emissions of GHG from military activities were 191 kt in 2015, which is a decrease by 78 % since 1990.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.29.

Table 3.29. Summary of source category description, CRF 1A5b, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.A.5.b	CO ₂	X (Liquid fuels)	X (Liquid fuels)		T2	CS	Yes
	CH ₄				T2, T3	CS	No, see Annex 5
	N ₂ O				T2, T3	CS	No, see Annex 5

CS Country Specific. T1 Tier 1.

* Shows key category (level) per fuel type

** Shows key category (trend) per fuel type

3.2.25.2 METHODOLOGICAL ISSUES

Emissions from military transport are based on data on fuel consumption¹²⁴ including all military activities and country specific emission factors and are considered to correspond to Tier 2 and Tier 3. Fuel consumption from some more administrative military activities, such as the Swedish Defence Material Administration (FMV), the Swedish Fortification Department (FORTV), the Swedish Defence Research Agency (FOI) and the National Defence Radio Institute (FRA), are not included in the calculations.

A special estimation for the use of FAME was conducted by the military for the years 1999-2001. None has been done for the other years.

CH₄ and N₂O emissions from the military are both based on a top-down approach, using fuel consumption (for aviation and navigation) and a bottom-up approach, using data from the HBEFA model (road transport). These estimates are considered to Tier 2. Emissions from military aviation are based on an average of LTO and cruise emission factors. Emissions from military navigation are estimated using emission factors from civil navigation. Emissions from the use of diesel oil by military stationed abroad is reported under Multilateral operations, CRF 1.D.2.

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

$$A = B - \sum \left[\frac{(C - D)}{(C \times E_i)} \right]$$

Where,

A = Military transport emissions

B = Total HBEFA emissions

C = Total fuel consumption National Statistics

D = Military fuel consumption Swedish Armed Forces

¹²⁴ Activity data on fuel consumption is supplied by the Armed Forces.

E_i = HBEFA emissions per vehicle type

Emissions of CH₄ and N₂O from the use of ethanol by military road transportation, is based on military consumption of ethanol for road traffic and default emission factors from 2006 IPCC guidelines. These estimates are considered to be Tier 1.

3.2.25.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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

3.2.25.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source specific procedures have been made.

3.2.25.5 SOURCE-SPECIFIC RECALCULATIONS

No source specific recalculations have been made.

3.2.25.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

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

During all stages from extraction of fossil fuels to final use, escape or release of gaseous fuels, volatile components or absorbed gases may occur. These fugitive emissions are intentional or unintentional escapes and releases of gases from extraction point to final oxidation. In particular, they may arise from the production, processing, transmission, storage and use of fuels, and include emissions from combustion only where it does not support a productive activity (e.g. flaring).

Fugitive emissions in Sweden stem from flaring of fuels in the various categories (iron and steel industry, the chemical industry, refineries and the pulp and paper industry), 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 and venting in the national natural gas and biogas transmission network (including storage).

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

3.3.1.1 SOURCE CATEGORY DESCRIPTION

There are no coal mines in Sweden and hence no fugitive emissions from coal mines occur (hence reported as NO).

Fugitive emissions from solid fuels instead include emissions from quenching and extinction at coke ovens (reported in CRF 1.B.1.b), and flaring of coke oven gas from the coke ovens (reported in CRF 1.B.1.c). CRF 1.B.1 is in fact not designed to include flaring, but since CRF 1.B.2 only refers to liquid and gaseous fuels, it is not possible to report flaring of coke oven gas in CRF Table 1.B.2. Flaring of blast furnace gas in the blast furnace and steel converter are reported in CRF 2.C.1 in accordance with the 2006 IPCC Guidelines.

Reported activity data is amounts of produced coke in CRF 1.B.1.b (Mton) and amounts of flared coke oven gas (COG) (Mton) in CRF 1.B.1.c.

The amounts of flared COG vary considerably between years, and during some years (2009, 2015) they were unusually high, resulting in increasing emissions in CRF 1.B.1. According to environmental reports¹²⁵, 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 3.30.

Table 3.30. Summary of source category description, CRF 1B1, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.B.1	CO ₂				T2	CS	Yes
	CH ₄				T2	CS	Yes
	N ₂ O				T2	CS	Yes

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

* Shows key category (level) per fuel type

** Shows key category (trend) per fuel type

3.3.1.2 METHODOLOGICAL ISSUES

The estimation of emissions from flaring of coke oven gas is included in the carbon balance calculations and other plant specific calculations made in cooperation with the two facilities. Data on SO₂ emissions from quenching and extinction at coke ovens are obtained directly from the operators of the two facilities; NO_x and NMVOC emissions from the same processes are calculated with default emission factors specified in the EMEP / EEA Guidebook.

3.3.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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

¹²⁵ SSAB, 2008, 2009, 2015

The uncertainty for the activity data (amount of flared coke oven gas) has been estimated to ± 50 %. The extent of flaring is by nature very variable between years, and the uncertainty in activity data is high compared to other activities. The emission factor uncertainty has been estimated to ± 5 % for CO₂ and ± 20 % for CH₄ and N₂O.

3.3.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

See section **Fel! Hittar inte referensälla.**

3.3.1.5 SOURCE-SPECIFIC RECALCULATIONS

Fugitive emissions of NO_x (0.0003 – 0.0004 kt) and NMVOC (0.008 – 0.009 kt) from coke production for the whole time series were included in the inventory in Submission 2018.

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.

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

3.3.2.1 SOURCE CATEGORY DESCRIPTION

In the Swedish inventory, fugitive emissions from a number of different activities related to production and handling of liquid fuels and natural gas are reported in this sector. These activities include hydrogen production at oil refineries (1.B.2.A.1), crude oil transport (1.B.2.A.3), activities in refineries such as catalytic, desulphurisation and storage and handling of oil (1.B.2.A.4), gasoline handling and distribution (1.B.2.A.5), natural gas and biogas transmission (1.B.2.B.4), distribution of natural gas, biogas and gasworks gas (1.B.2.B.5), venting of natural gas (1.B.2.C.1.2), and flaring of natural gas and oil (1.B.2.C.2).

In 1990-2005 the emissions of CO₂ in 1B2 were relatively constant – ~ 300 kt/year. Due to the start of production of hydrogen at refineries in 2006 the emissions of CO₂ more than doubled (>840 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 3.31.

Table 3.31. Summary of source category description, CRF 1.B.2, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level*	Trend**	Qualitative			
1.B.2.a	CO ₂	X (Oil)	X (Oil)		T3	PS	No, see Annex 5
	CH ₄				T1, T2	D, CS, PS	Yes
	N ₂ O				T2	CS	Yes
1.B.2.b	CO ₂				T2, T3	CS, PS	Yes
	CH ₄				T2, T3	CS, PS	Yes
1.B.2.c	CO ₂	X			T2, T3	CS, PS	Yes
	CH ₄				T2	CS	Yes
	N ₂ O				T2	CS	Yes

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

* Shows key category (level) per fuel type

** Shows key category (trend) per fuel type

3.3.2.2 METHODOLOGICAL ISSUES

3.3.2.2.1 Hydrogen production plants at refineries (CRF 1.B.2.A.1)

Since 2005, one hydrogen production facility at a refinery is in operation in Sweden, and another one was taken into operation in 2006. Emissions from these facilities are reported in CRF 1.B.2.A.1 in line with the IPCC 2006 Guidelines (Volume 2, Chapter 4, Section 4.2.2). Hydrogen production in Sweden also occurs at several facilities within the chemical industry – emissions from that production are reported in CRF 2.B.10.

CO₂ emissions are estimated using the IPCC Tier 3 method, and non- CO₂ emissions – using Tier 2 method. CO₂ emissions are taken from the company's report to the EU ETS system.

Activity data is reported as NE because one of the plants has changed reporting method so that activity data no longer represents amounts of feedstock - a mixture of butane, off-gas from one of the refinery units, and LNG (from 2014). Instead, to calculate CO₂ emissions reported to EU ETS, the facility from now one will use amounts of so called 'PSA (pressure swing adsorption) gas' - energy-poor off-gas from the hydrogen production unit ¹²⁶. PSA gas is a good proxy for activity data for this particular plant with a complicated feedstock structure; however, it is not a feedstock and thus cannot be summed up with feedstock data (naphta for 2006 – 2011 and LNG from 2011 onwards) from the other plant. Activity data for both facilities can be provided to reviewers upon request.

Non- CO₂ emissions are calculated with plant-specific activity data and national emission factors. Due to lack of specific emission factors, "other petroleum fuels"

¹²⁶ Ortiz, C., et al.. Överlappande mellan CRF 1 och 2, SMED memorandum, 2017

emission factor was used for naphta, and emission factor for methane-rich gas was used for PSA gas.

3.3.2.2.2 *Transport (CRF 1.B.2.A.3)*

Crude oil is transported to and from Sweden by tankers. In response to recommendations from the UNFCCC expert review teams in submission 2010, Sweden estimates emissions of CH₄ from transport of crude oil using the default IPCC method. National statistics available from Statistics Sweden on imported and exported amounts of crude oil is used as activity data. The activity data is corresponding to the data in the Reference Approach. Since no reliable country-specific measurements are carried out and no default IPCC emission factor for tanker ships is available in the 2006 IPCC Guidelines, the default emission factor for Western Europe from the Revised 1996 IPCC Guidelines (745 kg CH₄/PJ) is applied. Fugitive emissions of CO₂ from transport of crude oil are not estimated (NE) as no country-specific measurements have been carried out and no default IPCC emission factor for tanker ships is available.

3.3.2.2.3 *Refining/Storage (CRF 1.B.2.A.4)*

CO₂ emissions are estimated using the IPCC Tier 3 method, and non- CO₂ 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 (CO₂, CH₄, N₂O, NMVOC, SO₂), desulphurisation (SO₂), and from the storage and handling of oil (NMVOC, CH₄). Reported activity data is amounts of crude oil processed at the refineries (Mt).

Fugitive emissions of CH₄ from refineries include emissions from the process area as well as emissions from the refinery harbours when loading tankers. The estimate of fugitive CH₄ emissions are for two refineries based on reported data in the facilities' environmental reports. For the remaining three refineries the fugitive CH₄ emissions are estimated as 5 % of the total fugitive VOC emission. This estimate has been provided by one refinery that refines about 50 % of the crude oil in Sweden. Since no information from the two remaining refineries was obtained the same percentage has been used to estimate the fugitive CH₄ emissions also from these plants. The reported emissions of CH₄ 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 CH₄ 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 3.34, reported emissions of NMVOC and CH₄ as well as activity data can be seen. Due to secrecy reasons, data for 2015-2016 cannot be displayed.

The trend of hydrocarbon emission does not follow the fluctuations of the crude oil throughput very well. This is most likely due to the uncertainties in the method used by the refineries to estimate the emissions.

Table 3.32. Throughput of crude oil in refineries and estimated fugitive emissions of CH₄ (t) reported in CRF 1.B.2.A.4. Due to secrecy reasons, data for 2015-2016 cannot be displayed.

Year	Throughput of crude oil (t)	Total emissions of CH ₄ (t)
1990	17 330 000	460
1995	19 430 000	400
2000	20 253 120	577
2005	19 919 968	399
2010	20 278 888	469
2011	19 034 115	431
2012	21 021 566	436
2013	17 021 700	383
2014	19 320 478	398

Since submission 2009, emissions from combustion of cracker coke in refineries, earlier reported in CRF 1.A.1.B, were allocated to CRF 1.B.2.A.4 to be in line with the IPCC guidelines (hence the combustion is not carried out for energy purposes). This was based on a study performed by SMED¹²⁷. 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 CO₂ emissions are taken from the company's report to the EU ETS system. Non- CO₂ emissions (CH₄, N₂O, and NMVOC) are calculated with these plant specific activity data and national emission factors.

3.3.2.2.4 Gasoline handling and distribution (CRF 1.B.2.A.5)

Calculated fugitive emissions of NMVOC from the storage of oil products have been obtained from the environmental reports of the oil depots. The calculations are based on the amount of product handled in the depots. The calculations are based on methods given by Concawe 85/54¹²⁸ for the years 1990-2006 and on Concawe 03/07¹²⁹ for 2007 and onwards.

¹²⁷ Skärman, 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

¹²⁸ Concawe, 1986, Hydrocarbon emissions from gasoline storage and distribution systems, Report No 85/54.

¹²⁹ Concawe Report No. 3/07, Air pollutant emission estimation methods for E-PRTR reporting by refineries

The calculation of fugitive NMVOC emissions from gasoline distribution, 1990-2016, is based on methods given by Concawe¹³⁰, 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 stations¹³¹.

3.3.2.2.5 *Natural gas transmission (CRF 1.B.2.B.4)*

In 2013, a national method for estimating the Swedish emissions of natural gas was developed and described in Jerksjö et al.¹³². Emission estimates are based on information provided by Swedegas, the operator of the transmission pipeline and storage of natural gas in Sweden. Emission data includes transmission and storage of gas and was for the first time adopted in submission 2014.

The Swedish network for gas storage and transmission includes several different types of facilities: metering and regulation stations (M/R stations), compressor stations, ramification stations, valve stations, pig launcher & receiver stations, and a storage facility. According to Swedegas¹³³, many of the facilities are combined, e.g. valves located close to M/R stations. To enable biogas transmission in the network, two compressor stations were put into operation in 2014 – one combined with M/R station and one stand-alone facility.

In 2016, the method for estimating the emissions from the gas transmission network was revised since new measurements of methane emissions became available¹³⁴. Methane leakage rates per hour have been measured at all major types of facilities. Estimated emission factors (see table 3.33 below) have been applied to the number of facilities of each type. Emissions earlier reported as gas leakage have been re-allocated to the sector *CRF 1.B.2.C.1.2 Natural gas venting* since these emissions are controlled and associated with regular network maintenance work rather than with uncontrolled gas leakage.

¹³⁰ Concawe, 1986, Hydrocarbon emissions from gasoline storage and distribution systems, Report No 85/54.

¹³¹ Andersson, 2000.

¹³² 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.

¹³³ Bjur & Lindsjö, 2016

¹³⁴ Jerksjö, M., Salberg, H. 2016. Mätningar av metanläckage längs svenska naturgasnätets stamledning, IVL report C202 (in cooperation with Fluxsense)

Table 3.33 Method for estimation of gas leakage from the national gas transmission network

Facility type	CH ₄ EF g/hour	Number of facilities in 2016	Comment
M/R station	91	42	Number of facilities is known for the whole time series
Storage	200	1	In operation since 2006
M/R + compressor station	222	1	In operation since 2014
Compressor station	100	1	In operation since 2014
Valve station	30	26	For the years 1990-2014, the number of facilities is assumed to be in direct proportion to the network's length (320 km in 1990, 620 km in 2016)
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 3.34. Information on gas composition was obtained from Swedegas and constitutes average values from the period 2006 to 2012.

Table 3.34. 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

Methane leakage during gas transmission based on the recent measurements is comparable to the emissions calculated via the IPCC default emission factor, as shown in table 3.35 below.

Table 3.35. Estimated fugitive methane emissions from gas transmission (storage excluded)

Year	Swedegas kt	IPCC (2006) ¹ (kt)	IPCC (2006) ² (kt)
2006	0.070	0.061	0.442
2007	0.072	0.063	0.461
2008	0.074	0.058	0.422
2009	0.074	0.077	0.557
2010	0.074	0.103	0.749
2011	0.074	0.082	0.595
2012	0.074	0.071	0.514
2013	0.074	0.068	0.494
2014	0.075	0.056	0.405
2015	0.077	0.051	0.369
2016	0.079	0.057	0.417

¹Lower value = 6.6×10^{-5} kt per year and 10^6 Nm³ marketable gas

²Upper value = 4.8×10^{-4} kt per year and 10^6 Nm³ marketable gas

3.3.2.2.6 *Natural gas distribution (CRF 1.B.2.B.5)*

There are three types of gas networks for distribution of gas in Sweden.

1. The gas network for distribution of natural gas
2. Local biogas distribution network
3. Gasworks gas distribution network.

The gas network for distribution of natural gas is connected to the national transmission pipeline via M/R stations as mentioned above and had a total length of 2620 km in year 2012. This network delivers natural gas to the end users, which are industries or municipalities which in turn use the gas for energy production, to feed their town gas networks, etc. There are about 40 small local distribution networks for biogas in Sweden^{Fel! Bokmärket är inte definierat.}. The total length was 146 km in 2012. The biogas is of similar quality as natural gas and is distributed in similar distribution pipes as natural gas.

Most of the gasworks gas networks use natural gas and their distribution system has been modernised and considered to be of the same standard as the distribution system for natural gas. However, the gasworks gas networks in Stockholm and Gothenburg (the two largest cities in Sweden) are different. These networks consist to a large part of old pipes with considerable high leaking rate. Between 1990 and 2011, a facility in Stockholm produced gasworks gas from cracking light petroleum. In 2011, they started to use a mixture of natural gas and air. The city of Gothenburg produced gasworks gas of a similar quality as that in Stockholm during the period 1990 – 1993. In 1993, the city of Gothenburg shifted to a mixture of natural gas and air and since the beginning of 2011, only pure natural gas is distributed in Gothenburg. Activity data in terms of leakage of gasworks gas has

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 CH₄ and CO₂ have been calculated with data on chemical composition of gas from cracking and natural gas/air mixture. The methodology is described in Jerksjö et al¹³⁵.

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 2006¹³⁶) 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 Nm³ 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 Gas¹³⁷.

Data on gas mixtures, sources of activity data and emission factors used for emission calculations in CRF 1.B.2.B.5 for each gas distribution network are summarized in Table 3.36.

¹³⁵ 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.

¹³⁶ Wikkerlink. 2006.

¹³⁷ 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 3.36. 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 ¹³⁸)		No emission factors are used. Emissions are calculated based on the content of CH ₄ , CO ₂ and NMVOC in the gas mixtures considered.
Emission factor for CO ₂	No emission factors are used. Emissions are calculated based on estimated methane emissions and the content of CO ₂ and NMVOC in the natural gas.		
Emission factor for NMVOC			

* Including a number of city gas distribution networks, for instance Gothenburg gas distribution network since 2011.

Parameters used to calculate the content of methane, carbon dioxide and NMVOC in gasworks gas and natural gas air mixture are shown in Table 3.37 and Table 3.38, respectively. Information on gas composition was obtained from Stockholm Gas and Swedegas.

Table 3.37. 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

¹³⁸ Wikkerlink. 2006.

Table 3.38. Composition and physical properties of natural gas air mixture

Property	Unit	Value
Density of natural gas air mixture	kg/Nm ³	1.054
CH ₄ content	% by weight	30.4
CO ₂ content	% by weight	0.7
NMVOC content	% by weight	7.4
Air content	% by weight	61.5
Amount of CH ₄ per Nm ³ gas	kg/Nm ³	0.32
Amount of CO ₂ per Nm ³ gas	kg/Nm ³	0.0075
Amount of NMVOC per Nm ³ gas	kg/Nm ³	0.08

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

In submission 2011, an analysis was carried out with the aim to investigate if vented emissions from refineries already were included in reported emissions in other CRF categories. The conclusion from this study was that the emissions from venting at refineries most probably are included in other categories of fugitive emissions; mainly in CRF 1.B.2.A.4 but possibly partly in 1.B.2.C.2. Hence, it was concluded that the emissions reported in 1.B.2.C.1 in submission 2010 were double counted, and in submission 2011 and later, emissions in CRF 1.B.2.C.1.1 and 1.B.2.C.1.3 are reported as IE (in 1.B.2.A.4 and 1.B.2.C.2.). The fugitive CH₄ emissions from oil refineries reported in CRF 1.B.2.A.4 are based on measurements of total hydrocarbon emissions from the refinery areas. These emissions include leakages but also emissions from venting activities. It is therefore not possible to report fugitive emissions and emissions from venting separately. However, the hydrocarbon emissions from venting activities at refineries are assumed to be very small, since during normal operation conditions the vented gases enters the gas flare systems.

Venting of natural gas from transmission pipelines and the storage facility, reported under CRF 1.B.2.C.1.2, occurs as a part of maintenance. Swedegas reports estimates of the annual amounts of vented gas. Venting at M/R stations during ordinary maintenance procedures results in ~ 0.4 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 years¹³⁹ 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. For the years 2014-2016, 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

¹³⁹Hellström 2013-2015

relation of the amount of vented gas to the number of M/R stations in 2014-2015. Total amounts of vented gas from M/R stations are shown in figure 3.11.

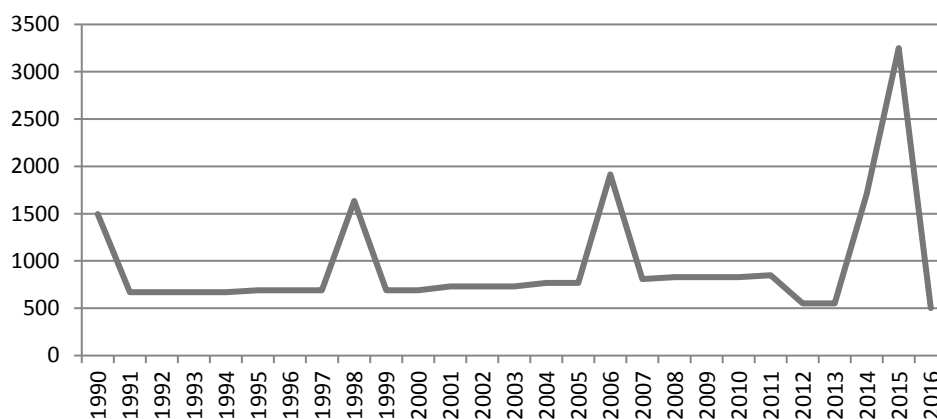


Figure 3.11. Gas venting at M/R stations, Nm³ natural gas

The reported emissions from the gas storage facility, dominated by venting, are shown in Table 3.39 in comparison with the corresponding values obtained using the 2006 IPCC Guidelines. For the years 2006, 2007 and 2012 the emissions are at the same level as the estimations according to 2006 IPCC Guidelines. For other years, except for 2013, Swedegas has reported emissions that are 2 to 7 times lower than using the 2006 IPCC Guidelines estimate. The large emission of natural gas from the gas storage in 2013 was due to a compressor failure¹⁴⁰. 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 moment¹⁴¹.

Table 3.39. Estimated total methane emissions from gas storage

Year	Swedegas			IPCC (2006) ¹ , (kt)
	Fugitives, (kt)	Venting, (kt)	Total emissions, (kt)	
2006	0.002	0.030	0.032	0.023
2007	0.002	0.034	0.035	0.024
2008	0.002	0.009	0.011	0.022
2009	0.002	0.004	0.006	0.029
2010	0.002	0.004	0.006	0.039
2011	0.002	0.004	0.006	0.031
2012	0.002	0.023	0.025	0.027
2013	0.002	0.070	0.072	0.026
2014	0.002	0.002	0.004	0.021
2015	0.002	0.004	0.005	0.019
2016	0.002	0.001	0.003	0.022

¹2.5×10⁻⁵ kt per year and 10⁶ Nm³ marketable gas

¹⁴⁰ Hellström 2013-2015

¹⁴¹ 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.

3.3.2.2.8 *Flaring (CRF 1.B.2.C.2)*

Flaring of liquid fuels was estimated and reported for the first time in the Swedish inventory in submission 2005. Data includes flaring of refinery gases at four refineries and one chemical industry, and flaring of LPG at three iron and steel plants and one pulp industrial plant. Reported activity data is amounts of flared gases in TJ. For a few plants that flare small amounts of gas, activity data is shown neither in the environmental reports, nor in the ETS data. Flaring at these plants was investigated in 2005, and the same values are used for later years. Emissions in this CRF category varies quite widely between years due to large variations in the amount of refinery gases that needs to be flared each year. Data has been collected directly from the plant operators. For the years 2005 and later, data from the EU ETS system has been used when possible. Data from the EU ETS system are verified against data from environmental reports and vice versa.

In submission 2010 EU ETS data was analysed carefully. It was concluded that the notation key for flaring of natural gas (NE in earlier submissions) could be changed, since no such flaring of pure natural gas could be found in the EU ETS data, and all plants that might be flaring are included in the EU ETS. However, certain amounts of natural gas can be used as feedstock in the refinery processes together with liquid fuels. Hence, it cannot be ruled out that the flared gases, which are mostly refinery gas and petrochemical by-products gases, might also contain some natural gas. Because of this the notation key IE is used rather than NO, referring to emissions reported under CRF 1.B.2.C.2.1 Oil.

Emissions from flaring of natural gas in connection with gas transmission pipeline maintenance (pigging) are reported for the first time in Submission 2016 under CRF 1.B.2.C.2.2. For the years 2014-2016, estimated amounts of flared gas have been obtained from the operator. For the years 2006, 1998 and 1990 estimates were made based on relation of the amount of flared gas to the number of M/R stations in 2014. The same emission factors and calorific values as for natural gas combustion in industries were used. Occurring greenhouse gas emissions are around 0.004-0.012 kt CO₂-eq. per year and increase between 1990 and 2014 together with the number of M/R stations.

3.3.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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

1.B.2.A.1: According to data reported to the EU ETS, both hydrogen production plants use the level 2 method to measure activity data, which means that the activity data uncertainty is ± 2.5 % or less. The emission factor uncertainties have not been available for the GHG inventory staff, and hence the same emission factor uncertainties as for the corresponding fuels in stationary combustion, i.e. ± 5 % for CO₂ are used. For the CH₄ emission factor, general uncertainty from 2006 IPCC Guidelines for oil refining activities (± 100 %) was used instead, following the

precautionary principle. For N₂O emission factor, the uncertainty is set to ± 25 % in accordance with GPG 2000.

1.B.2.A.3, 1.B.2.A.4: The uncertainty for the activity data have been estimated to ± 7.5 %. The emission uncertainty for fugitive emissions of CH₄ has been estimated to ± 400 %. The reason for the high emission factor uncertainty is not the use of inaccurate method but the large uncertainties for the measurements with high inter-annual variation. Uncertainties for emission factors for cracker coke combustion processes are estimated to ± 20 % for CH₄, ± 5 % for CO₂ and ± 40 % for N₂O.

1.B.2.A.5: Based on expert judgements, the uncertainties of collected emissions of NMVOC are ± 75 %.

1.B.2.B.4: Emissions have been revised in submission 2017 due to new measurement results available. The associated emission uncertainty is ± 50 % according to expert estimates.

1.B.2.B.5: Fugitive emissions from the distributing network in Stockholm constitute 80 – 90 % of the total emissions from gas distribution in Sweden. The emission data from the Stockholm distribution network is based on measurements provided by the operator and the associated uncertainty is estimated to ± 50 %. The total uncertainty concerning distribution of gas in Sweden is largely influenced by the contribution from the gas network in Stockholm, and is thus likewise estimated to ± 50 %.

1.B.2.C.1.2, 1.B.2.C.2.2: Estimates of emissions from natural gas venting are provided by the operator. The associated uncertainty is ± 50 % according to expert estimates. For gas flaring, the total emission uncertainties are affected by uncertainties in the emission factors, which are the same as for industrial combustion of natural gas – 10 % for CO₂, 30 % for CH₄ and N₂O.

1.B.2.C.2.1: The activity data uncertainties for different fuels and plants are as reported to EU ETS and are in the range ± 7.5 - 17.5 %. For the total uncertainty from all fuels we use ± 17.5 %. The emission factor uncertainties have not been available for the GHG inventory staff, and hence the same emission factor uncertainty as for the corresponding fuels in stationary combustion is used for CO₂, i.e. ± 5 %. For N₂O, the uncertainty in emission factor is estimated to ± 78 %. For CH₄ emission factor, general uncertainty from 2006 IPCC Guidelines for oil refining activities (± 100 %) was used instead, following the precautionary principle.

3.3.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The coherence between environmental reports and ETS data is checked when possible, and when differences occur, the facilities are contacted for verification.

For a few plants that flare small amounts of gas, activity data as amount of flared gas is shown neither in the environmental reports, nor in the ETS data. Flaring at these plants was investigated in 2005, and the same values are used for later years. These facilities are regularly asked to verify that the default value is still valid.

In addition, emissions from oil refineries are included in the cross-sectoral control tool that was developed in 2017. For more information, see section 3.2.7.

3.3.2.5 SOURCE-SPECIFIC RECALCULATIONS

1.B.2.A.1: LNG used as feedstock for hydrogen production at one of the facilities was reallocated from CRF 1A to CRF 1B, resulting in an increase of CO₂ by 106 kt for 2014 and by 59 kt for 2015. Change of activity data for the same facility resulted in the change of non- CO₂ emissions calculated via national emission factors, in particular in the range of -0.002 – 0.002 kt for CH₄ (-0.05 – 0.05 kt CO₂-eq.), -0.0002 – 0.0002 kt for N₂O (-0.06 – 0.6 kt CO₂-eq.) and -0.03 – 0.03 kt for CO. N₂O emissions for the period 2006-2011 have significantly (up to 0.6 kt CO₂-eq.) decreased due to the revision of national emission factors¹⁴².

1.B.2.A.3: As data is obtained with a one-year-delay, emissions have been updated for 2015, resulting in an increase for emissions CH₄ by about 0.043 kt.

1.B.2.A.4: Correction of methane/NMVOC ratios in diffuse emissions at several facilities resulted in increase of methane emissions (by ~0.25 kt CO₂-eq.) and decrease of NMVOC emissions. Emissions of NO_x (0.02-0.3 kt) and CO (0.004-0.09 kt) from catalytic cracker at one of the facilities are reported in CRF1A (combustion of refinery gas) and therefore are excluded from CRF 1B in Submission 2018.

1.B.2.A.5: No recalculations have been made in submission 2018.

1.B.2.B.4, 1.B.2.C.1.2: Re-allocation of some emissions from venting to transmission and storage has been performed. Emissions of CH₄ and NMVOC decrease by about 0.002 kt and 0.0004 kt respectively.

1.B.2.B.5: No recalculations have been made in submission 2018.

1.B.2.C.2.2: No recalculations have been made in submission 2018.

1.B.2.C.2.1: Change of assumed type of flared gas (from methane-rich gas to refinery gas) for two facilities has resulted in emission changes, in particular

¹⁴² Mawdsley, I. & Stripple, 2017

0.0004 – 0.002 kt increase for SO₂, 0.004 – 0.01 kt decrease for NO_x, 0.001 – 0.004 kt decrease for CO and 0.0002 – 0.0008 kt increase for NMVOC.

3.3.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan. Industrial processes and product use (CRF sector 2)

4 Industrial processes and product use (CRF sector 2)

4.1 Overview of sector

For Sweden the most important industries within the 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 in the chemical industry.

Greenhouse gas emissions from the industrial processes sector have decreased 224 kt CO₂-eq. from 7,120 kt CO₂-eq. in 1990 to 6,895 kt CO₂-eq. in 2016, a decrease of 3.2 % (Figure 4.1). The trend is mainly affected by decreased emissions of N₂O (-725 kt CO₂-eq.) and PFCs (-538 kt CO₂-eq.), but also by decreased emissions of CH₄ (-17 kt CO₂-eq.) and SF₆ (-43 kt CO₂-eq.). Compared to 1990, only HFCs (877 kt CO₂-eq.) and CO₂ (221 kt CO₂-eq.) show increased emissions in 2016. In Figure 4.1, it can be seen that in 2016, CO₂ is by far the largest contributor among the greenhouse gases in this sector, accounting for 82 % of the GHG emissions. Emissions of HFCs are the second largest greenhouse gas in 2016, accounting for 13 % of the sector emissions.

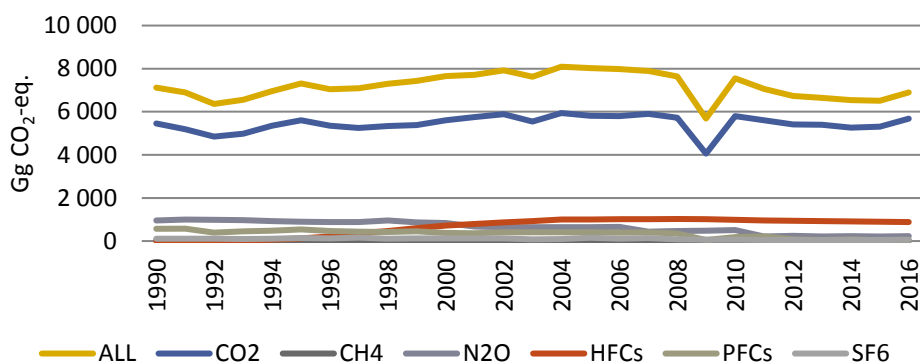


Figure 4.1. Total emissions of all greenhouse gases calculated as CO₂-eq. from CRF 2 industrial processes.

Among the industries in this sector, metal industry (CRF 2.C) is the largest contributor to greenhouse gas emissions in 2016, accounting for 3,140 kt CO₂-eq. or 46 % (Figure 4.2). Emissions in CRF 2.C in 2016 have decreased by 19 % (1,128 kt CO₂-eq.) since 1990. In Figure 4.2 it can be seen that there was a sharp decrease in greenhouse gas emissions from metal industry (CRF 2.C) in 2009. This was mainly due to the economic recession in 2009 which largely affected the production volumes of iron and steel in Sweden and thus the emissions are significantly reduced in 2009.

The second largest contributor of greenhouse gas emissions to this sector 2016 is mineral industry (CRF 2.A) with 1,996 kt CO₂-eq., or 29 % of the sector emissions. Compared to 1990 there is an increase in greenhouse gas emissions from mineral industry of about 19 % (323 kt CO₂-eq.) (Figure 4.2), mainly due to increased production of lime and clinker.

For chemical industry (CRF 2.B), greenhouse gas emissions have decreased since 1990. The reduction is closely linked to N₂O emissions from nitric acid production.

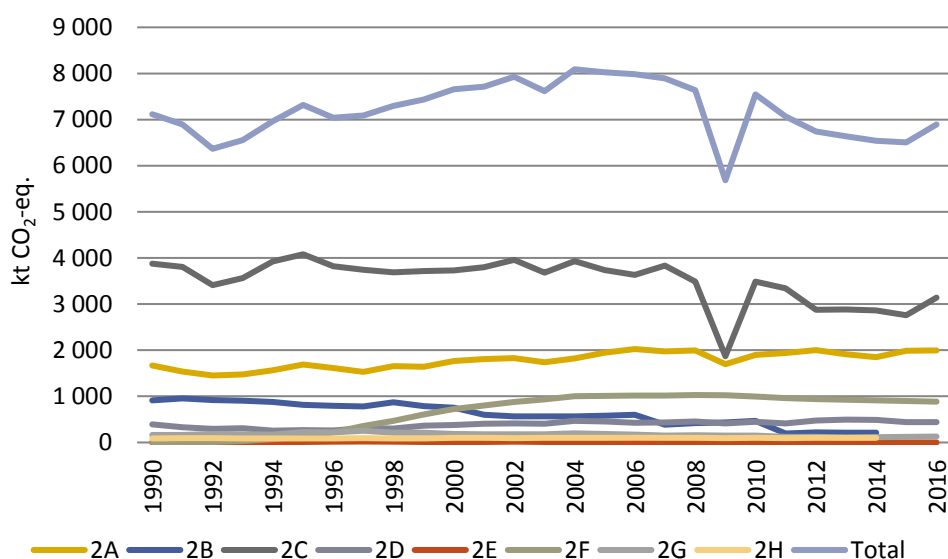


Figure 4.2. Total emissions of all greenhouse gases calculated as CO₂-eq. from the different industrial processes sub-sectors. 2A Mineral products. 2B Chemical industry, 2C Metal industry. 2D Non-energy products from fuels and solvent use. 2E Electronics industry, 2F Product uses as substitutes for ODS, 2G Other product manufacture and use, 2H Other. Emissions from the sectors 2B Chemical industry and 2H Other are not shown for 2015 due to data confidentiality.

The estimated emissions of fluorinated greenhouse gases consist of emissions from the use of these in various applications, as well as PFC emissions from the primary aluminium production process. The emissions of greenhouse gases from product uses as substitutes for ozone-depleting substances (CRF 2.F) have increased substantially, 877 kt CO₂-eq., since 1990 (Figure 4.2). The use of HFCs as refrigerants in refrigerators, freezers and air-conditioning equipment has contributed to the larger share in later years.

Emissions of greenhouse gases from non-energy products from fuels and solvent use (CRF 2.D) accounted for 442 kt CO₂-eq. in 2016, which is an increase of about 13 % since 1990.

The estimated greenhouse gas emissions from other product manufacture and use (CRF 2.G) consist of fluorinated greenhouse gases from electrical equipment (2.G.1) and sound-proof windows (2.G.2), and N₂O from product use (2.G.3). In

2016, the emissions accounted for 128 kt CO₂-eq., which is a decrease of about 23 % since 1990.

Process emissions from production of pulp and paper and mineral wool, reported in other production (CRF 2.H) have increased since 1990 but remain one of the sectors that contribute the least to greenhouse gas emissions in the IPPU sector.

The electronics industry (CRF 2.E) in Sweden does not generate greenhouse gas emissions, thus it is reported as not occurring (NO).

4.2 Mineral industry (CRF 2.A)

Reported emissions include estimates for cement production (2.A.1), lime production (2.A.2), glass production (2.A.3) and other process uses of carbonates including ceramics, other uses of soda ash and other uses of limestone, dolomite and sodium bicarbonate (2.A.4).

4.2.1 Cement production (CRF 2.A.1)

4.2.1.1 SOURCE CATEGORY DESCRIPTION

Cement production occurs at three facilities in Sweden (owned by one company), with one being dominant. Annual production of cement in Sweden is about 2,000-3,000 kt. Emissions from cement production stem both from combustion of fuels and from raw materials used in the processes. Emissions arising from fuel combustion are reported in the energy sector (CRF 1.A.2.g) with exception of SO₂ which is reported in 2.A.1.

For process-related emissions, facility data are obtained from environmental reports, EU ETS (European Union Emission Trading Scheme) and by direct contacts with the facilities. Process related CO₂ emissions from cement production arise as a by-product during the production of clinker as limestone is heated to produce lime. CO₂ emissions related to limestone used for flue gas cleaning are also reported in CRF 2.A.1 according to the 2006 IPCC Guidelines, but accounts only for about 0.2 % of total CO₂ emissions from the cement industry. Process related CH₄ and N₂O emissions from cement production are assumed to be negligible according to the 2006 IPCC Guidelines and thus reported as not applicable (NA).

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.1. An overview of the rationale for data sources used for key categories in the industrial processes sector is presented in Annex 3.5.

Table 4.1. Summary of source category description, CRF 2.A.1, according to approach 1.

CRF	Gas	Key Category Assessment 2016, 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 ₂ O	NA	NA		NA	NA	NA

PS Plant-specific. T3 Tier 3.

4.2.1.2 METHODOLOGICAL ISSUES

CO₂ 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 CO₂ emissions is based on clinker production and default EF from the GHG protocol, CKD correction factor and organic carbon contained in the raw material:

$$\text{CO}_2 = \text{Production of cement clinker (kt)} * 0.525 \text{ (kt CO}_2\text{/ kt clinker, i.e. default value in the GHG-protocol)} * \text{CKD correction factor} + \text{CO}_2 \text{ from organic carbon content of raw meal}$$

The emission estimates were made on initiative by the WRI (World Resources Institute) for the WBCSD (Working Group Cement CO₂ Emissions Inventory Protocol, Version 1.6.), see facts about the GHG protocol below and on their website¹⁴³. The protocol tool calculates CO₂ 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 CO₂ emissions 1991-1994 and 1996 based on mean values from adjacent years.

¹⁴³ <http://www.ghgprotocol.org>. 2005-10-20.

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 CO₂ 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 CO₂ emissions to the EU ETS and from this year onwards, CO₂ estimates as well as produced amount clinker are calculated according to the national guidelines (NFS 2007:5¹⁴⁴) for reporting to the EU ETS¹⁴⁵. 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 CO₂ emission factor is calculated on a plant-specific basis according to the national guidelines by using the stoichiometric relationship of Ca and MgO in the product (0.785 for CO₂/CaO and 1.092 for CO₂/MgO). Also CO₂ emissions from organic carbon contained in the raw material are included in the CO₂ emissions reported to the EU ETS.

Table 4.2 shows information on clinker production and total CO₂ emissions from clinker production. For the years prior to 2005 the table shows the calculated emissions from CKD and the resulting CKD correction factor as well as CO₂ emissions from organic carbon content of raw meal. Some minor corrections have been made regarding CO₂ emissions from limestone used in flue gas cleaning for the years 2013-2015, resulting in slightly higher total emissions for these years.

¹⁴⁴ NFS 2007:5 Naturvårdsverkets föreskrifter och allmänna råd om utsläppsrätter för koldioxid.
Available in Swedish:
http://www.naturvardsverket.se/Documents/foreskrifter/nfs2007/nfs_2007_05.pdf

¹⁴⁵ Lyberg, A., Cementa, Personal communication, September 2011

Table 4.2. Amount of produced clinker and associated CO₂ 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)
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
2006	2 660	1 442	1 439	IE	NA		IE
2007	2 493	1 339	1 337	IE	NA		IE
2008	2 644	1 396	1 395	IE	NA		IE
2009	2 336	1 263	1 260	IE	NA		IE
2010	2 454	1 324	1 322	IE	NA		IE
2011	2 544	1 361	1 359	IE	NA		IE
2012	2 769	1 479	1 477	IE	NA		IE
2013	2 599	1 395	1 390	IE	NA		IE
2014	2 602	1 398	1 394	IE	NA		IE
2015	2 826	1 529	1 524	IE	NA		IE
2016	2 847	1 538	1 534	IE	NA		IE

* From 2005 incl. CKD and organic carbon content

IE - Included elsewhere. NA – Not applicable.

Total emissions of NO_x by facility are found in the environmental reports or have been obtained directly from the company. Emissions originate mainly from fuel combustion and less from industrial processes. Hence IE is reported for NO_x in CRF 2.A.1 and emissions are reported in CRF 1.A.2.f.

SO₂ emissions from cement production are fully allocated to CRF 2.A.1 and have been obtained directly from the company or from the environmental reports. Reported emissions are decreasing over time since 1990.

4.2.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Activity data and CO₂ 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 CO₂ is judged to be ± 5 %.

All three cement producing facilities in Sweden are covered in the reported estimates and the time-series are considered complete, accurate and more or less consistent. As described above, for 1990-2004, constant CO₂ EF (0.525 kt CO₂/kt clinker produced) is used together with CKD correction factor and CO₂ emissions from organic carbon of raw meal. Since 2005, CO₂ emissions are retrieved from EU ETS, which are based on the content of CaO and MgO in clinker. This means

that different methods are used over time, however there is no indication that either methods lead to over- or underestimations of CO₂ emissions.

4.2.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The implied emission factor for total CO₂ emissions from 2005 and onwards (average 0.539 kt CO₂/kt clinker produced) is somewhat higher than the 2006 IPCC Guidelines Tier 1 default value (0.52 kt CO₂/kt produced clinker) and among the highest of the reported IEF:s found in inventory reports under the UNFCCC. The main reason for the higher implied emission factor is that the MgO content in clinker is accounted for in the reported emissions for Sweden. In addition, in line with the 2006 IPCC Guidelines, CO₂ emissions from limestone used for flue gas cleaning are included in CRF 2.A.1, which results in a further increase of the implied emission factor.

Figure 4.3 illustrates the CO₂ 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 CO₂ 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 CO₂ has been released per unit produced clinker. Table 4.3 lists the content of CaO and MgO for the years 2008-2016 for the largest facility (accounting for an average of 74 % produced clinker in the years 2008-2016). The correlation between CaO and MgO content and CO₂ IEF for the largest plant is illustrated in Figure 4.4. In Figure 4.4, CaO and MgO content is shown as a sum, however MgO in clinker has given rise to a slightly larger amount of CO₂ per unit than CaO, explaining the small differences of IEF and CaO and MgO content in the figure.

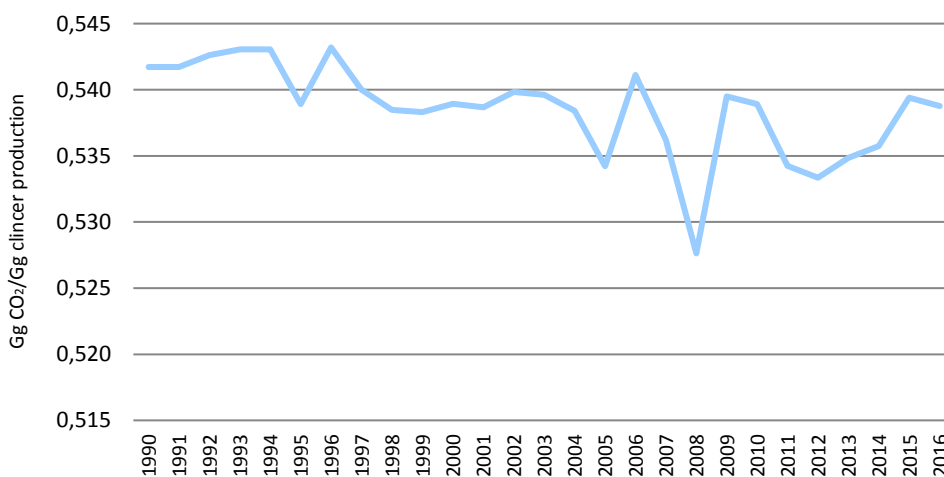


Figure 4.3. CO₂ IEF for total emissions from clinker production 1990-2016, excluding emissions from flue gas cleaning.

Table 4.3. CaO and MgO content in clinker produced in the years 2008-2016 in the largest facility (accounting for an average of 74 % produced clinker in the years 2008-2016).

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

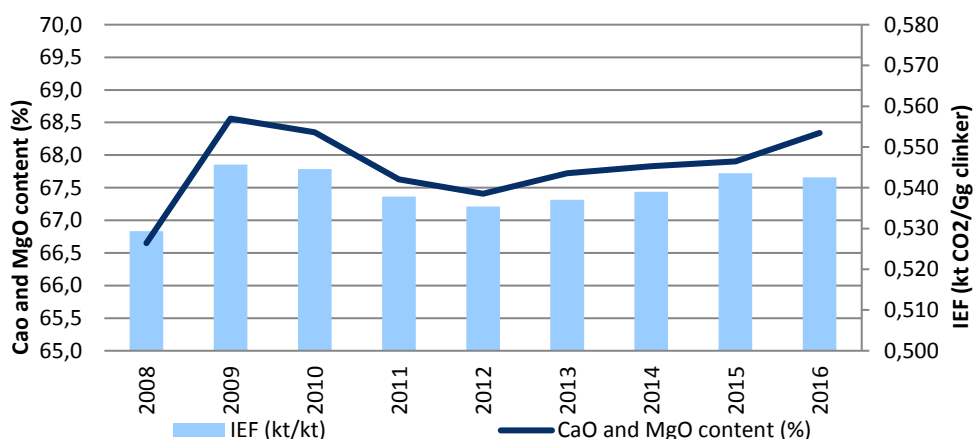


Figure 4.4. CO₂ IEF is compared to CaO and MgO content for respective year, indicating a strong correlation. Data is taken from the largest facility for the period 2008-2016 and exclude emissions from flue gas cleaning.

In response to previous UNFCCC review recommendations, discussions with the cement producers have led to the conclusion that CO₂ emissions from dust and from carbon content in the raw material are included in the estimations for the whole time series (see methodological issues above). In Table 4.2 above, information on clinker production, emissions from production, the calculated emissions from CKD before 2005 and the corresponding CKD correction factors are presented. Compared to the 2006 IPCC default value (1.02) the presented CKD correction factor is generally lower which is in line with the conception that dust emission in Sweden is low or nearly non-existent.

4.2.1.5 SOURCE-SPECIFIC RECALCULATIONS

As mentioned above, emissions of NO_x arise only to a smaller extent from the industrial process and mostly from fuel combustion. Therefore IE is reported for NO_x in CRF 2.A.1 and emissions are reported in CRF 1.A.2.f.

CO₂ from flue gas cleaning is obtained from ETS from submission 2018 onwards and has therefore been updated for 2013-2015. CO₂ emissions from flue gas cleaning increase therefore by about 2 kt per year.

4.2.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.2.2 Lime production (CRF 2.A.2)

4.2.2.1 SOURCE CATEGORY DESCRIPTION

In Sweden, quicklime, hydraulic lime and dolomitic lime is produced at a number of facilities, owned by a few companies. Produced lime is, for instance, used in blast furnaces, in sugar and carbide production and in the pulp and paper industry to bind impurities and purify the produced material. The production of lime has increased since 1990 (about 440 kt) and peaked in 2005 (about 730 kt). In 2009 there was a large decrease in lime production due to the economic recession.

CO₂ is emitted during lime production through calcination of the calcium carbonate (CaCO₃) in limestone, or through the decomposition of dolomite (CaCO₃·MgCO₃). 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 CH₄ and N₂O are not emitted during lime production and thus reported as not applicable (NA). Lime contains sulphur which is released as SO₂ during the production process.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.4.

Table 4.4. Summary of source category description, CRF 2.A.2, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.A.2	CO ₂	X	X		T3	D	Yes
	CH ₄	NA	NA		NA	NA	NA
	N ₂ O	NA	NA		NA	NA	NA

D Default. T3 Tier 3.

4.2.2.2 METHODOLOGICAL ISSUES

4.2.2.2.1 *CO₂ (kt)*

As of submission 2016, activity data and emissions for 2005 onwards (2009 onwards for sugar production) are based on EU ETS data. For 1990 to 2004 (or 2008), statistics are mainly received from the Swedish Lime Association, which is a trade organisation that collects data on lime from various industries. In Mawdsley 2015¹⁴⁶, it was concluded that EU ETS data and data from the Swedish Lime Association were comparable, however EU ETS data is received in time for the UNFCCC reporting, as opposed to data from the Swedish Lime Association. Thus, for later years (since 2005 or 2009), CO₂ emissions from lime production are based on the individual companies' data reported to the EU ETS. Reported emissions are used directly, and activity data is calculated using emission factors and purities according to the 2006 IPCC Guidelines.

Sugar industry

For 2009 onwards, EU ETS data is used for emission estimates from the sugar industry. For determining activity data and emissions of CO₂ within the sugar industry prior to 2009, the amounts of limestone for the production of quicklime are used. The quantities are obtained directly from the sugar producing company from 1999. For years prior to 1999 no data on used amounts of limestone are available. For those years the amounts of limestone used for production of quicklime are estimated using the quantity of coke used for lime production 1990 – 1998, together with the average ratio coke/limestone for the years 1999 to 2002. According to the company the used limestone consists to 97 % CaCO₃.

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, CO₂ is bubbled through the juice and most of the remaining lime is precipitated as CaCO₃. The precipitated “limestone” is sold and used in the agricultural sector. According to information from the company, around 88 % of the lime used was precipitated as CaCO₃ for the years before 2005. For later years this share has increased and varies between 91 and 94 %. No dolomitic lime is used.

Pulp and paper industry

From 2005 onwards, CO₂ 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 CO₂ 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

¹⁴⁶ Mawdsley, I. 2015. Change of activity data for lime production

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 onwards¹⁴⁷.

Based on the 2006 IPCC Guidelines, the purity of the limestone is set to 95 %. The corresponding figure for dolomite is 100 %. For the years before 1995, limestone quantities used as make-up lime are estimated using the average ratio between limestone used as make-up lime and produced Kraft pulp for the period 1995 – 2009 and corresponding production data for 1990 – 1994. This gives an average (1995 – 2008) of 2.1 kg limestone per Mg Kraft pulp (Table 4.6) and is used for estimations of limestone use for the years before 1995. Similarly, CO₂ emissions are estimated for 1990 – 1994 by using the average ratio between emitted CO₂ and used amounts of limestone for the period 1995 – 2008. Less than 1 % of total make-up lime within the pulp and paper industry is dolomitic lime.

Calcium carbide industry

In order to estimate CO₂ 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 CO₂/Mg limestone used.

Lime production plants

For all other production of quicklime, hydraulic lime and dolomitic lime, which occurs at lime production plants, EU ETS emission data for the individual lime plants are used from 2005 onwards, and emission factors and purities according to the 2006 IPCC Guidelines are used to calculate activity data.

Detailed data from 1990 to 2004 are obtained from the Swedish Lime Association. To avoid double counting of emissions, activity data for produced quicklime, hydraulic lime and dolomitic lime in the sugar industry and the pulp and paper industry has been deducted. Based on 2006 IPCC Guidelines, the purity of the limestone is set to 95 % for the production of lime in conventional lime mills. The corresponding figure for dolomite is 100 %. Between 2 % and 8 % of the total production of lime in conventional lime mills is dolomitic lime. Production data and reported CO₂ emissions for lime plants are shown in Figure 4.5 together with the implied emission factor. From 2005 onwards however, activity data is calculated based on CO₂ emissions from the EU ETS, and thus the emission factor is constant.

¹⁴⁷ Swedish Lime Association and The Swedish Lime Industry, personal communication

Table 4.5. Produced amounts of quick lime and dolomitic lime, emitted CO₂ and IEF (CO₂ 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	0.7554
1995	350	264	0.7550
2000	482	364	0.7549
2005	665	496	0.7456
2006	625	466	0.7456
2007	659	491	0.7456
2008	638	476	0.7456
2009	468	349	0.7456
2010	620	463	0.7456
2011	619	462	0.7456
2012	579	432	0.7456
2013	594	443	0.7456
2014	507	378	0.7456
2015	519	385	0.7456
2016	529	395	0.7456

4.2.2.2.2 SO₂ (kt)

Emissions of SO₂ from 1990 have been estimated for production of quicklime. The estimations from quicklime production were calculated using emission factors presented in environmental reports by one of the producers¹⁴⁸. The emission factor provided by the lime producer is substantially higher for 2008 than for earlier years. This resulted in an increase of reported SO₂ emissions for 2008 compared to earlier years. However in 2009 the reported SO₂ emissions were again on the same level as before 2008 due to less use of lime. For 2009-2016 the emission factor for 2008 has been used for the estimation of emissions of SO₂ due to lack of more recent information in the environmental reports.

Emissions of SO₂ from quicklime production intended for the pulp and paper industry are not included in the estimates reported in CRF 2.A.2 as they are included in CRF 2.H.1.

4.2.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties are estimated based on the 2006 IPCC Guidelines and is estimated to ± 5 % for activity data and ± 2 % for CO₂ 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 **Fel! Hittar inte referenskälla.**).

¹⁴⁸ Nordkalk, <http://www.nordkalk.com>

4.2.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Activity data reported in CRF 2.A.2 has also been compared with national statistics from Statistics Sweden in line with the IPCC Guidelines 2006¹⁴⁹.

The comparison (Figure 4.5) shows that national statistics are more irregular but for most years the coherence is good. The differences are especially high in 1998, 1999 and from 2003 and onwards.

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 Industry¹⁵⁰.

In 2015 a review of CRF 2A2 was made, where different data sources were compared and where it was determined that the best available data source for this source code is the EU ETS. The trade association was contacted and the lime production facilities were compared to the information in the EU ETS. One facility is not included in the inventory since it only gives rise to biogenic CO₂. This could also explain some of the discrepancies compared to national statistics, however inquiries have not been made since the trade association statistics and the EU ETS, both regarded as reliable sources, correspond to each other.

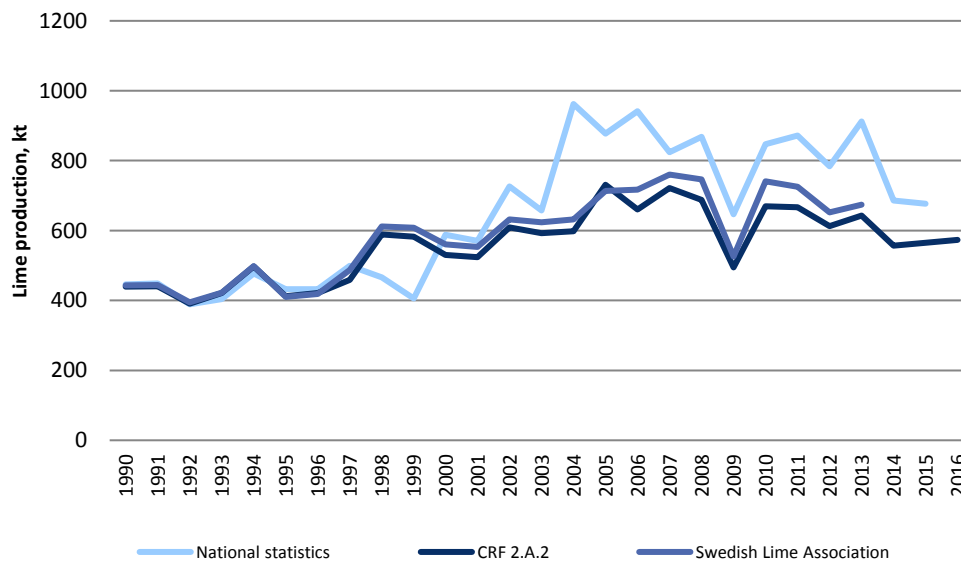


Figure 4.5. National total on produced amount of lime according to data from Statistics Sweden, the Swedish Lime Association and reported data in CRF 2.A.2

¹⁴⁹ Statistics Sweden. Data from the Industrial production database: www.scb.se

¹⁵⁰ Swedish Lime Association and The Swedish Lime Industry, Svenska Kalkföreningen, personal communication

For 2016, data from Statistics Sweden is currently confidential and will be published first in april 2018. As recommended by the ERT, other possible sources on national production of limestone have been explored but no such data sources were identified. Further investigations on why national statistics differ from reported AD will be carried out in submission 2019.

4.2.2.5 SOURCE-SPECIFIC RECALCULATIONS

Activity data and emissions from one plant have been added to inventory with 2015 being the first active year of the plant. The plant represents about 0.15% of the total CO₂ emissions reported in 2015. Some minor corrections have been performed regarding the activity data and CO₂ emissions for one plant in 2015, the differences to data reported in the last submission are however neglectible.

4.2.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.2.3 Glass production (CRF 2.A.3)

4.2.3.1 SOURCE CATEGORY DESCRIPTION

In Sweden there is one facility for container glass production and several small facilities for manual glass production. The only float glass producer ceased production in 2013. CRF 2.A.3 also includes glass wool production, which occurs at one facility.

From the float glass production, the total emissions of SO₂ and NO_x from the glass furnace are allocated to 2.A.3 since a separation into energy-related and process-related emissions is not possible. From the container glass production, SO₂ emissions originating from the raw material and small amounts of NMVOC are reported. All other emissions from the glass production facilities are from combustion for energy purposes, and are allocated to the Energy sector (CRF 1).

Emissions of CO₂ from the use of limestone and soda ash in glass and glass wool production are reported under glass production. The CO₂ emissions in 2009 are lower than in adjacent years due to the fact that the demand for glass was low in 2009. In addition, less amount of glass was manufactured from raw material that year - instead recycled glass was used to a larger extent. In 2013, one plant producing glass according to the float glass method was shut down and only very small emissions are reported for 2013 from this facility. Therefore, total CO₂ emissions from CRF 2.A.3 decreased with 65 % in 2013 compared to 2012 and, since NO_x emissions are only reported from this facility, the corresponding decrease in NO_x emission is 96 %. No NO_x emissions from CRF 2.A.3 occur in 2015 and 2016.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.6.

Table 4.6. Summary of source category description, CRF 2.A.3, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.A.3	CO ₂				T3	CS, D	NO, see Annex 5
	CH ₄	NA	NA		NA	NA	NA
	N ₂ O	NA	NA		NA	NA	NA

D Default. CS Country Specific. T3 Tier 3.

4.2.3.2 METHODOLOGICAL ISSUES

Emissions of CO₂ from the use of limestone and from the use of soda ash in glass production are reported in CRF 2.A.3 together with CO₂ emissions from other carbon containing raw material. Of the reported total CO₂ emissions in 2.A.3, approximately 41 % is caused by the use of soda ash and 58 % on the use of limestone and dolomite. The remaining CO₂ is emitted as a result of use of other carbon containing raw materials.

Activity data and emissions are mainly collected from the ETS or from the facilities' yearly environmental reports. For small glass production plants a constant amount of 0.9 kt CO₂ 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 CO₂, from weight of raw material to produced amount of glass or crystal. Both estimates result in CO₂ emissions of around 0.9 kt, annually.

The process-related SO₂ emissions from container and float glass production are reported for the period 1990 – 2016 in CRF 2.A.3. The reported NO_x emissions originate from the production of float glass. Data has been provided directly by the companies or collected from their environmental reports.

CO₂ emissions from the one glass wool producer in Sweden derive from the use of glass wool waste (glass wool production). Glass wool consists almost entirely of glass. A large proportion of the batch mixture, the so-called melt, consists of recovered glass material, e.g. recycled household glass and excess glass from the fiberization process. Also glass wool waste can be recycled and used in the production of glass wool by a method called the "Oxymelt" process. In this process the organic compounds (binders) are incinerated and the mineral part ("oxymelt glass") of the glass wool waste can be recovered and used as a resource for the production of new glass wool. The incineration of the organic binders gives rise to

emissions of CO₂. In the EU ETS, CO₂ emissions from the oxymelt process are reported since 2005 for the glass wool producer. Activity data, emission factor and CO₂ emissions data from the “oxymelt glass” process, based on information from EU ETS, is included for the years 2005-2016. The same information for 1991-2004 has been obtained from the company. In 1990 no oxymelt glass was used. The emission factor used is 0.13 kt CO₂ kt⁻¹ oxymelt glass.

NMVOC emissions from glass wool production are estimated from data received from the company directly or as reported in environmental reports together with earlier total estimates. Emitted NMVOCs consist of formaldehyde and phenol.

4.2.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainties of the direct CO₂ emissions in 2.A.3 are considered to be $\pm 7\%$ based on expert judgements. The expert judgements of the uncertainties of CO₂ in 2.A.3 were made without any knowledge of the missing oxymelt process that now is included. The estimated uncertainties are still considered to be valid.

4.2.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.2.3.5 SOURCE-SPECIFIC RECALCULATIONS

Emissions from one plant caused by the use of soda have been moved from CRF 2.A.4.b to CRF 2.A.3. Total CO₂ emissions reported in CRF 2.A.3 increase therefore by about 1kt or 5.5% for 2015.

4.2.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.2.4 Other process uses of carbonates (CRF 2.A.4)

4.2.4.1 SOURCE CATEGORY DESCRIPTION

In CRF 2.A.4, Sweden reports emissions from Ceramics (CRF 2.A.4.a), Other uses of soda ash (CRF 2.A.4.b) and Other (CRF 2.A.4.d). Non-metallurgical magnesium production does not occur in Sweden.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.7.

Table 4.7. Summary of source category description, CRF 2.A.4, according to approach 1.

CRF	Gas	Key Category Assessment 2016, 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 ₂ O	NA	NA		NA	NA	NA

D Default. T3 Tier 3.

4.2.4.1.1 *Ceramics (CRF 2.A.4.a)*

Sweden reports CO₂ emissions from production of clay based materials such as LECA, roofing tiles, bricks and ceramics. During the production CO₂ is emitted from the burning of fuels, reported in CRF 1.A.2.f, but CO₂ originating from the clay, the limestone and from other carbon containing material is also emitted. Reported CO₂ emissions represent the emissions from six facilities in total during the years 1990-2008 and from five facilities in total from 2009 and onwards since one facility closed down in 2008. One of the facilities is dominating the total CO₂ emissions. All CO₂ emissions from raw material used are reported in 2.A.4.a. In the past three years, production volumes have declined significantly.

4.2.4.1.2 *Other uses of soda ash (CRF 2.A.4.b)*

Due to difficulties in allocating emissions to their respective CRF code, all emissions from soda ash use is reported in CRF 2.A.4.b Other uses of soda ash. Soda ash is used in the production of glass wool, moist snuff and chemicals i.e. detergents, and until 2004 also in flue gas desulphurisation at energy plants. Soda ash is also used in production of glass (2.A.3).

4.2.4.1.3 *Other (CRF 2.A.4.d)*

Other process uses of carbonates which occur in Sweden and do not fit into any other category, are the use of limestone, dolomite and sodium bicarbonate for flue gas cleaning purposes in energy industries, whereby CO₂ is emitted. Sodium bicarbonate used within one pulp and paper industry is also reported in 2.A.4.d. Process-related CH₄ and N₂O are not emitted during the use of these carbonates and thus reported as not applicable (NA).

4.2.4.2 METHODOLOGICAL ISSUES

Specified sub-categories under this heading are “Ceramics”, “Other uses of soda ash”, and “Other”.

4.2.4.2.1 *Ceramics (CRF 2.A.4.a)*

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

For roofing tile, brick and ceramics production, activity and emission data from 2005 and onwards is acquired through the ETS. In line with the 2006 IPCC Guidelines, CO₂ emissions from limestone and dolomite as well as other carbon containing raw materials are reported in 2.A.4.a. As there is a lack of data before 2005, the reported emissions for 2005 are linearly interpolated for 1990-2004.

As activity data reported in 2.A.4.a produced amounts of LECA is reported due to lack of activity data for remaining facilities. The implied emission factor may vary somewhat from one year to another because of the specific composition of limestone, clay and additives with different carbon contents. In 2007, the carbon content in one of the additives for LECA production was unusually high which has resulted in comparatively high CO₂ emissions for that year. The use of limestone and other additives in LECA production has declined in favour of clay. During 2008-2016, clay contributed to between 76-83 % of all process-related CO₂ emissions from LECA production, compared to 42-53 % contribution during 1990-2003. The facility producing LECA corresponds to around 70 % of yearly reported CO₂ emissions in 2.A.4.a. In 2016 however, production has decreased and therefore emissions from that plant contributed only 46% to overall reported CO₂ emissions in CRF 2.A.4.a.

4.2.4.2.2 *Other uses of soda ash (CRF 2.A.4.b)*

CO₂ 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 CO₂ emissions.¹⁵¹ Activity data consists of soda ash use from ten plants within several areas:

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

Emissions have decreased by over 90 % since 1990. The reason behind this effect is the large changes in the use of soda ash at two chemical plants. One plant, spending considerable amounts of soda ash during the early 1990s, has since 1997 sharply reduced its consumption. Since the beginning of the new millennium the soda ash is bound in products, and thus no CO₂ is emitted from this plant. The other plant has reduced its soda ash consumption with about 90 % since 1990.

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 organisations¹⁵² and the dominant snuff manufacturer. The emissions are calculated by applying the emission factor for soda ash and assuming a calcination fraction of 1:

¹⁵¹ Nyström, A-K. 2004. CO₂ from the use of soda ash. SMED report 61 2004.

¹⁵² The Swedish Chemicals Agency (KemI), www.kemi.se

$$\text{CO}_2(\text{kt}) = \frac{44.0098}{105.9884} \times \text{soda ash (kt)}$$

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

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

4.2.4.2.3 *Other- Limestone and Dolomite use (CRF 2.A.4.d)*

Process-related CO₂ emissions from the use of limestone and dolomite in the production of cement (2.A.1), lime (2.A.2), glass and glass wool (2.A.3), ceramics (2.A.4.a), carbide (2.B.5), chemicals (2.B.10), iron and steel (2.C.1.a, 2.C.1.b and 2.C.1.c), iron pellets (2.C.1.e), other metals (2.C.7) and mineral wool (2.H.3) are reported in corresponding CRF source categories in accordance with the 2006 IPCC Guidelines. CO₂ emissions from the use of limestone, dolomite and sodium bicarbonate in flue gas desulphurisation at energy plants (also one pulp-and-paper plant) are reported in 2.A.4.d.

Data on the use of limestone and dolomite in this source category has been acquired from environmental reports, the ETS and through direct contacts with the companies. Activity data for sodium bicarbonate has been collected from the ETS for the years 2005 onwards. For the period 1990-2004 activity data has been estimated based on the average emissions for the period 2005-2008; equivalent to about 0.54 kt a year. The calculations are made by applying the emission factor for respective carbonate according to 2006 IPCC Guidelines Tier 3¹⁵³.

Formulas for CO₂ emissions from limestone, dolomite and sodium bicarbonate:

$$\text{CO}_2 \text{ (Gg)} = \frac{44.0098}{100.0892} \times f \times \text{limestone (Gg)}$$

$$\text{CO}_2 \text{ (Gg)} = \frac{88.02}{184.4} \times f \times \text{dolomite (Gg)}$$

$$\text{CO}_2 \text{ (Gg)} = \frac{44.0098}{84.007} \times f \times \text{sodium bicarbonate (Gg)}$$

where f is the purity of the carbonates, set to 97 % for limestone and 100 % for dolomite and sodium bicarbonate.

4.2.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty for activity data is ± 4 % and the uncertainty of the emission factor for CO₂ is ± 5 %. The time series is consistent and complete.

¹⁵³ IPCC. 2006 Guidelines for National Greenhouse Gas Inventories: Volume 3 section 2.5.

4.2.4.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Data from Statistics Sweden on import and export of carbonates has been compared to production data provided by the Geological Survey of Sweden (SGU) and known use included in the national inventory. When calculating carbonate use based on clinker production in CRF 2.A.1 the comparison shows a good coverage of carbonate use included in the inventory. The margin of error is however bigger than the amount reported in CRF 2.A.4. which makes this comparison difficult and less reliable.

4.2.4.5 SOURCE-SPECIFIC RECALCULATIONS

4.2.4.5.1 *Ceramics (CRF 2.A.4.a)*

No source-specific recalculations are performed in this submission.

4.2.4.5.2 *Soda ash use (CRF 2.A.4.b)*

Emissions from one plant caused by the use of soda have been moved from CRF 2.A.4.b to CRF 2.A.3. Total CO₂ emissions reported in CRF 2.A.4.b decrease therefore by about 1 kt or 63% for 2015.

4.2.4.5.3 *Other limestone and dolomite use (CRF 2.A.4.d)*

Activity data for two plants have been corrected for the entire timeseries 1990-2015. CO₂ emissions reported in CRF 2.A.4.d in 2015 decrease therefore by 5%.

4.2.4.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.3 Chemical industry (CRF 2.B)

Sources covered in the reporting are nitric acid production (2.B.2), carbide production (2.B.5) and other (2.B.10), which include a large variety of processes in the chemical industry. Included in 2.B.10 are also various processes which produce petrochemical products, which according to the 2006 IPCC Guidelines should be reported in 2.B.8, however, due to difficulties in separating these products they are allocated to CRF 2.B.10. No production of ammonia (2.B.1), adipic acid (2.B.3), caprolactam, glyoxal and glyoxylic acid (2.B.4), titanium dioxide (2.B.6), soda ash (2.B.7) or fluorochemicals (2.B.9) occurs in Sweden.

4.3.1 Ammonia production (CRF 2.B.1)

4.3.1.1 SOURCE CATEGORY DESCRIPTION

There is an annual production of about 5 kt of ammonia in Sweden, according to United Nations statistics¹⁵⁴. This ammonia is however not intentionally produced,

¹⁵⁴ UN. Commodity Production Statistical Database. Department of Economic and Social Affairs, Statistics Division,. As referred in FCCC Synthesis and Assessment report 2002 Part I.

but is a by-product in one chemical industry producing various chelates and chelating agents, such as EDTA, DTPA and NTA¹⁵⁵. Emissions from this industry are included in CRF 2B5. Ammonia production, 2.B.1, is thus reported as NO.

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

4.3.2.1 SOURCE CATEGORY DESCRIPTION

Production of nitric acid has taken place at three facilities in Sweden during 1990-2000. One of these facilities was shut down at the end of 2000, and a second one was shut down during 2001. Therefore, there is currently only one facility producing nitric acid in Sweden. The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.8. An overview of the rationale for the data sources used for key categories in the industrial processes sector is presented in Annex 3.5.

Table 4.8. Summary of source category description, CRF 2.B.2, according to approach 1.

CRF	Gas	Key Category Assessment 2016, 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 ₂ O		X		T2	PS	Yes

T2 Tier 2. PS Plant-specific.

4.3.2.2 METHODOLOGICAL ISSUES

Activity data, such as produced amount of nitric acid, have been obtained from the facilities and from official statistics. Emission estimates of N₂O 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 N₂O and NO_x emissions are continuously measured in one of the two production lines. From 2011 the emissions are continuously measured in both production lines.

Documentation has been received from the facility concerning production data, production capacity and abatement measures, used emission factors and the method used for estimating emissions as well as uncertainty in emission estimates and

¹⁵⁵ Kindbom, 2004. SMED report: Investigation on the occurrence of ammonia production in Sweden. 2004-05-11.

measurements. N₂O 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 N₂O 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 N₂O emissions are monitored using an automated system based on EU standards.^{156, 157}

Table 4.9. Activity data, emission factors and emissions of N₂O for nitric acid production.

Year	Production of nitric acid, (kt)	Calculated IEF, kg/t	Emissions of N ₂ O, (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
2006	272	5.42	1.47
2007	249	3.16	0.79
2008	266	3.26	0.87
2009	243	4.05	0.98
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

4.3.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty for activity data is $\pm 2\%$ and the uncertainty of the N₂O emissions, or emission factors for early years, is $\pm 5\%$. The time-series is consistent. The fluctuations in the calculated total EF for N₂O 1994 – 2000 (Table 4.11) are mainly due to fluctuations in one of the facilities. The IEFs are within the IPCC default interval (2-19 kg N₂O/Mg). Activity data and reported emissions have been acquired from reporting in e.g. environmental reports from the facility, but since the facility has shut down, it is no longer possible to check previously reported estimates. Beside emissions of N₂O also emissions of NO_x are reported.

The lower level of N₂O 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

¹⁵⁶ Joint Implementation Supervisory Committee, 2011. YARA Köping S2 N2O abatement project in Sweden.pdf

¹⁵⁷ Joint Implementation Supervisory Committee, 2011. YARA Köping S3 N2O abatement project in Sweden.pdf

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 N₂O and NO_x were reduced compared to previous years. The used abatement system is described in the BREF document for large volume inorganic chemicals¹⁵⁸. During 2009 the production of nitric acid was lower compared to previous years and also lower compared to later years. The higher N₂O implied emission factor in 2009 is due to that the N₂O 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 N₂O emissions. For some months in 2010 N₂O-reducing catalysts were used again, now in both production units at the facility. In one of the production units the catalyst was used from March and in the other unit from December. The fact that the catalysts were not used during all months of the year is the reason for the higher implied emission factor in 2010 compared to 2007 and 2008. From 2011 and onwards the catalysts in both production units were used the whole year with a significant decrease of N₂O emissions compared to earlier years. The time series 2011 – 2016 shows that the N₂O emissions tend to vary as much as $\pm 25\%$ from one year to another. In 2016, the emissions have returned to the same level as for 2014. Hence, no trend can be discerned. Uncertainty estimates are based on information from the company, which is considered to be the best available information.

4.3.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The company is contacted for verification of production capacity and to collect data on purification technology and its effectiveness.

The methodology for estimating N₂O emissions from nitric acid production has been discussed during a joint Nordic workshop in May 2015. A comparison of implied emission factors in Sweden, Finland and Norway (Figure 4.6), based on open UNFCCC data¹⁵⁹, shows similar trend in the three countries – a decrease by 85-90 % compared to the 1990-level. The drop in N₂O implied emission factor in Finland during 2010 is explained by the implementation of N₂O abatement technology (similar as installed in Sweden) at one of the Finnish largest plants. In all the three countries, nitric acid plants are currently equipped with automatic systems based on EU standards to continuously measure N₂O emissions, according to national experts.^{160,161}

¹⁵⁸ European Commission, 2007

¹⁵⁹ GHG data from UNFCCC http://unfccc.int/ghg_data/ghg_data_unfccc/items/4146.php , 2015

¹⁶⁰ Kolshus, H. Norwegian Environmental Agency. Personal communication. 2015

¹⁶¹ Forsell, P. Statistics Finland. Personal communication. 2015

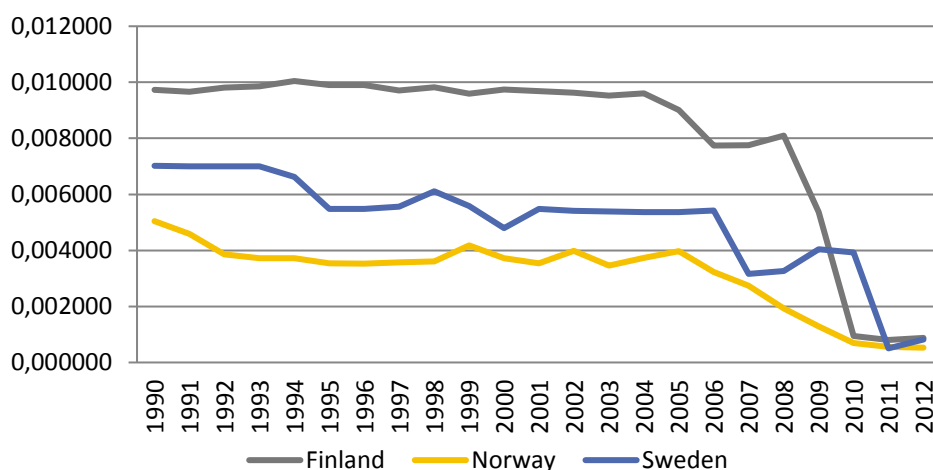


Figure 4.6. Implied N₂O emission factors for CRF 2.B.2 Nitric acid production in three Nordic countries, kt N₂O/Gg nitric acid

4.3.2.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations were performed in submission 2018.

4.3.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.3.3 Adipic acid production (CRF 2.B.3)

4.3.3.1 SOURCE CATEGORY DESCRIPTION

No production of adipic acid occurs in Sweden, and thus NO is reported for CRF 2.B.3.

4.3.4 Caprolactam, glyoxal and glyoxylic acid production (CRF 2.B.4)

4.3.4.1 SOURCE CATEGORY DESCRIPTION

No production of caprolactam, glyoxal or glyoxylic acid occurs in Sweden, and thus NO is reported for CRF 2.B.4.

4.3.5 Carbide production (CRF 2.B.5)

4.3.5.1 SOURCE CATEGORY DESCRIPTION

Silicium carbide production does not occur in Sweden but calcium carbide is produced at one facility. All process-related CO₂ emissions from the carbide plant with the exception of emissions from quicklime production are included in 2.B.5.b. Emissions from quicklime production is included in CRF 2.A.2. The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.10.

Table 4.10. Summary of source category description, CRF 2.B.5, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.B.5	CO ₂				T1	PS	Yes

D Default. PS Plant-specific.

4.3.5.2 METHODOLOGICAL ISSUES

To cover all sources of CO₂ from the production of calcium carbide, estimates of emissions from reduction of quicklime to calcium carbide and emissions from the use of calcium carbide have been made. However, CO₂ emissions from production of quicklime at the carbide plant are reported in CRF 2.A.2 in accordance with the 2006 IPCC Guidelines. In the tables and text below the estimated CO₂ emissions to be reported in CRF 2.B.5.b are presented.

4.3.5.2.1 CO₂ emissions from calcium carbide production

Calcium carbide is produced in an electric arc furnace at high temperature, 2000 – 3000 °C. Quicklime, CaO, is reduced with coke and forms CaC₂. In this process an energy rich gas is produced as a by-product. This gas is used as fuel within the facility and to some extent in other nearby plants and thus only a minor part of the gas is flared. To calculate the CO₂ emissions from the reduction of quicklime to calcium carbide, data on produced amounts of calcium carbide, share of gas flared and default emission factor from the 2006 IPCC Guidelines are used. Share of gas flared does not depend on carbide production numbers – thus, CO₂ emissions from carbide production correlate with share of gas flared rather than with carbide production, and IEF based on produced amounts are not relevant.

Table 4.11. Share of flared carbide oven gas and associated CO₂ emissions to be reported in CRF 2.B.5.b.

Year	Flaring time/carbide oven running time, %	CO ₂ from the reduction of CaO to CaC ₂ , (kt)
1990	6 %	3.8
1995	7 %	3.8
2000	14 %	6.0
2005	15 %	6.7
2006	13 %	5.6
2007	10 %	4.3
2008	8 %	3.8
2009	10 %	2.7
2010	9 %	3.3
2011	11 %	4.2
2012	23 %	8.6
2013	9 %	3.8
2014	10 %	4.0
2015	11 %	4.3
2016	3 %	1.1

4.3.5.2.2 *CO₂ emissions from use of calcium carbide*

In the Revised 2006 IPCC Guidelines it is stated that in addition to reporting CO₂ emissions from calcium carbide production, also CO₂ originating from the use of calcium carbide has to be reported. To be able to estimate CO₂ emission from use of calcium carbide only the amount of calcium carbide for acetylene production and the use within the country should be taken into account. Information from the calcium carbide producer in Sweden indicates that one third of the calcium carbide is used for acetylene production. Assuming that imported and exported amounts of acetylene have the same utilisation it is possible to reasonably well estimate the CO₂ emissions originating from acetylene use. Annual statistics on imported and exported amounts from 1998 and onwards are available from Statistics Sweden¹⁶². Amounts used for acetylene production for earlier years are estimated. The default emission factor presented in the 2006 IPCC Guidelines, 1.1 t CO₂/Mg calcium carbide use, has been used for the estimations.

¹⁶² www.scb.se

Table 4.12. Amount of calcium carbide used for acetylene production, and CO₂ emissions from acetylene use reported in CRF 2.B.5.b.

Year	Amount of calcium carbide for acetylene production, (kt)	CO₂ from use of calcium carbide for acetylene production, (kt)
1990	7	8
1995	6	7
2000	6	7
2005	9	10
2006	8	8
2007	8	9
2008	9	9
2009	4	5
2010	5	6
2011	5	6
2012	4	4
2013	7	8
2014	6	7
2015	6	6
2016	7	8

4.3.5.2.3 Time series reported in CRF 2.B.5. b

In Table 4.15, total CO₂ emissions for some years between 1990 and 2016 are presented. The total reported CO₂ emissions in CRF 2.B.5.b are based on:

- produced amounts of calcium carbide, share of gas flared and the default emission factor according to the 2006 IPCC Guidelines
- amount of calcium carbide used for acetylene production within the country and the default emission factor presented in 2006 IPCC Guidelines.

Amounts of produced carbide and used carbide are attributable to different processes with different emission factors, meaning that summarizing them in a one set of activity data would not be relevant. Besides, as mentioned above, share of flared gas (actual activity data used for calculation of emissions from the carbide production process) does not correlate with production numbers. Activity data for CRF 2.B.5.b is therefore reported as not applicable, NA.

Table 4.13. Time series reported in CRF 2.B.5 b. Activity data is reported as not applicable, NA.

Year	Activity data as produced calcium carbide, (kt)	CO ₂ emissions from production and use of calcium carbide, (kt)
1990	NA	11.9
1995	NA	10.6
2000	NA	12.6
2005	NA	16.6
2006	NA	14.1
2007	NA	13.2
2008	NA	13.2
2009	NA	7.56
2010	NA	9.31
2011	NA	10.1
2012	NA	13.0
2013	NA	11.3
2014	NA	10.8
2015	NA	10.7
2016	NA	9.2

CO₂ emissions from production of quicklime at the carbide production facility are in accordance with the 2006 IPCC Guidelines reported in 2.A.2.

4.3.5.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As can be seen in Table 4.13, CO₂ emissions in 2009 are low compared to adjacent years. This is because the amount of produced carbide that year was lower.

Based on expert judgements, the uncertainty of collected emissions of CO₂ is $\pm 6\%$.

4.3.5.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source specific procedures have been made in submission 2018.

4.3.5.5 SOURCE-SPECIFIC RECALCULATIONS

No recalculations have been made in submission 2018.

4.3.5.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.3.6 Titanium dioxide production (CRF 2.B.6)

4.3.6.1 SOURCE CATEGORY DESCRIPTION

No production of titanium dioxide occurs in Sweden, and thus NO is reported for CRF 2.B.6.

4.3.7 Soda ash production (CRF 2.B.7)

4.3.7.1 SOURCE CATEGORY DESCRIPTION

In 2004 a study was carried out to collect data on soda ash use and calculate CO₂ emission¹⁶³. From this study it became clear that no production of soda ash occur in Sweden, and is hence reported as NO in the CRF.

4.3.8 Petrochemical and carbon black production (CRF 2.B.8)

4.3.8.1 SOURCE CATEGORY DESCRIPTION

Petrochemicals and carbon black are produced in Sweden. However, emissions from these sources are reported in CRF 2.B.10 Other, since it is difficult to separate these emissions from emissions from other sources within the chemical industry. Moreover, part of the emissions originating from internal make-up fuels is reported in the CRF 1A since these emissions are very difficult to separate from other emissions from fuel use, which are to be reported in the energy sector. Thus, IE is reported for CRF 2.B.8.

4.3.9 Fluorochemical production (CRF 2.B.9)

4.3.9.1 SOURCE CATEGORY DESCRIPTION

No production of fluorochemicals occurs in Sweden, and thus NO is reported for CRF 2.B.9.

¹⁶³ Nyström, A-K. 2004. CO₂ from the use of soda ash. SMED report 61 2004.

4.3.10 Other (CRF 2.B.10)

4.3.10.1 SOURCE CATEGORY DESCRIPTION

This sub-category includes various chemical industries, such as sulphuric acid production, the pharmaceutical industry, production of base chemicals for plastic industry, various organic and inorganic chemical productions, and other non-specified chemical production, which are not covered elsewhere. Production of petrochemical products (ethylene, ethylene dichloride and vinyl chloride monomer and ethylene oxide) as well as carbon black, which are described in IPCC 2006 Guidelines under CRF 2.B.8, are included in 2.B.10 due to difficulties in separating these emissions. Approximately 70 larger industrial facilities are included in the emission estimates. Emissions of CO₂, CH₄, N₂O, NO_x, CO, NMVOC and SO₂ are reported in this sub-category. It is possible though that some emissions of NMVOC reported in CRF 2.B.10 should be reported in CRF 3C (e.g. pharmaceutical industries), but as it has been difficult to make the distinction clear between process emissions and solvent use, all NMVOC emissions from these facilities have been included in CRF 2.B.10.

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, CH₄ emissions decreased in 1999 due to a much lower production at one facility and N₂O emissions increased in 1999, 2004 and in 2014 due to the fact that one facility within "Pharmaceutical industry" reported higher emissions these years.

The SO₂ emissions reported in 2.B.10 decreased dramatically in 2004 in comparison to earlier years. This is due to that in December 2004 one facility for production of viscose staple fibre was shut down. The yearly SO₂ emissions from this facility represented between 8 and 20 % of the totally reported SO₂ emission in CRF 2 – Industrial Processes, 1990 - 2003.

CO emission from "Other inorganic chemical production" increased from below 200 Mg in 2005 to 500 Mg in 2006. This increase is due to unusually high CO emission in 2006 from one facility producing PVC. In 2007 the CO emissions were very low from one facility producing PVC. CO emissions raise in 2014 is due to rather high CO emission from one facility within organic chemical production.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.14.

Table 4.14. Summary of source category description, CRF 2B10, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.B.10	CO ₂	X	X		T3	PS	Yes
	CH ₄				T1, T3	PS, D	No, see Annex 5
	N ₂ O				T3	PS	No, see Annex 5

D Default. CS Country Specific. PS Plant-specific. T1 Tier 1. T3 Tier 3.

4.3.10.2 METHODOLOGICAL ISSUES

A total of approximately 70 facilities are included in the Swedish chemical industry. In the 2006 IPCC Guidelines, methods for estimating CH₄ emissions for several chemical products are presented and consequently the CRF Reporter is divided on those products. Since several plants in Sweden produce several chemicals products each but report emissions aggregated by plant, it is not possible to report emissions in accordance with the suggested split in the CRF Reporter. In Sweden, since submission 2006 the emissions are thus presented allocated to six separate branch categories: sulphuric acid production, pharmaceutical industry, production of base chemicals for plastic industry, organic chemical production, inorganic chemical production and other non-specified chemical production.

The primary information on emissions of CO₂, CH₄, N₂O, NO_x, CO, NMVOC and SO₂ is as reported by the companies in their environmental reports. For facilities reporting to the EU ETS, CO₂ emissions from the EU Register are compared to those provided in the environmental reports. Process-related CO₂ emissions in the chemical industries origin mainly from hydrogen production and combustion of internal gases. CO₂ emissions from the use of limestone and soda ash in the process are included for one plant as well. Limestone and soda ash activity data are collected from the plant's environmental reports and the 2006 IPCC Guidelines emission factors are used together with an assumed limestone purity of 97%.

The 2006 IPCC Guidelines include instructions to allocate emissions from fuels produced within the facility (internal make-up gases) in the corresponding IPCC source category. Sweden has followed the recommendations as far as possible; however, exceptions have been made for some chemical industries, due to the fact that CO₂ emissions in these industries are very difficult to separate from other emissions from fuel use, which are to be reported in the energy sector. In those cases IE has been reported in 2.B.10. For some facilities, there is a certain share of emissions (derived mainly from environmental reports) allocated to 2.B.10 while the remaining emissions are reported in the energy sector. Irrespective of the chosen method, comparisons have been made to ensure that all emissions are covered in either sector and that no double-reporting occurs. The tools and procedures used for this comparison and verification are described in more details in the section 4.3.10.4 – those will be further revised to develop a more unified allocation method before submission 2019.

The 2006 IPCC Guidelines include methods on reporting of methane emissions from production of ethylene oxide. Such production does occur in Sweden (one company). The company's own emission estimate is around 4 tons/year, based on measurements, however a complete time series is not available. Applying the default emission factor, given in the 2006 IPCC Guidelines, results in emissions of about ten times the amount estimated by the company, due to the fact that the plant uses catalytic oxidation, reducing methane emissions by about 90 % according to measurements. Thus, the default method is believed not to be representative and methane emissions from this company is reported NE, since they are less than 0.05 % of the national emissions, and the effort to collect sufficient data is disproportionate to the significance of the emissions.

In Sweden there is one company producing carbon black. CH₄ emissions are included from 1990 and onwards based on production data from the company's environmental reports and IPCC Guidelines default EF (0.06 kg CH₄/ton production). These emissions are included under 2.B.10 (Other inorganic chemical production) together with the process-related CO₂ emissions, and IE is reported for CRF 2.B.8. Energy-related CO₂ emissions from this facility are reported in the CRF 1.A.

Amounts of product in the chemical industry are attributable to different processes with different emission factors, meaning that summarizing them in a one set of activity data would not be relevant. Activity data for CRF 2.B.10.a is therefore reported as not estimated, NE.

4.3.10.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Based on expert judgements, the uncertainties of collected emissions of CO₂, CH₄ and N₂O are as follows: ±50 %, ±100 % and ±125 %, respectively.

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

4.3.10.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

In addition, 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 Sweden¹⁶⁴. Emissions reported in the environmental reports were compared to plant-specific data in the

¹⁶⁴ Gustafsson, T., Nyström, A-K., Gerner, A. Riktad kvalitetskontrollstudie av utsläpp från kemiindustrin i Sveriges internationella rapportering. SMED report 2010.

GHG inventory, significant discrepancies were investigated, and recommendations were provided on feasible improvements for submission 2011 as well as recommendations on further investigations¹⁶⁵. Overall, the QC-project showed that total reported GHG emissions from the chemical industries in the Swedish inventory are in coherence with the plant emission data.

Before submission 2018, a development project¹⁶⁶ was carried out with the specific purpose to improve emission allocation between the energy sector and IPPU and to establish a procedure for annual cross-sectoral control of reported emissions. Within this project, a new quality control tool has been developed to ensure that comparisons of emissions in the energy sector and in CRF 2.B.10.a are done on a more regular basis, for the same range of facilities, and using a unified procedure. In the tool, for each of the relevant facilities, emissions reported in the energy sector (CRF 1A) are summed up with the emissions reported in the CRF 2.B.10, and the sum is compared to both EU ETS data (if available) and environmental reporting provided by facilities. Quality control is therefore being conducted on a facility level. In case of discrepancies, they are easily identified and further investigated regarding potential gaps or double-counting.

There is still an allocation issue that is not solved by the new cross-sectoral comparison tool. For better compliance with the IPCC 2006 guidelines, further steps in the methodology development are being taken – those are aimed at investigating potential reallocations of emissions from combustion of make-up gases in the chemical industries (e.g. gases produced in a thermal cracker) from CRF 1.A to CRF 2.B.10. This work is ongoing, and feasible reallocations will be done in the submission 2019.

4.3.10.5 SOURCE-SPECIFIC RECALCULATIONS

Inorganic chemical production (relative changes in % below are given for this particular sub-sector):

NMVOC emissions for 2007-2015 from one facility have been recalculated due to updates in the method used by the facility. NMVOC emissions reported in the sub-sector decrease by 0.5-15 % (up to 0.03 kt) compared to Submission 2017.

CO₂ emissions have been recalculated for the whole time series, due to two main corrections and method changes:

- Correction of earlier double-counted emissions from limestone at one of the facilities; emissions from soda at the same facility ash were re-allocated from CRF 1A24 to CRF 2B10a in submission 2018;

¹⁶⁵ Most recommendations on further investigations refer to the energy sector

¹⁶⁶ Ortiz, C., Jonsson, M., Yaramenka, K., Helbig, T., Danielsson, H. Överlappande mellan CRF 1 och 2, SMED memorandum, 2017

- Allocation between emissions in the energy sector and in CRF 2B10a: the share of process-related emissions is corrected, and activity data was updated for one of the large facilities, for the whole time series.

The two changes together result in the changes lying within the interval from -26% (-16 kt) and +32% (+15 kt) .

Organic chemical production (relative changes in % below are given for this particular sub-sector):

For one plant, a part of CO₂ emissions from limestone used in the flue gas cleaning was allocated to another code, which resulted in the emission decrease by 0.1-0.3% (up to 0.2 kt) for the whole time series.

For another facility, NO_x emissions from boilers have been recalculated taking into account the share of internal gas combustion. The recalculation resulted in the emission decrease by up to 71% (0.02 kt) for the whole time series.

NMVOC emissions from one plant have been corrected by subtracting methane, which resulted in the emission decrease by 0.1-0.8% (up to 6 t) for 2004-2015.

4.3.10.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.4 Metal industry (CRF 2.C)

The sub-categories which are covered in the estimates include iron and steel production (2.C.1), ferroalloy production (2.C.2), aluminium production (2.C.3), SF₆ used in magnesium foundries (2.C.4) and other (2.C.7). Other (2.C.7) consists of estimates from one large non-ferrous smelter plant and one metal recycling plant. Other (2.C.7) also include emissions from lead production (2.C.5), zinc production (2.C.6), and emissions from copper production and nickel production since these emissions cannot be separated.

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

4.4.1.1 SOURCE CATEGORY DESCRIPTION

In Sweden, there are two primary iron and steel facilities equipped with blast furnaces, producing iron and steel products from virgin materials, and about ten secondary steel plants equipped with electric arc furnaces, producing iron and steel products from scrap and direct reduced iron. One of the facilities is using a shaft furnace process to produce stainless steel from recovered flue gas dust and other waste products. In total, there are approximately 20 different facilities included in the different estimates. Processes occurring besides the primary processes and secondary steel production are rolling mills, pickling and other refinement processes. From submission 2009 and onwards, emissions from two major iron ore mines and three facilities producing pellets in Sweden are reported in 2.C.1.e. Emissions from one sinter producing facility are reported in 2.C.1.d until 1995, when the production closed down.

Process emissions arising from reducing agents in the primary steel works and secondary iron and steel works are reported in CRF 2.C.1. As the plants also generate emissions from fuel combustion (CRF 1.A.1.c and CRF 1.A.2.a) and fugitive emissions (CRF 1.B.1.c), the text in this section is closely connected to the text in the corresponding section in the energy chapter. Emissions of N₂O do occur to a small extent according to the 2006 IPCC Guidelines¹⁶⁷, however no default method is available and since Sweden has not developed a country-specific method for estimating N₂O emissions, they are reported NE.

In the Swedish inventory, emissions from primary iron and steel production and secondary steel production are reported separately and fed into CRF Reporter under 2.C.1.b Pig iron and 2.C.1.a Steel, respectively. This enables process emissions from the two integrated iron and steel production plants in Sweden to be reported together (2.C.1.b Pig iron), and thus not introducing further sources of uncertainty due to additional data handling. One facility is producing direct reduced iron and its emissions are reported in 2.C.1.c Direct reduced iron.

¹⁶⁷ IPCC 2006 Guidelines. http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf

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.

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 4.15. An overview of the rationale for data sources used for key categories in the industrial processes sector is presented in Annex 3.5.

Table 4.15. Summary of source category description, CRF 2.C.1, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.C.1	CO ₂	X	X		T2, T3	PS	Yes
	CH ₄				T2	CS	No, see Annex 5
	N ₂ O	NA	NA		NA, NE	NA, NE	No, see Annex 5

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

4.4.1.1.1 Secondary steel production (CRF 2.C.1.a)

Reported CO₂ emissions include emissions from reducing agents such as coke, coal and electrodes in electric arc furnaces in secondary steel plants. These emissions are not primarily a result of combustion, but are necessary for the process and should hence be reported in CRF 2.C.1.a. Reported CO₂ emissions also include emissions from the use of limestone and dolomite in secondary steel industry.

The reported CO₂ emissions in CRF 2.C.1.a included data from eleven plants in 1990-2003 and ten plants from 2004. Also another five plants with process related NO_x, SO₂ and/or NMVOC emissions are included in this sector. These plants do not produce steel, and hence do not emit CO₂.

4.4.1.1.2 Primary iron and steel production (CRF 2.C.1.b)

There are two plants in Sweden that produce pig iron and steel as part of their integrated coke ovens, blast furnaces and steel converters. The primary purpose of the use of coal and coke in the blast furnace is to ensure oxidation and to act as reducing agents. The associated emissions are thus to be reported as industrial processes from iron and steel production in CRF 2.C.1, according to the IPCC Guidelines.

4.4.1.1.3 Direct reduced iron (CRF 2.C.1.c)

There is one plant in Sweden which produces iron sponge and iron powder using direct reduction of iron ore pellets.

4.4.1.1.4 *Sinter (CRF 2.C.1.d)*

During 1990-1995 a sinter plant was in operation at one of the integrated primary iron and steel plants. Operation of sinter plants produces CO₂ 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 CH₄, are emitted¹³⁰. SO₂ from the sulphur content in the ore is also considered to be emitted from the facility.

4.4.1.1.5 *Pellet (CRF 2.C.1.e)*

CO₂ emissions arise mainly from the use of limestone and dolomite, and to a smaller extent from bentonite and organic binder. SO₂ 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, CO¹⁶⁸, which however are not reported. Estimated emissions from combustion of fuels are included in the Energy sector (CRF 1). In 2014 the SO₂ emissions were lower than previous years due to new abatement technology at one facility and low sulphur content in the ore.

4.4.1.1.6 *CO₂ emissions reported in Other (CRF 2.C.1.f)*

No emissions of CO₂ reported in this source category.

4.4.1.2 METHODOLOGICAL ISSUES

4.4.1.2.1 *Secondary steel production (CRF 2.C.1.a)*

In most cases, data from the Swedish enquiry for the Swedish national allocation plan (NAP) for the EU ETS could be used for the years 1998-2002. Data for 1990-1997 and 2003-2004 has been collected directly from the plants. From 2005, the equivalent data are acquired from the ETS, from the facilities environmental reports and through contacts with the companies.

Data in the ETS includes information concerning carbon bound in products, slag, etc., but also other sources for process related CO₂ emissions. Prior to submission 2010, these other emissions were not included for all facilities. Estimates of these missing CO₂ emissions were performed using ETS data for 2005 – 2008 and production data for years prior to 2005. All CO₂ emissions presented for the facilities in ETS 2005 – 2014 are included in 2.C.1.a.

Reported CO₂ emissions until year 2008 are for all facilities, except the one which closed down in 2004, based on data in the ETS. Reported CO₂ emissions can therefore be classified to follow the 2006 IPCC Guidelines Tier 2, since according to the Guidelines reported emissions shall be based on all carbon input to and carbon output from the process. From 2009 to 2012 background data needed for estimation of process-related CO₂ emissions for one facility is collected from the

¹⁶⁸ Wieland, M.S. 2004.

facility's environmental report, since all data needed could not be retrieved from ETS for these years.

For non- CO₂ emissions, the companies' environmental reports are the main information source. NO_x, NMVOC and SO₂ emissions emitted from electric arc furnaces are reported in 2.C.1.a. NO_x emissions may also arise from pickling and NMVOC emissions from rolling mills. These sources are also included in the estimates.

4.4.1.2.2 *Primary iron and steel production (CRF 2.C.1.b)*

Sweden uses the recommended Tier 3 method according to the 2006 IPCC Guidelines and the calculations of CO₂ emissions are based on carbon mass-balances in order to reduce the risk of double counting or omitting CO₂ emissions.

The carbon contents of external input materials such as coking coal, coke, injection coal, limestone, etc., are balanced against final output materials; coke¹⁶⁹, pig iron, steel, tar, sludge, slag, etc. The remaining carbon contents are accounted for as CO₂ emissions:

$$CO_2 \text{ emissions}_{Total CRF1 and 2} = \left[\sum_i (MI_i * C_i) - \sum_p (MO_p * C_p) \right] * 44 / 12$$

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*).

Figure 4.7 gives an overview of the input and output materials, the carbon flows between the different processes (plant stations), and the CO₂-emitting sources.

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

In the steelworks, pig iron is transformed into various qualities of steel depending on the demand. Dolomite, pig iron, carbide, etc., are added depending on the different metallurgic processes. LD-gas is produced in the steel converter and used

¹⁶⁹ If put in stock or sold externally

as fuel or flared. Some steel is treated in the rolling mills where LPG and different oils are used as fuel.

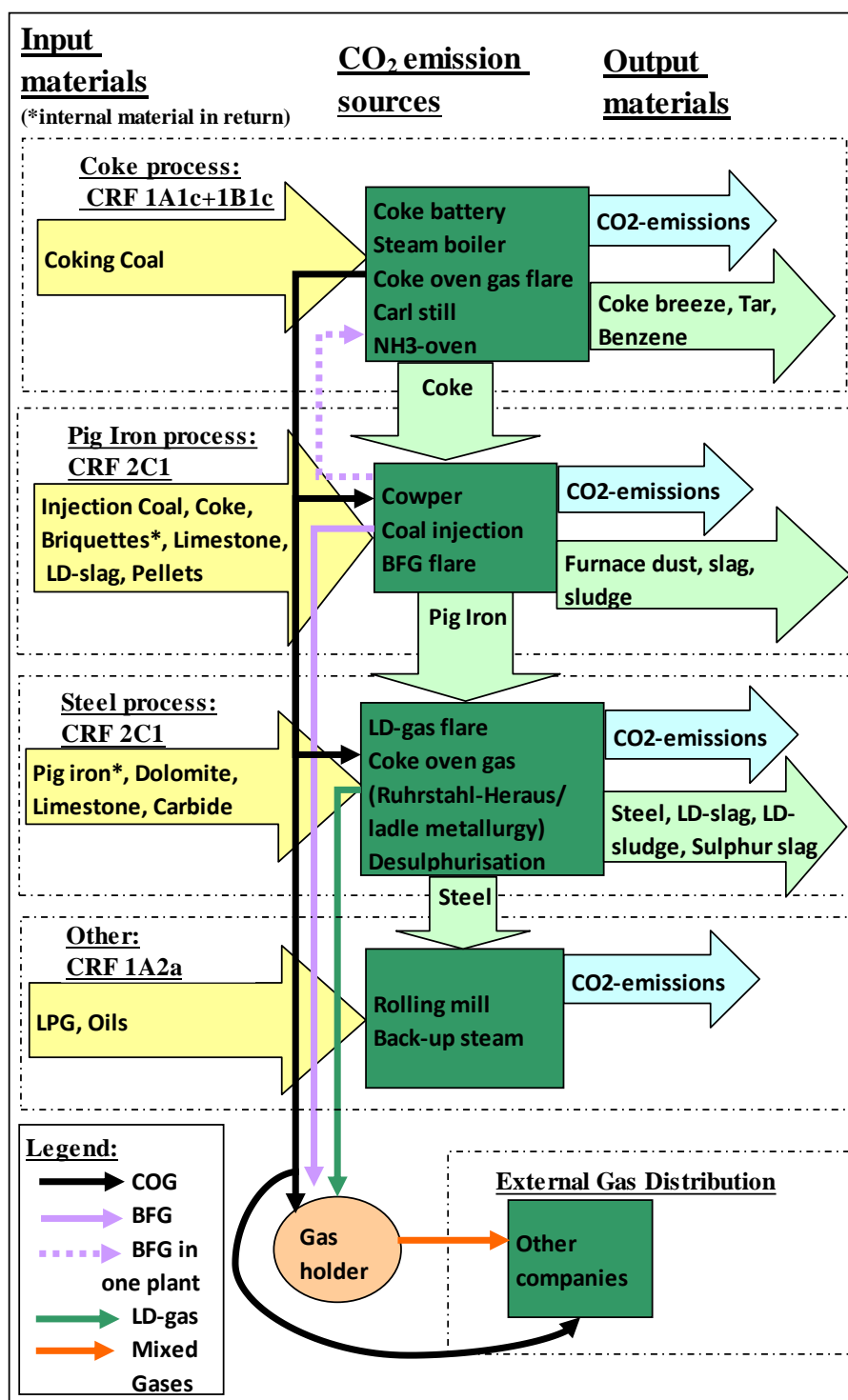


Figure 4.7. Carbon flow chart of integrated primary iron and steel plants in Sweden

Considerable amounts of energy gases (coke oven gas, blast furnace gas and LD-gas) from the different processes are collected in a gas holder and sold to external consumers (mainly in CRF 1.A.1.a electricity and heat production). These amounts of gases and their associated emissions are allocated to the source category where they are consumed and thus not accounted for in the iron and steel production. This is in accordance with the 2006 IPCC Guidelines¹⁷⁰ where allocation of emissions from delivered gases is described.

During the whole process from raw material to final product, emissions of CO₂ are released. The **allocation of total CO₂ emissions and energy consumption (TJ)** on plant stations and consequently CRF sub-sector is based on measured fuel consumption and associated CO₂ emissions (see Table 4.16 with example for 2014, due to secrecy reasons, data for 2016 cannot be displayed). Note that energy consumption (TJ) cannot be reported in CRF-reporter for 2.C.1.b.

Table 4.16. CO₂ emissions allocation for 2016 in integrated primary iron and steel production, and data sources used for allocation.

CRF	Plant station	CO ₂ emissions (kt)	Energy consumption (TJ)
1.A.1.a	Power and Heat Production (sold amount of energy gases)	*	7436
1.A.1.c	Coke Oven	415	4492
1.A.2.a	Combustion in Rolling Mills + Power and Heat Production	513	3772
1.B.1.c	Flare in Coke Oven (COG)	10.4	219
2.C.1.b	Blast Furnace + Steelworks (including Flaring of BFG and LD-gas)	2074	8983
Total within the facilities, emissive sources only (losses excluded, sold gases excluded)		3013	17466

* Emissions cannot be displayed due to secrecy reasons

Data sources 2003-2016 – environmental reports and personal communication; EU ETS reporting is used for verification

Main data sources used for allocation of emissions and energy flows in **2003-2016** are specified under Table 4.16. Amounts of solid fuels (COG, BFG, LD-gas) – combusted/ flared at different plant stations as well as sold outside – are available in the environmental reports. CO₂ emissions by station are obtained directly from one of the plants, and for the other plant all emissions are derived from environmental reports. Emissions from coke oven at this plant cover both COG combustion in coke ovens (CRF 1.A.1.c) and flaring (CRF 1.B.1.c) – emissions from flaring are calculated with national CO₂ emission factors, and the remaining emissions are allocated to CRF 1.A.1.c.

For **1990-2002**, CO₂ emissions for one of the plants were obtained directly from the plant. For the other plant, CO₂ emissions 1990-2002 are calculated using its pig

¹⁷⁰ See 2006 IPCC Guidelines: Volume 3: Industrial Processes and Product Use, Box 1.1 (page 1.8)

iron production 1990-2002 and an average CO₂ IEF 2003-2007. Allocation of CO₂ emissions on different sub-categories (CRF 1.A.1.c, 1.A.2.a, 1.B.1.c and 2.C.1.b) in 1990-2002 are based on the plant specific average distributions 2003-2007. Consumed amounts of different energy gases and other fuels 1990-2002 are derived by applying the 2006 IPCC Guidelines surrogate method using the average values 2003-2007 and the CO₂ emissions as the surrogate parameter. Activity data reported in CRF Reporter in CRF 2.C.1.b is produced amount of primary pig iron. Amounts of pig iron produced 1990-2002 were obtained directly from both plants.

Energy allocated to **products and losses** (primary and secondary products, distribution losses and transformation losses) is estimated as total energy in input materials and stock change subtracted by the measured energy in fuels used, and consequently emissions are not applicable. Detailed information about carbon inputs and stock changes by material is for the recent years derived from the EU ETS reporting data and for secrecy reasons cannot be displayed here. For earlier years, data on main input materials and their calorific values are summarized based on environmental reporting and personal communication with the facilities, see Tables 4.17 and 4.18 below¹⁷¹.

¹⁷¹ Gustafsson et al. 2011

Table 4.17 Material input in the Swedish iron and steel production processes, ton

Plant	Year	Coking coal	External coke	Injection coal	External scrap metals	Source
1	1990	937 000	60 000	100 000	175 000	Personal communication
1	1995	920 000	70 400	102 000	141 400	Personal communication
1	2000	920 700	56 300	146 700	63 900	Personal communication
1	2001	909 800	60 880	293 855	44 600	Personal communication
1	2002	820 339	174 449	304 900	41 040	Personal communication
1	2003	773 125	218 400	303 216	102 000	Personal communication
1	2004	940 000	94 600	319 000	130 100	Personal communication
1	2005	946 100	39 300	314 000	113 200	Environmental report
1	2006	944 700	16 900	318 000	89 700	Environmental report
1	2007	948 900	11 700	342 300	98 400	Environmental report
1	2008	942 600	23 300	324 500	118 000	Environmental report
1	2009	785 900	52 000	171 300	74 400	Environmental report
1	2010	895 800	117 900	286 500	114 700	Environmental report
2	1991	603 900	58 000	105 000	0	Environmental report
2	2004	624 290	200 760	154 539	99 783	Environmental report
2	2005	623 972	136 901	170 217	94 289	Environmental report
2	2006	619 416	93 125	149 269	109 950	Environmental report
2	2007	615 808	106 476	161 977	52 407	Environmental report
2	2008	503 430	102 209	115 875	41 613	Environmental report
2	2009	514 335	12 388	74 342	0	Environmental report
2	2010	583 274	127 310	94 754	16 476	Environmental report

Table 4.18 Calorific values by input material in the Swedish iron and steel production processes, GJ/ton

Plant	Coking coal	External coke	Injection coal	External scrap metals	Source
1	31.31	29.66	31.31	7.35	Personal communication
2	27.5	31	31	7.35	Environmental report

Detailed carbon **mass balances**, simplified energy balances and carbon and energy flow charts according to EU ETS are compiled for the two plants included in the reporting; due to secrecy reasons, they cannot be displayed here but can be provided for reviewers upon request. It is important to note that these mass balances are not used directly in the calculations of CO₂ emissions from integrated iron and steel facilities but mainly as a verification tool, for the following purposes:

- To assure that data on CO₂ emissions and energy flows at the facilities, available in their environmental reports, are consistent with the EU ETS reporting;
- To estimate non-emissive energy use (losses and product-bound materials);
- To verify energy use and emissions in the CRF 1.A.1.a attributable to combustion of solid fuels sold by the integrated iron and steel facility to the power sector.

Activity data (amount of pig iron produced) on integrated pig iron and steel production along with CO₂ 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 CO₂ emissions are also reported to the EU ETS since 2005. For some years, CO₂ 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 CO₂ emissions reported by the plants in their environmental reports are equal to those reported to the EU ETS. For 2003 onwards, information on activity data and emissions for all plants (CRF 1.A.1.c, 1.A.2.a, 1.B.1.c and 2.C.1.b) are taken from the environmental reports.

Emissions of **CH₄, 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 CH₄, NMVOC and CO from coke oven gas, blast furnace gas and LD-gas in the blast furnace and steel converter are allocated to CRF 2.C.1.b. Emissions of NO_x and SO₂ are based on detailed plant information from the environmental reports.

4.4.1.2.3 *Direct reduced iron (CRF 2.C.1.c)*

Emissions of CO₂ are calculated using the 2006 IPCC Guidelines Tier 3 method. Plant-specific data on emissions from carbon-containing input materials such as coke and anthracite and also specific carbon-contents of output iron and by-products are used for all years. From 2005, ETS data is used and for 1990-2004, information has been acquired from the plant. The emissions are verified using national statistics from Statistics Sweden on amounts of coke, anthracite and output material. CO₂ emissions from natural gas used for production of reduction gas used in the process are considered to be process-related and thus reported in 2.C.1.c. The remaining amounts of natural gas used by the facility are considered to be energy-related and the corresponding emissions are reported in the Energy sector (CRF 1.A.2.a). Limestone used in the production is included in the emissions from the production of iron powder in CRF 2.C.1.c. Reported activity data is produced amount of direct-reduced iron (iron sponge).

For CH₄ emissions from direct reduced iron, test calculations have been made with default emission factors applied for the total amount of natural gas used at the facility. The resulting CH₄ amounts are thousand fold below the national totals of 30 kt CO₂-eq, meaning that these emissions can be considered insignificant. CH₄ is therefore reported as NE.

4.4.1.2.4 *Sinter (CRF 2.C.1.d)*

During 1990-1995 a sinter plant was in operation at one of the integrated primary iron and steel plants. No plant-specific or national emission factors are available. Thus, in accordance with the 2006 IPCC Guidelines, emissions are estimated using production data and default emissions factors (0.2 t CO₂/t sinter produced and 0.7 kg CH₄/ t sinter produced). Production data has been collected from “Statistics of the Swedish Mining Industry”¹⁷² produced by the Geological Survey of Sweden (SGU).

4.4.1.2.5 *Pellet (CRF 2.C.1.e)*

Production data (iron pellets) are collected from the annual publication “Statistics of the Swedish Mining Industry”. SO₂ emissions have been supplied by the facilities for the entire time series. Amounts of bentonite and organic binder used for the production of iron ore pellets and the corresponding CO₂ 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. The 2006 IPCC Guidelines emission factor for limestone and dolomite use is used to calculate CO₂ emissions and a purity of 97 % and 100 % are used for respective carbonate. No data concerning the CO emissions is available and the time series is thus reported NE.

4.4.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

During the preparation of submission 2013 for reporting to UNFCCC a significant increase in the CO₂ 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 CO₂ 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 CO₂ 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 CO₂ 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

¹⁷² Geological Survey of Sweden. <http://www.sgu.se>.

administrative board to change their monitoring methodology for CO₂ according to 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 CO₂ 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.¹⁷³

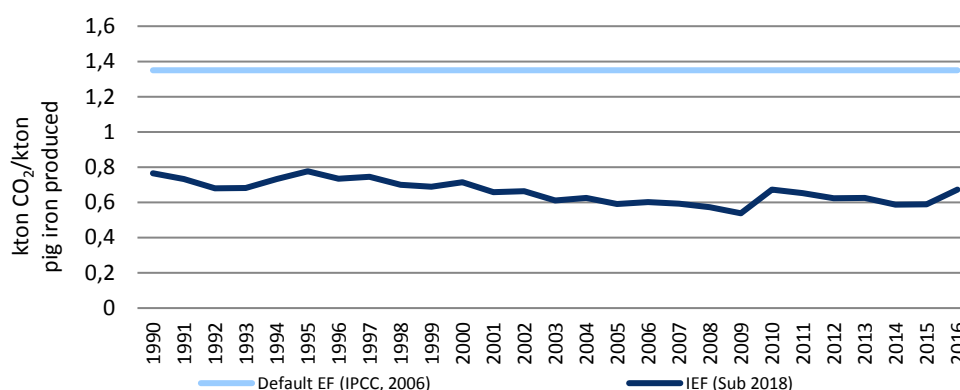


Figure 4.8 Default IPCC CO₂ EF for pig iron production and the CO₂ IEF for primary pig iron production in Sweden for submission 2018.

Figure 4.8 shows the default 2006 IPCC CO₂ EF for pig iron production and the CO₂ IEF for primary pig iron production in Sweden for submission 2018. It is obvious that the Swedish CO₂ IEF (0.54-0.78 kt CO₂/t pig iron) is significantly lower than the default IPCC value (1.35 kt CO₂/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 CO₂ emissions) produced in the processes (blast furnace and LD-steel converters) are used in the coke plant and for power and heat production purposes.

As the different process gases are allocated to different source categories according to a system, the implied emission factor for CRF 2.C.1.b can show an annual variation as a result of this allocation, which is not in correlation with the total emissions from the industry. However, several energy efficiency measures have been undertaken, e.g. increased temperature in the blast furnaces and increased recycling of energy gases and by-products¹⁷⁴, leading to a decrease in CO₂ IEFs since 1990 for primary pig iron and steel production, from 0.77 kt CO₂/kt iron in 1990 to 0.54 kt CO₂/kt pig iron in 2009 (see Figure 4.8).

¹⁷³ Skårman, T. and Gustafsson, T. 2013. Revision of estimated greenhouse gas emissions for integrated iron and steel production. SMED Report No 126 2013.

¹⁷⁴ ENET-Steel, 2007.

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 was in use, due to the overall weak economy. These activities or events may have contributed to the higher CO₂ IEF for 2010-2016.

The largest implication on the national total uncertainties from this category stems from uncertainties in CO₂ emissions in primary iron and steel production (CRF 2.C.1.b); based on judgement by SMED expertise the estimated uncertainty is ± 5 %. It should be noted, however, that total emissions of CO₂ from iron and steel production, including energy related emissions, are likely to deem lower uncertainty estimates.

4.4.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

All plants in this category report their emissions in environmental reports. For plants included in the EU ETS the reported data is scrutinized and compared to EU ETS data. EU ETS data is applied wherever it is judged to be appropriate in line with the 2006 IPCC Guidelines. Detailed carbon mass balances according to the EU ETS are compiled for both integrated iron and steel plants included in the reporting. This information is used for verification but for 2015-2016 cannot be displayed due to secrecy reasons. More information on QC activities related to EU ETS is included in Annex 8.1.

In addition, emissions from this source are included in the cross-sectoral control tool that was developed in 2017. For more information, see section 3.2.9.

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 CO₂ emissions (see section **Fel! Hittar inte referensköllan.**), there will be discrepancies in the annual CO₂ 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 CO₂ emissions between the two sources (reported CO₂ emissions to UNFCCC submission 2015 is approximately 85 % of the reported emissions to EU-ETS).

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 CO₂ IEF seems to have increased during the time period 1990-2014 (see Figure 4.10). However, this is due to the fact that the production of iron powder has increased with about 140 % over the time period whereas the production of iron sponge has been relatively stable. The reduction of iron to iron sponge gives rise to most of the process-related CO₂, although some CO₂ 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 CO₂ 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 CO₂ seems to be increasing when using sponge production as activity data. However, if calculated from total iron powder production it is decreasing.

As the main part of process-related CO₂ emissions stem from iron sponge production, this has been chosen as reported activity data. Figure 4.9 illustrates the different IEFs as well as the trend of the production ratio of iron sponge to iron powder production. Due to secrecy reasons, data for 2015 cannot be displayed.

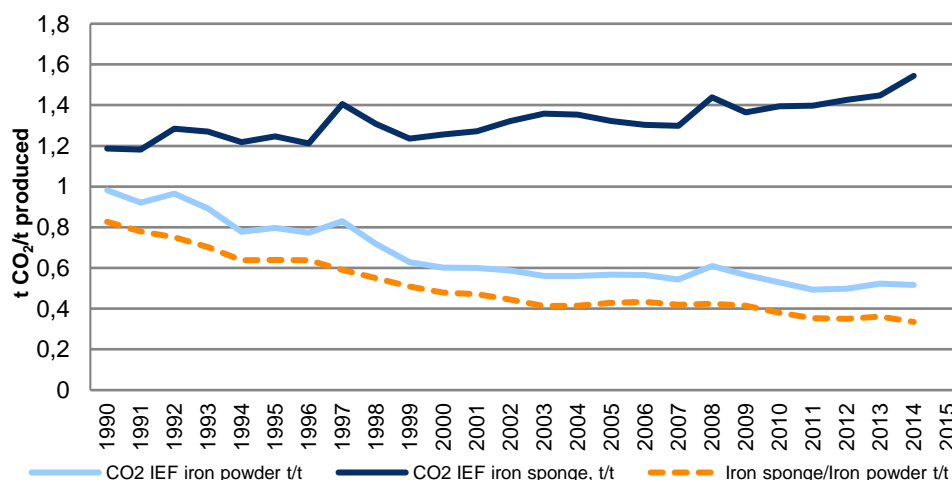


Figure 4.9. CO₂ implied emission factors in relation to iron sponge production and total iron powder production, as well as the production ratio of iron sponge to iron powder.

4.4.1.5 SOURCE-SPECIFIC RECALCULATIONS

2.C.1.a: No recalculations have been made in submission 2017.

2.C.1.b: Very small corrections have been made in the in-data for the years 1990-2002. The resulting changes in the emissions of methane and CO₂ from this source is about 0.00002-0.00003%.

2.C.1.c: No recalculations have been made in submission 2017.

2.C.1.d: No recalculations have been made in submission 2017.

2.C.1.e: The CO₂ emission for 2014 was adjusted in conjunction to submission 2017 from a previous rounded value to a more correct emission value. The CO₂ emission for 2014 is now 3.843 t lower than before.

The CO₂ emission for year 2015 was recalculated in submission 2018 using updated ECO2 data regarding consumption of dolomite and lime stone. The recalculation resulted in a reduction of the CO₂ emission by 2400 t.

4.4.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.4.2 Ferroalloy production (CRF 2.C.2)

4.4.2.1 SOURCE CATEGORY DESCRIPTION

Due to secrecy reasons, data for 2015 and 2016 cannot be displayed for this category. Ferroalloy production is reported for only one facility in Sweden. There is also ferroalloy production at one more plant, but since the main production at this facility is iron and steel, the emissions are reported in CRF 2.C.1. The production of ferrosilicon has decreased sharply since 2005, and between 2008 and 2011 and again in 2014, there was no production at all. As CH₄ emissions within CRF 2.C.2 stem only from ferrosilicon production, this led to zero emissions of CH₄ during these years. In addition, production of ferrosilicon leads to larger emissions of SO₂ compared to production of ferrochromium, which is why the reduced or non-existent ferrosilicon production since 2005 resulted in a distinct decrease in SO₂ emissions. The economic recession in 2009 had a great effect on production volumes of ferroalloys in Sweden and thus the emissions 2009 are significantly reduced compared to adjacent years.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.19.

Table 4.19. Summary of source category description, CRF 2.C.2, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.C.2	CO ₂	X			T3	PS	Yes
	CH ₄	NA	NA		NA	NA	NA
	N ₂ O	NA	NA		NA	NA	NA

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

4.4.2.2 METHODOLOGICAL ISSUES

The estimation of CO₂ emissions due to the production of ferroalloys are plant specific (in line with Tier 2). CO₂ emissions reported by the plant are calculated

based on consumed amounts of reducing agents (Tier 1a¹⁷⁵), i.e. electrodes and coke (and in 2003 coal), together with their specific carbon contents, and the amount of carbon bound in produced ferroalloys. The general carbon balance is:

$$\begin{array}{ccccccc} \text{Coke} & + & \text{Electrodes} & \rightarrow & \text{Ferroalloys} & + & \text{Emissions} & + & \text{Particles} \\ 95 \% & + & 5 \% & \rightarrow & 10 \% & + & 89.5 \% & + & 0.5 \% \end{array}$$

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

- Emission factors and thermal values used for stationary combustion for coke and coal and information from the company that the electrodes contain 90 % carbon.
- IPCC default factors for coal, coke and electrodes¹⁷⁶.

The following formula is used:

$$\begin{aligned} \text{CO}_2 \text{ (t)} &= \text{Coke (t)} \times \text{EF} \times \text{Thermal value} + \text{Coal (t)} \times \text{EF} \times \text{Thermal value} \\ &+ \text{Electrode (t)} \times \text{C-content} \times \frac{44}{12} - \text{CO}_2 \text{ in produced ferroalloys (t, plant data)} \end{aligned}$$

where 44/12 is the molecular weight ratio of CO₂ 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 CO₂ 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:

$$[(\text{AD}_{\text{coke}} \times \text{CC}_{\text{coke}} + \text{AD}_{\text{coal}} \times \text{CC}_{\text{coal}} + \text{AD}_{\text{graphite electrodes}} \times \text{CC}_{\text{graphite electrodes}} + \text{AD}_{\text{chrome ore}} \times \text{CC}_{\text{chrome ore}} + \text{AD}_{\text{added material}} \times \text{CC}_{\text{added material}}) - (\text{AD}_{\text{slag}} \times \text{CC}_{\text{slag}} + \text{AD}_{\text{produced metal}} \times \text{CC}_{\text{produced metal}} + \text{AD}_{\text{dust}} \times \text{CC}_{\text{dust}})] \times 44/12.$$

Where AD and CC denotes the Activity Data of each component and its Carbon Content, respectively. The ratio 44/12 is the molecular weight of carbon dioxide divided by the atomic weight of carbon.

Total amounts of carbon in the produced ferroalloys is presented in Table 4.21, and is calculated based on the carbon content in coke, coal, electrodes and dust. The amount of carbon in the produced ferroalloys varies between 0.1 % and 7 %. This

¹⁷⁵ <http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch2wb2.pdf>

¹⁷⁶ IPCC. Revised 1996 Guidelines for National Greenhouse Gas Inventories: Reference Manual, Table 2.12.

carbon is stored in the product and reported under CRF 1.AD.10 (Non-energy use of fuels and feedstocks) - coke and coal.

As activity data, the carbon content of coke, electrodes and slag binder is used. The reason for this is that the company produces both ferrochrome and ferrosilicon, which bind carbon to different extents. The relative production of each product varies greatly between years (Table 4.21), affecting CO₂ 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 CO₂ emissions.

CH₄ emissions from production of ferrosilicon alloys are reported from submission 2010 and calculated based on ferrosilicon alloy production (Tier 2¹⁷⁷). Data on non- CO₂ emissions has been obtained directly from the company for the whole time series. The reported emissions include NO_x and SO₂ from the process.

Table 4.20. Total emissions of CO₂ based on plant specific data (reported in the CRF), data based on Swedish EF and thermal values, and based on IPCC Guidelines default values. Due to secrecy reasons, data for 2015 and 2016 cannot be displayed.

Year	Plant specific data, (kt CO ₂)	Swedish values, (kt CO ₂)	IPCC default values, (kt CO ₂)
1990	243	244	263
1995	265	274	295
2000	240	266	287
2005	225	215	231
2006	220	209	225
2007	220	188	203
2008	194	164	177
2009	48	48	52
2010	107	96	104
2011	117	122	132
2012	101	100	108
2013	88	75	81
2014	110	100	109

¹⁷⁷ 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Table 4.8

Table 4.21. Total amount of carbon bound in produced ferroalloys and production data. Due to secrecy reasons, data for 2015 and 2016 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
2006	8.3	4.8	41.7	82.9
2007	8.4	4.6	37.6	80.8
2008	7.4	0	44.8	69.2
2009	1.8	0	5.7	23.2
2010	4.0	0	1.6	59.5
2011	4.7	0	80.1	0
2012	2.2	9.8	39.0	0
2013	2.7	0.9	49.0	0
2014	4.1	0	66.0	0

4.4.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties in this category have little impact on the estimated national total emission uncertainty. Emission uncertainties of CO₂ are judged by SMED expertise to be low at $\pm 5\%$ as plant-specific values and Swedish default values give similar results.

The time-series are considered to be consistent.

4.4.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

As presented in Table 4.20 verification of CO₂ emissions reported by the plant is obtained as calculated Swedish default values give similar results.

4.4.2.5 SOURCE-SPECIFIC RECALCULATIONS

The time series 2013 – 2016 has been recalculated 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. For reason of consistency the same method was also applied to recalculate the time series 1990 – 2012, although based on less detailed data.

4.4.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.4.3 Aluminium production (CRF 2.C.3)

4.4.3.1 SOURCE CATEGORY DESCRIPTION

There is one facility that produces primary aluminium in Sweden. The facility consists of two plants. One of the potlines (plant 1) includes 56 closed Prebake cells (CWPB), each of 150 kA. The other plant (plant 2) consisted of 262 cells and, until the beginning of 2008, operated three closed Prebake cells and 259 open cells with Söderberg anodes (VSS). The Söderberg anodes were produced in an electrode pulp factory at the facility. In 2012, 56 closed Prebake cells in plant 1 and 242 closed Prebake cells were in operation. From 2008, when all Söderberg cells were shut down, these pot-lines have gradually been replaced by closed Prebake cells. During the conversion from Söderberg technology to Prebake technology there were start-up problems that caused increased emissions of PFC, especially in 2010 and 2011.

The time series of emissions compiled for primary aluminium production include emissions of CO₂, PFCs, NO_x, CO, NMVOC and SO₂. Use of SF₆ as a cover gas is not occurring in Swedish aluminium foundries, thus reported as NO.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.22. An overview of the rationale for data sources used for key categories in the industrial processes sector is presented in Annex 3.5.

Table 4.22. Summary of source category description, CRF 2.C.3, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.C.3	CO ₂	X	X		T2	PS	Yes
	CH ₄	NA	NA		NA	NA	NA
	PFCs		X		T2	D	Yes

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

4.4.3.2 METHODOLOGICAL ISSUES

Reported production statistics and emissions data are based on information in the environmental reports or received directly from the company.

Emission data for CO₂ from the production of primary aluminium 2001 - 2016 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 CO₂ (t) for 1990-2000 is:

$$\text{Mass anodes (100\% C)} \times \frac{44}{12} \times (1 - 0.259^*)$$

* Average mass CO₂ bound in soot and rest anodes 2001-2008

The value for carbon bound in soot and rest anodes (0.259) is based on average of reported values for 2001-2008. For subsequent years the amounts bound in soot and rest anodes vary between 0.181 and 0.297. The low IEF for 1992 might be explained by the use of a too high percentage of carbon bound in soot and rest anodes. Apart from 1992, the variation in IEF between years is relatively small.

For the years from 2001 and onwards the emissions reported by the plant have been verified by collecting data on the amount of coal elements used and by calculating the emissions based on the equation above. Both methods show similar results.

The carbon bound in soot and in rest anodes is not emitted to the atmosphere as CO₂, and it is therefore excluded in the reported CO₂ 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 CO₂/kt produced Al) (Table 4.23).

Table 4.23. Implied emission factor for CO₂ for the production of aluminium.

Year	Aluminium production (kt)	Emissions of CO ₂ (kt)	IEF kt CO ₂ /kt Al
1990	96	133	1.4
1995	94	129	1.4
2000	101	145	1.4
2005	103	144	1.4
2006	102	142	1.4
2007	100	140	1.4
2008	82	114	1.4
2009	70	98	1.4
2010	96	135	1.4
2011	113	159	1.4
2012	131	200	1.5
2013	131	198	1.5
2014	114	173	1.5
2015	119	180	1.5
2016	124	190	1.5

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 4.24.

Table 4.24. Activity data, emissions of C₂F₆, CF₄ and calculated IEF for aluminium production

Year	Al production, CWPB, kt	Al production, VSS, kt	Total emissions, C ₂ F ₆ t	Total emissions, CF ₄ t	Calculated IEF			
					CWPB kg C ₂ F ₆ /t	VSS kg C ₂ F 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
2006	23.6	78.1	2.55	47.49	0.0023	0.0319	0.0192	0.6024
2007	23.3	76.5	2.57	47.92	0.0025	0.0329	0.0209	0.6200
2008	29.6	52.0	2.54	41.25	0.0215	0.0367	0.1774	0.6917
2009	69.7	-	0.54	4.45	0.0077	-	0.0638	-
2010	96.1	-	2.52	20.80	0.0262	-	0.2164	-
2011	113.3	-	2.90	24.00	0.0256	-	0.2118	-
2012	130.8	-	1.05	8.68	0.0080	-	0.0663	-
2013	131.0	-	0.68	5.62	0.0052	-	0.0429	-
2014	113.7	-	1.10	9.12	0.0097	-	0.0803	-
2015	119.4	-	0.47	3.86	0.0039	-	0.0323	-
2016	124.1	-	0.42	3.43	0.0033	-	0.0277	-

Reported emissions of NO_x are calculated from production statistics using emission factors defined by Swedish EPA¹⁷⁸. NMVOC emissions are calculated from reported emissions of tar, assuming that 70 % of the tar is emitted as NMVOC. 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 also the NMVOC emissions fell sharply. From 2009 and onwards, emissions of NMVOC are reported NE since no emission factor is specified in the EMEP / EEA Guidebook.

CO emissions were for the first time reported in submission 2008 and are for 2002 - 2016 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 SO₂ emissions during 1990 to 2005. For later years SO₂ emissions data are based on environmental reports published by the company.

The elevated SO₂ 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 SO₂ emissions were lower than previous year due to improved abatement technology. The improved abatement

¹⁷⁸ Ahmadzai, H. Swedish EPA. Personal communication. 2000.

technology is also shown in low SO₂ emissions in 2015 and 2016. 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.

4.4.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty for activity data is estimated to $\pm 2\%$. The uncertainty for CO₂ emission factor is estimated to $\pm 5\%$. Uncertainty for SO₂, NO_x and NMVOC are $\pm 30\%$, $\pm 50\%$, $\pm 75\%$, respectively.

As can be seen in Table 4.22 the IEFs show a downward trend from 1990 to 2007, especially so for CF₄. This reflects the company's on-going work aiming to reduce the time and frequency of the anode minutes. Between 2008 and 2011 the Söderberg pot-lines have gradually been replaced by closed Prebake cells.

By the end of December 2009, 120 of a total of 262 cells in plant 2 had been converted to the Prebake technology and in the beginning of December 2010 242 Prebake cells in plant 2 were in operation. At the end of December 2010 a power outage lead to major disturbances in plant 2 leading to both increased emissions and major production problems. On January 7 2011, 120 Prebake cells were shut down as a direct result of the power outage. At the end of June 2011 all Prebake cells in plant 2 were restarted and in operation.

The shutdown of Söderberg ovens explains the very large decline in PFC emissions in 2009 (-89 % compared to 2008) (Figure 4.10). Also the reported CO₂ 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 and also in 2016.

The reported time series are considered to be consistent.

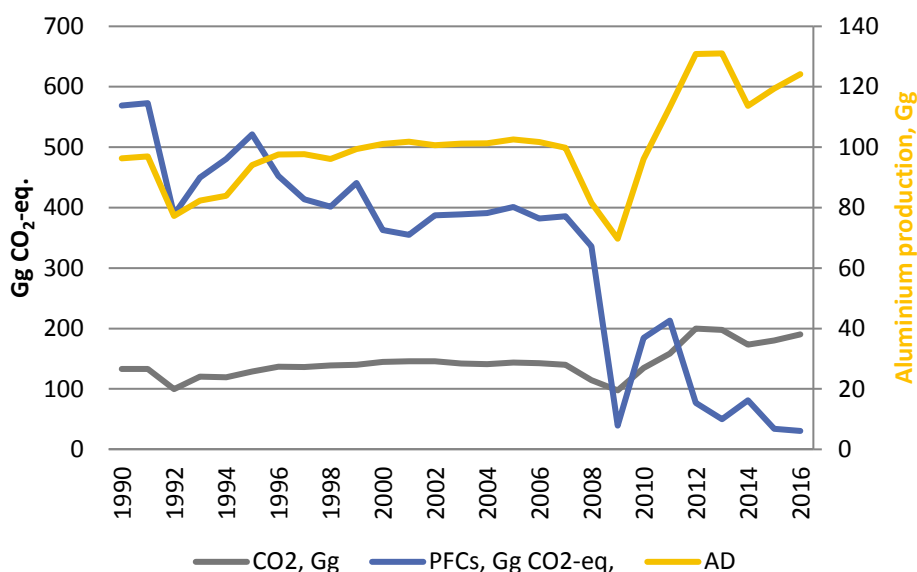


Figure 4.10. Time series for CO₂ and PCF emissions and produced amounts of primary aluminium in CRF 2.C.3.

4.4.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The implied emission factors for CO₂ and PFCs are analysed annually. Explanations for unexpected variation between years are obtained by direct contact with the company or from information in their legal environmental reports.

4.4.3.5 SOURCE-SPECIFIC RECALCULATIONS

Small changes in reported carbon dioxide emissions 2001-2004. These changes affect reported emissions 1990-2000 (changes between -4.21 to +0.27 kt CO₂).

4.4.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.4.4 Magnesium production (CRF 2.C.4)

4.4.4.1 SOURCE CATEGORY DESCRIPTION

There are no production of magnesium in Sweden, thus emissions of CO₂, NO_x, CO, NMVOC and SO₂ are reported as NO (Not occurring) in the CRF tables. However there are four magnesium foundries in Sweden, using SF₆ as a cover gas. For 2012 and 2013 one of the foundries also used HFC-134a. The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.23.

Table 4.25. Summary of source category description, CRF 2.C.4, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.C.4	SF ₆				Tier 2	D	Yes
2.C.4	HFC-134a				Tier 2	D	Yes

D Default.

4.4.4.2 METHODOLOGICAL ISSUES

The total amount of SF₆ and HFC-134a used annually in the magnesium foundries (CRF 2.C.4) is reported as emissions, according to the 2006 IPCC Guidelines. Data is obtained from companies using SF₆ and HFC-134a.

4.4.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

In submissions prior to Submission 2014 the total uncertainty in CRF 2.C.4 were ± 40 %. After comments from Expert Review Team during an In Country Review in September 2013, the uncertainty estimate has been revised. For the three sites where the data is obtained directly from the companies an uncertainty of 5 % is applied, according to data in the 2006 IPCC Guidelines. For the "unknown" plant a much higher uncertainty is applied. The total uncertainty has thus been estimated for CRF 2.C.4 to ± 20 %. Time series are considered to be consistent.

In 2013, the largest magnesium foundry reduced its use of SF₆, by replacing parts of this gas with HFC-134a, which has resulted in significantly lower emissions in 2013 compared to previous years. After 2013, the company has not used HFC-134a.

4.4.4.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

In response to questions raised during the 2011 submission UNFCCC review, data for 2009 has been checked with information from the Swedish Chemicals Agency's Products Register and the data was found to be consistent.

During the review of the 2017 submission, the Expert Review Team recommended Sweden to report both amounts of magnesium casted and emissions of SF₆ in CRF 2.C.4. Despite efforts, Sweden has not been able to find national data on amount of magnesium casted. Sweden will therefore continue to report "NE" for amounts of magnesium casted.

In Figure 4.11, below, implied emission factors for the targets of the magnesium foundries are presented, from 2009 to 2016.

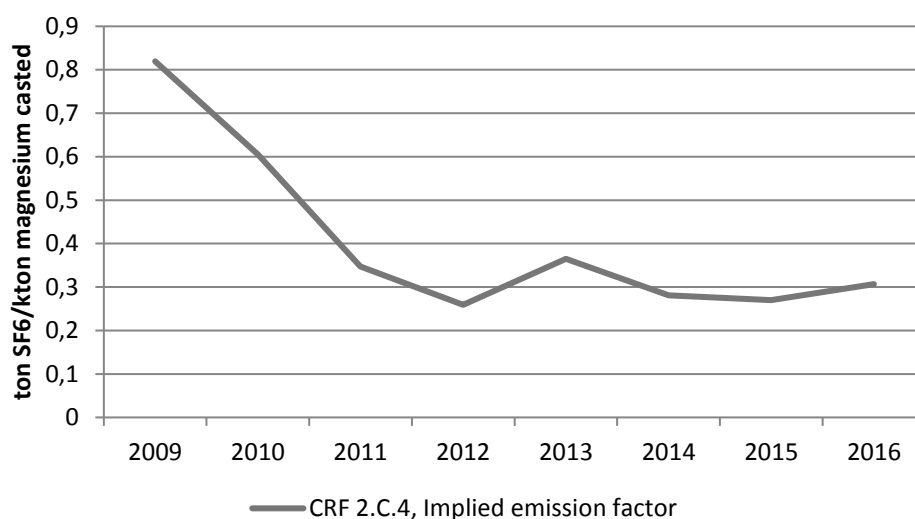


Figure 4.11. Implied emission factors for the targets Swedish magnesium foundry, 2009 – 2016.

4.4.4.5 SOURCE-SPECIFIC RECALCULATIONS

Correction of used amounts of SF₆ for one facility in 2015 led to decreased SF₆ emissions of 2.43 kt CO₂-eq.

4.4.4.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.4.5 Lead production (CRF 2.C.5)

4.4.5.1 SOURCE CATEGORY DESCRIPTION

Lead production does occur in Sweden. However, since Swedish non-ferrous metal smelters produce several metals in the same process, emissions cannot be separated and are all included in CRF 2.C.7.c Other metal production. Thus IE is reported in CRF 2.C.5.

4.4.6 Zinc production (CRF 2.C.6)

4.4.6.1 SOURCE CATEGORY DESCRIPTION

Zinc production does occur in Sweden. However, as Swedish non-ferrous metal smelters produce several metals in the same process, emissions cannot be separated and are all included in CRF 2.C.7.c Other metal production. Thus IE is reported in CRF 2.C.6.

4.4.7 Other metal production (CRF 2.C.7)

4.4.7.1 SOURCE CATEGORY DESCRIPTION

Due to secrecy reasons, data for 2015 and 2016 cannot be displayed for this category. This sub-category includes CO₂, NO_x and SO₂ 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 4.26.

Table 4.26. Summary of source category description, CRF 2.C.7, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.C.7	CO ₂	X	X		T3	PS	Yes
	CH ₄	NA	NA		NA	NA	No, see Annex 5

D Default. PS Plant-Specific.

4.4.7.2 METHODOLOGICAL ISSUES

Emissions of CO₂ 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.

CO₂ emissions from the smelter are calculated based on plant-specific data on raw material consumption and respective CO₂ 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 & Mawdsley¹⁷⁹). 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 4.27

¹⁷⁹ Yaramenka, K., Mawdsley, I. 2015

Table 4.27. Emission factors applied for estimating CO₂ emissions from the non-ferrous metals smelter plant in 1990-2013.

Raw material	Emission factor, Gg CO ₂ / Gg material
Lead cable	0.18
Limestone	0.44
Coke	2.89
Metal ashes	0.14
Concentrate	0.01
Electronic scrap	0.90
Electrode mass	3.00
Less valuable electronic scrap	2.24
Metal dust from steel	0.03
Coal	2.85

The metal recycling plant emits CO₂ from the melting of lead batteries composed of carbon containing plastics (polypropene). The total CO₂ emissions from the plant are reported by the company for all years from 1990. For the years 1990 to 2003 the reported total CO₂ emissions also include energy related emissions. From 2004 the amount of plastics, their carbon content, as well as the CO₂ emission from plastics are known from EU ETS. This information for 2004 is used for estimating the process related CO₂ part of the total CO₂ emissions from the plant for the years 1990 until 2003. Also CO₂ 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 SO₂ originate from the sulphur content in the raw materials used.

The reported activity data comprises amounts of copper, lead and zinc produced at the two above mentioned facilities. As shown in Figure 4.12 below, metal production does not show the same trend as CO₂ emissions. It does, however, correlate with the total raw material consumption at the smelter that dominates production (material consumption at the recycling plant is not available for the entire time series and has not been included in this comparison). The main reason for the different CO₂ emission trends is variations in the combination of raw materials at the smelting facility. Ratio of materials with high and low carbon content is a crucial factor determining implied emission factors for non-ferrous metal production.

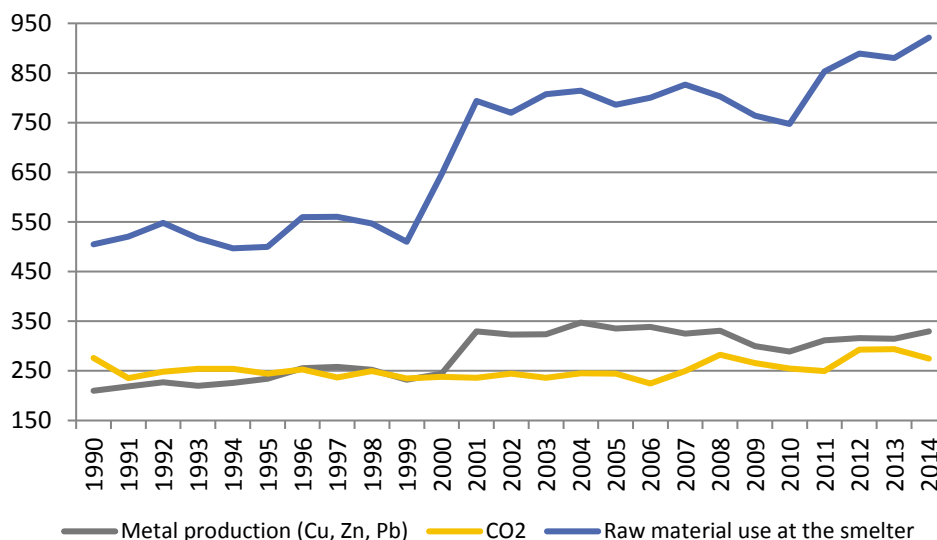


Figure 4.12. CO₂ emissions and activity data trends in CRF 2.C.7.c, kt. [Due to secrecy reasons, data for 2015 and 2016 cannot be displayed]

Shares of specific raw materials in the total material consumption at the smelting facility are presented in Figure 4.13. The dominating - by mass - raw material is metal concentrate, but materials with high carbon content affect the CO₂ emission trend much more. Figure 4.14 illustrates changes in the total consumption of five such materials – coal, coke, electrode mass, metal ashes and electronic scrap (including less valuable scrap) – and related changes in CO₂ emissions at the facility. A much stronger correlation between the emissions and raw material consumption is seen here than in Figure 4.12; this is because materials with low emission factors are excluded.

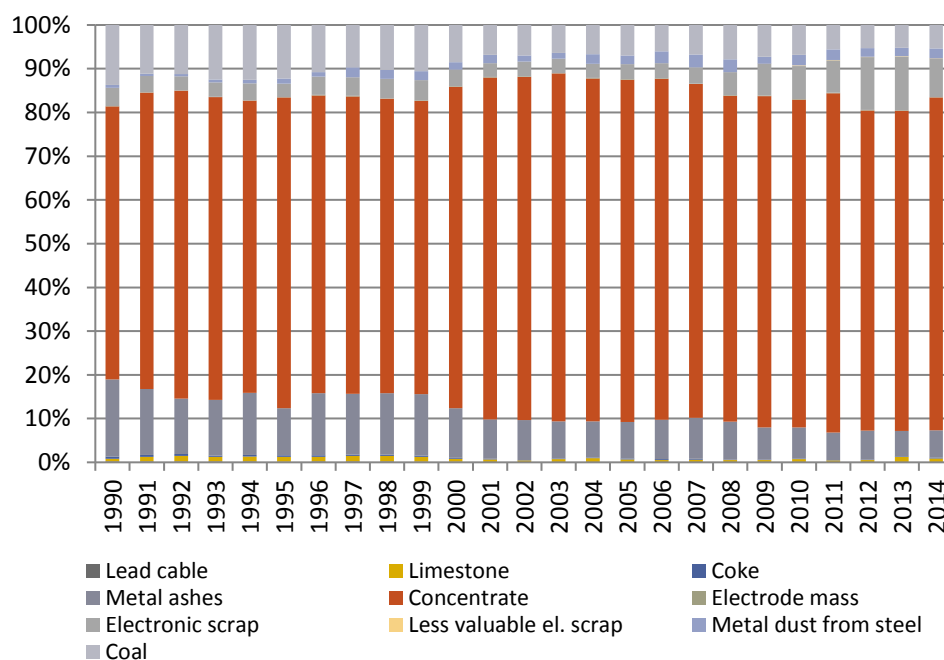


Figure 4.13. Raw materials used in the metal production at the smelting facility, shares in the total input. Due to secrecy reasons, data for 2015 and 2016 cannot be displayed]

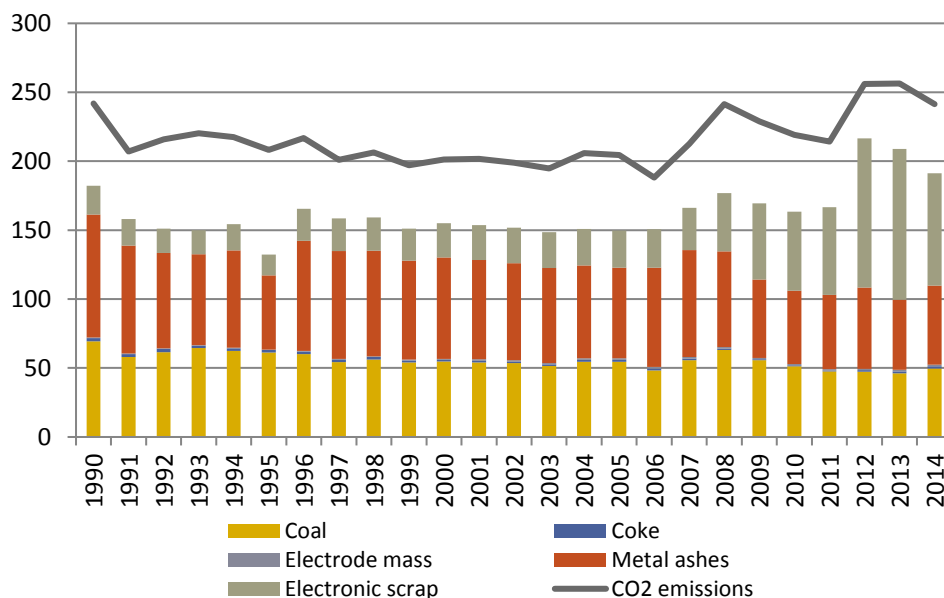


Figure 4.14. Consumption of raw materials with high carbon content and CO₂ emissions at the smelter, Gg. [Due to secrecy reasons, data for 2015 cannot be displayed]

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 CO₂ emissions, because it has been reached due to higher consumption of copper concentrate with a low emission factor, while the use of other materials, in particular coal, has not increased. Similar relations between emissions and metal production, characterized by rather low implied emission factor, continues until 2008 (see figure 4.12 above), when higher amounts of electronic scrap and much more modest increase in copper production cause a notable raise in CO₂ emissions. In 2012 the company has installed a new E-kaldo oven for smelting electronic scrap. This resulted in further increase in CO₂ emissions during 2012-2013 compared to previous years. In 2014 the amount of processed electronic scrap was rather low, which is seen in the emission decrease.

4.4.7.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty for activity data is estimated to ± 4 %. The uncertainty for CO₂ emission factor is estimated to ± 5 %. Time-series are considered to be consistent.

4.4.7.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

CO₂ emissions from the smelter have previously been calculated based on the amounts of coke, coal, limestone, plastics and other raw material used in the production, reported by the company together with carbon content in slag products. The emissions from coal and coke were calculated based on national thermal values (TV) and emission factors (EF). The IPCC default value was used for CO₂ emissions from limestone. In connection with the company's first reporting to EU ETS it was discovered that this method results in substantial underestimation of CO₂ emissions – about 100 kt in 2013. The reasons for the discrepancies have been

investigated, and a new method has been applied in Submission 2016. The new method is described in detail in Yaramenka & Mawdsley¹⁸⁰. The differentiation of raw materials is much wider in Submission 2016 than previously – category “plastic and other raw materials” is substituted with sub-categories “lead cable”, “metal ashes”, “concentrate”, “electrode mass”, “electronic scrap”, “less valuable electronic scrap” and “metal dust from steel production”, each with its own emission factor.

Both plants in this category report their emissions in yearly environmental reports. The reported activity data and emissions are analysed and compared to EU ETS data. More information on QC activities related to EU ETS is included in Annex 8.1.

In addition, emissions from this source are included in the cross-sectoral control tool that was developed in 2017. For more information, see section 3.2.10.

4.4.7.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations were performed in conjunction to submission 2018.

4.4.7.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.5 Non-energy products from fuels and solvent use (CRF 2.D)

4.5.1 Lubricant use (CRF 2.D.1)

4.5.1.1 SOURCE CATEGORY DESCRIPTION

In CRF 2.D.1 CO₂ 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 4.26.

Table 4.28. Summary of source category description, CRF 2.D.1, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.D.1	CO ₂	X	X		T1	D	Yes

D Default. T1 Tier 1.

¹⁸⁰ Yaramenka, K., Mawdsley, I. 2015

4.5.1.2 METHODOLOGICAL ISSUES

Amounts of lubricants per year are obtained from the Swedish Energy Agency and Statistics Sweden. Due to the delay of the data delivered by the Swedish Energy Agency, data for the latest reporting year is set equal to the previous year. Since, no obvious trend can be discerned and that no data is available for the current year this is considered to be the best available method. Data for 2016 is thus preliminary and will be updated in submission 2019. Some lubricants have a vapour pressure of 0.01 kPa or more at 293.15 K, meaning that CO₂ emissions from these lubricants are included in CRF 2.D.3_Other_Solvent_use. Therefore, these CO₂ emissions are subtracted from the amounts reported in CRF 2.D.1_Lubricants.

Emissions of CO₂ from oxidation of lubricants during use is calculated according to the following formula:

$$Emissions = \left[\frac{(SM_{TJ} \times CC_{SM} \times ODU_{SM} \times \frac{44}{12})}{1000} \right] - CO_{2D3}$$

Emissions = CO₂ 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 CO₂/C

/1000 = conversion from t to kt

CO_{2D3} = CO₂ emissions included in CRF 2.D.3_Other_Solvent_use

Factors used for CO₂ estimates are presented in Table 4.29.

Table 4.29. Parameters used when calculating emission from oxidation of lubricants

Parameter	Factor	Unit	References
CC _{SM}	20	Ton C/TJ	IPCC 2006
ODU _{SM}	20	%	IPCC 2006

The time series for CO₂ emissions and used amounts of lubricants in CRF 2.D.1 is presented in Figure 4.15.

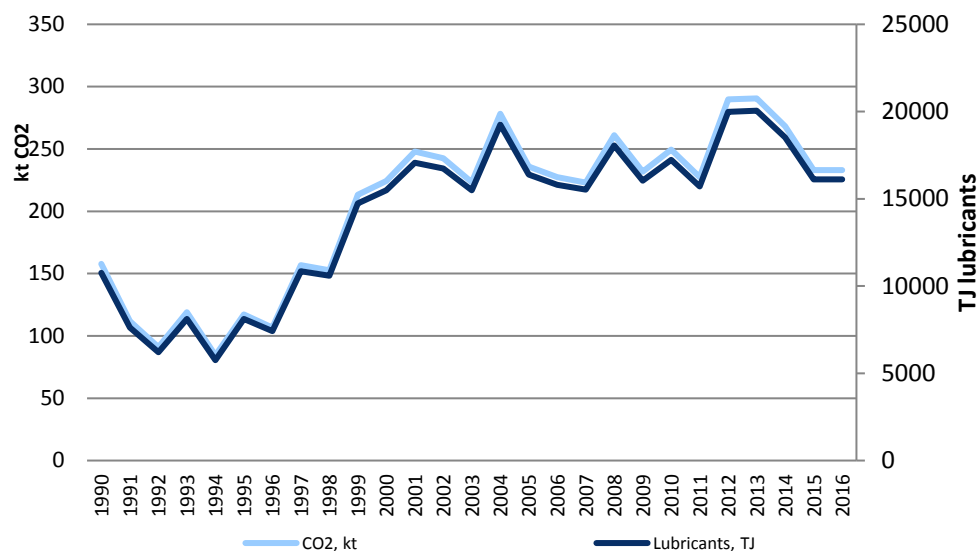


Figure 4.15. Time series for CO₂ (kt) and used amounts of lubricants (TJ) in CRF 2.D.1

4.5.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The applied methodology has been the same during all the years and is therefore considered to be consistent. The activity data is based on information from the Swedish Energy Agency (2005 – 2015) and from Statistics Sweden (1990 – 2004). Data for 2016 is preliminary and will be updated in submission 2019.

Uncertainties for CRF 2.D.1_Lubricants is in accordance with 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The total uncertainty of the EF used is set to $\pm 50\%$, and the uncertainty of activity data is set to $\pm 5\%$.

4.5.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.5.1.5 SOURCE-SPECIFIC RECALCULATIONS

As data from the Swedish Energy Agency was not available in time in submission 2018, input data for 2016 was estimated based on data for 2015 from the Swedish Chemicals Agency. In Submissions 2018, activity data for 2015 has been retrieved from the Swedish Energy Agency and were updated accordingly in the calculations. Thus the amount of lubricants consumed in 2015 decreased by 2406 TJ, resulting in a decrease of CO₂ emissions of about 39 kt. The emissions of CO₂ during 1995-2015 have been corrected due to an earlier calculation error, leading to a decrease of on average 3 kt per year.

4.5.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.5.2 Paraffin wax use (CRF 2.D.2)

4.5.2.1 SOURCE CATEGORY DESCRIPTION

Paraffin waxes are produced from crude oil and used in a number of different applications such as candles, corrugated boxes, paper coating and many others. Incineration of such products results in emissions of fossil CO₂. In CRF 2.D.2, CO₂ emissions from the use (incineration) of paraffin candles are reported, while emissions from incineration of e.g. corrugated boxes and coated paper are to be reported in the energy sector (CRF 1).

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.30.

Table 4.30. Summary of source category description, CRF 2.D.2, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.D.2	CO ₂				T1	D	Yes

D Default. T1 Tier 1.

4.5.2.2 METHODOLOGICAL ISSUES

Quantities of imported and exported candles (stearin and paraffin candles, tapers) are taken from Statistic Sweden's statistical database. Import and export data for the years 1990-2001 are considered to be uncertain, thus for these years the values for 2002 are applied. For the assumption of the fraction of paraffin candles of the total imported and exported candles, information from Norway's reporting to UNFCCC has been used (66 %), since domestic data is missing.

Amounts of imported paraffin waxes are obtained from the Product Register at the Swedish Chemicals Agency (KemI). Information on the amount of carbon in these paraffin waxes has been received from KemI. Data for 1990 - 1994 is missing in the Product Register, and for these years the value for 1995 is applied. Based on this data, CO₂ emissions are calculated using emission factors and other information presented in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. As there is a one-year lag in the data delivered by KemI, the carbon content for the latest reporting year is set equal to the previous year. This value is updated in the following submission.

The CO₂ 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 = CO₂ 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 CO₂/C

/1000 = conversion from t to kt

Factors used for the CO₂ estimates are presented in Table 4.31.

Table 4.31. Parameters used when calculating emission

Parameter	Factor	Unit	References
PF _%	66	%	National Inventory Report, Norway ¹⁸¹
VV _{Wax}	0.0402	TJ/t	Statistics Sweden
CC _L	20	Ton C/TJ	IPCC 2006
ODU _{Wax}	20	%	IPCC 2006

The time series for CO₂ emissions in CRF 2.D.2 is presented in Figure 4.16.

181

http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8108.php

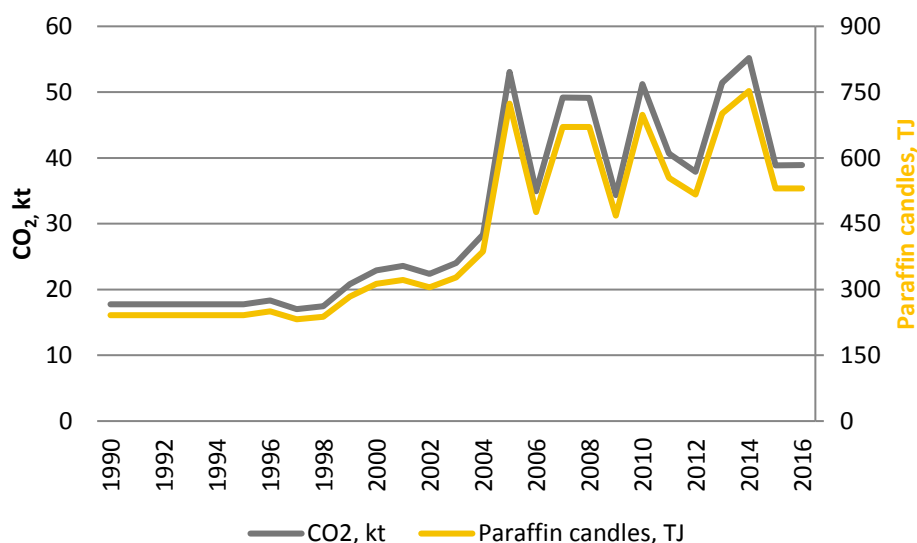


Figure 4.16. Time series for CO₂ (kt) and used amounts of paraffin candles (TJ) in CRF 2.D.2.

4.5.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The applied methodology is the same for all years and is therefore considered to be consistent. The amount of paraffin waxes for 2016 is preliminary and will be updated in submission 2019.

Uncertainties for CRF 2.D.2_Paraffin wax use is, as far as possible, in accordance with information in Chapter 3 of the 2006 IPCC Guidelines. Most of the CO₂ emissions reported in CRF 2.D.2_Paraffin wax use derives from the data on imported and exported amounts of candles. These statistics are judged to be of high quality with relatively low uncertainty. The share of reported CO₂ based on the carbon content of imported paraffin constitutes only 5-10 % of the total CO₂. 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 %.

4.5.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.5.2.5 SOURCE-SPECIFIC RECALCULATIONS

Activity data for 2015 has been updated, resulting in a decrease of about 0,03 TJ and about 0,002 kt of CO₂ emissions.

4.5.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.5.3 Other (CRF 2.D.3)

4.5.3.1 SOURCE CATEGORY DESCRIPTION

In this source category, emissions from asphalt roofing, road paving with asphalt and urea used as a catalyst are included. Also emissions from solvent use in chemical products, coating applications, degreasing, domestic solvents, dry cleaning, leather industry, printing, textile finishing, wood preservation and other uses are included.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.30.

Table 4.32. Summary of source category description, CRF 2.D.3, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.D.3	CO ₂	X			T1*	D*	Yes
					T3**	CS**	

D Default. CS Country Specific. T1 Tier 1. T3 Tier 3.

* Urea used as a catalyst

** Solvent and product use

4.5.3.1.1 Asphalt roofing

Since the end of the 1990's there have only been two companies in Sweden producing asphalt-saturated felt. Production and emission data provided by the manufacturers have been used for developing emission factors for estimations of the NMVOC emissions. Since Submission 2016 CO emissions have been estimated and reported. Emissions from asphalt roofing are reported in 2D3 Road paving with asphalt together with emissions from road paving with asphalt due to confidentially reasons.

4.5.3.1.2 Road paving with asphalt

Large changes have occurred in asphalt paving technology over the last decade, with a gradual change towards use of water-based emulsions instead of solvent-containing bitumen solutions. Industry representatives estimated that the naphtha content in the solutions used for road paving varied within the interval 17- 50 % during 2002-2014. In this inventory, only NMVOC emitted in the process of paving the roads is included. Emissions from road paving with asphalt are reported together with emissions from asphalt roofing due to confidentially reasons.

4.5.3.1.3 Urea used as a catalyst

Urea is used as a reducing agent in some types of NO_x reducing catalysts. These kind of catalysts are used in the transport sector, e.g. in trucks, passenger cars and ships, but also in stationary combustion plants. The increased use later years are mainly a consequence of increased use in heavy duty road vehicles since catalysts

have been more or less necessary to comply with the latest emission standards (Euro V and later). When reacting with the nitrogen oxides and oxygen at the catalyst surface the carbon from the urea molecule will result in CO₂ emissions.

4.5.3.1.4 Solvent use

Use of solvents and products containing solvents results in emissions of non-methane volatile organic compounds (NMVOC), which is regarded as an indirect greenhouse gas since it over a period of time will oxidise to CO₂ after being emitted to the atmosphere. The model used for estimating the CO₂ and NMVOC emissions reported in the various solvent use categories is described in more detail in Annex 3.3 and fully described in Skårman et al., 2016¹⁸².

Emission estimates reported for solvent use in CRF 2.D.3 include emissions from the source groups “Domestic solvent use” (all domestic use except use of coatings), “Coating applications” (industrial coating, domestic coating, non-industrial coating), “Degreasing” (use of degreasing in industry), “Dry cleaning” (non-domestic dry cleaning), “Chemical product use” (vehicle industry, rubber industry, paint industry, textile industry, leather industry), “Printing” (printing industry) and “Other solvent and product use” (all other use of solvents).

Emissions of CO₂ from solvents and products containing solvents have decreased by 38 % from 213 kt CO₂ in 1990 to 133 kt CO₂ in 2016 (see Figure 4.17). This can largely be explained by the reduced use of solvents in coating application due to a shift to water-based paints.

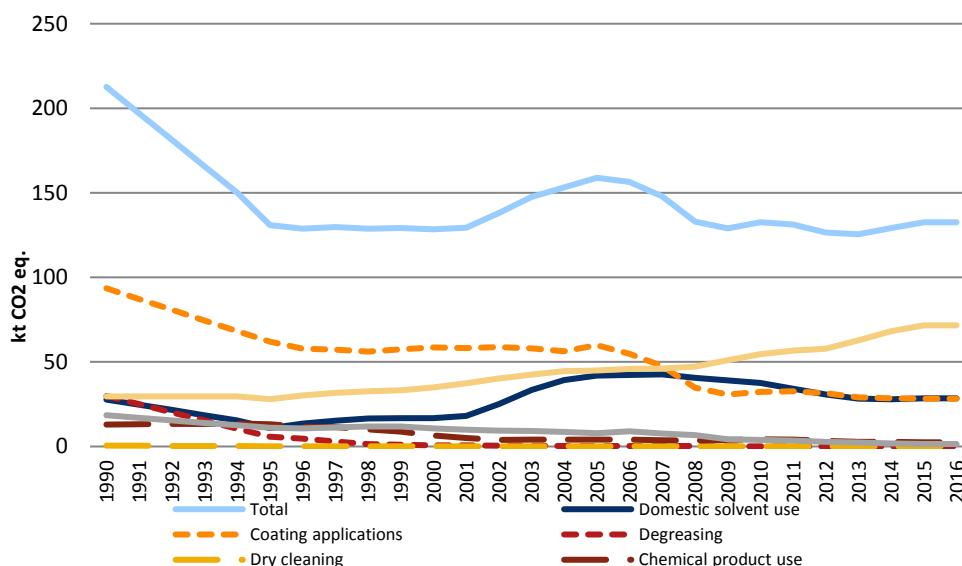


Figure 4.17. Total CO₂ emissions from the different solvent and other product use sub-categories.

¹⁸² Skårman et al., 2016. Swedish method for estimating emissions from Solvent Use. Further development of the calculation model. SMED report 192.

CO₂ emissions from coating applications have decreased by almost 70 % from 94 kt CO₂ in 1990 to 28 kt CO₂ in 2016. The largest source of CO₂ from solvents reported in CRF 2.D.3 is, in later years, “Other product and solvent use”. In this sub-sector an increase of emitted CO₂ from 1990 (30 kt CO₂) to 2016 (72 kt CO₂) can be observed.

4.5.3.2 METHODOLOGICAL ISSUES

4.5.3.2.1 *Asphalt roofing*

Data on the total Swedish production of asphalt-saturated felt was provided by the producing companies. Emission factors for asphalt roofing manufacture are presented in EMEP/CORINAIR Emission Inventory Guidebook.¹⁸³ These are based on studies performed during the 1970s in the USA and presented by EPA.¹⁸⁴ As stated in the guidebook, the level of uncertainty regarding the suggested emission factors is high, and it is recommended that better factors should be developed and used.

After contact with the industry, emission factors based on measurements and calculations made by the manufacturers were developed for estimating the NMVOC emissions from the Swedish production of asphalt-saturated felt.

The NMVOC emissions from the production of asphalt-saturated felt originate from the felt saturation and coating processes. In submission 2018 new information and measurements from both companies were presented leading to new calculations of NMVOC emissions for the whole time series. The new information also showed that no NMVOC emissions came from leakage from the asphalt storage tanks. The NMVOC emissions, 1990-2008, for one company are calculated by an emission factor based on measurements in 2009. The NMVOC emissions for 2009-2016 are based on measurements. For the other company the NMVOC emissions, 1990-2015, are calculated by an emission factor based on the measurements in 2016. However, emissions from asphalt roofing are reported in 2D3 Road paving with asphalt due to confidentially reasons.

4.5.3.2.2 *Road paving with asphalt*

Estimates for the early 1990s are taken from investigations and inventories made in the early 1990's. Data for the years 2002 – 2013 has been calculated based on information from the asphalt producers on the average amount of solvent (naphtha) in the mixtures used for road paving. The producers have also provided figures on the total amount of road paving mixtures delivered in Sweden. It is assumed that all solvents in the solvent-based bitumen are emitted when used. Emissions of NMVOC reported for the years in mid- and late 1990's were interpolated. In the

¹⁸³ EMEP/CORINAIR Emission Inventory Guidebook: http://reports.eea.eu.int/EMEP_CORINAIR4/en

¹⁸⁴ Shrager, Brian and Marinshaw, Richard. 1994. Emission Factor Documentation for AP-42, Section 11.2, Asphalt Roofing, Final Report. For U.S. Environmental Protection Agency, Office for Air Quality Planning and Standards, Emission Inventory Branch. MRI Project No. 4601-01.

calculations no emissions from imported solvent-based bitumen are used. The amount of imported solvent-based bitumen is most likely very small. In 2005 the emission of NMVOC was very high due to the fact that a heavy storm ruined many roads in southern Sweden. These roads needed to be restored quickly and solvent-based bitumen was used for this purpose. Due to the lack of producers' data emissions for 2014, 2015 and 2016 are estimated based on the implied emission factor – NMVOC emissions per ton asphalt – calculated with asphalt statistics¹⁸⁵ and emissions in 2013. Since data regarding the total amount of road paving mixtures delivered in Sweden is only available with a lag of one year, production data and emissions for 2015 are updated. As for 2016, activity data has been set equal to 2015 and will be updated in Submission 2019.

4.5.3.2.3 *Urea used as a catalyst*

There is no production of urea in Sweden, meaning that all used urea is imported. For estimation of CO₂ emissions from urea used in catalysts the net imports is used as activity data. Data is taken from the Product Register at the Swedish Chemical Agency, where 100 % pure urea for use in catalysts is specified as a category. The emissions are calculated with equation 3.2.2 presented in section 3.2.1.1 of the mobile combustion chapter in the Energy sector in 2006 IPCC Guidelines, based on the assumption of purity of 100%. No data is available prior 1995 and due to the fact that activity data for the last year is not provided in sufficient time, activity data and CO₂ emission for 2016 is estimated with data from 2015. CO₂ from the urea use is calculated in accordance with 2006 IPCC Guidelines. The CO₂ emissions for 1990-1994 is estimated from the average CO₂ emission from 1995-1999. See Table 4.33 for activity data and calculated emissions.

¹⁸⁵ EPA, Asphalt in figures <http://www.eapa.org/promo.php?c=174> , 2016

Table 4.33. Activity data and emissions of CO₂ 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
2006	15.4	11.3
2007	17.2	12.6
2008	20.1	14.8
2009	25.1	18.4
2010	20.6	15.1
2011	20.5	15.1
2012	34.4	25.2
2013	38.3	28.1
2014	49.7	36.5
2015	51.6	37.9
2016	51.6	37.9

4.5.3.2.4 Solvent use

Activity data regarding all solvent use sub-categories for year 1995 and onwards has been obtained from the Product register at the Swedish Chemicals Agency.

The Products Register does not provide reliable data for the period 1990-1994 for most industry categories. Data from reported time series compiled in a dedicated study on NMVOC emissions carried out by SMED in 2002 (Kindbom et. al, 2004) has been used for the estimations of emissions for 1990 for most sources.

Exceptions are the emissions for 1990 for “Degreasing”, “Vehicle industry” and “Other solvent and product use”. The 1990 emissions for “Degreasing” have been calculated with activity data from the GAINS-model and emission factors from EMEP/EEA. The 1990 emissions for the “Vehicle industry” are based on the information that the number of produced vehicles was around 22 % lower in 1990 than in 1995, and this information has been used to calculate the NMVOC and CO₂ emissions for 1990. The 1990 emissions for “Other product and solvent use” are based on the correlation between GDP (gross domestic product) (Ekonomifakta, 2016) and emissions from 1995 to 2013. From known GDP for 1990 and the mathematical function for the correlation between emissions and GDP, emissions of NMVOC and CO₂ have been calculated.

The emissions for 1991-1994 have been interpolated based on the available information for 1990 and the known data for 1995.

Emission factors given in the literature, for example the EMEP/EEA guidebook (EEA, 2013), EU legislations, and other countries IIR's, have been compiled and

included in the model. The used emission factors are presented in Annex 3.3. The model has been developed in order to make it possible to test different datasets of emission factors. Two emission factors have been developed for each activity; one for solvents used as raw material and one for the remaining quantities. The emission factors for raw material have been set very low, since most of the solvents will end up in the product and will not be emitted during production.

A new emission factor for products used diluted in water has been introduced in the new model. The new emission factor is set to 0.275 and it has been calculated based on available information given in the EMEP/EEA guidebook (Domestic solvent use). In the previous estimates these products were not treated separately and consequently the emission factor of 0.95 was used also for water diluted products.

The country specific emission factors have been developed in order to adjust to the old time series 1990-2001, developed by SMED in 2002 (Kindbom et. al., 2004). However, for some activities errors have been identified in previously reported data for 1990, and consequently those emissions have been corrected. Furthermore, application techniques, available information in the environmental reports for specific industries, as well as other pathways of release (e.g. water), have been considered when developing the country specific emission factors.

Domestic solvent use

Domestic solvent use is a moderate source of CO₂ and NMVOC but increases over time. This increase, starting in 2002, is due to an increased use of the product groups washer fluid, degreasing agents, and ignition fluids. However, a decrease in emissions from the use of ignition fluids can be seen for later years.

Two different emission factors are used for domestic solvent use which are used for the whole time series:

- Diluted 0.275 (product groups that are used diluted in water)
- Not diluted 0.95 (product groups that are not used diluted in water)

The separation between diluted and not diluted products is a new approach compared to the old calculation model.

Coating applications

Coating applications is a moderate source of CO₂ and NMVOC and has decreased over time. Coating in industry is the dominating source, followed by domestic coating, and that non-industry coating is of less importance. Emissions of NMVOC and CO₂ from coating application have decreased for the whole time series from 1990. The decrease is both due to reduced use of paints containing solvents and more efficient abatement technologies as indicated in available environmental reports.

Degreasing

Degreasing within the industry is a minor source of CO₂ and NMVOC and has decreased over time. The estimates are based on abatement efficiency factors given in EMEP/EEA guidebook and the distribution between different abatement technologies has been based on information available in the GAINS-model (scenario: EGEO_Baseline_CLE) for 1995, 2000, 2005 and 2010. Emissions of both NMVOC and CO₂ have decreased from 1990, mainly due to a decreased use of degreasing products, but also a shift in technology, i.e. lower emission factors for the later years.

Dry cleaning

Dry cleaning is a minor source of CO₂ and NMVOC. The time series for emissions of NMVOC and CO₂ from dry cleaning has decreased from 1990 mainly due to less use of dilution and thinner products.

Chemical product use

Chemical product use is a minor source of CO₂ and NMVOC. The vehicle industry is the predominant source of emissions for chemical product use. The emissions are decreasing over time. The decrease during the 90's is both due to reduced solvent content in used products, as well as more efficient abatement technologies according to information available in environmental reports for the rubber and vehicle industry. The sources in Chemical product use are:

- Vehicle industry
- Rubber industry
- Paint industry
- Textile and leather industry

Printing industry

Printing industry is a minor source of CO₂ and NMVOC. A steady decrease in the emissions of NMVOC and CO₂ from 1990 depends on a reduced use of solvent products within the industry as well as a technology shift.

Other solvent and product use

Other solvent and product use is a major source of CO₂ and NMVOC and has increased over time. The increased emissions for the activity are mainly due to a greater use of the product groups preservatives, refrigerants, metal mordants/etchants and coolant agents. These products account for about 70 % of the increase.

4.5.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

4.5.3.3.1 *Asphalt roofing and Road paving with asphalt*

The time series are considered to be consistent.

4.5.3.3.2 *Urea used as a catalyst*

No activity data as net imports of urea used in catalysts is available until 1995. From 1996 and onwards the reported time series are considered to be consistent. Activity data and CO₂ emission for 2016 are estimated to be same as 2015 due to that activity data from the product register not is reported in sufficient time to be able to perform the calculations and report in a timely manner.

The total uncertainty of the EF used is set to $\pm 5\%$, and the uncertainty of activity data is set to $\pm 40\%$.

4.5.3.3.3 *Solvent use*

Reported time series are considered to be consistent, except for the last year (2015) where data for previous year (2014) has been reported. This practice has been questioned by the ERT several times. The reason for Sweden to report activity data and emissions from solvent use with a delay of one year is due to the fact that activity data from the Product Register is not provided in sufficient time data to be able to perform the calculations and report in a timely manner. Also, as emissions are calculated over a running average of three years, the two years prior to the one added to the time series are affected and will be recalculated every submission.

The uncertainty for emissions of NMVOC and CO₂ for 1990 - 1994 is $\pm 25\%$. For activity data (1995 and onwards) the uncertainty is $\pm 15\%$. The uncertainties have been discussed and assigned in co-operation with the Swedish Chemicals Agency. Uncertainty estimates for the emission factors were estimated by expert judgement. Information available in environmental reports, in the GAINS model and in the EMEP/EEA guidebook has been taken into account when developing the emission factors. The uncertainty for emissions factors is judged to be $\pm 15\%$.

The combined uncertainty is calculated according to equation 3.1 in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 1 General Guidance and Reporting, chapter 3 (IPPC, 2006) (see below).

$$U_{total} = \sqrt{U_{AD}^2 + U_{EF}^2}$$

Where U = uncertainty, AD = activity data and EF = emission factor. U_{total} represents the combined uncertainty.

4.5.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

4.5.3.4.1 *Urea used as a catalyst*

Activity data from the Product Register as net imports of urea used in catalyst has been compared with estimated national sales of urea solutions during 2010-2013 done by one of Sweden's importers of urea solutions for catalysts. The sources agree well 2010 and 2011 but in 2012 the Product Register data is significant

higher. Since data from the importer were estimates and not official data we have chosen to go with the official data from the Product Register.

CO₂ emissions from urea use in road vehicles have beside the already described method also been calculated using the default method from IPCC 2006 Guidelines, as a quality check. The IPCC 2006 method only includes urea used in road vehicles and not in ships or stationary combustion plants. The importer estimates that of total used urea in 2010 (as pure urea and not urea water based solution) 25 % were used in ships, 35 % in road vehicles and 40 % in stationary combustion plants. The estimated urea use from road vehicles according to Guidelines is about 45 % of Sweden's estimates of total used urea in 2010.

Since 2010 the share of urea used in road vehicles has increased due to more road vehicles using urea based catalysts.

4.5.3.5 SOURCE-SPECIFIC RECALCULATIONS

4.5.3.5.1 *Asphalt roofing*

Due to new information from the companies the time series for asphalt roofing have been recalculated and updated leading to a NMVOC emission decrease by on average 0.1 kt per year for the time period 1990-2015. However these emissions are reported in 2D3 Road paving with asphalt due to confidentially reasons.

4.5.3.5.2 *Road paving with asphalt*

Due to the recurring one year lag of updating of the data the reported emissions from road paving with asphalt for 2015 were updated in submission 2018. The update resulted in a NMVOC emission decrease by 0.008 kt.

4.5.3.5.3 *Urea used as a catalyst*

Due to the recurring one year lag of updating of the data from the Product Register from the Swedish Chemicals Agency the reported emissions for 2015 were updated in submission 2018. The update resulted in a CO₂ emission increase by 1.4 kt.

4.5.3.5.4 *Solvent use*

As mentioned above, emissions are calculated over a running average of three years. Hence the two years prior to the one added to the time series are affected and will be recalculated every submission. In submission 2018, data for 2015 has been obtained and the years 2013-2015 have been updated accordingly. Table 4.34 shows the differences in emissions for NMVOC and CO₂ for the years 2013-2015 between submission 2017 and submission 2018.

Table 4.34. Comparison of CO₂ and NMVOC emission data from submission 2017 and submission 2018 from solvent use.

Year	CO ₂ , (kt)		NMVOC (kt)	
	Sub17	Sub18	Sub17	Sub18
2013	122	125	58	59
2014	123	129	59	60
2015	123	133	59	61

4.5.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.6 Electronics industry (CRF 2.E)

4.6.1 Integrated circuit or semiconductor (CRF 2.E.1)

4.6.1.1 SOURCE CATEGORY DESCRIPTION

HFC, PFC and SF₆ 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 4.35.

Table 4.35. Summary of source category description, CRF 2.E.1, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.E.1	HFCs	NA	NA		T1*	D*	Yes
	PFCs	NA	NA		T1*	D*	Yes
	SF ₆	NA	NA		T1*	D*	Yes

D Default. T1 Tier 1.

* From 2005 NO

4.6.1.2 METHODOLOGICAL ISSUES

Information concerning the annually used amounts of various fluorinated substances has been provided by the company, and as far as possible been compared to information from the Products Register at the Swedish Chemicals Agency. Emissions are calculated by using the 2006 IPCC Guidelines Tier 1 method using an average expected lifetime of one year.

4.6.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Emission estimates are judged to be of good quality. The quality of activity data is usually better for the later years than for the earlier years of the inventory. The time series are calculated using the same methodology for all years and are thus consistent.

4.6.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Cross-references with the Products Register at the Swedish Chemicals Agency could not be made for the reported time series, since the level of detail in the Products Register was insufficient.

4.6.1.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.6.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.6.2 TFT Flat panel display (CRF 2.E.2)

4.6.2.1 SOURCE CATEGORY DESCRIPTION

No production of TFT flat panel displays is currently known to occur in Sweden, thus NO is reported for CRF 2.E.2.

4.6.3 Photovoltaics (CRF 2.E.3)

4.6.3.1 SOURCE CATEGORY DESCRIPTION

No production of photovoltaics occurs in Sweden, thus NO is reported for CRF 2.E.3.

4.6.4 Heat transfer liquid (CRF 2.E.4)

4.6.4.1 SOURCE CATEGORY DESCRIPTION

There are no electronic industries using FCs in Sweden, thus NO is reported for CRF 2.E.4

4.6.5 Other (CRF 2.E.5)

4.6.5.1 SOURCE CATEGORY DESCRIPTION

NO is reported for CRF 2.E.5.

4.7 Product uses as substitutes for ODS (CRF 2.F)

Use and emissions of halocarbons have increased since 1990, especially in refrigeration and air-conditioning equipment, which is the major source of halocarbon emissions in Sweden in later years. The increase in emissions up to 2009 is mainly due to increased accumulated bulk of HFC in such equipment. Since 2009, the annual amount of HFC in equipment phased-out is more or less equal to the charge added in new equipment. This leads to more or less stable amounts of HFC installed in applications. However, due to falling initial leakage factors in CRF 2.F.1.e, falling annual leakage factors in CRF 2.F.1.d, CRF 2.F.1.e and 2.F.1.f (heat pumps) and falling leakage factors at decommissioning in 2.F.2, HFC emissions have started to decrease the last few years.

The largest source in 2016 is refrigeration and airconditioning (2.F.1) and the second largest is aerosols (2.F.4), followed by foam blowing (2.F.2, XPS-foam). The remaining source, fire protection (2.F.3), is a comparatively small emitter of fluorinated greenhouse gases.

All sub-categories are covered in the estimates except solvents (2.F.5). According to the information available, solvents containing HFCs or PFCs are not used in Sweden. An overview of reported emissions in CRF 2.F are shown in Table 4.36.

Table 4.36. Overview of submitted emissions data in CRF 2.F, kt CO₂-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	4.95	NO	NO	1.43	NO	NO
1995	123	NO	NO	7.29	NO	NO
2000	578	118	6.04	24.0	NO	NO
2005	883	89.9	6.55	31.9	NO	NO
2010	926	31.0	5.65	30.2	NO	NO
2011	893	34.4	2.30	31.4	NO	NO
2012	874	32.8	2.07	30.4	NO	NO
2013	861	34.9	1.27	30.7	NO	NO
2014	844	33.3	1.05	32.4	NO	NO
2015	832	31.7	0.838	33.1	NO	NO
2016	818	31.0	0.866	33.9	NO	NO

In estimating the emissions in all subcategories, as far as possible, a national model has been used, corresponding to the IPCC Tier 2 approach. The basis for the emission estimates are the annual bulk import and export statistics of fluorinated greenhouse gases recorded in the Swedish Chemicals Agency's Products Register. However, the register does not cover all chemicals already included in products imported to or exported from Sweden (e.g. air-air heat pumps, metered dose inhalers, refrigerates trucks and lorries, cars, trucks and busses). In order to make a

complete reporting of fluorinated greenhouse gas emissions and, as far as possible, to facilitate allocation of emissions onto the IPCC source categories, additional information from various trade associations and companies are collected annually. The Swedish model, a combination of top-down and bottom-up, is schematically illustrated in Figure 4.18 below.

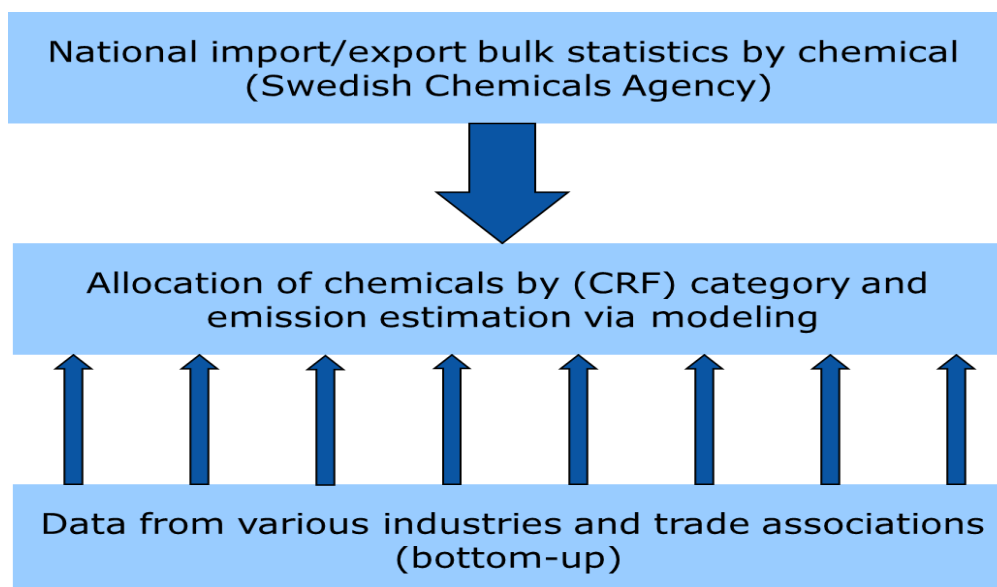


Figure 4.18. Schematic illustration of the Swedish national model used for estimation of emissions of fluorinated greenhouse gases

Based on an earlier inventory model on emissions of fluorinated greenhouse gases in Sweden covering the time period 1990-1999¹⁸⁶, the model was updated and refined e.g. concerning the calculations from the accumulated bank in 2005¹⁸⁷. The model takes into consideration changes in accumulated amounts each year resulting from additional amounts of HFC, PFC and SF₆ imported and used within the country, as well as the decline in accumulated stock caused by exports, emissions from operating systems and emissions from disposal. In 2011, a SMED study¹⁸⁸ was carried out to analyse the model's flexibility to adapt to the newly introduced international and national legislations on fluorinated greenhouse gases. In addition, the study aimed at updating model factors using available information, but also to analyse the accuracy of the estimates of e.g. emissions from disposal. The study resulted in several recalculations for the 2012 submission, but also suggestions on future improvements. In response to questions raised by the expert review team (ERT) in 2017 several changes in 2.F.1 has been performed in submission 2018. New data on amounts imported in products have been added to the model.

¹⁸⁶ Kindbom, K., Haeger Eugensson, M. and Persson, K. 2001. Kartläggning och beräkning av potentiella och faktiska utsläpp HFC, FC och SF₆ i Sverige. IVL B-1428.

¹⁸⁷ Kindbom, K. 2005. Revision of Methodology and Estimated Emissions of Fluorinated greenhouse Gases in Sweden. Report Series SMED Nr 16 2005, www.smed.se

¹⁸⁸ 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.

Emissions from commercial and industrial refrigeration and stationary air-conditioning were in previous submissions reported together in 2.F.1.a (commercial refrigeration). In submission 2018 these emissions are allocated to commercial refrigeration (2.F.1.a), industrial refrigeration (2.F.1.c) and stationary air-conditioning (2.F.1.f). Leakage rates and lifetimes have been changed from national factors to default factors from 2006 IPCC Guidelines for 2.F.1.a, 2.F.1.c and 2.F.1.f. Calculations of emissions from heat pumps, reported in 2.F.1.c, are however calculated using national emission factors. The model is described in more details in Annex 3:1.

Starting with submission 2015 the reporting is in accordance with the 2006 IPCC Guidelines. This means, for example, that the reporting include the new F-gases HFC-152, HFC-161, HFC-236cb, HCF-236ea, HFC-245fa, HFC-365mfc, C₁₀F₁₈, c-C₃F₆ and NF₃. Of the new gases only HFC-245fa is used in small amounts in Sweden. Consumption data is classified as confidential and the amounts have been summed up with another gas with a comparable GWP. Small amounts of HFC-143a with CAS number 460-73-1 and small but confidential amounts of HFC-134 are for the first time included in submission 2015. As for HFC-245fa, HFC-134 is summed up with another gas with comparable GWP.

Starting in submission 2017, amounts of gases recovered at decommissioning are reported for the first time in the CRF tables for CRF 2.F. Recovered amounts are calculated as amount in products at decommissioning minus emissions from disposal.

Due to a recurring one year lag of updating of the data from the Products Register from the Swedish Chemicals Agency, data on bulk import and export in 2015 are updated.

4.7.1 Refrigeration and air conditioning (CRF 2.F.1)

4.7.1.1 SOURCE CATEGORY DESCRIPTION

Emissions of HFCs and PFCs from heat pumps, stationary air-conditioning, mobile air-conditioning, refrigeration and freezing equipment are included in this category. Emissions of SF₆ from refrigeration and air conditioning equipment are not occurring (NO) in Sweden. The most important source of greenhouse gases to the category is emissions of HFC-134a from air-conditioning in cars, representing between 45 to 51% of the total emissions in 2.F.1 from 2006 onwards. It can be seen in Table 4.36 that emissions of HFCs and PFCs from 2.F.1 has increased from 5 kt CO₂-eq. 1990 to 818 kt CO₂-eq. 2016. The use of HFCs as refrigerants in refrigerators, freezers, heat pumps and air-conditioning equipment in vehicles (MAC) is the main reason for the large increase in emissions. In 2010 – 2016, however, the emissions of HFCs are lower compared to 2009, mainly due to reduced use of HFC-134a in MAC and in stationary refrigeration and air conditionare equipment.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.37.

Table 4.37. Summary of source category description, CRF 2.F.1, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.F.1	HFCs	X	X		T2	CS	Yes
	PFCs				T2	CS	Yes
	SF ₆	NA	NA		NO	NO	NO

CS Country Specific. T2a Tier 2a.

4.7.1.2 METHODOLOGICAL ISSUES

Input data for the calculation of emissions consists of information from various sources; the Swedish Chemicals Agency, equipment producers and importers. Table 4.38 presents values for chemical charge, lifetime and emission factors for the applications used in the Swedish inventory. They are based on information from the equipment producers and IPCC default values. Intervals given indicate changes between 1990 and the last inventory year used in the calculations.

Table 4.38. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of HFCs or PFCs used in calculations of emissions in Sweden. Intervals given indicate changes between 1990 and the last inventory year used in the calculations.

Application	Fluorinated substances	Lifetime**	Amount installed /unit, kg	Initial emissions, %	Lifetime emissions, %	Remained in product at disposal, %	Emissions at disposal, %
Stand-alone commercial applications (2.F.1.a)	HFCs	10	*	0.5	1	90	5
Medium and large commercial applications (2.F.1.a)	HFCs, PFC-218	7	*	0.5	10	90	5
Domestic refrigeration (2.F.1.b)	HFCs	20	0.1	2	1	90	5
Industrial refrigeration (2.F.1.c)	HFCs	15	*	0.5	7	90	5
Transport refrigeration (2.F.1.d)	HFCs	10	10 - 6	4.5	30 - 7	90	15
Mobile air-conditioning, lorries (2.F.1.e)	HFCs	6	1.2	1 – 0.5	15 - 10	90	15
Mobile air-conditioning, 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
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.

The information on refrigerant-related imported amounts of fluorinated gases from the Swedish Chemicals Agency's Products Register is compared to calculations made in the model, based on assumptions and information from other sources. Since not all sources are possible to trace separately in the inventory, the amounts imported to the country according to the products register is larger than calculated from the individual sources covered in the model. In order to account for the total volumes of refrigerant-related fluorinated substances, the amount of imported chemical to Sweden, derived from the Products Register, is assumed to be the correct data. From these data, the amounts of chemicals already accounted for in other applications, treated separately in the calculations, are subtracted. The resulting remainder of all refrigerant-related HFCs and PFCs from the Products Register is allocated as input data in the sub-sources Commercial applications (2.F.1.a), Industrial refrigeration (2.F.1.c) and Stationary AC (2.F.1.f). The chemicals concerned are HFC-23, HFC-32, HFC-125, HFC-134, HFC-134a, HFC-143a, HFC-152a, HFC-245fa and PFC-218 (C₃F₈). New data from the Swedish Refrigeration & Heat Pump Association show that not only air to air heat pumps are imported, pre-filled with refrigerants, but also that about 5% of all new installed liquid water, and about 30% of all air water heat pumps, are imported pre-

filled. The amounts of F-gases in imported heat pumps are thus not included in the bulk import statistics from the Swedish Chemicals Agency.

In previous submissions emissions from commercial, industrial and stationary applications were reported together in Commercial refrigeration, 2.F.1.a. As there currently is no national statistics that can be used for reallocation 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 F-gases in 2.F.1.a, 2.F.1.c and 2.F.1.f from submission 2016. The gases reported by Germany in these codes are also included in the Swedish reporting for 2.F.1.a, 2.F.1.c and 2.F.1.f. Most of the gases show similar trends in quantities used in Germany as used in Sweden in the period 1990 - 2014. Exception is HFC-143a where there is an increase in use in Sweden while it is decreasing in Germany.

According to Germany's NIR, the calculations for these three CRF codes are based mostly on models. The input for 2.F.1.a is the sales area of supermarkets or the number of stores (for low cost markets) and the quantity and type of refrigeration and freezing systems used per m² and per store (emission factor). The emission factor for 2.F.1.a is based on information from literature or by so-called "expert judgment". For 2.F.1.c, inputs to the calculations are the amount of food and beverages produced and estimation from the literature of the cooling effect required for the production of these foods and beverages. The calculations of emissions in 2.F.1.f are based on data on the number of produced and the number of installed heat pumps and emission factors.

The distribution of the F gases between 2.F.1.a, 2.F.1.c and 2.F.1.f has been developed for the period 1990 - 2014 and applied to corresponding amounts in the Swedish model. As before, it is the amount of HFCs and PFCs not allocated to other codes within 2.F that are allocated to 2.F.1.a, 2.F.1.c and 2.F.1.f.

In the UNFCCC review in September 2017, the ERT pointed out that the Swedish national leakage factors appear to be too low for emissions from installed volumes. The ERT also pointed out that the leakage factors for emissions from manufacturing were in many cases considerably higher in the Swedish F-gas model compared to other countries and to IPCC default factors. Therefore, it was important to, if possible, find new leakage factors relevant to Sweden. As mentioned earlier, there are currently no national statistics that can be used to find new national emission factors in CRF 2.F.1.a, 2.F.1.c and 2.F.1.f. Therefore, IPCC default factors (lowest value in range) have been used in the Swedish F-gas model for submission 2018, both for emissions from manufacturing and for emissions from installed amounts for 2.F.1.a, 2.F.1.c and 2.F.1.f. Calculations of emissions from heat pumps, reported in 2.F.1.c, are however calculated using national emission factors. In 2006 IPCC Guidelines emission factors given for Stand-alone Commercial Applications and for Medium & Large Commercial Refrigeration differ significantly. In order to be able to allocate quantities of F-gases within

2.F.1.a to these two types of applications, statistics from Finland has been used (data for 2000-2015). For 1990 - 1999, the distribution for 2000 has been applied.

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 (national lifetimes for heat pumps).

All factors used for emission estimates in 2.F.1.a, 2.F.1.b, 2.F.1.c, 2.F.1.d and 2.F.1.f are presented in Table 4.39, Table 4.40, Table 4.41, Table 4.42, Table 4.43, Table 4.44 and Table 4.45 below.

Table 4.39 Emission factors used (1990 – 2016) for emission estimates for Stand-alone Commercial Applications (2.F.1.a).

Year	Lifetime, years	EF Initial Emission, %	EF Operation Emission %/year	Emissions at disposal, %	Initial Charge Remaining, %
1990-2016	10	0.5	1	5	90

Table 4.40 Emission factors used (1990 – 2016) for emission estimates for Medium & Large Commercial Refrigeration (2.F.1.a).

Year	Lifetime, years	EF Initial Emission, %	EF Operation Emission %/year	Emissions at disposal, %	Initial Charge Remaining, %
1990-2016	7	0.5	10	5	90

Table 4.41 Emission factors used (1990 – 2016) for emission estimates for Domestic refrigeration (2.F.1.b).

Year	Lifetime, years	Charge, kg	EF Initial Emission, %	EF Operation Emission %/year	Emissions at disposal, %	Initial Charge Remaining, %
1990-2016	20	0.1	2	1	5	90

Table 4.42 Emission factors used (1990 – 2016) for emission estimates for Industrial refrigeration (2.F.1.c).

Year	Lifetime, years	EF Initial Emission, %	EF Operation Emission %/year	Emissions at disposal, %	Initial Charge Remaining, %
1990-2016	15	0.5	7	5	90

Table 4.43 Emission factors used (1990 – 2016) for emission estimates for Transport refrigeration (2.F.1.d).

Year	Lifetime, years	Charge, kg	EF Initial Emission, %	EF Operation Emission %/year	Emissions at disposal, %	Initial Charge Remaining, %
1990	10	10	4.5	30	15	90
1991	10	9.5	4.5	30	15	90
1992	10	9	4.5	25	15	90
1993	10	8.5	4.5	20	15	90

Year	Lifetime, years	Charge, kg	EF Initial Emission, %	EF Operation Emission %/year	Emissions at disposal, %	Initial Charge Remaining, %
1994	10	8	4.5	20	15	90
1995	10	8	4.5	15	15	90
1996	10	7.5	4.5	14	15	90
1997	10	7	4.5	13	15	90
1998	10	6.5	4.5	11.5	15	90
1999	10	6	4.5	10	15	90
2000	10	6	4.5	10	15	90
2001	10	6	4.5	10	15	90
2002	10	6	4.5	9	15	90
2003	10	6	4.5	9	15	90
2004	10	6	4.5	8	15	90
2005-2016	10	6	4.5	7	15	90

Table 4.44 Emission factors used (1990 – 2016) for emission estimates for heat pumps (2.F.1.f).

Year	Lifetime, years	Charge, kg	EF Initial Emission, %	EF Operation Emission %/year	Emissions at disposal, %	Initial Charge Remaining, %
1990	20	5	1	10	5	90
1991	20	5	1	9	5	90
1992	20	4.5	1	8	5	90
1993	20	4.5	1	7	5	90
1994	20	4	1	6	5	90
1995	20	4	1	5	5	90
1996	20	4	1	4	5	90
1997	20	3	1	3	5	90
1998	20	3	1	2	5	90
1999	20	2	1	1	5	90
2000	20	1	1	1	5	90
2001	20	1	1	1	5	90
2002	20	1	1	1	5	90
2003	20	1	1	1	5	90
2004-2016	15	1	1	1	5	90

Table 4.45 Emission factors used (1990 – 2016) for emission estimates for other stationary air-conditioning (2.F.1.f).

Year	Lifetime, years	EF Initial Emission, %	EF Operation Emission %/year	Emissions at disposal, %	Initial Charge Remaining, %
1990-2016	10	0.2	1	5	90

For emissions reported in 2.F.1.f comes around 95% of the emissions reported in 2.F. 1. f from heat pumps.

4.7.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The largest contribution to the total national emission uncertainty from this category stem from HFCs from mobile air conditioner, commercial and industrial refrigeration and from stationary air-conditioning. Based on SMED expert judgement AD and EF uncertainty are $\pm 10\%$ and $\pm 40\%$ for mobile air conditioner (2.F.1.e) and $\pm 25\%$ and $\pm 50\%$ for domestic (2.F.1.b) and transport refrigeration

(2.F.1.d). Uncertainties for emission factors for commercial refrigeration, industrial refrigeration and stationary air-conditioning (2.F.1.a, 2.F.1.c and 2.F.1.f (except for heat pumps)) are based on given default values in 2006 IPCC Guidelines and are $\pm 40\%$, $\pm 34\%$ and $\pm 36\%$, respectively. Uncertainty for AD for 2.F.1.a, 2.F.1.c and 2.F.1.f reported together, based on earlier SMED expert judgement, were set to $\pm 25\%$. This corresponds to an AD uncertainty of $\pm 40\%$ for each of the codes 2.F.1.a, 2.F.1.c and 2.F.1.f. The uncertainties are higher for early years.

The uncertainty of emission factors in 2. F. 1 has been compared with emission factor uncertainties for other countries. The comparison shows that the Swedish emission factor uncertainties for CRF 2.F.1.a, 2.F.1.c and 2.F.1.f are slightly lower compared to comparable countries such as the Netherlands and Austria (EF uncertainty $\pm 50\%$, submission 2016).

Data in the category is of varying quality, but generally considered, by expert judgment, to be of medium quality and is usually better for the later years than for the earlier years of the inventory. The time-series are calculated using the same methodology for all years and are thus considered to be consistent.

4.7.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

When data from equipment producers has been used it has been compared against IPCC default data and been judged as reasonable. Estimates have been checked with the trade association “Svenska Kyl & Värmepumpföreningen” (SKVP)¹⁸⁹, with experts at the Swedish EPA¹⁹⁰ and with the Swedish Car Recyclers Association¹⁹¹. 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 study¹⁹², based on contacts with the Swedish road vehicles manufacturers, several factors were modified for MAC 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 are presented in Table 4.46.

¹⁸⁹ Per Jonasson, Managing Director, Swedish Refrigeration & Heat Pump Association. Personal communication

¹⁹⁰ Swedish EPA . Ujfalusi, Bernekorn , and Björsell. Personal communication.

¹⁹¹ Michael Abraham, Managing Director, Swedish Car Recyclers Association. Personal communication

¹⁹² 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 4.46. Emission factors used (1990 – 2016) for emission estimates for MAC in lorries, cars and buses.

Year	Mobile air-conditioning, lorries						Mobile air-conditioning, cars						Mobile air-conditioning, buses					
	Lifetime, year	Charge, kg	EF Initial Emission, %	EF Operation Emission, %/year	Emissions at disposal, %	Initial Charge Remaining, %	Lifetime, year	Charge, kg	EF Initial Emission, %	EF Operation Emission, %/year	Emissions at disposal, %	Initial Charge Remaining, %	Lifetime, year	Charge, kg	EF Initial Emission, %	EF Operation Emission, %/year	Emissions at disposal, %	Initial Charge Remaining, %
1990	6	1.2	1	15	15	90	11	0.8	1	15	15	90	12	7	1	10	15	90
1991 – 1999, same as 1990																		
2000	6	1.2	1	12	15	90	11	0.8	1	12	15	90	12	7	1	10	15	90
2001	6	1.2	1	10	15	90	11	0.8	1	10	15	90	12	7	1	10	15	90
2002 – 2009, same as 2001																		
2010	6	1.2	0.5	10	15	90	11	0.7	0.5	7.5	15	90	12	7	0.5	10	15	90
2011-2016	6	1.2	0.5	10	15	90	11	0.7	0.5	5	15	90	12	7	0.5	10	15	90

As HFCs from mobile air-conditioning in cars is the most influential sub-source in the category, its underlying factors are compared to IPCC default values and differences are analysed (Table 4.47). 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 4.47. Comparison of IPCC default factors and Swedish factors for MAC in cars

Parameter	2006 IPCC	Swedish factors	Comment
Lifetime (y)	9 - 16	11	OK
Charge (kg)	0.5 - 1.5	0.8 - 0.7	OK
EF Operation Emission (%/year)	10 - 20	15 - 5	OK
EF Initial Emission (%)	0.2 - 0.5	1 - 0.5	OK
Initial Charge Remaining (%)	0 - 50	90	High; We assume that there is continuous maintenance and refilling of the equipment
Recovery Efficiency (%)	0 - 50	85	OK according to experts at Swedish EPA and the Swedish Car Recyclers Association

During the review of the 2015 and 2016 annual submissions the ERT requested documentation supporting the Swedish country specific emission factors used for estimates of emissions from disposal in CRF 2.F.1. The documents “Letter to Swe

Environmental Protection Agency regarding leakage at decommissioning_Swedish Refrigeration & Heat Pump Association.pdf” and “Swedish Car Recyclers Association.pdf” (Annex 3:6) supports the use of the existing national factors in the Swedish GHG inventory, in line with the requirements of the 2006 IPCC Guidelines. The national factors are based on information from the Swedish Refrigerants Code of Best Practices (“Svensk Kylnorm”) and national expert judgments from the relevant business associations (the Swedish Refrigeration & Heat Pump Association and the Swedish Car Recyclers Association). The documents are signed by the Managing Director of the Swedish Refrigeration & Heat Pump Association and the Managing Director of the Swedish Car Recyclers Association.

4.7.1.5 SOURCE-SPECIFIC RECALCULATIONS

General: Due to a recurring one year lag in the updating of the data from the Products Register from the Swedish Chemicals Agency, data on bulk import and export in 2015 were updated.

Beside this update many changes of emission estimates have been done for submission 2018. This includes:

- adding of amounts imported in products 1990-2015,
- reallocations and changes of lifetimes and leakage factors in 2.F.1.a, 2.F.1.c and 2.F.1.f, 1990-2015,
- update of number of lorries built in Sweden, 2011-2015,
- update of number of busses built in Sweden, 2011-2015,
- update of number of heat pumps imported to Sweden, 1990-2015,
- addition of registered fridge- and freeze lorries, 1990 – 2015 (only fridge- and freeze trailers were included earlier)

Comparison of reported emissions in CRF 2.F.1 in submission 2017 and 2018 is presented in Table 4.48.

Table 4.48. Comparison of reported emissions in CRF 2.F.1 in submission 2017 and 2018, kton CO₂-eq.

Year	Submission 2017	Submission 2018
1990	3	5
1991	6	8
1992	9	9
1993	35	27
1994	83	68
1995	142	123
1996	214	199
1997	264	271
1998	330	360
1999	419	477
2000	485	578
2001	538	653
2002	602	734
2003	660	800
2004	708	850
2005	754	883
2006	807	910
2007	851	929
2008	883	942
2009	903	949
2010	886	926
2011	850	893
2012	807	874
2013	773	861
2014	745	844
2015	711	832

4.7.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.7.2 Foam blowing agents (CRF 2.F.2)

4.7.2.1 SOURCE CATEGORY DESCRIPTION

This category consists of HFCs emissions from production and use of XPS foam in Sweden. Emissions of PFCs and SF₆ from foam blowing are reported as not occurring (NO). Emissions of HFCs peaked in year 2000 and have since then decreased due to reduced leakage during manufacturing, according to data from the manufacturer.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.49.

Table 4.49. Summary of source category description, CRF 2.F.2, according to approach 1.

CRF	Gas	Key Category Assessment 2016, 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.

4.7.2.2 METHODOLOGICAL ISSUES

Data is obtained from the producer on the used amount of HFC-134a and HFC-152a, emissions at production as well as the exported amount of chemicals in products each year. The use of HFCs in this application started in 1996. The company has also provided algorithms to calculate leakage of HFC-134a and HFC-152a during the product lifetime (Table 4.50). According to the information provided by the manufacturing company the HFC-134a remains in products for a very long time, while all HFC-152a is emitted during the first 10 years. Since 2008 no HFC-134a is used during manufacturing of XPS foam in Sweden. Thus, the reported emissions of HFC-134a from 2008 represent only emissions from stocks and disposal.

Table 4.50. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of HFCs used in calculations of emissions in Sweden. Intervals given indicate changes between 1996 and the last inventory year used in the calculations.

Application	Foam blowing (XPS)
Fluorinated substances	HFCs
Lifetime**	> 12
Amount installed /unit, kg	*
Emissions at manufacturing, %	46 - 35
Emissions per year during use	Declining
Remained in product at disposal	\$
Emissions at disposal, %	<76***

* Top-down calculations

** Lifetime means the average expected lifetime of a product, not the designed technical lifetime from its first commissioning.

*** Based on remaining HFC in products at disposal after 12 years. 2008 is the first year for emissions at disposal in Sweden.

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

The basis for the calculation is the amount of HFC-134a and HFC-152a that is introduced into products used in Sweden, and subsequently leaked from the products. Beside annual losses from products over time, the reported Swedish emissions in the CRF tables contain emissions from manufacturing.

The ratio of HFC-134a to HFC-152a in products in Sweden has not been constant over the years. This means that since expected leakage rates are very different for

the two chemicals, the resulting annual emissions from products varies according to chemical composition and product age in the national method.

4.7.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The quality of activity data, such as amount of chemical used in applications, is usually better for the later years than for the earlier years of the inventory. Data from the manufacturers is considered to be complete and cover all sources of HFC emissions in Sweden. The time series are calculated using the same methodology for all years and are thus consistent.

4.7.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The current calculation method provided by the company, used for reporting of emissions, has been compared to the Tier 2a method given in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

The leakage factors (year 1 to 15) in the national method are in Table 4.51 compared to the default factors from 2006 IPCC Guidelines.

Table 4.51. Leakage factor used for the first 15 years in the national method compared to 2006 IPCC Guidelines Table 7.6.

National method		2006 IPCC Guidelines, Table 7.6		
Year	Leakage factor	Leakage factor	Leakage factor	Leakage factor
	HFC-134a	HFC-152a	HFC-134a	HFC-152a
1	9.5 %	66 %	25 %	50 %
2	3.9 %	20 %	0.56 %	13 %
3	3.0 %	8.3 %	0.56 %	9.4 %
4	2.5 %	3.5 %	0.55 %	7.0 %
5	2.2 %	1.5 %	0.55 %	5.3 %
6	2.0 %	0.62 %	0.55 %	4.0 %
7	1.9 %	0.26 %	0.54 %	3.0 %
8	1.7 %	0.11 %	0.54 %	2.2 %
9	1.6 %	0.050 %	0.53 %	1.7 %
10	1.5 %	0.020 %	0.53 %	1.3 %
11	1.5 %	0 %	0.53 %	0.94 %
12	1.4 %	0 %	0.52 %	0.70 %
13	1.3 %	0 %	0.52 %	0.53 %
14	1.3 %	0 %	0.51 %	0.40 %
15	1.2 %	0 %	0.51 %	0.30 %

The calculated emissions according to the national method and to the method described in 2006 IPCC Guidelines are presented in Table 4.52. The product life time of XPS-foam is very long, several decades, and the total amounts of emitted chemical are in the long run comparable.

Table 4.52. Emissions of HFC-134a and HFC-152a from stock from the national method compared to calculated emissions using leakage factors in 2006 IPCC Guidelines.

Year	Emissions of HFC-134a and HFC-152a according to the national method (kt CO ₂ -eq.)	Emissions of HFC-134a and HFC-152a according to 2006 IPCC Guidelines (kt CO ₂ -eq.)
1996	12	12
1997	81	88
1998	88	98
1999	106	118
2000	118	124
2001	116	120
2002	110	113
2003	101	101
2004	111	109
2005	90	86
2006	75	67
2007	53	42
2008	48	36
2009	38	28
2010	31	23
2011	34	26
2012	33	24
2013	35	27
2014	33	26
2015	32	32
2016	31	25
SUM 1996 - 2016	1376	1323

4.7.2.5 SOURCE-SPECIFIC RECALCULATIONS

Update of export in product (HFC-152a) for 2015 (+ ~2 kton CO₂-eq)

4.7.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.7.3 Fire protection (CRF 2.F.3)

4.7.3.1 SOURCE CATEGORY DESCRIPTION

HFC may be used as extinguishing medium in fixed fire extinguishing systems. In Sweden, emissions of HFCs from fire extinguishers are reported since 1997. Emissions of PFCs and SF₆ 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 4.53.

Table 4.53. Summary of source category description, CRF 2.F.3, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.F.3	HFCs				T1a	CS	Yes
	PFCs	NA	NA		NO	NO	NO
	SF ₆	NA	NA		NO	NO	NO

CS Country Specific. T1a Tier 1a

4.7.3.2 METHODOLOGICAL ISSUES

All imports of HFCs to be installed in fire extinguishers are registered at the Swedish Chemicals Agency. From 2001, the use of HFC-227ea in fire extinguishers has been introduced in Sweden. Data has been obtained from the companies supplying such systems (Table 4.54).

Table 4.54. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of HFCs used in calculations of emissions in Sweden

Application	Fire extinguishing
Fluorinated substances	HFCs
Lifetime*	10
Amount installed /unit, kg	**
Emissions at manufacturing, %	0.5
Emissions per year during use, %	2 / 0.1***
Remained in product at disposal, %	95
Emissions at disposal, %	5

* Lifetime means the average expected lifetime of a product, not the designed technical lifetime from its first commissioning.

** Top-down calculations

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

4.7.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties are mainly associated with the exported amounts, which are relatively large.

The time series are calculated using the same methodology for all years and are thus consistent.

4.7.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

HFC's in fire protection equipment have been used in Sweden since 1997. In submissions prior to submission 2015 a "Lifetime" factor of 30 years was used. After contact with the industry it became evident that this factor was too high¹⁹³.

¹⁹³ 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.

The information from the industry revealed that there are regulated controls of the cylinders in fire protection systems in Sweden. The cylinders have to be controlled by an accredited personnel every 10th year. Because of this new information, the factor for "Lifetime" has been changed from 30 to 10 years. The industry also suggested a change of the "Emissions at disposal" factor from 1 % to 5 %.

4.7.3.5 SOURCE-SPECIFIC RECALCULATIONS

Due to the recurring one year lag in the updating of the data from the Products Register from the Swedish Chemicals Agency, data on bulk import and export in 2014 were updated.

Update of import figures for 2014 and 2015 (- 0.01 and -0.02 kton CO₂-eq, respectively)

4.7.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.7.4 Aerosols (CRF 2.F.4)

4.7.4.1 SOURCE CATEGORY DESCRIPTION

HFC may be used as propellant gas in aerosols, but also as the actual product e.g. in cleaning sprays. In asthma medication inhalers, HFC-134a (norflurane) and HFC-227ea (apaflurane) are sometimes used as propellant gases. Emissions of PFCs and SF₆ 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 4.55.

Table 4.55. Summary of source category description, CRF 2.F.4, according to approach 1.

CRF	Gas	Key Category Assessment 2016, 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.

4.7.4.2 METHODOLOGICAL ISSUES

Emission estimates cover technical aerosols as well as metered dose inhalers. The estimates consist of emissions from production of technical aerosols at one facility, and emissions from the use of imported technical aerosols and metered dose inhalers containing HFCs. The contribution from metered dose inhalers is relatively small, but has increased in later years.

The aerosol manufacturer provided information on the used amount of HFC-134a as well as emissions from production, and exported amounts of HFC-134a in

products. Table 4.56 presents the assumptions on product lifetime, emissions at manufacturing and disposal as well as remaining HFC in product at disposal. Due to technical issues in CRF reporter, yearly emissions from disposal are reported together with emissions from the use of aerosols.

For metered dose inhalers, statistics on the numbers of sold inhalers was, for the years 1990 until 2008, received from the Swedish retailer for medical products, Apoteket. From 2009 - 2013 the corresponding information has been received from the company Pharmacy Service AB and from 2014 onwards, the data are received from Swedish eHealth Agency. Information concerning the content of HFC in the inhalers is provided by the Swedish Medical Products Agency.

Table 4.56. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of HFCs used in calculations of emissions in Sweden

Application	Aerosols/ MDI
Fluorinated substances	HFCs
Lifetime*	2
Amount installed /unit, kg	**
Emissions at manufacturing, %	NA
Emissions per year during use, %	50
Remained in product at disposal, %	50
Emissions at disposal, %	100

* Lifetime means the average expected lifetime of a product, not the designed technical lifetime from its first commissioning.

** Top-down calculations

4.7.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The largest uncertainty in this source concerns the amount of HFC-134a imported in technical aerosols for which there are no statistics available. In 2000, a survey was sent to approximately 10 importers of technical aerosol products. The majority of the importers responded to the survey, and provided estimates on the amount of HFC imported each year in technical aerosols. In 2004 an update on estimated import was made for the whole time series, in cooperation with the Swedish Aerosol Association (Svenska Aerosolföreningen). The information from this survey was used to update the time series up to year 2003 at that time. The activity data also includes estimates of e.g. Novelty aerosols.

The quality of activity data, such as figures of estimated emissions or amount of fluid used in different applications is usually better for the later years than for the earlier years of the inventory. The time series are calculated using the same methodology for all years and are thus consistent.

4.7.4.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Data and information from the Products Register, hosted by the Swedish Chemicals Agency, could not be used directly for validation and reporting purposes due to confidentiality.

4.7.4.5 SOURCE-SPECIFIC RECALCULATIONS

Minor corrections of AD for metered dose inhalers have led to changes of reported emissions for 2014 and 2015 with less than 1 kg CO₂ eq yearly.

4.7.4.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.7.5 Solvents (CRF 2.F.5)

Efforts have been made to find national information concerning this sub-category. For instance potential users of solvents containing HFCs or PFCs were contacted. No information indicating that these kinds of solvents are used in Sweden was found. Emissions from solvents are consequently reported as NO, not occurring.

4.7.6 Other applications (CRF 2.F.6)

No other applications are covered in the Swedish inventory.

4.8 Other product manufacture and use (CRF 2.G)

4.8.1 Electrical equipment (CRF 2.G.1)

4.8.1.1 SOURCE CATEGORY DESCRIPTION

In Sweden, emissions of SF₆ from electrical equipment consist of two different parts, emissions from the production of gas-insulated switchgear (GIS), and emissions from SF₆ installed in distribution systems. Emissions of HFCs and PFCs are not occurring (NO) for this category.

The use of SF₆ for insulation purposes in operating power systems started to occur in Sweden in the middle of the 1970s¹⁹⁴. The end-of-life factor of 35 years indicates that SF₆ containing equipment now is beginning to be replaced. Therefore the Swedish reporting of SF₆ from Electrical Equipment (2.G.1) also include emissions from disposal.

¹⁹⁴ Matz Tapper, Swedenergy. Personal communication.

Swedenergy has estimated the SF₆ content in the operating Swedish power system from 1975 until 1990. Based on this information, estimates of SF₆ emissions from disposal are made¹⁹⁵.

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 4.57.

Table 4.57. Summary of source category description, CRF 2.G.1, according to approach 1.

CRF	Gas	Key Category Assessment 2016, 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	CS	Yes
					T3	PS	

CS Country Specific. PS Plant-specific. T2 Tier 2. T3 Tier 3

* Distribution

** Production

In submission 2017, amounts of gases recovered at decommissioning are reported for the first time in the CRF tables for CRF 2.G. Recovered amounts are calculated as amount in products at decommissioning minus emissions from disposal.

4.8.1.2 METHODOLOGICAL ISSUES

The larger part of annual SF₆ emissions in earlier years originated from the manufacture of GIS (Table 4.50), where emissions in 1995 and 1997 peak due to a leaking valve in 1995 and to rebuilding and accidental leakages in 1997. The SF₆ emissions from production have decreased in later years due to measures taken at the production facility. These estimates, obtained from industry, are of medium to high quality, with better quality in later years.

For the early 1990s, assumptions on the emitted amounts of SF₆ from GIS manufacture were made in cooperation with industry. Industry has also provided information concerning the used amount of SF₆ for GIS manufacture (Table 4.58), as well as the share of products that are exported from the country, which often exceeds 90 % of the production.

¹⁹⁵ 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 4.58. 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.

In Table 4.59 intervals given indicate changes between 1990 and the last inventory year used in the calculations. Emissions from installed amounts of SF₆ for insulation purposes in operating systems have previously contributed less to the annual emissions. In 2001-2002, a questionnaire was sent out to power companies from the trade association Swedenergy¹⁹⁶ (Svensk Energi) asking for the installed amounts of SF₆ in operating equipment, and the replaced amounts of SF₆ during service. The results showed an installed accumulated amount of approximately 80 t SF₆ and an annual leakage rate of 0.6 % (equals the amount replaced from the questionnaire) and these were used as input data in the inventory. For later years, data on replaced amounts of SF₆ in operating systems results in a calculated annual leakage rate of 0.5 % (Swedenergy and power distribution companies).

Table 4.59. Calculated emissions and accumulated stock of SF₆ for electrical equipment

Year	Accumulated stock, t	Annual losses SF ₆ , t	Emissions from GIS manufacture SF ₆ , t	Emissions from disposal SF ₆ , t	Total emissions SF ₆ , t
1990	60	0.36	3.0	NO	3.4
1995	70	0.42	3.5	NO	3.9
2000	101	0.61	0.68	NO	1.3
2010	184	0.92	0.30	0.086	1.3
2011	199	0.99	0.21	0.086	1.3
2012	206	1.0	0.10	0.086	1.2
2013	225	1.1	0.10	0.086	1.3
2014	227	1.1	0.06	0.086	1.3
2015	229	1.1	0.30	0.086	1.5
2016	250	1.3	0.34	0.086	1.7

In accordance with the methodology described for deriving amounts of refrigerant chemicals not accounted for, the same procedure was adopted for SF₆. When comparing the amounts of SF₆ accounted for in various applications with data from the Products Register, a rather large annual volume of SF₆ remains unallocated (between 10 and 35 %). Sources of SF₆ emissions that are covered in the

¹⁹⁶ Swedenergy. Matz Tapper. Personal communication.

calculations are the use in semi-conductor manufacture, in production of sound-proof windows, in magnesium foundries, in the production of gas-insulated switchgear and as insulation in electrical equipment. Information from the Products Register did not indicate that any areas of use have not been covered and are missing from the calculations.

For all sources, except as insulation in electrical equipment, the levels of annual SF₆ consumption is comparatively easy to estimate with some confidence since there are few end-users. It was thus concluded that the amounts of SF₆ not already accounted for elsewhere, most reasonably should be allocated to the electrical equipment source. However, even though information concerning SF₆ in electrical equipment is more difficult to judge concerning completeness, indications from end-users are that the difference between imported amounts according to the Products Register and those already accounted for in the calculations seem too large to annually be consumed for electrical insulation. One explanation to the difference could be that there is an underreporting of exported SF₆ from the Products Register, where no export at all of SF₆ is registered.

As the question of the remaining amount of SF₆ at present could not be unambiguously solved, the unaccounted SF₆ from the Products Register was allocated to be used as electrical insulation (accumulated stock).

4.8.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The quality of activity data is usually better for the later years than for the earlier years of the inventory. The time series are calculated using the same methodology for all years and are thus consistent.

4.8.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.8.1.5 SOURCE-SPECIFIC RECALCULATIONS

Due to the recurring one year lag in the updating of the data from the Products Register from the Swedish Chemicals Agency, data on bulk import and export in 2015 were updated. Also, due to new information from the GIS manufacturer, emissions for 2013-2015 are updated (+0.077, +0.27 and +0.41 kton CO₂-eq, respectively).

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 SF₆ and PFCs from other product use (CRF 2.G.2)

4.8.2.1 SOURCE CATEGORY DESCRIPTION

The estimated emissions from the use of SF₆ and PFC-218 in jogging shoes and SF₆ in sound-proof windows are reported in CRF 2.G.2. No production of SF₆ or PFC containing shoes has ever occurred in Sweden; hence reported emissions only represent emissions from disposal. Since 2008 SF₆ has not been used in production of sound-proof windows.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.60.

Table 4.60. Summary of source category description, CRF 2.G.2, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.G.2	HFCs	NA	NA		NO	NO	NO
	PFCs				T1*	D*	Yes
	SF ₆				T1*	D*	Yes
					T2**	PS**	
					T2***	CS***	

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

* Jogging shoes

** Sound-proof windows, manufacturing

*** Sound-proof windows, stock

4.8.2.2 METHODOLOGICAL ISSUES

For jogging shoes, a more or less rough estimate has been made. It has not been possible to obtain any national data, so a Norwegian estimate was scaled to the Swedish population.¹⁹⁷ According to the results from a study performed in early 2004¹⁹⁸ a phasing out of SF₆ and replacement with PFC-218 was started in 2003. The lifetime for shoes is, in accordance with 2006 IPCC Guidelines, set to 3 years in the national model (Table 4.58).

Manufacturers of windows have provided data on the amount of SF₆ used in the manufacture of barrier gas windows. The manufacturers have also provided estimates of the share of SF₆ 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.

¹⁹⁷ Weholt, Ø. 1999. Materialstrømsanalyse av SF₆. Beregning av potensielt og faktisk utslipp over tid

¹⁹⁸ Kindbom, K. and Skårman, T. 2004. Nya scenarier för fluorerade växthusgaser. U952, Swedish EPA.

In Table 4.61, intervals given indicate changes between 1990 and the last inventory year used in the calculations. With an assumed lifetime of 30 years for barrier gas windows, emissions of SF₆ from disposal will be needed to estimate within a few years.

Table 4.61. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of PFCs or SF₆, used in calculations of emissions in Sweden.

Application	Sound proof windows	Jogging shoes
Fluorinated substances	SF ₆	SF ₆ , PFC-218
Lifetime*	30	3
Amount installed / unit, kg	**	**
Emissions at manufacturing, %	5-50 ^{##}	NO
Emissions per year during usage, %	1	NO
Remained in product at disposal, %	100	100
Emissions at disposal, %	NO	100

* Lifetime means the average expected lifetime of a product, not the designed technical lifetime from its first commissioning.

** Top-down calculations

^{##} Different emissions at different production units.

4.8.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The quality of activity data is usually better for the later years than for the earlier years of the inventory. The time series are calculated using the same methodology for all years and are thus consistent.

4.8.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.8.2.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.8.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.8.3 N₂O from product use (CRF 2.G.3)

4.8.3.1 SOURCE CATEGORY DESCRIPTION

In CRF 2.G.3 sold amounts and use of N₂O are reported. Due to confidentiality, data for 2.G.3.a – Use of N₂O for Medical Applications and 2.G.3.b – N₂O from Propellant for Pressure and Aerosol Products cannot be reported separately. All emissions are therefore reported in 2.G.3. N₂O for use in fire extinguishers is not occurring in Sweden and thus reported as NO.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), are presented in Table 4.62.

Table 4.62 Summary of source category description, CRF 2.G.3, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.G.3	N ₂ O	X			T1	CS	Yes

CS Country Specific. T1 Tier 1

4.8.3.2 METHODOLOGICAL ISSUES

There are two companies in Sweden selling N₂O 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 - 2015). The time series of use of N₂O in Sweden are reported in N₂O from product uses - 2.G.3 Other (since data for use of N₂O for Anaesthesia and use of N₂O in Aerosol cans cannot be reported separately due to confidentiality). Activity data for year 2016 is not yet official and hence Sweden has chosen to report data from 2015 also for 2016. Data for 2016 will be updated in the next submission.

4.8.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Reported time series are considered to be consistent, except for last year (2016) where data for previous year (2015) has been reported. This practice has been questioned by the ERT several times. The reason for Sweden to report activity data and emissions in CRF 2.G.3 with a delay of one year is due to the fact that activity data from the Product Register is not provided in sufficient time to be able to perform the calculations and report in a timely manner.

4.8.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.8.3.5 SOURCE-SPECIFIC RECALCULATIONS

Due to the recurring one year lag of updating the data from the Product Register from the Swedish Chemicals Agency, the reported emissions of N₂O in CRF 2.G.3 for 2015 is updated in submission 2018.

4.8.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.8.4 Tobacco smoking and use of fireworks (CRF 2.G.4)

4.8.4.1 SOURCE CATEGORY DESCRIPTION

CRF 2.G.4 includes emissions from tobacco smoking and use of fireworks.

4.8.4.2 METHODOLOGICAL ISSUES

Emissions of NO_x, SO₂, NMVOC and CO from tobacco smoking and use of fireworks are included in CRF 2.G.4. Emissions from tobacco smoking are based on activity data from official statistics on sold amounts of tobacco for the entire time series. Activity data include only “legal” purchases of tobacco products in Sweden; products that are purchased through tax-free and cross-border trading are not included. For fireworks, activity data is made up of imported and exported amounts of fireworks. No significant production of fireworks occurs in Sweden.

4.8.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The time series is consistent as the same method is used throughout.

4.8.4.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.8.4.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations were performed in conjunction to submission 2018.

4.8.4.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.9 Other product manufacture and use (CRF 2.H)

Other production covers emissions from the pulp and paper industry (2.H.1), the food and beverages industry (2.H.2) and other (2.H.3) which includes battery production, mineral wool production and quarrying and mining of minerals other than coal. Emissions of fossil CO₂ are not estimated for 2.H.1 or 2.H.2. According to the IPCC Guidelines Reference Manual, emissions of fossil CO₂ from the sector are not likely.

4.9.1 Pulp and paper (CRF 2.H.1)

4.9.1.1 SOURCE CATEGORY DESCRIPTION

The pulp and paper industry in Sweden is an important source of industrial process emissions. Emissions from approximately 45 individual pulp and paper facilities were reported before 2002. After 2002 some plants were closed down and for 2016 emissions from 37 individual pulp and paper facilities are included in reported emissions. The Kraft process (sulphate) dominates in Sweden but there are also emissions from four sulphite facilities and 10 facilities that are mainly CTMP (Chemo Thermo Mechanical Pulp) or TMP (Thermo Mechanical Pulp) facilities reported in CRF 2.H.1.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.63.

Table 4.63. Summary of source category description, CRF 2.H.1, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.H.1	CO ₂	NA	NA		NA	NA	NA
	CH ₄				CS	CS	Yes
	N ₂ O				CS	CS	Yes

CS Country Specific.

4.9.1.2 METHODOLOGICAL ISSUES

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

The Swedish definition of process emissions includes the combustion of spent cooking liquor (black liquor) which gives rise to emissions of N₂O and CH₄. The black liquor contains organic compounds and chemicals and is combusted to recover Na and S, but also to utilise the energy in the black liquor. The recovered Na and S (as Na₂CO₃ and Na₂S) are recycled and used in the process again.

The estimated CO₂ process emissions that arise as a result of the use of limestone as make-up lime are allocated in CRF 2.A.2.

4.9.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainty in activity data is ± 5 % and uncertainty in emission factors (CH₄ and N₂O) are ± 20 %.

4.9.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.9.1.5 SOURCE-SPECIFIC RECALCULATIONS

Activity data is reported for the first time in submission 2018 and presented in figure 4.19 below. The various kinds of pulp produced in Sweden are categorized into sulphate, sulphite and mechanical pulp with production of sulphate pulp dominating throughout the years.

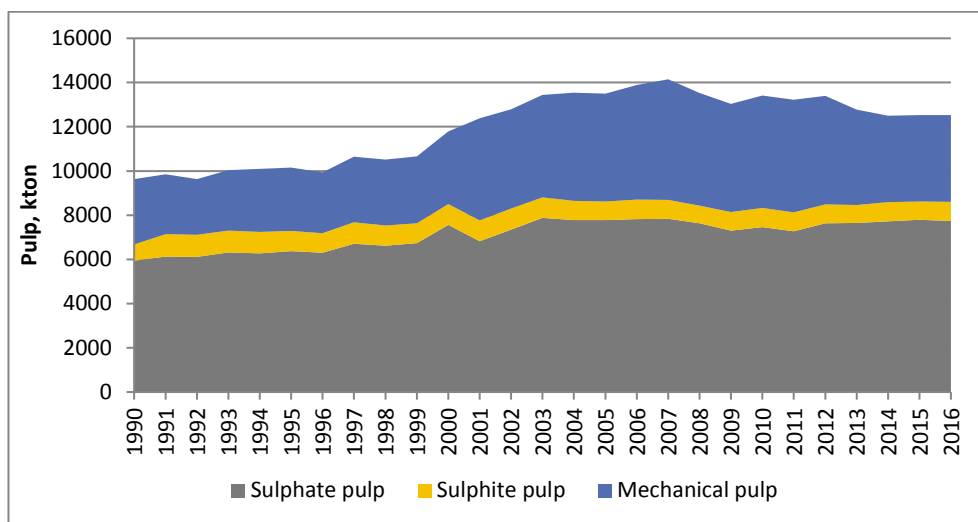


Figure 4.19. Production of pulp in Sweden 1990-2016.

Minor corrections have been performed for one plant for 2015. Emissions of NMVOC decrease therefore by about 0.1 kt whereas emissions of SO₂ and NO_x increase by less than 0.1 kt.

4.9.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.9.2 Food and drink (CRF 2.H.2)

4.9.2.1 SOURCE CATEGORY DESCRIPTION

The food and drink industry is a moderate source of NMVOC in Sweden. The industry consists of beer, wine and liquor producers, bread, sugar, yeast and margarine and solid cooking fat producers, coffee roasters and animal feed producers. Greenhouse gas emissions have not been estimated due to the lack of available methodology and data. Emissions of greenhouse gases are however considered to be insignificant.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.64.

Table 4.64. Summary of source category description, CRF 2.H.2, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.H.2	CO ₂	NA	NA		NA	NA	No, see Annex 5
	CH ₄	NA	NA		NA	NA	NA
	N ₂ O	NA	NA		NA	NA	NA

4.9.2.2 METHODOLOGICAL ISSUES

Estimates of NMVOC emissions are based on activity data from different official statistics. For wine the estimation of NMVOC emissions is based on data on sold amount¹⁹⁹ together with figures on import and export²⁰⁰. NMVOC emissions from beer production are based on the Swedish annual total production of beer²⁰¹. NMVOC emissions originating from the production of liquors, bread, sugar, yeast, margarine and solid cooking fat, coffee roasters and animal feeds are all based on statistics available at Statistics Sweden's website. For the NMVOC emission estimates, emission factors presented in Table 4.65 were used. Emissions of CO₂ are not estimated but are believed to be minor or of biogenic origin.

Table 4.65. NMVOC emission factors for the reported production activities in CRF 2.H.2 - Food and drink

Production activity	Emission factor	Unit	Reference (see footnotes)
Wine	0.8	kg/1000 litres	Fel! Bokmärket är inte definierat.
Beer	0.35	kg/1000 litres	Fel! Bokmärket är inte definierat.
Liquors	0.6	kg/1000 litres	202
Bread (sponge dough)	8	kg/Mg	Fel! Bokmärket är inte definierat.
Bread (white)	4.5	kg/Mg	Fel! Bokmärket är inte definierat.
Bread (whole meal and light rye)	3	kg/Mg	Fel! Bokmärket är inte definierat.
Bread (dark rye)	0	kg/Mg	Fel! Bokmärket är inte definierat.
Cakes	0.1	kg/Mg	Fel! Bokmärket är inte definierat.
Biscuits	0.1	kg/Mg	Fel! Bokmärket är inte definierat.
Breakfast cereals	0.1	kg/Mg	Fel! Bokmärket är inte definierat.
Sugar	10	kg/Mg	Fel! Bokmärket är inte definierat.

¹⁹⁹ Systembolaget. Försäljningsstatistik. <http://www.systembolaget.se/>

²⁰⁰ Statistics Sweden. <http://www.scb.se/>

²⁰¹ Bryggeriföreningen. <http://sverigesbryggerier.se>

²⁰² Based on information from one producer, 2001

Production activity	Emission factor	Unit	Reference (see footnotes)
Yeast	18	kg/Mg	Fel! Bokmärket är inte definierat.
Margarine and solid cooking fats	10	kg/Mg	Fel! Bokmärket är inte definierat.
Coffee roasting	0.55	kg/Mg	Fel! Bokmärket är inte definierat.
Animal feed	0.1	kg/Mg	Fel! Bokmärket är inte definierat.

4.9.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The time series is consistent.

4.9.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.9.2.5 SOURCE-SPECIFIC RECALCULATIONS

Activity data, thus affecting reported NMVOC emissions, have been updated, due to new information for statistics available at Statistics Sweden's website, for:

- Bread (sponge dough): Produced amount 2015
- Bread (white): Produced amount 2008-2015
- Bread (dark rye): Produced amount 2015
- Cakes: Produced amounts 2015
- Biscuits: Produced amounts 2012-2015
- Breakfast cereals: Produced amounts 2015
- Sugar: Produced amounts 2008-2015
- Margarine and solid cooking fats: Produced amounts 2015
- Animal feed: Produced amounts for 2015
- Coffee roasting: Produced amounts 2015
- Yeast: Produced amounts 2015
- Wine spirits, beer and cider: 2013-2015

The recalculations resulted in decreased NMVOC emissions of about 0.076 kt 2015.

4.9.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.9.3 Other (CRF 2.H.3)

4.9.3.1 SOURCE CATEGORY DESCRIPTION

In CRF 2.H.3, NMVOC emissions from battery production, CO₂ and NMVOC emissions from mineral wool production and NO_x emissions from Quarrying and mining of minerals other than coal 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 4.66.

Table 4.66. Summary of source category description, CRF 2.H.3, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.H.3	CO ₂				PS	D	No, see Annex 5
	CH ₄	NA	NA	NA	NA	NA	NA
	N ₂ O	NA	NA	NA	NA	NA	NA

D Default. PS Plant-Specific.

4.9.3.1.1 *Quarrying and mining of minerals other than coal, CRF 2.H.3.a*

The only emissions reported for the non-iron ore mining and dressing are, in this submission, NO_x released from use of explosives. Estimated emissions from combustion of fuels are included in the Energy sector (CRF 1).

4.9.3.1.2 *Mineral wool, CRF 2.H.3.b*

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

4.9.3.1.3 *Battery manufacturing, CRF 2.H.3.c*

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

4.9.3.2 METHODOLOGICAL ISSUES

4.9.3.2.1 *Quarrying and mining of minerals other than coal, 2.H.3.a*

Data on NO_x emissions from use of explosives within the non-iron ore mining industry are reported 2002 – 2016, but for the years 1990 – 2001 no information is presently available. Data on NO_x emissions are collected from the companies' environmental reports to the authorities.

4.9.3.2.2 *Mineral wool production, 2.H.3.b*

CO₂ 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 CO₂ 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 CO₂ /kt slag based on that the slag contains 1 % carbon and the CO₂ emissions are calculated by using the formula:

$$\text{Emissions of CO}_2 \text{ (Mg) from use of slag} = \text{Slag (Mg)} * 0.01 * (\text{C content}) * 44/12$$

Within mineral wool production, limestone and dolomite used also cause process emissions of CO₂ which are estimated based on activity data for each type of carbonate and corresponding emission factor:

$$\text{Emissions of CO}_2 \text{ (Mg) from use of limestone and dolomite} = \text{Limestone (Mg)} * 0.97 * 44.0098 / 100.0892 + \text{Dolomite (Mg)} * 88.02 / 184.4$$

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

4.9.3.2.3 *Battery manufacture, 2.H.3.c*

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

4.9.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty of direct CO₂ emissions is set to $\pm 6\%$ and the time series is consistent.

4.9.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.9.3.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations were performed during submission 2018.

4.9.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

5 Agriculture (CRF sector 3)

5.1 Overview of sector

In the agricultural sector emissions of nitrous oxide (N₂O), methane (CH₄) and carbon dioxide (CO₂) 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 remaining holdings are growing larger. Livestock farmers predominately engage in milk production and the main crops grown in Sweden are grain and fodder crops.²⁰³ The decrease of agricultural land area has continued since Sweden joined the European Union in 1995 but the acreages of land for hay and silage have had an increasing trend. Organic farming has increased from 6 % of the arable land area in 1996 to 18 % in 2016.²⁰⁴

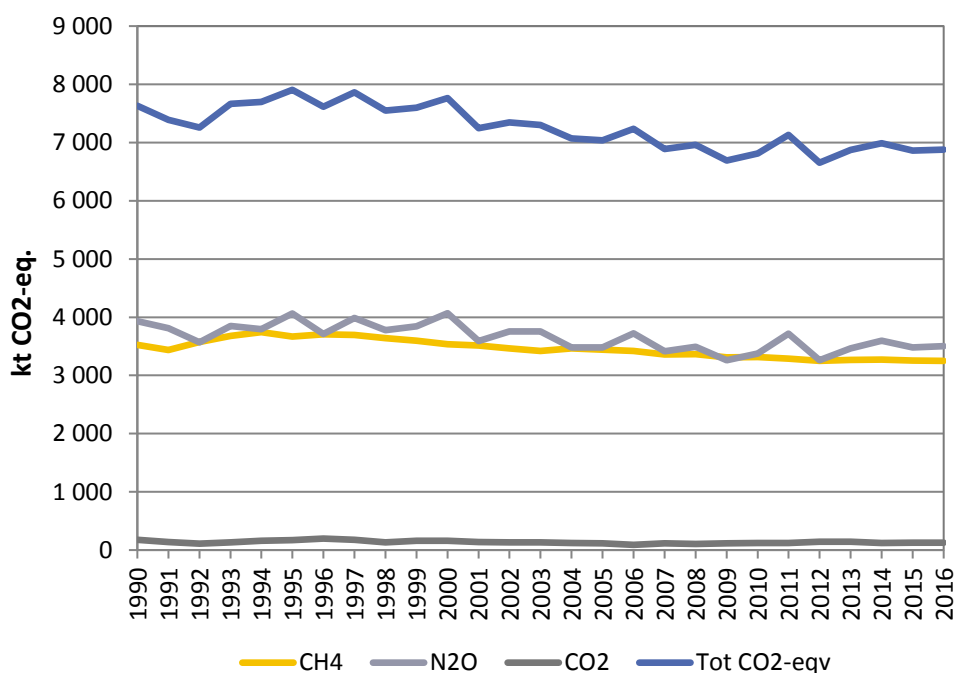


Figure 5.1. Total emissions of all greenhouse gases calculated as CO₂-eq. from CRF 3, agriculture.

²⁰³ Ministry of the Environment, 2001.

²⁰⁴ Swedish Board of Agriculture, www.jordbruksverket.se, <http://miljomal.nu>

Total greenhouse gas (GHG) emissions from the agricultural sector have decreased by 9.8 % since 1990, from 7 630 kt CO₂-eq. to 6 879 kt CO₂-eq. (figure 5.1). The most significant sub-sectors in Sweden are enteric fermentation (3.A) and agricultural soils (3.D), see figure 5.2.

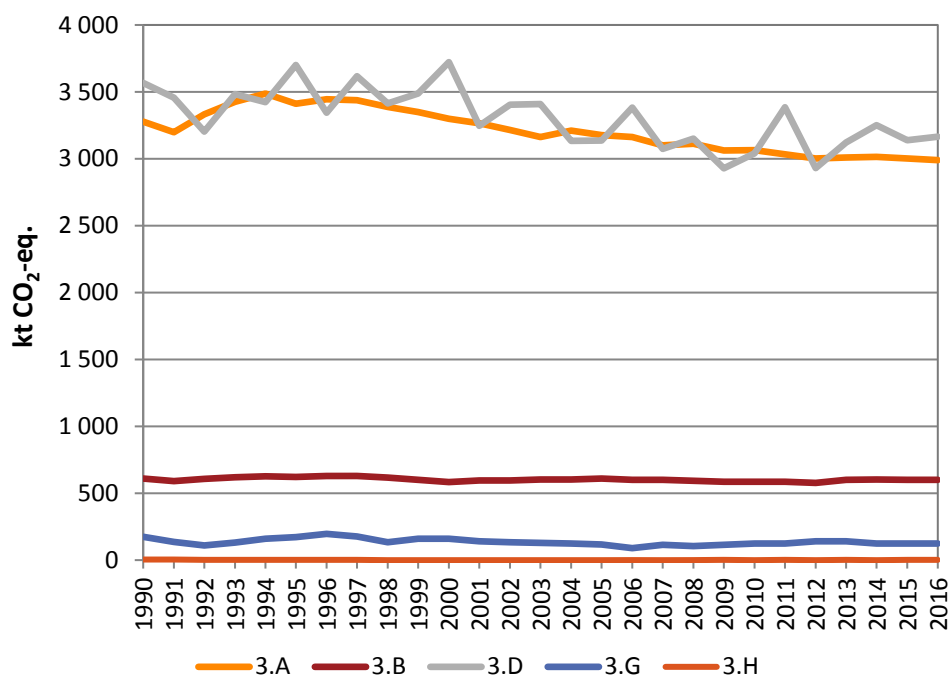


Figure 5.2. Total emissions of all greenhouse gases calculated as CO₂-eq. from the different agricultural sub-sectors. There are no emissions from 3.C, 3.E-F and 3.I-J.

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 farms²⁰⁵. The information on livestock refers to the situation prevailing in June of that year and is considered equivalent to a one-year average. Most of the information on livestock numbers comes from the Farm Register, but the distribution of calves (older and younger than 6 months respectively) is model-assisted: 60 % are assumed younger than 6 months and the rest are assumed older than 6 months. Concerning horses, the Farm Register underestimate the number of horses because only horses on farms are included (i.e. not horses for private leisure activities). However, three separate surveys²⁰⁶ 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

²⁰⁵ Swedish Board of Agriculture, JO 20-series.

²⁰⁶ Swedish Board of Agriculture, JO 24-series.

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 (**)	Dairy cows	Dairy cows	Dairy cows
Non-Dairy Cattle (**)	Suckler cows	Suckler cows	Suckler cows
	Heifers	Heifers	Heifers
	Bulls and steers	Bulls and steers	Bulls and steers
	Calves	Calves < 6 months Calves > 6 months	Calves
Swine (**)	Swine	Sows	NO
		Boars	
		Pigs for meat production	
		Piglets	
Sheep (**)	Sheep	Sheep	Sheep
Goats (**)	Goats	Goats	Goats
Horses (***)	Horses	Horses	Horses
Poultry	NE	Laying hens (**)	NO
		Chickens (**)	
		Slaughter Chickens (****)	
		Turkeys (**)	
Fur-bearing animals	NE	Minks (**)	NO
		Foxes (**)	
Other (****)	Reindeer	NO	Reindeer

(*) The age distribution of calves is accomplished by using standard values. (**) The Farm Register. (***) Statistics Sweden. (****) Swedish board of agriculture. (*****) Sametinget (The Sami Parliament of Sweden).

5.2 Enteric Fermentation (CRF 3.A)

5.2.1 Source category description

Enteric fermentation from cattle is the major source of methane emissions in CRF 3.A. About 85% of the emissions derive from this group. The total numbers of livestock in Sweden in 1990-2016 are 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), are presented in table 5.2.

Table 5.2. Summary of source category description, CRF 3.A, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qual.			
3.A.1 Dairy cattle	CH ₄	X			CS	CS	Yes
3.A.1 Non-dairy cattle	CH ₄	X	X		CS	CS	Yes
3.A.2 Sheep	CH ₄	X	X		T1	D	Yes
3.A.3 Swine	CH ₄				T1	D	Yes
3.A.4 Horses	CH ₄	X	X		T1	D	Yes

CS - Country Specific. T1 - tier 1. T2 - tier 2. D - Default.

5.2.2 Methodological issues

5.2.2.1 EMISSION FACTORS, METHANE

The livestock population (table 5.5 and table 5.6) for each category is multiplied by an emission factor and the total emission is calculated as:

$$emissions = \sum_i population_i \times EF_i$$

All emission factors (EF_i) for cattle are national. The IPCC guidelines recommends that the methane conversion rate should be zero for calves feeding only milk. Personal communication with Swedish experts resulted in that this period is assumed two months for calves of dairy breed and three months for other breeds. When no default emission factor exists for reindeer, the emission factor is estimated based on the live weight ratio between deer and reindeer according to the suggested formula in the guidebook. To estimate the average weight of reindeer in Sweden we have used statistics from the Sami parliament of Sweden (Sametinget) on slaughter weight and on the distribution of different types (i.e. cows, calves, bulls and oxen) of reindeer in the heard. With the assumption (also from the Sami parliament) that the slaughter weight represents half the live weight, the average reindeer weight was estimated to 64 kg. To estimate the emissions from swine, sheep, goats and horses the IPCC default values are used.

The country specific emissions factors for cattle are developed at the department of animal nutrition and management at the Swedish university of agricultural sciences (SLU)²⁰⁷. The methods and the activity data used are to a large extent developed within the NorFor²⁰⁸ organization. The NorFor organization is formed by experts in animal nutrition and information technology from the Nordic countries. One of their main activities is to develop and maintain a feed evaluation system called the NorFor Model. The system is currently in use in Denmark, Sweden, Norway and Iceland on approximately 9,000 dairy farms with some 1,000,000 head of cattle. A distinction between this system and the previous feed evaluation systems is that NorFor is based on net energy (NE) instead of metabolisable energy (ME). Data on how animals actually are fed on farms are not available to the same extent today as

²⁰⁷ Bertilsson, 2016.

²⁰⁸ <http://www.norfor.info>

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 AgriWise²⁰⁹ 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 dairies²¹⁰, complementing with the on farm consumption (including milk that does not meet the dairies quality demands) which is estimated to 5.6% of amount delivered. The live weight of dairy cows is assumed to be 650 kg. This is based on experiences from SLU's research herds as well as for research herds where both Holstein and red cows have this weight. The different equations used for the development of the emission factor are:

$$ECM = MilkYield \times ((383 \times Fat + 242 \times Protein + 783.2) / 3140)$$

ECM is the amount of energy corrected milk, MilkYield = total milk delivered to Swedish dairies, Fat = fat content of the milk, Protein = protein content of the milk.

$$ECM_{day} = ECM \times 1.056 / Population / 365$$

Amount of milk produced per cow and day, including on farm consumption.

$$ME = (0.507 \times 650^{0.75}) + ECM_{day} \times 5 + (1/12 \times (8.5 + 13 + 19.5))$$

ME = metabolisable energy required per day including maintenance, lactation and pregnancy. 0.507 = maintenance energy (MJ/kg live weight), 650 = average weight (kg), 5 = energy requirements to produce one kg of ECM (MJ). The energy additional requirement for pregnancy is estimated to be 8.5, 13 and 19.5 MJ per day in months 7, 8 and 9, respectively.

$$ME_{Corr} = 1.11 \times ME - 13.6$$

Metabolisable energy corrected for actual feeding levels.

$$ME_{Feed} = FracCO_{nc} \times Conc + (1 - FracCO_{nc}) \times Silage$$

Metabolisable energy content in the feed (MJ/kg). FracCO_{nc} = fraction of concentrates in the feed, Conc = energy content in concentrates (13.4 MJ/kg DM), Silage = energy content in silage (increases from 9.5 to 10.1 MJ/kg DM between 1990 and today).

$$FA = FracCO_{nc} \times Conc_F + (1 - FracCO_{nc}) \times Silage_F$$

²⁰⁹ <http://www.agriwise.org>

²¹⁰ Data from The Federation of Swedish Farmers (www.lrf.se)

Fatty acids content in the feed. Conc_F = fat content in concentrates (43 g/kg DM),
Silage_F = fat content in silage (12 g/kg DM).

$$DMI = ME_{Corr} / ME_{Feed}$$

DMI is the total dry matter intake per animal and day (kg DM/animal/day).

$$CH_4_{MJ} = 1.39 \times DMI - 0.091 \times FA$$

CH₄_{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 cows²¹¹.

$$EF_{Dairy} = (CH_4_{MJ} / 55.65) \times 365$$

And finally, EF_{Dairy} is the total methane emissions from enteric fermentation (kg/animal/year) where 55.65 MJ/kg CH₄ is the energy content of methane (see table 5.6).

5.2.2.1.2 Suckler cows

The same equations as for the dairy cattle are used for suckler cows, but with some modification of activity data. (i) The average amount of milk produced is estimated to 5.5 kg ECM per animal and day. Milk yields are assumed to be 14, 12, 12, 10, 10, 8 kg ECM/cow/day during lactation months 1 to 6, respectively. (ii) The live weight is estimated to be 750 kg. (iii) The additional energy requirement for pregnancy is estimated to be 10, 16 and 29 MJ per day in months 7, 8 and 9, respectively. (iv) FracCO_{nc} is zero, i.e. only silage feeding is assumed.

5.2.2.1.3 Heifers and bulls

The estimation of the emission factors for heifers and bulls differ slightly from the method used for dairy cattle and suckler cows. Especially a reduced amount of activity data are needed for the calculations. In table 5.3 the activity data used are presented, and in table 5.4 the intermediate calculation steps to estimate the different emission factors are given.

Table 5.3. Activity data used to estimate the emissions factors for enteric fermentation.

	Heifers			Bulls and steers		
	<1 year	1-2 years	>2 years	<1 year	1-2 years	>2 years
Live weight	200	385	580	250	500	625
Energy requirements (MJ)	45.5	70.5	93.5	71	106.5	107.5
Metabolisable energy in feed (MJ/kg DM)	11.5	10.1	10.1	12.3	11.7	10.4
FracCO _{nc}	0.50	0.15	0.15	0.7	0.5	0.1
Gross energy in feed (MJ/kg DM)	19.2	19.8	19.8	18.9	19.2	19.8

²¹¹ Nielsen et al. 2013

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 CH₄/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 CH₄ is estimated from the equation,

$$CH_4 \text{ MJ (fraction of GE)} = -0.046 \times \text{ConcP} + 0.071379$$

Where ConcP is the fraction of concentrates in the feed. The equation is used in NorFor and based on Danish trials²¹². From this the average annual energy lost as CH₄ is calculated from 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 CH₄) and multiplying it with 365 to get the annual emissions.

The total emissions are then estimated by multiplying the calculated emissions factors with the number of livestock in the different categories in the official statistics (i.e. heifers, bulls and steers and calves) (see table 5.7).

Table 5.5. Population size of different animal groups (1000s heads). See table 5.6 for dairy cattle.

Year	Non-Dairy Cattle				Swine				Sheep	
	Suckler cows	Heifers	Bulls and steers	Calves	Sow	Pig for meat production	Piglet	Boar	Sheep	Lamb
1990	75	337	206	524	221	1 276	758	8.6	162	244
1995	157	370	226	542	237	1 300	768	7.6	195	266
2000	167	365	224	500	202	1 146	566	4.2	198	234
2005	177	327	200	508	185	1 085	538	2.7	222	249
2010	197	322	191	479	154	937	427	2.3	273	292
2014	186	312	179	472	143	857	376	1.7	287	301
2015	184	311	178	467	140	830	384	1.5	289	306
2016	194	305	184	475	139	835	378	1.5	281	297

²¹² Nielsen 2012

Table 5.5 (continued).

Year	Horses	Goats		Other		Poultry			
	Horse	Goat	Kid	Reindeer	Fur-bearing animals	Laying hen	Turkey	Chicken	Slaughter Chicken
1990	316	2.9	1.4	271	297	6 400	122	2 200	4 476
1995	316	3.5	1.8	253	254	6 100	122	1 800	7 055
2000	316	3.5	1.8	221	276	5 700	122	1 700	7 896
2005	323	3.7	1.8	251	290	5 100	122	1 700	8 453
2010	363	3.7	1.8	250	180	6 061	130	1 647	9 159
2014	363	3.7	1.8	254	210	6 549	156	1 713	10 319
2015	363	3.7	1.8	250	210	7 571	156	1 842	11 044
2016	356	3.7	1.8	247	200	8 174	130	1 575	11 659

Table 5.6. Activity data used for estimating the emissions from enteric fermentation for dairy cattle.

Year	Dairy cows (number of heads)	Total milk delivered* (kt)	Average fat content (%)	Average protein content (%)	Yield per cow, kg ECM/yr	CH ₄ EF for Dairy Cattle
1990	576 409	3 432	4.31	3.36	6 503	112.2
1995	482 118	3 243	4.33	3.34	7 352	121.9
2000	427 621	3 297	4.18	3.28	8 240	130.6
2005	393 263	3 163	4.25	3.38	8 734	135.2
2010	348 095	2 862	4.23	3.41	8 928	135.7
2014	344 339	2 931	4.25	3.42	9 272	138.5
2015	339 823	2 933	4.25	3.42	9 401	140.0
2016	330 833	2 862	4.24	3.45	9 432	140.3

* Including on farm consumption.

Table 5.7. Methane from animals, used emission factors

Livestock subgroups	kg CH ₄ /head/year	Method
Dairy cows	See table 5.6	1
Suckler cows	92	1
Heifers	63.7	1
Bulls and steers	57.8	1
Calves	25.5	1
Swine	1.5	2
Sheep	8	2
Goats	5	2
Horses	18	2
Poultry	No fermentation assumed	
Reindeer	12.5	3

(1) Bertilsson, 2016. (2) IPCC 2006 Guidelines. (3) Estimated from the value for deer.

5.2.3 Uncertainties and time-series consistency

Between 1995 and 1996, there was an increase in the number of sows by 13 %. The reason for this sudden increase is that as from this year also uncovered gilts are included in this group. Since no estimate on the number of horses exists before 2004, the value for 2004 is used for all preceding years.

5.2.4 Source-specific QA/QC and verification

The time series for the different populations and milk production is checked for consistency. Annual increase or decrease is verified for the whole time series for all sub sources to decide that all annual changes are reasonable. We compare the time series for the emission with the time series for the activity data to confirm that are in agreement. We regularly conduct crosschecks of country-specific factors against the IPCC defaults. We annually utilize experts from the Swedish board of agriculture to conduct expert peer review of the methods used and we have regular meetings with authorities that provide activity data to the inventory to ensure that the quality of the data are of satisfactory quality and that they in turn use appropriate QC methods.

5.2.5 Source-specific recalculations

Since submission 2017 there have been two minor recalculation in 3.A. (i) The Swedish board of Agriculture revised the statistics on the cattle population in 2015, these changes were implemented in the inventory. (ii) We identified an error in the calculation of the emission factor for heifers calves in Bertilsson 2016. Instead of the previous used value of 26 kg CH₄/head/year the emission factor should be 24 kg CH₄/head/year.

The total effect in 3.A of the recalculations was a decrease of the estimated emissions with 8.90 and 3.95 kt CO₂-eq for 2014 and 2015, respectively.

5.2.6 Source-specific planned improvements

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

5.3 Manure Management (CRF 3.B)

5.3.1 Source category description

This category includes emissions of methane and nitrous oxide from manure management. It also includes indirect emission of N₂O through volatilisation of nitrogen during storage. A summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), are presented in table 5.8.

Table 5.8. Summary of source category description, CRF 3.B, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
3.B.1 Dairy cattle	CH ₄				T2	CS, D	Yes
	N ₂ O				T2	D	Yes
3.B.1 Non-dairy cattle	CH ₄	X	X		T2	CS, D	Yes
	N ₂ O	X			T2	D	Yes
3.B.2 Sheep	CH ₄				T1	D	Yes
	N ₂ O				T2	D	Yes
3.B.3 Swine	CH ₄				T2	CS, D	Yes
	N ₂ O				T2	D	Yes
3.B.4 Other	CH ₄				T1	D	Yes
	N ₂ O				T2	D	Yes
3.B.5 Indirect	N ₂ O				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 been collected every second or third year by Statistics Sweden²¹³. Data on stable periods (table 5.9) and manure management systems (table 5.10, table 5.11 and table 5.12) originate from this survey. Since dairy cows often are stabled at night and spend time in the stables during milking, the data on stable periods for this animal category is combined with the assumption that 38 % of its manure is excreted in the stable during the grazing period. Data on manure and nitrogen excretion are compiled by the Swedish board of agriculture and based on nutrient balance calculations. The underlying data are based on a variety of sources. The data for the most significant animal groups (i.e. cattle and swine) are from public reports produced by the Swedish Board of Agriculture. Some of the data for the less significant animal groups are based on expert opinions. See “Compilation of data on manure and nitrogen excretion” in the reference list for a complete list of the sources. For dairy cows the nitrogen and manure excretion are calculated based on milk production (see table 5.13). 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 5.14 and table 5.15, respectively. The data are estimated values per head, year and box. That is, the excretion if one, hypothetically, assumes that an animal of a specific animal category would stay in the box for a year. Total annual excretion per animal category is then estimated by multiplying these values with the estimated annual average population. Naturally, the number of animals in the different categories/age classes will vary somewhat during a year. I.e. piglets will grow and enter the next growth class. However, we use the value from the farm register as an approximation of the annual average.

²¹³ Statistics Sweden, MI 30-series. (the survey planned for 2015 was however postponed until 2016 due to limited funds)

Due to more intense swine production, the yearly excretion for sows and pigs for meat production were updated in 2001. All emission factors used in the calculations are presented in table 5.16.

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
2014	7.3	5.8	6.0	9.8	8.2	6	0	12
2015	7.3	5.8	6.0	9.8	8.2	6	0	12
2016	7.3	5.5	5.9	9.2	8.1	6	0	12

Table 5.10. Liquid waste management systems (fractions)

Year	Dairy cattle	Suckler cows	Heifers	Bulls and steers	Calves	Pigs for meat production	Other swine	Sheep, goats, horses, reindeer and Fur-bearing animals	Laying Hens, Chickens	Slaughter Chickens, Turkeys
1990	0.23	0.16	0.16	0.19	0.20	0.44	0.44	0	0.25	0.00
1995	0.31	0.21	0.22	0.26	0.26	0.63	0.63	0	0.25	0.00
2000	0.39	0.13	0.13	0.16	0.16	0.81	0.26	0	0.25	0.00
2005	0.51	0.06	0.20	0.23	0.19	0.93	0.32	0	0.21	0.00
2010	0.58	0.11	0.23	0.29	0.17	0.94	0.62	0	0.12	0.00
2014	0.64	0.11	0.26	0.33	0.17	0.95	0.58	0	0.09	0.00
2015	0.64	0.11	0.26	0.33	0.17	0.95	0.58	0	0.09	0.00
2016	0.68	0.11	0.27	0.40	0.22	0.97	0.63	0	0.09	0.00

Table 5.11. Solid waste management systems (fractions)

Year	Dairy cattle	Suckler cows	Heifers	Bulls and steers	Calves	Pigs for meat production	Other swine	Sheep, goats	Reindeer	Fur-bearing animals	Horses	Laying Hens, Chickens	Slaughter Chickens, Turkeys
1990	0.52	0.29	0.30	0.35	0.36	0.54	0.45	0.5	0	1	0.48	0.55	0.00
1995	0.44	0.23	0.25	0.29	0.29	0.35	0.26	0.5	0	1	0.48	0.55	0.00
2000	0.35	0.28	0.29	0.37	0.37	0.18	0.67	0.5	0	1	0.48	0.55	0.00
2005	0.22	0.19	0.17	0.27	0.23	0.06	0.46	0.5	0	1	0.48	0.73	0.00
2010	0.16	0.20	0.15	0.26	0.22	0.05	0.30	0.5	0	1	0.48	0.88	0.00
2014	0.11	0.20	0.12	0.25	0.16	0.03	0.36	0.5	0	1	0.48	0.78	0.00
2015	0.11	0.20	0.12	0.25	0.16	0.03	0.36	0.5	0	1	0.48	0.78	0.00
2016	0.07	0.15	0.09	0.13	0.14	0.02	0.20	0.5	0	1	0.48	0.90	0.00

Table 5.12. Deep litter waste management systems (fractions). Categorised as "Other" in the CRF-tables.

Year	Dairy cattle	Suckler cows	Heifers	Bulls and steers	Calves	Pigs for meat production	Other swine	Sheep, goats, reindeer, Fur-bearing animals	Horses	Laying Hens, Chickens	Slaughter Chickens, Turkeys
1990	0.01	0.07	0.08	0.09	0.09	0.02	0.11	0	0.02	0.20	1.00
1995	0.01	0.07	0.08	0.09	0.09	0.02	0.11	0	0.02	0.20	1.00
2000	0.01	0.08	0.08	0.10	0.10	0.01	0.07	0	0.02	0.20	1.00
2005	0.00	0.16	0.10	0.20	0.22	0.01	0.22	0	0.02	0.07	1.00
2010	0.01	0.15	0.11	0.19	0.30	0.01	0.07	0	0.02	0.00	1.00
2014	0.01	0.17	0.12	0.23	0.35	0.02	0.06	0	0.02	0.13	1.00
2015	0.01	0.17	0.12	0.23	0.35	0.02	0.06	0	0.02	0.13	1.00
2016	0.01	0.20	0.12	0.23	0.31	0.01	0.17	0	0.02	0.01	1.00

Table 5.13. Manure production and nitrogen excretion from dairy cows

Year	Manure production (kg VS DM/day/head)	Nitrogen excretion (kg/year/head)
1990	5.07	102.0
1995	5.19	110.5
2000	5.29	119.4
2005	5.32	124.3
2010	5.33	126.3
2014	5.35	129.7
2015	5.35	131.0
2016	5.36	131.3

Table 5.14. Manure production from other animal groups

Animal group	Manure production (kg VS DM/day)
Suckler cows	2.30 (in stables) 3.17 (during grazing)
Heifers	2.26
Bulls and steers	2.26
Calves < 6 months	0.60
Calves > 6 months	0.97
Sows	0.64 (1990-2001) 0.69 (as from 2002)
Boars	0.45
Pigs for meat production	0.37
Piglets	0.044

Data from the Swedish Board of Agriculture

Table 5.15. Nitrogen excretion from other animal groups

Animal group	Nitrogen kg/year/ head	Comment	Updated values on nitrogen prod. used from 2002, kg/ year/head	Comment
Suckler cows	63			
Heifers	47			
Bulls and steers	47			
Calves	28			
Sows	18.5		22.5	
Boars	13			
Pigs for meat production	9.5	2.5 prod. cycles/ year	10.8	3 prod. cycles / year
Piglets	1.2			
Sheep	14	Ewes incl. 1.8 lambs		
Lambs	0			
Goats	13	Does incl. 1.8 kids		
Kids	0			
Horses	48			
Laying hens	0.60	0.8 prod. cycles/ year		
Turkeys	0.69	2.3 prod. cycles/ year		
Chickens	0.22	2.2 prod. cycles/ year		
Slaughter Chickens	0.29	8.5 prod. cycles/ year		
Fur-bearing animals	4.59			
Reindeer*	10			

Data from the Swedish Board of Agriculture

*Data from Statistics Finland

Table 5.16. Emission factors for manure management

Manure management	Emission factors for CH ₄	Emission factor for N ₂ O	Note
MCF Solid manure	2 % of B ₀		1
MCF Liquid manure	3.5 % of B ₀		2
MCF Deep litter	17 % of B ₀		1
MCF Pasture/Range/Paddock	1 % of B ₀		1
Dairy Cattle - volatile solid	87 % of manure production (DM)		3
Dairy Cattle – B ₀	0.24 m ³ CH ₄ /kg VS		1
Non-Dairy Cattle –VS	87 % of manure production (DM)		3
Non-Dairy Cattle – B ₀	0.18 m ³ CH ₄ /kg VS		1
Swine – volatile solids	87 % of manure production (DM)		3
Swine – B ₀	0.45 m ³ CH ₄ /kg VS		1
Sheep – emission	0.19 kg CH ₄ /animal/yr		1
Goats – emission	0.13 kg CH ₄ /animal/yr		1
Horses – emission	1.56 kg CH ₄ /animal/yr		1
Poultry (Layers) – emission	0.03 kg CH ₄ /animal/yr		1
Poultry (Broilers) – emission	0.02 kg CH ₄ /animal/yr		1
Poultry (Turkeys) – emission	0.09 kg CH ₄ /animal/yr		1
Fur-bearing animals	0.68 kg CH ₄ /animal/yr		1
Reindeer – emission	0.36 kg CH ₄ /animal/yr		1
Waste Management System		% N₂O-N of N-supply	
Liquid manure		0.5 %	1
Solid manure		0.5 %	1
Deep litter		1 %	1
Pasture/Range/Paddock (Cattle)		2 %	1
Pasture/Range/Paddock (Sheep & other animals)		1 %	1

MCF=Methane Conversion Factor. B₀=maximum methane producing capacity for manure.
(1) IPCC 2006 Guidelines. (2) National, Rodhe et al. 2009. (3) Dustan 2002.

5.3.2.1 EMISSIONS OF METHANE (INCLUDING EXCRETION FROM GRAZING ANIMALS) (CRF 3.B(A))

The IPCC tier 2 methodology is used for estimating methane from manure management for cattle and swine, including excretions from grazing animals. The corresponding tier 1 methodology is used for the other animal groups²¹⁴. The formula to calculate the emission factors for each livestock group, *i*, according to IPCC guideline's tier 2 methodology is:

$$emissionfactor_i = VS_i \times B_{0i} \times 0.67 \times \sum_j MCF_j \times MS_{ij}$$

²¹⁴ According to current estimations, cattle and swine produce about 85-90 % of the total methane emissions from manure management.

Where VS_i is the volatile substance excreted per year, B_{0i} is the maximum methane producing capacity for manure produced by an animal within the livestock group, MCF_j is the conversion factor for methane production, given a specific manure management system j (where grazing animals are considered as one of the systems). MS_{ij} is the fraction of animal manure handled using manure system j .

The B_{0i} and MCF factors used are the default values from the IPCC guidelines, except for the country specific MCF for liquid manure, where the value of 3.5 % is used. This value is developed by Rodhe et al. (2009) and is showed to be more appropriate for Sweden's cool conditions. This study measured GHG emissions for one year in three pilot-scale plants with similar conditions to full-scale storage regarding slurry temperature, climate and filling/emptying routines. The study concluded that 3.5 % is an appropriate MCF value for the storage of liquid manure in Sweden, which has an average temperature clearly below the definition of "Cool" in the IPCC guidelines. The values reported in the CRF tables are sometimes aggregated. Hence, the implied emission factor for, e.g. "non-dairy cattle" will depend not only on different manure management systems and stable periods over the years, but also on the relative composition of the subgroup and the implied emission factor will therefore varies between years.

Information on waste management systems is collected at regular intervals from the survey, "Use of fertilisers and animal manure in agriculture"²¹⁵ and interpolated values are used for the intermediate years. Three manure management systems are considered apart from grazing animals: liquid systems (table 5.10), solid storage (table 5.11) and deep litter (table 5.12) (deep litter is categorised as "other" in the CRF-tables). National estimates of stable periods for cattle are from the same survey. Information on stable periods has been available since 1997. Before 1997, the data are extrapolated to 1990.

When studying the trends for the implied emission factor (IEF) there is a distinct increasing trend for both non-dairy and dairy cattle. This is caused by a decreased use of solid manure storage systems. For non-dairy cattle there is instead an increased use of deep litter systems and for dairy cattle, an increase in the use of liquid systems.

5.3.2.2 DIRECT EMISSIONS OF NITROUS OXIDE FROM MANURE MANAGEMENT (EXCLUDING EXCRETION FROM GRAZING ANIMALS) (CRF 3.B(B))

N_2O from manure management is estimated with the IPCC Guidelines, Tier 2 methodology. Default emission factors from the IPCC Guidelines are used in combination with national activity data. The emission of N_2O from manure management is calculated as:

²¹⁵ Statistics Sweden, MI 30-series.

$$N_2O = \sum_s \left(\sum_T N_T \times Nex_T \times MS_{(T,S)} \right) \times EF_s \times 44/28$$

where N_T is the number of heads of livestock in category T in the country, Nex_T is the annual average excretion of N per head of category T in the country, $MS_{(T,S)}$ is the fraction of total annual excretion for each livestock category T managed in manure management system S in the country (excluding pasture, range and paddock manure that is reported under 3.D). Even though dairy cattle generally spends the summer on pasture, part of the manure is still produced in the stable during milking and when spending the nights in the stables. This manure is excluded from the pasture, range and paddock manure and instead allocated to the appropriate manure system. Stable periods and manure management systems are the same as used in the methane calculations (table 5.9, table 5.10, table 5.11 and table 5.12). The emission factors are described in table 5.16. In the CRF tables, where some animal subgroups are aggregated, the implied emission factors for nitrogen excretion rate changes over the years, depending on the relative size of the respective subgroups aggregated.

5.3.2.3 INDIRECT EMISSIONS OF NITROUS OXIDE FROM MANURE MANAGEMENT

The indirect emissions of nitrous oxide due to volatilisation of nitrogen from manure are reported under two different categories, 3.B and 3.D.b. The indirect emissions from manure management are reported in 3.B, and the indirect emissions from application of manure as fertiliser are reported in 3.D.b (see section 5.4.2).

To estimate the indirect emissions in sector 3.B we use the tier 2 method. That is, we use country specific nitrogen excretion rates in the calculations, and utilize the national ammonia emission inventory in combination with the default emission factors for NOx from the EMEP/EEA Guidebook 2016 to estimate the amounts of nitrogen volatilised (i.e. $N_{volatilization-MMS}$). For a summary of the ammonia emission model, see below under the paragraph “The national ammonia emission inventory”. The indirect N_2O emissions are then estimated with the default EF_4 from the 2006 IPCC guideline.

$$N_2O = N_{volatilisation-MMS} \times EF_4 \times 44/28$$

All indirect emissions from manure management due to leaching and runoff are reported in agricultural soils (i.e. 3.D.b), and the notation key IE (included elsewhere) is used in 3.B. However, the nitrogen leaching from storage of manure are considered low, because Swedish law regulates that the storage must be designed to minimize the leaching and runoff from manure into the environment. Anyhow, the model used to estimate nitrogen loss from leaching and runoff (see sector 5.4.2.2.2) will also capture this part, but is instead reported in sector 3.D.b.

5.3.2.3.1 Nitrogen lost from manure management

To accurately estimate the total amount of nitrogen remaining after storage, i.e. the amount available for application to soils, nitrogen losses during storage as N_2O as

well as NO_x and N₂ are needed to take 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 N₂O and N₂ is calculated using the difference between the fractions in table 10.22 and table 10.23 in the 2006 guidelines (table 5.17).

Table 5.17. Default values from 2006 guidelines for nitrogen lost as N₂O, N₂ and leaching and run-off from manure management.

Animal group	Manure management system	Default fraction of N lost as N ₂ O, N ₂ and leaching and run-off
Dairy cattle	Liquid/Slurry	0
Dairy cattle	Solid storage	0.10
Dairy cattle	Deep bedding	0.10
Other cattle	Liquid/Slurry	0
Other cattle	Solid storage	0.05
Other cattle	Deep bedding	0.10
Swine	Liquid/Slurry	0
Swine	Solid storage	0.05
Swine	Deep bedding	0.10
Poultry	Poultry with litter	0.10
Other animals	Solid storage	0.03
Other animals	Deep bedding	0.10

The estimate of nitrogen lost as ammonia are mainly built on data collected through Statistics Sweden's survey on use of fertilisers and animal manure in agriculture²¹⁶. 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 Engineering²¹⁷. As from 2005, regional results are published at the web-site of Statistics Sweden²¹⁸. In short, the calculations are made as follows:

$$\begin{aligned}
 A &= (V + L + S) \\
 V &= D \times N \times P \times F(v) \\
 L &= D \times N \times P \times (1 - F(v)) \times F(l) \\
 S &= D \times N \times P \times T \times (1 - F(v)) \times (1 - F(l)) \times F(s)
 \end{aligned}$$

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)

²¹⁶ Statistics Sweden, MI 30-series.

²¹⁷ Swedish Environmental Protection Agency 1997

²¹⁸ Statistics Sweden, MI 37-series.

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 handling²¹⁹

P = stable periods²²⁰

T = Proportion of ammoniacal nitrogen

F(v) = emission of nitrogen through stable ventilation, % of total nitrogen content in stable manure²²¹.

F(l) = emission of nitrogen during storing, % of total nitrogen content in stable manure after ventilation losses²²².

F(s) = emission of nitrogen during spreading, % of ammoniacal nitrogen content in stable manure after ventilation and storing losses²²³.

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 farmers²²⁴. Data on ventilation-, storage- and spreading-losses originate from the Swedish Board of Agriculture and from Swedish Institute of Agricultural and Environmental Engineering. See the Swedish Informative Inventory Report to the LRTAP Convention for a detailed description of the calculations and used emission factors²²⁵.

5.3.3 Uncertainties and time-series consistency

Due to more intense swine production, the nitrogen production for sows and pigs for meat production was updated in 2002. The time series for the implied emission factor have some steep steps. This is mainly an effect of that the surveys on the distribution of different manure management systems are only done biannually and that a small relative difference in that survey have a significant effect on the emissions because the emission factors differ considerably between different systems.

5.3.4 Source-specific QA/QC and verification

Annual increase or decrease is verified for the whole time series for all sub sources to decide that all annual changes are reasonable. We compare the times series for

²¹⁹ Swedish Board of Agriculture 1995; Swedish Board of Agriculture 2000; Swedish Board of Agriculture 2001

²²⁰ Statistics Sweden, MI 30-series.

²²¹ Swedish Board of Agriculture 2005

²²² Swedish Institute of Agricultural and Environmental Engineering 2002

²²³ Swedish Institute of Agricultural and Environmental Engineering 2002

²²⁴ Statistics Sweden, MI 30-series.

²²⁵ http://www.ceip.at/ms/ceip_home1/ceip_home/status_reporting/

the emission with the time series for the activity data to confirm that are in agreement. We regularly conduct crosschecks of country-specific factors against the IPCC defaults. We annually utilize experts from the Swedish board of agriculture to conduct expert peer review of the methods used and we have regular meetings with authorities that provide activity data to the inventory to ensure that the quality of the data are of satisfactory quality and that they in turn use appropriate QC methods.

5.3.5 Source-specific recalculations

(i) The Swedish board of Agriculture have revised the population statistics on turkeys between the years 2013 and 2015. (ii) They also revised the population of cattle in 2015. (iii) Furthermore, we have now included indirect emissions from NO_x, previously only indirect emissions from NH₃ was accounted for. The total effect of the recalculations in 3.B was an increase of the estimated emissions with 1.33 kt and 2.30 kt CO₂-eq for 2014 and 2015, respectively

5.3.6 Source-specific planned improvements

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

5.4 Agricultural Soils (CRF 3.D)

Since the subsectors included under agricultural soils represent relatively different processes they are divided into separate paragraphs and treated independently in the key categories analyses. Table 5.18 gives an overview of all emission factors used in this sector.

Table 5.18. Emission factors for N₂O emissions from soils

Direct emissions from soils	Emission factor % N ₂ O-N of N-supply	Note
Mineral fertiliser	1 %	1
Manure	1 %	1
Crop residue	1 %	1
Manure during Pasture/Range/Paddock	See table 5.16	1
Background emission due to cultivation	Kg N ₂ O-N/ha/yr	
Cultivation of Histosols	13	2
Indirect emissions from soils	% N ₂ O-N of N-supply	
Atmospheric Deposition	1 % of emitted N	1
Nitrogen Leaching and run-off	0.75 % of N lost from leaching	1

(1) 2006 IPCC Guidelines, (2) 2013 IPCC Wetlands supplement.

5.4.1 Direct Soil Emissions (CRF 3.D.a)

5.4.1.1 SOURCE CATEGORY DESCRIPTION

This category includes the direct emission of nitrous oxide from managed soils. In terms of magnitude, the most important emissions are from the use of inorganic N fertilisers, followed by crop residues and cultivation of histosols. Also included in this category are emissions from 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 5.19.

Table 5.19. Summary of source category description for the entire category CRF 3.D.a, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
3.D.a.1	N ₂ O	X	X		T2	CS	Yes
3.D.a.2.a Animal manure	N ₂ O	X	X		T2	CS	Yes
3.D.a.2.b Sewage sludge	N ₂ O				T1	D	Yes
3.D.a.2.c Other	N ₂ O				T1	D	Yes
3.D.a.3	N ₂ O	X	X		T1	D	Yes
3.D.a.4	N ₂ O	X	X		T2	CS	Yes
3.D.a.5	N ₂ O				T2	CS	Yes
3.D.a.6	N ₂ O	X	X		T1	D	Yes

CS - Country Specific. T1 - tier 1. T2 - tier 2. D - Default.

5.4.1.1.1 Nitrous oxide emissions from inorganic N fertilisers (CRF 3.D.a.1)

Emissions from inorganic fertilisers are calculated as:

$$N_2O \text{ emission} = N_{FERT} \times EF_1 \times 44/28$$

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 5.20).

5.4.1.1.2 Nitrous oxide from organic N fertilisers (CRF 3.D.a.2)

To estimate the N₂O 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:

$$F_{AM} = \sum_T N_T \times Nex_T \times (1 - Frac_{LossMS}) \times (1 - Frac_{PRP})$$

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 , NO_x and N_2 (table 5.20), $Frac_{PRP}$ is the fraction of the nitrogen in pasture, range and paddock manure. To complete the annual amount of nitrogen applied to soils in 3.D.a.2 (i.e. F_{ON}), this value is complemented with N content from the much smaller sources, sewage sludge and other organic fertilizers applied to soils. Statistics on the use of sludge have been collected intermittently by Statistics Sweden and the Swedish EPA from sewage treatment plants (table 5.20). 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 5.20). The N_2O emissions are then estimated as:

$$N_2O \text{ emissions} = F_{ON} \times EF_1 \times 44/28$$

Table 5.20. Activity data used to estimate the direct soil emissions from inorganic and organic fertilisers.

Year	N in inorganic fertilisers (t)	N in applied organic fertilisers (t)	N in sewage sludge (t)	N in other organic fertilisers (t)	Fraction of N volatilised as NH_3 during storage of animal manure	Fraction of N volatilised as N_2O , NO_x , N_2 and leaching and run-off during storage of animal manure
1990	224 500	76 631	1 180	1 700	0.21	0.10
1995	198 300	79 794	2 304	1 700	0.20	0.09
2000	189 400	75 587	1 758	1 800	0.20	0.08
2005	161 568	74 029	1 053	1 743	0.20	0.07
2010	168 000	72 703	2 224	2 712	0.19	0.06
2014	181 090	73 264	2 374	4 386	0.19	0.06
2015	190 200	73 381	2 802	4 386	0.19	0.06
2016	186 000	73 413	2 802	5 358	0.19	0.06

Statistics on fertilisers and sludge are from Swedish Board of Agriculture and Statistics Sweden.

5.4.1.1.3 Urine and dung deposited by grazing animals (CRF 3.D.a.3)

To estimate the N_2O emissions from urine and dung deposited by grazing animals the default emission factor of 2 % is used for cattle and the default emission factor of 1 % is used for sheep, goats, horses and reindeer. No other animal categories are applicable in this category. The emissions are calculated as:

$$emissions = \sum_{Ti} N_{Ti} \times Nex_{Ti} \times Frac_{PRP_{Ti}} \times EF_{3PRP,i} \times 44/28$$

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 5.21), 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 5.13 and table 5.15.

Table 5.21. Waste management systems, fraction of manure deposited on pasture, range and paddock.

Year	Dairy cattle	Suckler cows	Heifers	Bulls and steers	Calves	Swine	Sheep, Goats	Reindeer	Horses	Poultry	Fraction of total amount of N excreted on pasture (Frac _{CRP})
1990	0.25	0.48	0.46	0.37	0.35	NO	0.50	1.00	0.50	NO	0.30
1995	0.25	0.48	0.46	0.37	0.35	NO	0.50	1.00	0.50	NO	0.31
2000	0.25	0.52	0.49	0.37	0.37	NO	0.50	1.00	0.50	NO	0.32
2005	0.26	0.59	0.54	0.30	0.37	NO	0.50	1.00	0.50	NO	0.33
2010	0.25	0.54	0.52	0.26	0.31	NO	0.50	1.00	0.50	NO	0.32
2013	0.25	0.52	0.50	0.19	0.32	NO	0.50	1.00	0.50	NO	0.31
2014	0.25	0.52	0.50	0.19	0.32	NO	0.50	1.00	0.50	NO	0.31
2015	0.25	0.52	0.50	0.19	0.32	NO	0.50	1.00	0.50	NO	0.31

Data from Statistics Sweden's biannual survey "Use of fertilisers and animal manure in agriculture".

5.4.1.1.4 Crop residue (CRF 3.D.a.4)

To estimate the emissions of N₂O from nitrogen circulation from crop residues, both above- and below-ground residues are taken into account. To estimate above- and below-ground nitrogen, respectively, we use the following equations together with a combination with 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 2012²²⁶ on how straw and tops from different crops are used.

$$\begin{aligned} \text{Above-ground } N_{(T)} &= \text{Crop}_{(T)} \times \text{Area}_{(T)} \times R_{AG(T)} \times N_{AG(T)} \times \text{Frac}_{\text{Renew}(T)} \\ &\quad \times (1 - \text{Frac}_{\text{Remove}(T)}) \end{aligned}$$

$$\text{Below-ground } N_{(T)} = \text{Crop}_{(T)} \times \text{Area}_{(T)} \times R_{BG(T)} \times N_{BG(T)} \times \text{Frac}_{\text{Renew}(T)}$$

Where $R_{AG(T)}$ is the ratio of aboveground residues dry matter to harvested yield (i.e. $AG_{DM(T)}/\text{Crop}_{(T)}$), and $R_{BG(T)}$ the corresponding value for belowground residues. $\text{Crop}_{(T)}$ 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. $\text{Frac}_{\text{remove}(T)}$ is the fractions of crop residues that are removed from the field and $\text{Frac}_{\text{renew}(T)}$ is the fraction 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 5.22 for all parameters that are used in the calculation of total N-content in crop residues. For cereals, national factors are used for fraction of aboveground residues and the corresponding N-content²²⁷. For other crops, a combination of

²²⁶ Statistics Sweden, 2012.

²²⁷ Mattson, 2005.

national factors and IPCC default values are used²²⁸. The estimated activity data used as input to the emission calculations are presented in table 5.23.

Table 5.22. 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})
Winter wheat	0.86	0.8750	0.0051	0.12	0.23	0.009
Spring wheat	0.86	0.9625	0.0044	0.10	0.28	0.009
Winter rye	0.86	1.0750	0.0059	0.22	0.22	0.009
Winter barley	0.86	0.8750	0.0077	0.22	0.22	0.014
Spring barley	0.86	0.8250	0.0077	0.10	0.22	0.014
Oats	0.86	0.8875	0.0073	0.10	0.25	0.008
Mixed grain	0.86	0.8625	0.0075	0.27	0.22	0.009
Triticale	0.86	0.9750	0.0076	0.12	0.22	0.009
Sugar beets	0.20	0.66	0.0225	0.007	0.20	0.014
Winter rape	0.91	1.50	0.0107	0.055	0.22	0.009
Spring rape	0.91	1.13	0.0107	0.055	0.22	0.009
Winter turnip rape	0.91	1.50	0.0107	0.055	0.22	0.009
Spring turnip rape	0.91	1.13	0.0107	0.055	0.22	0.009
Oil flax	0.91	1.13	0.0143	0.57	0.22	0.009
Potato	0.20	0.40	0.0325	0.013	0.20	0.014
Peas	0.85	0.80	0.0118	0.014	0.19	0.008
Peas for conservation	0.85	0.80	0.0118	0	0.19	0.008
Brown beans	0.85	0.80	0.0118	0.022	0.19	0.008
Temporary grass	0.835	0.25	0.024	0	0.54	0.012
Temporary grass for seed	0.835	0.84	0.0109	0.35	0.22	0.009
Green fodder	0.835	0.25	0.02	0	0.54	0.012
Maize	0.86	1.00	0.0094	0.19	0.22	0.007
Pasture ground	0.668	0.40	0.024	0	0.80	0.012

Table 5.23. Activity data for estimating N₂O emissions from crop residues.

Year	Total harvested product dry matter (t)	Total above-ground residues dry matter (t)	Total below-ground residues dry matter (t)	Total N content in above-ground residues (t)	Total N content in below-ground residues (t)
1990	12 483 111	7 471 588	3 841 472	52 486	41 565
1995	10 045 004	5 781 329	2 975 047	42 038	33 064
2000	10 075 608	6 134 616	3 151 367	42 995	33 868
2005	9 426 197	5 709 529	2 961 492	40 802	32 232
2010	9 822 911	5 550 227	2 871 874	38 750	31 064
2014	11 480 991	6 909 116	3 542 297	47 738	37 881
2015	11 810 112	7 169 692	3 661 566	46 693	38 739
2016	10 823 936	6 547 705	3 367 152	44 988	35 853

Data on crop yield and area are from the Swedish Board of Agriculture, JO10-, JO17- and JO19-series.

²²⁸ Andrist Rangel et al. 2016 and IPCC Guidelines 2006.

5.4.1.1.5 *Mineralization/immobilization associated with loss/gain of soil organic matter (CRF 3.D.a.5)*

Management change of land can cause loss of soil organic C through oxidation and, simultaneously, mineralisation of N that can be converted to N₂O 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 for eight different region using the ICBM-model as described in chapter 6. The emissions from cropland remaining cropland are reported here and all other categories are reported in the LULUCF sector. The reported annual N₂O emission from nitrogen mineralisation is calculated according to the 2006 IPCC guidelines, where i is the eight different production areas in Sweden.

$$N_2O = \sum_{LU_i} [\Delta C_{Mineral, LU_i} \times 0.1] \times EF_1 \times 44/28$$

5.4.1.1.6 *Cultivation of organic soils (CRF 3.D.a.6)*

In a literature survey assigned by the Swedish EPA, it was suggested that the background emission from organic soils vary with different crops. The emissions were also considered higher from ploughed soils than from pasture or temporary grasslands. The suggested emission factors were 6 and 1 kg N₂O-N ha⁻¹, respectively. The value from the wetlands supplement to the 2006 IPCC guidelines of 13 kg N₂O -N/ha is however implemented in the inventory since a Swedish/Finnish research group concluded that not enough data exists to generate reliable emission factors for different soil managements and soil types. The area of organic soils has only been estimated intermittently, the two latest referring to the situation in 2008²²⁹ and 2015²³⁰. The result shows that the decline in organic soil area is slightly slower relative to the decline in the total agriculture land area. Hence, to get the trend correct, we calculated the different fraction of organic soil to total agriculture land in 2008 and 2015. The resulting slope was then used to extrapolate the fraction of organic soil between 1990 and 2007. The result of this was that in 1990 the organic soil area was estimated to 4.8 %, and in 2016 to 4.9 % of total agriculture land.

$$N_2O = Area_{Histosols} \times EF \times 44/28$$

5.4.1.1.7 *Uncertainties and time-series consistency*

Two related parameters are the amount of nitrogen in sold fertiliser, estimated by the sales statistics, and the nitrogen in used fertilisers, estimated from interviews with farmers. Sales statistics are collected annually by the Swedish board of

²²⁹ Berglund, Berglund & Sohlenius, 2009

²³⁰ Pahkakangas 2016

agriculture and Statistics Sweden. Data has been collected in the same way from the larger producers and retailers since the early 1960s. Statistics on the use of fertiliser and manure have been collected biannually since the end of the 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, but that should 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 have been used in the GHG inventory. Another advantage of the sales statistics is that it is updated annually.

Historically, statistics on the use of sewage sludge have been published irregularly and in different reports, and the time series for the earlier years in the time series has been created through interpolation/extrapolation and certain assumptions. Gradually the quality of the data has increased and is for the latest years of adequate quality.

5.4.1.1.8 Source-specific QA/QC and verification

Annual increase or decrease is verified for the whole time series for all sub sources to decide that all annual changes are reasonable. We compare the times series for the emission with the time series for the activity data to confirm that are in agreement. We regularly conduct crosschecks of country-specific factors against the IPCC defaults. We annually utilize experts from the Swedish board of agriculture to conduct expert peer review of the methods used and we have regular meetings with authorities that provide activity data to the inventory to ensure that the quality of the data are of satisfactory quality and that they in turn use appropriate QC methods.

5.4.1.1.9 Source-specific recalculations

(i) Due to a recommendation from the Technical Expert Review Team (TERT) during the ESD review Sweden has now included nitrogen losses as N₂ during storage of manure in the inventory. The effect of this is a decrease of the estimated emissions from 3.D.a.2.a, animal manure applied to soils, due to that a higher fraction of the nitrogen is lost during storage. (ii) As a consequence of the method used by the Swedish national inventory of forests (see 6.3.1.1) the area of cultivated organic soils has been updated for several years. This affects the emissions from cultivation of histosols. (iii) The time series for amount of nitrogen applied to soils from other organic fertilizers have been revised by Statistics Sweden. (iv) The model to estimate the emissions from mineralization/immobilization associated with loss/gain of soil organic matter has been revised and the result is now based on independent carbon balances for eight different regions.

The total effect of the recalculations in 3.D.a was an increase of the estimated emissions with 36 kt CO₂-eq for 2014 and a decrease with 13 kt CO₂-eq for 2015.

5.4.1.1.10 Source-specific planned improvements

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

5.4.2 Indirect Emissions (CRF 3.D.b)

5.4.2.1 SOURCE CATEGORY DESCRIPTION

In addition to the direct emissions from managed soils also indirect emissions occur. The two pathways of indirect emissions from soils are through volatilization of nitrogen as NH₃ 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. Indirect emissions also occur from manure management, these emissions are described above.

To estimate the indirect N₂O emissions from atmospheric deposition the tier 1 methodology from the guidelines is used in combination with the default emission factors from the EMEP/EEA air pollutant emission inventory guidebook 2013 describing the fraction of N that volatilises as NH₃ from synthetic fertilisers and country specific fractions for organic fertilisers. The estimation of the emissions from nitrogen leaching and run-off is made with a country specific method. The summary of the latest key category assessment, methods and EF used, and information on completeness, are presented in table 5.24.

Table 5.24. Summary of source category description for the entire category CRF 3.D.b, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
3.D.b.1	N ₂ O	X			CS	D	Yes
3.D.b.2	N ₂ O	X			CS	D	Yes

CS - Country Specific. T1 - tier 1. D - Default.

5.4.2.2 METHODOLOGICAL ISSUES

5.4.2.2.1 Atmospheric deposition from agricultural soils

The formula used to estimate N₂O-N from atmospheric deposition is:

$$N_2O-N = [(F_{SN} \times Frac_{GASF}) + (F_{ON} \times Frac_{GASM}) + (F_{PRP} \times Frac_{GASG})] \times EF_4$$

Where F_{SN} is the annual amount of inorganic N fertiliser applied to soils. F_{ON} is the annual amount of managed animal manure, sewage sludge and other organic N fertiliser applied to soil. Frac_{GASF} is the fractions of N that volatilises from inorganic fertilisers. The proportion lost differs between different types of

fertilisers²³¹ (table 5.25). In table 5.26 the amount of nitrogen in sold ammonia-emitting products are shown, which directly explains variations in the $Frac_{GASF}$ between different years. $Frac_{GASM}$ describe the amount of nitrogen that volatilises from application of organic N fertilisers (table 5.27) and $Frac_{GASG}$ describe the fractions of N excreted on pastures that volatilises (table 5.28). Both these fractions are estimated by the model used for the national ammonia emission inventory.

Table 5.25. Emissions of ammonia from different fertiliser types.

Fertiliser	Lost as ammonia (g NH ₃ /kg N)
Anhydrous ammonia	19
Ammonium nitrate (AN)	15
Ammonium phosphate	50
Ammonium sulphate (AS)	90
Calcium ammonium nitrate (CAN)	8
Ammonium solutions (AN)	98
NK mixtures	15
NP mixtures	50
NPK mixtures	50
Other straight N compounds	10
Urea	155

Table 5.26. Amount of nitrogen in inorganic fertilisers (t).

Year	Anhydrous ammonia	Ammonium nitrate (AN)	Ammonium phosphate	Ammonium sulphate (AS)	Calcium ammonium nitrate (CAN)	Ammonium solutions (AN)	NK mixtures	NP mixtures	NPK mixtures	Other straight N compounds	Urea	Proportion of emitted fertiliser-N ($Frac_{GASF}$)
1990	0	28 877	0	3 797	65 151	913	2 221	15 596	56388	48828	2 729	0.0218
1995	0	25 507	0	3 354	57 548	806	1 962	13 776	51319	43129	899	0.0211
2000	0	18 429	0	1 966	58 474	1 101	2 216	11 440	50957	44516	301	0.0203
2005	68	6 561	574	653	76 931	27	1 636	7 954	59030	7895	239	0.0219
2010	0	10 511	0	513	93 535	669	1 390	2 540	52815	5565	462	0.0193
2014	0	7 054	0	634	97 574	807	825	662	65578	7826	130	0.0202
2015	0	15 266	0	902	106 196	30	767	991	60259	4933	856	0.0191
2016	0	13 670	0	1 395	95 546	1 328	694	1 092	62240	9148	887	0.0205

Statistics on fertilisers are from Swedish Board of Agriculture.

²³¹ EMEP/EEA air pollutant emission inventory guidebook 2016

Table 5.27. Amount of nitrogen in organic N fertilisers.

Year	Amount of nitrogen in animal manure applied to soils (t)	Amount of nitrogen in sewage sludge applied to soils (t)	Amount of nitrogen in other organic fertilisers applied to soils (t)	Fraction of applied organic N fertilisers that volatilises (Frac _{GASM})
1990	76 631	1 180	1 700	0.1721
1995	79 794	2 304	1 700	0.1739
2000	75 587	1 758	1 800	0.1738
2005	74 029	1 053	1 743	0.1725
2010	72 703	2 224	2 712	0.1669
2014	73 264	2 374	4 386	0.1692
2015	73 381	2 802	4 386	0.1691
2016	73 413	2 802	5 358	0.1616

Table 5.28. Amount of nitrogen excreted on pasture by grazing animals.

Year	Amount of nitrogen in urine and dung deposited by grazing animals (t)	Fraction of nitrogen from grazing animals that volatilises (Frac _{GASG})
1990	44 245	0.0765
1995	46 663	0.0766
2000	46 724	0.0769
2005	47 475	0.0766
2010	45 243	0.0761
2014	43 384	0.0758
2015	43 187	0.0758
2016	43 959	0.0759

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 model²³², which is a part of the SOIL/SOILN model²³². 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 soils²³³. Since then the model has been elaborated and tested on data from controlled leaching experiments, and these tests show that the model estimates the leaching from soil with good precision²³⁴. By using national data on crops, yields, soil, use of fertiliser/manure and spreading time, the leaching is estimated for 22 regions. These regions are based on similarities in agricultural production areas. On average data from this

²³² Johnsson, 1990; Swedish EPA, 2002; <http://www.naturvardsverket.se/Documents/publikationer/978-91-620-5995-8.pdf>

²³³ Johnsson et al., 1987.

²³⁴ Swedish EPA, 2002b.

model has been published about every five years, intermittent years have been interpolated (Table 5.29).

When calculating nitrogen leaching in the inventory, the average N leaching per hectare, calculated by the SOILNDB model, is multiplied by the total Swedish area of agricultural soil. This model is not developed to individually estimate the nitrogen leakage that derives from manure management or from managed soils, consequently all emissions from leaching and runoff are reported here and the notation key IE (included elsewhere) is reported in sector 3.B.

Table 5.29. Parameters used to estimate indirect emissions from nitrogen leaching and run-off.

Year	Average N leaching per hectare (kg/ha)*	Total amount of nitrogen lost from leaching and run-off (t)	Fraction of nitrogen lost through leaching and run-off (FracLEACH)
1990	24.6	76 020	0.1664
1995	21,0	64 156	0.1302
2000	20.5	62 025	0.1239
2005	18,0	53 908	0.1407
2010	18,0	52 655	0.1418
2014	19,0	53 725	0.1272
2015	19,0	53 395	0.1337
2016	19,0	53 004	0.1306

* Estimated with the SOIL/SOILN model.

To estimate the implied $Frac_{LEACH}$, which is required as additional information in CRF 3.D, the leached nitrogen according to the national model, is divided by the sum of applied nitrogen in inorganic fertilisers, organic fertilisers (including sewage sludge and other organic fertilisers), amount of N deposited by grazing animals, above- and below-ground crop residues and amount of N mineralised in mineral soils. This quotient varies between 0.17 and 0.12 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).

5.4.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The average nitrogen leaching from agricultural soils, i.e. the leach factor, is estimated by the Swedish University of Agricultural Sciences. The value for 1990 is calculated from an investigation that estimated nitrogen leaching for the years 1985 and 1994, however, only for the southern part of Sweden. So the value used is corrected to apply to the whole of Sweden. The reason for the continuous decrease between 1999 and 2005 is believed to mainly be dependent on an increase in the area of catch crops. However, an increased awareness of the eutrophication problem has also led to changes in fertilising patterns. This model is considered to be the best available in Sweden, taking many relevant factors into account. Since

statistics on the use of fertilisers and manure are produced every other year,²³⁵ the estimates can be updated at most every second year. However, due to economic reasons, the data has been published intermittently.

5.4.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Annual increase or decrease is verified for the whole time series for all sub sources to decide that all annual changes are reasonably. We compare the times series for the emission with the time series for the activity data to confirm that are in agreement. We regularly conduct crosschecks of country-specific factors against the IPCC defaults. We annually utilize experts from the Swedish board of agriculture to conduct expert peer review of the methods used and we have regular meetings with authorities that provide activity data to the inventory to ensure that the quality of the data are of satisfactory quality and that they in turn use appropriate QC methods.

5.4.2.5 SOURCE-SPECIFIC RECALCULATIONS

(i) The time series for the emissions of ammonia has been updated in the reporting to the LRTAP convention. This was a consequence of an updated time series from the Swedish board of agriculture on the amount of different types of mineral fertilizers sold yearly. In addition, the emissions factors for ammonia emitted from mineral fertilizers have been updated with the ones reported in the EMEP/EEA air pollutant emission inventory guidebook 2016. Consequently, the indirect emissions from 3.D.b.1, atmospheric deposition have also been affected. This was the revision that had the most significant effect on the indirect emissions, however, all recalculation mention above for the sectors 3.B and 3.D.a have a slight impact on the indirect emissions. (ii) As a consequence of the method used by the Swedish national inventory of forests (see 6.3.1.1) the total area of mineral soils has been updated for several years. This affects the emissions from nitrogen leaching and run-off.

The total effect of the recalculations in 3.D.b was a decrease of the estimated emissions with 14 kt and 16 kt CO₂-eq for 2014 and 2015, 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 CO₂ emissions from liming (CRF 3.G)

5.4.3.1 SOURCE CATEGORY DESCRIPTION

Lime is used in agriculture and horticulture to mitigate acidification and used for structural liming to improve soil properties. The amount applied is from 2010

²³⁵ Statistics Sweden, MI 30-series.

based on a survey among farmers on the usage of lime²³⁶. 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 Sweden²³⁷. The statistics on use of lime is also produced by Statistics Sweden every second year.

Table 5.30. Summary of source category description for the entire category CRF 3.G, according to approach 1.

CRF	Gas	Key Category Assessment 2016 (approach 2, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
3.G	CO ₂	X			T1	D	Yes

CS Country Specific. T1 tier 1. D Default.

5.4.3.2 METHODOLOGICAL ISSUES

The tier 1 method from the guidelines is used together with default emission factors. The applied quantities are separated into dolomite (CaMg(CO₃)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 5.31). 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 5.31. 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
2014	206 190	67 960
2015	206 190	67 960
2016	206 190	67 960

²³⁶ Statistics Sweden, MI30 series. (www.scb.se/mi1001)

²³⁷ Statistics Sweden, MI30 series. (www.scb.se/mi1001)

5.4.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

From 2010, there was a change in the estimation method for the applied amount of lime in agriculture. Between 1990 and 2009, the amount is estimated from the quantity lime sold for agricultural and horticultural purposes plus lime from sugar mills and steel production. This was produced from a survey among all distributors of lime in Sweden. As from 2010, the applied amount is instead estimated from a survey among farmers where they are asked about their usage of lime in the previous year. The reason for the change is that lately the usage of liming products that was not sold through distributors was becoming more common. For example, by-products from paper mills that sometimes was given for free to the farmers and consequently not included in the sale statistics. Between 2010 and 2012, both surveys were run in parallel to examine the difference between the two estimates. The comparison also confirmed the suspicion that the usage statistics results in higher amounts. However, these by-products have only been largely available in the end of the time-series, so the overall trend has not been affected by this.

5.4.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Annual increase or decrease is verified for the whole time series for all sub-sources to decide that all annual changes are reasonable. We compare the times series for the emission with the time series for the activity data to confirm that are in agreement. We regularly conduct crosschecks of country-specific factors against the IPCC defaults. We annually utilize experts from the Swedish board of agriculture to conduct expert peer review of the methods used and we have regular meetings with authorities that provide activity data to the inventory to ensure that the quality of the data are of satisfactory quality and that they in turn use appropriate QC methods.

5.4.3.5 SOURCE-SPECIFIC RECALCULATIONS

No recalculation has been made for this source since last submission.

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 CO₂ emissions from urea application (CRF 3.H)

5.4.4.1 SOURCE CATEGORY DESCRIPTION

During urea manufacturing CO₂ is removed from the atmosphere. This CO₂ is subsequently emitted when adding the urea to soils during fertilisation. The emissions from this category are small in Sweden because the use of urea is limited. When recalculated into fertiliser N, the nitrogen in urea corresponds to some 0.5% of the total amount of nitrogen applied from inorganic fertilisers in 2016.

Table 5.32. Summary of source category description for the entire category CRF 3.H, according to approach 1.

CRF	Gas	Key Category Assessment 2016 (approach 2, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
3.H	CO ₂				T1	D	Yes

CS Country Specific. T1 tier 1. D Default.

5.4.4.2 METHODOLOGICAL ISSUES

Data on the annual use of urea is from sales statistics are published annually by Statistics Sweden (see table 5.26). 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).

$$CO_2 = \text{Tonnes urea/yr} \times EF \times 44/12$$

5.4.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The same data source as the calculation of direct emissions of N₂O from inorganic N fertilisers is used. Hence, the description of the time series consistency is found above under that paragraph.

5.4.4.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Annual increase or decrease is verified for the whole time series for all sub sources to decide that all annual changes are reasonably. We compare the times series for the emission with the time series for the activity data to confirm that are in agreement. We regularly conduct crosschecks of country-specific factors against the IPCC defaults. We annually utilize experts from the Swedish board of agriculture to conduct expert peer review of the methods used and we have regular meetings with authorities that provide activity data to the inventory to ensure that the quality of the data are of satisfactory quality and that they in turn use appropriate QC methods.

5.4.4.5 SOURCE-SPECIFIC RECALCULATIONS

No recalculation has been made in this category since last submission.

5.4.4.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

6 Land Use, Land-Use Change and Forestry (CRF sector 4)

6.1 Overview of LULUCF

Sweden reports carbon stock changes from Forest land, Cropland, Grassland, Settlements and peat production areas under Wetlands. Except from peat production areas, Wetlands and Other land are considered unmanaged. However, on a request from reviewers, emissions/ removals from changes in living biomass and mineral soils are now reported for Forest land converted to Other land – even though such land is considered unmanaged.

The reporting also includes emissions and removals from the harvested wood products pool (HWP), N₂O emissions associated with nitrogen fertilization of Forest land (4[I]), N₂O and CH₄ emissions from drained organic soils and CH₄ emissions from drainage ditches on these soils (4[II]), CO₂ from dissolved organic carbon (DOC), N₂O emissions due to mineralisation caused by land use conversions or management change (4[III]), indirect N₂O emissions (4[IV]) as well as N₂O and CH₄ emissions from biomass burning (4[V]). The extent of reporting of carbon pools, emissions, methodological tiers and result from the key category assesment for the LULUCF-sector is summarized in Table 6.1.

Table 6.1.a and 6.1.b Status of reporting of carbon pools, other emissions, methodological tiers and key categories according to approach 1, CRF 4

6.1.a	Carbon pools				Other emissions				
	Living biomass	Litter	Dead wood	Soil carbon mineral/organic ¹	4(I)	4(II)	4(III) ²	4(IV)	4(V)
4. LULUCF	-	-	-	-	-	-	-	T2	-
4.A.1 (Forest Land remaining Forest Land)	T3	T3	T3	T3/T2	T1	T1	T2	-	T1
4.A.2 (Land converted to Forest Land)	T3	T2	T2	T2	NO	T1	T2	-	NO
4.B.1 (Cropland remaining Cropland)	T3	T3	T3	T3/T1	IE	T1	IE	-	IE
4.B.2 (Land converted to Cropland)	T3	T2	T2	T2	IE	T1	T2	-	IE
4.C.1 (Grassland remaining Grassland)	T3	T3	T3	T3/T1	NO	T1	T2	-	T1
4.C.2 (Land converted to Grassland)	T3	T2	T2	T2	NO	T1	T2	-	IE
4.D.1 (Wetlands)	NA	NA	NA	NA/T1	NA	T1	NA	-	NA

6.1.a	Carbon pools				Other emissions				
	Living biomass	Litter	Dead wood	Soil carbon mineral/organic ¹	4(I)	4(II)	4(III) ²	4(IV)	4(V)
remaining Wetlands)									
4.D.2 (Land converted to Wetlands)	NA	NA	NA	NA	NA	NA	NA	-	NA
4.E.1 (Settlements remaining Settlements)	T3	NE	NE	NE	NO	NE	NE	-	IE
4.E.2 (Land converted to Settlements)	T3	T2	T2	T2	NO	NE	T2	-	IE
4.F Other land	NA	NA	NA	NA	NA	NA	NA	-	NA
4.F.2.1 Forest land converted to Other land	T3	NA	NA	T1	NA	NA	T2	-	NA
4.G HWP	T3	-	-	-	-	-	-	-	-

¹ Includes DOC for organic soils, ² Includes N₂O and CH₄ from drained organic soils and CH₄ from ditches.

6.1.b	Key category assessment		
	Gas	Level	Trend
4 A 1 Forest land remaining forest land	CO ₂	X	X
4 A 2 1 Cropland converted to forest land	CO ₂	X	X
4 A 2 2 Grassland converted to forest land	CO ₂		X
4 A 2 4 Settlements converted to forest land	CO ₂	X	X
4 A Drained organic soils	CH ₄	X	X
4 A Drained organic soils	N ₂ O	X	X
4 B 1 Cropland remaining cropland	CO ₂	X	X
4 B Drained organic soils	CH ₄	X	X
4 C 1 Grassland remaining grassland	CO ₂	X	X
4 C 2 1 Forest land converted to grassland	CO ₂	X	X
4 D 1 1 Peat extraction remaining peat extraction	CO ₂	X	X
4 E 1 Settlements remaining settlements	CO ₂		X
4 E 2 1 Forest land converted to settlements	CO ₂	X	X
4 E 2 2 Cropland converted to settlements	CO ₂	X	X
4 G Total HWP from domestic harvest	CO ₂	X	X

6.1.1 Emission/removals in LULUCF 1990-2016

In 2016 the net removal from the Land Use, Land-Use Change and Forestry LULUCF-sector was estimated to -42 962 kt CO₂ including net removals in harvested wood products and to -34 735 kt CO₂ when excluding net removals in harvested wood products. The net removal decreased from 2015 to 2016 by 1 896 kt CO₂.

There is small but not very significant long-term trend with increasing net removals in the LULUCF-sector as a whole. There are inter-annual variations in different

subcategories but also long-term trends due to land-use changes, for instance the total area used for crop production is continuously decreasing.

Although inter-annual fluctuations in harvest rates are quite large, the long term trend of increase in harvest rates has levelled off in the last years resulting in a slightly increasing sink in living biomass. This is also due to a significant increase in gross removals (growth) in Sweden which currently amount to around 120 Mm³ stemwood (approx. 165 Mt CO₂ whole tree biomass per year). In 2016 the gross stemwood harvest was approximately 91.6 Mm³.

6.1.1.1 LAND USE CATEGORIES AND EMISSION/REMOVALS IN CARBON POOLS

Forest is the largest land-use category in Sweden. The total forest area (using FAO forest definition) is about 28 Mha. The productive forests (where annual stem wood production per hectare and year is larger than 1 m³), on which most of the reported changes in carbon pools occur, is about 23 Mha²³⁸.

Harvest of trees is more or less restricted to productive forests. There has been a continuous increase in felling during the reported period peaking in 2005 (due to wind throws originating from a severe storm). After that the felling has been more or less constant. The growth rate has also increased steadily. However, harvest fluctuates considerably between years due to changes in demand for forest products.

The largest carbon stocks are found in the living biomass and soil organic carbon pools on Forest land, and the largest annual stock change is the change in the living biomass pool (Figure 6.1 and 6.2). Due to increases in the living biomass pool net removal of between 30 – 50 Mton CO₂-eq. is reported for Forest land every year during the period.

The dead organic matter pool was a net source all years except for one year during the reported period, whereas the soil organic carbon resulted in net removals during all years except for one year of the reported period. Some soils are sources whereas others are sinks.

²³⁸ Swedish University of Agricultural Sciences, 2011

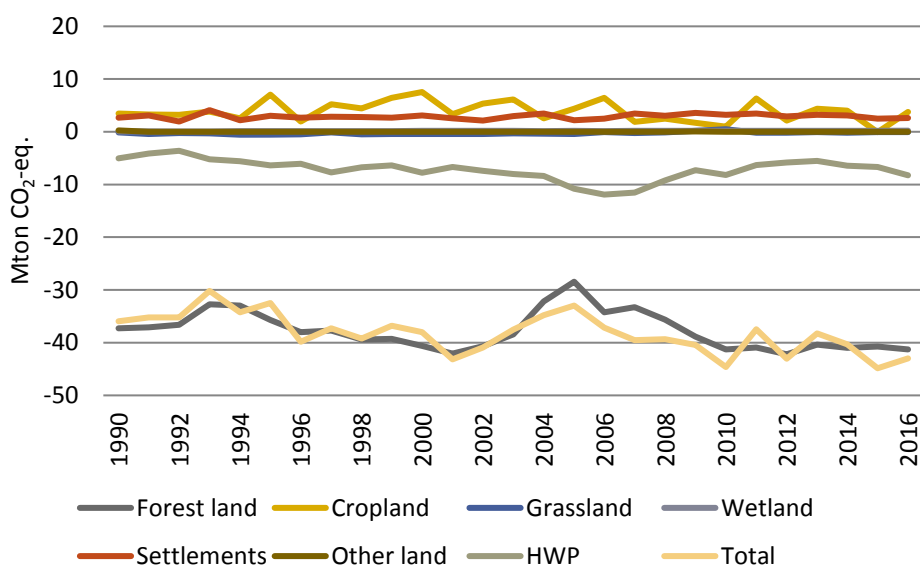


Figure 6.1. Net emissions/removals of GHG in the LULUCF sector from different land-use categories and HWP (which is reported separately) and the total for the sector.

The HWP pool is an important sink which is a mirror image of the living biomass pool as can be seen in figure 6.2. This is because increased harvests results in increases in the HWP pool and at the same time reduces the net removals of CO₂ in the living biomass pool.

The major source within the LULUCF-sector is the emissions from drained organic soils (Histosols) on Forest land and on Cropland. An area of about 4.0 Mha of the Forest land was considered as Histosols and around 1.0 Mha of the Histosols are drained. The Cropland area on Histosols is estimated to approx. 140 kha and all of that area is drained. The emissions from Histosols on cropland previously dominated the emissions but after a revision of emission factors, a continuous decline in cropland area and the inclusion of non- CO₂ emissions from Histosols, drained Histosols on forest land have now become the most important source.

There has been considerable variation in the reported sink for the soil organic carbon pool on mineral soils between submissions for specific years. These variations are partly caused by random variation in the sample. Since the total pool is huge and the changes in the pool are comparatively small the numbers are sensitive to random variation when small changes are multiplied by large areas. It can be noted that a change of 0.1 % in the pool is equivalent to more than 3 000 kt CO₂. The variation between years is reduced due to the method for extrapolation of data on plot basis. However, variation between submissions may still be substantial. The variation has decreased with time when more plots are re-inventoried. Last year the first results from the third forest soil inventory cycle were used in the calculations and this year another year of inventory data is added. This means that for 20 % of the plots there are now results from 3 sampling occasions. A summary of emissions/ removals is found in Tables 6.2a and 6.2b.

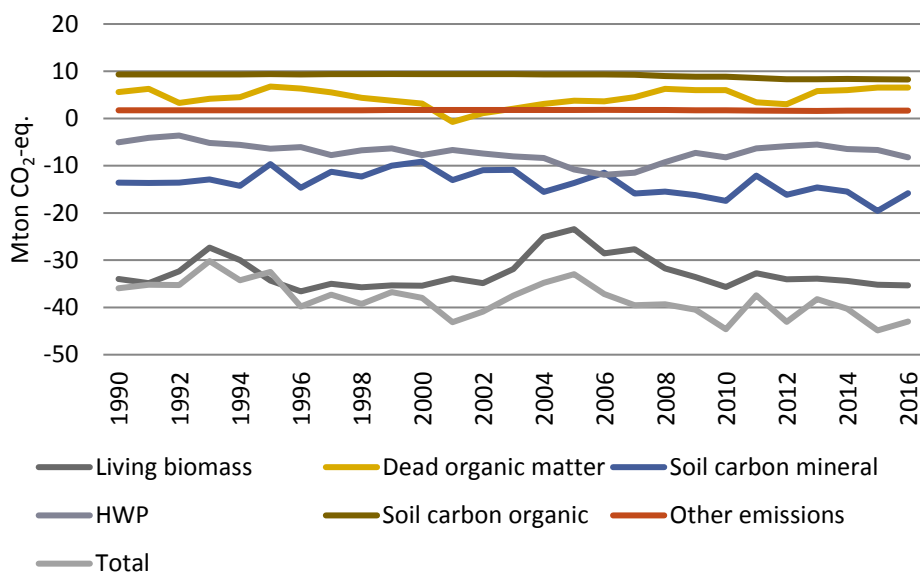


Figure 6.2. Net removals/emissions of GHG in the LULUCF sector from different carbon pools, other emissions (including CH₄ and N₂O from different sources), HWP and the total for the sector.

6.1.1.2 OTHER EMISSIONS 4(I), 4(II), 4(III), 4(IV) AND 4(V)

Data for categories commented below are presented in Table 6.2.b. Emissions of N₂O from nitrogen fertilization of forest land increased steadily from 2002 to 2010 but have decreased since then due a decrease in the use of fertilisers in forestry.

Emissions of N₂O and CH₄ from Histosols show no trend between 1990 and 2006, thereafter the emissions decrease. This is due to a decrease in the area of drained organic forest soils. Emissions from Wetlands used for peat extraction increases slightly over the entire reported period. Emissions of non- CO₂ gases from drained soils include emissions from soils as well as direct emissions from ditches. The total emission of non-CO₂ gases from drained organic soils amount to 1 478 kt CO₂ eq. in 2016, which is a decrease from 1 639 kt CO₂ eq. in 1990 in line with the decrease in drained organic forest soils area. Note that N₂O emissions from Cropland are reported in the agriculture sector.

Emissions of CO₂ from DOC reported from Histosols follow the same trend as the non-CO₂ emissions for all land use categories as they are based on the same area estimates.

N₂O emissions from mineralisation due to land use conversion and management change which is included for all land use change categories as well as land use categories (except Cropland remaining cropland) shows a slightly increasing trend until 2007 due to the accumulations of areas in land use change categories but levels off thereafter since land that has been 20 years in the transition categories is moved to the new land-use categories.

The burned area, which strongly drives the emissions from biomass burning, shows no trend. Except for 2014, the emissions from these categories correspond to less than 0.2 Mt CO₂-eq. per year during the entire period 1990-2016 (including CO₂ emissions that otherwise are reported IE as an emission from living biomass). However, the warm and dry summer of 2014 resulted in a large wildfire (figure 6.6) and the total emission that year was estimated to 0.31 Mt CO₂-eq. A summary of emissions/ removals is found in Tables 6.2a and 6.2b.

Table 6.2.a. Summary of net removals (-)/emissions (+) in living biomass (LB), dead wood, litter, dead organic matter (DOM), soil organic carbon (SOC) and harvested wood products (HWP) per land use category. Note that carbon stock change in organic soils also includes DOC.

6.2a	Net emissions / removals (minus=removal) [Mt CO ₂]																				
	Forest land					Cropland				Grassland				Wet- land SOC	Settlement				Other land		H
	LB	Dead wood	Litter	SOC		LB	DOM	SOC		LB	DOM	SOC			LB	DOM	SOC		LB	Min	
				Min	Org			Min	Org			Min	Org				Min	Org			
1990	-36.3	-4.1	10.0	-13.9	5.6	-0.1	0.0	0.0	3.4	0.2	-0.4	-0.2	0.3	0.1	2.0	0.1	0.5	0.0	0.3	NO	-
1991	-36.8	-3.5	10.0	-13.9	5.6	-0.1	0.0	-0.2	3.4	-0.2	-0.4	-0.2	0.3	0.1	2.2	0.1	0.6	0.0	0.0	NO	-
1992	-33.3	-6.5	10.0	-13.9	5.6	-0.1	0.0	-0.2	3.4	0.0	-0.4	-0.2	0.3	0.1	1.1	0.2	0.7	0.0	0.0	NO	-
1993	-30.3	-5.6	10.0	-13.9	5.6	0.0	0.0	0.3	3.3	-0.1	-0.4	-0.2	0.3	0.1	3.1	0.2	0.7	0.0	0.0	NO	-
1994	-30.7	-5.3	10.0	-13.9	5.6	-0.1	0.0	-0.9	3.3	-0.3	-0.4	-0.2	0.3	0.1	1.1	0.2	0.8	0.0	0.0	NO	-
1995	-35.8	-3.0	10.0	-13.9	5.6	-0.1	0.0	3.6	3.3	-0.3	-0.4	-0.2	0.3	0.1	1.9	0.2	0.8	0.0	0.0	NO	-
1996	-37.7	-3.4	9.9	-13.8	5.6	-0.1	0.0	-1.5	3.3	-0.2	-0.4	-0.2	0.3	0.1	1.5	0.2	0.9	0.0	0.0	NO	-
1997	-36.6	-4.2	9.9	-13.8	5.6	-0.1	0.0	1.8	3.3	0.1	-0.4	-0.2	0.3	0.1	1.6	0.3	0.9	0.0	0.0	NO	-
1998	-37.0	-5.3	9.7	-13.9	5.6	0.0	0.0	0.8	3.3	-0.3	-0.3	-0.2	0.3	0.1	1.5	0.3	0.9	0.0	0.0	NO	-
1999	-36.2	-6.0	9.8	-14.0	5.6	-0.2	0.0	3.2	3.3	-0.2	-0.3	-0.2	0.3	0.1	1.3	0.3	1.0	0.0	0.0	NO	-
2000	-36.8	-6.6	9.8	-14.0	5.6	0.0	0.0	4.0	3.3	-0.3	-0.3	-0.2	0.3	0.1	1.6	0.3	1.1	0.0	0.0	NO	-
2001	-34.4	-10.5	9.8	-14.0	5.6	-0.3	0.0	0.0	3.3	-0.2	-0.3	-0.2	0.3	0.1	1.0	0.3	1.1	0.0	0.0	NO	-
2002	-35.0	-8.7	9.7	-13.8	5.6	-0.2	0.0	2.0	3.3	-0.2	-0.3	-0.3	0.3	0.1	0.5	0.3	1.2	0.0	0.0	NO	-
2003	-32.8	-8.3	10.4	-14.8	5.7	-0.2	0.0	2.8	3.3	-0.1	-0.3	-0.1	0.3	0.1	1.3	0.3	1.2	0.0	0.0	NO	-
2004	-26.4	-10.0	13.0	-15.8	5.6	-0.2	0.0	-0.8	3.3	-0.1	-0.3	-0.2	0.3	0.1	1.7	0.4	1.3	0.0	0.0	NO	-
2005	-23.3	-9.4	13.1	-15.9	5.6	-0.3	0.0	1.1	3.3	-0.2	-0.3	-0.2	0.3	0.2	0.3	0.4	1.3	0.0	0.0	NO	-
2006	-29.0	-9.6	13.1	-15.8	5.6	-0.3	0.0	3.2	3.3	0.2	-0.3	-0.2	0.3	0.1	0.6	0.4	1.4	0.0	0.0	NO	-
2007	-28.8	-8.5	12.9	-15.8	5.5	-0.4	0.0	-1.3	3.3	0.1	-0.3	-0.3	0.3	0.2	1.4	0.4	1.4	0.1	0.0	NO	-
2008	-32.6	-6.9	13.1	-15.9	5.2	-0.3	0.0	-0.7	3.3	0.2	-0.3	-0.3	0.3	0.2	1.1	0.4	1.3	0.1	0.0	NO	-
2009	-35.4	-7.3	13.2	-15.9	5.1	-0.3	0.0	-1.5	3.2	0.5	-0.3	-0.3	0.3	0.2	1.7	0.4	1.3	0.1	0.1	NO	-
2010	-37.4	-7.3	13.2	-16.3	5.1	-0.3	0.0	-2.3	3.2	0.7	-0.3	-0.2	0.3	0.2	1.4	0.4	1.3	0.1	0.0	NO	-
2011	-34.3	-9.8	13.1	-16.2	4.9	-0.1	0.0	3.0	3.2	0.0	-0.3	-0.2	0.3	0.2	1.6	0.4	1.3	0.1	0.0	NO	-
2012	-34.8	-10.2	13.1	-16.2	4.6	-0.2	0.0	-1.1	3.2	0.0	-0.3	-0.2	0.2	0.2	1.0	0.4	1.3	0.1	0.0	NO	-
2013	-35.1	-7.7	13.4	-16.9	4.6	-0.2	0.0	1.2	3.2	0.1	-0.3	-0.1	0.2	0.2	1.3	0.4	1.3	0.1	0.0	NO	-
2014	-35.3	-8.0	13.9	-17.6	4.7	-0.2	0.0	0.8	3.1	0.0	-0.2	-0.1	0.2	0.2	1.1	0.4	1.4	0.1	0.0	NO	-
2015	-35.6	-7.5	13.9	-17.5	4.6	-0.2	0.0	-3.2	3.1	0.1	-0.2	-0.1	0.2	0.2	0.5	0.3	1.3	0.1	0.0	NO	-
2016	-36.0	-7.5	13.9	-17.6	4.6	-0.1	0.0	0.6	3.1	0.1	-0.2	-0.1	0.2	0.2	0.8	0.3	1.3	0.1	0.0	NO	-

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]								Total Mt CO ₂ - eq
	Fert.	Drainage		Min.	Ind.	Biomass burning			
	4 (I)	4(II)		4(III)	4(IV)	4 (V)			
Year	N ₂ O	CH ₄	N ₂ O	N ₂ O	N ₂ O	CO ₂	CH ₄	N ₂ O	
1990	0.16	18.69	3.92	0.18	0.03	IE	0.0820	0.0006	-35.9
1991	0.10	18.69	3.93	0.21	0.01	IE	0.0764	0.0005	-35.2
1992	0.07	18.70	3.93	0.23	0.01	IE	0.0773	0.0005	-35.2
1993	0.06	18.67	3.93	0.26	0.01	IE	0.0797	0.0005	-30.2
1994	0.05	18.73	3.95	0.27	0.01	IE	0.0764	0.0005	-34.2
1995	0.06	18.79	3.96	0.29	0.01	IE	0.0768	0.0005	-32.5
1996	0.06	18.76	3.96	0.29	0.01	IE	0.0820	0.0006	-39.8
1997	0.04	18.80	3.96	0.30	0.01	IE	0.4186	0.0029	-37.3
1998	0.04	18.78	3.96	0.32	0.01	IE	0.0222	0.0002	-39.2
1999	0.06	18.86	3.96	0.33	0.01	IE	0.1415	0.0010	-36.8
2000	0.06	18.87	3.95	0.36	0.01	IE	0.1406	0.0010	-38.0
2001	0.05	18.88	3.95	0.38	0.01	IE	0.1439	0.0010	-43.1
2002	0.03	18.87	3.96	0.41	0.01	IE	0.2321	0.0016	-40.9
2003	0.04	18.79	3.94	0.42	0.01	IE	0.2877	0.0020	-37.5
2004	0.05	18.66	3.92	0.45	0.01	IE	0.2569	0.0018	-34.8
2005	0.07	18.73	3.92	0.46	0.01	IE	0.2377	0.0016	-33.0
2006	0.08	18.59	3.94	0.48	0.01	IE	0.6235	0.0043	-37.2
2007	0.11	18.65	3.92	0.50	0.02	IE	0.1145	0.0008	-39.5
2008	0.14	18.37	3.78	0.48	0.02	IE	0.6319	0.0043	-39.3
2009	0.13	18.22	3.70	0.48	0.02	IE	0.0904	0.0006	-40.5
2010	0.19	18.15	3.69	0.47	0.03	IE	0.0338	0.0002	-44.6
2011	0.12	17.82	3.57	0.49	0.02	IE	0.1015	0.0007	-37.4
2012	0.11	17.42	3.39	0.49	0.02	IE	0.0455	0.0003	-43.1
2013	0.06	17.47	3.45	0.49	0.01	IE	0.1178	0.0008	-38.3
2014	0.05	17.54	3.50	0.52	0.01	IE	1.2127	0.0083	-40.3
2015	0.08	17.51	3.50	0.51	0.01	IE	0.0669	0.0005	-44.9
2016	0.07	17.46	3.49	0.49	0.01	IE	0.1224	0.0008	-43.0

6.2 Land-use definitions and the classification systems used and their correspondence to the land use, land-use change and forestry categories

6.2.1 Forest land

Sweden has defined Forest land according to the Global Forest Resources Assessment (FAO/FRA) 2005²³⁹. Forest land is land with a tree crown cover (or equivalent stocking level) of more than 10 % at maturity, with a minimum area of 0.50 hectare and the trees should be able to reach a minimum height of 5 m at maturity *in situ*. However, there are two small discrepancies between the FRA 2005 definition and the definition implemented in the Swedish inventory. In the Swedish inventory permanent forest roads (width>5m) are not considered Forest land, and no minimum width to constitute Forest land is considered (note that the strict terms of decision 11/CP.7 does neither mention the minimum width nor the forest roads²⁴⁰). Even if all these requirements are fulfilled, the land is only considered Forest land if the predominant land use is forestry. All Forest land is considered managed, i.e. even protection of forests in nature reserves is considered as management.

6.2.2 Cropland

Cropland is defined as regularly tilled agricultural land and all Cropland is assumed managed.

6.2.3 Grassland

Grassland is defined as agricultural land that is not regularly tilled and all Grassland is assumed managed. In the Swedish inventory this corresponds to natural grazing land.

6.2.4 Wetlands

Generally, Wetlands is assumed unmanaged and is defined as mires and areas saturated by fresh water. However, approx. 10 000 ha of the Wetland area is used for peat extraction and therefore assumed managed.

6.2.5 Settlements

Settlements are defined as infrastructure components such as roads and railways, power lines within forests, municipality areas, gardens and gravel pits. All Settlements are assumed managed.

²³⁹ Food and Agriculture Organization of the United Nations, 2004

²⁴⁰ FCCC/CP/2001/13/Add.1, p 58

6.2.6 Other land

Other land is defined as impediments (waste land) and includes most of the mountain area in northwest Sweden. All Other land is assumed unmanaged.

6.2.7 The connection between national and reported land use categories

The reported land use categories are based on 12 (originally 16) national land use categories (Table 6.3) monitored by the Swedish National Forest Inventory.

Table 6.3. National Land Use Categories (used in the NFI) and their connection to the UNFCCC Land Use Categories. The area estimate in this example is based on both temporary and permanent sample plots representing the average 2012-2016.

National Land Use Category (NFI)	Forest land	Other wooded land	Bare unprod. land	Other land	Total	Additional Explanation and corresponding UNFCCC-category (in bold).
Area [1000 ha]						
1. Productive Forest land	23612				23612	Land which hosts a potential yield of stem-wood exceeding one cubic metre per hectare and year. Forest land .
2. Grazing Land				512	512	Not regularly cultivated, Grassland .
3. Arable Land				2802	2802	Regularly cultivated, Cropland .
4. Mire	2223	1104	1806		5133	Land which hosts a potential yield of stem-wood lower than one cubic metre per hectare and year, Forest land (if forest according to FAO) or Wetlands (larger part) .
5. Rock Surface	674	134	151		959	Rocky or stony areas, Forest land or Other land .
6. Sub alpine Coniferous Woodland	845	77	18		940	Land-zone usually located between 1 and 7. Forest land (if forest according to FAO) or Other land
7. High Mountain	732*			4278**	5010	Usually unstocked or sparsely stocked, Forest land (if forest according to FAO) or Other land
9. Road and Railroad				512	512	For permanent use. Not only roadway and rail but also other connected areas as embankments, Settlements
10. Power line Within Forest				147	147	Minimum width 5 m, Settlements
13. Urban Land				1119	1119	Settlements of many different kinds. Settlements
14. Other land				69	69	Different kinds of land that is not covered by Other land use categories. Examples: gravel pits, halting places and slalom slopes, Settlements
15. Freshwater				4362	4362	Lakes, rivers, creeks, canals, pounds etc. Minimum width of 2 m, Wetlands .
UNFCCC-categories	FL	28086			28086	
	CL			2802	2802	
	GL			512	512	
	WL	1104	1806	4362	7272	
	S			1847	1847	
	OL	210	169	4278	4657	
Total	28086	1314	1975	13802	45177	

The land use categories “Protected area nature reserve”, “Other climate impediment” and “Military impediment” are included in other land use categories and the land use category “Sea” is not reported at all. An area of 732 kha (*) of High mountains (**) is assumed to be Forest land but no measurements of living biomass or other carbon pools are made in the field in these areas. Thus no carbon stock changes of living biomass is reported on this land. Observe that this example is based on both temporary and permanent sample plots representing average 2012-2016. Thus, the total land area is not exactly the same as the total reported area.

6.2.8 Consistency in reporting land use categories

The NFI has monitored land-use categories in a reasonably consistent way since 1983. Based on permanent sample plots, it is possible to trace both gross and net land-use transfers from 1983 to 2012. After 2012 only net changes can be estimated since 2012 is currently the last year with a full sample record (see section 6.2.9).

All land areas are included in the field inventory except high mountains and urban land. These latter land-use categories are inventoried by remote sensing to be able to correctly determine areas. It is assumed that their relative importance for the Swedish carbon budget is negligible. For the first time, one of the five inventory-cycles (the 2016 inventory) include field inventoried plots also in the high mountain area. The plan is that all sample plots in the high mountains will be inventoried in field until 2020 and successively re-inventoried in five-year cycles.

A few historical inconsistencies in the land-use category assessment have been identified and corrected. In the past (until 2003), protected areas (“Protected Area, Nature Reserve”; see section 6.2.7) were not regularly inventoried. From 2003 and onwards this areas are included in the land-use categories where it belongs. Usually there are data from at least one field inventory of “protected areas” earlier than 1990, but for some areas there are no data available. If no historical data are available, the change in carbon pools in former “protected areas” is assumed to be zero from 1990 to 2002. From 2003 and onwards changes will be reported based on field inventory data. The FRA 2005 definition of Forest land was introduced in the field inventory in 1998 and therefore land-use assessments in earlier inventories has been re-evaluated. A description on the treatment of former protected areas, re-evaluation of the assessment of land-use and the methodology for correcting inconsistencies in the land-use category assessment are described in more detail in the methodology section.

6.2.9 Land use and land-use change matrix

The land use and land-use change matrix in Table 6.4 is based on all of the 30000 (1990-2012) sample plots in the inventory. For example, the total area of Forest land remaining Forest land and conversions to Forest land (4.A.1 + 4.A.2.1 + 4.A.2.2 + 4.A.2.3 + 4.A.2.4 + 4.A.2.5) was 28172.44 kha in 2012. This implies

that, given the sample, the land-use matrix is consistent with reported areas²⁴¹. Due to a five-year inventory cycle, we can only provide a full record of data for the years 1990-2012. Therefore, land use for recent years (2013-2016) is extrapolated 1, 2, 3 or 4 years depending on the inventory cycle, respectively. In the CRF Table 4.1, land use and land-use change matrices for recent years (2013-2016) are based on measured net land use per year and assumptions.

Table 6.4. Land Use Categories 2011, 2012 and gross and net land use transfers 2011-2012 (based on about 30 000 permanent sample plots inventoried 1983-2016).

Area [kha]	"From"	"To" Year 2012					
	Year 2011	Forest Land	Crop- Land	Grass- Land	Wet- Land	Settle- ments	Other Land
F	28157.04	28144.57	0.00	3.19	0.09	9.19	0.00
C	2900.23	12.81	2872.65	9.89	0.00	4.89	0.00
G	495.81	9.13	2.21	483.68	0.78	0.00	0.00
W	7376.31	0.15	0.00	0.00	7376.16	0.00	0.00
S	1836.78	5.78	1.66	0.60	0.00	1828.63	0.11
O	4349.68	0.00	0.00	0.00	2.60	0.00	4347.08
Sum		28172.44	2876.52	497.37	7379.64	1842.70	4347.19

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 (NFI²⁴²) and the Swedish Forest Soil Inventory (SFSI²⁴³) are integrated in the same sample design, using the same permanent sample plots.

The NFI plots are re-inventoried every fifth year and the SFSI plots are re-inventoried every tenth year since changes in the soil are expected to be slower than changes in living biomass. Moreover, topsoil cores are only taken at every second sample plot and deeper soil horizons are only sampled on every fourth sample plot. The reported data of changes in the living biomass and dead wood

²⁴¹ Given sample, the consistency is valid for up to 15 significant figures but this is not the same as accuracy of the estimator. Uncertainty of estimates is stressed in chapter 6.4.3

²⁴² Ranneby et al., 1987

²⁴³ Swedish University of Agricultural Sciences, <http://www-markinventeringen.slu.se/>

pools are based on the NFI-measurements and changes in the litter and soil organic carbon pools are based on the SFSI-measurements.

The NFI/SFSI is an annual, systematic, cluster-sample inventory of Sweden's forests (Figure 6.3 and 6.4). Each year roughly a thousand survey sample clusters are inventoried in the field. One third of the clusters are temporary and two thirds are permanent. Only permanent sample plots are used for the UNFCCC reporting. The clusters are distributed all over the country in a pattern that is denser in the southern part than that in the northern part of the country (there is stronger autocorrelation in the North). The clusters (tracts) are square-shaped with sample plots along each side. Each cluster consists of four to eight sample plots, depending on region. Each year, about 6000 permanent survey sample plots are inventoried in the field. On each circular sample plot, with a radius of 10 or 20 m depending on the assessed variable, information is collected about the trees, the stand and the site. The main focus of the NFI is on monitoring forests for timber production and status of the environment.

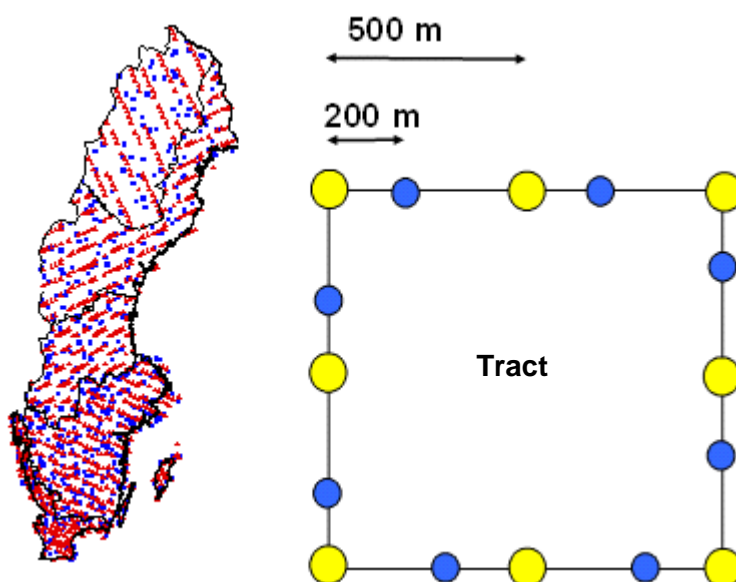


Figure 6.3. Covering the whole country of Sweden, each year a permanent sample grid (red) is re-inventoried and a temporary sample grid (blue) is inventoried. To be able to trace both gross and net land use transfers, only permanent sample plots are used in the reporting. When estimating changes of e.g. C, the accuracy is also higher using permanent than when using both temporary and permanent sampling plots. Each red dot represents a cluster of sample plots (Tract) and within Tract the yellow plots are used for the inventory while the blue plots are used for validation of harvests (estimates on up to one year old stumps).

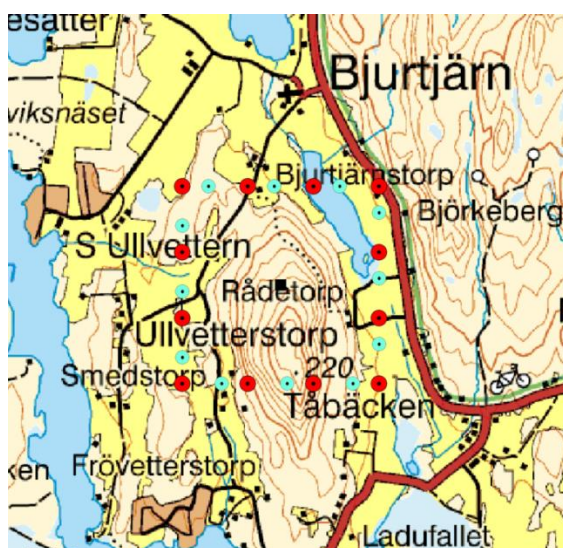


Figure 6.4. The sample plots (red) are covering all relevant land uses. On the example above, plots are located on e.g. Forest land, Cropland, Wetlands and some plots are divided into more than one land use category. On the plots, measurements are made to estimate standing biomass of trees. If at the next re-inventory, the trees remains and has been growing the plot represents a net sink but if they have been harvested the plot represents a source (stock change method). Volume of dead wood per decay classes are also measured on the plot. Soil samples from different soil horizons are sampled and analysed for C concentration and other properties. Litter is partly estimated using data from the plot and partly modelled. Observe that the size and number of tracts differs by county. An additional sample (blue) is used for estimates of harvests.

The SFSI uses the 10-m radius sampling plot. A number of variables are recorded including general site variables, soil and humus type. The litter and different soil layers are sampled for further laboratory analysis. The O, H or A horizon²⁴⁴ are sampled using an auger. The mineral soil used to be sampled in different but well defined layers according to the distance from the soil surface and to some extent depending on the soil type. From 2003 and onwards the soil sampling has been harmonized with an ongoing European inventory, i.e. Biosoil²⁴⁵ and soil samples are taken at fixed depths.

6.3.1.1 SAMPLE BASED ESTIMATIONS

The sample frame consists of a sampling grid covering the whole land and fresh water area of Sweden. A sea archipelago zone where islands covered by vegetation might occur is also included in the frame (but no sea area is reported). The frame is divided into 31 strata (i.e. representing counties) and a specific number of sample units are sampled per stratum. Each cluster (tract) of sample plots is assumed to be the sample unit. The inventoried area of a tract is given a specific area weight and will consequently represent a larger area. The weighing is generated so that the sum of all represented areas will be equal to the total county area.

²⁴⁴ O,H and A refers to the organic soil layers.

²⁴⁵ <http://biosoil.jrc.it/>

The land-use of whole plots or parts of plots may change with time but the total tract area will always represent the same area. At the county level, the reported value of a change in a carbon pool (for example a change in the living biomass pool for the land use category Forest land remaining Forest land) will be estimated by a ratio estimator²⁴⁶. Finally the reported value on national level is estimated as the sum of the county values (for further information, see Annex 3.2).

A five year inventory cycle is used and five different samples were randomly distributed (using a systematic grid) 1983, 1984, 1985, 1986 and 1987, respectively. Each of these samples consists of around 6000 sample plots. The expected value of an estimator is theoretically the same for any given sample but to reduce sample randomness all five samples are merged. Full sets of samples are currently only available for years until 2012 and consequently only 24000, 18000, 12000 and 6000 sample plots are available for the estimates of 2013, 2014, 2015 and 2016, respectively. Five years after any reporting year, all samples have been re-inventoried covering that particular year and the full set of data can be used to produce the estimate. Therefore, the four last years of the previous report are re-calculated and revised in each submission.

Since the effect of the random variation on the estimates of areas and carbon stock changes are larger for the four most recent years (as also noted in the annual review reports), Sweden now extrapolates each of the five sample series (cycles) using the trend for the five years prior to the year of the latest actual re-measurement, to enlarge the data set for the most recent years. In Figure 6.5, the extrapolation of each sample series and its consequences on the estimates are illustrated. The effect of the extrapolation levels out “strange” area and carbon stock variations evolving from the randomness of the sampling as exemplified in Figure 6.5²⁴⁷.

²⁴⁶ Thompson, 1992

²⁴⁷ This improvement and the information provided is a response to reviewers (ARR 2011)

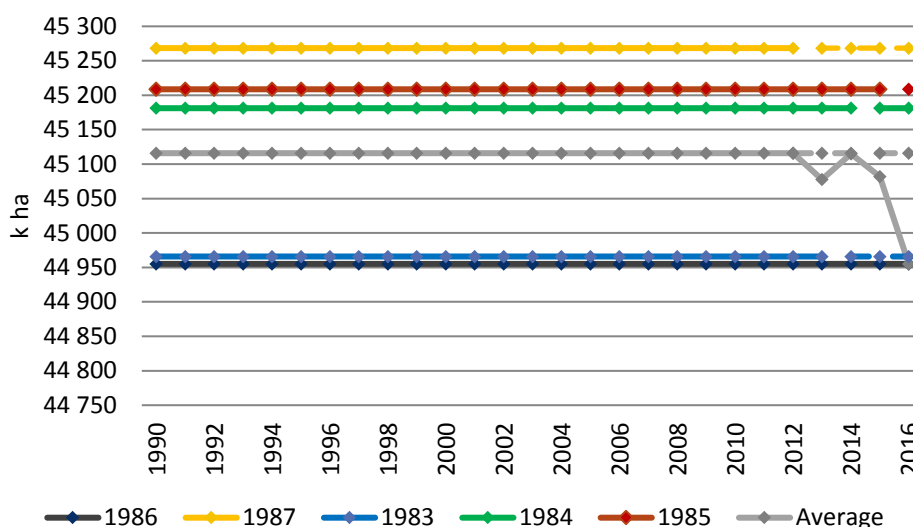


Figure 6.5. The total area of Sweden represented by five sub-samples (established in 1983, 1984, 1985, 1986 and 1987). Solid lines represent measured and dashed lines represent extrapolated values. The average solid line 1990-2016 represents average without extrapolated values and the average dashed line (2013-2016) represents the average with extrapolated values.

Sweden reports “human induced” carbon stock changes only, where “human induced” has the interpretation of “managed”, i.e. the carbon stock change on unmanaged land are set to zero. However, the actual stock in living biomass on unmanaged land is considered when calculating stock changes after conversions between unmanaged and managed land and vice versa. This is possible since trees are inventoried on almost any land. All areas, managed or unmanaged, are reported. On request by reviewers, emissions/ removals from changes in living biomass are now reported for Forest land converted to Other land (considered unmanaged).

6.3.1.2 THE LULUCF-REPORTING DATABASE

Around 30 000 permanent sample plots are used for the area based sampling. Land-use of each plot (or sub-plot for plots divided in two or more land use classes) is described from the year of the first inventory and every fifth year thereafter. If no land-use change has been identified for a plot, the land-use of years between consecutive inventories is held constant. If land use conversions are identified in field, the change in land use is set to the anticipated year of the conversion (see 6.3.1.3 and Table A.3.2.1 in Annex 3:2) or randomly. Biomass pools for years between inventories are linearly interpolated.

6.3.1.3 LAND USE TRANSFERS

If a land use conversion is identified and if all trees have been harvested between consecutive inventories, the biomass is assumed to drop to zero the anticipated year of harvest. The land use conversion and the harvest are matched to the same year. Otherwise, land use conversions are assumed to occur at a random year between consecutive re-measurements. Every plot that is converted to another land-use category is reported for 20 years in the land-use change category. After 20 years

the plot will be reported in the category to which it was transferred. If a second land-use conversion occurs within the 20 years, the counting starts all over again and the second transfer is reported for 20 years in the new land-use transfer category. Since information on previous land use has been recorded, it is possible to trace land-use transfers that have occurred since 1983/1987. Consequently it is possible to decide how many years a sample plot has belonged to a certain land-use category to which land-use category it was converted already from or even before the start of the reporting period (1990). This means that some land use transfer categories include areas converted already before 1990.

The FAO definition of Forest land was introduced in the Swedish NFI in 1998. Until 1998 Forest land was assessed based on the national definition²⁴⁸ of Forest land. Therefore, land-use categories have to be re-assessed for the period 1990-1997. There are two main types of cases of re-assessments which are handled as follows:

1. If the land-use category for a sample plot was registered as Forest land at the first inventory after 1997 and the national land-use category (see Table 6.4) had been the same at all earlier inventories since 1990, the plot are assumed to have always belonged to the land-use category Forest land.
2. If the land-use category was registered as Forest land at the first inventory after 1997 and the national land-use category (see Table 6.4) had changed since 1990, the first land-use category are assumed to remain until the year of conversion. If at consecutive inventories after that, the land-use category belonged to the same land-use category, the plot is assumed to belong to the category Forest land all years after the year of conversion.

Two types of inconsistently classified land-use transfers have been identified and corrected:

1. Inconsistency over time in applying land-use category definitions.
2. Inconsistency in delineating borders between plots divided into more than one land-use category.

One example of the first type is when at different inventories, the land-use category of a sample plot has been classified as Forest land at the first inventory, as Wetland at the next inventory and then again as Forest land at the third inventory without traces of human activities. A case like this is corrected so that the land-use category is assumed to be Forest land on all three occasions. This automatic rule is valid before 2003, but after this year, a land-use category could only be changed manually if traces of human activities are identified in the field. This year, all conversions from/ to Forest land and from/ to Wetlands or Other land, were carefully studied. The result was that many assumed “artificial” land-use

²⁴⁸ The former national definition of forest capture forest land where the production is (or have the potential to reach) at least 1 cubic meter per hectare and year.

conversions were removed. Another example of the first type is when a recreation forest close to a city has been converted from Settlements (section 6.2.7, national land-use category 13, “Urban land”, not measured for living biomass) to Forest land and the new land-use category consists of old trees. This has been corrected so the land-use is assumed as Forest land at both occasions. One example of the second type is when the delineation of a divided plot, representing more than one land-use category, has been changed at the re-inventory due to personal judgments rather than due to actual changes. These land-use changes should not be registered as land use changes and have been corrected by keeping the newer delineation, usually if the assumed incorrect new delineation deviates approximately less than 0.75 m² from the old delineation. If the affected area is larger, the new delineation is assumed to be correct. Rules for automatic and manual corrections of inconsistencies and the actual corrections are saved and could be verified on request.

6.3.2 Other sources of information for activity data

In addition to the NFI, information on specific activities is used as land use activity data for some of the reported categories. These are:

- The Swedish Civil Contingencies Agency for areas of wildfires
- The Swedish Forest Agency for areas of controlled burning,
- The Swedish Geological Survey for areas of peat extraction

6.4 Description of categories (CRF 4A, 4B, 4C, 4D, 4E, 4F and 4G)

6.4.1 Definition of carbon pools and other sources

6.4.1.1 LIVING BIOMASS (CRF 4A, 4B, 4C, 4D, 4E AND 4F)

The reported carbon pool changes refer to the biomass of all living trees with a height of at least 1.3 m. Thus, small trees, shrubs and other vegetation, such as herbs are not included in the figures. Both aboveground and belowground biomasses are reported. Aboveground biomass is defined as living biomass above stump height (1 % of tree height). Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*) and birch (*Betula pendula* and *Betula pubescens*) constitute about 92 % of the standing volume²⁴⁹. Broad-leaved species constitute most of the remaining 8 %. Belowground biomass is defined as living biomass below stump height (1 % of tree height) down to a root diameter of 2 mm (fine roots, <2 mm, are operationally defined as belonging to the dead organic matter pool or in the soil organic carbon pool). The living biomass pool is reported for all land-use categories assessed in the field inventory.

²⁴⁹ Swedish University of Agricultural Sciences, 2011

6.4.1.2 DEAD ORGANIC MATTER CRF-TABLES (CRF 4A, 4B, 4C, 4D, 4E AND 4F)

Dead organic matter has been divided into dead wood and litter for Forest land. For the rest of the reported categories dead wood and litter is reported aggregated as dead organic matter.

6.4.1.2.1 *Dead wood (CRF 4A, 4B, 4C, 4D, 4E and 4F)*

Dead wood is defined as fallen dead wood, snags or stumps including coarse and smaller roots down to a minimum “root diameter” of 2 mm. Dead wood of fallen dead wood or snags should have a minimum “stem diameter” of 100 mm (at the smaller end) and a length of at least 1.3 m. Dead wood of stumps with corresponding roots are reported under Forest land remaining Forest land (and Forest management under the Kyoto Protocol), while fallen dead wood and snags are reported for all relevant land-use categories.

6.4.1.2.2 *Litter (CRF 4A, 4B, 4C, 4D, 4E and 4F)*

Litter includes all non-living biomass not classified as dead wood, in various states of decomposition above the mineral or organic soil. This includes the litter, fomic, and humic layers. Live fine roots (<2 mm), are included in litter if found in the O horizon since they cannot be separated during sampling. Coarse litter is defined as dead organic material with a “stem diameter” between 10-100 mm and originating from dead trees. Fine litter from the previous season or earlier is regarded as part of the O horizon.

6.4.1.3 SOIL ORGANIC CARBON (CRF 4A, 4B, 4C, 4D, 4E AND 4F)

The soil organic carbon pool on forest land and grassland includes all carbon in the mineral soil below the litter, fomic and humic layers in mineral soils and all organic carbon in soils classified as Histosols²⁵⁰. The carbon pool considered is soil organic carbon down to a depth of 0.5 m measured from top of the mineral soil or, alternatively, from the soil surface and down to 0.5 m when the soil is classified as a Histosol. In cropland soils only the topsoil (depth of 0.25 m) is considered for carbon stock change calculations.

6.4.1.4 HWP (CRF 4G)

Harvested wood products are defined as wood material leaving the harvest site. Emissions from the HWP-carbon pool are based on pool changes of three product categories; sawn wood, wood based panels, and paper products. The system covers HWP from Swedish forests no matter where they are consumed. During recent years, stem volume corresponding to about 63 Mton CO₂ 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 and is considered oxidized instantly. About 80 % of the three product categories were consumed abroad and 20 % domestically.

²⁵⁰ Food and Agriculture Organization of the United Nations, 1994.

6.4.1.5 DIRECT N₂O EMISSIONS FROM N FERTILIZATION (CRF 4(I))

To increase the forest production, some older forest stands on mineral soils are occasionally fertilized –normally around ten years before final felling. Thus we assume that fertilization occur only on Forest land remaining Forest land. In 1990, the fertilized forest area was estimated to 69 200 ha²⁵¹. Since then, the annual fertilized area decreased for some years. In recent years, this area has varied a lot and peaked in 2010. The fertilized area was about 29 300 ha in 2016. The activity data (areas) are based on an annual questionnaire sent to approximately 70 large-scale forest companies and a sample of 2000 small forest owners. This information is part of the official statistics of Sweden and is collected by the Swedish Forest Agency. Large-scale forestry, defined as forest companies with more than 10 employees or owners of more than 5000 ha Forest land, contributes with approximately 90 % of fertilizer related emissions of N₂O and small-scale forestry with the remaining 10 % of the emissions. To estimate the total annual emission, area figures are multiplied with normal average amount of fertilizer N spread per hectare (ca 150 kg N per hectare). The normal average amount N spread out per hectare is obtained from the companies that are spreading out the fertilizer. There are only a few companies in this business.

6.4.1.6 N₂O AND CH₄ EMISSION FROM DRAINAGE AND REWETTING
AND OTHER MANAGEMENT OF ORGANIC SOILS (CRF 4(II))

N₂O from drained organic soils are included in the reporting. These emissions occur when the water table is lowered on organic soils, thereby causing a mineralisation of organic matter and nitrification or denitrification of nitrogen which leads to N₂O emissions. Drainage was used extensively during the early part of the 20th century as a way to increase productivity. The practice has more or less stopped due to the prohibition of new drainage, apart from the so called “protective drainage” that is applied after logging as a temporary measure to lower ground water level and the drainage of peatland for peat extraction.

Emissions of CH₄ from these soils are mostly occurring from the drainage ditches. On the drained soil itself, emissions of CH₄ are lower than it would be if the soil was not drained.

6.4.1.7 N₂O EMISSIONS FROM NITROGEN
MINERALIZATION/IMMOBILIZATION ASSOCIATED WITH
LOSS/GAIN OF SOIL ORGANIC MATTER RESULTING FROM
CHANGE OF LAND USE OR MANAGEMENT OF MINERAL SOILS
(CRF 4(III))

The conversion of land to other land uses is usually associated with a temporary increase in the mineralization of organic matter. Even management change of land causing loss of carbon is assumed to contribute to this mineralisation. Part of the released N may be converted to N₂O through denitrification. The loss of N due to

²⁵¹ Swedish Forest Agency, 2012

mineralisation is calculated for all land use categories and all land use change categories. The release of N_2O is based on the carbon losses from the soil. Emissions of N_2O from cropland remaining cropland is reported in the agriculture sector.

6.4.1.8 INDIRECT NITROUS OXIDE (N_2O) EMISSIONS FROM MANAGED SOILS (CRF 4(IV))

In addition to the direct emissions of N_2O from managed soils that occur through a direct pathway (i.e., directly from the soils to which N is applied), emissions of N_2O also take place through two indirect pathways, namely the volatilisation of N following the application of synthetic and organic N fertilisers and the leaching and runoff from land of N from additions of N through synthetic and organic fertiliser and N mineralised in mineral soils associated with loss of soil C from soil organic matter as a result of changes to land use or management

The indirect emissions are calculated using the results from direct emissions of N_2O (4(I) and 4(III)).

6.4.1.9 N_2O , CH_4 AND CO_2 FROM BIOMASS BURNING (CRF 4(V))

Forest fires are rare in Sweden. Wildfires have been monitored by the Swedish Civil Contingencies Agency since 1996²⁵² and the area of wildfires has varied from 400 to 13 000 ha yr⁻¹. Controlled burning to improve regeneration of trees after clear-cutting is monitored by a complete record from 1990 and onwards (Swedish Forest Agency). Controlled burning as part of nature conservation measures is monitored from 2006. In recent years, an area of approximately 300-3000 ha is burnt annually after clear cutting and 100-2000 ha is now annually burnt for nature conservation. The Swedish Civil Contingencies Agency (former Swedish Rescue Services Agency) reports the annual area of wildfires for three different land categories: "Forest", "Sparsely covered by trees" and "No tree cover". The definition of "Forest" almost corresponds to the national definition of productive forest. "Sparsely covered by trees" are areas sparsely covered by trees such as mires, forests in the mountain area and park areas. "No tree cover" is land with no trees such as agricultural land, open areas but also some mires. The assumed former stock on burned areas is based on estimates of aboveground living and dead biomass inventoried by the NFI by matching national definitions to the definition by the Swedish Civil Contingencies Agency. The area of wildfires is probably slightly underestimated since the reported numbers only include actual turnouts by the fire brigade. The accuracy of the burned amount of carbon per land category is probably low. This is due to a lack of knowledge about the burned stock in typically burned forests.

²⁵² Swedish Rescue Services Agency, 2004

6.4.2 Methodological issues

6.4.2.1 BASE METHODOLOGY (CRF 4A, 4B, 4C, 4D, 4E AND 4F)

Sweden reports emission/removals from carbon pools mainly according to the IPCC 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 (NFI²⁵³) has monitored the living biomass pool since 1983 and the dead wood pool since the mid-1990-ies. The Swedish Forest Soil Inventory (SFSI) has inventoried the soil organic and litter pools since 1993. A particular advantage with the Swedish NFI is that it has been undertaken using permanent sample plots on all relevant land use categories, which makes it possible to monitor net gains/removals in carbon pools for all land-use categories in a consistent and transparent manner (for further details, see Annex 3:2). The SFSI uses the same permanent sample plots as the NFI but soil sampling is made on Forest land and Grassland.

6.4.2.2 METHODOLOGY LIVING BIOMASS (CRF 4A, 4B, 4C, 4D, 4E AND 4F)

A national methodology (Tier 3) is used. The aboveground biomass per fraction is estimated by applying Marklund's²⁵⁴ biomass functions to trees on permanent sample plots of the NFI²⁵⁵. The belowground biomass is estimated by using Peterssons and Ståhl's²⁵⁶ biomass functions on biomass data from the same trees as for the aboveground biomass. The conversion factor 0.49 is used to convert biomass to carbon²⁵⁷. Estimates of the annual change in the carbon pools are based on repeated measurements. Consequently, the stock change of for example year 2000 is calculated as the difference in stock between year 2000 and year 1999. Since the estimates are based on representative allometric single tree regression functions or on direct measurements, a low risk of bias is assumed.

6.4.2.3 DEAD ORGANIC MATTER CRF-TABLES (CRF 4A, 4B, 4C, 4D, 4E AND 4F)

Dead organic matter has been divided into dead wood and litter for Forest land. For the rest of the reported categories dead wood and litter is reported aggregated as dead organic matter.

²⁵³ Swedish University of Agricultural Sciences, 2011

²⁵⁴ Marklund, 1987 and 1988

²⁵⁵ Ranneby et al., 1987

²⁵⁶ Petersson and Ståhl, 2006

²⁵⁷ Sandström et al., 2007

6.4.2.3.1 *Methodology dead wood CRF-tables (CRF 4A, 4B, 4C, 4D, 4E and 4F)*

A national methodology (Tier 3) is used to estimate the dead wood pool. The inventory of dead wood began in 1994 for northern Sweden and from 1995 for the whole country. The carbon content in dead wood was calculated using conversion factors from volume per decay class to biomass for the species Norway spruce, Scots pine, birch and other broadleaves. The volume is measured by the NFI. The methodology is further described in the Annex to NIR, chapter 3.1.5

Belowground dead wood originating from stump and root systems of harvested trees is reported based on indirect measurements of harvest. The harvest is estimated based on estimates of growth (stem volume, from measurements of increment bore cores of sample trees) converted to CO₂-eq. minus the net change in the living biomass carbon pool. Growth is estimated by the National Forest Inventory and represents “productive forest land” while the net change in the living biomass pool represents all Forest land (FAO-definition). As a consequence of this, the annual inflow to the stump carbon pool might be slightly underestimated. The harvest of stems is converted by conversion factors to stump and root biomass, and the conversion factors are calculated on estimates of stem volume²⁵⁸ and stump and root biomass²⁵⁹ applied to sample trees representing the standing stock of Swedish forests. The decay of stump systems is modelled²⁶⁰ by simple decomposition rate functions. The described methodology is consistently used during the reported period. Emissions from stump systems before 1990 are considered by using a similar methodology (1853-1989).

6.4.2.3.2 *Methodology litter CRF-tables (CRF 4A, 4B, 4C, 4D, 4E and 4F)*

A national methodology (Tier 3) is used to estimate the litter pool. The pool includes different sub-pools (litter and the organic soil horizon) that are estimated differently.

The carbon in the litter pool is estimated based on three different sources: (i) coarse litter (ii) annual litter fall and (iii) litter < 2 mm. Coarse litter is defined as dead organic material with a “stem diameter” between 10-100 mm and originating from dead trees. Coarse litter is not inventoried but calculated as 15 % of the aboveground dead wood measured according to 6.4.2.3.1. Litter fall is calculated using empirical functions based on stand properties and litter fall for deciduous species by biomass functions based on leaf biomass. This fraction of litter is regarded as an annual pool. The remaining part of this pool after one year is included in the O horizon and thus measured by the soil inventory. The fine litter

²⁵⁸ Näslund 1947

²⁵⁹ Petersson and Ståhl, 2006

²⁶⁰ Melin et al., 2009

(< 2 mm) is estimated through the O or H horizon sample which is taken on an area basis, weighed and analysed for carbon content (for further details, see Annex 3:2).

6.4.2.4 METHODOLOGY SOIL ORGANIC CARBON (CRF 4A, 4B, 4C, 4D, 4E AND 4F)

The change in the soil organic carbon pool is estimated using different approaches depending on the land use. For Forest land and Grassland on mineral soils, 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^{261,262} is used to calculate changes in the soil organic carbon stock on mineral soils. Emissions from cropland Histosols are estimated using an emission factor and the area of cropland Histosols.

6.4.2.4.1 *Forest land and Grassland on mineral soils (CRF 4.A.1 and 4.C.1)*

The method is a Tier 3 method. The estimates are based on repeated measurements on the NFI plots of several variables. The basic function used to determine the amount of carbon in a soil layer is based on the amount of carbon in a certain soil layer and the fraction of fine earth. The amount of fine earth is dependent on the bulk density and amount of gravel, stones and boulders in the soil (for further details, see Annex 3:2).

6.4.2.4.2 *Forest land and Grassland on organic soils (CRF 4.A.1 and 4.C.1)*

The method is a Tier 1 method. Changes in the soil carbon pool on organic soils are calculated by the use of emission factors. The emission factors rely on estimates of emissions divided into two different classes of nutrient status and two different climate regimes. The nutrient status is determined by using ground vegetation while climate is divided geographically. Emission factors are taken from the IPCC 2013 supplement for Wetlands²⁶³ (for further details, see Annex 3:2). Data on emissions from grasslands are scarce and most often taken from studies looking at intensively used grasslands where nutrients are commonly applied. For this reason, the emission factors for Grasslands provided in the IPCC 2013 supplement for Wetlands were put aside in favour of those applied on Forest land. Swedish Grasslands included in the reporting only consist of natural pastures which are considered to be closer to Forest land according to the soil conditions.

²⁶¹ the Introductory Carbon Balance Model

²⁶² Andrén & Kätterer, 2001

²⁶³ IPCC 2014

6.4.2.4.3 *Cropland on mineral soils (CRF 4B)*

The method to estimate the carbon balance of agricultural soils is a Tier 3 method. The carbon changes in the mineral soil are calculated based on data from eight agricultural production regions using the model ICBM-region. The ICBM model is described in Andrén & Kätterer²⁶⁴. 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 texture²⁶⁵(for further details see Annex 3:2).

6.4.2.4.4 *Cropland on organic soils (CRF 4B)*

The method to estimate the carbon balance of organic agricultural soils is a Tier 2 method. A national emission factor for cropland on organic soils is used to calculate the mean annual carbon loss per area. The total area of organic soils under agricultural production has been estimated in national surveys^{266,267}. The area of organic soil in these studies has been linked to the changes in total cropland area so that decreasing cropland area proportionally affects the area of cropland on organic soils (for further details see Annex 3:2).

6.4.2.5 METHODOLOGY FOR DEAD WOOD, LITTER AND SOIL ORGANIC CARBON FOR CONVERSION BETWEEN LAND-USE CLASSES CRF-TABLES 4A.2.1-5, 4B.2.1-5, 4C.2.1-5, 4D.2.1-3, 4E.2.1-5 AND 4F.2.1-5

The method to estimate the emission/removals in the dead wood, litter and the SOC pools associated with land use changes is a Tier 2 method. In general (except for dead wood and coarse litter) the carbon stock changes associated with conversion of lands is estimated using an emission/removal factor in combination with the land-use change area. For further details see Annex 3:2.

6.4.2.6 HWP (CRF 4G)

The methodology used is a Tier 3 method developed from the Tier 2 described in the IPCC 2006 guidelines. The calculation of emissions from HWP is based on carbon stock changes.

Products originating from Swedish forests are included regardless of where the products are consumed, which means that the import is excluded while the export is included. This is denoted as the production approach in the IPCC guidelines.

²⁶⁴ Andrén & Kätterer, 2001.

²⁶⁵ Eriksson 1997,1999

²⁶⁶ Berglund and Berglund, 2009

²⁶⁷ Pahkakangas S. Berglund Ö.,Lundblad M., Karlton E. 2016

Separate stock changes for the three categories sawn wood, wood based panels and paper products are calculated. Separate calculations are also undertaken for products consumed abroad and products consumed domestically.

The stock change depends on the difference between inflow of carbon in new products and outflow of discarded products, and is calculated using equation 12.1 from the IPCC 2006 GL. The outflow is calculated as a fraction of the previous year's pool and therefore a pool must be calculated in order to estimate an outflow. To achieve this, historical data mainly from the Swedish Forest Agency regarding production and trade starting from 1900 is used to build a pool for each product category. The period of data available is dependent on when the product first occurred, in some cases data is only available at the first occurrence of a product. In other cases data is first 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, i =import. Statistics for paper include paper made from pulp and paper made from recovered paper (RP). The origin of RP is unclear. It is possible to exclude RP of non-domestic origin from the domestic production of paper (although imported RP might originally come from exported paper), but following exported paper is more complex. About 90 % of the paper produced in Sweden is exported and, after being consumed abroad, is used to produce new paper abroad. To include paper from recovered paper of domestic origin used abroad to produce new paper, the quota [production of RP/consumption of paper] in the EU (to which about 75 % of the paper produced in Sweden is exported) is multiplied with the outflow of discarded paper. The product is added to next year's inflow of paper from pulp.

The conversion factors applied are 0.62 t per m³ for wood based panels, 0.42 t per m³ for sawn wood, and 0.9 t woody biomass per t of paper. Carbon content for each category is set to 0.5. The conversion factor for wood based panels was calculated as a mean value for the different panel categories produced, weighted with respect to produced volumes of the different categories respectively. A corresponding methodology was applied to sawn wood, i.e. a weighted mean value of wood densities for the harvested wood species, mainly Scots pine and Norway spruce, was calculated. Production of paper in tonnes was multiplied with 0.9 to adjust for added non-wood compounds during the manufacturing process. No such adjustment was made in cases when the inflow consisted of pulp instead of paper, for example, exported pulp.

The amount of HWP put into landfills is assumed to be 0.

6.4.2.7 CO₂ EMISSION FROM PEAT EXTRACTION (CRF 4D)

The method used to estimate CO₂ emission from peat extraction areas is a Tier 2 approach. A limited area of Wetlands (around 10 000 ha) used for peat extraction is considered managed and reported under Wetlands remaining Wetlands. The reported CO₂ emissions refer to mineralization when extracting peat for fuel and agricultural purposes. The emitted CO₂ is calculated as the product of the extracted area and an emission factor (for further details see Annex 3:2). The off-site emissions from horticultural peat are reported assuming that the carbon is gradually oxidised over time. A country specific method has been used for the calculations (see Annex 3:2).

Peat extraction is only ongoing on part of the production area. The peat extraction is usually proceeding many years on the same production area until this area is closed down and restored (for further details see Annex 3:2).

6.4.2.8 DIRECT N₂O EMISSIONS FROM N FERTILIZATION (CRF 4(I))

A Tier 1 methodology is used. All fertilization is assumed to occur on Forest land remaining Forest land²⁶⁸. In year 1990 calcium nitrate (Ca(NO₃)₂) was the dominant fertilizer but thereafter the fertilizer have been based on ammonium nitrate with 50 % NO₃-N and 50 % NH₄-N. The reported annual emission is calculated as the product of the applied amount and the emission factor (for further details see Annex 3:2).

6.4.2.9 N₂O AND CH₄ EMISSIONS FROM DRAINAGE OF SOILS AND CH₄ FROM DITCHES (CRF 4(II))

A Tier 1 methodology is used and the reported figures refer to N₂O and CH₄ for each land use category with different emission factors depending on nutrient status and climate and multiplied with corresponding areas. Emissions of CH₄ include emissions from the soil itself and from the ditches multiplied with the fraction of ditches. For further information and the emission factors used, see Annex 3:2.

6.4.2.10 N₂O EMISSIONS FROM NITROGEN MINERALIZATION/IMMOBILIZATION ASSOCIATED WITH LOSS/GAIN OF SOIL ORGANIC MATTER RESULTING FROM

²⁶⁸ 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.

CHANGE OF LAND USE OR MANAGEMENT OF MINERAL SOILS (CRF 4(III))

A Tier 2 methodology is used. The reported annual N₂O emission from nitrogen mineralisation associated with loss of carbon resulting from land use change or change in land use of mineral is calculated according to equation 11.8 in IPCC 2006 GL (IPCC²⁶⁹) using partially country specific parameters (for further details see Annex 3:2).

6.4.2.11 INDIRECT NITROUS OXIDE (N₂O) EMISSIONS FROM MANAGED SOILS (CRF 4(IV))

A Tier 2 method is used to calculate the indirect emissions based on the use of fertilizers and mineralisation equation 11.9 and 11.10 in IPCC 2006 GL. The reported annual N₂O indirect emissions are based on the amount of added fertiliser and the mineralisation of N and assumptions on the volatilization and leaching of N₂O.

6.4.2.12 EMISSIONS FROM BIOMASS BURNING (CRF 4(V))

A Tier 1 methodology and IPCC default emission factors are used. All land categories are monitored but the reported emission is assumed to occur only on Forest land remaining Forest land and on Grassland remaining Grassland. The exact location of the burned areas is not registered by the Civil Contingencies Agency (6.4.1.8) but the fires in tree covered areas are matching areas defined as Forests land. The NFI inventories fires (only used for verification) and this far no fire has been identified on land converted to Forest land. Thus we believe it's 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. But the definition is closest to the definition of Grassland and, thus, all fires on non-tree covered areas are reported under Grassland remaining Grassland. Calculations are based on the amount of biomass per area, burned area and emission factors. Observe that, to avoid double-counting, CO₂ emissions from wildfires and controlled burning is included in carbon stock changes in living biomass (for further details see Annex 3:2). Sweden assumed that 25 % of the pre-fire biomass stock is combusted during the fire. This is in line with the IPCC 2003²⁷⁰ GPG but the IPCC 2006 GPG suggest emission factors that are a little bit higher. However, Sweden finds a combusted proportion of 25 % more realistic. This proportion is based on subjective observations (in the field) of remaining biomass after several wildfire events in Sweden such as the example in Figure 6.6.

²⁶⁹ Intergovernmental Panel on Climate Change, 2006

²⁷⁰ Intergovernmental Panel on Climate Change, 2003



Figure 6.6. Post-fire biomass after Swedish forest fire in the county Västmanland 2014.

6.4.3 Uncertainties and time series consistency

Since the Swedish reporting system of the LULUCF-sector mainly is based on sampling, a national method is used to estimate the overall uncertainty. Uncertainties in the reported estimates arise from random and systematic errors. Random errors dominate the uncertainty for the part of the living biomass, dead organic matter and soil organic pools that are calculated based on sampling data whereas systematic errors dominate the uncertainty for other emissions/removals. Uncertainties per greenhouse gas is found in the Annex to NIR, Table A.3.2.15

Random errors could be estimated by straight forward statistical theory but systematic errors are often hard to quantify. Generally for Sweden, the systematic error induced by activity data is small compared to the error due to use of incorrect emission factors. Systematic errors are therefore induced by expert opinion and using the default error values according to IPCC ²⁷¹.

6.4.3.1 LIVING BIOMASS (CRF 4A, 4B, 4C, 4D, 4E AND 4F)

The estimated accuracy of the living biomass pool depends mainly on the sample design of the NFI. Results from the control inventory of the NFI indicate that measurement errors, registration errors and errors caused by the instruments (callipers) could be assumed to be close to zero. Potential bias induced by incorrectly specified models and an unrepresentative derivation data are ignored. Research by Ståhl et al. (2014)²⁷² and Breidenbach et al. (2014)²⁷³ indicate that the influence of model errors could be expected to be less than 1 % of the total error budget. Estimates for reporting years 1990-2012 are based on approximately 30000 sample plots and with a corresponding estimated standard error of 3 Mt CO₂/year (relative standard error of -10 %). The estimate of uncertainty is quite stable

²⁷¹ Intergovernmental Panel on Climate Change, 2006

²⁷² Ståhl et al., 2014.

²⁷³ Breidenbach et al., 2014.

between years but the relative estimates vary due to changes in net removals. Estimates for reporting years 2013, 2014, 2015 and 2016 are based on measurements on approximately 24000, 18000, 12000 and 6000 sample plots, respectively, combined with extrapolated data. This extrapolation increases the accuracy substantially, but to avoid a potential risk of systematic errors we also gradually update extrapolated data using data from re-measured sample plots (see Annex 3:2 for further details).

6.4.3.2 DEAD WOOD AND LITTER (CRF 4A, 4B, 4C, 4D, 4E AND 4F)

Estimates of dead organic matter are based on sampled data from the litter pool and dead wood pool from the NFI and the MI. There is probably a small error in the estimates of dead wood due to incorrect measured volumes and to errors connected to the conversion from volume to carbon. Coarse litter is calculated as 15 % of the dead wood. The error of this proportion might be large since the knowledge of the relation between the amount of dead wood and coarse litter is poor. Compared to previous submissions the accuracy of litter estimations has improved since the reported figures now are based on more repeated measurements of permanent sample plots. For changes in carbon in the O-horizon the measurements are based on samples from 1993-2002 (first inventory), from 2003-2012 (second inventory) and from 2013 - 2014 (the third inventory). Changes are interpolated for each plot between inventories. Changes for 2015 and 2016 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 dead wood measurements are from the period 1995 to 2016. 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 unknown systematic error.

6.4.3.3 SOIL ORGANIC CARBON (CRF 4A, 4B, 4C, 4D, 4E AND 4F)

The sample error for the soil organic carbon pool is calculated similarly to the living biomass calculation. A problem associated with our methodology is the risk of systematic errors in the sampling and analysis of data. Since there are rather small changes in large pools even a small systematic error may cause a trend in the material. From 2003 the sampling methods of soil samples have been changed compared to earlier inventories in order to avoid subjective judgments in sampling, e.g. regarding determination of soil horizon boundaries. This might give rise to 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 CO₂ emission from drained forest land is judged to 25 % and errors in the emission factor to 40 % as well. The uncertainty in activity data (carbon stock changes) for CO₂ emission

from mineralization when extracting peat is judged to 25 % and the uncertainty due to errors in the emission factor chosen is judged to 60 %.

One of the major difficulties in reporting changes in DOM and SOC is that the pools is very large and the changes small in comparison to the pools. As seen in Figure 6.7 the reported changes are considerable in terms of carbon and they do have an impact on the national carbon budget. However, the annual changes are still only in the order of a few % of the pool and can hardly be detected in the lower panel. When tested statistically the changes are not significant at $p=0.05$ and the system is sensitive to systematic errors like small changes in data collection between inventories.

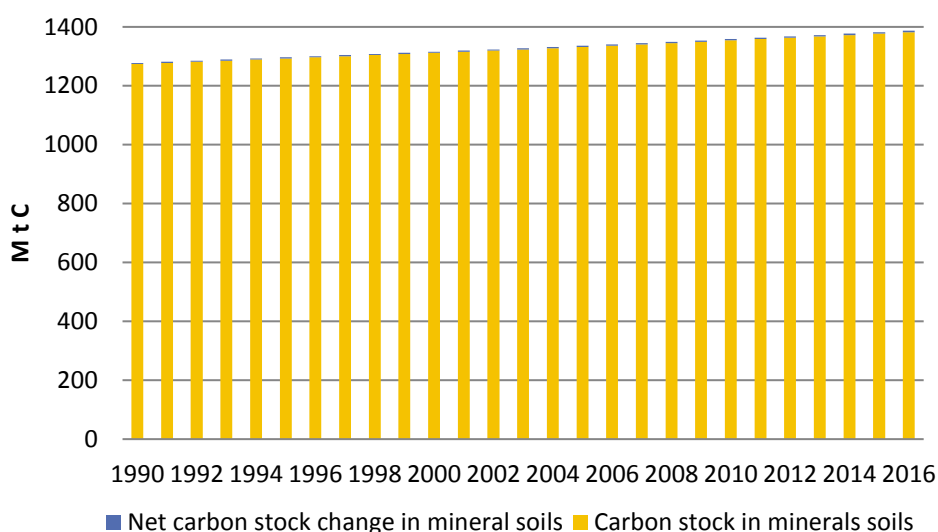


Figure 6.7. The reported change in soil carbon on mineral soils (blue bar) and the corresponding stock (yellow bar) for Forest land remaining Forest land.

6.4.3.4 HWP (CRF 4G)

Uncertainties in the data, conversion factors and oxidation of depleted products affect the HWP-estimates.

6.4.3.4.1 Data

Data from 1900 and onwards was used. The removals and HWP-production were crosschecked by the quota [(calculated total production of HWP of domestic harvest including black liquor and sawmill residues used for energy)/(removals of industrial round wood)]. The quota varied between 98 % and 107 % and averaged 102 % during 1990-2013, indicating a slight overestimation of the HWP-production. The production of black liquor was assumed to be equal to the production of chemical pulp of domestic origin. That is a rather rough assumption that causes some of the deviation.

6.4.3.4.2 *Conversion factors*

Wood density for round wood used by the sawmill- and wood based panels industry was set to 0.42 t/m³. More than 99 % of the round wood used by the sawmills in Sweden was from Norway spruce (55 %) and Scots pine (45 %), and the density for the two conifers was calculated using data from the NFI and models for stem volume and stem biomass. The resulting density was compared to data from the literature. Either sawn wood or wood based panels was split into subcategories. Since sawn wood is produced from two conifers of similar density there is no reason to calculate separately for different species. Wood based panels (WBP) are produced in such low quantities that subcategories would have very low impact on the result. Further, the only WBP produced in Sweden at present is particle board and plywood. The conversion factor used for paper was 0.45. It was crosschecked as the quota between domestic production of paper (from pulp only, not from recovered paper) of domestic origin and domestic consumption of pulp of domestic origin. Thus, the reliability of the conversion factors should be acceptable.

6.4.3.4.3 *Oxidation*

The half-life's used for the different product categories is by far the most uncertain component in the calculations. Therefore the uncertainty was estimated using varying half-life's. The half-life's was increased and decreased by 20 %, and the uncertainty was estimated as the difference between the calculations using adjusted half-life's and the calculations using the default half-life's. A Monte Carlo analysis was used to estimate a mean standard deviation for the total emission which was converted to the uncertainty reported in Table 10.10.

6.4.3.5 OTHER EMISSIONS (CRF 4(I) TO 4(V))

Generally for all N₂O and CH₄ emissions, the error in activity data is small compared to the error due to errors associated to the emission factors.

4(I): For N₂O emissions from N-fertilization, the error due to activity data is judged to 3 % (the Swedish Forest Agency) and the default total error to 25 %. However, a recommendation is that emission factors chosen should be within the range 0.25 % to 6 % and the interpretation is that a badly chosen emission factor could lead to an error that is much larger than 25 %.

4(II): For emissions from drainage, the error due in activity data is judged to 25 %. The uncertainty in the emission factors is mainly based on the confidence intervals presented by the IPCC. The uncertainty in the emission factors for N₂O and for CH₄ is both above 100 %.

4(III): The accuracy of estimates of N₂O emissions from mineralization associated with change in management or land-use is assumed to be lower than for N₂O

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 uncertainty level is suggested to be 100 %, also taking into account the uncertainties in IPCC default values.

4(IV): For the indirect emissions the error in activity data corresponds to the error from the fertilization estimates and to the mineralisation. The uncertainty in the emission factors for indirect N_2O emissions is well above 100 %.

4(V): Uncertainties from biomass burning arise from the errors in the estimated area that is burned and in the emission factors used. The emitted amounts per area unit depend on the biomass stock before the fire and the proportion of this biomass that actually is burned. The error of the estimated burned area is likely quite small but the knowledge of emitted amount per area is quite poor. The reported uncertainty is based on a default error coefficient from IPCC. According to the points raised in the discussion above on uncertainties in CO_2 emissions from biomass burning, the uncertainty of N_2O and CH_4 emissions from biomass burning are assumed to be 100 % (Managing uncertainties: A.1.4).

6.4.3.6 COMPLETENESS

Each source/sink category has been reported only once. This is mainly ensured by using only one source of information for the overall land area representation. Some sources combine activity data from different sources.

Sweden reports carbon stock changes in all carbon pools and all other emissions for all land use categories that are considered managed (Forest land, Cropland, Grassland, Settlements and a small area of Wetland) and for which methods are provided in the IPCC 2006 GL. The notation key “NO” is used when there is no observed occurrence for a certain category (i.e. uncommon land use changes) and when the reported activity does not result in emissions/removals. The notation key “IE” is used when it is not possible to separate emissions/removals on relevant land use categories and according to the use of the stock change method. In the latter case either gains or losses are reported “IE”. The notation key “NA” is used for emissions/removals from unmanaged land. The notation key “NE” is used for categories not estimated and comprises categories that currently are optional to report.

6.4.4 Category-specific time series consistency, verification and QA/QC

6.4.4.1 TIME SERIES CONSISTENCY AND VERIFICATION

The time series of changes in carbon stocks for the living biomass pool is consistently measured from 1990 and onwards. The trend has been validated and confirmed by the default method (growth minus drain) 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 because the inventory did not begin until the mid-1990th. Due to a relative high sampling error and a five-year inventory cycle, a trend is reported and thus it is quite difficult to match emissions/removals from dead wood to the correct year. This trend is estimated using a five-year, four-year, three-year, two-year and one-year running average for years 2011, 2012, 2013, 2014 and 2015, respectively. The dead wood pool constitutes a small net removal. This could partly be explained by the fact that, since 1990, an increasing amount of dead wood and snags have been left after harvest, however, no proper validation has been made.

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 more harmonised with the reporting of changes living biomass, while the annual variation in removals is larger using validation data (Figure 6.8).

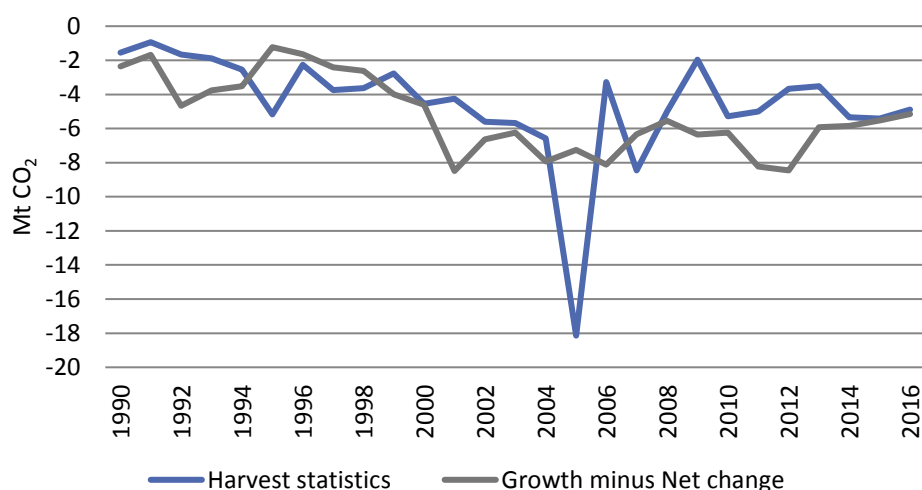


Figure 6.8. The reported net-removal from stumps (part of dead wood) is indirectly calculated from growth minus net-removal from living biomass (inflow) minus modelled decomposition (outflow). The validating net-removal from stumps is based on harvest statistics (inflow) minus modelled decomposition (outflow).

The soil organic carbon has been sampled annually since 1993. In 2003 a revision of sampling methodology was made to harmonize sampling with international monitoring programs. Studies on the effects of these changes in sampling with respect to soil carbon pool estimates have not revealed any systematic differences. The time series for dead organic matter and soil organic carbon in forests have been compared to results from two process-oriented models. Models and measurements agreed well in estimation of the soil carbon pool and in the direction

of change, but there were small changes with respect to the rate of change between the models and the measurements²⁷⁴.

6.4.4.2 QUALITY ASSURANCE (QA)

The quality assurance system of the data collection within NFI used for the UNFCCC and Kyoto reporting has been described by the Swedish University of Agricultural Sciences²⁷⁵. These routines were improved during 2006 cooperating with SLU (Swedish University of Agricultural Sciences). SLU also works closely with the Swedish EPA to enhance the QA/QC.

6.4.4.3 QUALITY CONTROL (QC)

An internal quality control has been performed. For reported activity data, descriptions of definitions, description of underlying models, description of sampling design and emission factors used were studied and no errors were found. This was also valid for descriptions of land areas, eventual transcription errors and references. Both calculations and units of estimates were cross checked and judged as reasonable. Original data from the NFI constitute official statistics of Sweden and were not checked. All data (and methodologies used) is archived by the SLU.

6.4.5 Source-specific Recalculations

Recalculations can be divided into four categories of which the two first ones can be considered “ordinary” recalculations due to the applied methodology using random sampling.

The first category is recalculations due to updated NFI-data which mainly affects the estimates for the previous four years as described in section 6.3.1.1. Small corrections of historical land use changes may affect estimates for earlier years, especially for categories using area as activity data.

The second category is recalculations related to extended datasets for litter and soil from the MI. Since the whole dataset is included using extrapolation and interpolation techniques this may generate updated data for the entire time series.

The third category is when new activity data (not related to NFI or MI) or emission factors have become available (i.e. better sales statistics, information on biomass burning or emission factors related to land-use change).

The fourth category is when the methods have been improved.

6.4.5.1 LAND USE

It is difficult (even in field inventories) to estimate land use for land that is close to the threshold of the definition of different land use categories. This is especially challenging for Forest land, Wetlands and Other land. To avoid “artificial” land use conversions between these categories (i.e. land use conversions that can not be

²⁷⁴ Ortiz *et al.* 2009.

²⁷⁵ Karlun *et al.*, 2005.

attributed to a real land use change but only to a perceived change in stand conditions) all sample plots that have changed between these land use categories have been studied and corrected using specific rules. Land-use change is now only accepted if there is proof of a land use change. Examples of proof are when trees have died on the plot or tree growth has increased. This has reduced land reported in land use conversion categories. It has no real effect on changes in living biomass since the net removal is very small on these land areas.

6.4.5.2 LIVING BIOMASS

To improve the accuracy of estimates in the current submission, the living biomass pool and areas have been recalculated for the years 2012-2016. Each estimate for these years is now based on 6000 more sample plots and incomplete inventory cycles have been extrapolated to 2016, see also section 6.3.1.1 and figure 6.9.

To enhance the consistency between UNFCCC and KP reporting, the allocation of carbon stock changes has been revised. This means for instance that a decrease in carbon stock due to a land use conversion from Forest land to Settlements is (from submission 2014) reported under (or allocated to) Forest land converted to Settlement. Previously, this stock change was reported as an emission under Forest land remaining Forest land and a removal under Forest land converted to Settlements. The new reporting method is consistent with the methodology used for reporting carbon stock changes in living biomass under the KP.

On request from reviewers, Living biomass on Forest land converted to Other land is now reported even if Sweden considers such land unmanaged. The conversion class Forest land converted to Other land is quite uncommon (estimated to 1.5-11 kha) and often with a sparse tree cover. The net removal on such land is close to zero.

For the first time, the NFI monitors biomass in the mountain area (mainly Other land). This is made for one cycle while an area of 915 kha of Other land is reported as Forest land for each of the four remaining cycles. This will not change the reported change in living biomass yet, but probably slightly in the future.

The total effect of the recalculation on Living biomass on Forest land remaining forest land is illustrated in Table 6.5a and Figure 6.9.

6.4.5.3 DEAD WOOD, LITTER AND SOIL ORGANIC CARBON

The pools dead organic matter and soil organic carbon on mineral soils on Forest land remaining forest land and Grassland remaining Grassland have been recalculated for the whole time series from 1990 to 2016 due to introduction of more re-inventoried sample plots from the SFSI. Data from the third inventory starting in 2013 have in this submission been used for the calculation of carbon

stock changes in litter and mineral soils. That means that changes are calculated based on three separate measurements in time on 20% of the plots.

Emissions from organic soils as well as carbon pool changes for land-use change categories have been recalculated due to updated activity data from the NFI (areas) and the SFSI (areas of histosols and drained soils).

Emissions and removals from mineral and organic soils for land use change categories have been recalculated in Submission 2018 since data on on peat cover from the NFI was recalculated. Also, the carbon stock change factors were changed for some of the categories due to new information on the effect of land use change on litter and soil carbon.

On a request from reviewers, Soil carbon stock changes on Forest land converted to Other land is now considered in the reporting (even if Sweden considers such land unmanaged).

6.4.5.4 NON-CARBON EMISSIONS

No recalculations have been made for nitrogen emissions from nitrogen fertilization (4I). Recalculations have been made for non-carbon emissions (4II) from drained organic soils due to slightly adjustments in activity data (areas). Due to recalculations of the carbon stock changes, e.g. the activity data to calculate emissions from mineralisation associated with land use change or change in management all estimates under (4III) have been updated. These emissions have also been recalculated due to updated C:N ratios for some of the land use and land use change categories. No changes in underlying activity data for wildfires (4V) have been made.

The recalculations are summarized in Table 6.5.a. and Table 6.5.b.

6.4.5.5 HWP

Reported emissions from the HWP-pool since 1990 submitted this year differs slightly from the reported emissions submitted in earlier years. The difference is due to an error in the calculations in one of the refinement steps. Domestically consumed residues from saw mills were adjusted for residues from imported saw logs twice. The scale of this difference is marginal.

Table 6.5.a. and Table 6.5.b. Recalculations of carbon stock changes and other emissions between submission 2015 and submission 2016 in the LULUCF-sector. Positive numbers indicate an increase in emissions or a decrease in removals and negative numbers indicate an increase in removals or a decrease in emissions.

6.5a	Difference in carbon stock changes between Submission 2016 and 2017 [Mt CO ₂]																				
	Forest land					Cropland				Grassland				Wet- land	Settlement				Other land		HWP
	LB	DW	Litter	SOC		LB	DOM	SOC		LB	DOM	SOC			SOC	LB	DOM	SOC		LB	
				Min	Org			Min	Org			Min	Org	Min				Org	Min		Org
1990	0.00	0.06	2.30	-1,41	0,30	0.00	0.00	0.00	-0.02	0.00	0.02	-0.58	0.07	0.00	0.02	-0.17	-0.14	-0.02	NA	NA	0,0
1995	-0.01	0.05	2.34	-1,41	0,28	0.00	0.00	0.00	-0.03	-0.01	0.02	-0.55	0.07	0.00	0.00	-0.32	-0.28	-0.06	NA	NA	0,0
2000	-0.07	0.08	2.31	-1,40	0,25	0.00	0.00	-0.01	-0.03	0.03	0.02	-0.60	0.07	0.00	0.00	-0.44	-0.37	-0.07	NA	NA	0,1
2005	-0.05	0.03	5.80	-2,25	0,12	0.00	0.00	-0.01	-0.04	0.04	0.00	-0.78	0.02	0.00	0.01	-0.53	-0.48	-0.08	NA	NA	0,0
2011	0.28	-0.06	6.05	-0,47	-0,57	-0.01	0.00	-0.01	-0.04	0.00	0.00	-0.34	0.00	0.00	0.07	-0.50	-0.43	-0.05	NA	NA	0,0
2012	-0.01	-0.16	6.07	0,28	-0,74	-0.10	0.00	0.00	-0.04	-0.09	-0.01	-0.34	-0.06	0.00	0.31	-0.53	-0.48	-0.05	NA	NA	0,0
2013	0.16	1.84	6.40	0,39	-0,73	-0.12	0.00	-0.01	-0.05	-0.02	0.00	-0.32	-0.03	0.00	0.18	-0.50	-0.46	-0.05	NA	NA	0,1
2014	0.30	-0.10	7.07	-0,23	-0,68	-0.16	0.00	0.00	-0.05	-0.04	0.00	-0.32	-0.05	0.00	0.38	-0.48	-0.44	-0.02	NA	NA	0,0
2015	0.43	-0.31	7.05	-0,24	-0,73	-0.19	0.01	0.38	-0.04	0.22	0.01	-0.32	-0.05	0.00	0.60	-0.44	-0.42	-0.01	NA	NA	0,1

6.5 b		Other emissions [k ton substance]							Total	
Year	Fert. 4 (I)	Drainage 4 (II)		Mineralisation 4 (III)	Indirect 4 (IV)	Biomass burning 4 (V)			[Mt CO ₂ -eq]	[%]
	N ₂ O	CH ₄	N ₂ O	N ₂ O	CO ₂	CO ₂	N ₂ O	CH ₄		
1990	0.0	0.3	0.5	-0.2	0.0	NA	0.0	0.0	0.8	2
1995	0.0	0.3	0.4	-0.2	0.0	NA	0.0	0.0	0.2	1
2000	0.0	0.2	0.4	-0.2	0.0	NA	0.0	0.0	-0.1	0
2005	0.0	-0.1	0.3	-0.3	0.0	NA	0.0	0.0	1.8	5
2011	0.0	-1.9	-0.5	-0.2	0.0	NA	0.0	0.0	3.7	9
2012	0.0	-1.9	-0.5	-0.2	0.0	NA	0.0	0.0	3.7	9
2013	0.0	-2.3	-0.7	-0.2	0.0	NA	0.0	0.0	3.7	8
2014	0.0	-2.3	-0.7	-0.2	0.0	NA	0.0	0.0	6.4	15
2015	0.0	-2.4	-0.7	-0.2	0.0	NA	0.0	0.0	4.9	11

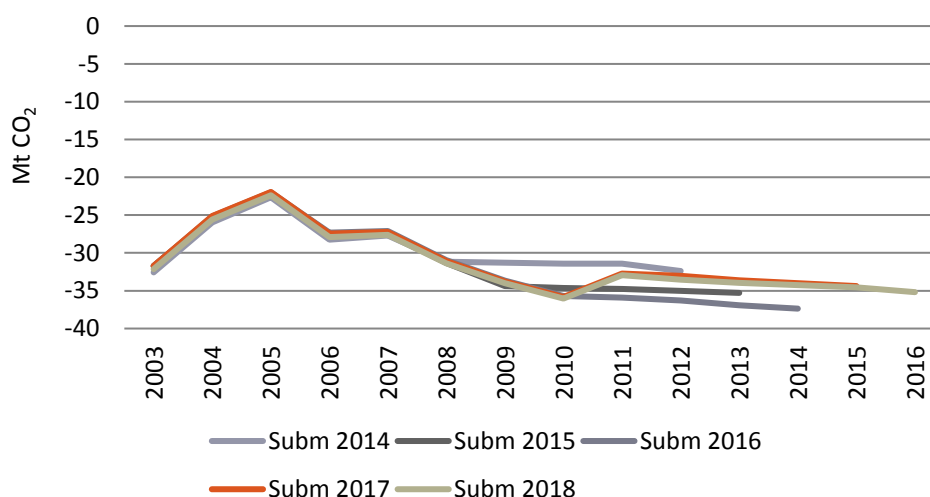


Figure 6.9. Reported living biomass on Forest land remaining forest land (4A1) according to different submissions. The values (the five latest reported years) are continuously recalculated.

6.4.6 Planned improvements

There are no planned improvements for the next submission, but new research and successive development of methods may result in improvements the coming years.

7 Waste (CRF sector 5)

7.1 Overview of sector

In this sector, the most important emissions of greenhouse gases are those of methane (CH₄) from Solid waste disposal, CRF 5.A. Other sources of greenhouse gases are Biological treatment of solid waste, CRF 5.B and Wastewater treatment and discharge, CRF 5.D, from where emissions of methane and nitrous oxide (N₂O) are reported. In addition, emissions of carbon dioxide (CO₂), methane CH₄), nitrous oxide, nitrogen oxides (NO_x), sulphur dioxide (SO₂), non-methane volatile organic compounds (NMVOC) and carbon monoxide (CO) are reported from (hazardous) Waste incineration, CRF 5.C.

Greenhouse gas emissions in CO₂-eq. from the waste sector has decreased constantly since the early 1990s (Figure 7.1), mainly because of decreasing quantities of organic waste deposited at landfills, which has reduced emissions of methane from landfills. Also, the quantities of recovered landfill gas were increasing from 1990 until 2003. Methane emissions from landfills (CRF 5.A) are by far the most important source of emissions of greenhouse gases in this sector. Biological treatment of solid waste (CRF 5.B) is the only subsector that shows an increasing trend on greenhouse gas emissions. The activities (both composting and anaerobic digestion of solid waste) have increased since the early 1990s in order to reduce quantities of solid waste to landfills.

For nitrous oxide there has been a reduction in the quantity of nitrogen discharged from municipal wastewater treatment plants from the mid-1990s when nitrogen treatment in wastewater treatment plants in Sweden was developed.

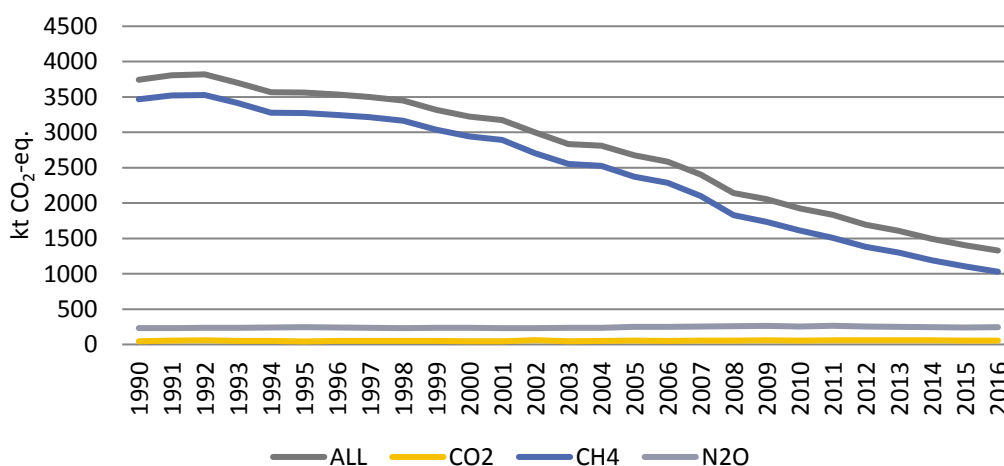


Figure 7.1. Total emissions of all greenhouse gases calculated as CO₂-eq. from CRF 5 Waste.

Figure 7.2 shows that greenhouse gas emissions from the Waste sector (CRF 5) largely come from solid waste disposal (CRF 5.A). Methane in sub-sector 5.A represents between 91.4 % and 68.4 % of the total reported greenhouse gases in the Waste sector during the period 1990 – 2016. Emission of greenhouse gases from waste incineration is small, 4.5 % of the emission of CRF 5 in 2016.

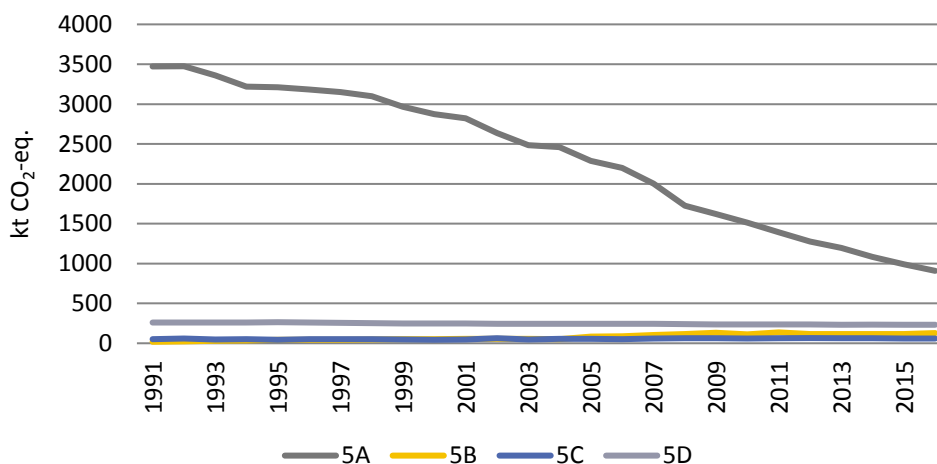


Figure 7.2. Total emissions of all greenhouse gases calculated as CO₂-eq. from the different waste sub-sectors (5A – Solid waste disposal, 5B – Biological treatment of solid waste, 5C – Incineration and open burning of waste, 5D Wastewater treatment and discharge).

7.1.1 Biogas production in Sweden

According to a survey²⁷⁶ by the Swedish Energy Agency completed by Avfall Sverige & SMED on biogas production and utilization, the production of biogas in Sweden in 2016 was 2 052 GWh, which is equivalent to 147 kt of methane. The corresponding amount in 2005 was 1 285 GWh (equivalent to 92.2 kt of methane)²⁷⁷. Most of the biogas is produced within the Waste sector (CRF 5). See further below in the CRF 5.A, CRF 5.B and CRF 5.D sections.

7.2 Solid waste disposal (CRF 5.A)

Waste management in Sweden has been developed considerably over the past twenty years. Legislation, such as the implementation of EU directives and national tax policies in the waste management field, has forced and encouraged investments in new technical solutions and waste treatment methods. There has been a comprehensive extension of the treatment capacity of Swedish incineration plants for household waste (with energy recovery) and development of waste management practices other than solid waste disposal on land (landfilling).

²⁷⁶ Swedish Energy Agency, 2017

²⁷⁷ Swedish Energy Agency, 2007

Since Sweden is a country with a developed mining and quarrying industry, mining waste is by far the most dominating single waste category in generation of waste and landfilling. In year 2014, 96 % of the landfilled non-hazardous waste (or 81.9 Mt of 85.0 Mt) was mining waste. An overview of waste streams in Sweden 2014 is presented in Figure 7.3.

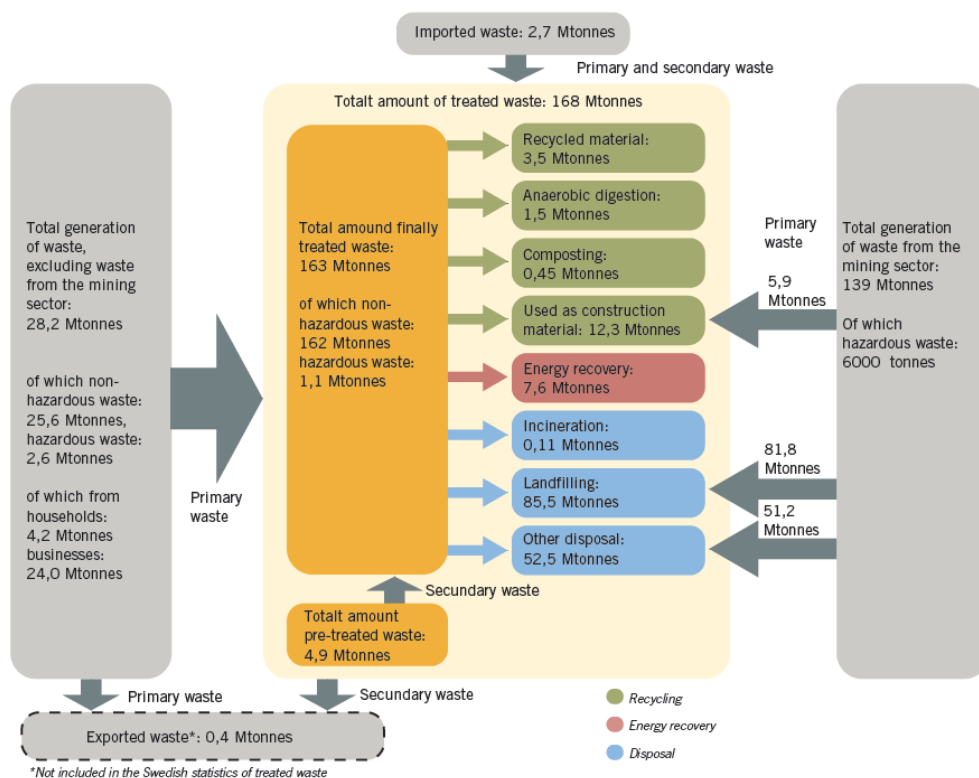


Figure 7.3. Waste streams in Sweden 2014 according to the Swedish EPA²⁷⁸.

In the 1990s, the amount of deposited waste (other than mining waste) decreased significantly. This is especially notable for household waste (in Sweden also referred as “Municipal waste”), which is the largest contributor of greenhouse gases of all waste categories. Only 0.7 % of the generated household waste was deposited in 2016²⁷⁹ which can be compared with 43.8 % in 1990. The remaining part of the generated household waste in 2016 was either incinerated (48.5 %), recycled (34.6 %) or treated biologically (16.2 %).

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 40²⁸⁰ sites in 2016.

²⁷⁸ Swedish EPA 2016

²⁷⁹ Avfall Sverige / Swedish Waste Management 2017

²⁸⁰ Avfall Sverige / Swedish Waste Management 2017

7.2.1 Legislation and policies

Practises regarding landfills were regulated in 1969. Since then, the unmanaged (or illegal) landfills are very uncommon in Sweden.

Depositing has become an expensive waste management solution for disposal of waste. Since January 1st 2000, there is taxation on depositing, currently 500 SEK²⁸¹ per t of waste liable to taxation. Another important change is the implementation of the national prohibitions on the landfilling of burnable and organic wastes in the 9-10 §§ of the Landfill Ordinance (2001:512). The landfilling of combustible wastes has been prohibited since 2002, and in 2005 the ban was extended to organic wastes. These prohibitions are regulated in more detail through regulation NFS 2004:4 from the Swedish EPA.

At the end of 2008, a new EU regulation for deposition came into force and almost 50 % of landfills for municipal waste were closed, according to the trade association Avfall Sverige – Swedish Waste Management.

Sweden has some concerns about the unmanaged waste: *littering*. This occurs in particular around recycling stations. Other kinds of littering of organic waste are the disposal of smaller amounts of garden waste from households in nature or that residuals from the hunted animals are disposed in situ. When littering is discovered however, the clean-up is performed or the cost for the clean-up is paid by the responsible operator. If the responsible operator cannot be found, the relevant municipality is responsible to perform the clean-up of the site.

7.2.2 Managed waste disposal sites (CRF 5.A.1)

7.2.2.1 SOURCE CATEGORY DESCRIPTION

Sweden is reporting data on emissions of methane (CH₄) from CRF 5.A.1.a Managed waste disposal sites: Anaerobic.

For methane from CRF 5.A.1.b Managed waste disposal sites: Semi-aerobic and CRF 5.A.2 Unmanaged waste disposal sites, Sweden is reporting NO (not occurring), since there are no known semi-aerobic²⁸² or unmanaged waste disposal sites for organic waste or municipal solid waste in use²⁸³ in Sweden.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 7.1.

Table 7.1. Summary of source category description, CRF 5.A.1, according to approach 1.

²⁸¹ Avfall Sverige / Swedish Waste Management 2015

²⁸² Sundqvist, 2014

²⁸³ Nygren, 2010

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources estimated
		Level	Trend	Qualitative			
5.A.1	CO ₂	NA	NA		NA, NO	NA, NO	NA
	CH ₄	X	X		T2	D, CS	Yes
	N ₂ O	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:

$$\begin{cases} 1 - e^{-0.5k}, & i = 0 \\ e^{-k(i-0.5)} \cdot (1 - e^{-k}), & i = 1, 2, \dots \end{cases}, \text{ where } k \text{ is the generation rate constant.}$$

This model corresponds to the assumption that all waste is deposited on 1 July, which is approximately equivalent to a uniformly distributed deposition.

Comparisons between the suggested IPCC gas potentials and Swedish estimates show that the IPCC values tend to be higher, but considering the large methodological uncertainties, which is the same in both cases, the difference should be within a reasonable interval.

Historical data has been extrapolated five half-life periods back in time, which means that, for the calculations of 1990, all deposited gas potentials since 1952 are considered. All available historical information on national deposited quantities is used in the calculation. The quality of data on household waste is high since 1980, but data on organic industrial waste is scarce. The consequence is that many assumptions on historical deposited waste quantities have been made, which have greater impact on the calculated emissions in 1990 than in 2014.

Table 7.2 Methane emission from Swedish landfills according to IPCC FOD method, deposited MSW*, sludges and total (excl. mining waste), 1990-2005.

Year	Gas emissions FOD method kt CH ₄	Deposited MSW* in kt	Deposited sludge from wastewater handling and pulp industry in kt	Total deposited waste (excl. mining waste)** in kt
1990	137	2 323	1 400	5 563
1991	139	2 223	1 262	5 161
1992	139	2 203	1 174	4 977
1993	134	2 199	1 086	4 824
1994	129	2 166	860	4 547
1995	128	1 974	850	4 330
1996	127	1 856	880	4 145
1997	126	1 842	975	4 203
1998	124	1 678	700	3 868
1999	119	1 756	620	3 853
2000	115	1 529	587	3 720
2001	113	1 488	514	3 488
2002	105	1 338	341	3 006
2003	99	1 034	223	2 688
2004	98	810	113	2 380
2005	92	541	58	2 067

* Includes household and similar waste, park and garden waste, industry- and non-industry specific waste (organic fractions), construction and demolition waste (organic fraction).

** Includes household and similar waste, park and garden waste, industry- and non-industry specific waste (organic and inorganic fractions), construction and demolition waste (organic and inorganic fractions) and sludge from wastewater handling and pulp industry.

Table 7.2 presents emissions and waste data used for the years before 2006. The waste data are from various sources and uses national waste categories. These waste categories are different from the ones used currently in Sweden.

Table 7.3. Methane emission from Swedish landfills according to IPCC FOD method, deposited solid waste (containing Degradable Organic Carbon), sludges (containing DOC) and total (incl. mining waste), 2006-2016.

Year	Gas emissions FOD method kt CH ₄	Deposited solid waste (containing DOC)* in kt	Deposited industrial effluent sludges and common sludge* in kt	Total deposited waste (excl. mining waste)* in kt	Total deposited mining waste* in kt
2006	88	1 249	180	4 143	61 820
2007	80	1 144	144	4 260	60 450
2008	69	1 039	108	4 376	59 080
2009	65	871	141	4 376	59 080
2010	61	648	164	3 300	47 200
2011	56	656	132	3 050	62 650
2012	52	664	99	2 800	78 100
2013	48	609	111	3 250	79 950
2014	43	555	123	3 700	81 800
2015	40	555	123	3 700	81 800
2016	36	555	123	3 700	81 800

* Activity data and statistics for 2006, 2008, 2010 and 2012 are from Sweden's reporting to the Commission according to the Waste Statistic Regulation. Activity data and statistics for 2007, 2009, 2011, 2013, 2015 and 2016 are interpolated/extrapolated values.

Table 7.3 is presenting emissions and waste data used from 2006. The waste data are from Sweden's reporting to the Commission according to the Waste Statistic Regulation and uses waste categories as defined in the regulation.

Landfill gas extraction

Methane recovery is of great importance for the final emissions of methane in Sweden. 2006 Guidelines recommends that methane recovery should only be reported when references documenting the amount of methane recovery are available, which is the case in Sweden. In Sweden, landfills started to extract landfill gas in 1983 (a single plant). The business increased until year 2003 when gas was recovered in 72 plants. Information on recovered gas (in energy units) is provided by Avfall Sverige and converted to quantity (t) by Statistics Sweden (see Table 7.4).

In year 2016, landfill gas was extracted at 72 landfills²⁸⁴ whereof 39 were active landfills. 10.1 % of the produced biogas in Sweden was produced at landfills. The biogas production (collected gas) on landfills decreased from 457 GWh to 208 GWh between 2005 and 2016, since the amounts of deposited organic waste has decreased significantly the past years, due to the implementation of waste treatment policies. About 23 % of the biogas produced²⁸⁵ (collected gas) at landfills was flared in 2016 (see Table 7.5).

²⁸⁴ Avfall Sverige / Swedish Waste Management & SMED 2017

²⁸⁵ Avfall Sverige / Swedish Waste Management & SMED 2017

Biogas from landfills is mainly used for heating but also for production of electricity. In year 2016, about 1.5 GWh was used as vehicle fuel, which is an increase from year 2015 by 1.3 GWh.

Table 7.4. Recovered and flared methane from landfill gas, t.

Year	Recovered and flared gas	Year	Recovered and flared gas
1982	0 ¹	2003	36 449 ⁵
1983	NE ²	2004	30 135 ⁵
1990	12 000 ³	2005	294 18 ⁵
1991	12 210 ³	2006	24 567 ⁶
1992	14 430 ³	2007	24 553 ⁶
1993	20 800 ⁴	2008	28 381 ⁶
1994	27 500 ⁴	2009	24 784 ⁶
1995	30 000 ⁴	2010	22 048 ⁶
1996	30 000 ⁵	2011	20 474 ⁶
1997	30 000 ⁵	2012	19 457 ⁶
1998	30 000 ⁵	2013	17 387 ⁶
1999	33 000 ⁵	2014	16 865 ⁷
2000	34 000 ⁵	2015	15 895 ⁷
2001	32 400 ⁵	2016	14 913 ⁷
2002	35 947 ⁵		

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, 2015-2017.

Table 7.5 shows quantities of produced energy from landfill gas and how much that is flared in Sweden. The energy is used for production of electricity and for heating. Emissions from flaring and the utilization of the landfill is reported in CRF 1.

Table 7.5. Energy recovery and flaring at landfills in Sweden, MWh²⁸⁶.

Year	2005	2010 ¹	2015 ¹	2016 ¹
Energy recovery	340 000	267 994	157 681	160 085
Whereof prod. of electricity	20 000	20 450	17 017	9 570
Flaring	70 000	39 293	63 858	47 758
Total	410 000	307 287	221 946	221 946

1) Avfall Sverige (Swedish Waste Management) & SMED, 2015-2017

²⁸⁶ Avfall Sverige (Swedish Waste Management)

Other parameters

The Methane Correction Factor (MCF) for modern Swedish landfills is equal to one (1.0) (Table 7.6). Waste management was centralised during the 1970s. Before 1980, landfills were smaller and presumably less compact. Information that helps establish the MCF (cover material, mechanical compacting and levelling of waste) is missing. For calculations before 1980 the 2006 Guidelines default value for uncategorized SWDS was used. This value is the same as the former IPCC default value.

The IPCC default value 50 % is used for the methane content in landfill gas (F) (Table 7.6). The value of DOC_F 0.5 has been chosen according to IPCC methodology.

The oxidation factor is estimated to be 10 %, and the half-life of the methanogenesis is 7.5 years.²⁸⁷ The choice of the half-life factor has also been motivated by the rather wet climate conditions in Sweden ($MAP/PET > 1$), and that the 2006 IPCC Guidelines recommends the default value of 7 for such climate conditions.

Table 7.6 Other used parameters in the methane emission calculations.

Parameter	Value	Motivation
MCF - 1979	0.6	IPCC Uncategorized SWDS
MCF 1980 -	1	IPCC Managed - anaerobic(*)
F	50 %	IPCC Default
DOC_F	0.5	IPCC Default
OX	10 %	National(**)
$t_{1/2}$	7.5 years	National(***)

(*) Swedish EPA, 1999b, (**) Swedish EPA, 1997b, (***) Swedish EPA, 1993b.

Until about 1975, waste burning at landfills was a common waste treatment method, but it ceased about five years later. There is no information on the waste fraction that was burned, except that burning was practiced at 311 of the 847 landfills in 1975.²⁸⁸ An assumption is therefore made that before 1976, 37 % of all deposited household waste was burned.

7.2.2.2.2 WASTE STATISTICS IN SWEDEN, 1980 - 2005

The Swedish EPA made the first national survey in Sweden in 1980, collecting data on deposited waste (only for household waste and similar). Statistics Sweden collected similar data in 1985, 1990 and 1994. Since 1994, the Swedish Waste Management (former RVF) has carried out an annual survey on deposited waste. Thus, household waste is the best documented waste category, with high quality data available since 1980. Household waste is also the most important category for

²⁸⁷ Börjesson, 2000

²⁸⁸ Swedish EPA, 1983.

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 and composted.

There are no time series of data available on landfilled organic industrial waste (except from data on sludge from pulp industry).

7.2.2.2.3 *WASTE STATISTICS IN SWEDEN, 2006 AND ONWARD*

The Regulation of the European Parliament and the Council No 2150/2002 of 25 November 2002 on waste statistics (hereafter referred to as “the Waste Statistics Regulation” or “WStatR”) establishes rules and content for the reporting of waste statistics to the EU. Reporting in accordance with the regulation is to take place every second year. Reporting shall be submitted each time 18 months after the end of the reporting period. The first round of reporting by all member states was completed by 30 June 2006 and concerned waste generation and recovery and disposal of waste for the year 2004.

The treatment of waste is to be reported by treatment method categories. The method of treatment relates to various recovery and disposal operations (“R and D codes”) are compiled into 6 different groups. Group 4, “Disposal operations: Land filling, deep injection, surface impoundment, permanent storage and others”, is relevant for “Solid waste disposal, CRF 5A”.

The Swedish EPA is responsible for the reporting in accordance with the regulation. So far, waste data has been reported for the reference years 2004, 2006, 2008, 2010, 2012 and 2014. No waste statistics on landfilling are compiled for the intermediate years by the Swedish EPA.

In 2010, a study²⁸⁹ was carried out in order to analyse possibilities to use the reported waste data to WStatR for the calculations of CH₄ from solid waste

²⁸⁹ Edborg, Stenmarck, Sundquist & Szudy, 2010

landfills. The study recommended implementation of WStatR-data from reference year 2006 and onwards. The advantages of WStatR-data in relation to waste statistics for 1980-2005 are mainly that:

- WStatR-data uses more specific and better developed descriptions of waste classifications.
- It is produced regularly (every second year). Therefore it is to a less extent based on extrapolations of old waste data and expert judgements. This means it is more sensitive for rapid changes in amounts of waste and DOC content.
- WStatR-data has per definition 100 % coverage (completeness).

Relevant waste categories (those who are containing Degradable Organic Carbon) were chosen, and the DOC content of the chosen waste categories was investigated by analysing the statistical source material in cooperation with waste experts. Interpolations and extrapolations have been made for the intermediate years.

Estimation of DOC content

Official waste statistics in Sweden that is reported in accordance with WStatR to Eurostat, uses the Waste Statistical Nomenclature (EWC Stat) as nomenclature for the statistical waste categories. This is the case for all member states in the European Union.

The EWC Stat codes are statistical aggregates of various sub codes called LoW codes (List of Waste codes). In the European Union, The List of Waste nomenclature contains more than 800 unique codes

In Sweden, the official waste statistics are produced by collecting microdata by using “LoW” codes. Since “LoW” is very detailed, it is also possible to estimate the DOC content (fraction of DOC) very accurate on the EWC Stat-level.

The national statistical waste database, which is used for storage of microdata and production of official waste statistics, has been the source of information when estimating the DOC-values for the EWC Stat-codes. The reference year 2010 was chosen for the microdata, since it was (at the time of the analysis) regarded as the most complete and suitable set of microdata regarding the degree of use of LoW in the national statistical waste database.

EWC Stat codes with conceivable DOC content were chosen and the related microdata was extracted from the database. For each EWC Stat code, information on the identification of landfills, LoW codes and quantities of waste were gathered. The DOC content for each LoW code was judged by waste experts based on its definition and, in some cases, by studying the environmental reports from where the information of the microdata originated. When the DOC content for each LoW code was set for all LoW codes within each EWC Stat code, the DOC content for the EWC Stat code was estimated by weighting the DOC content of the LoW

codes. This was done by using the information on the waste quantity for each LoW code. The quantification of uncertainty associated with the DOC values is made by waste expert judgements (see further in section “Uncertainties and time –series consistency”).

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).

Year	Household waste (and similar)		Garden waste		Sludge from wastewater treatment, wet weight	
	Quantity	DOC content	Quantity	DOC content	Quantity	DOC content
1980	1 450 ¹	..	..	..	..	..
1985	1 040 ²	..	..	..	..	..
1986	1 020 ³	..	..	..	..	..
1988	1 080 ⁴	..	..	..	..	..
1990	1 400 ⁵	0.20 ¹⁷	70 ⁵	0.17 ¹⁹	900 ⁵	0.07 ²⁰
1994	1 380 ⁶	..	80 ⁶	0.17 ¹⁹	610 ⁶	0.07 ²⁰
1995	1 200 ⁷	0.19 ¹⁷	60 ⁷	0.17 ¹⁹	540 ⁷	0.07 ²⁰
1996	1 110 ⁸	..	70 ⁸	0.17 ¹⁹	470 ⁸	0.07 ²⁰
1997	1 150 ⁸	0.18 ¹⁸	50 ⁸	0.17 ¹⁹	455 ⁸	0.07 ²⁰
1998	1 020 ⁹	..	45 ⁹	0.17 ¹⁹	490 ⁹	0.07 ²⁰
1999	972.5 ¹⁰	..	45 ¹⁰	0.17 ¹⁹	490 ¹⁰	0.07 ²⁰
2000	869.5 ¹¹	0.18 ¹⁸	53 ¹¹	0.17 ¹⁹	345 ¹¹	..
2001	880 ¹²	..	44 ¹²	0.17 ¹⁹	330 ¹²	..
2002	820 ¹³	..	40 ¹³	0.17 ¹⁹	215 ¹³	..
2003	575 ¹⁴	..	33 ¹⁴	0.17 ¹⁹	155 ¹⁴	..
2004	380 ¹⁵	0.16 ¹⁸	0*		102 ¹⁵	..
2005	210 ¹⁶	..	0*		58 ¹⁶	..

1) Swedish EPA, 1983. 2) Statistics Sweden, 1988; RVF. 3) RVF, 1988. 4) RVF, 1990.

5) Statistics Sweden, 1992. 6-16) RVF, 1996-2006. 17) Ohlsson, T, 1998. 18) RVF, 2005:5.

19) IPCC 1996, Reference manual. 20) Sweco Viak, 2000-08-30.

* Included in household waste from reference year 2004.

.. Interpolated/extrapolated value

The composition of household waste has been investigated in many studies over the years. Ohlsson²⁹⁰ presents a historic overview of Swedish investigations, the first of which was carried out in 1977. The time series indicates a rather constant

²⁹⁰ Ohlsson, 1998 and REFORSK, 1998

composition of components, except the paper content, which declines during the 1990s.

The chosen composition²⁹¹ 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.²⁹² 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.

²⁹¹ Ohlsson, 1998

²⁹² RVF, 2005

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 %.²⁹³ The gas potential of the sludge is reduced by 50 % because it is treated.²⁹⁴ By using formulas for L_0 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.²⁹⁵

Industrial waste

As noted above, statistics on deposited industrial waste are not divided into organic waste categories. Special studies of organic waste are considered to be the most important information sources of industrial waste categories. In 2004 a study on deposition of organic waste was carried out by Profu and financed by the Swedish EPA.²⁹⁶ The estimates have been made with information from many different sources, such as national statistics, screening inspections of waste content, information on capacity of energy recovery from waste and extrapolation back in time using the industries part of Gross National Product (GNP). The study shows that great amounts of paper and wood have been deposited in construction and demolition waste, as well as in the category of “non-specific” industrial waste.

The first study on “specific” organic industrial waste was published in 1993;²⁹⁷ 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.

²⁹³ Recounted from RVF, 1996.

²⁹⁴ Sweco Viak, 2000.

²⁹⁵ Swedish EPA, 1993.

²⁹⁶ Profu, 2004.

²⁹⁷ Swedish EPA, 1993

Table 7.9. Organic industrial waste, early 1990s (Swedish EPA, 1993).

Waste category	Produced quantity, kt/yr	Deposited fraction, %	Deposited quantity, kt/yr	Gas potential, Mm ³ CH ₄ /yr
Sludge from pulp industry	1000	50	500	31.5
Carcasses	8	35	2.8	0.63
Waste from slaughter houses	40	5	2	0.45
Sludge from slaughterhouses	45	8	3.6	0.28
Entrails	30	5	1.5	0.09
Manure from slaughterhouses	10	5	0.5	0.03
Draff	5.5	0.5	0.0275	0.03
Waste from sugar beet industry	100	0.5	0.5	0.02
Waste from potato industry	46	0.5	0.23	0.01
Returned bread	13	3	0.39	0.11
Mycelia waste	2	1	0.02	0.01
Scrows waste	5.5	100	5.5	0.8
Waste from fishing industry		50	0	0.5
Whey	1 000	0	0	0
Tinned foods industry	53	50	26.5	1.55
Total:				
Sludge from pulp industry			500	31.5
Other			43.6	4.5

Data on deposited sludge from the pulp industry is available from a survey carried out annually from 1994 up to year 2000 by the Swedish EPA. In 2004, data on deposited sludge from the pulp industry is taken from the Swedish Forest Industries Federation. Data for the intermediate years have been interpolated. The reports contain detailed information on waste and waste treatment for each pulp and paper producer. Intermediate values (1991-1993) have been interpolated (Table 7.10).

Table 7.10. Values of deposited wastewater sludge from the pulp industry, wet weight.

Year	Quantity kt/year
1990	500 ¹
1994	250 ²
1995	310 ³
1997	520 ⁴
1998	210 ⁵
1999	130 ⁶
2000	242 ⁷
2001	184 ⁸
2002	126 ⁸
2003	68 ⁸
2004	10.5 ⁹
2005	0 ⁹

1) Swedish EPA, 1993. 2) Swedish EPA, 1995. 3) Swedish EPA, 1996b. 4) Swedish EPA, 1998b. 5) Swedish EPA, 1999. 6) Swedish EPA, 2000. 7) Swedish EPA, 2001. 8) Value interpolated no similar survey carried out. 9) Swedish Forest Industries Federation.

A study on organic industry-specific waste was published in 1996²⁹⁸. In accordance with the report, the deposited waste categories are presented in Table 7.11. The gas potentials were calculated by Sweco Viak.

Table 7.11. Organic Industrial Waste 1996.

Waste category	Deposited quantity, kt/yr	Gas potential, Mm ³ CH ₄ /yr
Waste from slaughter houses	22.5	0.88
Waste from potato and vegetable industries	11.5	0.64
Total:	34	1.52

Swedish EPA, 1996

The final gas potential is used as gas potentials in the methane calculations for 1996 and later. By using the two reports, values are interpolated between 1990 and 1996.

In addition to the gas potentials from these industries, the gas potentials for paper and cardboard waste from industries, which is not included in the referred reports, have to be added. Information on these gas potentials is extracted from a survey ("Waste from the manufacturing and minerals extraction industries in 1998") made by the Swedish EPA and Statistics Sweden.²⁹⁹ 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.

²⁹⁸ Swedish EPA, 1996

²⁹⁹ Statistics Sweden, 2000

Composition of deposited waste

Table 7.12 illustrates the estimated composition of deposited waste (excl. mining waste) 1990-2005.

Table 7.12. Composition of deposited waste (%).

Year	Paper	Food	Plastic	Glass	Textile	Napkins	Sludge from waste water	Sludge from pulp industry	Wood	Other inert	Other organic
1990	7.1	13.5	2.1	0.6	0.7	1.3	16.2	9.0	0.3	34.9	14.3
1991	7.4	14.6	2.2	0.7	0.8	1.5	15.5	9.0	0.3	34.5	13.6
1992	7.5	15.4	2.3	0.7	0.8	1.5	15.1	8.5	0.3	34.2	13.7
1993	7.5	16.1	2.4	0.7	0.8	1.6	14.5	8.0	0.4	34.1	14.0
1994	7.7	17.2	2.6	0.8	0.9	1.7	13.4	5.5	0.4	35.8	14.2
1995	6.8	15.8	2.4	0.7	0.8	1.6	12.5	7.2	0.3	36.9	15.1
1996	6.3	15.9	2.3	0.7	0.8	1.5	11.3	9.9	0.3	36.1	14.8
1997	5.6	16.0	2.5	0.7	0.8	1.6	10.8	12.4	0.3	35.5	13.8
1998	5.4	15.6	2.4	0.7	0.8	1.5	12.7	5.4	0.3	41.0	14.2
1999	5.2	15.0	2.3	0.7	0.8	1.5	12.7	3.4	0.3	40.7	17.5
2000	5.4	13.5	2.5	0.8	0.7	1.2	9.3	6.5	0.2	45.5	14.6
2001	5.8	14.2	2.7	0.8	0.8	1.2	9.5	5.3	0.2	45.2	14.4
2002	6.3	15.5	2.9	0.9	0.9	1.3	7.2	4.2	0.2	46.9	13.8
2003	5.0	13.0	2.3	0.7	0.7	1.1	5.8	2.5	0.1	55.4	13.5
2004	2.8	10.4	1.8	0.4	0.4	0.9	4.3	0.4	0.1	63.1	15.5
2005	1.9	7.8	1.2	0.2	0.2	0.6	2.8	0.0	0.1	72.2	13.0

7.2.2.2.5 *Used statistics on deposited waste, 1952-2014*

Used statistics 1952-2005

Table 7.13 shows the activity data 1952-2005 used in the calculations of methane emissions from solid waste disposal on land.

Table 7.13. Overview over used statistics on deposited waste and interpolated/-extrapolated values: Solid waste.

Year	Standard value: deposited household waste/citizen (kg)	Fraction of deposited household waste	Fraction of burned household waste on landfills	Deposited household waste and similar, (kt)	Deposited park and garden waste, (kt)	Deposited organic industrial waste(**), (kt)	Deposited industrial waste (not industry specific), organic fraction(**), (kt)	Deposited construction and demolition waste, organic fraction(**), (kt)
1952	290	76 %	37 %	992	58	56	207	63
1954	290	76 %	37 %	1005	59	56	215	66
1956	290	76 %	37 %	1018	60	56	226	70
1958	290	76 %	37 %	1030	60	56	234	73
1960	290	76 %	37 %	1041	61	56	250	77
1962	290	76 %	37 %	1056	62	56	272	80
1964	290	76 %	37 %	1072	63	56	301	83
1966	290	76 %	37 %	1088	64	56	325	87
1968	290	76 %	37 %	1105	65	56	345	90
1970	290	76 %(*)	37 %	1122	66	56	364	94
1972	290	76 %	37 %	1129	66	56	372	97
1974	290	66 %	37 %	987	67	56	406	101
1976	290	66 %	30 %	1109	67	56	452	116
1978	290	58 %	15 %	1186	67	56	517	145
1980			0 %	1450(*)	68	56	628	177
1982				1300	68	56	627	182
1984				1100	68	56	579	161
1986				1020(*)	68	56	602	165
1988				1080(*)	69	56	624	170
1990				1400(*)	70(*)	56	622	175
1992				1390	75	58.2	554	126
1994				1380(*)	80(*)	60.3	564	82
1996				1110(*)	70(*)	62.5	536	78
1998				1020(*)	45(*)	62.5	477	73
2000				869.5(*)	53(*)	62.5	473	71
2001				880(*)	44(*)	62.5	439	62
2002				820(*)	40(*)	62.5	370	45
2003				575(*)	33(*)	62.5	323	40
2004				380(*)	0(***)	62.5	321	47
2005				210(*)	0(***)	62.5	231	37

(*) Taken from statistical sources. Other values are interpolated or extrapolated.

(**) Estimate. (***) Included in household waste from reference year 2004.

Table 7.14. Overview over used statistics on deposited waste and interpolated/extrapolated values: Sludge, wet weight.

Year	Deposited sludge from waste water treatment, (kt)	Deposited sludge from pulp industry, (kt)
1952	748	500
1956	768	500
1960	786	500
1964	809	500
1968	834	500
1972	852	500
1976	862	500
1980	871	500
1984	875	500
1988	890	500
1992	750	424
1996	470(*)	410(*)
2000	345(*)	242(*)
2001	330(*)	184
2002	215(*)	126.3
2003	155(*)	68
2004	102(*)	10.5(*)
2005	58(*)	0(*)
2005	58(*)	0(*)

(*) Taken from statistical sources. Other values are interpolated or extrapolated.

Used statistics 2006-2009

Table 7.15 shows waste statistics for 2006 and 2008 used in the calculations of methane emissions from solid waste disposal on land. Waste statistics for 2007 and 2009 are interpolated/extrapolated. It also shows estimated DOC content for each waste category.

Table 7.15. Overview over used statistics* 2006 and 2008 on deposited waste, kt, and estimated DOC content, %.

EWC- Stat code	Description of waste categories	2006 ^(*)	2008 ^(*)	DOC content
03.1	Chemical deposits and residues	C	176.946	2
03.2	Industrial effluent sludges: <u>Dry matter</u>	11.914	10.580	9
05.	Health care and biological wastes: <u>Hazardous</u>	C	0.004	8
05.	Health care and biological wastes	C	0.010	8
07.2	Paper and cardboard wastes	38.977	2.296	36
07.5	Wood wastes	C	1.840	40
07.6	Textile wastes	0.228	0.972	24
09A	Animal and vegetal wastes (<i>excl. 09.11 & 09.3</i>)	11.548	6.058	15
09.11	Animal waste of food preparation and products	0.303	0.343	15
09.3	Animal faeces, urine and manure	0.372	0.075	9
10.1	Household and similar wastes	203.821	119.986	18
10.2	Mixed and undifferentiated materials	482.743	222.442	3.1
10.3	Sorting residues	311.483	507.599	2.5
11A	Common sludges (<i>excl. dredging spoils</i>): <u>Dry matter</u>	26.383	13.142	28
Total		1 428.879	1 146.601	

* Waste statistics for 2006 and 2008 are from Sweden's reporting to the Commission in accordance to the Waste Statistic Regulation.. (C: Confidential)

Used statistics 2010-2016

Table 7.16 shows waste statistics for 2010, 2012 and 2014 used in the calculations of methane emissions from solid waste disposal. Waste statistics for 2011, 2013, 2015 and 2016 are interpolated/extrapolated. The EWC-stat codes as well as the DOC content differs a bit compared to those in Table 7.15. This is due to changes in the EWC-stat codes implemented in the 2010 year data. Due to the changes in EWC-codes there was also an investigation on the DOC-contents regarding the codes changed³⁰⁰.

³⁰⁰ Sundqvist & Szudy, 2012

Table 7.16. Overview over used statistics* 2010, 2012 and 2014 on deposited waste, kt, and estimated DOC content, %

EWC- Stat code	Description of waste categories	2010^(*)	2012^(*)	2014^(*)	DOC cont.
02A	Chemical wastes	85.323	93.600	126.000	5
03.2	Industrial effluent sludges: <u>Dry matter</u>	1.282	7.780	19 100	12.5
03.2	Industrial effluent sludges: <u>Dry matter Hazardous</u>	7.000	10.400	9.590	2
05.	Health care and biological wastes: <u>Hazardous</u>	0	0	0	8
05.	Health care and biological wastes	0	0	0	8
07.2	Paper and cardboard wastes	0.577	0	0	36
07.5	Wood wastes	0.057	6.460	4.390	40
07.6	Textile wastes	0	0	0.580	24
09.1	Animal and mixed food waste	1.183	0.400	0.250	13
09.2	Vegetal wastes	2.304	0.240	0.070	20
09.3	Animal faeces, urine and manure	0	0	0	9
10.1	Household and similar wastes	17.013	26.800	21.900	18
10.2	Mixed and undifferentiated materials	262.226	289.000	116.000	8.5
10.3	Sorting residues	279.583	247.000	286.000	2.5
11A	Common sludges (<i>excl.</i> <i>dredging spoils</i>): <u>Dry matter</u>	26.228	5.310	1.560	28
Total		682.776	686.990	585.440	

* Waste statistics for 2010, 2012 and 2014 are from Sweden's reporting to the Commission in accordance to the Waste Statistic Regulation.

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 now can be

estimated with better precision. The uncertainty for emission year 1990 for AD is 40 % which compared with 25 % for 2016, while the uncertainty of EF remains 50 %. This means the uncertainty has decreased from the base year (1990) to the most recent year (2016), which illustrates the improvements that has been made by using the new data source.

The time series in the waste sector are calculated consistently and in line with the 2006 Guidelines. When statistics are not produced annually, interpolation and extrapolation have been necessary tools for imputation.

7.2.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

7.2.2.4.1 *Quality Assurance and Quality Control*

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

7.2.2.4.2 *Verification of data and reducing compiling errors*

Statistics Sweden and the IVL has on behalf of the Swedish EPA scrutinized the activity data (quantities of deposited; household waste, park and garden waste, sludge from waste water treatment) used for calculations. The accuracy in these activity data is judged to be good.

7.2.2.5 SOURCE-SPECIFIC RECALCULATIONS

Emissions of methane from CRF 5.A Solid waste disposal has been recalculated for the years 2008-2014, due to the availability of new data on landfill gas extraction. The new data is a result from a project where the availability of historical gas extraction data from closed landfills was investigated. It resulted in -1.8 % to +0.32 % lower/higher emission for the years 2008-2014.

7.2.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan. Therefore no activities are specified in this section.

7.3 Biological treatment of solid waste (CRF 5.B)

In Sweden, biological waste treatment such as composting and anaerobic digestion of solid waste are common waste management practices.

Biological treatment of waste has a long tradition in Sweden, but the interest and importance has varied during the years. Already during the 1950's there were three more technically advanced composting plants in operation, treating unsorted household waste. However, the waste composition changed during the 50's and the composting plants were closed down due to operational problems.

The next composting period started around 1975, and during the next ten years about 14 more advanced plants were built. These were based on a technology similar to what today is called Mechanical-Biological-Treatment (MBT). These were built with governmental subsidies (50 % of the investment). It was difficult to find markets for the products from these plants (compost, RDF and metals) and the plants have difficult operational problems. One after one the plants closed down and around 1990 there were only a few plants still in operation. Of importance in this context may be that from the 1980's all waste treatment plants were equipped with weighing-machines and computerized registering systems.

In the beginning of the 1990's there were an increasing interest for composting source separated household waste, as food waste and garden waste. Several plants were put in operation, and some of the earlier MBT plants were reconstructed to manage source separated biowaste. The role of composting of source-separated biowaste become more and more important during the 1990's and several new plants were put in operation. The growth of composting also was encouraged by a landfill tax that was put in action from 2000. Composting also continued to grow in the beginning of the 2000's, encouraged by increased landfill tax and bans on landfilling of combustible waste from 2002 and on organic waste from 2005. The standards of the composting plants also was raised when the problems of emissions of methane (CH₄) and nitrous oxide (N₂O). From around 2005 all compost plants treating food waste were obliged to have a closed process, collecting and treating the off-gases from the compost. From 2005 the composting has been at a rather constant level, but with some changes between the years. Since then about 500 000 – 600 000 t have been composted annually³⁰¹.

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 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

³⁰¹ Avfall Sverige / Swedish Waste Management 2010-2015

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 2016³⁰² the amount of waste to anaerobic digestion were 1 615 000 t, and is forecasted to still increase some years in the future.

Of interest in this context is that both the compost and the digestate are used. The compost is mostly used as raw material for garden soil and similar. The digestate is to more than 97 %³⁰³ 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 2016, 46 % of the produced biogas in Sweden was produced at anaerobic treatment plants for solid waste. The biogas production at these plants increased by 11 712 % from 1990 to 2016. 3.8 % of the biogas produced at anaerobic treatment plants for solid waste was flared in 2016, and 88.1 % was upgraded into fuel for vehicles. Emissions from flaring and the utilization of the biogas is reported in CRF 1.

7.3.1 Composting (CRF 5.B.1) and anaerobic digestion at biogas facilities (CRF 5.B.2)

7.3.1.1 SOURCE CATEGORY DESCRIPTION

Sweden is reporting data on emissions of methane (CH₄) and nitrous oxide (N₂O) from CRF 5.B.1 Composting, and methane from CRF 5.B.2 Anaerobic digestion at biogas facilities. Emissions from home composting are not estimated.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 7.17.

³⁰² Avfall Sverige / Swedish Waste Management 2017

³⁰³ Avfall Sverige / Swedish Waste Management 2010

Table 7.17. Summary of source category description, CRF 5.B, according to approach 1.

CRF	Gas	Key Category Assessment 2016, 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 ₂ O				T1	D	Yes
	CO ₂	NA	NA		NA	NA	NA
5.B.2	CH ₄				T1, T2	D, CS	Yes
	N ₂ O	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

$$\text{EQUATION 4.1}$$

$$\text{CH}_4 \text{ EMISSIONS FROM BIOLOGICAL TREATMENT}$$

$$\text{CH}_4 \text{ Emissions} = \sum_i (M_i \cdot EF_i) \cdot 10^{-3} - R$$

Where:

- CH₄ Emissions = total CH₄ emissions in inventory year, Gg CH₄
- M_i = mass of organic waste treated by biological treatment type *i*, Gg
- EF = emission factor for treatment *i*, g CH₄/kg waste treated
- i* = composting or anaerobic digestion
- R = total amount of CH₄ recovered in inventory year, Gg CH₄

Nitrous oxide

$$\text{EQUATION 4.2}$$

$$\text{N}_2\text{O EMISSIONS FROM BIOLOGICAL TREATMENT}$$

$$\text{N}_2\text{O Emissions} = \sum_i (M_i \cdot EF_i) \cdot 10^{-3}$$

Where:

- N₂O Emissions = total N₂O emissions in inventory year, Gg N₂O
- M_i = mass of organic waste treated by biological treatment type *i*, Gg
- EF = emission factor for treatment *i*, g N₂O/kg waste treated
- i* = composting or anaerobic digestion

7.3.1.2.2 Emission factors used

Default emission factors from Table 4.1 in 2006 Guidelines (according to the changes in 9th Corrigenda for the 2006 IPCC Guidelines, July 2015) are used in the calculations (see Table 7.18) with an exception of the country-specific emission

factors used from year 2006 when calculating methane emissions from anaerobic digestion (see Table 7.19).

Table 7.18 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 ₂ O Emission Factors (g N ₂ O/kg waste treated) on a wet weight basis.
Composting	4	0.24
Anaerobic digestion at biogas facilities	0.8 (Year 1990-2005)	Assumed negligible

The emissions of nitrous oxide from CRF 5.B.2 Anaerobic digestion at biogas facilities are reported as NA (not applicable) since the 2006 Guidelines assumes that the emissions are negligible.

Table 7.19 Country-specific emission factors used; CRF 5.B.2 Anaerobic digestion at biogas facilities.

Year	CH ₄ Emission Factors (g CH ₄ /kg waste treated) on a wet weight basis.
2006	1.6 ¹
2007	1.7 ²
2008	1.9 ³
2009	1.7 ⁴
2010	1.0 ⁵
2011	1.3 ⁶
2012	1.1 ⁷
2013	1.1 ⁸
2014	1.1 ⁹
2015	1.1 ¹⁰
2016	1.1 ¹¹

1-7) are calculated with data from Sammanställningar av mätningar inom Frivilligt Åtagande, 8-11) are extrapolated from 7).

The country-specific emission factors are higher than the default factor, and covers the additional emission that comes with upgrading the generated methane into fuel for vehicles. The upgrading of methane into fuel for vehicles in this sector has increased from 4.92 kt to 59.70 kt (or 1 113 %) from year 2006 to year 2016³⁰⁴.

7.3.1.2.3 Statistics used as activity data

The statistics used as activity data is produced by Swedish Waste Management (Avfall Sverige former RVF). The data is judged to be of high quality.

³⁰⁴ Swedish Energy Agency, 2017

Table 7.20 Composted waste and waste to anaerobic digestion.

Year	Composted waste kt (wet weight)	Waste to anaerobic digestion, kt (wet weight)
1990	70 950 ¹	..
1991	..	..
1992	..	..
1993	..	..
1994	..	..
1995	246 000 ²	44 650 ²
1996	..	..
1997	235 000 ³	..
1998	..	..
1999	280 000 ⁴	..
2000	290 000 ⁵	..
2001	..	..
2002	301 525 ⁶	220 316 ⁶
2003	293 188 ⁷	223 463 ⁷
2004	273 952 ⁸	244 374 ⁸
2005	459 830 ⁹	258 070 ⁹
2006	452 390 ¹⁰	283 730 ¹⁰
2007	515 290 ¹¹	356 090 ¹¹
2008	568 700 ¹²	405 580 ¹²
2009	630 500 ¹³	535 930 ¹³
2010	566 210 ¹⁴	661 620 ¹⁴
2011	690 100 ¹⁵	555 050 ¹⁵
2012	558 831 ¹⁶	695 940 ¹⁶
2013	528 470 ¹⁷	945 550 ¹⁷
2014	467 920 ¹⁸	1 227 990 ¹⁸
2015	418 340 ¹⁹	1 616 110 ¹⁹
2016	476 140 ²⁰	1 614 920 ²⁰

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, 14-20) Svensk Avfallshantering 2011-2017.

Waste to anaerobic digestion increased by 191 % from 2011 to 2016. Some municipalities have changed treatment method for biological waste from composting to anaerobic digestion. The number of anaerobic digestion plants increased from 16 to 34 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 “CH₄ Emission Factors (g CH₄/kg waste treated) on a wet weight basis: ± 30 % (Expert judgement).

Activity data “Fraction of MSW sent to composting facility”: $\pm 5\%$ (Expert judgement).

Anaerobic digestion at biogas facilities

Emission factor “CH₄ Emission Factors (g CH₄/kg waste treated) on a wet weight basis: $\pm 25\%$ (Expert judgement).

Activity data “Fraction of MSW sent to anaerobic digestion at biogas facilities”: $\pm 5\%$ (Expert judgement)

7.3.1.3.2 Nitrous oxide

Composting

Emission factor “N₂O Emission Factors (g N₂O/kg waste treated) on a wet weight basis: $\pm 50\%$ (Expert judgement).

Activity data “Fraction of MSW sent to composting facility”: $\pm 5\%$ (Expert judgement)

The time series in the waste sector are calculated consistently and in line with the 2006 Guidelines. When statistics are not produced annually, interpolation and extrapolation have been necessary tools for imputation.

7.3.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

7.3.1.4.1 Quality Assurance and Quality Control

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

7.3.1.5 SOURCE-SPECIFIC RECALCULATIONS

Recalculation of methane emissions from anaerobic digestion at biogas facilities has been made for the year 1990-2001, due to revised activity data for waste to anaerobic digestion for the year 1995, combined with extrapolations/interpolations of activity data for year 1990-1994 and 1996-2001. The extrapolations 1990-1994 were made by using recently available data on energy production at anaerobic digestion plants. A minor correction of activity data was also made for the year 2015. The recalculations resulted in increasement of methane emissions from 0.0 % to 346.5 % for the years 1995-2015. Emissions of methane from anaerobic digestion for 1990-1994 was reported for the first time in submission 2018.

7.3.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan. Therefore no activities are specified in this section.

7.4 Incineration and open burning of waste (CRF 5.C)

7.4.1 Waste incineration (CRF 5.C.1)

SOURCE CATEGORY DESCRIPTION

Sweden has one plant for incineration of hazardous wastes. Emissions from incineration of hazardous waste, and in later years also MSW and industrial waste, from this plant are reported in CRF 5.C.1. The fossil and biogenic fraction of CO₂ emissions are, according to the IPCC 2006 Guidelines, reported separately. Emissions from other MSW incineration plants combusting waste for energy purposes are included in CRF 1. The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), are presented in Table 7.21.

Table 7.21. Summary of source category description, CRF 5.C, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF)			Method	EF	All sources Estimated
		Level	Trend	Qualitative			
5.C	CO ₂				T3	PS	Yes
	CH ₄				T2	PS	Yes
	N ₂ O				T2	PS	Yes

PS Plant Specific. T2 Tier 2. T3 Tier 3.

METHODOLOGICAL ISSUES

For this source category, the methodology and time series consistency are in line with the 2006 IPCC Guidelines.

Emissions from incineration of hazardous waste, and in later years also MSW and industrial waste, from one large plant are reported in CRF 5.C. Reported emissions are for the whole time series obtained from the facility's Environmental report or directly from the facility on request. CO₂, SO₂, NO_x and CH₄ are measured continuously in the fumes at the plant. NMVOC are until 2007 as reported by the facility. For 2007 - 2015 are the NMVOC emissions calculated, based on IEF for 2007 and yearly incinerated amounts of waste. For 2016 the NMVOC emissions have been obtained directly from the facility.

In 2003 capacity was increased substantially at the plant by taking one new incinerator into operation. The new incinerator incinerates a mixture of MSW, industrial waste and hazardous waste. As presented in Table 7.22, emissions of CO₂ from incineration of biogenic waste are reported in CRF 5.C.1.1.b and CO₂ from incineration of non-biogenic waste are reported in CRF 5.C.1.2.b. Emissions of CH₄ and N₂O from incineration of biogenic and non-biogenic waste are reported in CRF 5.C.1.2.b.

Table 7.22. Notation keys for emissions reported in CRF 5.C.

CRF	Greenhouse gas source and sink categories	CO ₂		CH ₄ and N ₂ O	
		Notation key	Emissions included in CRF	Notation key	Emissions included in CRF
5.C.1.1.a	Biogenic municipal solid waste	IE	5.C.1.1.b	IE	5.C.1.2.b
5.C.1.1.b	Biogenic other waste (hazardous)	Emissions reported		IE	5.C.1.2.b
5.C.1.2.a	Non-biogenic municipal solid waste	IE	5.C.1.2.b	IE	5.C.1.2.b
5.C.1.2.b	Non-biogenic other waste (hazardous)	Emissions reported		Emissions reported	

As a consequence of increased capacity, the emissions from 2003 are increased compared to earlier years. Only a minor part (1 – 2 %) of the total amount of waste incinerated for energy purposes in Sweden are incinerated in the facility included in 5.C. All other emissions from incineration of MSW are reported in CRF 1.

Emissions reported are CO₂, CH₄, N₂O, NO_x, SO₂, NMVOC and CO.

In submission 2013 the time series of reported biogenic and fossil CO₂ was revised. For the years 2008, 2009, 2010 and 2011 the company has, beside total emissions of CO₂, also reported CO₂ with respect to biogenic or fossil origin. The company has based their reporting of biogenic and fossil CO₂ on a detailed study performed in 2008. In this study they found that 63 % of the totally emitted CO₂ had biogenic origin. This finding is in good agreement with newly published results from a Swedish study showing that about one third of the carbon in solid waste is of fossil origin³⁰⁵. As the mixture of incinerated wastes has been almost the same for all years from 2003, when the new incinerator was taken into operation, the company considered this biogenic percentage of the totally emitted CO₂ to be valid also for the years 2003 to 2008. For the period before 2003 the company considers reported CO₂ emissions to be almost 100 % fossil.³⁰⁶

³⁰⁵ Swedish Waste Management. RAPPORT U2012:05. Determination of the fossil carbon content in combustible municipal solid waste in Sweden.

³⁰⁶ Personal communication, Hanna Eriksen, Hanna.Eriksen@sakab.se, 2012-08-23

Before 2008 occasional measurements of CH₄ in the flue gas was performed. The company reported CH₄ 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 CH₄ in CRF 5C. For 2008 – 2016 reported CH₄ emissions are based on continuous measurements in the flue gas. Also N₂O from waste incineration is reported for the whole time series. The estimates are based on occasional measurements of the N₂O concentrations in the flue gas together with information on yearly flue gas volumes 2003 – 2016. For 1990 until 2002 the volumes are not known and for these years the flue gas volumes have been estimated using the average of the ratios between volumes and incinerated amounts of waste for 2003 to 2008. Activity data and emission factors used for the CH₄ and N₂O estimates are presented in Table 7.23.

Table 7.23. Activity data and emission factors used for estimations of CH₄ and N₂O emissions in CRF 5.C.

Year	Total amounts of incinerated waste	Flue gas volume	N ₂ O	CH ₄
	kt	1000 m ³	EF, g/1000 m ³	IEF, kg/kt
1990	30	220 674*	15.00	7.73**
1995	33	240 637*	15.00	7.73**
2000	28	205 778*	15.00	7.73**
2005	126	1 099 338	15.00	7.73**
2006	122	902 039	15.00	7.73**
2007	140	915 032	15.00	7.73**
2008	146	1 189 691	15.00	7.73
2009	162	1 107 410	15.00	5.32
2010	115	1 007 061	15.00	7.84
2011	163	1 229 605	15.00	6.09
2012	158	1 194 418	15.00	7.81
2013	153	1 128 670	15.00	7.73
2014	153	1 201 632	15.00	5.27
2015	155	1 162 650	15.00	3.58
2016	153	1 133 767	15.00	4.62

* = estimated volume

** = IEF for 2008 used for estimations 1990 - 2007

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 N₂O 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 CO₂ but corresponding information for measured amounts of CH₄ is likely to be in order of ± 10 %. Due to lack of other information the emissions data uncertainty for CO₂ and CH₄ are set to ± 10 %.

As can be seen in Table 7.22 the implied emission factor (IEF) for CH₄ varies slightly. Reported emissions for 2008 – 2016 are based on continuous measurements and the reason for the variation may be explained by variations in the composition of the incinerated waste.

SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations are performed.

SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

7.4.2 Open burning of waste (CRF 5.C.2)

SOURCE CATEGORY DESCRIPTION

In Sweden, accidental fires of landfills and storages of waste fractions occur, resulting in emissions of CO₂, CH₄ and N₂O. 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 CO₂, CH₄ and N₂O amounted to about 4 kt CO₂-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 2003³⁰⁷. 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 CO₂-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 CO₂ emissions occur.

7.5 Wastewater treatment and discharge (CRF 5.D)

In Sweden, wastewater treatment is practised both in municipal wastewater treatment plants, in private wastewater systems and in some industries. Both methane and nitrous oxide are emitted from these activities.

There are almost 500 municipal wastewater treatment plants in Sweden with treatment capacity for more than 2,000 personal equivalents. 95 % of the wastewater is treated mechanically, chemically and biologically. In some larger

³⁰⁷ Bränder i avfall vid deponier och förbränningsanläggningar (2003) RVF rapport 2003:11, ISSN 1103-4092

plants, or plants with sensitive recipients, special nitrogen treatment is performed. These wastewater treatment plants also receive wastewater from industries without internal wastewater treatment.

There are also a number of smaller plants or private plants of varying standard.³⁰⁸ In addition, there are also approximately 1.3 million people in Sweden not connected to any wastewater treatment plant. This population is connected to on-site treatment.

The industrial wastewater is treated both internally and in municipal wastewater treatment plants. The industries with internal wastewater treatment are situated both by the coast and in the inland.

The majority of the wastewater treatment facilities (municipal and industrial) in Sweden are using aerobic processes, where no methane is supposed to be generated because of the use of aeration in the wastewater treatment process. In 2016 there were only six (6) facilities using anaerobic wastewater treatment processes in Sweden, all of them are in the food industry and in the pulp and paper industry (for more information, see below on biogas production).

Biogas production at wastewater treatment facilities

Considerable quantities of heat and bioenergy are recovered from sewage and wastewater.³⁰⁹ 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.

In 2016, 34,6 %³¹⁰ of the produced biogas in Sweden was produced at wastewater treatment plants (anaerobic digestion of sludge). The biogas production at wastewater treatment plants (anaerobic digestion of sludge) increased by 26.8 % from 2005 to 2016. 10.9 % of this biogas was flared and 61.6 % was upgraded into fuel for vehicles.

There are no activities such as anaerobic digestion of sludge from industrial wastewater treatment in Sweden.³¹¹ In year 2016, four facilities in the food industry and two facilities in the pulp and paper industry practiced anaerobic wastewater treatment. 6.2 % of the produced biogas in Sweden was produced in these industries. The biogas production at these industries increased by 103.2 % from 1990 to 2016. 26.6 % of the biogas produced was flared. At the moment, no methane is upgraded into fuel for vehicles within these activities.

³⁰⁸ Swedish EPA & SMED, 2003

³⁰⁹ Ministry of the Environment, 2001.

³¹⁰ Swedish Energy Agency, 2017

³¹¹ Memo "Occurrence of treatment of sludge by anaerobic digestion in Swedish industries", Statistics Sweden, 2011 "

Emissions from flaring and the utilization of the biogas is reported in CRF 1.

7.5.1 Domestic wastewater (CRF 5.D.1) and Industrial wastewater (CRF 5.D.2)

7.5.1.1 SOURCE CATEGORY DESCRIPTION

Sweden is reporting data on emissions of methane (CH₄) and nitrous oxide (N₂O) from CRF 5.D.1 Domestic wastewater and CRF 5.D.2 Industrial wastewater.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 7.24.

Table 7.24 Summary of source category description, CRF 5.D, according to approach 1.

CRF	Gas	Key Category Assessment 2016, excluding LULUCF			Method	EF	All sources Estimated
		Level	Trend	Qualitative			
5.D.1	CO ₂	NA	NA		NA	NA	NA
	CH ₄				T2	CS	Yes
	N ₂ O	X			T1	D, CS	Yes
5.D.2	CO ₂	NA	NA		NA	NA	NA
	CH ₄				T2	CS	Yes
	N ₂ O				T1	D	Yes

CS (Country Specific), D (Default), T1 (Tier 1), T2 (Tier 2).

7.5.1.2 METHODOLOGICAL ISSUES

7.5.1.2.1 Methodologies used (CH₄)

Equations 6.1 and 6.4 in The 2006 IPCC Guidelines for National Greenhouse Gas Inventories are used when calculating methane emissions (see below).

Domestic wastewater (CRF 5.D.1)

EQUATION 6.1 TOTAL CH₄ EMISSIONS FROM DOMESTIC WASTEWATER

$$CH_4 \text{ Emissions} = \left[\sum_{i,j} (U_i \cdot T_{i,j} \cdot EF_j) \right] (TOW - S) - R$$

Where:

- CH₄ Emissions = CH₄ emissions in inventory year, kg CH₄/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 CH₄ / kg BOD
R = amount of CH₄ recovered in inventory year, kg CH₄/yr

Industrial wastewater (CRF 5.D.2)

EQUATION 6.4 TOTAL CH₄ EMISSIONS FROM INDUSTRIAL WASTEWATER

$$CH_4 \text{ Emissions} = \sum_i [(TOW_i - S_i) EF_i - R_i]$$

Where:

- CH₄ Emissions = CH₄ emissions in inventory year, kg CH₄/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 CH₄/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 CH₄ recovered in inventory year, kg CH₄/yr

For methane emissions from industries with anaerobic wastewater treatment, Sweden has chosen a country-specific method to estimate the emissions. By using statistical information on generated energy, produced quantities of methane are calculated. According to wastewater treatment expertise³¹², the loss of CH₄ in the energy recovery process should be within the range of 1-2 %. The upper value (2 %) of the loss is used as emission factor.

³¹² Ek, 2014

7.5.1.2.2 *Emission factors used (CH₄)*

Domestic wastewater (CRF 5.D.1)

B₀: The maximum methane producing capacity (B₀) is set to 0.25 kg CH₄/kg BOD (equals to 0.1 kg CH₄/kg COD).

In the 2006 Guidelines, default value of B₀ = 0.6 kg CH₄/kg BOD is given.

Theoretically; 1 kg BOD (or degradable COD) gives 0.35 m³ CH₄. Based on the specific weight of CH₄, this gives 0.25 kg CH₄/ kg BOD. This is the absolute maximum theoretical value; whereas 0.6 kg CH₄/kg BOD cannot be correct. Our recommendation is that the default value in 2006 Guidelines should be modified.

MCF: The methane correction factor (MCF) for “anaerobic stabilisation” (which is the only system generating methane in the subsector) is estimated to 0.7.

EF: The emission factor (EF=B₀*MCF) is calculated to 0.175 kg CH₄/kg BOD.

Industrial wastewater (CRF 5.D.2)

B₀: The maximum methane producing capacity (B₀) is set to 0.1 kg CH₄/kg COD (equals to 0.25 kg CH₄/kg BOD).

In the 2006 Guidelines, default value of B₀ = 0.25 kg CH₄/kg COD is given.

Theoretically; 1 kg BOD (or degradable COD) gives 0.35 m³ CH₄. Based on the specific weight of CH₄ this gives 0.1 kg CH₄/ kg COD. This is the absolute maximum theoretical value; whereas 0.25 kg CH₄/kg COD cannot be correct. Our recommendation is that the default value in 2006 Guidelines should be modified.

MCF: The methane correction factor (MCF) for “anaerobic stabilisation” is estimated to 0.7.

EF: The emission factor (EF=B₀*MCF) is calculated to 0.07 kg CH₄/kg COD.

For the country-specific method, the estimate of the loss of CH₄ in the energy recovery process is³¹³:

-5 % for year 1990-2000,

-descending for year 2001-2009,

-2 % from year 2010 and onwards.

Example: In 2016, 128 GWh³¹⁴ (or 9.2 kt CH₄) was recovered. By using the value 2 % as the leakage factor, the emission of CH₄ is calculated to 0.184 kt for 2016.

7.5.1.2.3 *Statistics used as activity data (CH₄)*

Domestic wastewater (CRF 5.D.1)

Activity data for methane emissions from domestic wastewater treatment (5D1) is basically data on population in two categories (A and B):

³¹³ Szudy, Ek, Linné, Olshammar, 2017

³¹⁴ Swedish Energy Agency, 2017

(A) population connected to wastewater treatment facilities >25 pe and
(B) population connected to wastewater treatment facilities <25 pe.
(A) is calculated by using the total population in Sweden minus (B). The population not connected to wastewater discharge system (B) is the estimate based on data³¹⁵ for 1995, 2000 and 2005 (1 300 000 people).

Industrial wastewater (CRF 5.D.2)

Data on COD load in the food industry (which is the only industry relevant in the calculations where Equation 6.4 in 2006 Guidelines is used) needs to be derived. A removal efficiency of COD of 90 % is assumed in the food industry (the same as at domestic WWTPs). The reported COD load in the food industry, after treatment, was 594 t year 2010³¹⁶, which gives a number of 5 940 t before treatment. The reported COD load in the food industry, is assumed the same for all years. The amount of imported food products to Sweden have increased but at the same time period, the amount of exported products has increased as well, as well as the overall food consumption.

Activity data for the country-specific method are statistical data on energy recovery from anaerobic processes. Data published by the Swedish Energy Agency are available for year 2005-2016. For 1990, 1995 and 2000 data on biogas production at wastewater treatment facilities has been compiled within a project³¹⁷ for investigating historical data on biogas production. See further in section “Biogas production at wastewater treatment facilities”.

7.5.1.2.4 Methodologies used (N₂O)

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).

<p style="text-align: center;">EQUATION 6.7 N₂O EMISSIONS FROM WASTEWATER EFFLUENT</p> $N_2O \text{ Emissions} = N_{\text{EFFLUENT}} \cdot EF_{\text{EFFLUENT}} \cdot 44 / 28$

Where:

N₂O emissions = N₂O emissions in inventory year, kg N₂O/yr

N_{EFFLUENT} = nitrogen in the effluent discharged to aquatic environments, kg N/yr

EF_{EFFLUENT} = emission factor for N₂O emissions from discharged to wastewater, kg N₂O-N/kg N

The factor 44/28 is the conversion of kg N₂O-N into kg N₂O.

7.5.1.2.5 Emission factors used (N₂O)

The 2006 Guidelines emission factor (0.005 N₂O-N/kg N) is used for:

³¹⁵ Statistics Sweden MI 11 SM 0701, Korrigerad version

³¹⁶ Statistics Sweden MI 22 SM 1201

³¹⁷ Szudy, Ek, Linné, Olshammar, 2017

Effluent from WWTPs > 2000 pe
Effluent from WWTPs < 2000 pe
Effluent from industrial wastewater

A national emission factor (0.0074 N₂O-N/kg N) is used for direct (or internal) N₂O emissions from biological nitrogen removal in WWTPs >2000 pe. The national value³¹⁸ is based on six annual environmental reports from two WWTPs > 2000 pe, where the amount of nitrogen in inlet converted to N₂O was reported.

7.5.1.2.6 *Statistics used as activity data (N₂O)*

National statistics on nitrogen in discharged wastewater from municipal wastewater treatment plants and industries are used as activity data.

Domestic wastewater (CRF 5.D.1)

According to Swedish environmental protection law, all municipal wastewater treatment plants designed for more than 2,000 person equivalents, including industry, must report their discharges in environmental reports delivered to their supervision agency. Data from these reports is compiled and national statistics is published every second year by the Swedish EPA.³¹⁹ The production time for these publications varies, and sometimes the statistics is not available until two years after the reference year.

Table 7.25. Discharges of nitrogen from large municipal wastewater treatment plants (from treatment of domestic, commercial and industrial waste water).

Year	Municipal wastewater treatment plants (t)
1990	26 200
1992	25 310
1995	25 940
1998	21 376
2000	18 977
2002	18 036
2004	17 779
2006	18 347
2008	18 433
2010	17 419
2012	17 120
2014	15 743

Source: MI 22 SM, Swedish EPA and SMED

The statistics on influent and discharges of nitrogen excludes municipal wastewater treatment plants designed for less than 2,000 person equivalents, and people in rural areas, who are not connected to municipal wastewater treatment. CO₂ The

³¹⁸ Westling, Tjus & Ek, 2014

³¹⁹ Statistics Sweden, MI 22 SM, Swedish EPA and SMED.

nitrogen load per person for the population excluded in the statistics is assumed to be the same as for persons connected to WWTPs >2000, and is estimated after subtraction of the 20 % industrial load. The fraction of industrial and commercial co-discharged protein has a default = 1.25, meaning that the per capita load after the industrial load has been subtracted is $1/1.25 = 80\%$. The number of people connected to WWTPs < 2000 is estimated by subtracting total population in Sweden with the number of people connected to WWTPs > 2000 pe.

Industrial wastewater (CRF 5.D.2)

Data from environmental reports from industrial wastewater handling is compiled to statistics and published every second year (except statistics on the pulp- and paper industry, which is available yearly). The industrial sector covers; pulp and paper industry, oil refineries, chemical industry, iron and steel industry, food manufacturing industry, manufacturing of wood products and mining and quarrying industry. The production time for these publications varies, and sometimes the statistics is not available until two years after the reference year.

Table 7.26. Discharges of nitrogen from mining and quarrying and manufacturing industries: Pulp and paper industry (total), Oil refineries (total), Chemical industry (inland and coastal), Iron and steel industry (inland and coastal), Food manufacturing industry (inland and coastal), Manufacturing of wood products (inland and coastal) and Mining and quarrying (total), (t)

Year	Pulp and paper (tot.)	Oil ref. (tot.)	Chemical (inl.)	Chemical (coast.)	Iron and steel (inl.)	Iron and steel (coast.)	Food (inl.)	Food (coast.)	Wood prod. (inl.)	Wood prod. (coast.)	Mining (tot.)
1990	5 500	..	..	..	..	..	..	..	..	..	..
1992	3 630	..	..	..	..	..	..	..	..	..	..
1994	3 200	..	..	..	..	..	..	..	..	..	..
1995	3 844	80	..	385	..	70	..	0	..	..	..
1997	3 433	..	..	..	..	..	..	..	..	..	..
1998	3 307	78	..	423	..	230	..	1	..	..	..
1999	3 042	..	..	..	..	..	..	..	..	..	..
2000	3 241	38	..	361	..	114	..	..	..	..	..
2001	3 014	..	..	..	..	..	..	..	..	..	..
2002	3 169	68	..	268	..	72	..	3	..	..	..
2003	3 162	..	..	..	..	..	..	..	..	..	..
2004	3 039	30	..	224	..	54	..	11	2	6	451
2005	3 222	..	..	..	..	..	..	..	..	..	..
2006	3 200	39	..	144	..	74	..	17	2	3	496
2007	2 825	..	..	..	..	..	..	..	..	..	..
2008	2 830	26	256	139	807	68	89	27	2	2	480
2009	2 600	..	..	..	..	..	..	..	..	..	..
2010	2 590	45	205	140	769	84	96	25	0	4	321
2011	2500	..	..	..	..	..	..	..	..	..	..
2012	2560	30	178	133	700	84	86	17	0	2	310
2013	2325	..	..	..	..	..	..	..	..	..	..
2014	2470	30	179	138	490	77	101	25	0	0	610
2015	2550	..	..	..	..	..	..	..	..	..	..
2016	2 185	..	..	..	..	..	..	..	..	..	..

Source: NV 4657, NV 4434, NV 4657, NV 4924, NV 4987, NV 5114, Swedish Forest Industries Federation, MI 22 SM, Swedish EPA and SMED

7.5.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Because of the simplifications in the used top-down model and the difficulties in estimating many of the parameters, the estimated emissions in the waste sector are uncertain. The used uncertainties are presented below.

7.5.1.3.1 Methane

Domestic wastewater

Emission factor "Maximum CH₄ producing capacity (B₀)": ± 30 % (Default)

Emission factor "Fraction treated anaerobically": ± 10 % (Default: Centralized well managed plant, digester, reactor)

Activity data "Human population": ± 5 % (Default)

Activity data "BOD per person": ± 30 % (Default)

Activity data "Correction factor for additional industrial BOD discharged into sewers": ± 20 % (Default)

Industrial wastewater

Emission factor "Maximum CH₄ producing capacity (B₀)": ± 30 % (Default)

Emission factor "Methane correction factor (MCF)": ± 20 % (Expert judgement)

Activity data “Total organic degradable material in wastewater (TOW)”: $\pm 10\%$ (Expert judgement)

7.5.1.3.2 *Nitrous oxide*

Domestic wastewater

Emission factor “kg N₂O-N/kg N”: $\pm 50\%$ (Expert judgement)

Activity data “Total nitrogen in influent and effluent” $\pm 10\%$ (Expert judgement)

The statistics of discharges from municipal wastewater treatment plants are biased from sources of inaccuracy such as under coverage, non-response or no observations and sample errors “within” the treatment plants. No objective methods of calculating accuracy measures have been developed, but data on nitrogen is considered to have a margin of inaccuracy of well under 10 % at national level.

2006 Guidelines states that “Large uncertainties are associated with the IPCC default emission factors for N₂O from effluent. Currently insufficient field data exist to improve this factor. Also, the N₂O 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 N₂O”. It is referred as an expert judgement.

Industrial wastewater

Emission factor “kg N₂O-N/kg N”: $\pm 50\%$ (Expert judgement)

Activity data “Total nitrogen in influent and effluent” $\pm 10\%$ (Expert judgement)

The statistics of discharges from municipal wastewater treatment plants are biased from sources of inaccuracy such as under coverage, non-response or no observations and sample errors “within” the treatment plants. No objective methods of calculating accuracy measures have been developed, but data on nitrogen is considered to have a margin of inaccuracy of well under 10 % at national level.

2006 Guidelines states that “Large uncertainties are associated with the IPCC default emission factors for N₂O from effluent. Currently insufficient field data exist to improve this factor. Also, the N₂O 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 N₂O”. It is referred as an expert judgement.

The time series in the waste sector are calculated consistently and in line with the 2006 Guidelines. When statistics are not produced annually, interpolation and extrapolation have been necessary tools for imputation.

7.5.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

7.5.1.5 SOURCE-SPECIFIC RECALCULATIONS

Emissions of methane from CRF 5.D.2 Industrial wastewater has been recalculated for year 1990-2009, due³²⁰ to the availability of new data on biogas production at wastewater treatment facilities for 1990, 1995 and 2000 as well as new factors used for estimating of the loss of CH₄ in the energy recovery process. The recalculations resulted in increasement of methane emissions from 13.7 % to 158.4 % for the years 1990-2009.

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.

³²⁰ Szudy, Ek, Linné, Olshammar, 2017

8 Other

Not applicable for Sweden.

9 Recalculations and improvements

The recalculations performed are due to comments and implemented recommendations from the national and international review teams, and national prioritizations. Some recalculations have been done to correct for small errors in earlier inventories detected during the work with the present inventory. The explanations and justifications for the recalculations made in this submission since the previous submission, together with descriptions on their implications for the emission levels, are given in more detail in the sector-specific chapters.

Below, a summary description of the most significant revisions of methods and data are described by sector.

9.1 Explanations and justifications for recalculations

9.1.1 Energy, CRF 1

9.1.1.1 STATIONARY COMBUSTION

Emission factors for the whole industry sector was revised for several fuels and whole time series. These corresponds to emission factors in CRF 1A1b, 1A1c and 1A2.

Activity data for the other sector CRF 1A4a, 1A4b, 1A4c and some parts of 1A2g have been updated in submission 2018. Combustion of liquid fuels in 1A4c was revised from 2005 to 2016 in submission 2018 due to revision of the annual energy balances. In addition combustion in CRF 1A4a, 1A4b, 1A4c and some parts of 1A2g was revised for 2015 due to revision of the annual energy balances.

Emissions from the natural gas transmission network (fugitives as well as venting) have been recalculated due to new methane measurement results available.

Emissions from flaring at refineries and chemical industry facilities have been recalculated based on detailed information provided by facilities while reporting to EU ETS.

9.1.1.2 MOBILE COMBUSTION

In submission 2018, the road emission model HBEFA (version 3.3) implemented updated emission factors for NO_x regarding Euro IV and Euro VI diesel passenger cars. The transition to the new model with updated emission factors for Euro 4-6

diesel passenger cars leads to higher emissions of nitrogen oxides and the difference is increasing with time.

As from submission 2018, the emissions of CH₄ from gas buses as well as emissions of CH₄ and N₂O from passenger cars running on gas, are estimated by HBEFA for the years 2005-2016 and with an implied emission factor from HBEFA for previous years. As a result, the emissions of CH₄ and N₂O from gas vehicles have decreased noticeably. The emissions of NMVOC from gas buses were estimated for the first time by HBEFA in submission 2018.

The emission model for off-road vehicles and mobile machinery has been updated in submission 2018 as following:

- New sales data for some off-road vehicles was implemented for the years 2005-2016. The sales data was provided by *the Swedish trade association for suppliers of mobile machines*.
- The allocation key in the model was updated, as new information was received from both the swedish trade association and the vehicle register.
- The age of some of the oldest tractors was adjusted. These tractors were as a result included in younger age groups in the model, whereas they in previous submissions were mistakenly grouped together in the oldest age category.

The updated model for working machinery shows increased emissions of CO₂ equivalents for the first and last 3-4 years in the time series, but the greatest difference between the submissions are the reallocation of emissions between sectors.

9.1.2 Industrial processes and product use, CRF 2

The model for calculating emissions of HFCs and PFCs from refrigeration and air conditioning (CRF 2.F.1) in Sweden, have been updated. This update includes:

- adding of amounts imported in products 1990-2015,
- reallocations and changes of lifetimes and leakage factors in 2.F.1.a, 2.F.1.c and 2.F.1.f, 1990-2015,
- update of number of lorries built in Sweden, 2011-2015,
- update of number of busses built in Sweden, 2011-2015,
- update of number of heat pumps imported to Sweden, 1990-2015,
- addition of registered fridge- and freeze lorries, 1990 – 2015 (only fridge- and freeze trailers were included earlier)

9.1.3 Agriculture, CRF 3

Since submission 2017 the Swedish board of Agriculture made a minor revision on the cattle population in 2015 and the turkey population between 2013 and 2015, these changes were implemented in the inventory. We did also identify an error in the calculation of the emission factor for enteric fermentation for heifers calves. Instead of the previous used value of 26 kg CH₄/head/year the emission factor was corrected to 24 kg CH₄/head/year.

Due to a recommendation from the Technical Expert Review Team (TERT) we now include nitrogen losses as N_2 and NO_x during storage of manure. Previously only emissions as NH_3 was accounted for.

As a consequence of the method used by the Swedish national inventory of forests the area of cultivated organic soils has been updated for several years. The model to estimate the emissions from mineralization/immobilization associated with loss/gain of soil organic matter has also been revised and the result is now based on independent carbon balances for eight different regions.

The time series for the emissions of ammonia has been updated in the reporting to the LRTAP convention. Consequently, the indirect emissions from 3.D.b.1, atmospheric deposition was also affected.

9.1.4 LULUCF, CRF 4

The major difference between the two latest submissions for the LULUCF-sector is due to an ordinary update according to the methodology used. In addition there is updates related to HWP, N-mineralisation and identification of land use change.

Reported emissions from the HWP-pool since 1990 submitted this year differs slightly from the reported emissions submitted in earlier years. The difference is due to an error in the calculations in one of the refinement steps. Domestically consumed residues from saw mills were adjusted for residues from imported saw logs twice. The scale of this difference is marginal.

Submission 2018 is also updated with respect to C:N ratios for calculation of N-mineralisation and carbon stock change factors for some land use change categories.

Assumed artificial land use conversions from/ to Forest land and to/ from Wetlands/ Other land, have been removed (6.4.5.1). On request from review, for the first time Forest land converted to Other land has been reported (6.4.5.2). To improve completeness in field measurements, for the first time one of the five inventory-cycles includes field inventoried plots also in the high mountain area (6.4.5.2). These three improvements have slightly changed the allocation of land into land use categories but have nearly no influence on reported changes in carbon pools.

9.1.5 Waste, CRF 5

Emissions of methane from CRF 5.A Solid waste disposal has been recalculated for the years 2008-2014.

Recalculation of methane emissions from anaerobic digestion at biogas facilities has been made for the year 1990-2001 and 2015.

Emissions of methane from CRF 5.D.2 Industrial wastewater has been recalculated for year 1990-2009.

For more detailed information on recalculations: see the sections “Source-specific recalculations” in chapter “Waste (CRF sector 5)”.

9.2 Implications for emission levels

See Table 9.1 below.

Table 9.1. Recalculations of GHG emissions between submission 2018 and submission 2017 by CRF sector and total.

Year	Recalculation difference													
	Total (excl. LULUCF)		Total (incl. LULUCF)		CRF 1		CRF 2		CRF 3		CRF 4		CRF 5	
	kt CO ₂ -eq.	%	kt CO ₂ -eq.	%	kt CO ₂ -eq.	%	kt CO ₂ -eq.	%	kt CO ₂ -eq.	%	kt CO ₂ -eq.	%	kt CO ₂ -eq.	%
1990	122	0.2%	656	1.9%	-100	-0.2%	-40	-0.6%	16	0.2%	778	-2.1%	3	0.1%
1991	51	0.1%	222	0.6%	-94	-0.2%	-36	-0.5%	76	1.0%	273	-0.8%	3	0.1%
1992	100	0.1%	240	0.7%	-95	-0.2%	-27	-0.4%	18	0.2%	340	-1.0%	4	0.1%
1993	96	0.1%	168	0.4%	-103	-0.2%	-28	-0.4%	30	0.4%	264	-0.9%	5	0.1%
1994	148	0.2%	104	0.3%	-120	-0.2%	-32	-0.5%	-1	0.0%	252	-0.7%	5	0.2%
1995	230	0.3%	-8	0.0%	-123	-0.2%	-36	-0.5%	-77	-1.0%	222	-0.7%	6	0.2%
1996	153	0.2%	-25	-0.1%	-120	-0.2%	-39	-0.6%	1	0.0%	128	-0.3%	6	0.2%
1997	134	0.2%	-23	-0.1%	-136	-0.3%	9	0.1%	-13	-0.2%	111	-0.3%	6	0.2%
1998	132	0.2%	-39	-0.1%	-120	-0.2%	32	0.4%	-51	-0.7%	93	-0.2%	6	0.2%
1999	159	0.2%	-35	-0.1%	-108	-0.2%	66	0.9%	-122	-1.6%	124	-0.3%	6	0.2%
2000	49	0.1%	-110	-0.4%	-105	-0.2%	90	1.2%	-40	-0.5%	-61	0.2%	6	0.2%
2001	12	0.0%	-120	-0.5%	-114	-0.2%	110	1.5%	-14	-0.2%	-108	0.3%	5	0.2%
2002	15	0.0%	-245	-0.8%	-107	-0.2%	133	1.7%	-45	-0.6%	-231	0.6%	5	0.2%
2003	54	0.1%	124	0.4%	-106	-0.2%	144	1.9%	-95	-1.3%	178	-0.5%	4	0.1%
2004	-30	0.0%	1 862	5.7%	-103	-0.2%	151	1.9%	-20	-0.3%	1 832	-5.0%	3	0.1%
2005	133	0.2%	1 663	5.2%	-221	-0.4%	142	1.8%	-57	-0.8%	1 796	-5.2%	3	0.1%
2006	132	0.2%	1 998	7.3%	-227	-0.5%	111	1.4%	-18	-0.2%	2 130	-5.4%	2	0.1%
2007	78	0.1%	2 015	8.6%	-183	-0.4%	83	1.1%	20	0.3%	2 094	-5.0%	2	0.1%
2008	163	0.3%	1 937	9.0%	-190	-0.4%	65	0.9%	-8	-0.1%	2 100	-5.1%	-30	-1.4%
2009	161	0.3%	2 840	18.7%	-175	-0.4%	52	0.9%	-26	-0.4%	3 001	-6.9%	-12	-0.6%
2010	143	0.2%	3 257	19.7%	-191	-0.4%	49	0.7%	13	0.2%	3 400	-7.1%	-14	-0.7%
2011	230	0.4%	3 428	17.6%	-199	-0.4%	37	0.5%	-43	-0.6%	3 658	-8.9%	-25	-1.4%
2012	183	0.3%	3 565	34.4%	-191	-0.5%	61	0.9%	-26	-0.4%	3 748	-8.0%	-26	-1.5%
2013	123	0.2%	6 313	58.3%	-188	-0.5%	87	1.3%	-26	-0.4%	6 436	-14.4%	4	0.2%
2014	-30	-0.1%	4 912	56.7%	-88	-0.2%	100	1.6%	14	0.2%	4 882	-10.8%	3	0.2%
2015	-64	-0.1%	5 712	179.8%	3	0.0%	92	1.4%	-31	-0.4%	5 648	-11.2%	0	0.0%

9.3 Implications for emission trends

The total emissions of GHG have changed for all inventory years due to the recalculations. Below a more detailed description is presented of implications for emission trends due to recalculations of the base year emissions and the last recalculated year's emissions. Note that this section does not include implications for emission trends in the LULUCF sector.

In Table 9.2 it can be seen that compared to the base year emissions used to estimate the assigned amounts for the second commitment period, the base year emissions in submission 2017 are about 422 kt CO₂-eq. lower.

Data on assigned amount will eventually be updated after the review of EU:s initial report.

Table 9.2. Difference between initially calculated Base year emissions and Base Year emissions submission 2018 by GHG, excluding LULUCF.

GHG	Base Year* emissions Submission 2015 (kt CO ₂ eq.)	Base Year* emissions Submission 2018 (kt CO ₂ eq.)	Difference between Base Year emissions Submission 2018 and Assigned Amount (kt CO ₂ eq.)
CO ₂	57 547	57 506	-41
CH ₄	7 990	7 602	-388
N ₂ O	5 841	5 730	-111
F-gases	680**	797	117
Total	72 057**	71 636	-422

*1995 for F-gases and 1990 for other GHG emissions (excluding LULUCF), ** as corrected by the ERT during the review of the Initial report for the second commitment period.

In Table 9.3 it can be seen that in submission 2017 the trend from the base year to 2015 shows a 25 % decrease. It can also be seen that the recalculation of GHG emissions in submission 2018 increased the downward trend between the base year and 2015 by 207 kt CO₂-eq. or 0.24 % points compared to submission 2017.

Table 9.3. Impact on emission trends (base year to 2015) due to recalculations of GHG emissions between submission 2018 and submission 2017 by GHG, excluding LULUCF.

GHG	Submission 2017		Trend Base Year* to 2015 Submission 2018		Difference between submission 2018 and submission 2017	
	kt CO ₂ eq.	%	kt CO ₂ eq.	%	kt CO ₂ eq	% points
CO ₂	-14 202	-25%	-14120.8	-25%	81	0.12%
CH ₄	-2 767	-36%	-2783.6	-37%	-16	-0.39%
N ₂ O	-1 165	-20%	-1164.2	-20%	1	-0.14%
F-gases	46.61251	6%	187.4211	24%	141	17.79%
Total	-18 088	-25%	-17881.2	-25%	207	0.24%

*1995 for F-gases and 1990 for other GHG emissions (excluding LULUCF)

9.4 Recalculations and other changes made in response to the UNFCCC review process

In Table 9.4 the two latest UNFCCC review report recommendations are presented together with the status of implementation in Sweden and references to sections in this NIR. In table 9.5 the provisional main findings reported during the 2016 review are listed with comments if relevant.

Information on responses and implementation of UNFCCC review report recommendations included in the previous Swedish submissions are available in previous Swedish NIR's.

http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8812.php

Table 9.4 Status of implementation of each recommendation listed in the two most recently published individual UNFCCC review report, including reasons for not implementing such a recommendation, and reference to relevant section of this NIR.

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/sec tion in the NIR
G.1 QA/QC and verification	The ERT noted that table ES.1 in the NIR 2016 does not include information on the new gases “unspecified mix of HFCs and PFCs” and NF3, while CRF tables 10s5 and 10s6 both include information on such gases. During the review, the Party stated that a correction to table ES.1 is planned for the 2017 inventory submission. The ERT recommends that Sweden strengthen its QA/QC process to ensure that all cross-sectoral tables contain up-to-date information and are consistent with the sectoral inventory chapters and the CRF tables.	FCCC/ARR/2 016/SWE	Resolved.	Chapter 1, Table ES.1
G.2 QA/QC and verification	The ERT noted that the Party specified in the NIR that several layers of QC activities are performed on the inventory, including checks by the QC team (the team of inventory compilers) followed by checks by the QC coordinator. However, the roles and responsibilities were not transparently described for the various stages of the QC process. During the review, the Party provided a relevant explanation. The ERT recommends that Sweden improve the transparency of the QA/QC process by describing in the NIR the roles and responsibilities for the various stages of the process.	FCCC/ARR/2 016/SWE	Resolved.	NIR p. 49
G.3 QA/QC and verification	The ERT noted that several sections of the NIR (e.g. sections 3 (p.28) and 10.2.3 (p.482)) and annex 3.2 (section 1.2.3) contain references to the IPCC good practice guidance for LULUCF; however, this document has been superseded by the 2006 IPCC Guidelines. The ERT recommends that Sweden correct the outdated references to the IPCC good practice guidance for LULUCF in its NIR.	FCCC/ARR/2 016/SWE	Resolved.	References removed in NIR, except p. 28 and 365, where 2003 guidelines are used as comparison.

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/sec tion in the NIR
Energy/ International statistics	26. A comparison of the fuel consumption data reported by Sweden in its CRF tables with the corresponding data reported to the International Energy Agency (IEA) identified differences of 7.5 % for residual fuel oil (or 4,501 TJ). In response to a question raised by the ERT during the review, Sweden explained that the amount of residual fuel oil for international navigation reported in the CRF tables is based on the national energy statistics. The ERT noted that liquid fuel consumption for navigation is based on robust energy consumption surveys and that the application of an excise tax on navigation fuels ensures the accuracy of the fuel consumption data for marine bunkers. The ERT recommends that Sweden initiate a process to harmonize the fuel consumption data used for international reporting of marine bunkers to reduce the observed difference between the data reported in the CRF tables and the IEA data.	FCCC/ARR/2 014/SWE Para 26	The difference between the fuel consumption data reported by Sweden in its CRF tables and the corresponding data reported to the International Energy Agency for 2015 was minor and is most likely due to the usage of slightly different conversion factors.	
Energy/ Petroleum refining: liquid fuels – CO ₂	29. The ERT observed that in addition to the five refineries that Sweden transparently reports on, there are a few other plants with the Swedish Standard Industrial Classification 232 that should be reported under the category petroleum refining. However, clear documentation of the AD for liquid fuels used in these plants has not been provided in the NIR. In response to a question raised by the ERT during the review, Sweden demonstrated that the AD for these plants are available in the quarterly fuel statistics and emission estimates are calculated using country-specific EFs, and that the fuel consumption and emissions from these plants are included in petroleum refining (CRF table 1A1b). Sweden further explained that information on this matter has been clarified in its 2015 NIR. The ERT agreed with Sweden's assessment and recommends that the Party improve the transparency of its NIR by including information on how the plants with the Swedish Standard Industrial Classification 232 are reported in the CRF tables in its next annual submission.	FCCC/ARR/2 014/SWE Para 29	Implemented	See NIR 3.2.7.1

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/sec tion in the NIR
Energy/ Other sectors: biomass – CH ₄ and N ₂ O	30. The ERT noted that Sweden did not transparently report charcoal use in the NIR and specifically under the category residential (other sectors). During the review, the Party confirmed that charcoal use occurs in Sweden but that combustion-related CH ₄ and N ₂ O emissions from charcoal use have not been reported in the 2014 annual submission for the whole time series. The ERT further notes that guidance is provided in the Revised 1996 IPCC Guidelines on EFs for CO ₂ , CH ₄ (table 1-7) and N ₂ O (table 1-8). During the review, Sweden informed the ERT that it intends to use a tier 1 methodology by applying AD sourced from official statistics from the Food and Agriculture Organization of the United Nations (FAO) and default CH ₄ and N ₂ O EFs from the Revised 1996 IPCC Guidelines to estimate these emissions, and to officially resubmit its GHG inventory thereafter. In the list of potential problems and further questions, the ERT recommended that Sweden estimate emissions from charcoal use using the AD based on the data submitted officially to FAO together with country-specific or default EFs provided in tables 1-7 and 1-8 of the Revised 1996 IPCC Guidelines.	FCCC/ARR/2 014/SWE Para 30	Implemented	Section 3.2.22
Energy/ Navigation: liquid fuels – CO ₂	33. The ERT noted in figure 3.6 of the NIR that there are significant fluctuations in fuel consumption based on the energy statistics for navigation with a 41.3 % decrease between 2010 and 2012 without an explanation. These inter-annual fluctuations could be influenced by the methodology used to split fuel consumption between navigation and marine bunkers. In response to a question raised by the ERT during the review, Sweden explained that the split between domestic and international fuel consumption for navigation is based on the results from a national survey conducted by all coal and oil trading companies in Sweden. Hence, the different fuels are separated in the survey. The ERT agrees with the methodology used by Sweden, where the application of value-added tax to fuels consumed for navigation is used to split liquid fuels between navigation and marine bunkers. The ERT recommends that Sweden: provide an explanation of the observed fuel consumption trends between 2000 and 2012.	FCCC/ARR/2 014/SWE Para 33	The Swedish Energy Agency will implement a new version of the survey "Monthly fuel, gas and inventory statistics" in January 2018, to resolve issues related to the energy statistics. Fuel used for navigation and international bunkers are among those issues. This survey is the base for the the fuel consumption data reported by Sweden for mobile combustion in its CRF tables. The result of the new survey will be implemented in submission 2020.	Section 3.2.19

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/sec tion in the NIR
E.1 Comparison with international data – liquid fuels – CO ₂ (26, 2014) Comparability*	Initiate a process to harmonize the fuel consumption data used for international reporting of marine bunkers to reduce the observed difference between the data reported in the CRF tables and the IEA data.	FCCC/ARR/2 016/SWE	Not longer relevant.	
E.3 1.A.3.d Domestic navigation – liquid fuels – CO ₂ (33, 2014) Transparency*	Provide an explanation of the observed fuel consumption trends between 2000 and 2012.	FCCC/ARR/2 016/SWE	Resolved.	NIR p. 168- 172
E.4 Fuel combustionrefe rence approach – peat – CO ₂	<p>The ERT noted that in 2014, AD for peat in the reference approach were not available and AD for 2013 (7.75 PJ) were used instead. Meanwhile, the average annual decline in AD for peat was about 19 per cent between 2010 and 2013. During the review, the Party explained that as of the 2016 submission and unlike in earlier submissions, Sweden decided to use the yearly energy balances as AD, and that the AD for peat for 2014 were not available from the energy balances for the 2016 submission. The Party indicated that for the 2017 and future submissions, AD for peat for the entire time series would be available in time for inclusion in the inventory.</p> <p>The ERT recommends that Sweden recalculate previous emissions from peat using AD from yearly energy balances in order to maintain time-series consistency.</p>	FCCC/ARR/2 016/SWE	The issue is resolved. Since submission 2017 Sweden uses the yearly available data for Peat from the Energy Balances. The whole time series was recalculated in submission 2017 using AD from the Energy Balances.	Annex 2

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/sec tion in the NIR
E.5 1.A. Fuel combustion – sectoral approach – all fuels	<p>The ERT noted that CO₂ emissions from the following sources were estimated using country-specific EFs:</p> <ul style="list-style-type: none"> (a) 1.A.2.f (NIR, table 3.13 – non-metallic minerals) (b) 1.A.2.g (NIR, table 3.14 – other industries) (c) 1.A.3.a (NIR, table 3.17 – civil aviation) (d) 1.A.3.c (NIR, table 3.20 – railways) (e) 1.A.3.d (NIR, table 3.22 – navigation) (f) 1.A.3.e (NIR, table 3.23 – other transportation) (g) 1.A.4.a (NIR, table 3.25 – commercial/institutional) (h) 1.A.4.b (NIR, table 3.27 – residential) (i) 1.A.4.c (NIR, table 3.29 – agriculture/forestry/fisheries) (j) 1.A.5.b (NIR, table 3.31 – other mobile) <p>The Party stated that the methods used were tier 1 in the NIR and the CRF tables; however, according to the 2006 IPCC Guidelines (volume 2, section 1.2.1.2), the use of country-specific EFs along with suitable AD for fuel combustion categories signifies a tier 2 approach. During the review, the Party indicated that references to the tier applied for categories 1.A.2.f, 1.A.2.g, 1.A.3.a, 1.A.3.c, 1.A.3.e, 1.A.4.a, 1.A.4.b, 1.A.4.c and 1.A.5.b would be updated in the next submission. Regarding category 1.A.3.d, the Party explained that a tier 1 method is appropriate because Sweden does not have any information on boat types or engine types and the tier 2 method requires country-specific EFs with greater specificity regarding the classification of modes (e.g. ocean-going ships and boats), fuel type (e.g. fuel oil) and even engine type (e.g. diesel) (2006 IPCC Guidelines, p.3.47).</p> <p>The ERT recommends that Sweden correctly reference the methodologies applied for the emission estimates in fuel combustion categories.</p>	FCCC/ARR/2 016/SWE	This issue is resolved. In submission 2018 all of the Tiers for the various CRF-codes are updated to Tier 2 since Sweden uses national EF.	Methodology chapter in 1.A.2.f, 1.A.2.g, 1.A.3.a, 1.A.3.c, 1.A.3.d, 1.A.3.e, 1.A.4.a, 1.A.4.b, 1.A.4.c, .A.5.b

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/sec tion in the NIR
E.6 1.A.3.b Road transportation – liquid fuels – CO ₂ , CH ₄ and N ₂ O	The ERT noted that LPG consumption in category 1.A.3.b was reported as “NO” in CRF table 1.A(a). This would suggest that LPG is not used in cars, trucks or motorcycles; however, the ERT determined that there are about 20 LPG stations in Sweden.c During the review, the Party confirmed that LPG consumption does occur in Sweden and that the proportion of LPG used in these vehicle types was 0.14 per cent of the total consumption in 2014. The Party informed the ERT that the emissions from LPG passenger cars would be estimated in the next submission. The ERT concluded that CO ₂ , CH ₄ , and N ₂ O emissions from the category 1.A.3.b presented a potential underestimation of emissions for 2014, and included this issue in the list of potential problems and further questions raised by the ERT. In response, the Party further explained that the emissions from LPG cars for 2014 (CO ₂ , CH ₄ and N ₂ O emissions combined) amount to 1,474.55 t CO ₂ eq, which is 0.0027 per cent of the total CO ₂ eq emissions in Sweden, and provided documentation to support the finding that the total of all insignificant sources is less than 0.1 per cent of national emissions, excluding LULUCF The ERT recommends that Sweden provide documentation in the NIR to support the claim of insignificance for LPG consumption in accordance with decision 24/CP.19, annex I, paragraph 37(b).	FCCC/ARR/2 016/SWE	Resolved.	NIR page 163; CRF table 1.A(a)s3
E.7 1.A.5.b Mobile – biomass – CH ₄ and N ₂ O	The ERT noted that there was an inconsistency in the NIR with regard to the description of the estimation of CH ₄ and N ₂ O emissions from biomass used for transportation fuel in the military in category 1.A.5.b (other – mobile). According to the NIR (p.69), emissions in the energy sector from FAME used in military transportation between 1999 and 2001 were not estimated. However, according to annex 5 to the NIR (p.155), CH ₄ and N ₂ O emissions from biomass used for other – mobile (category 1.A.5.b) were not estimated for the periods 1999–2001 and 2007–2012. During the review, the Party clarified that biomass FAME was used by the military in the period 1999–2001 while biomass ethanol (not FAME) was used by the military in the period 2007–2012. The Party indicated that this discrepancy would be corrected in the 2017 submission The ERT recommends that Sweden harmonize the information presented in the NIR for the category 1.A.5.b so that the CH ₄ and N ₂ O emissions from the category are reported consistently.	FCCC/ARR/2 016/SWE	Resolved.	NIR page 187

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/sec tion in the NIR
E.8 1.B.1.b Solid fuel transformation – biomass – CH ₄	<p>In the 2016 annual submission, Sweden reported AD for category 1.B.1.b. (solid fuel transformation) for the latest year (1,037.41 Mt CH₄ for 2014). However, the Party did not estimate the fugitive CH₄ emissions from the category (reported as “NA” in CRF table 1.B.1). The ERT noted that footnote 5 to CRF table 1.B.1 recognizes that there are no methods for estimating fugitive emissions from coke and charcoal production in the 2006 IPCC Guidelines. During the review, the Party explained that there are no country-specific CH₄ EFs for this category and it would not be good practice to use resources in order to develop such a method. The ERT noted that, in accordance with the 2006 IPCC Guidelines (volume 2, table 2.1), emissions from charcoal production are to be included in the category 1.A.1.c (manufacture of solid fuels and other energy industries). Therefore, the ERT concluded that this case presented a potential underestimation of CH₄ emissions from charcoal production for 2014 and included this issue in the list of potential problems and further questions raised by the ERT. In response, the Party further explained that charcoal is produced by small companies. The emissions from these companies are included in the estimates for small industries (category 1.A.2.g (other (manufacturing industries and construction))), for which AD are aggregated from the energy balance, which in turn is based on intermittent surveys. The Party indicated that it is not possible to separate the charcoal producers’ emissions from the rest of the aggregate, and hence the fugitive CH₄ emissions from charcoal production are reported in category 1.A.2.g.</p> <p>The ERT recommends that Sweden report fugitive CH₄ emissions from charcoal production separately in category 1.A.1.c and describe in the NIR where in the CRF tables these emissions are reported.</p>	FCCC/ARR/2 016/SWE	Resolved. Notation key for 1.A.1.c.ii has been changed to IE.	CRF Table 1.A(a)s 1

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/sec tion in the NIR
Industrial processes and solvent and other product use/ Consumption of halocarbons and SF ₆ – HFCs	43. The ERT noted the lack of transparency in the reporting on and accounting for collection/destruction, in particular within the above-mentioned national model. In response to a question raised by the ERT during the review, Sweden confirmed that the model includes emissions from collection/destruction/disposal of F-gases. The ERT accepts the response by the Party and recommends that Sweden include this information in the next annual submission to improve the transparency of its reporting.	FCCC/ARR/2 014/SWE Para 43	Implemented	Section 4.7
Industrial processes and solvent and other product use/ Consumption of halocarbons and SF ₆ – HFCs	44. The ERT found that Sweden did not include in its NIR information on the variation of annual leakage rates corresponding to new or old equipment, as recommended in the previous annual review report. In response to a question raised by the ERT during the review, Sweden explained that it was not possible to include information on the variation of leakage rates in the 2014 NIR as it was available after the date of submission, but that it intends to improve the transparency of the information on leakage rates in its next annual submission. The ERT reiterates a recommendation contained in the previous review report that the Party provide the information above in a tabular format in the NIR of the next annual submission to improve the transparency of its reporting.	FCCC/ARR/2 014/SWE Para 44	Implemented	Section 4.7.1

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/sec tion in the NIR
Industrial processes and solvent and other product use/ Consumption of halocarbons and SF ₆ – HFCs	45. The ERT observed high EF uncertainties for the category refrigeration and air conditioning equipment (26 % for HFCs) compared with the uncertainties provided in the IPCC good practice guidance and the estimates of neighbouring countries. In response to a question raised by the ERT during the review, Sweden explained that the annual leakage rates are partly not based on manufacture information and are also derived from expert judgement. The ERT recommends that the Party document the methodology used to derive the uncertainty data using expert judgement in the NIR of the next annual submission and revise the uncertainty estimates, if appropriate.	FCCC/ARR/2 014/SWE Para 45	Uncertainties for emission factors for commercial refrigeration, industrial refrigeration and stationary air-conditioning (2.F.1.a, 2.F.1.c and 2.F.1.f (except for heat pumps)) are now based on given default values in 2006 IPCC Guidelines and are ±40 %, ±34 % and ±36 %, respectively. The uncertainty of emission factors in 2. F. 1 has been compared with emission factor uncertainties for other countries. The comparison shows that the Swedish emission factor uncertainties for CRF 2.F.1.a, 2.F.1.c and 2.F.1.f are slightly lower compared to comparable countries such as the Netherlands and Austria (EF uncertainty ±50 %, submission 2016).	Section 4.7.1
I.1 2.F. Product uses as substitutes for ozone-depleting substances – HFCs (43, 2014) (56, 2013). Transparency*	Provide information in the NIR confirming that the national model used to calculate emissions from the consumption of halocarbons and SF ₆ includes emissions from the collection, destruction and disposal of F-gases.	FCCC/ARR/2 016/SWE	Implemented	Section 4.7

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/sec tion in the NIR
I.3 2.F.1 Refrigeration and air conditioning – HFCs (45, 2014) Transparency*	Document in the NIR the methodology used to derive the uncertainty data using expert judgement and revise the uncertainty estimates, if appropriate.	FCCC/ARR/2 016/SWE	Partly implemented	Section 4.7.1
I.4 2. General (IPPU)	The ERT noted that Sweden often used “D” (default) as a reference to the methodology used in the tables in the NIR titled “Summary of source category description”. Specifically, this was found for categories 2.A.2, 2.B.5, 2.B.10, 2.C.2, 2.C.4 and 2.C.7. During the review, the Party provided information on the methodologies applied for each listed category: tier 1 for categories 2.A.2, 2.B.5 and 2.B.10; tier 2 for category 2.C.4; and tier 3 for categories 2.C.2 and 2.C.7. The ERT recommends that Sweden transparently report the methodology applied for categories 2.A.2, 2.B.5, 2.B.10, 2.C.2, 2.C.4 and 2.C.7 in the IPPU sector in both the NIR and the CRF tables.	FCCC/ARR/2 016/SWE	Resolved.	Tables “Summary of source category description”.
I.6 2.C.4 Magnesium production – SF6	The ERT noted that SF6 emissions from magnesium production are reported (e.g. 0.69 tSF6 for 2014); however, the AD and the IEF are reported as “NE”. During the review, Sweden confirmed that this was an error, and indicated that it would be corrected in the 2017 annual submission. The ERT recommends that Sweden ensure that both the AD and SF6 emissions are reported for magnesium production.	FCCC/ARR/2 016/SWE	Despite efforts, Sweden has not been able to find national data on amount of magnesium casted. We will therefore continue to report “NE” in the CRF Table 2(II)B-Hs1 for activity data for activity data for SF6 and continue to report NO or IE for HFC-134a. Implied emission factor for the largest foundry 2009-2016 will be included in NIR. (see NIR 4.4.4.1) In addition, for transparency, in table2(I).A-Hs2, Sweden will report “NO” for activity data, since there is no magnesium production within the country (only magnesium foundries).	Section 4.4.41

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/sec tion in the NIR
I.7 2.D.1 Lubricant use – CO ₂	<p>The ERT noted that CO₂ emissions from lubricant use were held constant between 2013 and 2014 (264.26 kt CO₂ eq). Between 1990 (155.84 kt CO₂) and 2013, CO₂ emissions increased by 69.6 per cent. During the review, Sweden explained that emissions for 2014 are the same as for 2013 because the data source has a one year delay. The Party explained during the review that emissions for 2014 would be updated in the 2017 submission. The increase between 1990 and 2013 results from the increased use of lubricants and is consistent with other data sources. The ERT believes that this issue, if it appears in future submissions, should be considered further in future reviews in order to confirm there is not an underestimation of emissions.</p> <p>The ERT recommends that Sweden provide in the NIR a detailed explanation of and justification for the chosen method for estimating CO₂ emissions from lubricant use (e.g.holding AD constant for the latest year) to ensure transparency of the methodological approach to estimating emissions from lubricant use.</p>	FCCC/ARR/2 016/SWE	As there is no clear trend over the past five years, simple extrapolation forward is considered as the best available solution. The Swedish Energy Agency has been consulted in the past in terms of delivering data at an earlier point in time, but it is not possible to do so.	Section 4.5.1.2
I.8 2.D.3 Other (nonenergy products from fuels and solvent use) – CO ₂	<p>The ERT noted that CO₂ emissions from urea used as catalyst are reported as “NE” for the period 1990–1994 because of a lack of AD. During the review, Sweden explained that it would include a complete time series in the 2017 annual submission, probably by using an average of available data to extrapolate to 1990.</p> <p>The ERT recommends that Sweden use a method to resolve any data gaps in accordance with the 2006 IPCC Guidelines to estimate CO₂ emissions from urea catalysts for the years for which AD are not available.</p>	FCCC/ARR/2 016/SWE	Activity data are now reported completely in NIR and CRF in Submission 2018.	Section 4.5.3.2.3

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/sec tion in the NIR
I.9 2.F.1 Refrigeration and air conditioning – HFCs	The ERT noted that the product life factor for HFC-125 emissions from commercial refrigeration for 2014 (1.64 per cent) is among the lowest of all reporting Parties (whose values range from 1.5 to 100 per cent). Between 1993 (4.27 per cent) and 2014 (1.64 per cent), the product life factor decreased by 61.6 per cent. During the review, Sweden explained that it aims to examine this issue further for the 2017 annual submission. The ERT recommends that Sweden provide additional documented information in order to justify its use of a country-specific product life factor for HFC-125 emissions for category 2.F.1.	FCCC/ARR/2 016/SWE	There currently are no national statistics available that can be used to find new national emission factors in CRF 2.F.1.a, 2.F.1.c and 2.F.1.f. Therefore, IPCC default factors (lowest value in range) have been used in the Swedish F-gas model for submission 2018, both for emissions from manufacturing and for emissions from installed amounts for 2.F.1.a, 2.F.1.c and 2.F.1.f. Calculations of emissions from heat pumps, reported in 2.F.1.c, are however calculated using national emission factors. (NIR 4.7.1.2)	Section 4.7.1.2
I.10 2.F.1 Refrigeration and air conditioning – HFCs	The ERT recommends that Sweden include, in the NIR, reference to the personal communications from the Swedish Refrigeration and Heat Pump Association and the Swedish Car Recyclers Association to support the use of the country-specific disposal loss factors. Further, the ERT encourages Sweden to undertake an independent monitoring study and report the appropriate findings in the NIR in order to technically validate the use of the very high country-specific HFC recovery factors for this category.	FCCC/ARR/2 016/SWE	Resolved	NIR Annex 3:5
I.12 2.H Other (industrial processes and product use) – CH ₄ and N ₂ O	The ERT noted that Sweden reported CH ₄ and N ₂ O emissions from pulp and paper (e.g. for 2014, Sweden reported emissions of 0.32 kt CH ₄ and 0.27 kt N ₂ O); however, the AD are reported as “NE”, and no description of the AD is provided. During the review, Sweden explained that reporting of AD would be considered for the 2017 annual submission. The ERT recommends that Sweden report AD for this category.	FCCC/ARR/2 016/SWE	Sweden has reported Activity Data (amount of produced pulp) in submission 2018.	NIR section 4.9.1. CRF table 2(I.A- Hs2).

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/sec tion in the NIR
Agriculture/ General	48. The inventory for the agriculture sector is complete in term of categories, gases, coverage and years and most of the categories have been reported with sufficient transparency. However, data on the nitrogen (N) content of some synthetic fertilizers and the country-specific method used to calculate the N ₂ O emissions from N leaching and runoff were not provided in the NIR. The ERT recommends that Sweden include this information in its annual submission to improve transparency.	FCCC/ARR/2 014/SWE Para 48	The recommendations have been implemented in submission 2015	Se table 5.23 in the NIR and the description of the SOIL/SOILN model is given in paragraph 5.4.2.2.2.
Agriculture/ Indirect emissions – N ₂ O	53. Sweden used a country-specific method to calculate the N ₂ O emissions from N leaching and run-off using the follow equation: emissions = area x nitrogen leaching x EF x 44/28.5 However, the calculation method provided in the Revised 1996 IPCC Guidelines and the IPCC good practice guidance is that applied N multiplies the fraction of leaching and run-off (FracLEACH). Sweden did not use the actual FracLEACH, but estimated the implied FracLEACH. The implied FracLEACH was between 0.19 and 0.25 from 1990 to 2012, and was lower than the IPCC default value of FracLEACH (0.30). In response to a question raised by the ERT during the review seeking clarification on the reason why the implied FracLEACH was lower than the IPCC default value, the Party explained that the “nitrogen leaching” referred to the Swedish model, which was developed to calculate Sweden’s emissions of N and phosphorus to the Baltic Sea and was more accurate for the national conditions compared to the IPCC default value because of the use of country-specific AD and parameters on a fine geographic scale. Sweden also provided the ERT with a report ⁶ on the model. The ERT commends Sweden for developing the calculation method and implied FracLEACH to better reflect the national conditions. The ERT recommends that Sweden include enhanced justification of the approach used in its next annual submission.	FCCC/ARR/2 014/SWE Para 53	The recommendation has been implemented in submission 2015	A description of the SOIL/SOILN model is given in paragraph 5.4.2.2.2. In the footnote a hyperlink is also given to a more detailed description of the model.

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/sec tion in the NIR
LULUCF/ General	56. The ERT noted that Sweden's QA/QC procedures are generally well designed, and that the Party continues to make efforts to improve the QA/QC system for the LULUCF sector. However, the ERT observed several errors related to the LULUCF sector in the NIR, which were confirmed by the Party in response to a question raised by the ERT during the review to be errors in the reporting of information and data in the NIR tables. The ERT reiterated the recommendation that Sweden improve its QA/QC procedures and report the correct estimates in a consistent manner in the NIR of its next annual submission.	FCCC/ARR/2 014/SWE Para 56	The recommendation has been implemented in submission 2015 by improving (more time spend) the stepwise process of checking data between different sources and parts of the Submission (NIR/CRF)	No particular documentati on in NIR.
LULUCF/ Forest land remaining forest land – CO ₂	57. In response to a question raised by the ERT during the review regarding the provision of detailed information on dead wood, Sweden provided the ERT with additional information describing the definition, criteria of decay classes, density and carbon concentration by species used and most of the related documentation referenced in the annual submission, including the approach used to derive the country-specific methodologies, and the models used to estimate emissions and removals from dead wood. Nevertheless, the AD on the volume of dead wood, the density of the decay classes for each species and the carbon concentration for birch are not transparently described in the NIR and information was not provided to the ERT during the review. Furthermore, specific information (e.g. decomposition functions) for below-ground dead wood are not transparently described in the NIR. The ERT recommends that the Party include additional and clearer descriptions of the AD, EFs and other parameters used to estimate removals and emissions from dead wood.	FCCC/ARR/2 014/SWE Para 57	The recommendation has not been implemented in submission 2016. Submission 2018: The methodology for reporting lying and standing dead wood is now better explained. This includes the average densities per species. The exact densities per decay class for dead wood and species are found in a reference (Sandström et al. 2007). The carbon concentration for conversion of biomass to carbon is specified. The decomposition rate is 4.6% used for decaying stumps and its derivation is supported by a reference (Melin et al. 2009).	Submission 2018, Annex 3:2, chapter 3.1.5

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/sec tion in the NIR
6 N ₂ O emissions from disturbance associated with land-use conversion to cropland – N ₂ O	58. The ERT noted that Sweden applies a tier 1 methodology and default EFs for the reporting of N ₂ O emissions from disturbance associated with land-use conversion to cropland. Therefore, the ERT reiterates the recommendation in the previous review report that Sweden make efforts to develop country-specific carbon/nitrogen ratios based on measurements of soil organic carbon (SOC) to improve the accuracy of the N ₂ O emission calculations using a tier 2 method.	FCCC/ARR/2 014/SWE Para 58	The recommendation has partly been implemented in submission 2015 by the use of the IPCC 2006 GL. Carbon sock changes as well as specific C:N ratios have been used. The default ratio of 15 was used for forest land, grassland and settlements whereas a ratio of 10 was used for cropland. There are plans to further improve the method.	See annex 3:2 and section 1.8.3 in Submission 2015.
LULUCF/ Settlements – CO ₂	59. The inventory for the LULUCF sector is generally transparent but the ERT noted that the Party applied various assumptions about the EFs for litter and SOC. Sweden describes the litter and SOC EFs used for land conversions to roads, power lines and proper settlements in the NIR. Sweden assumes that all or some litter will decompose over 20 years, although litter is generally removed instantly under most construction. In response to a question raised by the ERT during the review, Sweden explained that the litter is moved from the place where it originates, but it is still unclear whether the litter is moved to the same land category or to a different one. The ERT recommends that Sweden include a clearer explanation the management of litter in its next annual submission.	FCCC/ARR/2 014/SWE Para 59	The recommendation has been resolved.	See 6.4.2.4.2 and Annex 3:2.
L.4 4 (III) Direct N ₂ O emissions from N mineralization / immobilization – N ₂ O (58, 2014) (78, 2013)	Make efforts to develop country-specific carbon/nitrogen ratios based on measurements of SOC to improve the accuracy of the N ₂ O emission calculations using a tier 2 method.	FCCC/ARR/2 016/SWE	Individual C:N ratios for LU and LUC-categories as well as regional values for CLremCL have been used	See Annex 3.2, section 3.2.3.

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/sec tion in the NIR
L.5 4. General (LULUCF)	The ERT noted that, while emissions and land-use changes are required to be reported annually, Sweden only reports the net area changes for the four most recent years. The ERT recommends that Sweden provide annual land-use change matrices for all years in CRF table 4.1.	FCCC/ARR/2 016/SWE	Submission 2018: Now implemented	CRF 4.1
L.7 4. General (LULUCF) – CO ₂ , CH ₄ and N ₂ O	The ERT noted that on several occasions, the rationale for the assumptions used is not documented in the NIR, including the assumptions that land converted to forest land was not harvested (key category), that all fertilization is assumed to occur on forest land remaining forest land, and that biomass burning occurs only on forest land remaining forest land and on grassland remaining grassland. The rationale for these assumptions was provided to the ERT during the review. The ERT recommends that Sweden provide, in the NIR, the rationale for the assumptions that impact the emissions reported for the key categories in the LULUCF sector (forest land remaining forest land, land converted to forest land, direct N ₂ O emissions from N inputs to managed soils, and biomass burning).	FCCC/ARR/2 016/SWE	Submission 2018: The rationale behind different assumptions is better explained. That land converted to Forest land is not fertilized and that all fertilization on Forest land remaining Forest land (FM) is better motivated (NIR chapters 10.1 and 10.3.1.1.2). Biomass burning in forest is assumed to occur only on Forest land remaining Forest land (FM) and this assumption is supported by text in NIR chapter 10.3.1.1.2. Under the UNFCCC, all terrestrial non-forest wildfires are reported under Grassland (Cropland IE, NIR 6.4.1.8). Land converted to forest land/ or under AR (from 1990) is considered not harvested (10.3.1.4)	Several see text

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/sec tion in the NIR
L.8 4.F.2 Land converted to other land – CO ₂	<p>The Party has not reported carbon stock changes for conversions of forest land, cropland, grassland, wetlands and settlements to other land (reported as “NA” in CRF table 4.F). The 2006 IPCC Guidelines (volume 4, sections 9.1 and 9.3) state that emissions from the loss of living biomass in the land use prior to conversion to other land should be reported.</p> <p>[...]</p> <p>The ERT recommends that Sweden report emissions from the loss of living biomass and emissions/removals from mineral soil carbon for all conversions to other land.</p>	FCCC/ARR/2 016/SWE	Living biomass and soil organic carbon for Forest land converted to Other land is now considered in the reporting.	See CRF 4.F and section 6.4.5.
L.9 4.G Harvested wood products – CO ₂	<p>The ERT noted that CRF table 4.G is blank for the years prior to 1990. AD for the production of HWP are required to be reported from 1960; therefore, Sweden’s submission is not complete. During the review, the Party provided information on the sources of data used to estimate production of HWP for the period 1960–1990.</p> <p>The ERT recommends that Sweden complete CRF table 4.G and the additional information box on factors used to convert from product units to carbon (which Parties can do by setting a custom node year within the data entry screen for HWP AD in the CRF Reporter).</p>	FCCC/ARR/2 016/SWE	Updated in submission 2017	See CRF 4.Gs2

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/sec tion in the NIR
Waste/ Solid waste disposal on land – CH ₄	63. Emissions from solid waste disposal on land amounted to 1,094.49 Gg CO ₂ eq applying the IPCC tier 2 methodology with country-specific parameters and IPCC default values. Since 1990, emissions from this category have decreased by 61.9 %. Sweden has reported in the NIR the degradable organic carbon (DOC) values of various wastes without clear background explanation that supports how the DOC values have been obtained. In response to a question raised during the review, Sweden explained that official waste statistics are produced by collecting waste data using a detailed waste nomenclature and that this makes it possible to estimate the DOC content accurately on the European Waste Catalogue stat level when waste is aggregated. The ERT agrees with the assessment made by Sweden and noted that transparency in the methodology used to aggregate DOC estimates in tables 8.16 and 8.17 of the NIR can be improved. The ERT recommends that Sweden provide a description on how the aggregated DOC values reported in the NIR are estimated, as well as quantification of uncertainty associated with the DOC values, in its next submission.	FCCC/ARR/2 014/SWE Para 63	The recommendation has been resolved in submission 2016.	See section 7.2.3.2.3 in Submission 2016.
Waste/ Wastewater handling – CH ₄ and N ₂ O	64. Emissions from wastewater handling amounted to 459.92 Gg CO ₂ eq and have decreased by 8.4 % since 1990. Sweden estimated CH ₄ emissions by applying the check method for the small wastewater treatment plant, and reported no CH ₄ emissions from the large plant using aerobic wastewater treatment processes. During the review, Sweden indicated that results from the implementation of an IPCC default methodology will be presented in the 2015 submission. The ERT welcomes these proposed improvements and recommends that Sweden use the IPCC default method in accordance with the decision tree to estimate CH ₄ emissions from domestic wastewater handling. Because anaerobic conditions can be partly formed, even in aerobic treatment plants, the ERT encourages Sweden to determine a country-specific CH ₄ correction factor value for the large wastewater treatment plant, as well as for the untreated discharge system, to improve the quality of the inventory in the next annual submission.	FCCC/ARR/2 014/SWE Para 64	The recommendation has been resolved in submission 2015.	Section 7.5.2.2 and 7.5.2.3

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/sec tion in the NIR
W.4 5.A.1 Managed waste disposal sites – CH ₄	Sweden has provided a description of how aggregated DOC values for the major waste fractions reported in the NIR are estimated (see also W.1 in table 3). However, the data presented are not comparable or transparent (e.g. the data on pp.414 and 415 differ from those on p.407, and it is not clear which values were used for the fractions of waste) and the data on the reaction constant k values used for each waste category (or fractions of the municipal waste) have not been provided. The ERT recommends that Sweden include information on the content of Swedish household waste as a percentage or the DOC content value for the major waste fractions (specified in table 7.8 on p.407 of the NIR) in the waste.	FCCC/ARR/2 016/SWE	Resolved. Additional information is now provided on fraction of degradable organic carbon – DOC.	Section 7.2.2.2.4 (Table 7.7)
KL.1 General (KP- LULUCF)	CRF table NIR-2 of the 2016 submission does not contain area values; instead, the notation keys “IE”, “NO” and “NA” are used. During the review, the Party explained that it is difficult to complete this table because a full cycle of the national forest inventory is only completed every five years. In the past, the Party was able to calculate and report these areas manually because land-use conversions associated with afforestation/reforestation, deforestation, forest management and other activities were quite uncommon. Since 1990, land may have been converted several times and a manual solution is no longer possible because of the complexity of the calculations. However, in response to a question during the review on multiple land-use changes, Sweden explained that such changes were not common, with only 32 plot intersections with three land-use categories identified. The ERT notes that completion of this table is one of the reporting requirements set out in decision 6/CMP.9, paragraph 1, and enables the accurate assessment of annual GHG inventories. The ERT recommends that Sweden complete CRF table NIR-2 on an annual basis in accordance with this mandatory reporting requirement.	FCCC/ARR/2 016/SWE	Submission 2018: Now implemented.	NIR chapter 6.2.9 and 10.2.2, CRF NIR2

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/sec tion in the NIR
KL.2 General (KP- LULUCF)	Decision 2/CMP.7, annex, paragraph 5, requires Parties to report and account for, in accordance with Article 7 of the Kyoto Protocol, all emissions arising from the conversion of natural forests to planted forests. The Party confirmed during the review that it reported all forest land as managed forest land. Accordingly, there are no natural forests, which the Party interprets as forests that have been included under forest management, to convert to planted forests. The ERT accepts the Party's explanation that all emissions arising from the conversion of natural forests to planted forests are included in the inventory submission. The ERT recommends that Sweden increase the transparency of its reporting by including information on the definitions selected by the Party for natural forests and planted forests, and the application of these definitions, in its reporting in accordance with the requirements of decision 2/CMP.8, annex II, paragraph 5(d).	FCCC/ARR/2 016/SWE	Submission 2018: Not relevant for Sweden, all forests reported.	NIR 10.5.4
KL.5 Forest management – CO ₂ , CH ₄ and N ₂ O	The Party provided information on the FMRL, but the technical corrections did not cover changes in the forest management area or provide reasons for the deviation between forest management activities and the FMRL. The ERT recommends that Sweden provide, in the NIR, information on the technical corrections in accordance with the annex to decision 2/CMP.7 and annex II to decision 2/CMP.8, including how the technical corrections impact areas under forest management and the reasons for the deviation between forest management activities and the FMRL.	FCCC/ARR/2 016/SWE	The actual and predicted area of FM have now been considered in the TC.	See 10.5.6.
KL.8 Harvested wood products – CO ₂	In CRF table 4(KP-I)A.1, the Party reported emissions from HWP for afforestation/reforestation land as "NE", while the NIR (p.473) states that these emissions are reported and the methodology used by Sweden (p.490) indicates that these emissions are reported under forest management. During the review, the Party confirmed that these emissions should have been reported as "NO" in CRF table 4(KP-I)A.1 because no afforestation/reforestation land has yet been harvested. The ERT recommends that Sweden correct the information on HWP in the NIR (which incorrectly indicates that HWP are estimated and reported under forest management) and report the notation keys consistently in the NIR and in CRF table 4(KP-I)C.	FCCC/ARR/2 016/SWE	HWP from afforestation/reforestation land is reported as R in table NIR-I Subm2018 for 2013-2016 and NR for 1990. In table 4(KP)C_subm2018 corresponding category is reported as NO.	10.3.1.4

CRF category/ issue	Review recommendation	Review report/ paragraph	Response / status of implementation	Chapter/sec tion in the NIR
KL.9 Harvested wood products – CO ₂	<p>The Party used country-specific HWP conversion factors for panels and sawnwood. The ERT commends the Party for moving to a higher tier method. However, the rationale for the conversion factors has not been provided in the NIR. During the review, the Party explained how the factors were calculated and which sources of data were used for the calculations. The Party also explained that the conversion factor for sawn wood should be 0.42 rather than 0.52, as currently reported in the NIR.</p> <p>The ERT recommends that, in the NIR, Sweden correct the conversion factor for sawn wood and include information on the rationale for the country-specific HWP conversion factors for panels and sawn wood.</p>	FCCC/ARR/2 016/SWE	The methodology behind the conversion factors is explained.	6.4.2.6

Table 9.5 Provisional main findings reported by the ERT during the 2018 technical review of the annual submission of Sweden

CRF category/source - substance/issue type	Provisional Main Finding	Comment with reference to chapter/section in NIR (if relevant)
G.4 Transparency	The amount of NF3 is reported as 'NA' in Table ES.1 of the NIR and CRF tables 10s5 and 10s6. During the review Sweden explained that the notation key for NF3 will be corrected to 'NO' in the NIR of the next submission. The ERT recommends Sweden to use the notation key "NO" for NF3 both in table ES.1 of the NIR and in CRF tables.	Notation keys for NF3 and also för Unspecified mix of HFCs and PFCs changed from NA to NO in table ES1.
G.5 Transparency	The ERT noted that table 9.5 showed some issues as "not considered" while the issues have been resolved in the NIR. Examples of these are issues: G.1, E.3 and L.5 in table 3 above. The ERT recommends Sweden to update table 9.5 in the NIR in order to reflect the real status of the issues.	Table 9.5 has been updated in submission 2018.
E.7 1.B.1.b - Solid Fuel Transformation – biomass - CH ₄ (E.8, 2016) Transparency	The ERT noted that, in accordance with the 2006 IPCC Guidelines (volume 2, table 2.1), emissions from charcoal production are to be included in the category 1.A.1.c (manufacture of solid fuels and other energy industries). Therefore, the ERT concluded that this case presented a potential underestimation of CH ₄ emissions from charcoal production for 2014 and included this issue in the list of potential problems and further questions raised by the ERT. In response, the Party further explained that charcoal is produced by small companies. The emissions from these companies are included in the estimates for small industries (category 1.A.2.g (other (manufacturing industries and construction))), for which AD are aggregated from the energy balance, which in turn is based on intermittent surveys. The Party indicated that it is not possible to separate the charcoal producers' emissions from the rest of the aggregate, and hence the fugitive CH ₄ emissions from charcoal production are reported in category 1.A.2.g. The ERT recommends that Sweden report fugitive CH ₄ emissions from charcoal production separately in category 1.A.1.c and describe in the NIR where in the CRF tables these emissions are reported.	Charcoal production in Sweden and the related emissions from the activity is derived from small companies that are included in the emission estimates from small industries (CRF 1.A.2.g). Since the activity data for this sector is aggregated from the national energy balances, it is thereby not possible for Sweden to separate the emissions that are related to charcoal production from the aggregate. Hence, the fugitive CH ₄ emissions from charcoal production are reported in CRF 1.A.2.g. In earlier submissions, the notation key for fugitive CH ₄ emissions in 1.A.1.c was mistakenly reported as NO but is now reported as IE.
E.8 Fuel combustion – reference approach – solid, liquid, gases – CO ₂ Transparency	The ERT commends the Party for the efforts to date to revise the RA approach and seek improvements to reconcile the RA-SA discrepancies, and acknowledges that resolving the RA-SA discrepancy will require consultation and resolution of data discrepancies across multiple organisations and agencies, including the steelworks operator and the Swedish Energy Agency. The ERT encourages the Party to	In submission 2018 a project that seek improvements to reconcile the RA-SA discrepancies resulted in insight in discrepancies about NEU. In addition the RA-SA comparison in NIR and

CRF category/source - substance/issue type	Provisional Main Finding	Comment with reference to chapter/section in NIR (if relevant)
	<p>progress the research to improve the estimates for the RA, and reports on progress in its next submission, including to take account of known differences (such as emissions allocated in IPPU).</p> <p>Further the ERT recommends that the Party revises and extends the analysis and documentation of findings from the RA-SA comparison in the NIR and provide in the CRF table 1.A(c) reference to the explanations in the NIR where discrepancies between the approaches are more than 2 per cent.</p>	<p>Annex4 is revised in order to give clearer explanations of the discrepancies larger than 2%. However, during this submission not all discrepancies are clearly enough thus during next year the project will continue in order to find explanations for the remaining gaps between RA and SA which will be reported in submission 2019.</p>
<p>E.9 1.A.2.a Iron and steel – Solid – CO₂ Transparency</p>	<p>The IEFs of CO₂ emissions from solid fuels for iron and steel fluctuated quite a lot in recent years since 2006 (for example, 214.5/170.2 t/TJ for 2005/2006, 221.3/165.6 t/TJ for 2008/2009), while for the years earlier than 2006 they were relatively stable to around 215 t/TJ. The Party explained that the inter-annual variations were caused by variations in the relative amounts of blast furnace gas and coke oven gas, respectively, between years, and the composition of each gas was also quite variable (NIR page 136).</p> <p>The ERT commends the Party provided these explanations that improved the transparency of the reporting. Noting the existing explanations did not fully explain the overall trend of the IEFs especially for the years earlier than 2006 when the IEFs were quite stable and no changes on working conditions had been reported.</p> <p>The ERT recommends that the Party explore more comprehensive causes of this trend and update the explanations in the NIR for the next submission.</p>	<p>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.</p>
<p>E.10 1.A. Fuel combustion – sectoral approach – solid, liquid, gases – CO₂, CH₄, N₂O Transparency</p>	<p>The Party reported that as plant-specific data were adopted for the emissions estimates of 1.A.1.a, 1.A.1.b, 1.A.2.a, 1.A.2.b, 1.A.2.c, 1.A.2.d, 1.A.2.e and 1.A.2.f, these categories were reported as confidential (NIR pages 130, 134, 136, 138, 141, 144, 146, 148, 149, 151; CRF tables 1A(a)s1, 1A(a)s2).</p> <p>During the review, a print-out of CRF tables 1A(a)s1, 1A(a)s2 with figures filled for all subcategories including the confidential ones for the recent 3 years were made available for the ERT as confidential materials.</p>	<p>In submission 2018 Sweden has worked with collecting more consents in order to reduce the amount of confidential cells in the CRF tables. In submission 2016 less cells are hidden as a result of the collected consents. For emissions in 2016 only CRF 1A2a, 1A2f and 1A2g are hidden for some fuel</p>

CRF category/source - substance/issue type	Provisional Main Finding	Comment with reference to chapter/section in NIR (if relevant)
	<p>Noting the progress achieved by the Party that more energy data have become available from the Swedish Energy Agency, including, inter alia, energy balance sheets, energy in Sweden facts and figures (a yearly collection of energy statistics that published at Swedish Energy Agency website), monthly and quarterly energy surveys, the ERT recommends that the Party find ways to minimize the number of categories reported as confidential for the sake of transparency, while protecting the confidentiality of the company data, for example, by 1) using weighted average EFs for one industry instead of direct citation of the facility data; or 2) collecting sufficient consents from plant operators and report emissions in the CRF and NIR not as confidential information.</p> <p>The ERT further recommends that the Party prepare a simple schematics to explain the flow of data and the relationships between GHG inventories and EU ETS, and GHG inventories and energy balance and make it available to the next ERT through the UNFCCC Secretariat as a confidential material to facilitate the technical review of the Party's GHG inventories.</p>	<p>groups which is a major improvement compared to all the hidden cells in emission year 2015.</p> <p>Sweden will still prepare a simple schematics with the flows of data in order to facilitate the review of the inventory for submission 2018 because there are still cells that are confidential in CRF 1A but also in CRF 2.</p>
I.4 2. General (IPPU) (I.4, 2016) Transparency	The ERT recommends that Sweden transparently report the methodology applied for categories 2.C.2 and 2.C.7 in the IPPU sector in both the NIR and the CRF tables (see issue I.3 above).	Sweden has corrected the method and EF description in NIR (4.4.2 and 4.4.7) as well as in the CRF tables.
I.5 2.C.4 - Magnesium Production – SF6 (I.6, 2016) Transparency	<p>SF6 emissions from magnesium production are reported (e.g. 0.69 tSF6 for 2014); however, the AD and the IEF are reported as “NE”. During the review, Sweden confirmed that this was an error, and indicated that it would be corrected in the 2017 annual submission</p> <p>The ERT recommends that Sweden ensure that both the AD and SF6 emissions are reported for magnesium production.</p>	<p>Despite efforts, Sweden has not been able to find national data on amount of magnesium casted. We will therefore continue to report “NE” in the CRF Table 2(II)B-Hs1 for activity data for activity data for SF6 and continue to report NO or IE for HFC-134a. Implied emission factor for the largest foundry 2009-2016 will be included in NIR. (see NIR 4.4.4.1)</p> <p>In addition, for transparency, in table2(I).A-Hs2, Sweden will report “NO” for activity data, since there is no</p>

CRF category/source - substance/issue type	Provisional Main Finding	Comment with reference to chapter/section in NIR (if relevant)
		magnesium production within the country (only magnesium foundries).
I.7 2.D.1 - Lubricant Use – CO ₂ (I.7, 2016) Transparency	The ERT recommends that Sweden provide in the NIR a justification for the chosen method for estimating CO ₂ emissions from lubricant use (e.g. holding AD constant for the latest year) to ensure transparency of the methodological approach to estimating emissions from lubricant use (see issue I.6 above).	As there is no clear trend over the past five years, simple extrapolation forward is considered as the best available solution. The Swedish Energy Agency has been consulted in the past in terms of delivering data at an earlier point in time, but it is not possible to do so. (See NIR Section 4.5.1.2)
I.11 2.H Other (industrial processes and product use) – CH ₄ and N ₂ O (I.12, 2016) Transparency	The ERT noted that Sweden reported CH ₄ and N ₂ O emissions from pulp and paper (e.g. for 2014, Sweden reported emissions of 0.32 kt CH ₄ and 0.27 kt N ₂ O); however, the AD are reported as “NE”, and no description of the AD is provided. During the review, Sweden explained that reporting of AD would be considered for the 2017 annual submission. The ERT recommends that Sweden report AD for this category.	AD is reported in submission 2018. See NIR section 4.9.1.5.
I.12 2.C.1 Iron and steel production – CO ₂ Transparency	The ERT commends the Party on the development of the new CRF1-CRF2 balance sheet and recommends that the Party reviews and updates the description of: (i) the methodology, and (ii) data reconciliation checks for integrated steelworks in the NIR in order to improve transparency, presenting information on: (iia) comparison of emissions reported in the national inventory across 1A1a, 1A1c, 1A2a, 1B1c and 2C1b against operator data from EU ETS or environmental reports, and (iib) comparison of AD from the integrated steelworks and the national energy balance for primary and secondary fuels, to provide sufficient detail for ERTs to assess the accuracy and completeness of the submission whilst protecting commercially confidential data. The ERT notes that many details of plant design, use of process gases, options to allocate emissions and develop time series consistent methodologies for the integrated steelworks are included in the 2011 SMED Report 97 “Emissions from Integrated I&S Industry in Sweden”, which is public domain and the ERT encourages the Party to present extracts from that report as an annex to the NIR. Further to improve transparency of the key input data that govern the emission estimates from integrated steelworks, the ERT recommends that the Party include a	The methodology description has been updated regarding main data sources and emission allocation (section 4.4.1.2.2). It should be noted that operator data from EU ETS do not contain emissions per code (1A1a, 1A1c, 1A2a, 1B1c and 2C1b), with exception of 1A1a (sold gases), but only per material. The current methodology to estimate emissions and energy use (including losses) has been updated since SMED report 97 2011 so that mainly data from environmental reporting and data obtained directly from facilities are used in the emission calculations and allocation, as shown in Table 4.16.

CRF category/source - substance/issue type	Provisional Main Finding	Comment with reference to chapter/section in NIR (if relevant)
	full time series of the coking coal CEF used to generate the emission estimates, including references for the data source across the time series.	Emissions reported in EU ETS are used for verification and for assessment of losses (non-emissive energy use). A time series of the coking coal CEF will be developed in cooperation with the facilities for Submission 2019.
I.13 2.C.1 Iron and steel production – CO ₂ Accuracy	<p>The ERT commends the Party for progressing research into this issue, and encourages the Party to progress the research to harmonise and improve the accuracy of the data reported by the steelworks operator and the Swedish Energy Agency, and recommends that Sweden reports on progress in the next submission, including to report on updates to AD and emission estimates across the time series of Energy and IPPU sources affected by the integrated steelworks (i.e. 1A1a, 1A1c, 1A2a, 1B1c, 2C1b). The ERT acknowledges that full reconciliation of this issue is unlikely for the 2018 submission, and encourages the Party to provide full details of AD and emissions to future ERTs to facilitate assessment of the completeness and accuracy of future submissions, and to report on the time-frame to complete the research.</p> <p>The ERT also encourages the Party to progress its efforts to analyse and report on the Reference Approach-Sectoral Approach comparison, seeking to take account of “known issues” that lead to differences in the emissions reporting (e.g. to correct for the emissions from solid fuel transformation and emissions reported in IPPU), in order to derive a more useful RA-SA comparison.</p>	<p>In the current submission, AD and emissions for 2016 are displayed in Table 4.16. Only emissive sources within the facilities are included in the table (emissions from sold gases as well as losses are excluded due to secrecy reasons).</p> <p>AD (as TJ energy) and emissions per code (1A1c, 1A2a, 1B1c and 2C1b) for the whole time series will be summarized and included in the NIR in Submission 2019.</p> <p>In submission 2018 the comparison between RA and SA will be revised in order to clarify the known and unknown explanations for discrepancies to facilitate the review. The comparison is made by fuel groups. New for this submission is that a comparison between NEU in the Energy Balance sheets and the GHG inventory is made which explains some of the discrepancies for solid fuels.</p>
I.14 2.F.1 Refrigeration and air conditioning – HFCs and PFCs) Accuracy	The ERT commends the Party on progressing research to improve the accuracy of the Swedish F-gas model and recommends that Sweden update the product life factors in the next submission, as outlined during the review week, to either utilise new country-specific factors with supporting evidence, or to apply default factors from the 2006 IPCC Guidelines, ensuring that time series consistency is maintained	There currently are no national statistics available that can be used to find new national emission factors in CRF 2.F.1.a, 2.F.1.c and 2.F.1.f. Therefore, IPCC default factors (lowest value in

CRF category/source - substance/issue type	Provisional Main Finding	Comment with reference to chapter/section in NIR (if relevant)
	in the Swedish model. The ERT also recommends that the Party includes the new data on F-gases in pre-filled units imported into the country, within the next submission. The ERT acknowledges that implementing a comprehensive improvement to the national F-gas model and to conduct rigorous QA/QC of such model revisions (e.g. peer review), in particular to incorporate new data and ensure time series consistency and to revise model uncertainties, may not be achievable in time for the 2018 submission. The ERT therefore encourages the Party to ensure that sufficient resources are made available to implement these improvements in a timely manner, and recommends that in the next submission the Party reports on model improvements and presents a clear plan of tasks and associated time-frame for completing the model improvements if not achieved for the 2018 submission.	range) have been used in the Swedish F-gas model for submission 2018, both for emissions from manufacturing and for emissions from installed amounts for 2.F.1.a, 2.F.1.c and 2.F.1.f. Calculations of emissions from heat pumps, reported in 2.F.1.c, are however calculated using national emission factors. (NIR 4.7.1.2) A time table for the model improvements has been developed.
I.15 2.F.1 Refrigeration and air conditioning – HFCs and PFCs Transparency	The Party reported emission factors for initial charging of commercial refrigeration in NIR Table 4.42 that were inconsistent with the rates presented in the CRF table 2(II)B.Hs-2, for example in 1995 the NIR states 5.7% whereas the CRF table indicates 3.5%. The ERT noted that the initial charge in NIR Table 4.42 is 3.5kg, and considered that this may indicate either a typographical error in the NIR or an incorrect leakage rate applied in the Swedish RAC model. During the review, the Party explained that due to the aggregation of multiple sources within the Swedish model that are reported in 2F1a, such as heat pumps (the leakage rate for which is 1% and presented in NIR table 4.41), the tables in the NIR and CRF tables do not match, but further noted that in the 2018 submission the Party will report the emissions data in individual source categories, with heat pumps reported under 2F1f. To improve transparency of the submission, the ERT encourages the Party to progress its research and recommends that the Party report emissions from heat pumps separately under 2F1f in the next submission including any details of recalculations from the re-design of the RAC model. Further, the ERT encourages the Party to ensure that the changes in reporting are subject to rigorous QA/QC in order to ensure that leakage rates for individual sub-sectors are applied correctly in the model, and to ensure consistency between the NIR and CRF tables.	Implemented (NIR 4.7.1)
I.16 2.D.3 Other (non-energy products from fuels and solvent use) –	The Party updated the reporting for urea use as a catalyst in the CRF table 2(I)A.Hs-2 to add new estimates for 1990-1994 that had previously been reported as “NE”, in response to a recommendation in the previous review (see Table 3, item I.7 on	Activity data is indeed reported inconsistently and are now reported completely in NIR and CRF in

CRF category/source - substance/issue type	Provisional Main Finding	Comment with reference to chapter/section in NIR (if relevant)
CO ₂ Transparency	<p>Completeness). However the Party did not document in the NIR any of the method changes (e.g. extrapolation approach to fill the data gap) nor did the NIR include any mention of the recalculations, and the NIR Table 4.33 of the 2017 submission still reported "NE" for 1990. Furthermore, the NIR includes no methodological details for the emission estimates from urea use as a catalyst, other than to say that the method is in accordance with the 2006 IPCC Guidelines. The recalculations and the estimation method are therefore not reported transparently, and the information in the NIR and CRF were inconsistent.</p> <p>During the review, the Party confirmed that the emission estimates for this source category are calculated using Table 3.2.2 from section 3.2.1.1 of the mobile combustion chapter of the 2006 IPCC Guidelines, assuming 100% purity of the urea. Further, the Party explained that the reporting in the NIR and CRF would be updated in the 2018 submission.</p> <p>The ERT recommends that the Party update the NIR in the 2018 submission to explain the method, source data, assumptions and the extrapolation back to 1990 and to correct the discrepancies between the NIR and the CRF.</p>	Submission 2018. The emissions are calculated with equation 3.2.2 presented in section 3.2.1.1, as assumed by the ERT, based on the assumption of purity of 100%. This information have been added to NIR in Submission 2018. (Section 4.5.3.2.3)
I.17 2.B.10 Other (chemical industry) – CO ₂ Transparency	<p>The ERT recommends that the the Party progress its ongoing research to improve the reporting of the chemical sector emissions in line with the 2006 IPCC Guidelines, and to report on progress and any recalculations in the next submission. The ERT recommends that the Party improve the description of: (i) the methodology, and (ii) data reconciliation checks for the chemical production sector in the NIR in order to improve transparency, presenting information on: (iia) comparison of emissions reported in the national inventory across 2B and 1A against operator data from EU ETS or environmental reports, and (iib) comparison of AD from the chemical installations and the national energy balance for primary and secondary fuels, to provide detailed data for ERTs to assess the accuracy and completeness of the inventory, whilst protecting commercially confidential data. The ERT encourages the Party to provide the CRF1-CRF2 balance table noted in item I.12, as this will significantly improve the transparency of the sector estimates and completeness of Energy and IPPU.</p>	<p>The methodology description has been updated regarding emission allocation and cross-checks with reporting in the energy sector (sections 4.3.10.2, 4.3.10.4).</p> <p>The ongoing work on improving allocation between sectors will continue.</p> <p>Results of the CRF1-CRF2 balance tables will be provided upon request for review of Submission 2019.</p>
I.18 2.C.7 Other (metal industry) – CO ₂ Transparency	<p>The ERT commends the Party on its extensive efforts to improve the emission estimates in recent research, and encourages the Party to progress its ongoing research and recommends that Sweden further improves the reporting of the 2C7 Other sector emissions in line with the 2006 IPCC Guidelines, and report on</p>	See section 3.2.10 for information on the ongoing work on improving emission estimates. Results of the CRF1-CRF2 balance tables will be

CRF category/source - substance/issue type	Provisional Main Finding	Comment with reference to chapter/section in NIR (if relevant)
	progress and any recalculations in the next submission. The ERT encourages the Party to provide the CRF1-CRF2 balance table noted in item I.12, as this will significantly improve the transparency of the sector estimates and completeness of Energy and IPPU.	provided upon request for review of Submission 2019.
I.19 2. General (IPPU) – All GHGs Transparency	The ERT acknowledges that Sweden encountered problems with the CRF reporter software and that this contributed to inconsistencies and incompleteness of the CRF tables, and agrees with all of the Party's proposed actions to resolve these issues in the next submission. The ERT recommends that the Party corrects the errors in the NIR and CRF in the next submission, including to: provide the AD and IEF across the time series for 2D2 Paraffin wax use; provide the time series of AD, IEFs and emissions for each sub-source of 2B5b within the NIR and report "NA" as the AD in the CRF; correct the NIR text for 2B2 nitric acid production to remove the comment on data confidentiality and present time series data in the NIR tables; and to correct the AD in the CRF for the 2A2 lime production source category for 2015. Further the ERT encourages the Party to improve the quality checking of the NIR and CRF in order to minimise errors and inconsistencies in future submissions.	The issues have been corrected in NIR and in the CRF tables (see section 4.5.2, 4.3.5 and 4.3.2).
I.20 2.A.2 Lime production – CO ₂ Transparency	The ERT notes that completeness of lime production estimates is challenging where many industry sub-sectors (such as sugar, paper and pulp) also generate and use lime, and commends the Party on the detailed study in 2015 to assess the completeness and consistency of data reported through a range of mechanisms in Sweden. The ERT recommends that the Party improve the NIR description of the source-specific QAQC and verification to improve the transparency of the submission, for example to provide a summary of the findings of the 2015 study whilst maintaining data confidentiality and noting the results of consultation with data providers to explain observed differences in AD and emissions data. Further the ERT encourages the Party to revisit the analysis of the comparison of AD reported by Statistics Sweden with other data sources, and to consult with data providers to seek to reconcile known differences and improve the verification that the inventory data are complete.	See NIR section 4.2.2.4 The study from 2015 suggests to use AD provided by the EU ETS as this data is available in time for submission, which has been applied since submission 2016.
I.21 2.A.4 Other process uses of carbonates – CO ₂ Completeness	Noting that the key data providers to inform such a mass balance check for limestone and dolomite use are the Geological Survey of Sweden (SGU - for production data) and Statistics Sweden (for imports, exports), and both of these organisations are Government Agencies involved in the national system, the ERT recommends the Party to access the available data on production, imports, exports	See NIR section 4.2.4.4

CRF category/source - substance/issue type	Provisional Main Finding	Comment with reference to chapter/section in NIR (if relevant)
	and known consumption of limestone and dolomite, in order to assess any potential under-reporting of emissions due to incomplete coverage of emissive uses of limestone and dolomite via the EU ETS dataset that is currently used for the national inventory, and report in the next submission on the comparison between (i) the activity data of limestone and dolomite reported in the inventory across all source categories, and (ii) the activity data of limestone and dolomite that is derived from "imports + production – exports – known uses".	
A.2 3.A.1 Cattle – CH ₄ Transparency	<p>The Party reported incorrect unit for milk delivered for dairy cattle (NIR page 313, table 5-6).</p> <p>The ERT noted that the unit for total milk delivered is ton. The figures for the whole time series are too small for national total milk production.</p> <p>During the review, the Party explained that the unit is not correct. It should be 1000 t.</p> <p>The ERT recommends that the Party enforce the implementation of its general QC procedures, which, according to the NIR (p. 52) include the assessing the correctness of units, in particular the unit used for total milk delivered and report on such improvement in its next the NIR.</p>	Resolved
A.3 3.B.3 Swine – CH ₄ and N ₂ O Transparency	<p>The Party reported liquid waste manure management systems (fraction) for "Pigs for meat production" was 0.95, for "Other swine" was 0.58, in both years of 2013 and 2014 in 2017 submission. While in 2016 submission, liquid waste manure management systems (fraction) for "Pigs for meat production" was 0.97, for "Other swine" was 0.74 for both year of 2013 and 2014. Solid waste manure management systems and deep litter manure management systems fractions for "Pigs for meat production" and "Other swine" were also different in the two submissions.</p> <p>The ERT noted that there is no explanation in the NIR for such changes.</p> <p>During the review, the Party explained that a development project was carried out to improve the calculations model for the reporting of ammonia for the LRTAP Convention (NIR page 322). Manure management systems distribution for dairy cattle and subcategories of non-dairy cattle were updated. It is not clearly described in the NIR (page 322) that the manure management systems of swine were also affected.</p> <p>The ERT recommends that the Party report recalculations for all specific sources in its next NIR, including the impact in the MMS for swine.</p>	Resolved. All recalculation made between the two latest submissions are now described in the NIR.

CRF category/source - substance/issue type	Provisional Main Finding	Comment with reference to chapter/section in NIR (if relevant)
A.4 3.D.b.1 Atmospheric deposition – N ₂ O Transparency	The party reported the emissions of ammonia from 8 different fertilizer types (NIR page 331, table 5.24). The source for emissions of ammonia from 8 different fertilizer types was not provided by the Party in the NIR. The Party did not report the emissions of ammonia from NK and NPK in the NIR. The unit for FracGASF of different fertilizer type (page 331, table 5.24) was incorrect. The ERT noted it is not transparent to derive FracGASF contained in table 5.25. During the review, the Party explained that the source of loss as ammonia for different fertilizer types are from EMEP/EEA air pollutant emission inventory guidebook 2013. The party stated that the unit of FracGASF is incorrect only in the NIR. Estimate of indirect N ₂ O emission from ammonia volatilization was correct. FracGASF for other NK and NPK fertilizers is the same as ammonium nitrate which are also from EMEP/EEA guidebook 2013. The ERT recommends that the Party enforce the implementation of its general QC procedures according to the NIR (p. 52) to check the data sources, the correctness of units, completeness of FracGASF values for all fertilizer types in its next the NIR.	Resolved
L.1 4.(III) - Direct N ₂ O emissions from N mineralization/immobilization – N ₂ O (L.4, 2016) Accuracy	Make efforts to develop country-specific carbon/nitrogen ratios based on measurements of SOC to improve the accuracy of the N ₂ O emission calculations using a tier 2 method.	Has been taken care of in Submission 2018. See also table 9.4
L.4 4.F.2 - Land Converted To Other Land – CO ₂ (L.8, 2016) Completeness	The Party has not reported carbon stock changes for conversions of forest land, cropland, grassland, wetlands and settlements to other land (reported as "NA" in CRF table 4.F). The 2006 IPCC Guidelines (volume 4, sections 9.1 and 9.3) state that emissions from the loss of living biomass in the land use prior to conversion to other land should be reported. The ERT recommends that Sweden report emissions from the loss of living biomass and emissions/removals from mineral soil carbon for all conversions to other land.	Implemented and Reported in Submission 2018.
L.6 4 (II) Emissions and removals from drainage and rewetting and other management of organic/mineral soils – CH ₄ Transparency	The Party reported that ditches are included under 9. road and railroad,(Settlements) (NIR page 347), while emissions from ditches are related to drainage that mostly happens in. forest land, grassland or wetlands. During the review, the Party explained that ditches as referred to under "9. Road and railroad" are ditches alongside roads and railroads and they are not the same ditches as the ones that are established to drain forest land, grassland or cropland.	Awaiting the final outcome of the review, the definitions of land use categories have been revised. Emissions from ditches only include ditches on organic soils.

CRF category/source - substance/issue type	Provisional Main Finding	Comment with reference to chapter/section in NIR (if relevant)
	<p>The Party provided also information on the estimation of CH₄ emissions from ditches, based on country specific values.</p> <p>The ERT recommends that the Party improve the transparency by reporting in the NIR ditches along road and that the emission factor per ha for ditches are country specific: the area of ditches is estimated based on a factor for the fraction of the drained area and it is 2.5 percent for Forest land and 5 percent for Grassland and Cropland and this factor is applied to the country specific EF by land use.</p>	
L.7 4.A Forest land –)	<p>The Party reported that for organic soils CRF 4A "Emission factors are applied without any consideration to carbon inputs from litter (NIR page 96), whilst in CRF table 4A carbon stock changes in litter are reported.</p> <p>During the review, the Party explained that previous emission factors used by the Party for drained organic soils did not include carbon gain in soils from litter and root mortality and therefore it was added separately. The new emission factors from IPCC WL supplement that the Party use include this. The ERT encourages that the Party deletes in next submission the erroneously wording that carbon inputs from litter were not considered.</p>	Litter is not reported separately for mineral and organic soils. However, to not confuse the reader the sentence related to the consideration of litter input related to EFs for organic soils have been deleted in section 6.4.2.4.2
L.8 4.C Grassland – CO ₂ Transparency	<p>The Party reported that it would use the CO₂ specific emission for drained organic soil in forest land as included in the Wetland Supplement for drained organic soil in grassland (NIR page 97).</p> <p>The ERT noted that this is not in accordance with the 2013 Supplement to the 2006 IPCC Guidelines (volume Wetlands, chapter 2, table 2.1) because this section provide a default value for drained organic soil in grassland.</p> <p>During the review, the Party explained that the emission factor values included in the Wetland Supplement are based on more studies which are representative for the climatic zones considered for Sweden while the emission factor that was previously used was only based on one study and so this new value is considered to be more accurate. Using this emission factor makes it also possible to differentiate the area estimate and the calculations based on nutrient status. The reason to apply to grassland the emission factor for forest land is (as when using the previously too) that grassland in the Swedish reporting is defined as natural grazing land with soil conditions closer to forest land (often some trees left and also with bare rocks and definitely not tilled) than to grassland as defined for the Wetland Supplement.</p>	Text on Grassland EF:s improved in Submission 2018 (section 6.4.2.4.2.

CRF category/source - substance/issue type	Provisional Main Finding	Comment with reference to chapter/section in NIR (if relevant)
<p>L.9 4.A Forest land – Transparency</p>	<p>The ERT recommends that the Party improve the transparency and provide the information on the choice of the country specific CO₂ emission factor for drained organic soil in grassland in the next submission</p> <p>The Party reported that 6.73 kha of forest land (managed) changed from 2014 to 2015 to other land, while other land is defined by Sweden as unmanaged (NIR page 347; CRF table 4.1). The Party reported all areas, managed or unmanaged. The Party reported “human induced” carbon changes only, where “human induced” has the interpretation of “managed”, i.e. the carbon stock change on unmanaged land are set to zero (NIR page 353).</p> <p>The ERT noted that this is not in accordance with the 2006 IPCC Guidelines (volume 4, chapter 3) because a hierarchy of land use categories is applicable . Additionally it was not transparent whether this land use conversion was accompanied with a loss of forest cover, and if so for what area.</p> <p>During the review, the Party explained that</p> <p>a) when during the NFI a plot is saturated by water (even if it was forest land remaining forest land) this area is reported as a land use change (even when the land cover has not changed) to wetland. As wetlands are defined by the Party unmanaged, this former forest land moves into the 'unmanaged land;'</p> <p>b) When during the NFI a plot in unmanaged land is noticed as meeting the forest definition, this former unmanaged land (reported as unmanaged other land) will be reported as other land changed to forest land under the Convention and added to the area of Forest Management under KP. Emissions and removals are calculated using the average values and calculations as forest land;</p> <p>c) All land that meets the forest definition (FAO) is reported as forest land if there is no evidence of any other predominantly land use (for instance if the land meets the FAO-definition but is used for grazing). If there is unmanaged land (wetland or other Land) that is judged to meet the forest definition (FAO) it will be reported as wetland or other land conversion to forest land. If there are sparsely growing trees on a mire that do not meet the forest definition it will remain under the wetland remaining wetland category. All areas are reported in table 4.1 where it belongs;</p> <p>d) Living biomass is measured on almost all land and the change in stock estimate is considering the biomass before and after a land use conversion. If (in the</p>	<p>This paragraph was discussed with the ERT and comments have been sent to clarify the issue. No changes are made in this Submission apart from the revision of LUC between FL and WL/OL and vice versa as mentioned in chapter 6.</p> <p>Submission 2018: On request, Sweden reports Forest land converted to Other land.</p> <p>[But... The hierarchy in IPCC 2006 GPG volume 4 chapter 3 can be interpreted as referring to managed land only. The introduction of IPCC 2006 GPG states that carbon stock changes and areas should be reported for managed land while only areas for unmanaged land. Within some limits, Parties can define if land is considered managed or not. There is no rule in the IPCC 2006 GPG that claims that managed land cannot become unmanaged.</p> <p>Sweden considers all Forest land as managed and all Other land as unmanaged. If Forest land, that is on the threshold between Forest land and Other land, for natural reasons becomes dryer and no longer fulfills the definition of forest, the land is converted to Other land (unmanaged). The few</p>

CRF category/source - substance/issue type	Provisional Main Finding	Comment with reference to chapter/section in NIR (if relevant)
	<p>mountain area) the biomass is not measured before a land use conversion, a zero change in stock is assumed.</p> <p>The ERT recommends that the Party:</p> <p>a) Follows the hierarchy of land use categories in the IPCC 2016 GL, Volume 4, section 3.2 and reporting all forest land that continues to have a forest cover under forest land in line with the definition of forest land for the Party. In case the forest cover was permanently lost (and not temporary unstocked), that land area should be reported as deforestation. To increase transparency the Party could consider the use of a subcategory for this land use;</p> <p>b) Checks if in the unmanaged land (especially wetland) any area are included that where earlier classified as forest land. In such a case the ERT recommends that the Party applies the same rules as for in use for deforestation (NIR page 488) and report such land as forest land consistently over time. Additionally the ERT recommends that the Party documents the procedure describing when forest land changes to other land and take in this procedure in consideration that the definition of forest land in use by the Party does not restrict forest land to productive forest and that the IPCC guidelines also includes under managed land as land that perform ecological or social functions;</p> <p>c) Improve the transparency by reporting in the NIR how the carbon pools others than biomass are estimated.</p>	<p>and trees are still there and grows slowly.</p> <p>Its quite clear that under the KP this land cannot leave the reporting but there is no similar rule under the UNFCCC.</p> <p>Before Sweden solved this by F to O left the reporting under UNFCCC and O to F was included. If the stock was e.g. 67 for O and 68 for F after the conversion, 1 unit was reported under O to F]</p> <p>Response to ERTs conclusions about what the Party explained.</p> <p>a) It's a gradual change, and at a threshold, land is converted and also the land cover is gradually converted</p> <p>b) Correct</p> <p>c) Correct</p> <p>d) correct</p> <p>Comments to recommendations from the ERT:</p> <p>a) Sweden now reports Forest land converted to Other land. However, we don't follow that land that permanently has lost its forest cover should be reported under deforestation, because "deforestation" is not defined under the UNFCCC</p> <p>b) Sweden already keeps full track of all land use conversions (and when) on 30000 sample plots from before the base year and onwards.</p> <p>c) –</p>

CRF category/source - substance/issue type	Provisional Main Finding	Comment with reference to chapter/section in NIR (if relevant)
L.10 4. General (LULUCF)	The Party reported the total unmanaged land using the notation key IE (CRF table 4.1) and reported also that Wetlands and Other land are considered unmanaged and that only the total areas for Wetland and Other land are reported (NIR page 338). The ERT noted that this is not in line with the footnote 3 to CRF table 4.1. that state that Parties may report only the total area of unmanaged land area and enter the notation key IE under the individual unmanaged land use categories. The ERT encourages that the Party reports the total area of unmanaged land area in CRF table 4.1.	Sweden commented on this paragraph and believe that IE should be used either for total unmanaged land or for individual inmanaged land categories.
L.11 4 (V) Biomass burning – CO ₂ , CH ₄ , N ₂ O Transparency	The Party reported that report it uses a country specific value of 0.25 for the combustion factor (proportion of prefire fuel biomass consumed). The Party reports that it finds a combusted proportion of 25% more realistic with a reference to a picture of post-fire biomass after Swedish forest fire in the country Västmanland 2014 (figure 6.6 on page 365 of the NIR) (NIR page 365). The ERT noted that this is a very minor documentation of a country specific value. During the review, the Party explained that the amount burned biomass is an expert judgement, based on discussion by experts on wildfires. The picture is the largest wildfire in one hundred years (the photo from Västmanland 2014) of about 15 000 ha. After that fire a lot of biomass had died (and is thereafter reported as dead wood) but the burned proportion was estimated to 25% (based on opinion by a group of people visiting many places within the burned area). The ERT recommends that the Party improve the transparency and provide the information how the country specific value was estimated in the next submission.	Has been updated in Submission 2018.
W.2 5.C.1 Waste incineration – indirect gases Transparency	In CRF Table 5, the Party reports the indirect gases from waste incineration. The ERT noticed that these are not mentioned in the NIR in Chapter 9, since it is a good practice to include indirect emissions according to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 7: Precursors and Indirect Emissions. During the review week, Party answered that SO ₂ , NO _x and CO are continuously measured in the flue gases and reported by the facility in the yearly environmental reports. NMVOC are until 2007 as reported by the facility. From 2007 and onwards are the NMVOC emissions calculated, based on IEF for 2007 and yearly incinerated amounts of waste. Documentation of emissions estimates of indirect greenhouse gases will be included in submission 2018 of NIR. The ERT recommends Party to improve the transparency of reporting and present information in their NIR in the next submission.	The recommended information is in Submission 2018 included in NIR (section 7.4.1).

CRF category/source - substance/issue type	Provisional Main Finding	Comment with reference to chapter/section in NIR (if relevant)
KL.1 Forest management – Add gas(es) Transparency	<p>The Party reported that the area of FM increases since 2004 up to 28.30 Mha in 2015 (NIR table 10.6) but did not provide additional data clarifying such increase while in almost all situations the area of FM is expected to decrease due to deforestation.</p> <p>During the review, the Party explained that Land use change from Forest to Wetland or Other land (if it happens) is not defined as deforestation since such land use changes are considered non-anthropogenic and these land areas are kept as FM since accounted land cannot leave accounting. Similarly, the corresponding land use change from Wetland and Other land to Forest land is not considered Afforestation/Reforestation and therefore reported as FM and therefore the area may increase if these LUC is larger than Deforestation.</p> <p>The ERT recommends that the Party check whether these land use changes are not taken place in combination with deforestation activities. In case the Forest land lose it forest cover permanently this area should be reported as deforestation and the related carbon changes should be estimated and reported under Deforestation.</p>	<p>Submission 2018: Sweden has followed the advice and carefully studied all conversions from Forest land to unmanged land for all plots over time. This is about a gradual degradation when e.g. a tree covered mire (Forest land) gradually becomes more saturated by water until it no longer fulfills the forest definition (Wetlands). It's not about a permanent loss in forest cover but a natural land use conversion (The KP claims that D should be human induced. Thus, the KP indicates that non-human induced land use conversions from Forest land exists.).</p>
KL.2 Article 3.3 activities – Add gas(es) Transparency	<p>The Party reported that inventory cycles without a full record to 2015 are extrapolated (see 6.3.1.1. and Figure 6.6 in the NIR). This results in extrapolations of areas. Related to NIR-2 table, Sweden report that it find it inaccurate to extrapolate areas of land use conversions (NIR page 475).</p> <p>During the review, the Party explained that it extrapolates areas for land use/ land use conversions using the trends. But the comment to NIR-2 table should be read as that the Party do not extrapolate land use conversions for individual plots.</p> <p>The ERT recommends that the Party improve the transparency related to the comment to NIR-2 table to clarify that the extrapolate areas for land use/ land use conversions is done using the trends, (not using extrapolate land use conversions for individual plots).</p>	<p>Submission 2018: Implemented by reporting NIR2</p>
KL.6 Harvested Wood Products – CO ₂ (KL.9, 2016) Transparency	<p>The ERT recommends that, in the NIR, Sweden include information on the rationale for the country-specific HWP conversion factors for panels and sawn wood (see issue KL5).</p>	<p>Concidered in Submission 2018, section 6.4.2.6. See table 9.4.</p>

PART 2: SUPPLEMENTARY INFORMATION REQUIRED UNDER ARTICLE 7, PARAGRAPH 1

10 KP-LULUCF

10.1 General information

Sweden provides supplementary information under Article 7 of the Kyoto Protocol (KP) for the Land Use, Land-Use Change and Forestry sector. The requested information is further specified in decision 16/CMP.1, 2/CMP.8, 6/CMP.9 and the Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (IPCC³²¹).

Sweden reports and accounts for Afforestation and Reforestation (AR) and Deforestation (D) under article 3.3 and Forest management (FM) under article 3.4.

Sweden has elected commitment period accounting for LULUCF for the second commitment period.

All carbon pools are reported as well as CO₂ and non- CO₂ emissions associated to the different reported activities. Direct N₂O emissions from N fertilization and emissions from forest fires are reported only under FM. Forests reported under AR are still too young to be fertilized. Forest fires –both natural and wildfires– are uncommon and, this far, has not been registered on ARD-land. Controlled burning is assumed not to occur on ARD land. Emissions of N₂O and CH₄ from drained organic soils and CH₄ emissions from ditches are reported for drained and rewetted organic soils under relevant activities. N₂O emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions and management change in mineral soils are also reported for relevant activities (AR, D, FM) (see Tables 10.1, 10.2 and 10.3).

Table 10.1. Status of reporting under KP-LULUCF with comments.

	Table	Status of reporting
NIR-1	SUMMARY TABLE	R
NIR-2	LAND TRANSITION MATRIX	R
NIR-2.1	LAND TRANSITION	NA, all forest land reported (no definition of "natural forest" or "planted forest" provided by COP/MOP or IPCC)
NIR-3	KEY CATEGORIES	R
4(KP)Recalculations	RECALCULATIONS	R
4(KP)	SUMMARY TABLE	R
4(KP-I)A.1	AR	R

³²¹ Intergovernmental Panel on Climate Change, 2014

Table		Status of reporting
4(KP-I)A.1.1.	AR, NATURAL DISTURBANCES	NA this year
4(KP-I)A.2	D	R, the voluntary subdivision is currently D(Cropland), D(Grazing land) and D(Settlements). If D-land is further converted to either Wetlands, Other land or Forest land such land is reported as D (Settlements). This far, such multi-step transitions of land are uncommon.
4(KP-I)A.2.1.	D, OTHERWISE 3.4	R, D with secondary classification AR or FM
4(KP-I)B.1	FM	R
4(KP-I)B.1.1	FM, FMRL and TECHNICAL CORRECTION	R
4(KP-I)B.1.2	FM, CEF	NA, Carbon equivalent forests not relevant for Sweden
4(KP-I)B.1.3	FM, NATURAL DISTURBANCES	NA, this year
4(KP-I)B.2	CM	NR, not elected
4(KP-I)B.3	GM	NR, not elected
4(KP-I)B.4	REVEGETATION	NR, not elected
4(KP-I)B.5	WDR	NR, not elected
4(KP-I)C	HWP	R
4(KP-II)1	N-FERTILISATION	R (FM)
4(KP-II)2	DRAINED AND REWETTED SOILS	R (FM, AR, D)
4(KP-II)3	MINERALIZATION DUE TO LAND USE CONVERSION	R (FM, AR, D)
4(KP-II)4	BIOMASS BURNING	R, [Wildfires: NO(D), NO(AR), R(FM),]; [Controlled burning: NO(D), NO(AR), R(FM)]

Table 10.2. Status of reporting carbon pools under the KP.

Activity		CHANGE IN CARBON POOL REPORTED						
		Above-ground biomass	Below-ground biomass	Litter	Dead wood	Soil		HWP
						Mineral	Organic	
Article 3.3 activities	AR	R	R	R	R	R	R	R
	D	R	R	R	R	R	R	IO
Article 3.4 activities	FM	R	R	R	R	R	R	R
	CM	NR	NR	NR	NR	NR	NR	
	GM	NR	NR	NR	NR	NR	NR	
	RV	NR	NR	NR	NR	NR	NR	
	WDR	NR	NR	NR	NR	NR	NR	

Table 10.3. Status of reporting GHG sources.

Activity		GREENHOUSE GAS SOURCES REPORTED							
		Fertilization	Drained, rewetted and other soils		Nitrogen mineralization in mineral soils	Indirect N ₂ O emissions from managed soil	Biomass burning		
			CH ₄	N ₂ O			CO ₂	CH ₄	N ₂ O
Article 3.3 activities	AR	NO	R	R	R	NO	NO	NO	NO
	D	NO	R	R	R	NO	NO	NO	NO
Article 3.4 activities	FM	R	R	R	R	R	IE	R	R
	CM		NR		NR		NR	NR	NR
	GM		NR		NR		NR	NR	NR
	RV	NR	NR	NR	NR	NR	NR	NR	NR
	WDR	NR	NR	NR		NR	NR	NR	NR

10.1.1 Emissions/removals from AR, D and FM

The activities Afforestation and Reforestation (AR) and Deforestation (D) are quite rare in Sweden compared to the entire forest land area, each representing additionally a little bit more than 10 kha annually in average. Due to the steadily increasing total area, AR shows an increasing trend in removals due to increased growth whereas emissions from D are more reliant on the amount of biomass harvested on the annual deforested areas. The estimated area under Forest management (FM) is 27.9 Mha and is slightly decreasing (Tables 10.4, 10.5, 10.6 and 10.7).

Table 10.4. Summary of net removals (-)/emissions (+) in aboveground living biomass (LBa), belowground living biomass (LBb), dead wood, litter, and soil organic carbon (SOC) per Article 3.3 activity.

	AR [Mton CO ₂]						D [Mton CO ₂]					
	LBa	LBb	Dead wood	Litter	SOC		LBa	LBb	Dead wood	Litter	SOC	
					Min	Org					Min	Org
2013	-0.985	-0.324	-0.019	-0.294	0.096	0.218	1.334	0.451	0.000	0.479	0.758	0.086
2014	-1.043	-0.343	-0.025	-0.292	0.088	0.221	1.131	0.376	-0.001	0.477	0.731	0.098
2015	-1.082	-0.356	-0.024	-0.300	0.089	0.223	0.748	0.252	-0.001	0.485	0.727	0.100
2016	-1.137	-0.375	-0.030	-0.310	0.089	0.233	0.948	0.317	-0.002	0.517	0.759	0.102

Table 10.5. Summary of net removals (-)/emissions (+) in aboveground living biomass (LBa), belowground living biomass (LBb) dead wood, litter, and soil organic carbon (SOC) per Article 3.4 activity.

	FM (Mton CO ₂)					
	LBa	LBb	Dead wood	Litter	SOC	
					Min	Org
2013	-27.1	-8.93	-7.69	13.55	-17.68	4.45
2014	-25.5	-8.31	-8.03	14.04	-17.67	4.55
2015	-25.5	-8.39	-7.48	14.10	-17.67	4.55
2016	-25.7	-8.48	-7.47	13.98	-17.18	4.54

Table 10.6. The accumulated area under activities AR, D and FM.

(kha)	AR	D	FM
1990	12.3	13.9	28109.2
1991	22.2	28.6	28094.5
1992	27.1	36.6	28086.5
1993	41.6	53.5	28069.6
1994	50.5	62.7	28060.4
1995	58.5	72.2	28051.1
1996	71.1	81.5	28041.8
1997	76.3	94.5	28028.8
1998	81.6	104.2	28022.2
1999	96.6	116.5	28010.0
2000	102.5	127.8	27999.2
2001	110.5	135.9	27992.9
2002	116.5	145.3	27983.5
2003	126.6	153.6	27977.0
2004	138.4	169.0	27962.3
2005	146.4	171.9	27961.5
2006	157.6	178.0	27967.2
2007	175.6	190.6	27966.2
2008	191.8	200.7	27962.2
2009	209.9	214.5	27958.3
2010	236.7	230.8	27943.2
2011	257.6	246.5	27932.8
2012	284.5	258.9	27920.6
2013	303.9	270.0	27909.9
2014	322.9	283.9	27896.2
2015	343.4	295.6	27884.9
2016	363.1	311.0	27869.8

Table 10.7. Emissions of non- CO₂ gases from reported activities emission [kt] for AR, D and FM for the first, second and third year of the second commitment period.

	Year	4(KP-II)1 kt N ₂ O	4(KP-II)2 kt CH ₄	4(KP-II)2 kt N ₂ O	4(KP-II)3 kt N ₂ O	4(KP-II)4 kt N ₂ O	4(KP-II)4 kt CH ₄
AR	2013	-	0.219	0.086	0.025	-	-
	2014		0.221	0.086	0.023	-	-
	2015		0.238	0.093	0.023		
	2016		0.258	0.101	0.023		
D	2013	-	0.048		0.144	-	-
	2014		0.049		0.139	-	-
	2015		0.051		0.138		
	2016		0.055		0.143		
FM	2013	0.065	8.134	3.007	-	0.110	0.001
	2014	0.062	8.228	3.064		1.189	0.008
	2015	0.091	8.225	3.063		0.066	0.000
	2016	0.080	8.218	3.061		0.119	0.001

The KP-reporting uses the same institutional arrangements, national system and corresponding QA/QC procedures as for the UNFCCC reporting. Emissions reported under Article 3, paragraph 3 and 4 are not overlapping with those emissions reported under KP Annex A. The section below focuses on differences in aggregating underlying data between the UNFCCC- and the KP-reporting.

The same underlying methodology is used for the reporting under the KP of the LULUCF-sector as described for the UNFCCC reporting of LULUCF (chapter 6). The estimates of emissions/ removals and areas are based on permanent sample plots inventoried by the Swedish National Forest Inventory covering all land and fresh water areas. A major difference from the UNFCCC reporting is that the living biomass pool is separated into aboveground and belowground living biomass in the reporting under the KP. Only emissions/removals on land under the activities AR, D and FM are reported under the KP.

10.1.2 Definitions of forest and any other criteria

For reporting purposes under the Kyoto Protocol, Forest land is defined, according to the FAO definition, as land with a tree crown cover (or equivalent stocking level) of more than 10 %, an area of more than 0.5 ha and a minimum height of 5 m. Both crown cover and height refers to maturity *in situ*, and consequently, Forest land could temporary be unstocked due to human intervention such as final felling. Normally such land is regenerated within a few years and Forest land is not considered deforested if not confirmed in field. Assessed land that meets the forest criteria above but where other land-use is predominating is not considered Forest land. For example, agriculture land normally fulfils the forest criteria except for the predominant land use and is not considered Forest land. Tree-rows narrower than 10 m are not considered forests. Roads and power-line routes within forests are considered forest only if they are narrower than 5 m. Tree covered areas less than

0.5 ha does not fulfil the forest criteria and is reported as belonging to the neighbouring land use category – this implies that carbon stock changes in living biomass may be reported under any land use category (activity).

The definition of Forest land is consistent with former reporting under the UNFCCC and to other international bodies such as the FAO. However, to be able to trace both gross and net land use transfers, only permanent sample plots are used in the reporting under the UNFCCC and the KP while both temporary (only visited once) and permanent (fixed position and re-inventoried) sample plots are normally used for most assessments and reporting of the Swedish forest situation to other bodies. In both cases the expected values of estimates are the same but estimates might vary from randomness of the sample.

All Forest land is assumed managed. Thus, the definition of Forest land and the assumption that all Forest land is managed are consistent with reporting under the UNFCCC. The underlying data are also consistent for the whole reporting period. The KP-reporting of FM and AR harmonize (areas) virtually with the UNFCCC-reporting of Forest land and land converted to Forest land. However, land that is converted from Forest land to another land use category could either be reported under D or under FM depending on the definition of D. Since Sweden consider only conversion to managed land as D, Forest land converted to Wetland or Other land (both unmanaged) are reported under FM (KP) but under Forest converted to Wetland/Other land under the UNFCCC. This explains the small difference in area between FM+AR and Forest land+land converted to Forest land (see Table 10.5b).

Under the Kyoto Protocol it is central to distinguish between definitions of land use categories, activities and spatial assessment units (Figure 10.1). The definition of Forest land includes criteria for minimum area but this is not the case for activities. For Sweden the spatial assessment unit is a permanent sample plot (radius 10 m) and since this plot could be delineated into more than one land use category, deforestation close to 0 m² could be detected. Area-based sampling is used and each sample plot represents a certain area in the estimation algorithm so that all sample plots together represent the total land and fresh water area of Sweden. The Swedish NFI has the advantage that the sample frame covers all land- categories required for the UNFCCC-reporting. This is essential when both gross and net land use transfers over time have to be traced.

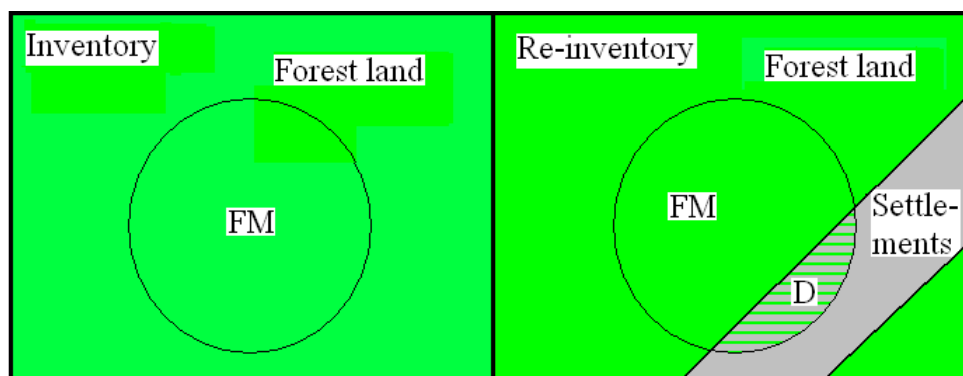


Figure 10.1. Example distinguishing the concepts of land use category, activities under the Kyoto Protocol, and spatial assessment unit in the Swedish sample based inventory. At the first inventory, only the land use category Forest land exists in an area but at the re-inventory part of the Forest land has been deforested to the land use category Settlements. Activities under the Kyoto Protocol are estimated using area based sampling by circular sampling plots (the spatial assessment unit). At the first inventory, the whole plot represents the activity Forest management (FM) but at the re-inventory the plot represent the activities FM and Deforestation (D), respectively. Observe that both land use categories and activities have definitions but Sweden has no minimum area limit set for estimating activities.

10.1.3 Elected activities under Article 3, paragraph 4, of the Kyoto Protocol

For the accounting of LULUCF-activities under article 3.4 during the second commitment period, no voluntary activity has been elected.

10.1.4 Description of how the definitions of each activity under Article 3.3 and each elected activity under Article 3.4 have been implemented and applied consistently over time

Sweden defines Deforestation (D) as land use conversions from Forest land (all forest land area is regarded managed) to Cropland, Grasslands or Settlements (all land under these three categories are assumed managed). Afforestation/ Reforestation (AR) are defined as land use conversions in the opposite direction (Figure 10.2). Land use categories are strictly defined (see NIR chapter 6.2) and land use conversions are observed in field using a five-year inventory cycle. The approximately 30 000 permanent sample plots were laid out between 1983 and 1987 and have thereafter been re-inventoried in a consistent way (Figure 10.3). If the land use of a sample plot or part of a sample plot is assessed as converted between consecutive inventories the conversion is assumed to occur at a random year between the re-measurements. AR on former Cropland, Grasslands and Settlements are connected with an active human decision. Normally regeneration is following shortly after the land conversion. All AR land is by national legislation considered as Forest land and the same definition of Forest land is used in the Forestry act (1979:429 2 § 1.) as for the UNFCCC reporting. The activity Forest management (FM) is assumed occurring on all land fulfilling the forest definition. (see 10.1.1). Land could only be reported under one activity or none (to avoid double counting). Land use conversions are confirmed in field.

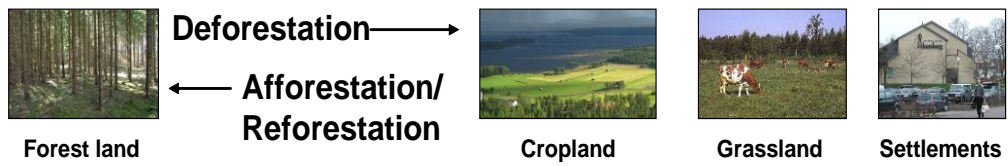


Figure 10.2. D is defined as land use conversions from Forest land (managed) to another managed land use class (all Cropland, Grasslands and Settlements are assumed managed). AR are defined as land use conversions in the opposite direction (C, G or S to F)

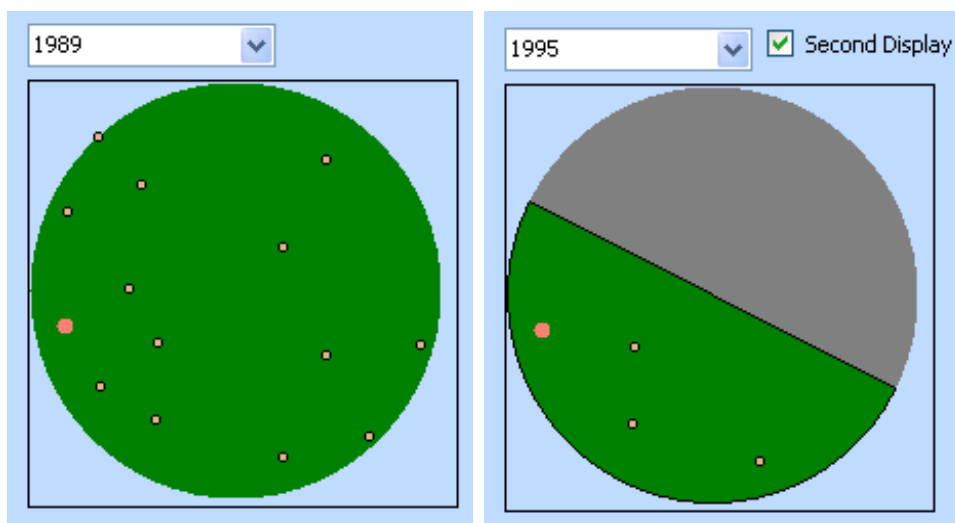


Figure 10.3. The figure shows data for a specific sample plot in the Swedish LULUCF-database. The individual tree biomass on approximately 30 000 permanent sample plots are matched to land use and traced back to before the base year in a consistent way. Applying area based sampling all 30000 permanent sample plots represents the whole land and fresh water area in Sweden and carbon stock changes are estimated using the stock change method on these plots. Part of this specific plot was deforested between 1991 and 1992. The positioning of trees is central when matching carbon stock changes in living biomass to activity (about 75 % of deforested plots are divided into more than one land use category). The position and biomass of the marked tree (right panel) is identified at both inventories and demonstrates the possibility to match individual trees to activities over time.

10.1.5 Descriptions of precedence conditions and/or hierarchy among Article 3.4 activities, and how they have been consistently applied in determining how land was classified.

Precedence conditions are: D, AR and FM. From 1990, land under D cannot leave this category and may therefore have secondary classification AR, FM or none. From 1990, land under AR can only leave this category for D. Land under AR usually has secondary classification FM (if reported under Forest land remaining Forest land or conversion to Forest land under the UNFCCC) or none if converted to unmanaged land. From 1990, land areas under FM that are naturally degraded cannot leave the category and remain under FM. FM has no secondary classification. Some land use conversions are very uncommon and thus some of the above described combinations may not exist.

10.2 Land-related information

10.2.1 Spatial assessment unit used for determining the area of the units of land under Article 3.3

The “Spatial assessment unit”, which is the same as for the UNFCCC-reporting, is used to determine the area of accounting for ARD. The “Spatial assessment unit” is defined as the minimum area used to detect a land use conversion.

Sweden monitors land use transfers based on field measurements using circular sample plots (radius 10 m). If any part of a plot is converted from one land use category to another, it can be detected. Thus, the “Spatial assessment unit” will be a sample plot part and activities down to an area close to 0 m² could be detected. The same “Spatial assessment unit” has consistently been used in both the UNFCCC and the KP-reporting (Figure 10.1).

10.2.2 Methodology used to develop the land use matrix

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

The Swedish National Forest Inventory covers all land and fresh water areas before the base year and onwards on sample plots with a fixed position (permanent sample plots). This makes it possible to consistently trace both gross and net land use transfers over time.

The accumulated AR and D-areas steadily increase by time when estimates are based on a full set of inventory plots (30 000 plots). However, if the estimate is based only on the most recently re-measured plots (6000 plots, this might not always be the case. This is due to the five-year inventory cycle, where the estimates for the five most recent years are based on a decreasing number of plots. To avoid a risk of an incorrect decrease in AR and D area and to improve the accuracy of the estimates, inventory cycles without a full record to 2016 are extrapolated (see 6.3.1.1 and Figure 6.6). The extrapolations of areas and living biomass are based on the trend of the five previous years to the actual year. Several options to make this extrapolation have been used in the past but the method chosen has the advantage that the total land and fresh water area is constant over time. “Five years” is chosen as a trade-off between being enough to reduce random variation and be reasonably up to date. In each submission, data for the four last years of the previous report are re-calculated to limit a potential small risk of bias induced by the extrapolation (a pilot study by historical data indicated that the result of re-calculated data using measured full records of sample plots does not deviate significantly from extrapolated data). IPCC recommends a five-year inventory cycle and to re-calculate data when the intention is to improve the accuracy. Chapter two in IPCC 2006 GL describes that extrapolation is a valid approach to improve estimates for years with missing data. The methodology has also the advantage to improve the accuracy of estimates. The extrapolation has one disadvantage that the NIR-2 table cannot be filled in appropriately, because we find it inaccurate to extrapolate areas of land use conversions. Thus the net areas per activity are exactly the same in the NIR-2 table as in other tables but the transfers between activities are based on the four most recent years (2012-2016).

10.2.3 Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations

Sweden uses a geographical boundary encompassing units of land (Reporting method 1) and has adopted approach 3 (Figure 2.2.1 and Table 2.2.1 in the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the KP) for reporting emissions/removals under article 3 of the KP (Figure 10.4a and 10.4b). In practice a sample frame of approximately 30 000 permanent sample plots is covering all relevant managed land in Sweden (see chapter 6). The sample frame is divided into 31 strata and the distance between sample units within stratum is based on autocorrelation. A five-year inventory cycle is used and each year about 6000 sample plots are inventoried over the whole country. Each sample plot has an identification code and a registered geographical position. This information is confidential due to sampling reasons. However, on request (i.e., in connection with an in country review) it is possible to visit any plot. A certain year, each sample plot (or a part of a sample plot) could only represent one activity (D, AR or FM) or none. The status of activities on sample plots could be traced back from the current year to the base year (1990; Figure 10.4a and b).

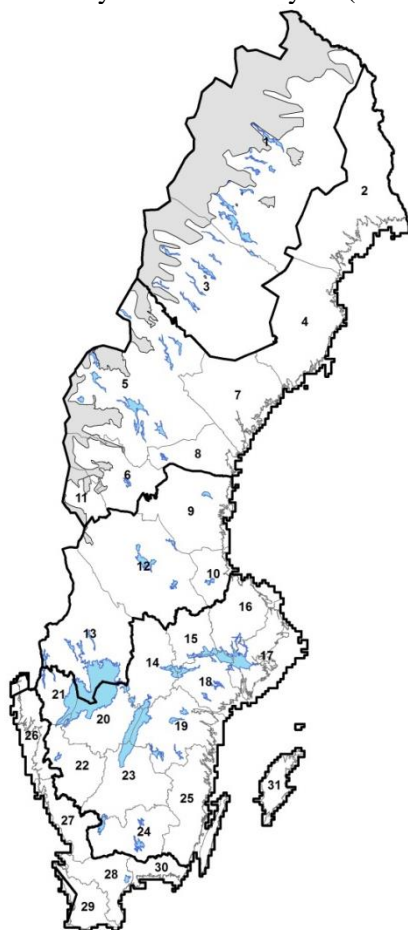


Figure 10.4a. The country is divided into five regions with similar sample design and within 31 strata used for stratification.

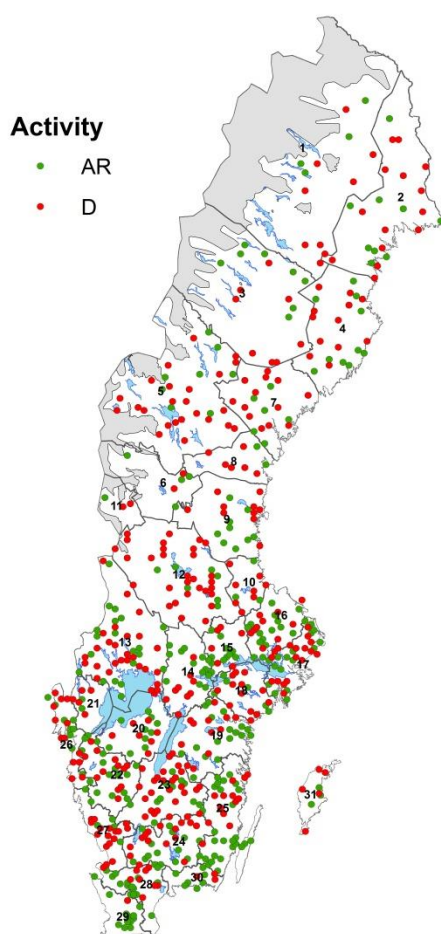


Figure 10.4b. The location of sample plots partly or completely reported under AR and D in Sweden (1990-2016). (On request from the 2013 in country review, the figure is now presenting AR and D per stratum).

10.3 Activity-specific information

10.3.1 Methods for carbon stock change and GHG emission and removal estimates

In most cases, methodologies, models and assumptions under the KP-reporting are consistent with the UNFCCC-reporting. This chapter focuses on discrepancies.

10.3.1.1 DESCRIPTION OF THE METHODOLOGIES AND THE UNDERLYING ASSUMPTIONS USED

10.3.1.1.1 *Carbon pools*

The living biomass pool changes is estimated in exactly the same way as under the UNFCCC reporting using the stock change method and area based sampling (See 6.4 + NIR Annex 3:2). However, the living biomass is reported separately for aboveground and belowground biomass, respectively.

The dead wood, litter and soil organic pools are calculated using the same methods as for the UNFCCC-reporting (See 6.4 + Annex 3:2) using the area distribution associated with the reported activities under the Kyoto protocol (ARD and FM).

All methods used for Living biomass is Tier 3, Litter, Dead wood for FM is Tier 3 and Tier 2 for other activities. Soil organic carbon on mineral soils for FM is Tier 3 whereas it is Tier 2 for ARD. Organic soils for all activities are calculated using a Tier 1 approach.

10.3.1.1.2 Other emissions

Emissions of CO₂, N₂O and CH₄ are estimated in the same way as under the UNFCCC (see 6.4). The estimates of N₂O emissions from fertilisers are based on activity data over used quantities combined with emission factors with no information of the actual geographical distribution of fertilizer used. The fertilization is strictly regulated by the Forestry act and no fertilizer is assumed to be applied in young forests. Therefore all emissions are assumed to occur under the activity FM and none under AR and the reported figure under “Forest Land remaining Forest Land” (UNFCCC, TABLE 4(I)) should correspond to the reported figure under FM (TABLE 4(KP-II)1)). It should be noted that fertilization is very restricted in Sweden. The annual fertilized area is expected to increase in the coming years but to cover less than 0.5 % of the total area of Forest land.

In line with the UNFCCC-reporting (TABLE 4(II)), N₂O and CH₄ emissions from drained and rewetted organic soils (TABLE 4(KP-II)2) are now reported. The emission factors used are the same as used for the UNFCCC-reporting where AR corresponds to managed land converted to Forest land, D to land converted from Forest land to managed land and FM to Forest land remaining Forest land.

The reporting of N₂O emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions and management change in mineral soils (TABLE 4(KP-II)3) are reported for AR, D and FM. The same methods are used as for the UNFCCC-reporting.

All forest fires (TABLE 4(KP-II)4) are reported under FM and this figure should correspond to the figure reported under UNFCCC (UNFCCC, TABLE 4(V)). Forest fires may occur in all kinds of forests but no fires have been registered by the National Forest Inventory on land reported under activities AR.

Indirect emissions of N₂O are calculated as in the UNFCCC-reporting (based on application of fertilisers and mineralisation of N) but included under (TABLE 4(KP-II)1)) together with the direct emissions.

10.3.1.1.3 Activities and the relationship to UNFCCC-categories

Kyoto Protocol Article 3.3 activity areas are accumulated from 1990 and onwards and, normally, do not leave the class.

AR areas may increase due to conversions from managed land (Cropland, Grassland and Settlement) to Forest land and decrease due to land use conversions in the opposite direction. These areas are reported under deforestation. D can only increase by land use change from Forest land to Cropland, Grassland or Settlement. FM areas can increase due to land use change from unmanaged land (Wetland and Other land) and decrease by land use conversions to Cropland, Grassland or Settlement (reported under D). Thus, land uses conversions from Forest land, reported under FM, to unmanaged land remains in the FM reporting. This implies that Forest land remaining Forest land plus Land converted to Forest land under the convention reporting is not exactly the same as Forest management plus AR during the commitment period, since FM will not decrease when Forest land is converted to unmanaged land while Forest land remaining forest land will (Figure 10.5a-d). In addition, for the UNFCCC-reporting converted land stays in the conversion class for twenty years and is thereafter reported under the land use category it was converted to. The twenty-year accumulation of land under the UNFCCC-reporting may begin before the base year and is therefore not suitable to, for example, compare D under the Kyoto Protocol with Forest land converted to Cropland, Grassland or Settlements under UNFCCC. Using conversions from Forest land as a “proxy” for D has led to several misunderstandings when assessing the outcome of the UNFCCC and the KP reporting.

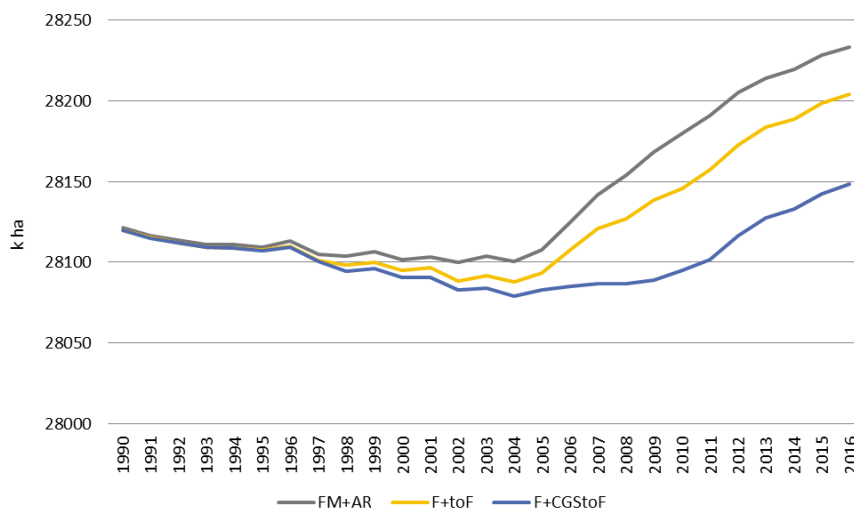


Figure 10.5a. Explaining the deviance between FM+AR and F+toF: In 1990 FM and AR (in practice always with secondary classification FM) constitute the same area as Forest land remaining Forest land+Cropland converted to Forest land+Grassland converted to Forest land+Settlement converted to Forest land+Wetlands converted to Forest land+Other land converted to Forest land. After 1990, land under FM converted to unmanaged land is still reported under FM but not as Forest land under the UNFCCC. In similarity, the same may be valid for AR (AR converted to unmanaged land) but no such conversions have yet been registered.

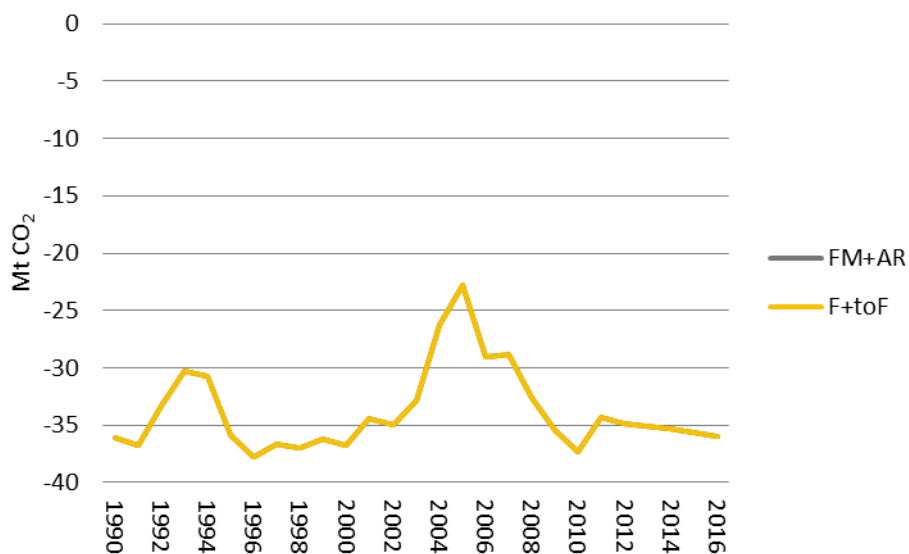


Figure 10.5b. For change in living biomass [Mton CO₂/year] the reported removal is very similar for FM+AR and F+toF –even after 2003 when the automatic rule for correcting inconsistency in land use conversions was removed. (The FM+AR graph is behind the F+toF graph).

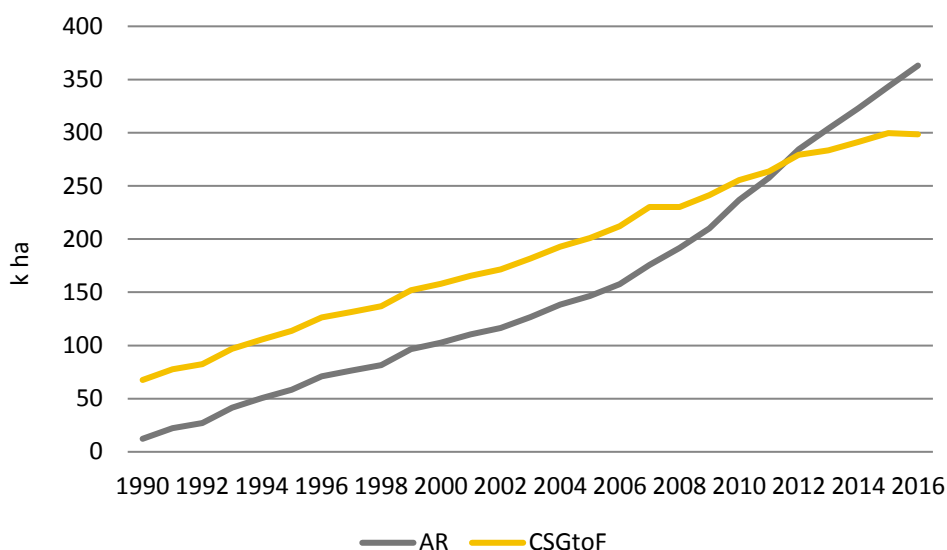


Figure 10.5c. AR is accumulated from 1990 and (more or less) never leaves this category, while Cropland, Grassland or Settlements converted to Forest land under the UNFCCC already exists 1990 (normally from 1983-1987). After 20 years (around 2003-2007) converted land under the UNFCCC is reported under the category it was transferred to (Forest land remaining Forest land).

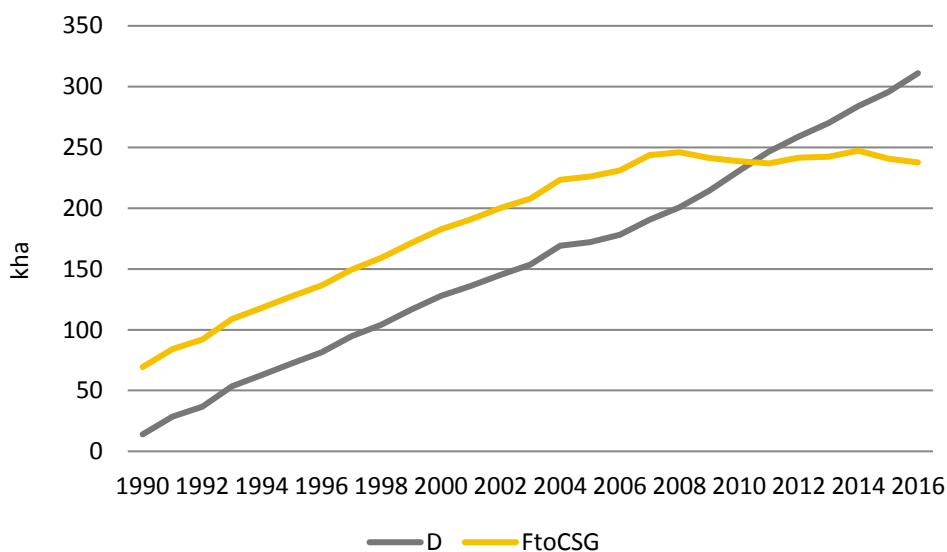


Figure 10.5d. D is accumulated from 1990 and never leaves this category, while Forest land converted to Cropland, Grassland or Settlements under the UNFCCC already exists 1990 (normally from 1983-1987). After 20 years (around 2003-2007) converted land under the UNFCCC is reported under the category it was transferred to.

10.3.1.2 POOLS REPORTED UNDER ARTICLE 3.3 AND ELECTED ACTIVITIES UNDER ARTICLE 3.4

Sweden reports and accounts for all carbon pools (aboveground biomass, belowground biomass, litter, dead wood, soil organic carbon and HWP) as well as for all non-carbon pool emissions.

10.3.1.3 NATURAL DISTURBANCES

Sweden has indicated the intention to apply the provision to exclude emissions from natural disturbances. Emissions from natural disturbances in 2013, 2014, 2015 and in 2016 did not exceed the background level+ the margin for neither Afforestation/Reforestation under article 3.3 nor for Forest management under article 3.4.

10.3.1.3.1 Identification of lands subject to the exclusion due to natural disturbances

Referring to decision 2/CMP.8, Annex II, paragraph 2 (f) (i), lands subject to the exclusion due to natural disturbances, including their georeferenced location, year and types of disturbances shall be identified. No land was subject to exclusion in years 2013, 2014, 2015 or 2016.

10.3.1.3.2 Annual emissions and subsequent removals areas excluded from the accounting;

Referring to decision 2/CMP.8, Annex II, paragraph 2 (f) (ii), the estimation of annual emissions resulting from natural disturbances and the subsequent removals during the commitment period in areas excluded from the accounting shall be described. No land was subject to exclusion in 2013, 2014, 2015 or in 2016.

10.3.1.3.3 Land-use change occurring on lands for which the Natural disturbances provision apply

Referring to decision 2/CMP.8, Annex II, paragraph 2 (f) (iii), Parties shall show that no land-use change has occurred on lands for which the provisions contained in decision 2/CMP.7, annex, paragraph 33, are applied and explain the methods and criteria for identifying any future land-use changes on those land areas during the second commitment period. No land was subject to exclusion in 2013, 2014, 2015 or in 2016.

10.3.1.3.4 Demonstration that the events or circumstances related to excluded emissions from Natural disturbances were beyond the control of the Party

Referring to decision 2/CMP.8, Annex II, paragraph 2 (f) (iv), Parties shall demonstrate that the events or circumstances were beyond the control of, and not materially influenced by, the Party in the commitment period, by demonstrating practicable efforts to prevent, manage or control the events or circumstances that led to the application of the provisions contained in decision 2/CMP.7, annex, paragraph 33. No land was subject to exclusion in 2013, 2014, 2015 or in 2016.

10.3.1.3.5 Efforts taken to rehabilitate, where practicable, the land for which the natural disturbances provisions are applied

Referring to decision 2/CMP.8, Annex II, paragraph 2 (f) (v), Parties shall demonstrate efforts taken to rehabilitate, where practicable, the land for which the provisions contained in decision 2/CMP.7, annex, paragraph 33, are applied. No land was subject to exclusion in 2013, 2014, 2015 or in 2016.

10.3.1.3.6 *Salvage logging*

Referring to decision 2/CMP.8, Annex II, paragraph 2 (f) (vi), Parties shall show that emissions associated with salvage logging were not excluded from accounting. No land was subject to exclusion in 2013, 2014, 2015 or in 2016.

10.3.1.4 HWP

The methodology used for accounting for net emissions from the HWP pool was identical to the method used for the reporting of HWP under the UNFCCC described in chapter 6 with the exception of the exclusion of HWP originating from deforestation (D) events. The methodology was also in agreement with decision 2/CMP.7 and the KP-supplement. According to paragraph 31 in decision 2/CMP.7, HWP resulting from D shall be accounted for on the basis of instantaneous oxidation. Thus, HWP from D was subtracted from the total production of HWP from Swedish forests, resulting in HWP from forest management (FM), during 1990-2016 by estimating: i) the deforested area, ii) harvested volume on the deforested area, iii) the sawlog fraction, iii) the volume of sawn wood, iv) the volume of woodchip, v) the fractions of sawn wood, paper and wood based panels from D. The deforested area was derived from the NFI, and the harvested volume from D was calculated: $(\text{mean volume/ha}) \times (\text{deforested area, ha})$. Mean volumes for Swedish forests were calculated using NFI-data. D was assumed to occur irrespective of forest developmental stage and therefore the mean volume was used to estimate the harvested volume.

Functions were used to calculate the proportion of industrial roundwood and proportion of sawlogs by using min top diameter, min sawlog diameter, and basal area weighted mean diameter for the whole country as independent variables³²². Min top diameter was set to 5 cm, and min sawlog diameter to 13 cm. Basal area weighted mean diameter for each year was calculated for all trees measured on forest land by the NFI. Pulpwood proportion was calculated as: $[(\text{proportion of industrial round wood}) - (\text{proportion of sawlogs})]$. The estimated harvested volume from D was multiplied with the proportions of each assortment in order to obtain the harvested volume of sawlogs and pulpwood. The volume of sawnwood from D was calculated by multiplying the volume of sawlogs with the exchange of sawnwood from sawlogs within FM, and was subtracted from the total inflow of sawnwood. Woodchips are made from the remaining fraction of the sawlogs adding the pulpwood volume and constitutes the raw material for paper and wood based panels. The quota chipsD/chipstotal was used to exclude inflow of paper and wood based panels from D.

HWP from AR was reported as not occurring, since no harvest were detected on areas subjected to AR since 1990.

³²² Ollas, 1980

10.3.1.5 INFORMATION ON WHETHER OR NOT INDIRECT AND NATURAL GHG EMISSIONS AND REMOVALS HAVE BEEN FACTORED OUT

Sweden does not factor out effects from elevated carbon dioxide concentrations above pre-industrial levels, indirect nitrogen deposition, the dynamic effects of age structure resulting from activities prior to 1 January 1990. However, the accounting for Forest management using a reference level equals out such effects since they are included both in the reference level and in the reported figures.

10.3.1.6 CHANGES IN DATA AND METHODS SINCE PREVIOUS SUBMISSIONS (RECALCULATIONS)

Changes in reported data and methods follow the changes as described in section 6.4.5 for the UNFCCC-reporting of LULUCF.

Table 10.8. Differences in areas between submission 2017 and 2018.

(Mha)	Submission 2017			Submission 2016			Difference [%]		
	AR	D	FM	AR	D	FM	AR	D	FM
2013	0.304	0.270	27.910	0.310	0.270	28.249	-2.0 %	0.0 %	-1.2 %
2014	0.323	0.284	27.896	0.329	0.285	28.273	-1.8 %	-0.4 %	-1.3 %
2015	0.343	0.296	27.885	0.353	0.297	28.295	-2.7 %	-0.5 %	-1.4 %
2016	0.363	0.311	27.870						

Table 10.9. Differences in reported change in living biomass between submissions.

(Mt CO ₂ /yr)	Submission 2017			Submission 2016			Diff. 2017-2016		
	AR	D	FM	AR	D	FM	AR	D	FM
2013	-1.31	1.79	-36.04	-1.31	1.70	-34.03	0.00	0.09	-2.01
2014	-1.39	1.51	-33.77	-1.40	1.28	-34.36	0.01	0.23	0.59
2015	-1.44	1.00	-33.94	-1.47	0.32	-34.75	0.03	0.68	0.81
2016	-1.51	1.26	-34.15						

10.3.1.7 UNCERTAINTY ESTIMATES

Estimates of carbon stock changes are based on the same underlying data as the reporting under the UNFCCC. These estimates originate mainly from a sampling design with the intention to keep systematic errors as low as possible. The systematic error is reduced by using representative functions, by direct measurements in field and at laboratory. We assume that the major source of uncertainty arise from random variation due to sampling. The sampling error is estimated using statistical theory for living biomass and partly for other carbon pools (all Tier 3). A consistent methodology for estimating carbon pools has been used from 1990 and onwards. Therefore, we expect the uncertainty to be the same for all years where all sample units are used to estimate the annual change. The uncertainties for other categories are assumed by expert judgment. From submission 2013, Sweden provides separate formal estimates of uncertainty of AR and D, respectively.

Based on 30000 sample plots the accuracy of estimates of carbon stock changes for ARD activities are certain in absolute but uncertain in relative terms. The estimated accuracy (Standard Error) for living biomass for AR and D is around 0.2 and 0.5 Mt CO₂ per year, respectively. This is valid when estimates are based on all 30000 sample plots. However, if based on one year sample (6000 plots), the estimated accuracy (Standard Error) for living biomass for AR and D is much higher and to increase the accuracy Sweden uses extrapolated data for the most recent years. Since ARD is quite uncommon in Sweden and quite close to zero the relative error might be large. The corresponding estimated accuracy for FM is 3 Mt CO₂ per year (when based on 6000 sample plots, around 7 Mt CO₂ per year). 3 Mt CO₂ per year should be compared with a total stock of more than 4000 Mt CO₂ (relative error 0.07 %). For other carbon pools than living biomass, the uncertainty is based on assumptions³²³.

³²³ This section is an amendment due to a request from reviewers (ARR 2011) to improve the information on uncertainties in estimates of ARD.

Table 10.10. Estimated and assumed uncertainty for KP-activities (Uncertainty=2•relative “standard error”).

Activity	Category	2-Relative Standard Error, %		
		CO ₂	N ₂ O	CH ₄
FM	Living biomass	20	-	-
	Dead organic matter	50	-	-
	Soil organic carbon	35	-	-
	Direct and indirect, 4(KP-II)1	-	50	-
	Drainage, 4(KP-II)2		100	100
	Biomass burning, 4(KP-II)4	-	100	100
	HWP, 4G	25	-	-
AR	Living biomass	30	-	-
	Dead organic matter	50	-	-
	Soil organic carbon	35	-	-
	Drainage, 4(KP-II)2		100	100
	Mineralisation, 4(KP-II)3		100	
D	Living biomass	67	-	-
	Dead organic matter	50	-	-
	Soil organic carbon	35	-	-
	Drainage, 4(KP-II)2		100	100
	Mineralisation, 4(KP-II)3	-	100	-

10.3.1.8 INFORMATION ON OTHER METHODOLOGICAL ISSUES

There are currently no methods identified that needs further clarification than those already explained.

10.4 Article 3.3

10.4.1 Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2020 and are direct human-induced

Sweden defines D as land use conversions from Forest land (all managed) to Cropland, Grasslands or Settlements (all land under these three categories are assumed managed). AR is defined as land use conversions in the opposite direction (Figure 10.2). Land use categories are strictly defined (see NIR chapter 6.2) and land use conversions are confirmed in field at consecutive inventories. The estimates are based on area sampling using the approximately 30 000 permanent sample plots (see chapter 6 for further details on the NFI). The inventory has been consistent since 1983.

This implies that Sweden uses the broad interpretation of “direct human induced” and an active human removal of trees followed by a land use conversion from Forest land to a managed non-forest land use category is considered direct human induced deforestation. This is also valid for the choice to actively abandon managed land in favour for the management of forests (afforestation/reforestation).

The management of Forest land on abandoned former managed non-forest land is regulated by the Forestry act (1979:429). The intention of a human induced land use conversion should be permanent. If, for example, a land owner decides to convert former Cropland to Forest land by planting trees, this action is considered AR, but if the land owner in the future decides to cultivate this land back to Cropland, then the land will be reported under D. No such reversed-conversions have been identified (this far).

The NFI is used to confirm that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2020 and are direct human-induced. If the land use of a sample plot or part of a sample plot is considered converted between consecutive inventories the year of conversion is randomly distributed.

10.4.2 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation

Final felling is a natural step in the rotation cycle of forestry. Also storms may result in large areas of felled trees (wind-throws). If final felling or disturbances as storms have been identified between two consecutive inventories this is not enough to classify the plot as D. However, if for instance a new road, a power line or other land use preceding the definition of forest is located on the former Forest land, the plot is considered D. The emission from “loss of biomass” is matched to the conversion year. If final felling has occurred on a plot between two consecutive inventories with no sign of D, but D is confirmed at the next re-inventory, then the year of D is “re-calculated” to match the “loss of biomass” to the conversion year.

10.4.3 Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested

Annually, about 200 000 ha³²⁴ of Forest land is losing its forest cover as a natural step in the forest rotation cycle. The position and status of every sample plot that has lost forest cover is known but D is not reported until confirmed in field (see 10.4.2).

³²⁴ Swedish University of Agricultural Sciences, 2010

10.5 Article 3.4

10.5.1 Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human induced

The activity FM is assumed to occur on all Forest land (not reported as AR) and land areas with precedence classification FM is reported under Article 3.4 FM. The area under FM is quite stable over the reported period. Land reported under AR usually has secondary classification FM. Since all land use categories, including Forest land, are consistently monitored in field since 1983 it is possible to trace back all land use categories and land use conversions to at least 1990. Land under activity FM is accumulated from 1990 but could leave the category for D at any time. If land under activity FM is converted to unmanaged land by natural degradation it will remain classified as FM in the reporting. "Human induced" is assumed equivalent with "managed" and all Forest land is assumed managed. Most forest biomass is actively managed for timber and pulp production and remaining forest biomass is managed for nature conservation. The definition used coincides with definition of Forest land according to the Forestry act (1979:429).

10.5.2 For Parties included in Annex I that elect cropland management and/or grazing land management and/or revegetation and/or wetland drainage and rewetting, anthropogenic GHG emissions by sources and removals by sinks for each year of the commitment period and for the base year

Not applicable (not elected)

10.5.3 Information that demonstrates that emissions by sources and removals by sinks resulting from forest management under Article 3, paragraph 4, and any elected activities under Article 3, paragraph 4, are not accounted for under activities under Article 3, paragraph 3;

Land can only be reported under one activity or none (see section 10.1.4). Using the precedence conditions: D, AR, FM, or no activity, makes it possible to check that a sample unit is reported only once under one activity. The sum of areas is the same every year and secondary classification is also checked. Finally, the consistent sample based design from before 1990 and onward makes it simple to avoid overlaps and by mistake exclude land.

10.5.4 Information on how all emissions arising from the conversion of natural forests to planted forests are accounted for in accordance with any supplementary

methodological guidance developed by the IPCC and adopted by the CMP;

Not relevant for Sweden. There is no official definition of “natural forests” in Sweden or by the IPCC. On the other hand since all forest land is assumed managed all forests are also reported.

10.5.5 Information that demonstrates methodological consistency between the reference level and reporting for forest management during the second commitment period, including the area accounted for, the treatment of harvested wood products, and the accounting of any emissions from natural disturbances;

The coverage of pools and other emissions in the Forest management reference level (FMRL) was consistent with the information provided in the 2011 National inventory report according to the UNFCCC-LULUCF format with three carbon pools. However, due to technical reasons the boundaries between pools according to KP-LULUCF in the historical data and the projected data differ slightly.

Emissions and removals from harvested wood products in the projection were calculated using the same methodology as for the historical data at that time. The numbers include HWP data also for article 3.3-activities. This is consistent with the methodology in the projection of living biomass, which includes all forest land. Natural disturbances as reported at the time for the submission of the FMRL were also included in the estimate. For further information of the development of the FMRL, see the official submission from 2011³²⁵.

Since the submission of the FMRL, the mandatory reporting of Forest management has been amended to include emissions/removals from the harvested wood products pool (HWP), DOC and non- CO₂ emissions from organic soils, mineralization due to management change and indirect N₂O and induced the need to perform a technical correction (see further information below).

³²⁵ Anonymous 2011

10.5.6 Any technical corrections made pursuant to decision 2/CMP.7, annex, paragraph 14, to ensure consistency between the reference level and reporting for forest management during the second commitment period

Following decision 2/CMP.7 and the guidance to identify the need for a technical correction in section 2.7.6 of the IPCC 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol³²⁶ Sweden has performed a technical correction for the forest management reference level. In this submission the correction was calculated due to the following reasons:

- Carbon stock change in Living biomass representing the period 2005-2009 has been updated due to slightly revised data from the NFI.
- The historical dataset for Soil organic carbon and litter representing the period 2000-2009 has been updated using new inventory data from the soil inventory.
- The historical dataset used to calculate average values for 2000-2009 has been revised due to revised areas of forest remaining forest land and the area of drained organic soils. This revision affects the estimates of CO₂, DOC, N₂O and CH₄ (including ditches) from drained organic soils.
- As the area of reported FM area decrease over time, the FMRL and the corresponding TC has been weighted using the relationship between the extrapolated area for FM for the years 2017-2020 and the area used in the simulations of the FMRL.

All of the issues, except the area issue, listed above affects the historical estimates and the projected values.

The forest management reference level was recalculated to -32.2 Mt CO₂-eq. and the technical correction applied to the original value was estimated to 9.2 Mt CO₂-eq.

Table 10.11 illustrates the differences in the different components included in the reference level.

³²⁶ IPCC 2014

Table 10.11. Background data for the technical correction of the forest management reference level.

Forest management (Submission 2011)		Reported	Projection		
		2007	2015	2020	2013-2020
Living biomass	Mt CO ₂	-19.55	-23.66	-22.80	
Litter	Mt CO ₂	-1.42	-1.37	-0.60	
Dead wood	Mt CO ₂	-10.26	-6.51	-5.38	
Soil organic carbon	Mt CO ₂	-5.76	-5.58	-5.48	
Fertilisation (N ₂ O)	Mt CO ₂ -eq	0.04	0.03	0.03	
Biomass burning (N ₂ O, CH ₄)	Mt CO ₂ -eq	0.03	0.07	0.07	
HWP	Mt CO ₂	-9.52	-5.59	-4.67	
TOTAL EXCL. HWP	Mt CO ₂ -eq	-36.95	-37.09	-34.23	
TOTAL WITH HWP	Mt CO ₂ -eq	-46.47	-42.61	-38.83	
FM area	Kha	28 076	28 180	28 180	
FMRL	Mt CO₂ -eq				-36.06
FMRL with HWP	Mt CO₂-eq				-41.34
Forest management (Submission 2018)		2007	2015	2020	2013-2020
Living biomass	Mt CO ₂	-27.97	-23.66	-22.80	
Litter	Mt CO ₂	12.95	11.84	12.61	
Dead wood	Mt CO ₂	-8.49	-6.51	-5.38	
Soil organic carbon	Mt CO ₂	-10.71	-9.90	-9.80	
Fertilisation (N ₂ O)	Mt CO ₂ -eq	0.04	0.03	0.03	
Drainage (N ₂ O, CH ₄)	Mt CO ₂ -eq	1.41	1.40	1.40	
Biomass burning (N ₂ O, CH ₄)	Mt CO ₂ -eq	0.03	0.01	0.01	
HWP	Mt CO ₂	-11.20	-7.04	-5.16	
TOTAL	Mt CO ₂ -eq	-32.78	-26.80	-23.94	
TOTAL WITH HWP	Mt CO ₂ -eq	-43.98	-33.83	-29.09	
FM area	Kha	27 966	27 962	27 958	
FMRL	Mt CO ₂ -eq				-25.75
FMRL with HWP	Mt CO₂-eq				-32.18
Difference (Submission 2011-Submission 2018)		2007	2015	2020	2013-2020
Living biomass	Mt CO ₂	8.42	0	0	
Litter	Mt CO ₂	-14.37	-13.21	-13.21	
Dead wood	Mt CO ₂	-1.77	0	0	
Soil organic carbon	Mt CO ₂	4.95	4.32	4.32	
Fertilisation (N ₂ O)	Mt CO ₂ -eq	0	0	0	
Drainage (N ₂ O, CH ₄)	Mt CO ₂ -eq	-1.41	-1.40	-1.40	
Biomass burning (N ₂ O, CH ₄)	Mt CO ₂ -eq	0.03	0.06	0.06	
HWP	Mt CO ₂	1.68	1.45	0.49	
TOTAL	Mt CO ₂ -eq	-4.17	-10.29	-10.29	
TOTAL WITH HWP	Mt CO ₂ -eq	-2.49	-8.78	-9.74	
FM area	Kha	110.00	218.00	222.00	
Technical correction	Mt CO₂-eq				10.3
Technical corr. with HWP	Mt CO₂-eq				9.2

10.6 Other information

10.6.1 Key category analysis for Article 3.3 activities and any elected activities under Article 3.4

The IPCC 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (2.3.6) recommends that whenever a category is identified as key under the UNFCCC the associated activity under the KP should also be treated as a Key-Category. If the correspondence between the UNFCCC categories and the KP activity is poor, a qualitative assessment is recommended. The correspondence could be based on Table 2.1. 1 (ibid.).

Sweden defines land use conversions from Cropland, Grassland and Settlements to Forest land as AR and land use conversions in the opposite direction as D. Forest land remaining Forest land and Wetland or Other land converted to Forest land are assumed to correspond to the activity FM. Thus, the Key-category analysis indicates that FM, AR and D are Key categories for the Kyoto Protocol. All these activities are monitored using higher Tiers. Forest land converted to Settlements for N₂O is also identified as a Key-category and is assumed to correspond to D. This category is monitored using Tier 2.

10.7 Information relating to Article 6

Information relating to Article 6 is provided in Annex 6:1 and 6:3.

10.8 Coming improvements

See section 6.4.6.

11 Information on accounting of Kyoto units

11.1 Background information

Each Party must include information on its aggregate holdings and transactions of Kyoto Protocol units in its annual report. The reporting will be submitted according to the special report standard, the Standard Electronic Format (SEF) with the annual inventory on 15 April. Sweden began the annual reporting in 2009.

Sweden's Standard Electronic Format report for 2017 containing the information required in paragraph 11 of the annex to decision 15/CMP.1 The SEF will be submitted to the UNFCCC Secretariat electronically.

11.2 Summary of information reported in the SEF tables

Annual Submission Item	Party provided content
15/CMP.1 annex I.E paragraph 11: Standard electronic format (SEF)	Sweden's Standard Electronic Format report for 2017 will contain the information required in paragraph 11 of the annex to decision 15/CMP.1. See document/files: <i>RREG1_SE_2017_2_1.xlsx</i> , <i>RREG1_SE_2017_2_1.xml</i> and <i>RREG1_SE_2017_2_1.zip</i>

11.3 Discrepancies and notifications

Annual Submission Item	Party provided content
15/CMP.1 annex I.E paragraph 12: List of discrepant transactions	Refer to Separate Electronic Attachment "SIAR Reports 2017-SE v 1.0.xls" Worksheet R2.
15/CMP.1 annex I.E paragraph 13 & 14: List of CDM notifications	No CDM notifications were received by the National Registry during the 2017 reporting period, pursuant of 15/CMP.1 annex I.E paragraphs 13 & 14. Refer to Separate Electronic Attachment "SIAR Reports 2017-SE v 1.0.xls" Worksheet R3.
15/CMP.1 annex I.E paragraph 15: List of non-replacements	No non-replacements occurred during the 2017 reporting period, pursuant of 15/CMP.1 annex I.E paragraph 15. Refer to Separate Electronic Attachment "SIAR Reports 2017-SE v 1.0.xls" Worksheet R4.
15/CMP.1 annex I.E paragraph 16: List of invalid units	No invalid units exist as at 31 December 2017, pursuant of 15/CMP.1 annex I.E paragraph 16. Refer to Separate Electronic Attachment "SIAR Reports 2017-SE v 1.0.xls" Worksheet R5.
15/CMP.1 annex I.E paragraph 17: Actions and changes to address discrepancies	No actions and changes to address discrepancies have been performed during the reported period due to that no discrepancies occurred.

11.4 Publicly accessible information

Annual Submission Item	Party provided content
15/CMP.1 annex I.E Publicly accessible information	<p>The following information is now deemed publicly accessible and as such is available via the homepage of the SE registry and Swedish Energy Agency – https://www.energimyndigheten.se/en/sustainability/eu-ets---implementation-in-sweden/the-swedish-emissions-trading-registry/public-information/</p> <p>or via the link directly to the account holder information.</p> <p>In accordance with the requirements of Annex E to Decision 13/CMP.1, all required information for a Party with an active Kyoto registry is provided with the exceptions as outlined below.</p> <p>Account Information (Paragraph 45) and Account holders authorised to hold Kyoto units in their account (Paragraph 48)</p> <p>In light of the amendments introduced by Article 78 of the revised Registries Regulation that came into force in October 2010 and 2013 and for security reasons, it is considered that the representative identification information as required in paragraph 45 and paragraph 48 is held as confidential.</p> <p>Since there are no provisions in Swedish law on which kyoto unit types legal entities are authorised to hold in the Swedish National Registry, It is difficult to provide a list of legal entities authorized to hold party holding accounts. All legal entities (person or organisation) authorized to participate in the Swedish national registry under the Kyoto mechanisms, must have a separate holding account for each legal entity according to the Data Exchange Standards (DES). The list of legal entities that currently have party holding accounts in the Swedish registry can be found through a report tool on the following public website: https://www.energimyndigheten.se/en/sustainability/eu-ets---implementation-in-sweden/the-swedish-emissions-trading-registry/public-information/</p> <p>JI projects in Sweden (Paragraph 46)</p> <p>No Article 6 (Joint Implementation) projects have been reported for conversion to ERU under an Article 6 project. The list of the conversion that occurred in the Swedish registry can be found through a reports on the following public website:</p>

Annual Submission Item	Party provided content
15/CMP.1 annex I.E Publicly accessible information	<p>https://www.energimyndigheten.se/en/sustainability/eu-ets---implementation-in-sweden/the-swedish-emissions-trading-registry/public-information/</p> <p>Holding and transaction information of units (Paragraph 47)</p> <p>Holding and transaction information is provided on a holding type level, due to more detailed information being declared confidential by EU Regulation. Publicly available information via the following link, https://www.energimyndigheten.se/en/sustainability/eu-ets---implementation-in-sweden/the-swedish-emissions-trading-registry/public-information/</p> <p>Article 6 of EU Regulation 389/2013/EC, provides that “All information, including the holdings of all accounts and all transactions made, held in the registries and the Community independent transaction log shall be considered confidential for any purpose other than the implementation of the requirements of this Regulation, Directive 2003/87/EC or national law.”</p> <p><u>Paragraph 47c</u></p> <p>The total quantity of ERUs issued and converted on the basis of Article 6 projects (Joint Implementation), are displayed in the public accessible information on the web site.</p> <p><u>Paragraph 47e</u></p> <p>Sweden does not perform LULUCF activities and therefore does not issue RMUs</p> <p><u>Paragraph 47g</u></p> <p>No ERUs, CERs, AAUs and RMUs have been cancelled on the basis of activities under Article 3, paragraphs 3 and 4 to date.</p> <p><u>Paragraph 47h</u></p> <p>No ERUs, CERs, AAUs and RMUs have been cancelled following determination by the Compliance Committee that the Party is not in compliance with its commitment under Article 3, paragraph 1 to date.</p> <p><u>Paragraph 47j</u></p> <p>No ERUs, CERs, AAUs and RMUs have been retired, other than retirements of CERs and AAUs as an outcome of the EU compliance retirement within EU Emission Trading Scheme (EU ETS) and not through retirement under article 3, paragraphs 3 and 4. Retired CERs and AAUs are presented in the SEF report.</p>

Annual Submission Item	Party provided content
15/CMP.1 annex I.E	<u>Paragraph 47k</u> Sweden did not carry over ERUs, CERs, and AAUs from the previous commitment period, no carry over for ERUs, CERs, and AAUs are reported.
Publicly accessible information	<u>Paragraph 48</u> List of legal entities authorized by Party provided via the following link http://ec.europa.eu/clima/policies/ets/registry/docs/se_legal_en.xls

The previous Annual Review recommendations	No recommendations regarding changes in registry for 2017. FCCC/ARR/2016/SWE.
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11.5 Calculation of the commitment period reserve (CPR)

11.5.1 Assigned Amount

The individual assigned amount for Sweden was established at 315 554 578 assigned amount units (AAUs), in accordance with the notification of the terms of the agreement to fulfil the commitment jointly by the European Union, its Member States, and Iceland (Council decision (EU) 2015/1339). Sweden's assigned amount was defined as the sum of the annual emission allocations for the period 2013 – 2020 determined pursuant to decision No 406/2009/EC. That amount, based on global warming potential values from the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, was determined under Annex II to Commission decision 2013/162/EU and adjusted by Commission Implementing decision 2013/634/EU.

Since Sweden's land-use change and forestry did not constitute a net source of greenhouse gases in 1990, no addition has been made in regards to that sector. Article 3.7bis of the Kyoto Protocol states that parties for whom land-use change and forestry constituted a net source of greenhouse gas emission in 1990 shall include in their 1990 emissions base year those equivalent emissions minus removals by sinks for the purpose of calculating its assigned amount.

11.5.2 Commitment Period Reserve (CPR)

Parties are required by decision 11/CMP.1 under the Kyoto Protocol and paragraph 18 of decision 1/CMP.8 to establish and maintain a commitment period reserve as part of their responsibility to manage and account for their assigned amount. The commitment period reserve equals: (i) the lower of either 90 % of a Party's assigned amount pursuant to Article 3(7bis), (8) and (8bis), or (ii) 100 % of its most recently reviewed inventory, multiplied by 8.

According to definition (i), the commitment reserve would amount to 90 % of Sweden's assigned amount, which is equal to 283 999 121 t of CO₂-eq.

According to definition (ii), the commitment period reserve would amount to eight times the sum of the most recent greenhouse gas inventory. The commitment period reserve according to definition (ii) based on submission 2018 of the greenhouse gas inventory is reported in Table 11.1.

The commitment period reserve is therefore established in line with definition (i), amounting to 283 999 121 assigned amount units.

Table 11.1. The commitment period reserve.

Year	Inventory Total (t CO₂-eq.)	Commitment Period Reserve according to definition (ii) (t CO₂-eq.)
2013	55 537 398	444 299 181
2014	53 836 241	430 689 927
2015	53 690 357	429 522 860
2016	52 892 716	423 141 728

11.6 KP-LULUCF accounting

Sweden reports and accounts for activities under article 3.3 and the activity Forest management under article 3.4 of the Kyoto protocol. Detailed descriptions on definitions of activities and carbon pools as well as methods for the quantification of emissions and removals related to these activities can be found in chapter 10 of the NIR. For 2016 the activities under article 3.3 constituted a net source of about 1.2 Mt CO₂eq. Forest management under article 3.4 constituted a net removal of 46 Mt CO₂eq. According to section C and paragraph 13 in 2/CMP.7 “For the second commitment period, additions to the assigned amount of a Party resulting from forest management under Article 3, paragraph 4, and from forest management project activities undertaken under Article 6, shall not exceed 3.5 % of the base year greenhouse gas emissions excluding land use, land-use change and forestry pursuant to Article 3, paragraphs 7 and 8, or any amendments thereto, times the duration of the commitment period in years.”. 3.5 % of the base year emission is 2.5 Mt CO₂eq/year and for the entire second commitment period the additions to the assigned amount resulting from Forest management can be up to 20 Mt CO₂eq. However it may be noted that Sweden has elected commitment period accounting. The referred figures for article 3.3 and article 3.4, FM, represent only 2016.

12 Information on changes in national system

No changes to the national system has been made.

13 Information on changes in national registry

The following changes to the national registry of Sweden have therefore occurred in 2017.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(a) Change of name or contact	None
15/CMP.1 annex II.E paragraph 32.(b) Change regarding cooperation arrangement	No change of cooperation arrangement occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(c) Change to database structure or the capacity of national registry	<p>The version of the EUCR released after 8.0.7 (the production version at the time of the last Chapter 14 submission) introduced minor changes in the structure of the database.</p> <p>These changes were limited and only affected EU ETS functionality. No change was required to the database and application backup plan or to the disaster recovery plan. The database model is provided in Annex A.</p> <p>No change to the capacity of the national registry occurred during the reported period.</p>
15/CMP.1 annex II.E paragraph 32.(d) Change regarding conformance to technical standards	<p>Changes introduced since version 8.0.7 of the national registry are listed in Annex B.</p> <p>Each release of the registry is subject to both regression testing and tests related to new functionality. These tests also include thorough testing against the DES and were successfully carried out prior to the relevant major release of the version to Production (see Annex B).</p> <p>No other change in the registry's conformance to the technical standards occurred for the reported period.</p>
15/CMP.1 annex II.E paragraph 32.(e) Change to discrepancies procedures	No change of discrepancies procedures occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(f) Change regarding security	No changes regarding security occurred during the reported period.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information	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 of the registry internet address occurred 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	Changes introduced since version 8.0.7 of the national registry are listed in Annex B. Both regression testing and tests on the new functionality were successfully carried out prior to release of the version to Production. The site acceptance test was carried out by quality assurance consultants on behalf of and assisted by the European Commission.

14 Information on minimization of adverse impacts in accordance with Article 3, paragraph 14

The Swedish reporting of information regarding minimizations of adverse impacts in accordance with Article 3, paragraph 14 of the Kyoto Protocol is presented below. The outline follows that of decision 15/CMP.1 § 23 and § 24.

14.1 Changes in information provided under Article 3, paragraph 14

No new information has been added to this report. Changes have been made regarding the reference, as there is updated information available in Sweden's seventh National Communication on Climate Change.

14.2 Paragraph 23

Each Party included in Annex I shall provide information relating to how it is striving, under Article 3, paragraph 14, of the Kyoto Protocol, to implement its commitments mentioned in Article 3, paragraph 1, of the Kyoto Protocol in such a way as to minimize adverse social, environmental and economic impacts on developing country Parties, particularly those identified in Article 4, paragraphs 8 and 9, of the Convention

According to the provisions of Article 2 of the Kyoto Protocol, each party with quantified commitments under the Protocol is to introduce policies and measures to achieve the emission reductions to which it has made a commitment. The measures implemented are to be compatible with overarching objectives of sustainable development. Measures which would mean that all greenhouse gases regulated by the Protocol can decrease and cover all sectors of society are emphasised. The parties to the Kyoto Protocol are to aim to introduce policies and measures so that adverse effects are minimised. Such effects include adverse effects of a changed climate, effects on international trade and social, environmental and economic effects on other parties, particularly on developing countries.

In connection to the implementation of policies and measures in Sweden, an impact assessment is carried out, including an environmental impact assessment as a basis for decision-making. Such an analysis as far as possible also includes assessing the risk of adverse effects in other countries. Formulation of proposals for changes of policy instruments is undertaken in a consultation procedure that makes it possible for operators concerned to give their comments on the proposals. In consultations that include suggestions for new rules or guidelines that may affect trade with other country shall be notified within the EU and to be alerted under the WTO's rules. This process makes it possible for other countries to influence the design of

proposals for changed policy instruments and highlight any negative side effects that may arise.

Further, under Sweden's policy for global development (PGD), all policy areas are to interact in a coherent way so that the country can make an effective contribution to equitable and sustainable global development. When decisions in a given policy area are judged to affect this goal of equitable and sustainable global development, an impact assessment has to be carried out. The policy's two perspectives – a rights perspective and the perspective of poor people on development – are to serve as a guide. In the framework of the PGD, coordination and collaboration take place, for example, through a reference group on trade policy at the Ministry for Foreign Affairs. Regular meetings of this group, which includes representatives of business, the Swedish International Development Cooperation Agency (Sida) and civil society organizations have created a basis for broad consultation on trade policy.

The Swedish research activities, as indicated in Chapter 8 of Sweden's seventh National Communication on Climate Change (NC 7), among other things contribute to a sustainable global development. There are several examples of interdisciplinary research efforts focused on improving knowledge of effects globally (socially, economically and ecologically) of large-scale introduction of measures to reduce greenhouse gas emissions. Because of Sweden's focus on increased use of bioenergy, both through increased domestic production but also through imports in particular from developing countries, this area has been specially prioritised in systems-science research in the country.

Results from research have already influenced, and will in future influence, the development of policy. The special sustainability criteria devised for vehicle biofuels under the EU Renewables Directive is one such example.

Both positive and negative effects must be taken into account. Sweden contributes to a number of measures that may have positive effects on the prospects of developing countries adapting to climate change and implementing their own measures to reduce their greenhouse gas emissions. A description is given in Chapter 7 of NC 7 of such efforts in the areas of technology transfer, capacity building and support for adaptation measures.

Finally Sweden wishes to emphasise that its climate strategy with its broad focus on many different types of measures covering the majority of sectors of society (both in and outside the country) and all greenhouse gases governed by the Kyoto Protocol has a form which fundamentally limits (minimises) the risk of adverse effects.

14.3 Paragraph 24 (a)

Annex II Parties shall incorporate information on how they give priority to the following actions:

(a) The progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse-gas-emitting sectors, taking into account the need for energy price reforms to reflect market prices and externalities

Sweden has to a large extent reformed the energy markets and phased out any market imperfections. The market price on electricity is deregulated and governed by the balance between demand and supply on a cross-border electricity market. In Sweden fossil fuels used outside the EU emissions trading scheme (ETS) is subject to a carbon dioxide tax to reflect the external cost. In EU ETS it is mainly the price of allowances that reflects the external effect of carbon dioxide emissions and the market failure.

14.4 Paragraph 24 (b)

Removing subsidies associated with the use of environmentally unsound and unsafe technologies.

Sweden does not extract oil, natural gas or coal, and therefore, has no subsidies on these fuels. With the introduction of the EU ETS for carbon dioxide emissions a cost has been imposed on environmentally harmful technologies such as fossil fuel based heat- and electricity production and industries.

14.5 Paragraph 24 (c)

Cooperating in the technological development of non-energy uses of fossil fuels, and supporting developing country Parties to this end

The chemical industry including refineries contributes to a fairly small share of the overall Swedish industrial production. This technological field is not a high priority in the Swedish research policy.

14.6 Paragraph 24 (d)

Cooperating in the development, diffusion, and transfer of less-greenhouse-gas-emitting advanced fossil-fuel technologies, and/or technologies, relating to fossil fuels, that capture and store greenhouse gases, and encouraging their wider use; and facilitating the participation of the least developed countries and other non-Annex I Parties in this effort

Sweden has an almost fossil free heat- and power production and therefore don't give priority to research and technology development in the field of advanced fossil based techniques for electricity and heat production technology. Since there is an

automotive industry in Sweden, research programmes in the areas of hybrid technologies, automatic control systems for more energy-efficient internal combustion engines and the use of diesel oil for hydrogen production have been carried out over a long period of time. The programmes are designed in particular to contribute to reduced fuel consumption for road vehicles. A development which is also of value for more fuel efficient passenger- and goods transport in non-Annex 1 countries, particularly those who are dependent on imports of oil, diesel and petrol.

Carbon Capture and Storage technology has in recent years been given priority in the Swedish research and climate policy.

Since 2014, geological storage of carbon dioxide is allowed in Sweden in accordance to an ordinance (Förordning (2014:21) om geologisk lagring av koldioxid), and the Geological Survey of Sweden (SGU) is the supervisory agency. The SGU also monitors advances in the CCS area – both in terms of legislation and of research and development. Further, SGU participates in European networks and research partnerships on CCS.

At the EU level, the European Union has decided to invest in the development of CCS technology and support the establishment of demonstration plants with the aim to enhance the development of CCS technology. One example of an EU financed project is a project called White Rose, in Great Britain, which includes the reduction of carbon dioxide emissions by 90 % from a coal power plant, transport on land and in the sea, as well as storage under the north part of the North Sea. White Rose is funded by the European NER300 programme, which is a fund set up by the European Commission to encourage low-carbon energy projects.

14.7 Paragraph 24 (e)

Strengthening the capacity of developing country Parties identified in Article 4, paragraphs 8 and 9, of the Convention for improving efficiency in upstream and downstream activities relating to fossil fuels, taking into consideration the need to improve the environmental efficiency of these activities

Sweden contribute to technology development in developing countries through development assistance and CDM projects, see chapter 4 of Sweden's seventh National Communication on Climate Change. The focus on transfer of technologies is primarily on energy efficiency technologies and on the introduction of renewable energy, but also to contribute to capacity-building. By providing knowledge about how CDM projects evolve, are administered and implemented for approval, which Sweden has made in African countries, the ability to inter alia obtain technology that enhances the efficiency of fossil fuel-intensive activities as well as other climate-related environmental technology projects improves.

14.8 Paragraph 24 (f)

Assisting developing country Parties which are highly dependent on the export and consumption of fossil fuels in diversifying their economies

Sweden assists developing countries which are dependent on imports for its fossil fuel consumption with the transfer of more energy-efficient technologies, renewable energy technologies and capacity-building which enhances diversification of the economy in these countries (see chapter 7 of NC 7). Inter alia, the Government has signed cooperation agreements on environmental or energy technology with a number of countries, among them the United States, Brazil, China, Russia and India. Special emphasis within the frame of this cooperation has been given to the field of environmental and energy technologies, including sustainable urban planning.

In addition to development cooperation projects, Sweden is engaged in CDM projects in biomass based electricity generation, wind energy, biogas production, hydro-electric power production and energy efficiency projects which contribute to economic development and diversification of the economy in fossil fuel dependent developing countries. Capacity-building about how CDM projects evolve, are administered and implemented for approval, which Sweden has made in African countries, support a greater diversification of the economy in the countries concerned. (see chapter 4 of NC7).

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16 Units and Abbreviations

t	1 (metric) tonne = 1 megagram (Mg) = 10^6 g
toe	tonne oil equivalent 1 toe = 41.87 GJ
Mg	1 megagram = 10^6 g = 1 tonne
Gg	1 gigagram = 10^9 g = 1 kilotonne (kt)
Tg	1 teragram = 10^{12} g = 1 megatonne (Mt)
TJ	1 terajoule
A	
AR	Afforestation and Reforestation
ARTEMIS	Assessment and Reliability of Transport Emission Models and Inventory Systems
AWMS	Animal Waste Management System
C	Carbon or Confidential
CH ₄	Methane
EMIR	Emissions database of the county administrative boards
ERT	Expert Review Team
CFCs	Freons
CKD	Cement kiln dust
CO	Carbon monoxide Carbon dioxide
COP	Conference Of the Parties
CORINAIR	EMEP/CORINAIR Emission Inventory Guidebook
CRF	Common Reporting Format
D	Deforestation
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 Agriculture Organisation of the UN
FOD model	IPCC First Order Decay model
FOI	Swedish Defence Research Agency
FORTV	Swedish Fortification Department
FRA	Forest Resource Assessment
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 ₂ O	Nitrous oxide
NAP	Swedish national allocation plan
NA	Not Applicable
NBF	National Board of Forestry
NCV	Net Calorific Value
NE	Not Estimated
NFI	National Forest Inventory
NIR	National Inventory Report
NMVOC	Non Methane Volatile Organic Compounds
NO	Not Occuring
NO _x	Nitrogen oxides
NSFSV	National Survey of Forest Soils and Vegetation
MTC	Motor Test Center
O ₃	Ozone
PA	Production approach

PAH	Polycyclic aromatic hydrocarbons
PDCA	Plan, Do, Check, Act
PFCs	Perfluorocarbons
QA/QC	Quality assurance and Quality control
Quarterly statistics	Quarterly fuel statistics
RIS	Riksinventeringen av skog (national forest inventory)
RME	Rapeseed Methyl Ester fuel
RVF	Swedish Association of Waste Management
SF ₆	Sulphur hexafluoride
SDC	Forest industry information association
SGU	Geological Survey of Sweden
SVJ	Swedish Board of Agriculture
SLU	Swedish University of Agricultural Sciences
SMED	Swedish Environmental Emissions Data
SMHI	Swedish Meteorological and Hydrological Institute
STA	Swedish Transport Administration
STAg	Swedish Transport Agency
SO ₂	Sulphur dioxide
SPBI	Swedish Petroleum and Biofuel Institute
Swedish EPA	Swedish Environmental Protection Agency
TSP	Total amount of suspended particles
TPS	Technical Production System
UNFCCC	United Nations Convention on Climate Change
VBA	Visual Basic for Applications
VETO	Mechanistic model for simulations on road traffic
VTI	Swedish Road- and Transport Research Institute
WBCSD	World Business Council for Sustainable Development
WRI	World Resource Institute