

National Inventory Report Sweden 2012

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, on an annual basis, submit national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol. This report is also a submission under the Kyoto Protocol.

This is Sweden's National Inventory Report (NIR) for the year 2012 and it is written in line with the guidelines of the Annotated outline of the National Inventory Report including reporting elements under the Kyoto Protocol. It contains national greenhouse gas emission inventories for the period 1990 to 2010, and descriptions of methods used to produce the estimates. The methods used to calculate the emissions and removals are in accordance with the Revised IPCC 1996 Guidelines for National Greenhouse Gas Inventories and the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. The report is prepared in accordance with the Reporting Guidelines, agreed by the UNFCCC at the eighth session of the Conference of the Parties (COP) in New Delhi 2002 and subsequent decisions.

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

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Contents

PREFACE	3
SAMMANFATTNING	14
(Summary in Swedish)	14
S 1. Bakgrund	14
S 2. Sammanfattning av nationella utsläpp och upptag samt trender, inklusive KP-LULUCF	14
S 2.1 Växthusgaser	14
S 2.2 KP-LULUCF	15
S 3. Översikt över utsläppsberäkningar och trender sektorsvis, inklusive KP-LULUCF	18
S 3.1 Växthusgaser	18
S 3.2 KP-LULUCF	20
S 4. Översikt av utsläppsberäkningar och trender för indirekta växthusgaser och SO ₂	21
EXECUTIVE SUMMARY	22
ES 1. Background Information	22
ES 2. Summary of National Emissions and Removal Related Trends, including KP-LULUCF	22
ES.2.1 GHG inventory	22
ES.2.2 KP-LULUCF activities	23
ES 3. Overview of Source and Sink Category Emission Estimates and Trends, including KP-LULUCF	26
ES.3.1 GHG inventory	26
ES.3.2 KP-LULUCF activities	28
ES 4. Overview of Emission Estimates and Trends of Indirect GHGs and SO ₂	29
1 INTRODUCTION	31
1.1 Background Information	31
1.1.1 Climate change	31
1.1.2 Greenhouse gas inventories	33
1.1.3 Supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol	33
1.2 Institutional arrangements	34
1.2.1 Legal arrangements	34
1.2.2 Institutional arrangements	35
1.3 Inventory planning, preparation and management	38
1.3.1 Quality system	38
1.3.2 Training, awareness and skills	42
1.3.3 Inventory planning (PLAN)	42
1.3.4 Inventory preparation (DO)	43

1.3.5 QA/QC procedures and extensive review of GHG inventory and KP-LULUCF inventory (CHECK)	45
1.3.6 Finalization, publication and submission of the inventory	47
1.3.7 Data storage	47
1.3.8 Follow-up and improvement (ACT)	48
1.4 Brief general description of methodologies and data sources used	49
1.4.1 GHG inventory	49
1.4.2 KP-LULUCF inventory	50
1.5 Brief description of key categories, including for KP-LULUCF key categories	51
1.5.1 GHG inventory (including and excluding LULUCF)	51
1.5.2 KP-LULUCF inventory	53
1.6 Information on QA/QC	53
1.6.1 QA/QC Procedures	53
1.6.2 Verification activities	53
1.6.3 Treatment of confidentiality issues	53
1.7 General uncertainty evaluation	53
1.7.1 GHG inventory	53
1.7.2 KP-LULUCF activities	56
1.8 General assessment of completeness	57
1.8.1 GHG inventory	57
1.8.2 KP-LULUCF	58
2 TRENDS IN GREENHOUSE GAS EMISSIONS	59
2.1 Description and interpretation of emission trends for aggregated greenhouse gas emissions	59
2.1.1 Sweden's commitment under the Kyoto Protocol and the EU Burden Sharing Decision	61
2.1.2 Sweden's commitment for the non-ETS emissions according to the Effort Sharing Decision	62
2.1.3 Overview of emissions trends per sector	62
2.2 Description and interpretation of emission trends in relation to gas	63
2.2.1 CO ₂	64
2.2.2 CH ₄	64
2.2.3 N ₂ O	65
2.2.4 Fluorinated greenhouse gases	66
2.3 Description and interpretation of emission trends in relation to source	66
2.3.1 Energy excluding transport	67
2.3.2 Transport	72
2.3.3 Industrial processes	75
2.3.4 Solvents and other products use	77
2.3.5 Agriculture	78
2.3.6 Land Use, Land Use Change and Forestry - LULUCF	80

2.3.7 Waste	82
2.3.8 International bunkers	84
2.4 Description and interpretation of emission trends for indirect greenhouse gases and SO ₂	85
2.4.1 NMVOC	85
2.4.2 NOX	86
2.4.3 CO	87
2.4.4 SO ₂	88
2.4.5 Description and interpretation of emission trends for KP-LULUCF inventory in aggregate and by activity, and by gas	89
3 ENERGY (CRF SECTOR 1)	90
3.1 Overview of sector	90
3.2 Fuel combustion (CRF 1.A)	92
3.2.1 Comparison of the sectoral approach with the reference approach	93
3.2.2 International bunker fuels	94
3.2.3 Feedstocks and non-energy use of fuels	95
3.2.4 CO ₂ capture from flue gases and subsequent CO ₂ storage	96
3.2.5 Country-specific issues	96
3.2.6 Public electricity and heat production (CRF 1.A.1.a)	96
3.2.7 Petroleum refining (CRF 1.A.1.b)	100
3.2.8 Manufacture of solid fuels and other energy industries (CRF 1.A.1.c)	103
3.2.9 Iron and steel (CRF 1.A.2.a)	104
3.2.10 Non-Ferrous Metals (CRF 1.A.2.b)	107
3.2.11 Chemicals (CRF 1.A.2.c)	109
3.2.12 Pulp, Paper and Print (CRF 1.A.2.d)	111
3.2.13 Food Processing, Beverages and Tobacco (CRF 1.A.2.e)	113
3.2.14 Other Industries (CRF 1.A.2.f)	114
3.2.15 Civil Aviation (CRF 1.A.3.a)	118
3.2.16 Road transport (CRF 1.A.3.b)	122
3.2.17 Railways (CRF 1.A.3.c)	127
3.2.18 Navigation (CRF 1.A.3.d)	128
3.2.19 Other transportation (CRF 1.A.3.e)	132
3.2.20 Commercial/institutional (CRF 1.A.4.a)	134
3.2.21 Residential (CRF 1.A.4.b)	137
3.2.22 Agriculture/forestry/fisheries (CRF 1.A.4.c)	139
3.2.23 Other stationary (CRF 1.A.5.a)	141
3.2.24 Other mobile (CRF 1.A.5.b)	142
3.3 Fugitive emissions from solid fuels and oil and natural gas (CRF 1.B)	144
3.3.1 Fugitive emissions from solid fuels (CRF 1.B.1)	144
3.3.2 Oil and natural gas (CRF 1.B.2)	145

4 INDUSTRIAL PROCESSES (CRF SECTOR 2)	155
4.1 Overview of sector	155
4.2 Mineral products (CRF 2.A)	157
4.2.1 Cement production (CRF 2.A.1)	157
4.2.2 Lime production (CRF 2.A.2)	161
4.2.3 Limestone and dolomite use (CRF 2.A.3)	166
4.2.4 Soda ash use (CRF 2.A.4)	170
4.2.5 Asphalt roofing (CRF 2.A.5)	172
4.2.6 Road paving with asphalt (CRF 2.A.6)	173
4.2.7 Other (CRF 2.A.7)	175
4.3 Chemical industry (CRF 2.B)	178
4.3.1 Ammonia production (CRF 2.B.1)	178
4.3.2 Nitric acid production (CRF 2.B.2)	179
4.3.3 Carbide production (CRF 2.B.4)	181
4.3.4 Other (CRF 2.B.5)	184
4.4 Metal production (CRF 2.C)	187
4.4.1 Iron and steel production (CRF 2.C.1)	187
4.4.2 Ferroalloy production (CRF 2.C.2)	196
4.4.3 Aluminium production (CRF 2.C.3)	199
4.4.4 SF ₆ used in aluminium and magnesium foundries (CRF 2.C.4)	202
4.4.5 Other metal production (CRF 2.C.5)	203
4.5 Other production (CRF 2.D)	205
4.5.1 Pulp and paper (CRF 2.D.1)	205
4.5.2 Food and drink (CRF 2.D.2)	206
4.6 Production of Halocarbons and SF ₆ (CRF 2.E)	208
4.7 Consumption of Halocarbons and SF ₆ (CRF 2.F)	209
4.7.1 Refrigeration and air conditioning equipment (2.F.1)	210
4.7.2 Foam blowing (2.F.2)	214
4.7.3 Fire extinguishers (2.F.3)	215
4.7.4 Aerosols/metered dose inhalers (2.F.4)	216
4.7.5 Solvents (2.F.5)	218
4.7.6 Other applications using ODS substitutes (2.F.6)	218
4.7.7 Semiconductor manufacture (2.F.7)	218
4.7.8 Electrical equipment (2.F.8)	220
4.7.9 Other (2.F.9)	222
4.8 Consumption of Halocarbons and SF ₆ Potential Emissions (CRF 2.F.P)	224
4.8.1 Potential emissions	224
4.9 Other, CRF 2G	224
5 SOLVENT AND OTHER PRODUCT USE (CRF SECTOR 3)	225
5.1 Overview of sector	225
5.2 Paint application (CRF 3.A)	227

5.2.1	Source category description	227
5.2.2	Methodological issues	227
5.2.3	Uncertainties and time-series consistency	227
5.2.4	Source-specific QA/QC and verification	227
5.2.5	Source-specific recalculations	227
5.2.6	Source-specific planned improvements	228
5.3	Degreasing and Dry cleaning (CRF 3.B)	228
5.3.1	Source category description	228
5.3.2	Methodological issues	228
5.3.3	Uncertainties and time-series consistency	228
5.3.4	Source-specific QA/QC and verification	228
5.3.5	Source-specific recalculations	229
5.3.6	Source-specific planned improvements	229
5.4	Chemical products, Manufacture and Processing (CRF 3.C)	229
5.4.1	Source category description	229
5.4.2	Methodological issues	229
5.4.3	Uncertainties and time-series consistency	229
5.4.4	Source-specific QA/QC and verification	230
5.4.5	Source-specific recalculations	230
5.4.6	Source-specific planned improvements	230
5.5	Other (CRF 3.D)	230
5.5.1	Source category description	230
5.5.2	Methodological issues	230
5.5.3	Uncertainties and time-series consistency	231
5.5.4	Source-specific QA/QC and verification	231
5.5.5	Source-specific recalculations	231
5.5.6	Source-specific planned improvements	231
6	AGRICULTURE (CRF SECTOR 4)	232
6.1	Overview of sector	232
6.2	Enteric Fermentation (CRF 4.A)	235
6.2.1	Source category description	235
6.2.2	Methodological issues	236
6.2.3	Uncertainties and time-series consistency	240
6.2.4	Source-specific QA/QC and verification	240
6.2.5	Source-specific recalculations	240
6.2.6	Source-specific planned improvements	240
6.3	Manure Management (CRF 4.B)	240
6.3.1	Source category description	240
6.3.2	Methodological issues	241
6.3.3	Uncertainties and time-series consistency	247
6.3.4	Source-specific QA/QC and verification	247

6.3.5	Source-specific recalculations	247
6.3.6	Source-specific planned improvements	247
6.4	Agricultural Soils (CRF 4.D)	248
6.4.1	Direct Soil Emissions (CRF 4.D.1)	248
6.4.2	Pasture, Range and Paddock Manure (CRF 4.D.2)	262
6.4.3	Indirect Emissions (CRF 4.D.3)	264
6.4.4	Other (CRF 4.D.4)	266
7	LAND USE, LAND-USE CHANGE AND FORESTRY (CRF SECTOR 5)	268
7.1	Overview of LULUCF	268
7.2	Description of categories 5A, 5B, 5C, 5D, 5E and 5F	273
7.2.1	Characteristics of categories	273
7.2.2	Information on approaches used for representing land areas and on land-use databases used for the inventory preparation	274
7.2.3	Land-use definitions and the classification systems used and their correspondence to the LULUCF categories	280
7.2.4	Definition of carbon Pools, CRF 5A, 5B, 5C, 5D, 5E and 5F	283
7.2.5	Emissions of N ₂ O, CO ₂ and CH ₄ , CRF 5(I), 5(II), 5(III), 5(IV) and 5(V)	284
7.3	Methodological issues	286
7.3.1	CRF-tables 5A, 5B, 5C, 5D, 5E and 5F	286
7.3.2	CRF 5(I), 5(II), 5(III), 5(IV) and 5(V)	289
7.4	Uncertainties and time series consistency	290
7.4.1	Uncertainties	290
7.4.2	Living biomass, CRF 5A, 5B, 5C, 5D, 5E and 5F	291
7.4.3	Dead organic matter, CRF 5A, 5B, 5C, 5D, 5E and 5F	291
7.4.4	Soil organic carbon, CRF 5A, 5B, 5C, 5D, 5E and 5F	292
7.4.5	Other CO ₂ emissions, CRF 5(IV) and 5(V)	293
7.4.6	N ₂ O and CH ₄ emissions, CRF 5(I), 5(III) and 5(V)	293
7.4.7	Completeness	294
7.4.8	Time series consistency and verification	294
7.5	QA/QC	295
7.5.1	Quality assurance	295
7.5.2	Quality control	295
7.6	Source-specific Recalculations	295
7.7	Coming improvements	298
7.7.1	Informal reporting of HWP	298
8	WASTE (CRF SECTOR 6)	301
8.1	Overview of sector	301
8.2	Solid waste disposal on land (CRF 6.A)	302
8.2.1	Managed waste disposal on land (CRF 6.A.1)	304
8.3	Waste water handling (CRF 6.B)	321

8.3.1 Industrial, domestic and commercial wastewater (CRF 6.B.1 and CRF 6.B.2)	321
8.4 Waste incineration (CRF 6.C)	330
8.4.1 Source category description	330
8.4.2 Methodological issues	330
8.4.3 Uncertainties and time-series consistency	332
8.4.4 Source-specific QA/QC and verification	332
8.4.5 Source-specific recalculations	332
8.4.6 Source-specific planned improvements	332
9 OTHER	333
10 RECALCULATIONS AND IMPROVEMENTS	334
10.1 Explanations and justifications for recalculations	334
10.2 Implications for emission levels	334
10.2.1 Energy, CRF 1	334
10.2.2 Industrial processes, CRF 2	334
10.2.3 Solvents and other products use, CRF 3	334
10.2.4 Agriculture, CRF 4	335
10.2.5 LULUCF, CRF 5	335
10.2.6 Waste, CRF 6	335
10.3 Implications for emission trends	337
10.4 Recalculations and other changes made in response to the review process	338
10.5 Major changes in methodological descriptions	357
11 KP-LULUCF	361
11.1 General information	361
11.1.1 Definitions of forest and any other criteria	363
11.1.2 Elected activities under Article 3, paragraph 4, of the Kyoto Protocol	364
11.1.3 Description of how the definitions of each activity under Article 3.3 and each elected activity under Article 3.4 have been implemented and applied consistently over time	364
11.1.4 Descriptions of precedence conditions and/or hierarchy among Article 3.4 activities, and how they have been consistently applied in determining how land was classified.	365
11.2 Land-related information	366
11.2.1 Spatial assessment unit used for determining the area of the units of land under Article 3.3	366
11.2.2 Methodology used to develop the land use matrix	366
11.2.3 Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations	366
11.3 Activity-specific information	367
11.3.1 Methods for carbon stock change and GHG emission and removal estimates	367
11.4 Article 3.3	372

11.4.1 Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2012 and are direct human-induced	372
11.4.2 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation	373
11.4.3 Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested	373
11.5 Article 3.4	374
11.5.1 Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human induced	374
11.5.2 Information relating to Cropland Management, Grazing Land Management, and Revegetation, if elected, for the base year	374
11.5.3 Information relating to Forest Management	374
11.6 Other information	374
11.6.1 Key category analysis for Article 3.3 activities and any elected activities under Article 3.4	374
11.7 Information relating to Article 6	375
12 INFORMATION ON ACCOUNTING OF KYOTO UNITS	376
12.1 Background information	376
12.2 Summary of information reported in the SEF tables	376
12.3 Discrepancies and notifications	376
12.4 Publicly accessible information	378
12.5 Calculation of the commitment period reserve (CPR)	380
12.5.1 Assigned Amount	380
12.5.2 Commitment Period Reserve (CPR)	381
12.6 KP-LULUCF accounting	381
13 INFORMATION ON CHANGES IN NATIONAL SYSTEM	382
14 INFORMATION ON CHANGES IN NATIONAL REGISTRY	383
15 INFORMATION ON MINIMIZATION OF ADVERSE IMPACTS IN ACCORDANCE WITH ARTICLE 3, PARAGRAPH 14	388
Paragraph 23	388
Paragraph 24 (a)	389
Paragraph 24 (b)	389
Paragraph 24 (c)	390
Paragraph 24 (d)	390
Paragraph 24 (e)	390
Paragraph 24 (f)	391
16 OTHER INFORMATION	392
16.1 References	392

Section 1	392
Section 3	392
Section 4	395
Section 5	397
Section 6	397
Section 7	401
Section 8	404
Section 10	409
Section 11	409
16.2 Units and Abbreviations	410

Sammanfattning

(Summary in Swedish)

S 1. Bakgrund

Växthusgaser har alltid funnits i atmosfären, men på grund av mänsklig aktivitet har koncentrationen av många av dem ökat, vilket intensifierar växthuseffekten. 1988 bildades Intergovernmental Panel on Climate Change (IPCC) och två år senare konstaterade de att antropogen klimatpåverkan utgjorde ett globalt hot och efterfrågade en internationell överenskommelse för att hantera problemet. FN:s generalförsamling inledde förhandlingar om en ramkonvention kring klimatförändringar (UNFCCC), vilken trädde i kraft 1994. Det långsiktiga målet är att stabilisera halterna av växthusgaser i atmosfären på en nivå som förhindrar skadliga antropogena klimatförändringar från att äga rum. Det viktigaste tillägget till konventionen förhandlades fram i Kyoto, Japan, 1997. Kyotoprotokollet innebär bindande åtaganden gällande utsläppsmängder för Annex I-länderna, vilket innebär att dessa länders utsläpp av växthusgaser under åren 2008-2012 i medeltal ska vara minst 5 % lägre än under basåret 1990.

Enligt Artikel 4 och 12 i UNFCCC måste medlemsstaterna årligen rapportera sina utsläpp från källor och upptag i sänkor för alla växthusgaser som inte omfattas/kontrolleras av Montrealprotokollet. Rapporteringen ska innefatta utsläppssiffror i ett speciellt format (CRF) och en nationell inventeringsrapport (NIR).

Denna rapport utgör Sveriges NIR 2012. Rapporten omfattar utsläpp till luft av de direkta växthusgaserna CO₂, CH₄, N₂O, HFC, PFC, SF₆ och de indirekta växthusgaserna NO_x, CO, NMVOC och SO₂. Rapporten innehåller information om Sveriges inventering av växthusgaser för alla år från 1990 till 2010, inklusive beskrivningar av metoder, datakällor, osäkerheter, den kvalitetssäkring och kvalitetsstyrning (QA/QC) som görs och en trendanalys.

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

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

S 2.1 Växthusgaser

Totala utsläppet av växthusgaser i Sverige, uttryckt i koldioxidekvivalenter, var ca 66,2 miljoner ton år 2010 med 4,1 % osäkerhet (Tabell S 1), vilket är en ökning med ca 6,6 miljoner ton jämfört med 2009. Utsläppen har minskat med ca 9 %, eller ca 6,5 miljoner ton, mellan 1990 och 2010. Osäkerheten är beräknad till $\pm 2,1$ % i trenden, dvs. minskningen ligger i intervallet 6,9 % - 11 %.

Nettoupptaget för sektorn Markanvändning, Förändrad markanvändning och Skogsbruk (LULUCF) har beräknats till ca 34 miljoner ton koldioxidekvivalenter 2010 (Tabell S 1). Den årliga förändringen i sänkan är mycket liten i förhållande till poolernas storlekar (levande biomassa, dött organiskt material och markkol). Beräkningarna är på grund av detta behaftade med stora osäkerheter. Osäkerheterna tillsammans med löpande metodutveckling kan ge stora förändringar i rapporterade värden mellan submissionerna

Utsläppen av koldioxid var ca 53 miljoner ton år 2010 vilket är ca 7 % lägre jämfört med 1990 (Tabell S 1). Energisektorn, inklusive transporter, står för ca 89 % av de totala koldioxidutsläppen och är därmed den största källan till koldioxidutsläpp i Sverige. Koldioxid står för ca 80 % av de totala utsläppen av växthusgaser.

Metanutsläpp (CH_4) kommer framför allt från jordbruk och avfallsdeponier och var ca 5,3 miljoner ton 2010 räknat som koldioxidekvivalenter (Tabell S 1). Sedan 1990 har utsläppen av metan minskat med ca 26 %, vilket främst beror på åtgärder inom avfallssektorn och jordbrukssektorn.

2010 var totala utsläppen av lustgas (N_2O) ca 7 miljoner ton räknat som koldioxidekvivalenter (Tabell S 1), vilket är en minskning med ca 16 % jämfört med 1990. Utsläpp av lustgas kommer huvudsakligen från jordbrukssektorn, men också från energiproduktion, industriprocesser och hantering av avloppsvatten. Jordbrukssektorn står för den största delen av minskningen.

Totala utsläppen av fluorerade gaser (PFCs, HFCs och SF_6) 2010 var 1,1 miljon ton uttryckt i koldioxidekvivalenter (Tabell S 1). Detta innebär en ökning av utsläppen med 121 % jämfört med 1990. Ökningen beror främst på att ozonförstörande ämnen ersatts av HFCs.

S 2.2 KP-LULUCF

Sverige rapporterar artikel 3.3 och 3.4 under Kyoto protokollet. För dessa aktiviteter har Sverige valt att bokföra upptag/utsläpp för hela åtagandeperioden (och ej på årsbasis).

Aktiviteter under artikel 3.3, nybeskogning /återbeskogning (AR), är relativt ovanliga i Sverige. Sedan 2008 har arealen nybeskogad/återbeskogad mark ökat med ca 5 000 ha per år. Upptaget för alla poolerna har beräknats till 0.8 miljoner ton CO_2 ekvivalenter 2010. Andelen mark som avskogats, (D), har ökat något från 2008. Det totala utsläppet 2010 har beräknats till 2.2 miljoner ton CO_2 ekvivalenter. Under artikel 3.4 har Sverige valt bokföring av skogsbruk. För denna aktivitet är upptaget ca 36.9 miljoner ton CO_2 ekvivalenter 2010. Rapporteringen under Kyotoprotokollet artikel 3.3 och 3.4 harmonierar med UNFCCC rapporteringen för skogsmark och mark som konverterats till skogsmark (arean).

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

Tabell S 1 Utsläpp av växthusgaser ämnesvis (Gg CO₂ ekvivalenter)

UTSLÄPP AV VÄXTHUS- GASER CO₂ eq.(Gg)	CO₂ inkl. netto CO₂ från LULUCF	CO₂ exkl. netto CO₂ från LULUCF	CH₄ inkl. CH₄ från LULUCF	CH₄ exkl. CH₄ från LULUCF	N₂O inkl. N₂O från LULUCF	N₂O exkl. N₂O från LULUCF	HFCs	PFCs	SF₆	Total (inkl. LULUCF)	Total (exkl. LULUCF)
1990	15 548	56 890	7 052	7 050	8 407	8 326	4	377	107	31 495	72 755
1995	23 320	58 854	6 954	6 952	8 083	8 020	132	343	127	38 960	74 429
2000	15 144	54 133	6 368	6 365	7 634	7 560	568	241	94	30 048	68 959
2001	16 084	55 064	6 325	6 322	7 452	7 376	615	236	111	30 823	69 724
2002	16 942	55 978	6 147	6 142	7 347	7 274	666	261	104	31 467	70 425
2003	20 210	56 626	6 004	5 998	7 307	7 228	710	258	69	34 558	70 889
2004	22 894	55 789	6 025	6 019	7 271	7 188	769	254	81	37 295	70 101
2005	22 292	53 282	5 892	5 887	7 121	7 026	790	257	142	36 494	67 384
2006	16 278	53 242	5 820	5 808	7 147	7 049	818	245	111	30 420	67 273
2007	14 966	52 003	5 580	5 578	6 888	6 780	838	248	151	28 672	65 599
2008	13 223	50 139	5 389	5 375	7 035	6 910	867	225	84	26 821	63 599
2009	10 795	46 664	5 281	5 278	6 863	6 745	869	35	81	23 923	59 671
2010	18 690	52 884	5 255	5 255	7 151	7 013	849	158	73	32 177	66 232

Tabell S 2 Utsläpp av växthusgaser sektorsvis (Gg CO₂ ekvivalenter)

KÄLLOR TILL OCH SÄNKOR AV VÄXTHUSGASER CO ₂ equiv.	Energi	Industriprocesser	Användning av lösnings- medel och andra produk- ter	Jordbruk	Markanvändning, förändrad markan- vändning och skogsbruk	Avfall
1990	53 606	6 330	332	9 065	-41 259	3 421
1995	55 442	6 644	309	8 801	-35 469	3 233
2000	50 557	6 812	278	8 397	-38 911	2 916
2001	51 431	6 810	269	8 343	-38 901	2 871
2002	52 217	6 951	276	8 255	-38 958	2 726
2003	53 152	6 679	292	8 148	-36 331	2 618
2004	51 928	7 071	311	8 182	-32 806	2 609
2005	49 565	7 004	303	8 042	-30 890	2 470
2006	49 580	6 999	300	8 016	-36 853	2 378
2007	48 170	6 948	297	7 939	-36 926	2 245
2008	46 392	6 833	311	8 002	-36 778	2 061
2009	44 640	5 010	311	7 770	-35 748	1 940
2010	49 359	6 841	311	7 873	-34 055	1 848

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

S 3.1 Växthusgaser

De metoder som använts för att beräkna utsläpp och upptag överensstämmer med 'Revised IPCC 1996 Guidelines for National Greenhouse Gas Inventories' och 'IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories'. Inventeringen och rapporten är framtagen i enlighet med 'Reporting Guidelines', som beslutades av UNFCCC under den åttonde sammankomsten av Conference of the Parties (COP) i New Delhi 2002 och efterföljande beslut.

De sektorer som innefattas av inventeringen och de källor som används för aktivitetsdata och/eller utsläppsdata presenteras i Tabell S 3. Utsläppen är hämtade direkt från dessa datakällor eller beräknade baserat på aktivitetsdata.

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

CRF	Sektor	Primär källa till aktivitetsdata/utsläppsdata
1	Energi	
	-Stationär förbränning	Statistiska undersökningar av energiförbrukning
	-Transport	Transportmyndigheter
2	Industriprocesser	Miljörapporter
		Statistiska undersökningar av energiförbrukning
		Direktkontakt med företag
		EU:s utsläppshandelssystem
3	Lösningsmedel och annan Produktanvändning	Nationella data från Produktregistret på Kemikalieinspektionen
		Nationella experter
		Miljörapporter
4	Jordbruk	Officiella statistiska rapporter
		Organisationer och Forskare
5	Förändrad Markanvändning och Skogsbruk	Sveriges lantbruksuniversitet
		Skogsstyrelsen
6	Avfall	Avfall Sverige (fd RVF)
		Skogsindustrierna
		SCB
		Naturvårdsverket
		Miljörapporter

Utsläppen från energisektorn varierar på grund av temperatur- och nederbördsförhållanden samt det ekonomiska konjunkturläget men trenden för perioden 1990-2010 är minskande utsläpp. Utsläppen av växthusgaser från energisektorn inklusive transporter var ca 49,4 miljoner ton i koldioxidekvivalenter 2010 (Tabell S 2), vilket är ca 75 % av de totala utsläppen. Utsläpp av växthusgaser från trafiken ökade med drygt 7 % från 1990 till 2010.

Utsläppen av växthusgaser har under 2010 ökat jämfört med 2009. Bakomliggande orsaker är återhämtningen av ekonomin och ökat behov av uppvärmning på grund av kallare väder. Ungefär en tredjedel av ökningen av utsläppen från energisektorn år 2009 kan hänföras till den ekonomiska återhämtningen efter nedgången som inleddes hösten 2008.

Utsläppen av koldioxid från produktion av el och fjärrvärme uppgick till cirka 10 miljoner ton 2010, vilket var högre än den nivå som 1990 och det näst högsta sedan 1990 under med undantag för 1996.

För industriprocesser är koldioxid den dominerande växthusgasen med 78 %, sedan kommer fluorerade växthusgaser med ca 16 % dikväveoxid med ca 6 % och metan med 0,2 %. Utsläppen kommer framför allt från produktion av järn och stål samt mineralindustrin. De totala utsläppen från industriprocesser var omkring 6,8 miljoner ton koldioxidekvivalenter år 2010 (Tabell S 2), vilket motsvarar drygt 10 % av totala utsläppen. Totala utsläppen från industriprocesser ökade med 1,8 miljoner ton koldioxidekvivalenter eller ca 36 % mellan 2009 och 2010. De ökade utsläppen 2010 beror främst på en ökad produktion främst inom metallindustrin till följd av den ekonomiska återhämtningen efter nedgången som inleddes hösten 2008 och fördjubades 2009.

Sedan 1990 har de totala utsläppen i denna sektor varierat, vilket framför allt beror på att produktionsvolymerna varierar med ekonomiska cykeln. 2010 var utsläppen 8 % högre än 1990.

Användningen av Lösningsmedel och andra produkter ger huvudsakligen upphov till utsläpp av flyktiga organiska ämnen (VOCs), lustgas (N_2O) och en del koldioxid. 2010 var utsläppen av koldioxid och lustgas drygt 0,3 miljoner ton uttryckt i koldioxidekvivalenter (Tabell S 2), vilket utgör knappt 0,5 % av de totala växthusgasutsläppen. Jämfört med 1990 har utsläppen i denna sektor minskat med ca 6 %. Ca 15 % av koldioxidutsläppen kommer från användningen av färg, även om dessa utsläpp har minskat p.g.a. en övergång till vattenbaserade färger.

Jordbruk är den största källan till utsläpp av lustgas och metan. 2010 var de totala utsläppen från jordbrukssektorn knappt 8 miljoner ton uttryckt i koldioxidekvivalenter (Tabell S 2) varav ca 62 % utgjordes av N_2O och ca 38 % av CH_4 . Det är en minskning med ca 13 % jämfört med 1990. Utsläpp av metan kommer framför allt från boskapens matsmältningsprocesser och fekalier. De viktigaste anledningarna till de minskade utsläppen är en minskad boskapshållning och en minskad tillämpning av mineralgödsel-medel i jordbruket. Lustgas kommer framför allt från omvandling av kväve i jorden, vilken påverkas av användningen av gödsel och handelsgödsel och odlingen av kvävefixerande växter.

Beräkningarna av nettoupptaget för LULUCF under 2010 visar på en något lägre nettosänka jämfört med föregående år (Tabell S 2). Minskningen beror sannolikt på en

ökande trend i avverkningsintensitet men data för de fyra sista åren är delvis extrapolerade varför effekter av avverkningsnivåer för enskilda år inte avspeglas i redovisningen. Under 2010 inventerades 20 % av provytorna som används för att beräkna sänkan. Det innebär att underlaget för statistiska beräkningar av sänkans storlek har en stor inbyggd osäkerhet och beräkningar för kommande år kan ge betydligt förändrade resultat.

Avfallsdeponier är den näst största källan till utsläpp av metan. Av avfallssektorns utsläpp under 2010 dominerar metanutsläppen från avfallsdeponier med ca 85 % medan lustgas från avloppsvatten står för 9 % och koldioxidutsläppen från förbränning av farligt avfall för 6%. 2010 var de totala utsläppen från avfallssektorn drygt 1,8 miljoner ton (Tabell S 2) uttryckt i koldioxidekvivalenter, vilket motsvarar ca 3 % av de totala utsläppen. Utsläppen från sektorn har minskat med 46 % jämfört med 1990. Utvinning av deponigas, deponiförbud och deponiskatter är huvudorsakerna till utsläppsminskningen.

Totala utsläpp av växthusgaser uppgick 2010 till ca 66,2 miljoner ton koldioxidekvivalenter varav utsläpp ej inkluderade i utsläppshandel stod för 43,6 miljoner ton. Detta innebär att de svenska utsläppen år 2010 var 9 % lägre än för basåret vilket innebär att Sverige kommer att kunna uppfylla sina åtaganden med god marginal.

S 3.2 KP-LULUCF

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

När det gäller aktiviteten skogsbruk under artikel 3.4 så har nettoinlagringen minskat de sista åren. Den nedåtgående trenden bero sannolikt på att avverkningarna fortsatt ligger på en relativt hög nivå men som nämnts tidigare är osäkerheten i beräkningarna för de sista åren stor och det är därför svårt att dra några säkra slutsatser kring vad skillnader mellan år beror på.

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

Tabell S 4 Utsläpp av indirekta växthusgaser och SO₂ (Gg)

GAS	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
NO _x	271	248	206	197	192	188	180	176	175	169	159	154	162
CO	1280	1127	824	784	749	729	678	661	627	618	607	612	640
NM VOC	359	278	223	212	206	206	201	197	195	197	196	197	197
SO ₂	105	69	42	41	40	41	37	36	36	33	31	30	35

Utsläppen av kväveoxider (NO_x) var ca 162 kton 2010 (Tabell S 4), vilket är en minskning med ca 40 % jämfört med 1990. Vägtrafikens utsläpp av NO_x har minskat med 47 % mellan 1990 och 2010. Utsläppen har ökat med ca 2,7 % mellan 2009 och 2010. De största källorna till utsläpp av kväveoxider är vägtrafik, arbetsmaskiner, sjöfart och el- och värmeproduktion. I tätorter är vägtrafiken den största källan till kväveoxidutsläpp, men införandet av katalysatorer i bilar och den påföljande successivt mer skärpta avgasstandarderna har bidragit till en generell minskning av kväveoxidnivåer i tätbebyggda områden. Den ökande användningen av fjärrvärme och NO_x-avgiften i början på 1990-talet har också resulterat i stora minskningar av kväveoxidutsläpp från energisektorn.

Utsläppen av kolmonoxid (CO) har minskat från 1280 kton 1990 till 640 kton 2010 (Tabell S 4), en reducering på 50 %. Omkring 96 % av utsläppen kommer från energisektorn varav ca 42 % kommer från transport.

Utsläpp av flyktiga organiska ämnen (NM VOC) var ca 197 kton 2010 (Tabell S 4), vilket är en minskning med 45 % jämfört med 1990. De huvudsakliga källorna till NM VOC är vägtrafik, vedeldning inom bostadssektorn och produkter innehållande lösningsmedel. Icke-obligatoriska miljöstandarder för nya installationer av vedeldningspannor och minskade utsläpp från produkter innehållande lösningsmedel har bidragit till minskningen av utsläpp.

Utsläppen av svaveldioxid (SO₂) har minskat från 105 kton 1990 till ca 35 kton 2010 (Tabell S 4), en reducering på ca 67 %. Minskningen beror framför allt på en övergång till lågsvavelhaltiga bränslen, både för vägtrafik och uppvärmning. Svavelskatt, som infördes 1991, spelar en stor roll för utvecklingen. Svaveldioxidutsläpp härrör främst från energiproduktion, transporter och industriprocesser.

Executive Summary

ES 1. Background Information

Greenhouse gases have always been present in the atmosphere, but now concentrations of several of them are rising as a result of human activity, which intensifies the greenhouse effect. An Intergovernmental Panel on Climate Change (IPCC) was established in 1988 and two years later they came up with the conclusion that anthropogenic climate change is a global threat and asked for an international agreement to deal with the problem. The United Nations started negotiations to create a framework convention on climate change (UNFCCC), which came into force in 1994. The long-term goal is to stabilize the amount of greenhouse gases in the atmosphere at a level where harmful anthropogenic climate changes is prevented. The most important addition to the convention was negotiated in 1997 in Kyoto, Japan. The Kyoto protocol involves binding obligations for the Annex I countries to decrease their emissions of greenhouse gases (GHG) with at least 5% during 2008-2012 compared to the base year 1990. According to Articles 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC), parties are required to annually submit national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol. The submission of inventories should including emissions in the Common Reporting Format (CRF) and a National Inventory Report (NIR).

This report constitutes Sweden's NIR 2012 for anthropogenic emissions of direct greenhouse gases CO₂, CH₄, N₂O, HFC, PFC, SF₆ 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 2010, including descriptions of methods, data sources, uncertainties, the quality assurance and quality control (QA/QC) activities carried out and a trend analysis.

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

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

ES.2.1 GHG inventory

Total greenhouse gas emissions in Sweden, expressed in carbon dioxide equivalents, were about 66.2 million tonnes for 2010 with an uncertainty of 4.1 % (Table ES 1). The emission increased by about 6.6 million tonnes compared to 2009. Emissions have fallen by about 9 % or approximately 6.5 million tonnes between 1990 and 2010. The uncertainty in the

trend is a percentage point range relative to the inventory trend and should be interpreted as ± 2.1 %, that is emissions have decreased by 6.9 % - 11 %.

The net uptake of the land use, land-use change and forestry (LULUCF) has been estimated at 34 million tonnes carbon dioxide equivalent in 2010 (Table S1). The annual change of the sink is very small compared to the size of pools (living biomass, dead organic matter and land-based carbon). For this reason, the estimations are associated with uncertainties. The uncertainties and change of methods can result in substantial effects on the annual values and between different submissions.

Emissions of CO₂ were around 53 million tonnes in 2010, which is about 7 % lower than in 1990 (Table ES 1). About 89 % of total carbon dioxide emissions come from the energy sector, including transport, which is the largest source of carbon dioxide in Sweden. Carbon dioxide's share of the total GHG emissions is approximately 80 %.

Emissions of methane (CH₄) arise mainly from agriculture and landfill sites, and in 2010 were approximately 5.3 million tonnes, expressed in CO₂-equivalents (Table ES 1). Since 1990, emissions have decreased about 26 %, primarily due to measures implemented in the waste sector and agriculture.

In 2010, the total emissions of nitrous oxide (N₂O) were around 7 million tonnes, expressed in CO₂-equivalent (Table ES 1), a reduction of 16 % compared to 1990. Emissions arise mainly from agriculture, but also from energy production, wastewater handling and industrial processes. The agricultural sector accounts for the bulk of N₂O decline.

Total emissions of fluorinated gases (PFCs, HFCs and SF₆) in 2010 were approximately 1.1 million tonnes expressed in carbon dioxide equivalents (Table ES 1). This corresponds to an increase of about 121 % compared to 1990. The increase is due to the replacement of the ozone-depleting substances by HFCs.

ES.2.2 KP-LULUCF activities

Sweden reports Articles 3.3 and 3.4 of the Kyoto Protocol. For these activities, Sweden has chosen to report the uptake/emission for the entire commitment period but not on an annual basis.

The activities under Article 3.3, afforestation / reforestation (AR), are relatively rare in Sweden. Since 2008 the area afforested / reforested land increased by about 5 000 ha per year. The uptake for all the pools have been estimated at 0.8 million tonnes of CO₂ equivalents in 2010. The proportion of land that is deforested, (D), increased slightly compared to 2008. The total emission in 2010 is estimated at 2.2 million tonnes of CO₂ equivalents. Under Article 3.4, Sweden has chosen accounting of forestry. For this activity, the uptake is approximately 36.9 million tons of CO₂ equivalents in 2010. Reporting under the Kyoto Protocol Article 3.3 and 3.4 is in harmony with the UNFCCC reporting for forest and land converted to forest land (area).

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

Table ES 1 Greenhouse gas emissions by gas (Gg CO₂ equivalents)

GREENHOUSE GAS EMISSIONS CO₂ eq.(Gg)	CO₂ incl. net CO₂ from LULUCF	CO₂ excl. net CO₂ from LULUCF	CH₄ incl. CH₄ from LULUCF	CH₄ excl. CH₄ from LULUCF	N₂O incl. N₂O from LULUCF	N₂O excl. N₂O from LULUCF	HFCs	PFCs	SF₆	Total (incl. LULUCF)	Total (excl. LULUCF)
1990	15 548	56 890	7 052	7 050	8 407	8 326	4	377	107	31 495	72 755
1995	23 320	58 854	6 954	6 952	8 083	8 020	132	343	127	38 960	74 429
2000	15 144	54 133	6 368	6 365	7 634	7 560	568	241	94	30 048	68 959
2001	16 084	55 064	6 325	6 322	7 452	7 376	615	236	111	30 823	69 724
2002	16 942	55 978	6 147	6 142	7 347	7 274	666	261	104	31 467	70 425
2003	20 210	56 626	6 004	5 998	7 307	7 228	710	258	69	34 558	70 889
2004	22 894	55 789	6 025	6 019	7 271	7 188	769	254	81	37 295	70 101
2005	22 292	53 282	5 892	5 887	7 121	7 026	790	257	142	36 494	67 384
2006	16 278	53 242	5 820	5 808	7 147	7 049	818	245	111	30 420	67 273
2007	14 966	52 003	5 580	5 578	6 888	6 780	838	248	151	28 672	65 599
2008	13 223	50 139	5 389	5 375	7 035	6 910	867	225	84	26 821	63 599
2009	10 795	46 664	5 281	5 278	6 863	6 745	869	35	81	23 923	59 671
2010	18 690	52 884	5 255	5 255	7 151	7 013	849	158	73	32 177	66 232

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

Table ES 2 Greenhouse gas emissions by sector (Gg CO₂ equivalents)

GHG SOURCE AND SINK CATEGORIES CO₂ equiv.	Energy	Industrial Processes	Solvent and Other Product Use	Agriculture	Land Use, Land- Use Change and Forestry	Waste
1990	53 606	6 330	332	9 065	-41 259	3 421
1995	55 442	6 644	309	8 801	-35 469	3 233
2000	50 557	6 812	278	8 397	-38 911	2 916
2001	51 431	6 810	269	8 343	-38 901	2 871
2002	52 217	6 951	276	8 255	-38 958	2 726
2003	53 152	6 679	292	8 148	-36 331	2 618
2004	51 928	7 071	311	8 182	-32 806	2 609
2005	49 565	7 004	303	8 042	-30 890	2 470
2006	49 580	6 999	300	8 016	-36 853	2 378
2007	48 170	6 948	297	7 939	-36 926	2 245
2008	46 392	6 833	311	8 002	-36 778	2 061
2009	44 640	5 010	311	7 770	-35 748	1 940
2010	49 359	6 841	311	7 873	-34 055	1 848

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

ES.3.1 GHG inventory

The methods used to calculate the emissions and removals are in accordance with the Revised IPCC 1996 Guidelines for National Greenhouse Gas Inventories and the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. The report is prepared in accordance with the Reporting Guidelines, agreed by the UNFCCC at the eighth session of the Conference of the Parties (COP) in New Delhi 2002 and subsequent decisions.

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

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

CRF	Sector	Main source for activity/emission data
1	Energy	
	-Stationary combustion	Statistical survey on energy consumption
	-Transport	Transport authorities
2	Industrial processes	Environmental reports
		Statistical survey on energy consumption
		Direct contact with companies
		CO ₂ Data from the European trading scheme (ETS)
3	Solvent and Other Product Use	National data from the Products register at the Swedish Chemicals Agency
		National experts
		Environmental reports
4	Agriculture	Official statistical reports
		Organisations and researchers
5	Land Use Change and Forestry	Swedish University of Agricultural Sciences
		Swedish Forest Agency
6	Waste	Swedish Association of Waste Management
		The Swedish Forest Industries Federation
		Statistics Sweden
		Swedish Environmental Protection Agency
		Environmental reports

Greenhouse gas emissions from the energy sector including transport, were about 49.4 million tonnes, expressed as carbon dioxide equivalents, in 2010 (Table ES 2), which is equivalent to 75 % of the total emissions. From 1990 to 2010, there was a 7 % increase of greenhouse gas emissions from road traffic. In 2010 the greenhouse gases emissions have increased compared to 2009. Underlying causes are the economic recovery following the economic downturn that began in the autumn of 2008, and increased need for heating due to colder weather.

Emissions of carbon dioxide from the production of electricity and district heating totalled about 10 million tonnes in 2010, which was higher than the level as in 1990 and the second highest amount during the time series, except for 1996.

For industrial processes, the most dominant greenhouse gas is carbon dioxide, contributing 78 %, followed by the fluorinated greenhouse gases by 16 %, nitrous oxide by about 6 % and methane by 0.2 %.

Emissions from industrial processes are primarily derived from the production of iron and steel. The total emission in 2010 were approximately 6.8 million tonnes expressed as carbon dioxide equivalents (Table ES 2), which is approximately 10 % of the total emissions. The total emissions increased by 1.8 million tonnes of carbon dioxide equivalents or about 36 % between 2009 and 2010. The increase in 2010 was primarily due to increased in metal production, reflecting the economic growth after the economic turndown that started in autumn 2008 and deepened in 2009.

Since 1990, total emissions in this sector have varied, primarily because production volumes vary with economic cycles. In 2010, emissions were 8 % higher than in 1990.

The use of Solvents and Other products mainly gives rise to emissions of volatile organic substances (VOCs), nitrous oxides (N₂O) and some carbon dioxide. In 2010, emissions of carbon dioxide and nitrous oxide expressed in carbon dioxide equivalents were almost 0.3 million tonnes (Table ES 2), which corresponds to about 0.5 % of the total greenhouse gas emissions. Compared to 1990, emissions have decreased with about 6 %. Almost 15 % of carbon dioxide emissions arise from paint application, even though these emissions have decreased due to a transition to water-based paints.

Agriculture is the largest source of methane and nitrous oxide emissions. In 2010, total greenhouse gas emissions expressed in carbon dioxide equivalents were almost 8 million tonnes (Table ES 2) in which 62 % consisted of nitrous oxide and 38 % of methane. The emissions decreased by about 13 % compared to 1990. Methane emissions arise primarily from the digestive processes of cattle and from their manure. The most important reasons for the reduced emissions are reduced livestock keeping and reduced application of N-fertilisers in agriculture. Nitrous oxide emissions originate mainly from transformation of nitrogen that takes place in the ground, which is influenced by the use of manure and commercial fertiliser and the cultivation of nitrogen-fixing crops.

The estimates of net uptake of LULUCF in 2010 show a slightly lower net decrease than the previous year (Table S2). The decrease is probably due to an increasing trend in logging intensity, but data from the last four years is partly extrapolated and that is the reason why the effects of logging levels for individual years are not reflected in the reporting.

During the inventory year 2010, only 20 % of the surface samples were inventoried to calculate to the sink. This means that the basis for statistical estimates of the size of the sink has a large uncertainty, and estimates for future years can significantly change results.

Waste sector emissions in 2010 is dominated by methane emissions from landfills by about 85 %, while nitrous oxide emissions from waste water accounts for 9 % and carbon dioxide emissions from the incineration of hazardous waste is 6 %. In 2010, the total emissions from the waste sector were about 1.8 million tonnes (Table ES 2), expressed as carbon dioxide equivalents or about 3 % of the total GHG emissions. Compared to 1990 the emissions in 2010 have reduced by about 46 %. The collection of landfill gas, a ban on landfill deposit and the introduction of a landfill tax have played a key role for the decrease in emissions.

The total emissions of greenhouse gases in 2010 were about 66 million tonnes expressed as carbon dioxide equivalents and the emissions that come from sectors outside the trading system were 43.6 million tonnes. This means that emissions in Sweden in 2010 were 9 % below the base year emissions, which indicates that Sweden will comfortably fulfil its commitment.

ES.3.2 KP-LULUCF activities

As the activities under Article 3.3 (afforestation and deforestation) are relatively uncommon in Sweden, it is difficult to draw any conclusions on the differences between years. The net uptakes and emissions in 2010 were approximately at the same levels as 2009.

Net removals related to Forest management under Article 3.4, decreased during the previous years. This is mainly an effect of reduced felling.

The downward trend is likely due to a continued filling at a relatively high level, but as mentioned earlier, the uncertainty in the estimates for the last few years is large and it is therefore difficult to draw firm conclusions about the reason for the differences between years.

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

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

GAS	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
NO_x	271	248	206	197	192	188	180	176	175	169	159	154	162
CO	1280	1127	824	784	749	729	678	661	627	618	607	612	640
NM VOC	359	278	223	212	206	206	201	197	195	197	196	197	197
SO₂	105	69	42	41	40	41	37	36	36	33	31	30	35

Emissions of nitrogen oxides (NO_x) were about 162 ktonnes in 2010 (Table ES 4), a reduction of 40 % compared to 1990. Road traffic emissions of NO_x have decreased by 47 % between 1990 and 2010 and increased by about 2.7 % between 2009 and 2010. The largest sources of emissions of nitrogen oxides are road traffic, mobile machinery, maritime transport and electricity and heating production. In areas where people congregate, road traffic is the most significant contributor to emissions of nitrogen oxides, but the introduction of catalytic converters in the late 1980's and the subsequent successively more stringent emission standards have contributed to a general reduction of nitrogen oxide levels in built-up areas. The increased use of district heating and the "NO_x charge" of the early 1990s have also resulted in a great reduction of emissions of nitrogen oxides from the energy sector.

Emissions of carbon monoxide (CO) have decreased from 1280 ktonnes in 1990 to 640 ktonnes in 2010 (Table ES 4), a reduction of 50 %. About 96 % of emissions come from energy sector of which 42 % comes from transport.

Emissions of volatile organic compounds (NMVOC) were 197 ktonnes in 2010 (Table ES 4), a decrease of 45 % compared to 1990. The main contributors to NMVOC emissions are road traffic, wood combustion in the residential sector and solvents- containing products. Non-compulsory environmental standards for new installations of wood-burning boilers and reduced emissions from solvent-containing products have contributed to the decrease in emissions.

Emissions of sulphur dioxide (SO₂) have decreased from 105 ktonnes in 1990 to about 35 ktonnes in 2010 (Table ES 4), a reduction of about 67 %. Sulphur dioxide emissions derive from the energy, transport and industrial sectors. The reduction is mainly due to a transfer from fuels with high sulphur levels to low-sulphur fuels, both for road traffic and heating. A tax on sulphur, introduced in 1991, has been important in this transition.

PART 1: ANNUAL INVENTORY SUBMISSION 2012

1 Introduction

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

This report constitutes Sweden's NIR 2012. The report contains information on Sweden's inventories for all years from 1990 to 2010 including descriptions of methods, data sources, uncertainties, quality assurance and quality control (QA/QC) activities carried out, and a trend analysis. In order to ensure the transparency, consistency, comparability, completeness and accuracy of the inventory, the report contains information on inventories for all years from the base year to the year of the current annual inventory submission.

This section presents background information on climate change and greenhouse gas (GHG) inventories. It also contains a description of institutional arrangements for the inventory preparation, brief descriptions of the process of inventory preparation, methodologies and data sources used and the key sources in the Swedish inventory. Finally there is information about the progress of quality assurance/quality control (OA/QC) work, the general uncertainties in the inventory and on the completeness of inventoried emissions.

1.1 Background Information

1.1.1 Climate change

In consequence of scientific indications that human activities influence the climate and an increasing public awareness about local and global environmental issues during the middle of the 1980s, climate change was brought up on the political agenda. The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 and two years later they concluded that anthropogenic climate change was a global threat and asked for an international agreement to deal with the problem.

The United Nations started negotiations to create a framework convention on climate change (UNFCCC), which came into force in 1994. A decade later UNFCCC had 188 member states (including EU as a part). The long-term goal is to stabilize the amount of greenhouse gases in the atmosphere at a level where harmful anthropogenic climate changes are prevented. After the UNFCCC came into force, the framework convention has developed and every year a Conference of the Parties (COP) is held. The most important addition to the convention was negotiated in 1997 in Kyoto, Japan. The Kyoto protocol involves binding obligations for the Annex I countries (including all EU member states and other industrialized countries). Together the emissions of greenhouse gases in these countries should be at least 5 % lower during 2008-2012 compared to the base year 1990 (for fluorinated greenhouse gases it is allowed to use 1995 as a base year).

In the spring 2002 Sweden, together with the other EU member states, ratified the Kyoto protocol and the 16th of February 2005 it came into force. EU and its member states uses a paragraph in the Kyoto protocol which gives them the right to, instead of national emission objective, have a joint EU objectives of a decrease in emissions with 8 %. Within EU the 8 is shared among the member states in accordance with the burden sharing agreement¹. For Sweden the agreement involves an allowed increase in emissions of 4 %. Sweden has chosen to go beyond the EU target. Reduced Climate Impact is one of the 16 Swedish Environmental Quality Objectives and is supported by long and short-term emissions targets. In 2009, Sweden adopted a vision that in 2050 the country will have no net emissions of greenhouse gases in the atmosphere. A comprehensive reduction strategy is set out to 2020.

2008–2012: Swedish greenhouse gas emissions will decrease by four per cent in comparison with 1990.

2020: Greenhouse gas emissions in Sweden (this applies to activities outside the emissions trading scheme) will decrease by 40 per cent in comparison with 1990.

2050: The vision is for Sweden in 2050 not to have any net emissions of greenhouse gases into the atmosphere

The objective also involve that Sweden should encourage the global work to aim at the objective to stabilize the concentration of greenhouse gases in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

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

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

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

¹ 2002/358/EC

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

Compared with carbon dioxide, all other greenhouse gases occur at very low concentrations. Per molecule, however, these substances are much more effective as greenhouse gases than carbon dioxide, which means that they still make a considerable contribution to the greenhouse effect. Furthermore, some of the fluorine compounds have such a long atmospheric lifetime that they will contribute to the greenhouse effect for ten thousands of years to come.

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

1.1.2 Greenhouse gas inventories

The inventory covers anthropogenic emissions of direct greenhouse gases CO₂, CH₄, N₂O, HFC, PFC, SF₆ 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 climate in different ways. Ozone (O₃) is also a greenhouse gas but, since it is formed by the chemical reactions of nitrogen oxides, hydrocarbons and/or carbon monoxide, a separate report is not necessary.

The obligations of the Kyoto protocol have led to an increased need for international supervision of the emissions reported by the parties. The Kyoto protocol therefore contains rules for how emissions should be estimated, reported and reviewed. Emissions of the direct greenhouse gases CO₂, N₂O, CH₄, HFCs, PFCs and SF₆ are calculated as CO₂ equivalents and added to produce a total. Together with the direct greenhouse gases, also the emissions of NO_x, CO, NMVOC and SO₂ are reported to UNFCCC. These gases are not included in the obligations of the Kyoto protocol. When a method used to estimate emissions is improved, a need to recalculate the whole time series may arise in order to maintain consistency. This means that data presented can be changed in the next submission.

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

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

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

In addition to the reporting of carbon pool changes, direct N₂O emissions from N fertilization and emissions from forest fires are reported under FM. Forest fires – both natural and wildfires – are uncommon and, this far, has not been registered on AR-land.

N₂O emissions from disturbance associated with land use conversion from Forest land to Cropland are reported under D.

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 national system is to be designed in compliance with UNFCCC decision 20/CP.7. Under the terms of Decision No. 280/2004/EC of the European Parliament and of the Council, the national system has to be in place by the end of 2005. 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.

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 fulfills 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

Ordinance (2005:626) Concerning Climate Reporting provides the basis for the Swedish national system and describes the roles and responsibilities of the gov-

ernment agencies in the context of climate reporting. Through this, sufficient capacity for timely performance is ensured.

There are legislations in Sweden which is not primarily intended to apply to climate reporting but indirectly supports the work by providing a basis for the estimation of greenhouse gas emissions and removals. Under Chapter 26 Section 19 of the Environmental Code (1998:808), there is an obligation for annual environmental reports to be submitted for certain environmentally hazardous activities so that government agencies can undertake supervision.

The General Statistics Act (SFS 2001: 99) and the associated Ordinance (2001:100) Concerning Official Statistics impose an obligation on companies and other organisations 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

Sections 6-19 of the Ordinance (2005:626) Concerning Climate Reporting 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 1.1 and the associated text below describe in broad terms which organizations are involved in the work of compiling documentation for the yearly inventory report and for other reporting to the European Commission and the UNFCCC. Depending on the role of the government agencies in climate-reporting activity, this responsibility may range for example from supplying data and producing emission factors/calorific values to carrying out calculations to estimate emissions or conducting a national peer review (red). In addition to what is described in the Ordinance, the Swedish Environmental Protection Agency (Swedish EPA) engages the SMED consortium as consultants with expert skills to conduct the inventory and reporting in the area of climate change.

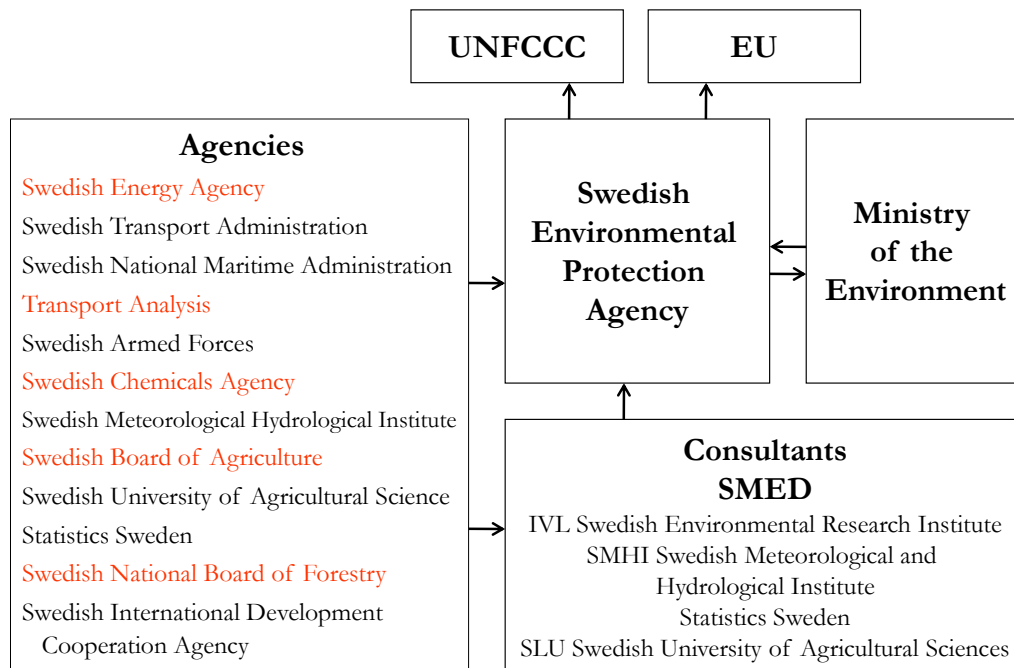


Figure 1.1 The Swedish national system.

1.2.2.1 SINGLE NATIONAL ENTITY

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

Ms. Agnes von Gersdorff

agnes.von-gersdorff@environment.ministry.se

Postal address SE 103 33 Stockholm, Sweden

telephone +46 8 405 10 00

1.2.2.2 SWEDISH EPA RESPONSIBILITIES

The Swedish EPA is responsible for co-ordinating the activities for producing the inventory, maintaining the reporting 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. Finally, the Swedish EPA is responsible for national publication of the greenhouse gas inventory.

The National inventory compiler at the Swedish EPA is Ms. Maria Lidén.

1.2.2.3 AGENCIES RESPONSIBILITIES

Agencies responsibilities according to Ordinance (2005:626) Concerning Climate Reporting is described in table 1.1 below.

Table 1.1. Agencies responsibilities according to Ordinance (2005:626) Concerning Climate Reporting

Sector	Data and documentation provided by	Peer review conducted by	Other responsibilities
Energy	Swedish Energy Agency the Swedish Transport Administration, the Swedish Transport Agency, the National Maritime Administration the Swedish Armed Forces	Swedish Energy Agency (energy sector excluding transports) Transport Analysis (transports)	The Swedish Energy Agency also assists the Swedish EPA in the work of developing documentation concerning flexible mechanisms and emissions projections as well as extracts from and information about changes to the national register.
Industrial Processes	Swedish Chemicals Agency (fluorinated greenhouse gases)	The Swedish EPA (CO ₂ , CH ₄ and N ₂ O) Swedish Chemicals Agency (fluorinated greenhouse gases)	
Solvents and Other Product Use	Swedish Chemicals Agency	Swedish Chemicals Agency	
Agriculture	Swedish Board of Agriculture Statistics Sweden	Swedish Board of Agriculture	
Land Use, Land-Use Change And Forestry Sector	Swedish University of Agricultural Sciences, Statistics Sweden, the National Board of Forestry, the Swedish Meteorological and Hydrological Institute (SMHI) and the Swedish Board of Agriculture	National Board of Forestry Swedish Board of Agriculture (agriculture related parts)	
Waste Reporting relating to efforts in developing countries		Swedish EPA	The Swedish International Development Cooperation Agency (Sida) is responsible for presenting documentation to the Swedish EPA.

1.2.2.4 THE SMED CONSORTIUM

The Swedish EPA engages consultants with expert skills to conduct the inventory and reporting 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 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 runs for nine years and thus covers the whole first commitment period under the Kyoto Protocol.

² <http://www.smed.se/>

SMED receives data and documentation from responsible authorities as described above and produces most of the data and documentation in the Swedish inventory. 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. The Swedish Meteorological and Hydrological Institute is main responsible for production of gridded emission data. 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 sector, the solvents and other products use sector and also parts of the waste sector and energy sector.

On behalf of the Swedish EPA, SMED also conducts development projects necessary for improving the inventory.

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 18/CP.8, the Common Reporting Format (CRF), Decision 13/CP.9, the new CRF for the Land Use Change and Forestry Sector, the IPCC 1996 Guidelines for National Greenhouse Gas Inventories, which specify the reporting obligations according to Articles 4 and 12 of the UNFCCC (IPCC Guidelines, 1996) as well as the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC GPG, 2000) and the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC GPG-LULUCF, 2003).

It could 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

In order to fulfill the obligations of reporting to the UNFCCC and the EU, the Swedish EPA has set up a quality system as part of the national system. The structure of the quality system follows the PDCA cycle (Plan, Do, Check, Act) illustrated in figure 1.2 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.

Procedural Arrangements



Figure 1.2 Structure of the quality system.

The responsibilities of the Swedish EPA and the other government agencies for the quality system are described in Ordinance (2005:626) Concerning Climate Reporting. Under Section 3, the Swedish EPA and other government agencies which take part in the climate-reporting work have to ensure that the methodologies applied in the reporting and inventories of emissions and removals attain the quality required for it to be possible for Swedish climate reporting to be done in the correct manner and with correct information.

The government agencies have to have internal routines to plan, prepare, check and act/follow up the quality work and consult one another with the aim of developing and maintaining a coordinated quality system.

The responsibility of SMED to maintain and develop an internal quality system is described in the framework contract between the Swedish EPA and the consultants. The SMED quality system is described in a detailed manual including several appendices.⁴ It 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 improve-

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

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

ment 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.

The illustration in figure 1.3 below shows a process description of the annual Swedish inventory.

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

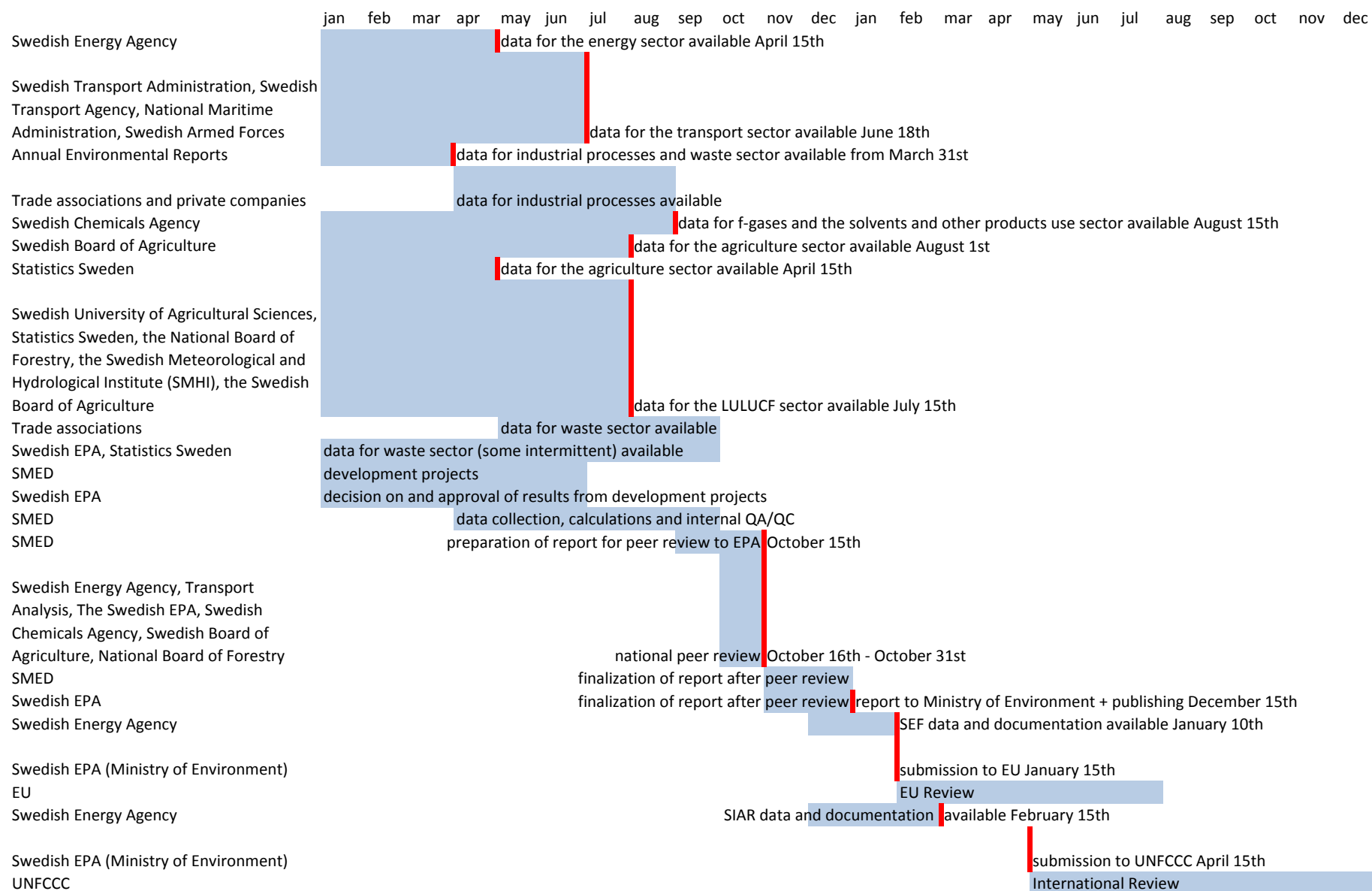


Figure 1.3 Overview of inventory planning, preparation and management.

1.3.2 Training, awareness and skills

Training, awareness and skills in climate reporting are essential to maintain the level of quality required according to specified requirements. Skills are ensured for the Swedish EPA and the majority of the government agencies involved in the work by the government agency being the sector government agency with staff who have particular skills in different specialist areas.

Skills on the part of SMED 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.

1.3.3 Inventory planning (PLAN)

Planning of the inventory for 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 coming year are set 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

Priorities are distributed to SMED approximately in October.

Based on the priorities and on detailed information in the list on suggestions on improvements (see section 1.3.8 below), SMED compiles a list of suggested development projects for the coming years. The list of suggested development projects is discussed between SMED and the Swedish EPA. During the winter the Swedish EPA decides on what projects should be performed.

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. The Swedish EPA each year contacts responsible authorities and discusses needs for updates.

1.3.4 Inventory preparation (DO)

SMED gather data and information from various government agencies, organisations and companies over the period from April to August with the aim of being able to carry out emission calculations. 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 1B2a1 in line with 2006 IPCC Guidelines. For non- CO₂ emissions, regular emission factors for stationary combustion are used.

Activity data for transfer losses of gas works gas are taken from the annual energy balances. 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.

1.3.4.4 INDUSTRIAL PROCESSES

The reported data for industrial processes is mainly based on information from environmental reports. According to Swedish environmental legislation, operators performing environmentally hazardous activities that require a permit by law are required to compile and send an annual environmental report to their supervisory authority. The County Administrative Boards audit the data from the operators' environmental reports.

The data in the environmental reports refer to emissions derived from plant specific measurements or estimates such as mass balances. The use of default emission factors is limited.

In some cases, when there are a large number of smaller companies within a specific sector, and all the environmental reports are not available, a combination of information available from environmental reports and production statistics at national level is used to estimate national emissions. Emission factors used are usually derived nationally based on available information from some facilities in a specific sector, and applied to the national level. The use of default emission factors is limited.

For most CO₂ emissions from industrial processes, activity data on e.g. the produced amount of clinker, limestone, etc. is collected directly from the operators. In some cases data on CO₂ emissions from the European trading scheme is used for 2005 and later years. Activity data on fuels used in CO₂ emitting processes are collected from the same surveys as those used for energy emissions for manufacturing industries, as described above.

Emissions of fluorinated greenhouse gases are estimated based on national import and export statistics from the Swedish Chemicals Agency.

1.3.4.5 SOLVENT AND OTHER PRODUCT USE

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

1.3.4.6 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.

1.3.4.7 LAND USE, LAND USE CHANGE AND FORESTRY

Estimates presented in the LULUCF sector are mainly based on data from the SLU. The SLU is responsible for the National Forest Inventory, which focuses on living biomass, and for the Swedish Forest Soil Inventory, that focuses on dry organic matter and on soil organic carbon. The two inventories are integrated and use the same infra-structure for the field sample.

1.3.4.8 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 (CHECK)

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 8.1 in IPCC Good Practice Guidance (2000), have been carried out as follows:

- Transcription errors in data input
- Calculations are made correctly
- Units and conversion factors are correct
- Integrity of database files

- Consistency in data between source categories
- Correct movement of inventory data between processing steps
- Recalculations, checked and documented
- Completeness check
- Comparison of last submission's estimates to previous estimates
- Documentation of changes that may influence uncertainty estimates

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. After completion of the initial compilation of the inventory, a QC-team within SMED reviews all QC checklists. In addition, the project management team performs checks of submission data using the functionality of the CRF Reporter (i.e. checks of completeness, time-series consistency and recalculation explanations).

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 Consumption of halocarbons and SF ₆	Differences between country specific emission factors and default emission factors from IPCC Guidelines are documented.

When the reporting tables and the NIR are completed by SMED, a quality coordinator performs a final quality control before delivery of the inventory to the Swedish EPA.

1.3.5.2 QUALITY ASSURANCE

Key categories should be subject to external peer review according to the Tier 2 of the Good Practice Guidance. The Swedish QA/QC system includes national peer reviews by sectoral authorities. The peer review is defined in the Ordinance (2005:626) Concerning Climate Reporting 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 annual peer review. This means, among other things, ensuring that the peer reviewers have received the necessary training.

The peer review includes methodology and emissions factors used, as well as comparisons of activity and emission data with other national statistics. 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 1.3.8.

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 1.3.8. See also section 10.

The 2012 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.

1.3.6 Finalization, publication and submission of the inventory

The Swedish Environmental Protection Agency delivers the greenhouse gas inventory and the KP LULUCF inventory to the Ministry of Environment 20 working days before the reporting date, which is in mid-December. At the same time, the inventory is published nationally⁵.

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 X relates to emissions year X-2, in other words emissions which took place during 2010 are reported in early 2012.

1.3.7 Data storage

A system for handling emission data, entitled Technical Production System (TPS)⁶, has been developed and was implemented for the first time in submission 2007. It supports data input from text files and Microsoft Excel sheets, and provides different types of quality gateways. For instance the system makes it possible for multi-

⁵ www.naturvardsverket.se

⁶ <https://tps.naturvardsverket.se/>

ple users such as the SMED consortium and the national independent reviewers to view data, plot time series and make comparisons between different years and submissions. 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 also allows for different types of data output, e.g. to the CRF Reporter or to MS Excel. Finally, TPS is used for data archiving of each submission. For access to the TPS, login with password is requested.

The CRF-tables were generated using the export function in CRF Reporter.

In addition to TPS, documentation, data and all calculations for each submission are stored at each organizations servers and, for collective use and archiving, at two projects at Projectplace⁷. One project is for documents shared between Swedish EPA, other involved agencies and SMED and the other project is primarily for SMEDs use however the Swedish EPA also has access to the project. At Projectplace, all documents are stored in versions, in other words when documents are changed a new version is automatically created. This function ensures that important information is not lost and facilitates backtracking of changes. Login with password is requested for access to projects at Projectplace.

1.3.8 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.

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.

⁷ www.projectplace.com

1.4 Brief general description of methodologies and data sources used

1.4.1 GHG inventory

Emission estimates are mainly based on activity data from national or official Swedish statistics, e.g. energy statistics, European Union Emission Trading Scheme (EU ETS)⁸, environmental reports⁹, agricultural and forestry statistics, as well as data on production (e.g. cement) and consumption (e.g. fluorinated gases: F-gases) obtained directly from the major producers and consumers, respectively.

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

The methodologies used for Sweden's greenhouse gas emissions inventory are in accordance with the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines)¹⁰ and, in general, in line with IPCC's Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (Good Practice Guidance)¹¹ and IPCC's Good Practice Guidance for Land Use, Land-Use Change and Forestry (GPG-LULUCF)¹². Some parts of the methodologies are taken directly from the IPCC Guidelines, the Good Practice Guidance and the EMEP/CORINAIR Emission Inventory Guidebook (CORINAIR).¹³ Information from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines)¹⁴ is used in some parts of the inventory.

In Table 1.3, all Tier methods used, which differ from Tier methods recommended in IPCC Guidelines or Good Practice Guidance, are presented. There is also a brief explanation of why the recommended methods have not been used. Note that for sectors where no specific recommendations are made in the IPCC Guidelines or Good Practice Guidance, these sectors are not included in Table 1.3. 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.

⁸ See Annex 8.1

⁹ See Annex 8.3

¹⁰ The IPCC Guidelines can be found at: <http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm>

¹¹ The Good Practice Guidance can be found at: <http://www.ipcc-nggip.iges.or.jp/public/gp/english/>

¹² The GPG-LULUCF can be found at: <http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.html>

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

¹⁴ The 2006 IPCC Guidelines can be found at: <http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html>

Table 1.3. Methods used that differ from recommended methods in the IPCC Guidelines or Good Practice Guidance for all sectors.

Sector	Used method Tier	IPCC Guide-lines 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).
Industrial processes: Emissions of PFC from aluminium production	2	3	No measurements are performed, so Tier 3 cannot be applied. The method used is Tier 2.
Industrial processes: Emissions of SF ₆ from electrical insulation	2a	3	There is not enough information available to perform Tier 3.
Industrial processes: Semiconductor manufacture	1	2	There is not enough information available to perform Tier 2.
Waste: N ₂ O from waste water	National	1	Sweden uses national statistics on nitrogen emissions. Nitrogen emissions are only model calculated for the rural population.

SMED has carried out the calculations. In a few cases, estimates are based on expert judgements.

The combined effect of various greenhouse gases has been calculated using global warming potential factors (GWP). These are developed by the IPCC and are used as a means of comparing the relative significance of various gases in terms of their greenhouse effect, expressed as carbon dioxide equivalents.

Emission factors and thermal values for the energy sector are provided in Appendix 1.

1.4.2 KP-LULUCF inventory

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

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

The carbon pool changes associated to the activities reported under the Kyoto protocol is estimated in exactly the same way as under the UNFCCC reporting, using the stock change method and area based sampling for most of the carbon pools. However, the living biomass is reported separately for above-ground and below-

ground biomass, respectively, and the Dead organic matter is reported separately for Litter and Dead wood.

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

1.5.1 GHG inventory (including and excluding LULUCF)

According to Good Practice Guidance, key categories in a national inventory 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 tiers, tier 1 assessment and tier 2 assessment. The two tier assessments differ in the sense that the tier 2 assessment includes information of uncertainties. According to Good Practice Guidance, the results from the tier 2 assessment should be utilised if the tier 2 results differ from the tier 1 results. Hence, in the Swedish inventory, the results from the tier 2 assessment is the basis for applying and describing higher tier methodologies and when prioritizing efforts in improving the quality of the inventory estimates.

The resulting tier 1 and tier 2 key categories are presented in CRF table 7 and Table 1.4. In Annex 1 the methodology is discussed in detail and corresponding background tables, according to tables 7.A1 - 7.A3 of the Good Practice Guidance are presented.

As can be seen in Table 1.4 most tier 2 key categories are part of the tier 1 assessment. A few additional categories are however identified as key due to their high uncertainty, e.g. CH₄ in CRF 1.A.4.b (Residential) and in CRF 1.A.4.c (Agriculture/Forestry/Fisheries). Note that it is common that the tier 2 assessment render fewer key categories than the tier 1 assessment.

Table 1.4. Tier 1 and tier 2 key categories 2010 in terms of level and trend

IPCC Source Category	GHG	Tier 1	Tier 2
1.AA.1.A (Public Electricity and Heat Production)	CH4	T	T
1.AA.1.A (Public Electricity and Heat Production)	CO2	LT	LT
1.AA.1.A (Public Electricity and Heat Production)	N2O	LT	LT
1.AA.1.B (Petroleum Refining)	CO2	LT	LT
1.AA.1.C (Manufacture of Solid Fuels and Other Energy Industries)	CO2	L	
1.AA.2.A (Iron and Steel)	CO2	LT	L
1.AA.2.C (Chemicals)	CO2	LT	L
1.AA.2.D (Pulp, Paper and Print)	CO2	LT	
1.AA.2.E (Food Processing, Beverages and Tobacco)	CO2	LT	
1.AA.2.F (Other Manufacturing Industries and Construction)	CO2	LT	LT
1.AA.2.F (Other Manufacturing Industries and Construction)	N2O	L	L
1.AA.3.A (Civil Aviation)	CO2	LT	
1.AA.3.B (Road Transportation)	CH4	T	T
1.AA.3.B (Road Transportation)	CO2	LT	LT
1.AA.3.D (Navigation)	CO2	LT	LT
1.AA.3.E (Other Transportation)	CO2	L	
1.AA.4.A (Commercial/Institutional)	CO2	LT	LT
1.AA.4.B (Residential)	CH4	T	LT
1.AA.4.B (Residential)	CO2	LT	LT
1.AA.4.B (Residential)	N2O		L
1.AA.4.C (Agriculture/Forestry/Fisheries)	CH4		T
1.AA.4.C (Agriculture/Forestry/Fisheries)	CO2	LT	L
1.AA.5.B (Military Use)	CO2	T	T
1.AA.5.B (Military Use)	N2O		T
1.B.2 (Oil and Natural Gas)	CH4		LT
1.B.2 (Oil and Natural Gas)	CO2	LT	LT
2.A.1 (Cement production)	CO2	LT	
2.A.2 (Lime Production)	CO2	LT	
2.B.2 (Nitric Acid Production)	N2O	LT	T
2.C.1 (Iron and Steel Production)	CO2	LT	LT
2.C.2 (Ferroalloys Production)	CO2	T	
2.C.3 (Aluminium production)	PFC	T	T
2.F.1 (Refrigeration and Air Conditioning Equipment)	HFC	LT	LT
4.A (Enteric Fermentation)	CH4	LT	LT
4.B (Manure Management)	CH4	LT	
4.B (Manure Management)	N2O	LT	LT
4.D.1 (Direct Soil Emissions)	N2O	LT	LT
4.D.2 (Pasture, Range and Paddock Manure)	N2O	L	LT
4.D.3 (Indirect Emissions)	N2O	LT	LT
4.D.4 (Agricultural Soils. Other)	N2O	L	LT
5.A (Forest Land)	CO2	LT	LT
5.B (Cropland)	CO2	LT	LT
5.B (Cropland)	N2O		T
5.C (Grassland)	CO2	LT	L
5.E (Settlements)	CO2	LT	LT

6.A (Solid Waste Disposal on Land)	CH4	LT	LT
6.B (Wastewater Handling)	CH4	L	L
6.C (Waste Incineration)	CO2	T	

L Level. T Trend.

1.5.2 KP-LULUCF inventory

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

Carbon dioxide emissions for land use categories Forest land, Cropland, Grassland and Settlements are considered key categories under the UNFCCC. Emissions under categories 5I, 5IV and 5V are never identified as key categories for any gas under the UNFCCC. Under the UNFCCC, 5III N₂O emissions from land use conversions to Cropland was identified as a key-category for trend including uncertainty.

Activities Forest management, Afforestation/ Reforestation and Deforestation were considered key-categories (CO₂). Part of 5III N₂O emissions from land use conversions to Cropland corresponds to D from Forest to Cropland. However, this category was not identified as key-category because most of the emissions under the UNFCCC refer to land use conversions from Grasslands to Cropland and due to a “conservative” high assumed uncertainty (100%). Every key category is estimated using higher tiers.

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

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

1.7 General uncertainty evaluation

1.7.1 GHG inventory

An uncertainty analysis has been performed according to the Tier 1 method, described in detail in Annex 7 and Good Practice Guidance section 6.3.2. The analysis has been performed both including LULUCF and excluding LULUCF. Accord-

ing to the IPCC Guidelines, uncertainty estimates are an essential part of an emission inventory. They should be derived for each variable used in the inventory (measured emissions, activity data and emission factors) and aggregated into uncertainty estimates in total national emissions and emission changes over time (trends). The 2006 IPCC Guidelines identify that: “An uncertainty analysis should be seen, first and foremost, as a means to help prioritise national efforts to reduce the uncertainty of inventories in the future, and guide decisions on methodological choice”.

During 2005, a SMED study was performed, aiming at improving the transparency and quality in the present uncertainty estimates in the Swedish National Greenhouse Gas Inventory by making the underlying documentation and structures for uncertainty estimates more consistent and traceable. This will facilitate easier replication and updating of results as well as enable internal and external reviews of assigned uncertainties. To simplify the methodology, there have not been any adjustments for correlation between gases, even though many of them have the same activity data and therefore are correlated. The study is described in Annex 7 and in detail in a SMED report.¹⁵

The Good Practice Guidance Tier 1 method is based on emission estimates and uncertainty coefficients for activity data and emission factors. The analysis was done for the sectors Energy, Industrial Processes, Solvent and Other Product Use, Agriculture, LULUCF and Waste. Uncertainty coefficients have in many cases been assigned based on expert judgement or on default uncertainty estimates provided in the Good Practice Guidance, since not enough background data was available to make actual statistical uncertainty calculations. Hence, care should be taken when interpreting and assessing the uncertainty results.

Uncertainty estimates have been performed for the base year 1990 and 2010 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 very important information when planning future inventories and, above all, using and evaluating the inventory results. The 2005 study did not include improvement of single uncertainties, for instance by contacting external experts for better information on uncertainties on different sources. Further work considering uncertainties will focus on such improvements.

¹⁵ Gustafsson, 2005

In conjunction with the tier 1 uncertainty calculations of emission levels for 1990 and 2010, uncertainty introduced to the trend 1990-2010 is calculated following the IPCC tier 1 method.

1.7.1.1 RESULTS

The results of the uncertainty calculations according to the tier 1 uncertainty approach are presented in Annex 7. The overall uncertainty for 2010 GHG emissions (in CO₂ equivalents) in Sweden is calculated to be $\pm 4.1\%$, excluding LULUCF (Figure 1.4). The overall uncertainty largely stems from uncertainty in the agricultural sector (CRF 4). The national estimated uncertainty neither include corrections for the correlation that may exist between gases (i.e. based on the same activity data), nor include corrections for non-reported sources. Therefore, the actual uncertainty of the estimated emissions per compound and of the aggregated greenhouse gas emissions will be somewhat different.

As can be seen in Figure 1.4, when including LULUCF in national total emissions the uncertainty is higher ($\pm 25\%$), and this is an effect of large and relatively uncertain carbon sinks.

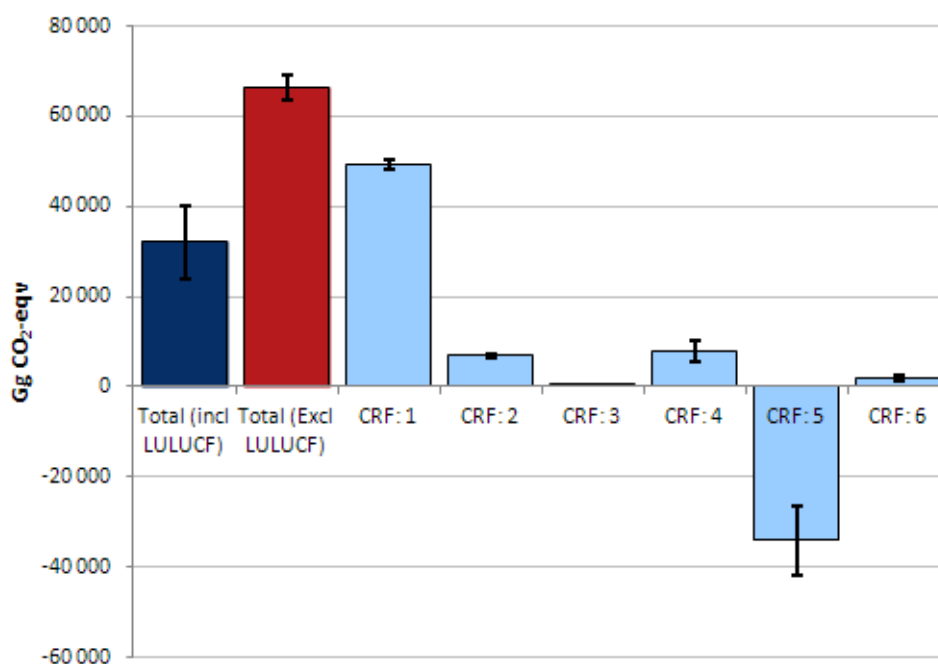


Figure 1.4 Uncertainty estimates, as 95% confidence intervals, in national total emissions (excluding and including LULUCF) and by sector.

Table 1.5 shows the ten sources with the largest uncertainty contributions in the Swedish inventory for 2010, excluding LULUCF.

Table 1.5. The ten sources with the largest uncertainty contributions in the Swedish inventory for 2010, excluding LULUCF.

IPCC Source Category	GHG	Year 2010 emissions or removals (Gg CO ₂ -eqv)	Activity data uncertainty (%)	Emission factor uncertainty (%)	Combined uncertainty (%)	Contribution to variance in year 2010 (%)
4.D.1 (Direct Soil Emissions)	N ₂ O	2482	15	66	67	38
4.D.4 (Agricultural Soils. Other)	N ₂ O	687	35	150	154	15
4.D.3 (Indirect Emissions)	N ₂ O	830	28	122	125	15
6.A (Solid Waste Disposal on Land)	CH ₄	1279	25	50	56	7
1.AA.3.B (Road Transportation)	CO ₂	18962	2	3	3	5
4.D.2 (Pasture, Range and Paddock Manure)	N ₂ O	406	35	150	154	5
1.AA.1.A (Public Electricity and Heat Production)	CO ₂	10014	1	6	6	5
4.A (Enteric Fermentation)	CH ₄	2713	2	11	11	1
1.AA.2.F (Other Manufacturing Industries and Construction)	CO ₂	4564	6	3	6	1
1.AA.4.B (Residential)	CH ₄	293	14	99	100	1

It could be noted that estimated overall uncertainty in submission 2011, excluding LULUCF, was ± 6.3 % for year 2009, i.e. higher than the estimated overall uncertainty for year 2010 in submission 2012. This is mainly due to somewhat different assumptions regarding correlations between emission factor uncertainties. The uncertainty of the trend of national total greenhouse gas emissions excluding LULUCF was ± 2.1 % (compared to $\pm 2.2\%$ in submission 2011). The uncertainty in the trend is a percentage point range relative to the inventory trend and should be interpreted as $\pm 2.1\%$ to the estimated percentage difference between total GHG emissions 1990 and 2010, i.e. there is a 95% probability that the decrease in GHG emissions in Sweden 1990 to 2010 is between 6.9 % and 11 %.

1.7.2 KP-LULUCF activities

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

1.8 General assessment of completeness

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

1.8.1 GHG inventory

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

1.8.1.1 ENERGY

Estimated emissions are considered to be complete for most sources. Emissions of CH₄ and N₂O from liquid bio fuels used in military transportation are however not estimated. There might also still be some lack in completeness as regards in-house generated fuels in the chemical industry and in smaller companies.

1.8.1.2 INDUSTRIAL PROCESSES

For most sources, and particularly for the most important ones, the estimates are in accordance with the requirements concerning completeness as laid out in the Good Practice Guidance. However, some exceptions do exist. These are primarily in sub-sectors with a large number of smaller facilities with minor emissions.

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

1.8.1.3 SOLVENT AND OTHER PRODUCT USE

The estimated emissions from solvent and product use are considered to be complete, since a new method was developed during 2005 in order to obtain all activity data concerning the sector from the Products register at the Swedish Chemicals Agency.

The estimated emissions of N₂O are also considered to be complete, since national data from the Products register is used in the inventory.

1.8.1.4 AGRICULTURE

All relevant agricultural emissions and sources are reported in the inventory. Reindeer, which are normally not considered as a part of the agricultural sector, are included in the inventory. The majority of the country's horses does not belong to farms, but are included in the agricultural sector of the inventory. There are, however, some marginal animal groups, which are not included, such as fur-bearing animals (minks, foxes and chinchillas). These groups are very small and there is no methodology developed for estimating their GHG emissions.

All sales of fertilizers are included in the inventory, also quantities used in other sectors. N-fixing crops used in temporary grass fields, and sludge used as fertilizer is also included. This means that all anthropogenic inputs to agricultural soils are covered.

1.8.1.5 LAND USE, LAND USE CHANGE AND FORESTRY

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

The inventory of the LULUCF-sector is complete in the sense that all carbon pools and other sources, defined based on the IPCC GPG for LULUCF, 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. Emissions/removals from below ground biomass of dead stump systems are from this submission included in the dead organic matter pool.

1.8.1.6 WASTE

The effects of possible leakage of methane and nitrous oxide from the wastewater treatment processes have not been estimated. All other data are complete.

1.8.2 KP-LULUCF

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

2 Trends in greenhouse gas emissions

2.1 Description and interpretation of emission trends for aggregated greenhouse gas emissions

Total greenhouse gas emissions in Sweden, calculated as carbon dioxide equivalents, totalled 66.2 million tonnes (excl. LULUCF) in 2010. Aggregated greenhouse gas emissions varied over the period but in all cases were below the 1990 level during the period 1999-2010. Emissions decreased by 6.5 million tonnes or 9% between 1990 and 2010. The uncertainty in the trend is a percentage point range relative to the inventory trend and should be interpreted as $\pm 2.1\%$. The trend in emissions from 1990 is a result of decreasing emissions from the residential and service sector, the agriculture sector and the waste sector and since 2007 the emissions from the transport sector have started to stagnate. Between 2003 and 2009, emissions have decreased every year compared to the previous year but in 2010 the emissions increased instead compared to 2009.

In 2010 the emissions increased compared to 2009 due to very cold weather and due to the recovery in the industry from the economic downturn. The cold winters in 2010, both in the beginning and in the end of the year, increased the need for heating. In combination with lower nuclear production than normal this led to increased use of fossil fuels in the electricity and heat production. During the autumn of 2008, an economic downturn began which was deepened during 2009 and has affected a number of sectors. The recession has led to that many industrial sectors have reduced production considerably, with diminished emissions in 2009 as a consequence. In 2010 most of the industries have started to recover from the economic downturn. However, the emissions from most of the industries are still below the 2008 level.

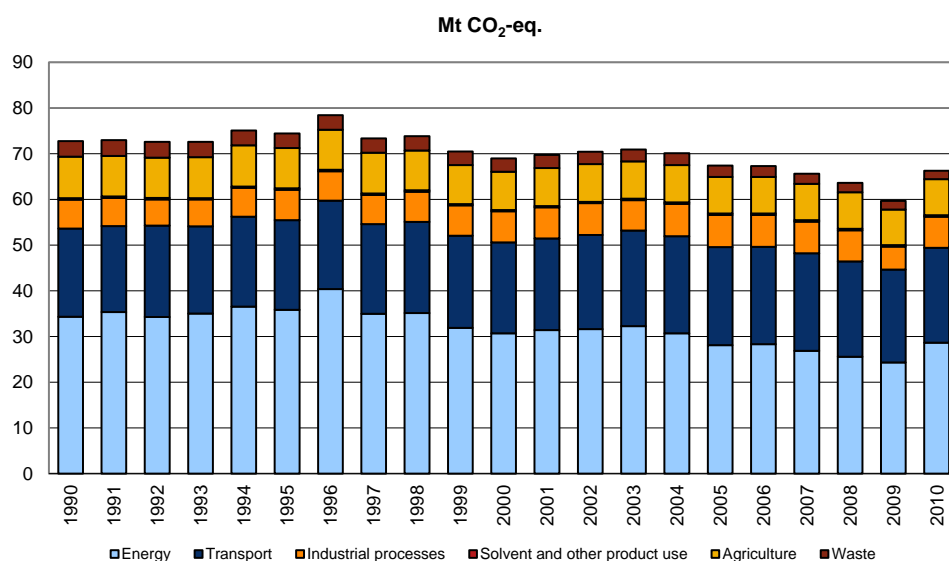


Figure 2.1 Total emissions of all greenhouse gases calculated as CO₂ equivalents from the different sectors.

The Land Use, Land-Use Change and Forestry sector (LULUCF) resulted in annual net removals in Sweden during the period 1990-2010. The size of the sink varied over the period. The net removals in 2007-2010 may however be revised somewhat in the coming years due to the methodology used.

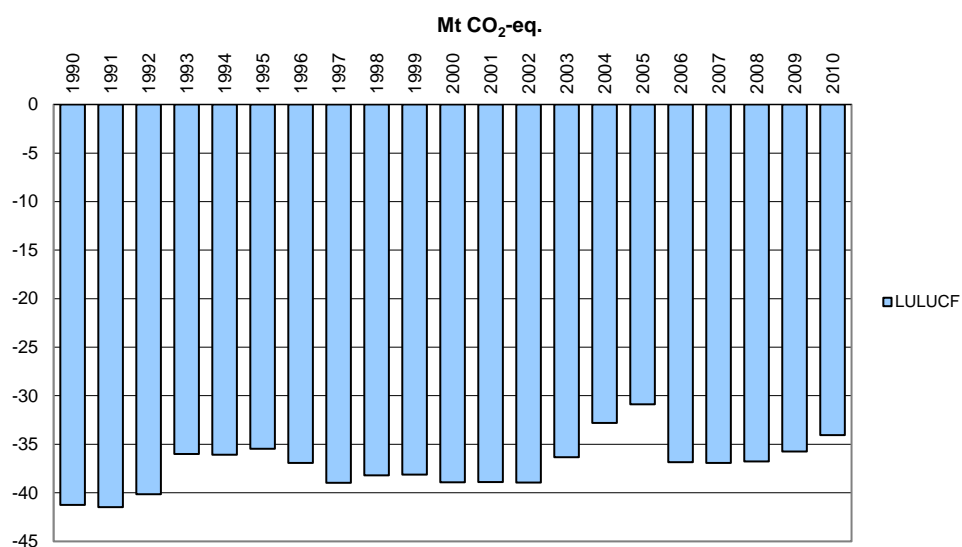


Figure 2.2 Total net removals and emissions from land use, land use change and forestry (LULUCF), calculated as CO₂ equivalents.

GDP growth averaged around 2% over the period 1990-2010. The GDP was falling at the start of the 1990s, but has been increasing by an average of around 3% per year since 1994, except 2008 and 2009, when growth fell by 0.5% and 5% respectively. GDP in 2010 increased by around 5%. Despite economic growth of around 50% between 1990 and 2007, emissions of greenhouse gases have still been able to

be reduced. Even per capita emissions of greenhouse gases (excl. LULUCF) have gone down, from 8.5 tonnes per person in 1990 to 7 tonnes per person in 2010.

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

According to Sweden's commitment under the Kyoto Protocol and the EU burden sharing decision, Sweden's greenhouse gas emissions must not exceed 104% of the emissions in the base year. The base year is 1990 for all emissions except fluorinated greenhouse gases, for which it is 1995. The base year's emissions were 72.2 million tonnes carbon dioxide equivalents, when the assigned amount was established. The assigned amount for Sweden is calculated to 75 million tonnes per year as an average (Assigned Amount Units (AAU)). In addition, Sweden can also credit itself with a net removal of carbon dioxide of a maximum 2.13 million tonnes per year (Removal Units (RMU)), according to article 3.3 and 3.4 in the Kyoto Protocol. This means that Sweden's emissions of greenhouse gases will be allowed to comprise a maximum of 77.13 million tonnes per year on average for 2008-12. Of these emission allowances, an average of approximately 22.3 million tonnes per year has been allocated within the EU emissions trading scheme.

Total greenhouse gas emissions in 2010 were 66.2 million tonnes of carbon dioxide equivalents in Sweden. The allocation for the trading sectors were 23.5 million tonnes in 2010 and the emissions from sectors outside the trading scheme were 43.6 million tonnes carbon dioxide equivalents. This means that the total emissions in Sweden in 2010 were around 13% below the assigned amount, including the net effect of allocation to the EU ETS and the carbon sink. This suggest that Sweden will meet its commitment. The national surplus of Assigned Amount Units and Removal Units was around 10 million tonnes in 2010. The corresponding surplus in 2008 was around 12.8 million tonnes and 12.8 million tonnes in 2009. It is not yet decided what to do with the surplus of AAU:s, if it should be cancelled, saved or sold. Note that these figures are uncertain and only preliminary since the final calculations on target fulfilment will be made in 2014.

Mt CO ₂ -eq.	2008	2009	2010
Non EU ETS Emissions	43.5	42.2	43.6
EU ETS Verified emissions	20.1	17.5	22.7
Allowances EU ETS	20.8	22.1	23.5
Total emissions	63.6	59.7	66.2
Total emissions incl. net effect of EU ETS	64.3	64.3	67.1
Assigned amount incl LULUCF	77.13	77.13	77.13
Emissions incl. effect of EU ETS and LULUCF relative to Assigned Amount	-17%	-17%	-13%

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

Sweden's commitment for the sectors outside the EU Emissions Trading Scheme according to the EU's Climate and Energy Package is that emissions have to decrease by 17% between 2005 and 2020. The Swedish target according to the 2009 climate policy resolution of the Swedish Parliament is for emissions by non-trading sectors to decrease by 40% or around 20 million tonnes between 1990 and 2020 (of which one third can be reduced by emission reductions in other countries). This is equivalent to a decrease of 33% between 2005 and 2020. Emissions from the non-trading sectors totalled 46.3 million tonnes in 2005 calculated with the same scope of the trading scheme as in 2008-12 (including aviation). Emissions totalled 43.6 million tonnes in 2010, which is a decrease of 6% compared with 2005. The economic downturn led to far lower emissions in 2009, but most of the decrease has taken place in those sectors that are included in the EU Emissions Trading Scheme. Also the increase in 2010 has mainly taken place in those sectors that are included in the EU ETS.

Mt CO ₂ -eq.	2005 (scope 2008-12)	2008	2009	2010	2005-2010 (%)
Non EU ETS	46.3	43.5	42.2	43.6	-6%
EU ETS	21.1	20.1	17.5	22.7	8%
Total emissions	67.4	63.6	59.7	66.2	-2%

2.1.3 Overview of emissions trends per sector

Emissions of greenhouse gases from different sectors of society developed in different directions over the period from 1990 to 2010. The greatest reductions in emissions over the period 1990-2010 took place in the residential and service, agriculture, waste and some industrial sectors. Increases in emissions occurred principally in the transport sector and in certain industrial sectors. The emissions were, however, reduced or moderated in a number of sectors in 2008-2009 as a consequence of, among other things, the economic downturn that began in the autumn of 2008 and the increased share of renewable fuels and reduced fuel consumption in the transport sector. The industrial sectors have consequently increased their emissions again in 2010 compared to 2009 following the economic recovery.

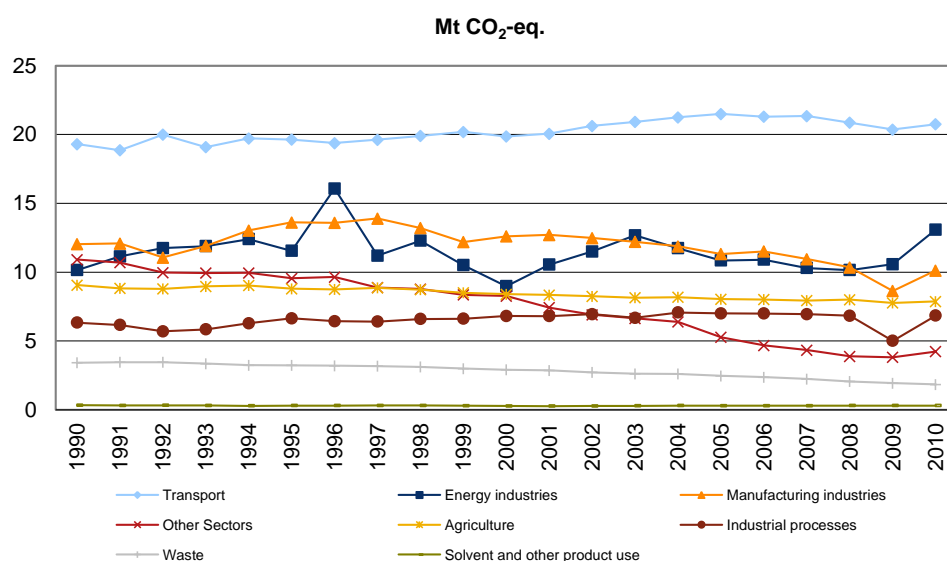


Figure 2.3 Total emissions of all greenhouse gases calculated as CO₂-equivalents by sectors.

2.2 Description and interpretation of emission trends in relation to gas

In 2010, emissions (excl. LULUCF) of *carbon dioxide* totalled 52.9 million tonnes, which is equivalent to almost 80% of aggregated greenhouse gas emissions. Emissions of *methane* were 5.3 million tonnes of carbon dioxide equivalents and account for just over 8% of emissions, while emissions of *nitrous oxide* totalled 7.0 million tonnes, equivalent to almost 11%. Only almost 2% or 1.1 million tonnes of carbon dioxide equivalents out of the aggregated greenhouse gas emissions were emissions of *fluorinated greenhouse gases*. The share of different greenhouses gases was roughly the same over the period 1990-2010.

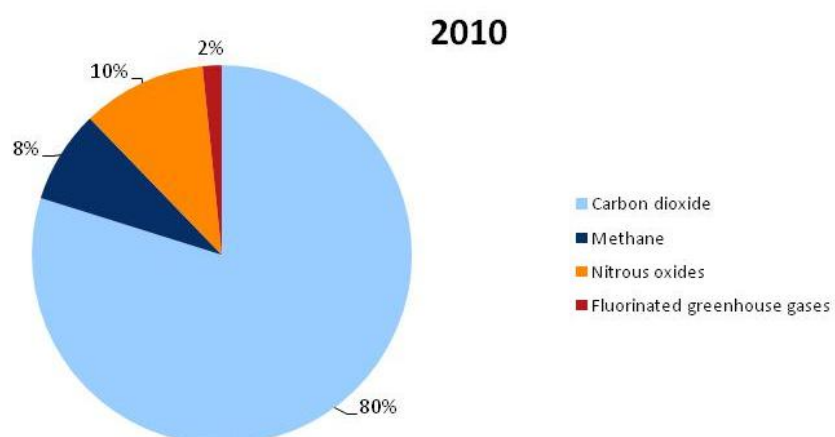


Figure 2.4 Greenhouse gas emissions by gas (2010).

2.2.1 CO₂

In 2010, total *carbon dioxide* emissions in Sweden totalled 52.9 million tonnes, excl. LULUCF. 51% of carbon dioxide emissions came from the energy sector, 39% of carbon dioxide emissions came from the transport sector and the remaining 10% came from industrial processes, solvent and other product use and waste. Emissions were 7% lower in 2010 than in 1990, and it is the energy sector that has shown the greatest reduction.

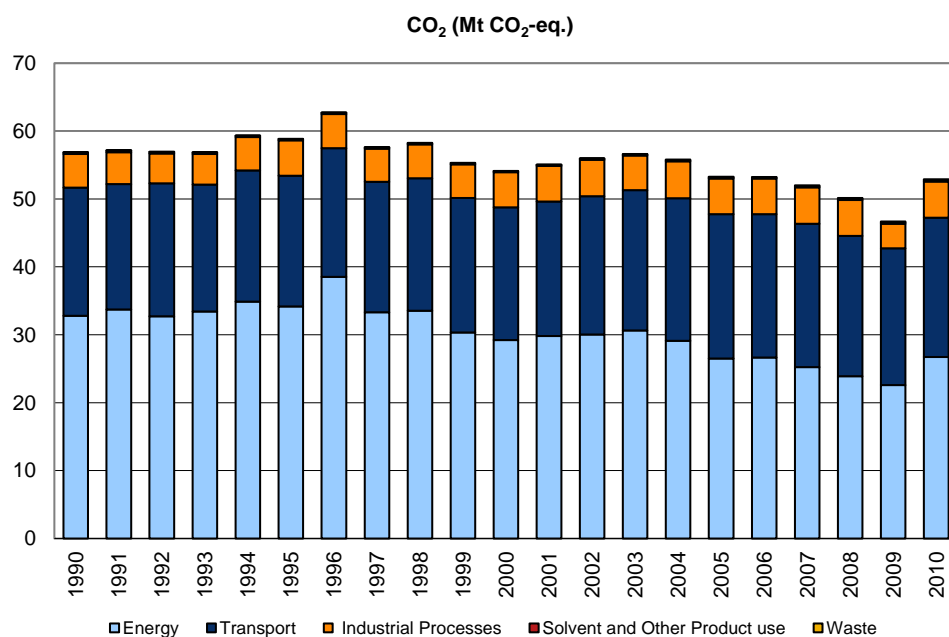


Figure 2.5. Total emissions of CO₂ from different sectors.

2.2.2 CH₄

Emissions of *methane* come primarily from agriculture and landfills, but around 13% is emitted in the energy and transport sector and from industrial processes. Emissions of methane, excl. LULUCF, totalled 252 ktonnes in 2010, which is equivalent to 5.3 million tonnes calculated as carbon dioxide equivalents or 8% of total greenhouse gas emissions. Emissions have fallen by 26% since 1990, largely due to measures taken in the waste sector.

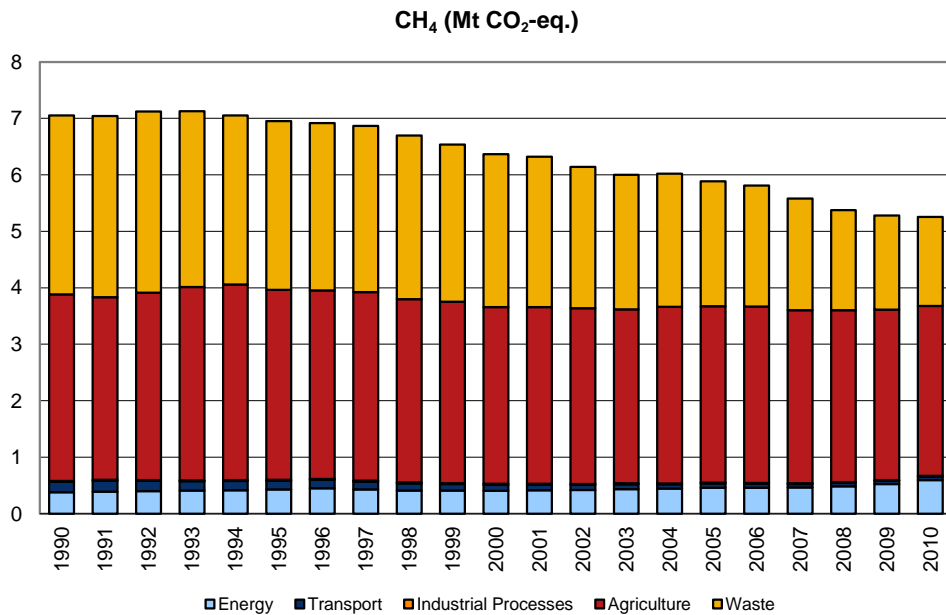


Figure 2.6 Total emissions of CH₄ from different sectors, calculated as CO₂-equivalents.

2.2.3 N₂O

In 2009, emissions of *nitrous oxide* totalled 23 ktonnes or 7 million tonnes of carbon dioxide equivalents (excl. LULUCF). All sectors produce nitrous oxide emissions, but the emissions came chiefly from the agriculture sector, which accounted for 68% of emissions. Compared with 1990, emissions have decreased by 15%, and it is primarily emissions from the agriculture sector that account for the decrease.

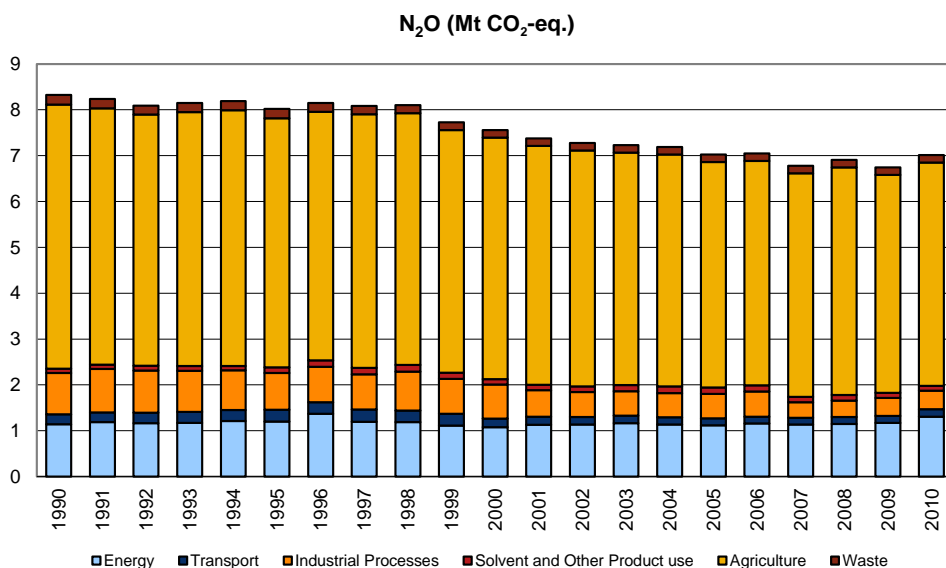


Figure 2.7 Total emissions of N₂O from different sectors calculated as CO₂-equivalents.

2.2.4 Fluorinated greenhouse gases

Emissions of fluorinated greenhouse gases (F-gases) are reported in the industrial processes sector. Total emissions of fluorinated greenhouse gases in 2010 amounted to 1.1 million tonnes calculated as carbon dioxide equivalents and account for almost 2% of total emissions. Emissions increased by 121% between 1990 and 2010.

Emissions of HFCs increased in particular, from just under 4 ktonnes of carbon dioxide equivalents in 1990 to 849 ktonnes in 2010. PFCs emissions, on the other hand, have decreased. In 1990 emissions of PFCs amounted to 377 ktonnes of carbon dioxide equivalents, and in 2010 they had fallen to around 158 ktonnes. Emissions of SF₆ varied between 1990 and 2010. In 1990 they totalled 107 ktonnes and in 2010 they amounted to 73 ktonnes of carbon dioxide equivalents.

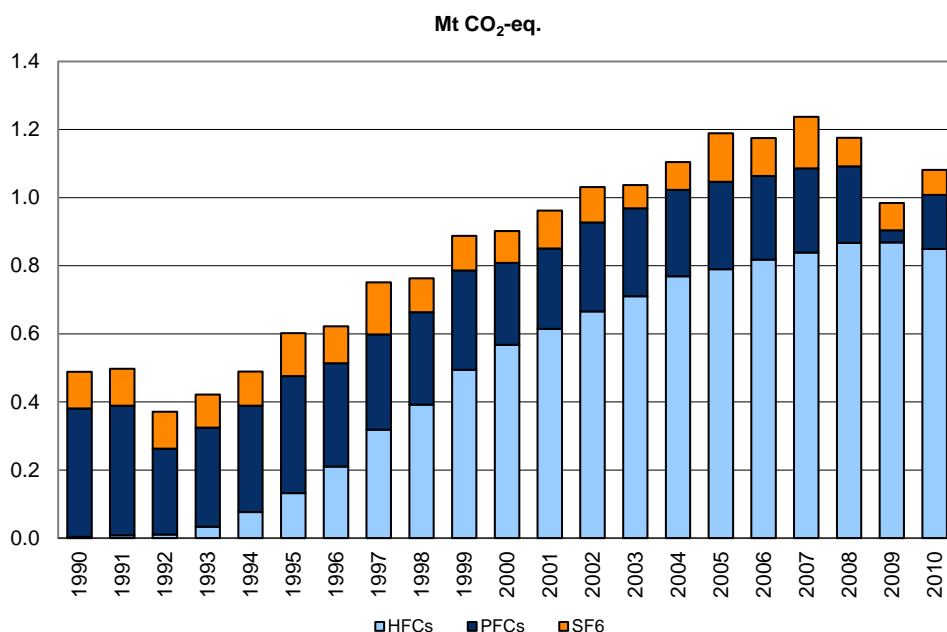


Figure 2.8 Total emissions of SF₆, PFC and HFC, calculated as CO₂-equivalents

2.3 Description and interpretation of emission trends in relation to source

The emissions from the transport and industry sectors account for a considerable part of the total emissions in Sweden beside the emissions from energy industries and energy use. In 2010 the emissions from the energy sector, excluding transport, made up 43% of total greenhouse emissions, in which the energy industry accounted for 20%, industrial combustion for 15%, the residential and service sector for 6% and fugitive emissions and other for 2%. Domestic transport accounted for 31% of total greenhouse gas emissions, agriculture for 12%, industrial processes for 10%, the waste sector for 3% and the use for solvents and other products for 0.5%.

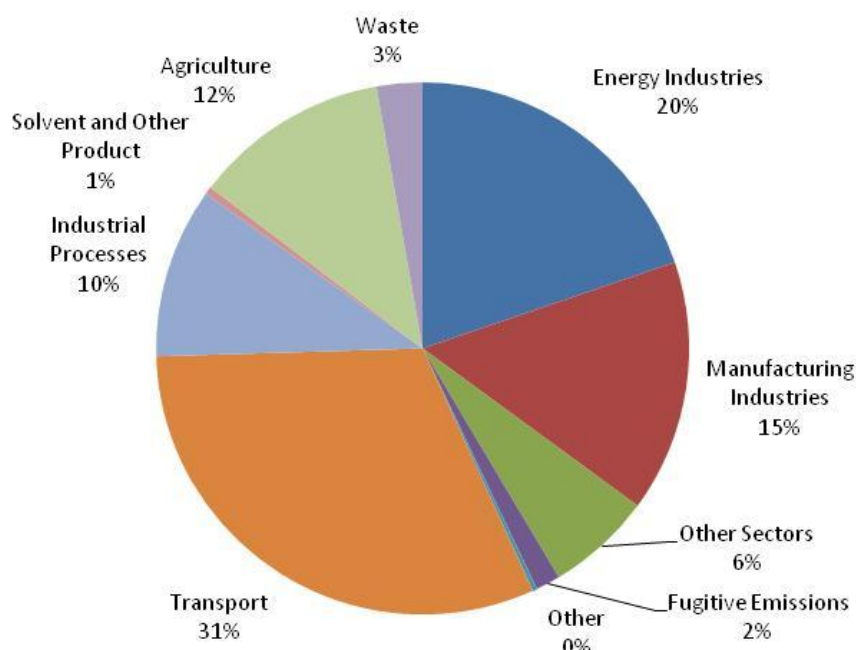


Figure 2.9 Greenhouse gas emissions by sector (2010).

2.3.1 Energy excluding transport

Emissions of greenhouse gases by the energy sector amounted to 28.6 million tonnes of carbon dioxide equivalents in 2010, which is equivalent to 43% of total emissions. Carbon dioxide emissions dominate emissions by the energy sector, while emissions of methane and nitrous oxide are small.

Emissions by the energy sector include emissions from the production of electricity and district heating, refineries, manufacture of solid fuels, industrial combustion, fugitive emissions, other and the residential and service sector, including combustion in agriculture, forestry and fisheries

Emissions by the energy sector vary depending on temperature and precipitation conditions, the state of the economy and also on instruments that have been changed since 1990. But the trend over the period 1990-2010 was for a slight reduction in emissions. In comparison with 1990, emissions were 17 % lower in 2010 and the decrease is principally due to the use of oil for heating in the residential and service sector having declined and district heating being increasingly based on biomass fuels.

Calculated in terms of carbon dioxide equivalents, total emissions from electricity and district heating production amounted to 10.6 million tonnes, from refineries to 2.2 million tonnes and from industrial combustion to 10.1 million tonnes in 2010. The emissions of the residential and service sector of 4.2 million tonnes include emissions from combustion in the residential

and service sector and combustion in agriculture, forestry and fisheries. Fugitive emissions from fuels come, for instance, from refineries and amounted to almost 1 million tonnes in 2010 and emissions from other were 0.2 million tonnes.

Increases in greenhouse gas emissions can be seen between 2009 and 2010 in almost all subsectors in the energy sector. Underlying causes are the recovery of the economy and increased need for heating due to colder weather. The increase due to colder weather has been analyzed with a normal-correction calculation method, which under some uncertainties, give the result that normal-corrected emissions from heating and electricity production are fairly similar during 2008-2010. The fact that the cold weather has had such a large impact on the emissions of electricity production is due to a number of coinciding factors. Simultaneously with the cold weather there has e.g. been low production in the nuclear power plants and new natural gas capacity has been built.

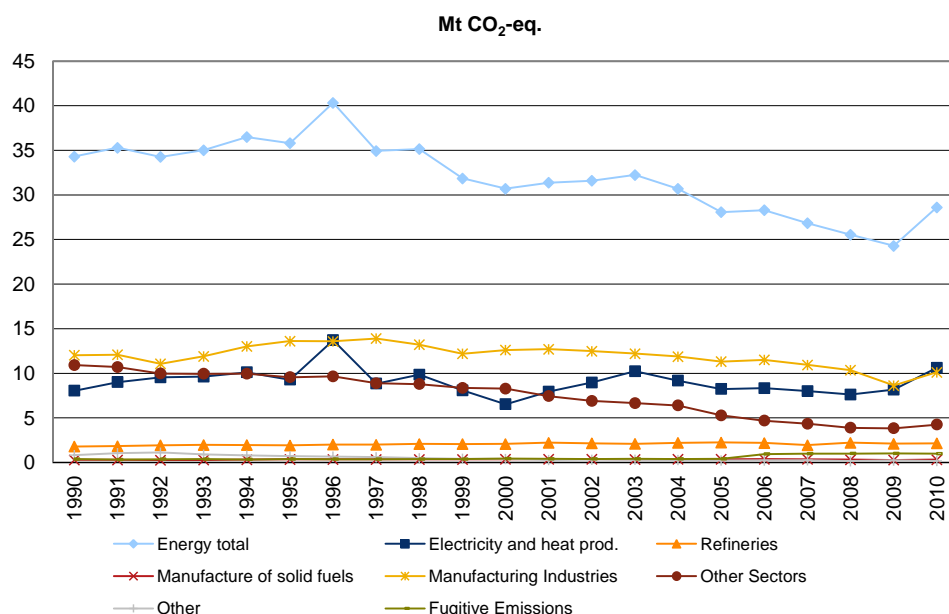


Figure 2.10 Emissions of all greenhouse gases from the Energy sector, total and by subsector.

2.3.1.1 CARBON DIOXIDE FROM THE ENERGY SECTOR, EXCLUDING TRANSPORT

2.3.1.1.1 Electricity and heat production

Emissions of carbon dioxide from the production of electricity and district heating totalled around 10 million tonnes in 2010, which was higher than the level as in 1990 and the second highest amount during the time series, except for 1996.

Temperature and precipitation conditions, which vary between years, have an impact on hydropower production and heating needs in individual years

and thus lead to a variation in emissions between years. This is illustrated by the high emissions in 1996, which was a cold and dry year, and by the low emissions in 2000, which was a warm year with heavy precipitation and thus good availability of hydropower.

During the period 2000-2010 the variation in emissions is smaller. This may be due to the integration of the Swedish electricity network in the Nordic electricity network and that the capacity in electricity transfer increased to other countries outside the Nordic countries. Therefore the deficient production of hydropower in 2003 was offset by imports of electricity while shortage of hydropower in 1996, which was another year of low hydropower production, was partially offset by increased oil condensing production.

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

During the period 1990-2010, the use of district heating increased from 41 TWh in 1990 to 60.2 TWh in 2010. On the other hand, emissions have not increased significantly as the expansion has principally taken place through increased use of biomass fuels. Use of biomass fuels, peat and waste in 1990 totalled 10.4 TWh, and it had risen to 46.6 TWh in 2010 at the same time as the use of oil and coal decreased. Energy and carbon dioxide taxes have, among other things, contributed to this trend.

Both 2009 and 2010 were notable for an upturn in combustion in combined heat and power and in conventional thermal power. Electricity demand was higher in 2010 than in 2009 mainly due to increased heating demand due to cold weather. Electricity demand in industry was higher than in 2009 but lower than all other years since 2000. In other Nordic countries there was also high electricity demand. Swedish nuclear reactors had lower production in both 2009 and 2010, lower than they have had for several decades due to unforeseen shutdowns in connection with renovation and modernisation. Inflow to reservoirs during the year was normal in 2010, but reservoirs were lower than average in the beginning of the year when it was cold. Some net importing of electricity took place in 2010 in Sweden (2 TWh) as well as in the Nordic countries. Wind-power production continued to increase sharply. The increase has been 370 % during the last 5 years. The fact that production of biomass fuel-based combined heat and power was higher than in previous years in 2010 is in part due to the electricity certificates system, which improves the profitability of renewable electricity production. The weather in 2010 resulted in a higher heating demand than the previous years since 1985. The increasing heating demand affected both district heating and electric heating. Combustion of natural gas for production of electricity and district heating has also increased significantly between 2008 and 2010. All together these factors lead to higher emissions of carbon dioxide from

both electricity and district heating in 2010 compared to the emissions in 2009.

2.3.1.1.2 Refineries

Production of refined products increased in Sweden during the period, leading to an increase in carbon dioxide emissions from the refineries from 1.8 million tonnes in 1990 to 2.1 million tonnes in 2010 or almost 20%. The emissions were marginally higher in 2010 than in 2009. The emissions from refineries are also reported in the fugitive emissions sector and in 2006-2009 the total emissions from refineries were higher than the previous years as a new installation was started. Emissions were higher in 2008 than for 2007; however the increase was mostly due to a substantial plant shutdown in 2007 for purposes of performing maintenance repairs.

2.3.1.1.3 Other Sectors

Emissions of carbon dioxide in 2010 were 3.6 million tonnes in the residential and service sector including combustion in agriculture, forestry and fisheries. This is a decrease of 65% in comparison with 1990. The reduction is due to emissions of carbon dioxide from houses and commercial premises having dropped from almost 8.8 million tonnes in the year 1990 to almost 1.9 million tonnes in the year 2010 in consequence of a switch from oil to district heating and in recent years also to heat pumps and pellet-fired boilers.

The total use of fossil fuels strongly decreased during the period 1990-2010. Though the emissions in 2010 increased slightly from 2009 due to colder weather and increased heating demand. 2010 was 14 % colder than a “normal” year.

In 2009, only approximately 1.5% of detached, semi-detached and terraced houses had oil as their sole source of heating in 2008 while the proportion of houses with combined heating systems in which oil were used was 1%. The positive trend is principally due to energy and carbon dioxide taxes, rising oil prices and investment grants for connection to the district-heating network. The trend in energy consumption for heating per unit of floor space area in recent years has decreased for houses as well as for commercial premises and apartment blocks. The conversion losses originating from energy use in the sector have also been somewhat reduced. Causes may be energy efficiency improvements and increased use of heat pumps. Another contributing factor to the favourable development has been the warm weather in several years.

At the same time as carbon dioxide emissions in homes and commercial premises are falling sharply, emissions from energy use in agriculture, forestry and fisheries are increasing slightly and totalled 1.7 million tonnes in 2010. Emissions increased by 6% between 1990 and 2010.

2.3.1.1.4 Manufacturing industries

Carbon dioxide emissions from industrial combustion were around 9.6 million tonnes in 2010. Emissions in 2010 were 16% lower than in 1990, but they have varied upwards and downwards over the years, principally due to economic fluctuations and the difference in relative prices between electricity and oil. A small number of energy-intensive industries account for a large proportion of carbon dioxide emissions in the sector. The iron and steel industry, the pulp and paper industry and chemical industry account for almost equal shares in the emissions – 18%, 15 % and 13% of emissions.

There is a downward trend in emissions between 2002 and 2010, principally due to reduced emissions from the pulp and paper industry caused by fuel substitution. The decreases were greater in 2008 and 2009 during the economic recession, but in 2010 both production volumes, energy demand and carbon dioxide emissions increased again.

Viewed over a longer period from 1970 on, industry has reduced its use of oil and increased its use of electricity. Between 1990 and 2010 the use of oil decreased by 32% Specific oil use (kWh per added value at 2000 prices) and specific electricity use also decreased over the period 1990-2010, by 70% and 55% respectively.

2.3.1.1.5 Fugitive emissions and Other

Emissions from the fugitive emissions sector come for example from refineries. Emissions were 0.9 million tonnes of carbon dioxide in 2010. Emissions from “Other” (principally military emissions) decreased between 1990 and 2010 and totalled 0.2 million tonnes of carbon dioxide in 2010.

2.3.1.2 EMISSIONS OF METHANE AND NITROUS OXIDE FROM THE ENERGY SECTOR

Only a small proportion of emissions from the energy sector are emissions of methane and nitrous oxide. Almost 5 % of emissions from the energy sector are emissions of nitrous oxide, and approximately 2% are emissions of methane.

Methane emissions from the energy sector excl. transport have increased by 57% between 1990 and 2010. The increased emissions are principally due to increased use of biofuels in the residential and service sector and in the production of electricity and district heating. Almost two-thirds of emissions originate from the residential and service sector, including energy use in agriculture. The greatest percentage increase has however happened within the electricity and district heating where emissions sharply increased.

Nitrous oxide emissions have increased with 14% between 1990 and 2010 due to the last years increase in combustion in the energy sector.

2.3.2 Transport

Greenhouse gas emissions from domestic transport totalled 20.7 million tonnes of carbon dioxide equivalents in 2010, which is 7.5% higher than the 1990 level. However, the trend has stagnated somewhat since 2005. Greenhouse gas emissions 2010 from road traffic were 19.1 million tonnes, from domestic aviation 0.5 million tonnes, from domestic navigation 0.7 million tonnes, from railways 0.1 million tonnes and from other machinery 0.3 million tonnes.

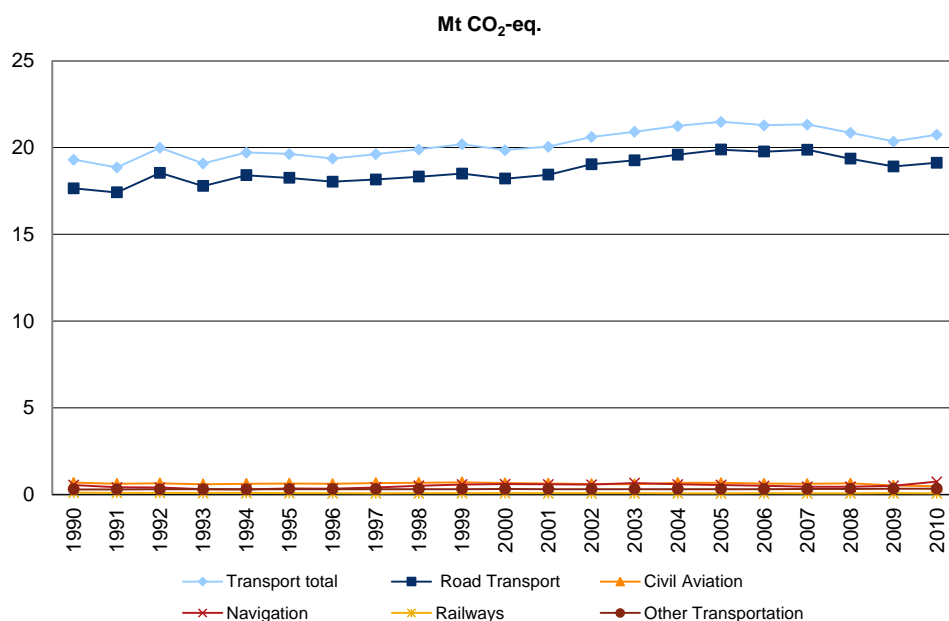


Figure 2.11 Emissions from the transport sector, total and per subsector

2.3.2.1 EMISSIONS OF CARBON DIOXIDE FROM THE TRANSPORT SECTOR

Carbon dioxide from road traffic accounts for the greatest share of the transport sector's greenhouse gas emissions and totalled 19 million tonnes in 2010, which is 9.6% higher than 1990 emissions. Emissions increased from 1990 to 2005 before stagnating and then decreasing somewhat as a result of an increased share of renewable fuels and reduced fuel consumption in combination with the economic downturn in 2008-2009.

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

2009 also led to reduced emissions from diesel-powered heavy duty vehicles in 2009 and to somewhat lower overall use of diesel fuel in the road transport sector.

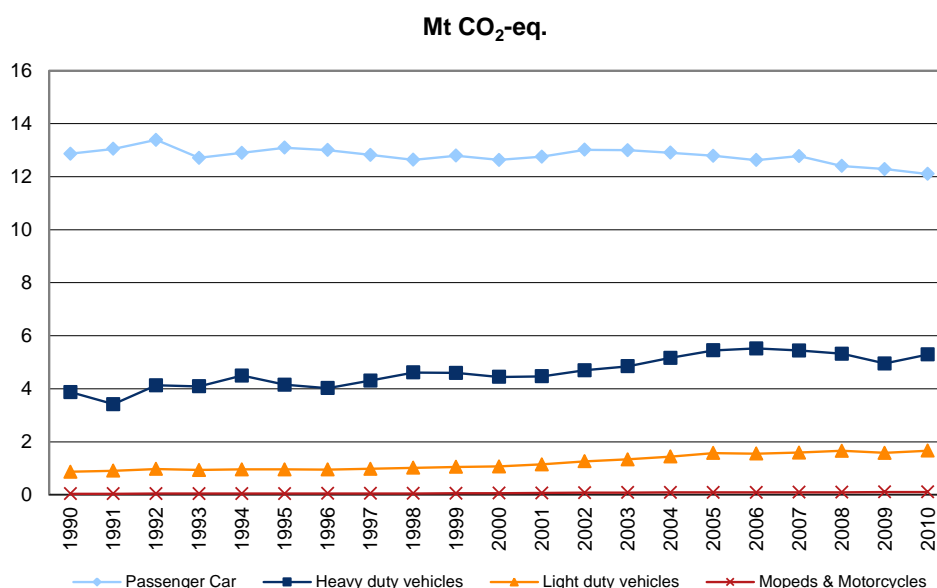


Figure 2.12 Emissions of CO₂ from different vehicle categories. Note that the emissions from different vehicle categories are based on transport mileage and not fuel consumption.

Several points have been significant in limiting emissions from road transport. Among other factors, increased fuel taxes, tax exemption for transport biofuels, carbon dioxide-based vehicle tax and tax relief for green cars, together with rising market price for petrol and diesel, have contributed to more fuel-efficient cars, an increased number of fuel-flexible cars and consequently a switch to renewable fuels. The use of renewable fuels has been principally boosted by the fact that since 2004 they have been exempt from carbon dioxide tax and energy tax. Large-scale blending of ethanol into petrol began in 2003, with the result that almost all petrol sold in Sweden now contains 5% ethanol. Blending of FAME into diesel also increased in 2009. The use of biofuels for fuel-flexible cars also increased from 2004 to 2008, particularly ethanol (E85), but in 2009-2010 the use of E85 decreased somewhat as a result of high ethanol prices and lower petrol prices.

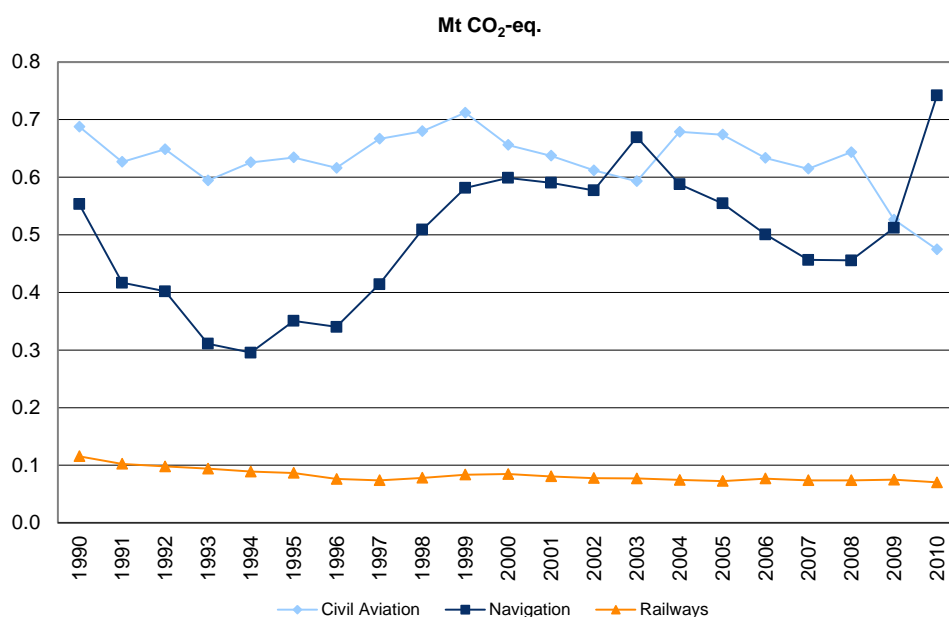


Figure 2.13 Emission of CO₂ from aviation, navigation and railways.

In 2010, emissions of carbon dioxide from domestic aviation were 0.5 million tonnes, which is 31% lower than the level for 1990. However, the emissions varied during the period. Domestic aviation has decreased in later years because the share of train and to some extent car journeys has increased. The fact that more people are choosing train or car rather than flying for domestic travel is considered to be due in part to a decline in the availability of short-haul aviation and to new security requirements and routines having reduced the advantages of flying in terms of speed and flexibility.

Carbon dioxide emissions for domestic navigation are estimated at 0.7 million tonnes in 2010, which is around 35% higher than in 1990. Emissions have decreased after a sharp rise between 1994 and 2003.

Railway carbon dioxide emissions from diesel-powered trains account for a marginal share of transport sector emissions and have decreased by around 40 per cent since 1990.

2.3.2.2 METHANE AND NITROUS OXIDE FROM THE TRANSPORT SECTOR

Emissions of methane and nitrous oxide account for a very small share of greenhouse gas emissions by the transport sector. Methane emissions totalled 0.06 million tonnes of carbon dioxide equivalents in 2010 and have fallen by 70% since 1990 as a result of better exhaust emission control. Nitrous oxide emissions totalled 0.17 million tonnes of carbon dioxide equivalents in 2010. Emissions of nitrous oxide increased from 1990 to 2000 in connection with the switch to cars fitted with catalytic converters. Emissions have since decreased with better exhaust treatment technology.

2.3.3 Industrial processes

Emissions from industrial processes come in particular from the production of iron and steel and from the cement and lime industries. Some examples of emission sources are the use of coke in blast furnaces, the use of dolomite and limestone in production in the mineral industry and the use of coal in the reduction of copper. There are also emissions of fluorinated greenhouse gases in this sector. Total emissions from the sector amounted to 6.8 million tonnes of carbon dioxide equivalents in 2010, which is equivalent to 10% of aggregated emissions. Carbon dioxide emissions are dominant at 78%, followed by fluorinated greenhouse gases at approximately 16%, nitrous oxide at approximately 6% and methane at 0.2%.

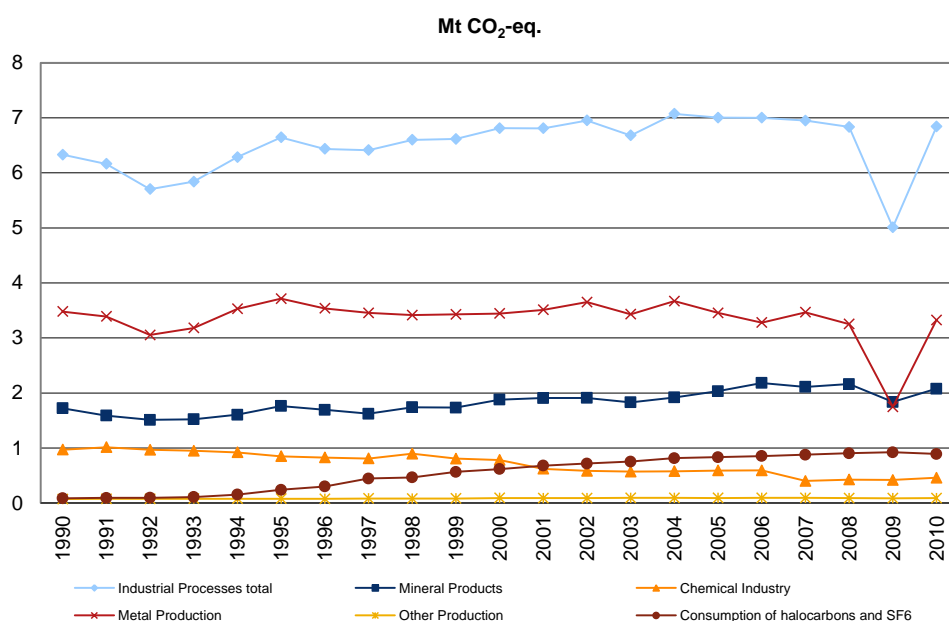


Figure 2.14 Emissions from the Industrial processes sector, total and per subsector.

The total emissions in this sector have varied somewhat since 1990, principally due to variation in production volumes and economic fluctuations. The development may, however, differ for different industries. Emissions from the mineral industry have increased, for example, while those from the chemical industry have decreased over the same period. In 2009 emissions from industrial processes were much lower than in 2008 and 2010, principally due to the decrease in the metal industry, but emissions from the mineral products industry also decreased. The decrease in emissions in 2009 was principally due to reduced production as a result of the economic downturn which began in 2008 and deepened in 2009.

Carbon dioxide emissions from the mineral industry increased over the period 1990-2008. This was principally due to improving economic conditions in the building sector, both in Sweden and in other countries to which cement is exported. Emissions decreased in 2009 as a result of a decline in production resulting from the weakness of the economy. However, the emissions increased again in 2010 but

are not at the same level as in 2008 yet. Emissions from the iron and steel industry have been at about the same level during the period spanning 1990-2010, except for 2009. Emissions from this industry are also reported however in the energy sector, which means that emissions from the iron and steel industry are not fully reflected in this sector. Total emissions from the iron and steel industry have increased by 28% during the entire period spanning 1990-2008, and the emissions have increased most in recent years. The iron and steel industry was severely affected by the economic downturn in 2008-2009, and emissions in 2009 were 38% lower than in 2008. In 2010 the industry recovered and the emissions were 4% lower than in 2008. The emissions from the chemical industry decreased by 53% during the period 1990-2010. Since 2007, emissions have been very low in comparison with preceding years. This is primarily due to a new treatment technology having been installed that has resulted in reduced emissions of nitrous oxide in nitric acid production.

2.3.3.1 FLUORINATED GREENHOUSE GASES (HFC, PFC, SF₆)

Fluorinated greenhouse gases have a number of uses. Most emissions of fluorinated greenhouse gases in Sweden today are due to leakage from refrigeration and air-conditioning systems and air conditioning in vehicles. Other sources are foam manufacturing, medical inhalers, aluminium production and magnesium foundries. Total fluorinated greenhouse gas emissions in 2010 amounted to almost 1.1 million tonnes calculated as carbon dioxide equivalents and account for almost 2% of total emissions. Emissions of fluorinated gases are showing an increasing trend over the period from 1990, principally due to a sharp increase in HFC emissions. One explanation for the increase is that HFCs in many cases have replaced the ozone-depleting substances CFCs and HCFCs as refrigerants. The ozone-depleting substances decreased sharply between 1990 and 2009 and have now been more or less completely phased out. Another explanation for the increase in HFCs is that the number of refrigeration and air-conditioning systems, air conditioning in vehicles and heat pumps has increased, particularly in the recent years.

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

In 2010 the emissions from fluorinated greenhouse gases increased compared to 2009 but were lower than in 2008. Emissions of fluorinated greenhouse gases decreased by 14% in 2009 in comparison with 2008, due to reduced emissions of PFCs. PFC emissions come principally from the aluminium industry, and these emissions have decreased in recent years as a result of investments in a new tech-

nology since 2007. Only the new technology was used in 2009, and combined with lower production as a result of the weakness in the economy, this led to a sharp decrease in emissions.

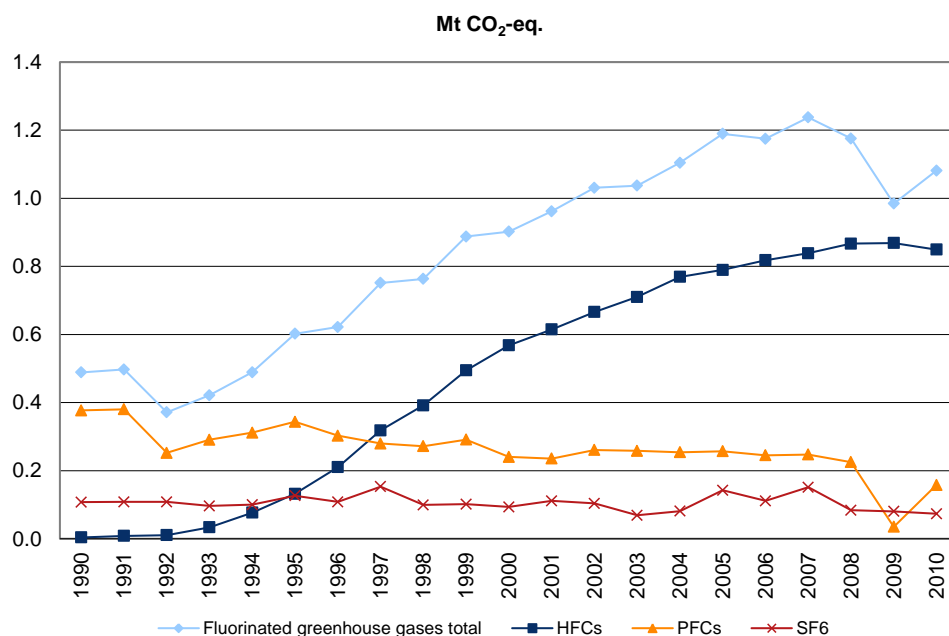


Figure 2.15 Emissions of fluorinated greenhouse gases, total and per gas.

2.3.4 Solvents and other products use

The use of solvents principally leads to emissions of volatile organic compounds, and the carbon content of these emissions is assumed, according to the reporting guidelines, to be oxidised to carbon dioxide. The use of other products, such as spray cans and gas springs, also leads to emissions of nitrous oxide. Emissions of carbon dioxide and nitrous oxide calculated as carbon dioxide equivalents in 2010 totalled 0.3 million tonnes, which is 0.5% of total emissions. In comparison with 1990, emissions have decreased by 6%. Approximately 15% of carbon dioxide emissions come from paints, but these emissions have been reduced by a shift to water-based paints.

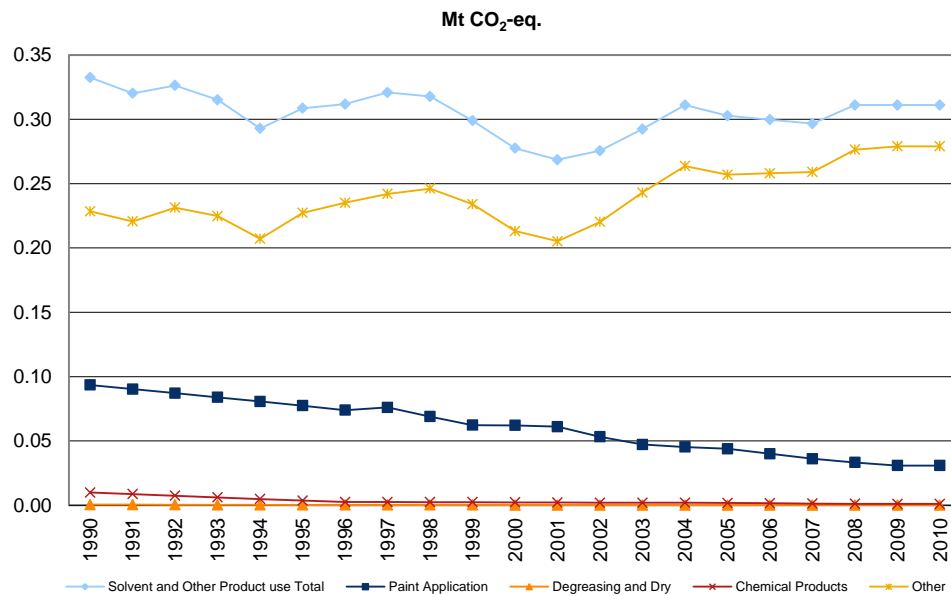


Figure 2.16 Emissions from the use of solvents and other products, total and per subsector.

2.3.5 Agriculture

Agriculture is the largest source of methane and nitrous oxide emissions. Emissions of these greenhouse gases in 2010 amounted to 7,9 million tonnes of carbon dioxide equivalents, of which around 62% was made up of nitrous oxide and almost 38% of methane. Aggregated emissions decreased by 6% over the period 2000-2010, and they have fallen by 13% since 1990. This is principally due to two factors: firstly the number of cattle has decreased, resulting in lower methane release, and secondly lower application of nitrogen fertiliser to agricultural land has resulted in decreased release of nitrous oxide. In comparison with 2009, emissions have decreased by 0.03 million tonnes or 0.4%.

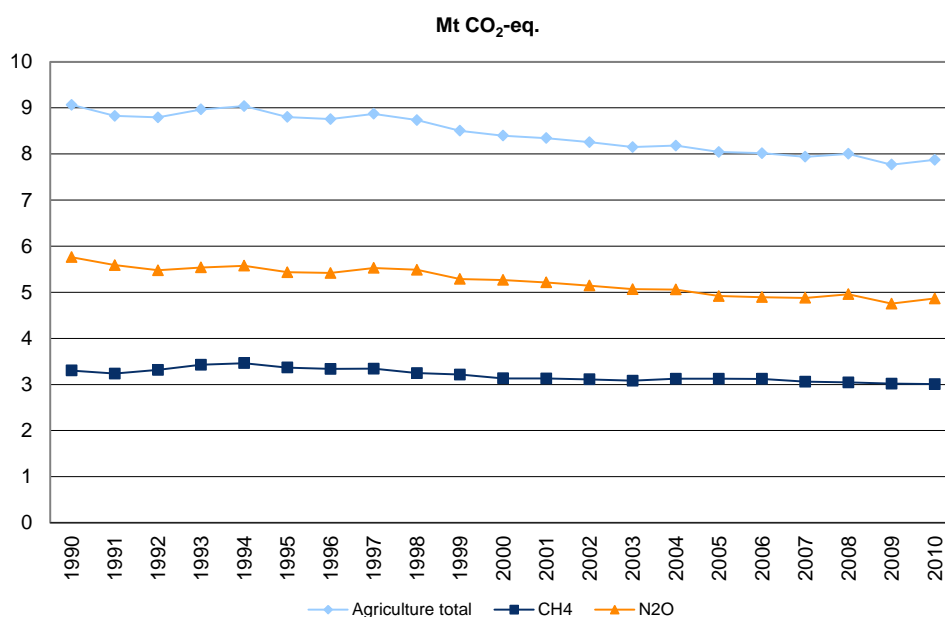


Figure 2.17 Emissions from agriculture, total and per gas.

2.3.5.1 EMISSIONS OF METHANE FROM AGRICULTURE

Methane emissions come principally from the digestion and manure of cattle, while other types of livestock are of relatively low significance. The most important reason for the decreased emissions is reduced livestock farming and it was mainly the number of dairy cows that decreased from 1990 to 2010. A large reduction took place in 1990 and 1991, when a large number of farms abandoned milk production. Some of these changed over to extensive meat production with the aid of government conversion grants, and the number of beef cattle therefore increased during the first half of the 1990s. Following Sweden's accession to the EU in 1995, the EU's Common Agricultural Policy (CAP) stabilised livestock numbers for livestock that have the right for subsidies, for example cattle. The long-term trend is nevertheless for a successive decrease in both cattle and swine, while the number of sheep and chickens for slaughter has increased. Overall, this signifies a decrease in methane emissions from both livestock and their manure. Methane emissions per dairy cow have increased slightly due to increased milk yield, greater quantity of manure and a higher proportion of slurry management, but emissions per produced quantity of milk have fallen slightly at the same time.

2.3.5.2 EMISSIONS OF NITROUS OXIDE FROM AGRICULTURE

Nitrous oxide emissions come principally from the supply and conversion of nitrogen in soil. Nitrogen is supplied to the soil through the use of farmyard manure and commercial fertilisers, the growing of nitrogen-fixing crops and atmospheric precipitation. Cultivation as such, particularly of peat soils, also results in significant release of nitrous oxide, as does conversion of the nitrogen that leaches to lakes and watercourses. The reduced emissions since 1990 are due to the use of both mineral fertiliser and farmyard manure having decreased. The quantity of farmyard

manure is declining principally as a consequence of the decreasing number of dairy cows. The action programme which has been implemented to lower nitrogen losses from agriculture has to some extent reduced the indirect emissions of nitrous oxide from leached nitrogen and ammonia deposition. The expansion of slurry management for pigs and dairy cows has also reduced emissions. Unlike in the case of methane, nitrous oxide emissions from slurry systems are substantially lower than from traditional solid manure management.

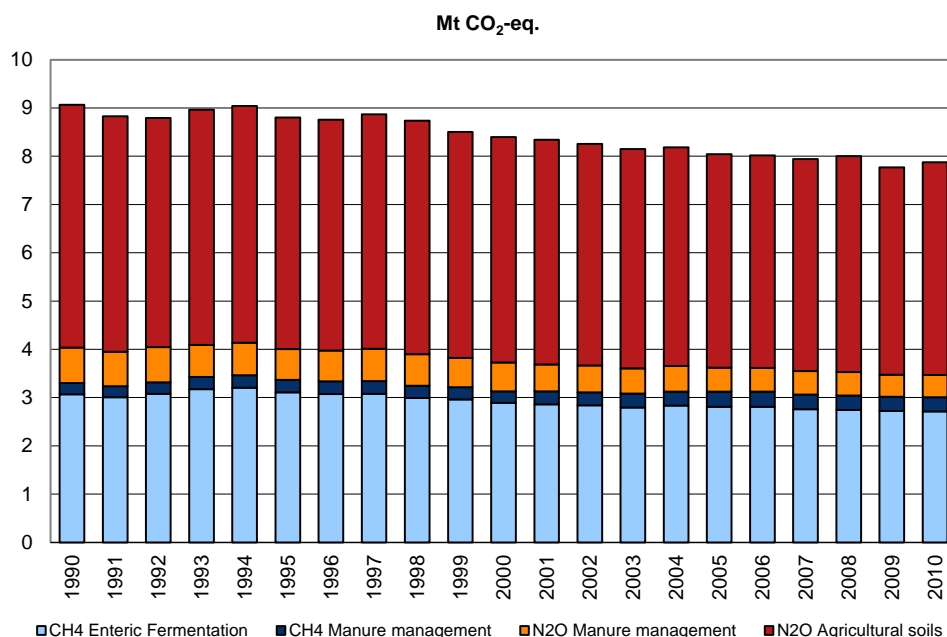


Figure 2.18 Emissions from agriculture, total and per gas and subsector.

2.3.6 Land Use, Land Use Change and Forestry - LULUCF

The Sector Land Use, Land Use Change and Forestry (LULUCF) constituted an annual net removal in Sweden during the whole period 1990-2010. During the period the net removals has varied between 31 and 41 million tonnes of carbon dioxide equivalents but the long-term trend points to a small decrease in net removals from the sector. The decrease in net removal is mainly due to an increased harvest rate and over the last years the decrease was also enhanced due to the effect of two severe storms in the beginning of 2005 and in 2007, respectively. The storm in 2005 brought down a large quantity of timber. According to the Swedish National Board of Forestry, gross fellings ranged between 64 Mm³ and 96 Mm³ over the period 1990-2010, with the exception of 2005 when felling, including wood felled by storms, was estimated at 122 Mm³.

However, the uncertainty is greater in data for 2007-2010 since the number of sample plots for these years are not complete, and extrapolations are needed. Only 20% of sample plots have been used in the estimate for 2010, implying that the results are associated with a high uncertainty and may change in future estimates.

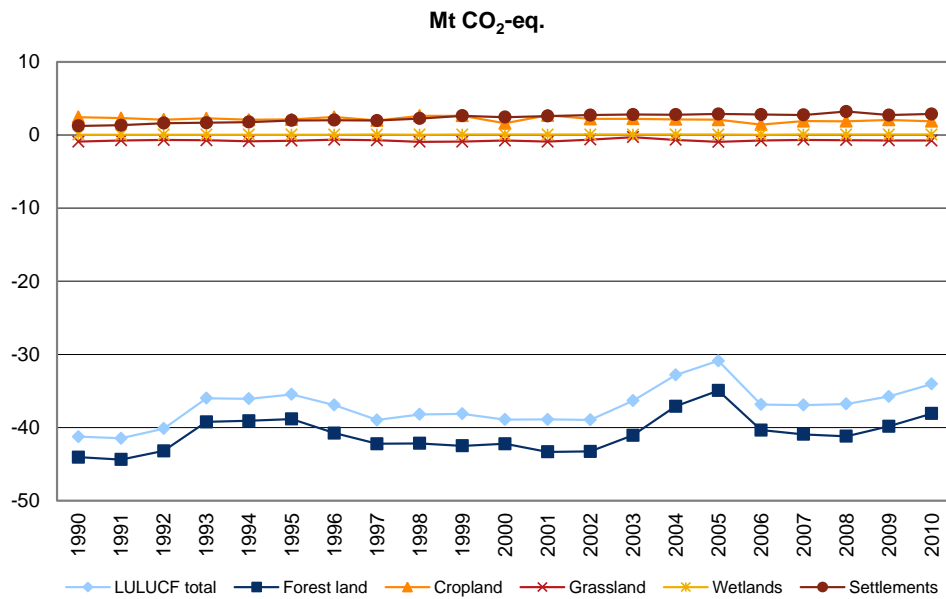


Figure 2.19 Emissions (+) and removals (-) of greenhouse gases from the LULUCF sector

The total size, variation and trend of the net removals in the LULUCF-sector are mainly affected by the carbon stock change in the Forest land. The carbon stock change in living biomass in the forest counts up for the major part of this net removals. The net removal in living biomass in Forest land varied between approximately 23 and 38 million tonnes of carbon dioxide during the period 1990-2010. Cropland is responsible for emissions of carbon dioxide when organogenic soils are cultivated. Emissions varied during the period 1990-2010 between 2 and 2.7 million tonnes of carbon dioxide. The subsectors grassland, wetlands and settlements account for very small areas (and associated carbon stock changes) compared to forest land, which leads to higher uncertainty in data. The carbon stock change in grassland and wetlands is small. Emissions from settlements were in the range of 1-3.5 million tonnes of carbon dioxide during the period spanning 1990-2010.

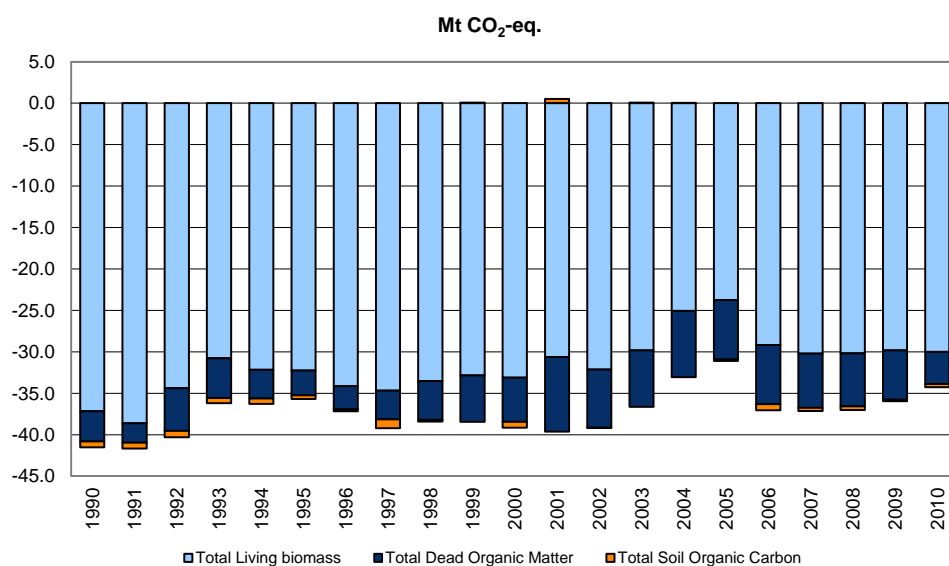


Figure 2.20 Emissions (+) and removals (-) of carbon dioxide from different carbon pools.

The net removal in the LULUCF-sector is calculated as the total carbon stock change in the three carbon pools of living biomass, dead organic matter (dead wood and litter including the humus layer of soil) and soil organic carbon for different land use categories. The three carbon pools living biomass, dead organic matter soil organic carbon contribute as an aggregate to a net removal. In addition, emissions of N₂O from fertilization and disturbance associated with conversion to cropland, CO₂ emissions from lime application and N₂O, CH₄ and CO₂ from biomass burning are calculated, but these emissions are very small. Annual emissions from these categories of CO₂ varied between 90-192 ktonnes, emissions of CH₄ varied between 0.5-13 ktonnes and emissions of N₂O varied between 50-140 ktonnes per year, calculated as carbon dioxide equivalents.

2.3.7 Waste

Total emissions from the waste sector in 2010 amounted to around 1.8 million tonnes of carbon dioxide equivalents or almost 3% of total greenhouse gas emissions. In comparison with 1990, emissions were 46% lower in 2010. Emissions from the waste sector are dominated by methane emissions from landfills with almost 70%, while emissions from wastewater account for 23% and emissions from incineration of hazardous waste for around 6%.

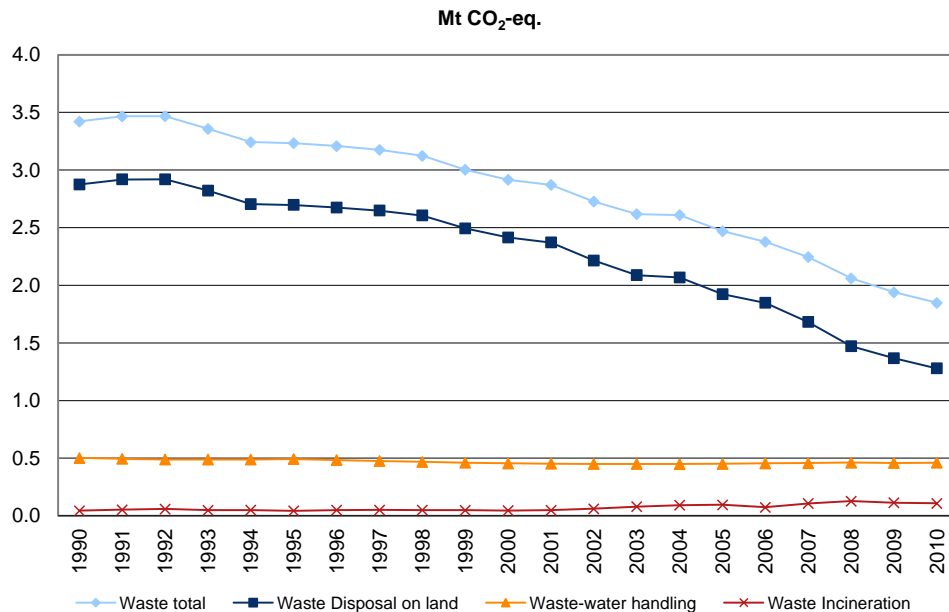


Figure 2.21 Emissions from Waste sector, total and per subsector.

Landfills are the largest source for emissions of methane gas, after livestock farming, as methane is formed when organic waste is placed in landfills. Methane emissions have declined steadily since the early 1990s, partly because the amount of organic material in landfills has declined and partly due to the increased collection and management of methane gas from landfills.

Several policy instruments have been significant in this trend. During the 1990s there was, for instance, the introduction of producer responsibility for a number of different groups of articles, for example packaging, waste paper, office paper and tyres. It is also believed that the demand for municipal waste planning that was introduced in 1991 has contributed to the expansion of methane collection and to the reduction in the amount of degradable material deposited in landfills.

A tax on landfill waste was introduced in 2000, and bans on the landfill disposal of combustible waste (in 2002) and organic material (in 2005) have subsequently been introduced. The bans have contributed to a substantial change in waste management in Sweden. 99 per cent of household waste was recycled in 2010. The landfilling of other types of waste has also fallen sharply.

Emissions from wastewater handling were around 0.5 million tonnes of carbon dioxide equivalents in 2010 and accounted for 0.8% of total emissions. Emissions have fallen by 8% since 1990 due to improved sewage treatment.

Emissions from incineration of waste were around 0.1 million tonnes in 2010. Emissions have increased somewhat in recent years in comparison with the level of emissions from 1990 to 2002. The increase in emissions is due to an increased quantity of waste being incinerated as capacity has increased since 2003.

2.3.8 International bunkers

Emissions of greenhouse gases from international bunkering of fuels amounted to around 8.9 million tonnes of carbon dioxide equivalents in 2010. This includes refuelling in Sweden by international navigation and international aviation and emissions from this fuel are not included in the reporting of the total emissions from Sweden which is calculated in the Kyoto Protocol commitments. International bunkering of fuel is substantially greater than fuel use for domestic navigation and aviation.

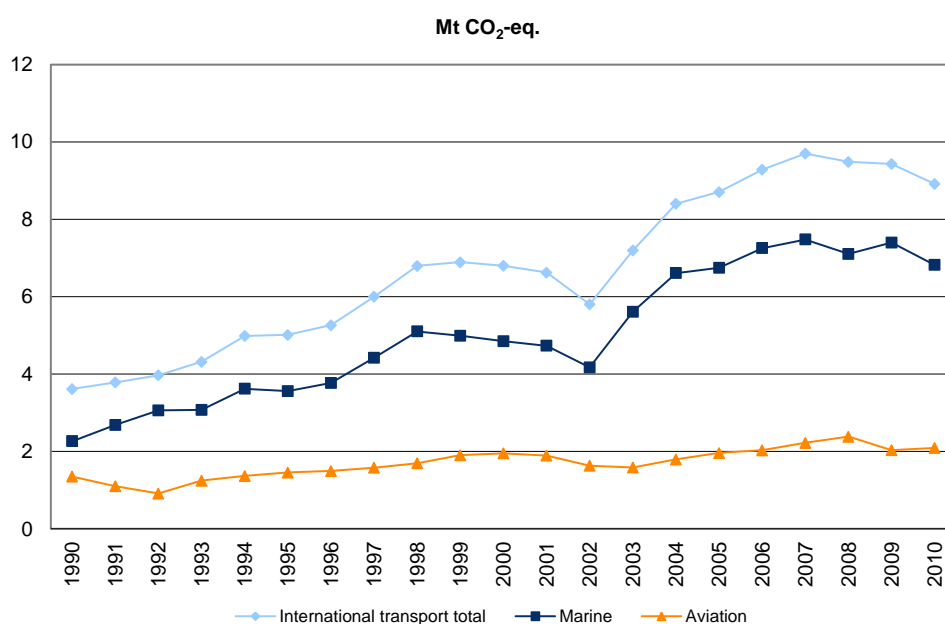


Figure 2.22 Emissions from international bunkers, total and per subsector.

Emissions from international navigation totalled 6.8 million tonnes of carbon dioxide equivalents in 2010. This is a decrease of 8% compared with 2009 but an increase of 201% since 1990. Part of the explanation for the increase is that international freight transport activity has increased due to an increased quantity of freight and globalisation of trade and the systems of production having led to freight being transported over longer distances. Another explanation could be that Swedish refineries are producing low-sulphur Eo2-5, which fulfils strict environmental requirements, and this has led to more shipping lines having chosen to refuel in Sweden. The fluctuations in bunkered volumes between different years also depends on the price of fuel in Sweden in comparison with other ports in other countries.

Greenhouse gas emissions from the international bunkering of aviation was 2.1 million tonnes of carbon dioxide equivalents in 2010. This is an increase of 3% compared with 2009 and an increase of 55% since 1990. Emissions from the international bunkering of aviation have varied over time. The long-term trend is increasing although there have been declines in the early 1990s as well as at the beginning of the 2000s and in 2009. The reduced emissions these years are among other things due to the economic downturn which has led to less travelling.

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

2.4.1 NMVOC

Emissions of non-methane volatile organic compounds (NMVOCs) totalled around 197 ktonnes in 2010, and emissions have decreased by 45% in comparison with 1990. Road traffic and combustion of wood in households together dominate emissions, but machinery, some industrial activity and use of solvents are also significant for emissions. Road traffic leads to the greatest emissions in the area of transport, but road traffic has also shown the greatest reduction in emissions due to new exhaust emission requirements. Environmental requirements in the new installation of wood-fired boilers and reduced emissions from products containing solvents have also contributed to lower emissions.

NMVOC emissions from the energy sector (excl. transport) totalled 51 ktonnes in 2010, a decrease of 16% in comparison with 1990. Most of the decrease occurred in the early 1990s and related to fugitive emissions from oil refineries.

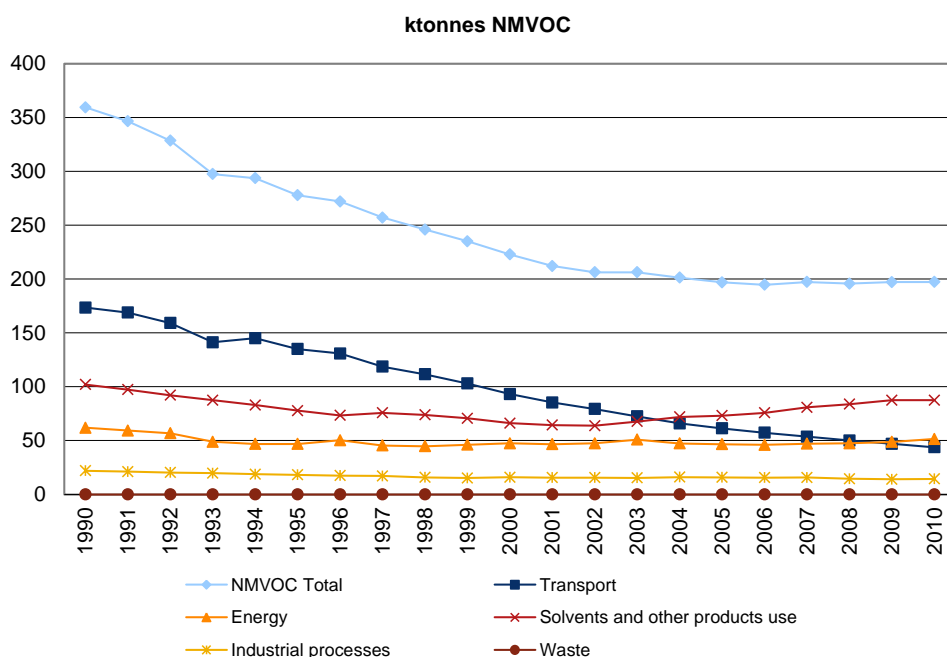


Figure 2.23 Total emissions of NMVOC and emissions from the different sectors.

2.4.2 NO_x

Emissions of nitrogen oxides amounted to 162 ktonnes in 2010, a decrease of 40% in comparison with 1990. Nitrogen oxides are formed in all combustion in the energy and transport sectors, and the largest emission sources are road traffic, machinery, navigation and production of electricity and heating. Emissions of nitrogen oxides from the energy sector, excluding transport, totalled 64 ktonnes in 2010, a decrease of 30% compared with 1990. The largest sources of emissions are machinery in industry, agriculture and forestry and combustion in the production of electricity and heating and in industry.

27% of emissions in the energy sector in 2010 came from electricity and district heating production. As a result of the NO_x charges introduced in the early 1990s and the treatment measures they encouraged, emissions in terms of produced quantity of energy have decreased. Some variation in the absolute quantity of emissions is visible over the years, related to temperature and consequently the need for heating and to precipitation, which affects the need for combustion-based production of electricity. Emissions were therefore lower, for example, in 2000 than in 2003, which was a dry year.

Emissions from machinery in industry account for 17% of emissions of nitrogen oxides by the energy sector (excluding transport). These decreased by 39% during the period 1990-2010. Machinery in agriculture and forestry taken together accounts for 16% of the emissions in the energy sector. There has also been a decrease here in recent years.

Traffic is a large source of emissions of nitrogen oxides, and the emissions come largely from road traffic at 83 ktonnes, but the introduction of catalytic converters in cars and the subsequent successive tightening of exhaust emission requirements have contributed to a general decrease in concentrations of nitrogen oxides in urban areas. Road-traffic emissions of NO_x decreased by 47% between 1990 and 2010 and increased by 3% between 2009 and 2010.

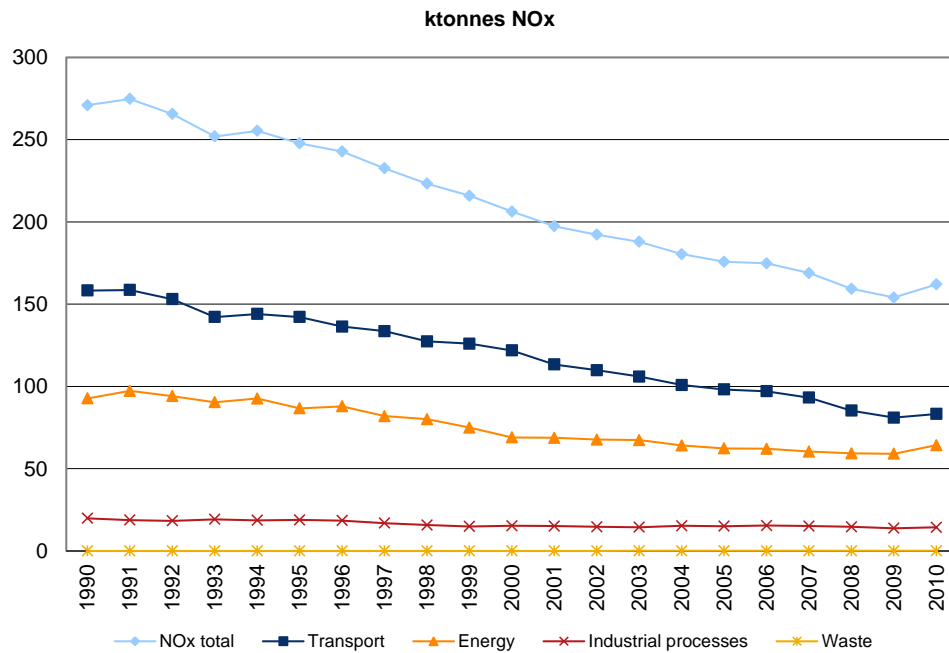


Figure 2.24 Total emissions of NO_x and emissions from the different sectors.

2.4.3 CO

Emissions of carbon monoxide have developed in the same way as NO_x emissions. Emissions have decreased from 1280 ktonnes in 1990 to 640 ktonnes in 2010. 40% of emissions came from the transport sector and 43% from the „Other Sectors“.

Energy sector emissions of carbon monoxide increased from around 234 ktonnes in 1990 to around 359 tonnes in 2010. Around 78% of emissions from the energy sector came from household energy use.

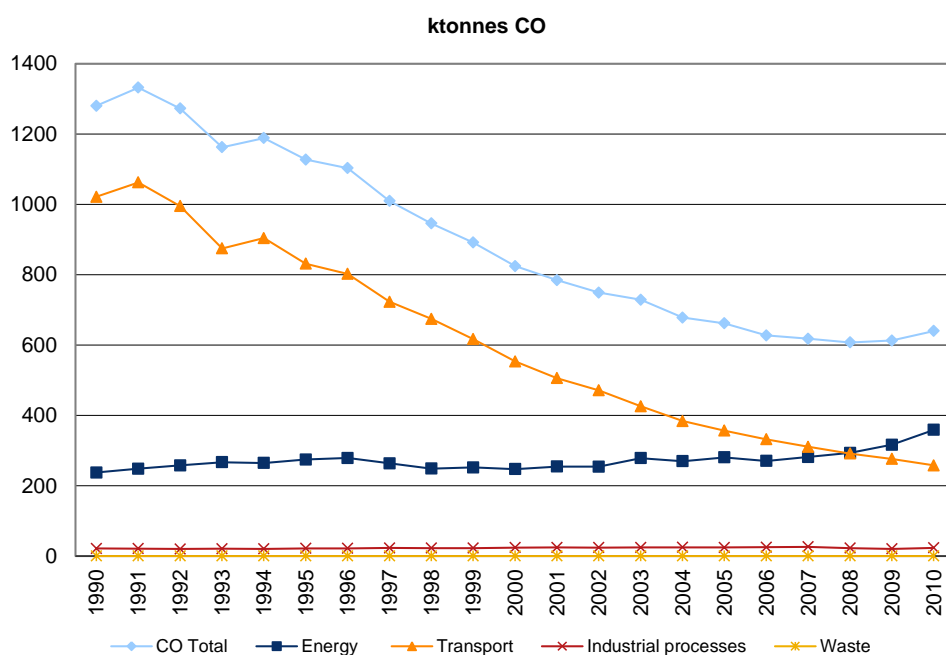


Figure 2.25 Emissions of CO, total and by sectors.

2.4.4 SO₂

Sulphur dioxide emissions come from the energy, transport and industry sectors and continued to decrease during the 1990s. In 2010, emissions totalled 35 ktonnes, which is a decrease of 67% compared with 1990. The continued decrease is due to a change-over from fuels with high-sulphur levels to low-sulphur fuels, for both vehicles and heating.

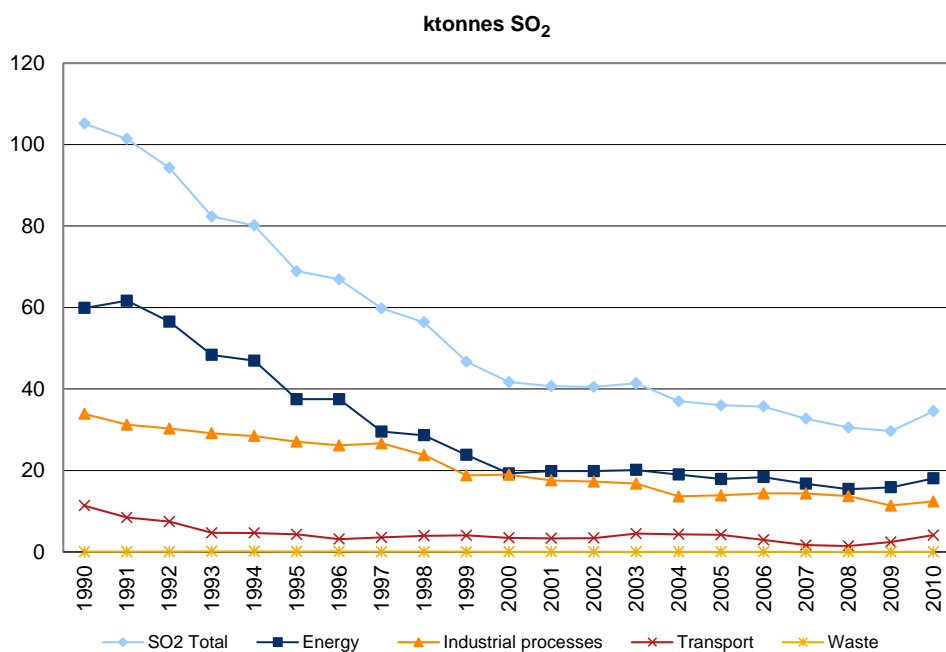


Figure 2.26 Total emissions of SO₂ and emissions from the different sectors.

Energy sector emissions of sulphur dioxide (excl. transport) continued to decrease during the 1990s and in 2010 emissions totalled 18 ktonnes, a decrease of 70% compared with 1990. The continued decrease is due to a shift from fuels with higher sulphur levels to low-sulphur fuels, both for industry and for production of electricity and district heating. The sulphur tax introduced in 1991 has been significant in this shift. Other factors which contribute to reduced emissions include the consideration of industries under the Environmental Code. Emissions increased between 2009 and 2010 by 18% from electricity and district-heating and by 16% from manufacturing industry as a result of increased combustion.

Road traffic emissions of SO₂ have fallen by 99% since 1990 as a result of lower sulphur levels in motor fuels, and totalled 0.1 ktonnes in 2010. Sulphur emissions from domestic navigation have decreased by 23% since 1990 and are now 3.9 ktonnes due to a switch to oils with lower sulphur content.

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

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

3 Energy (CRF sector 1)

3.1 Overview of sector

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 are relatively low in Sweden compared with other industrialized nations. This is due to a relatively high use of hydropower and nuclear power and low use of fossil fuels, as well as the use of energy and carbon dioxide taxation for limiting the emissions of carbon dioxide.¹⁶

It can be seen in Figure 3.1 that in the energy sector, emissions of CO₂ contribute about 96 % of total greenhouse gas emissions (in CO₂ equivalents) 2010. Emissions of total greenhouse gases from the energy sector have decreased by 7.9 % from 53,606 Gg CO₂ equivalents in 1990 to 49,359 Gg CO₂ equivalents in 2010, mainly due to reduced fossil fuel consumption in the residential sector (CRF 1.A.4) (Figure 3.2).

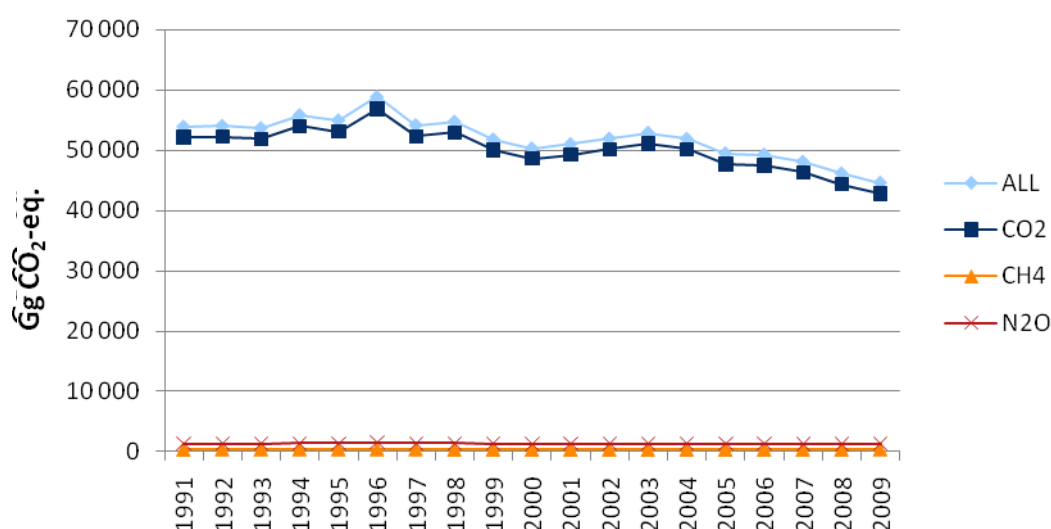


Figure 3.1. Total emissions of all greenhouse gases calculated as CO₂ equivalents from CRF 1 Energy.

¹⁶ Ministry of the Environment, 2001

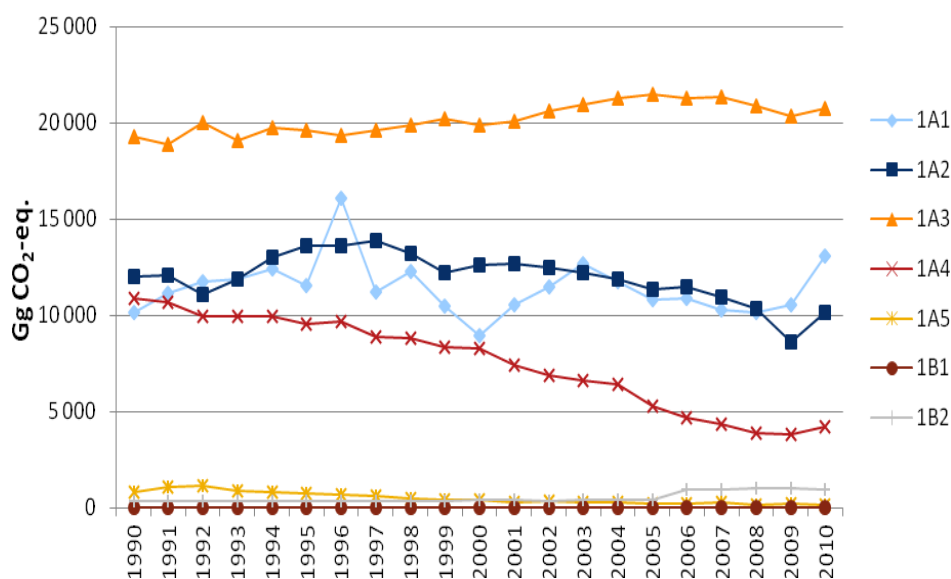


Figure 3.2. Total emissions of all greenhouse gases calculated as CO₂ equivalents from the different sub-sectors within the Energy sector.

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

As shown in Figure 3.2, the transport sector (CRF 1.A.3) accounts for the largest, and increasing, 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 reduced consumption of fossil fuels. 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 increase in emissions from CRF 1.A.1 in 2010 is 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. 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.

Table 3.1 shows the impact of recalculations reported in submission 2012 for GHG emissions by sector and sub-sectors for 1990, 1995, 2000 and 2005-2009. The recalculations are mainly due to:

- Revised emission factor for CO₂ from derived steelwork gases in CRF 1.A.1.a
- Changes in emissions from off-road vehicles and working machinery compared to submission 2011 due to updated activity data, emission factors and sectoral reallocation, which affects CRF 1.A.2, 1.A.3 and 1.A.4.
- Revised activity data for the Other sectors (1.A.4 and parts of 1.A.2) for 2008-2009

More detailed descriptions of the recalculations are found under sector specific sections below.

Table 3.1 Impact of recalculations of GHG emissions submission 2012 in the energy sector (1990, 1995, 2000, 2005-2009).

Impact of recalculations submission 2012 (Gg CO ₂ eq.)									
CRF	1A1	1A2	1A3	1A4	1A5	1B1	1B2	Total CRF 1	% CRF 1
1990	225	-234	277	105	0	NA	5	379	0.7%
1995	296	-251	269	109	-2	NA	3	424	0.8%
2000	197	-256	161	111	-6	NA	7	214	0.4%
2005	97	-268	133	96	0	NA	2	59	0.1%
2006	393	-341	138	93	-6	NA	-4	274	0.6%
2007	252	-384	103	99	-8	NA	-6	56	0.1%
2008	149	-93	150	31	-11	NA	4	230	0.5%
2009	132	-105	3	3	-10	0	4	27	0.1%

0: value less than 0.5. NA: no recalculation is performed.

3.2 Fuel combustion (CRF 1.A)

Emissions from fuel combustion, CRF 1.A, are allocated to a number of subsectors. In CRF 1.A.1, emissions from 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, are reported. CRF 1.A.2 includes combustion-related emissions in manufacturing industries and construction. 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. Emissions from transports (aviation, road traffic, railways and navigation) are reported in CRF 1.A.3. Only domestic activities are included in CRF 1.A.3; emissions from international aviation and navigation are allocated to the category 1C1, international bunkers, and not included in the national total. In CRF 1.A.4, emissions from households, service, agriculture, forestry and fisheries are reported. CRF 1.A.5 is intended for “other” combustion, which in the Swedish inventory includes emissions from military operations. Flaring, e.g. combustion where the energy is lost and not used, is reported in CRF 1B.

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 Tiers are used for different sub-sectors as discussed in sections below.

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

3.2.1 Comparison of the sectoral approach with the reference approach

A detailed discussion on the reference approach and its differences compared to the sectoral approach is provided in Annex 4. **Figure 3.3** shows the differences in fuel consumption and CO₂ emissions between the Reference and Sectoral Approach for the whole time series 1990-2010. It is obvious that fuel consumption and CO₂ emissions from the Sectoral Approach exceed the Reference Approach for most years. For a number of years the difference is larger than $\pm 2\%$.

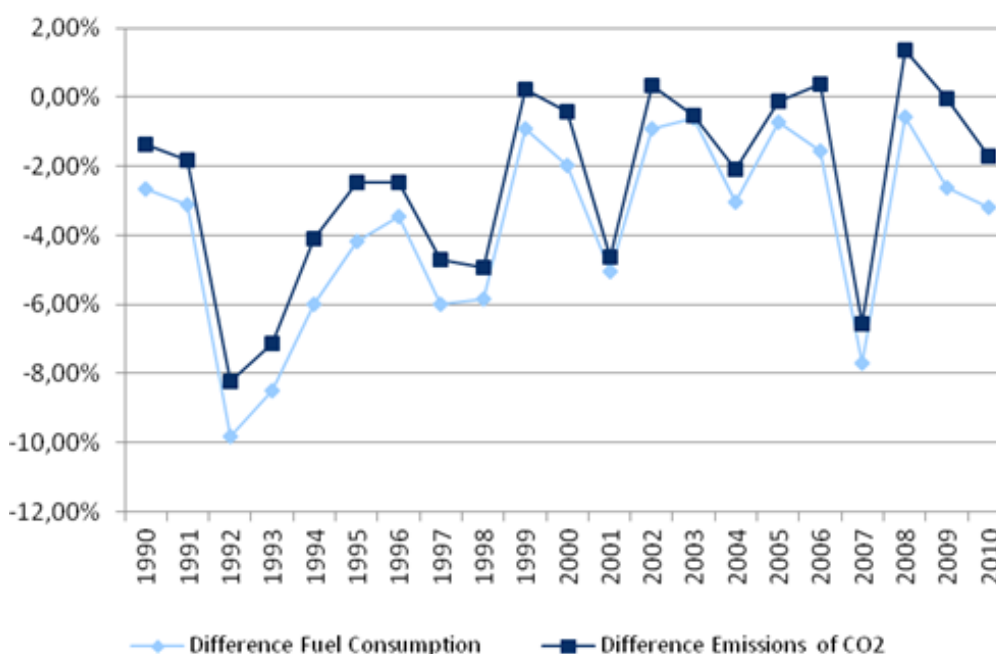


Figure 3.3 Differences between Reference Approach and Sectoral Approach (Reference minus Sectoral).

For most years, the difference in CO₂ emissions is smaller than the difference in energy consumption. This indicates that some of the emission factors used in the reference approach might be too high. Data on fuel group level indicates that this problem is related to liquid fuels. For solid fuels, the difference in energy and emissions, respectively, is not consistent between years. This is related to solid fuels used in iron and steel industry, see below.

Statistical differences in energy balances contribute to a large share of differences especially in the early 1990's. Large differences for 1997, 1998, 2001 and 2007 are mainly attributed to liquid fuels and most notably crude oil.

The iron and steel industry accounts for a large share of solid fuels used in Sweden. Thanks to several studies and resulting improvements in recent years, the in data quality for the sectoral approach is considered to be high. However, the activity data for the reference approach and non-energy use of fuels for these industries needs to be reviewed as there are some questions about the allocation between CRF 1.A.b and 1.A.d.

As described above, there are a number of issues related to the reference approach and non-energy use of fuels. A study aiming to solve the problems, or at least find more detailed explanations to the differences, will be carried out in 2012 and the purpose is to implement the resulting improvements in submission 2013.

3.2.2 International bunker fuels

This sector includes emissions from refuelling in Sweden used for international navigation and international aviation. All gases are covered.

According to IPCC guidelines, international bunkers are not included in national totals. To evaluate Swedish emissions, international bunkers are of course important, especially as international bunkering of fuel is substantially greater than the fuel use for domestic navigation and aviation. Emissions have increased significantly since 1990 due to among other things increased travelling and increased transportation of goods. See also section 2.

3.2.2.1 INTERNATIONAL BUNKERS, CRF 1C1

Emissions from international bunkers for aviation and navigation are not included in the national total, but instead reported separately as a memo item in CRF 1.C.1, in accordance with the 1996 revised IPCC Guidelines.

The ERT has noticed that the data reported to the IEA are generally higher than what is reported to the UNFCCC. A study in 2010 showed that the differences between the IEA and the UNFCCC reporting can to some extent be explained by revision policies of the different reporting obligations. Since the UNFCCC has a high demand on consistency of time series, efforts are made to ensure high quality of times series.¹⁷

International bunkers from aviation are fuels purchased in Sweden and used for flights to destinations abroad. This includes the whole flight cycle, i.e. both LTO and Cruise, see also Annex 2.

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

International bunkers from navigation are defined as fuels bought in Sweden, by Swedish or foreign-registered ships, and used for transport to non-Swedish des-

¹⁷ Hedlund & Lidén 2010

tinations. The division on international and domestic fuels is based on information from the monthly survey on supply and delivery of petroleum products.

In 2011, the fuel consumption by national and international navigation has been studied in a project and the results are presented in the report “Emissions from navigation and fishing including international bunkers”¹⁸. Fuel data in the Monthly fuel, gas and inventory statistics has been analyzed. The fuel data is collected from oil companies and other providers of petroleum products and coal. The survey also collects stock data from companies with a large consumption of oil in the manufacturing industries and energy industries. The population consists of approximately 70 companies, and all of them are included in the survey.

In 1993, 24 companies reported fuel amounts for domestic navigation and 15 companies reported amounts for international maritime bunkers. During the period 1993-2010 many companies have been closed or taken over by larger companies. In 2010, very few companies remained – only eight companies reported fuel amounts for Domestic navigation or International maritime bunkers. With such a small population, it was possible to study each company carefully. Suppliers of significant quantities of bunker oil ($\sim 100\,000\text{ m}^3 - 2\,000\,000\text{ m}^3$) have been examined more closely.

The response from the companies was very good and produced reliable information. Data on domestic and international bunker fuel in the Monthly fuel, gas and inventory statistics have been found to be of high quality. As a consequence of that VAT is applied on national fuel consumption, but not on international bunkers, all respondents to the survey are able to separate these fuel amounts with high accuracy. Fuels used for domestic and international navigation have been separated correctly and in line with IPCC Guidelines.

3.2.2.2 MULTILATERAL OPERATIONS, CRF 1.C.2

Emission from multilateral operations are not included in the national total but instead reported separately as a memo item in CRF 1.C.2, in accordance with the 1996 revised IPCC Guidelines. These emissions are calculated based on information from the military on the amount of fuel purchased in Sweden but used abroad by Swedish forces participating in international operations.

3.2.3 Feedstocks and non-energy use of fuels

Activity data on feedstocks and non-energy use of fuels is collected from the quarterly fuel statistics. As also noted in Annex 2 section 1.1.1, in the survey form for the quarterly fuel statistics, respondents are among many other things asked to specify whether fuels are used as raw materials or for energy purposes. This facilitates the use of data for CRF table 1.A.d, non-energy use of fuels.

Data on carbon from coke, bound in produced ferroalloys is collected directly from the only ferroalloy producer and is added to the remaining data on carbon from coke. Estimates of carbon stored are derived by multiplying given energy amount with emission factors for CO₂ (as given in Annex 2 section 1.2 and Appen-

¹⁸ Eklund et al. 2011. Emissions from navigation and fishing including international bunkers

dix 1) multiplied by 12/44 (the weight of one atom of carbon is by definition 12/44 the weight of one molecule of CO₂).

CO₂ emissions derived from non-energy use of fuels and reported under CRF 1.B and CRF 2 (e.g. flaring of gases and iron and steel process emissions) are added under CRF 1.A.d and linked to the CRF 1.A.b as carbon stored (see Annex 4).

3.2.4 CO₂ capture from flue gases and subsequent CO₂ storage

So far, storage of CO₂ does not occur in Sweden¹⁹. There are, however, several research projects going on where CO₂ is captured from flue gases at a pilot scale.²⁰

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 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.

¹⁹ Geological Survey of Sweden, 2010

²⁰ E-on 2010-11-04, Fortum 2010-11-04

Production of district heating is currently to a large extent based on biomass and waste. There has been a change from fossil fuels towards biomass since 1990. In 1990, 15 % of fuels used were biomass and 15 % was waste. In 2010, 55 % of all fuels used for district heating were biomass while waste accounted for 18 %. 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 221 PJ (2010) but, due to the more frequent use of biomass, greenhouse gas emissions from district heating were only slightly larger than in 1990.²¹

The number and distribution of Swedish power stations in 2009 are presented in Table 3.2²². Changes since 1990 in number of plants and their installed effect have been minor in the electricity sector, but the number of plants that only produce district heating has increased.

Table 3.2. Number and distribution of Swedish energy stations in 2009.

Type of plant	Number of plants	Gross Production GWh	Gross Production TJ
Total power stations	2 447	136 681	492 052
Power generation not based on fuels	2 261	68 094	245 138
	1 359	2 484	8 942
	902	65 610	236 196
Power generation based on fuels	186	68 587	246 913
	3	52 172	187 819
	183	16 415	59 094
- Manufacturing industries, ISIC 10-37	45		
- Energy plants, ISIC 40	114		
- Others	24		

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. Summary of source category description, CRF 1.A.1.a.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1A1a	CO ₂	X	X		T2	CS	Yes
	CH ₄		X		T2	CS	Yes
	N ₂ O	X	X		T2	CS	Yes

CS Country Specific. T2 Tier 2.

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.

²¹ All numbers are according to data used in the Greenhouse gas inventory this submission.

²² Data for 2010 currently not available. Statistics Sweden EN10SM 1001.

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.

The most important fuels in recent years are wooden fuels followed by domestic waste. Greenhouse gas emission factors for these fuels are national and were developed in a study made in 2004.²³

Emissions from energy plants integrated with the iron and steel industry are allocated to CRF 1.A.2.a. This is discussed in chapter 3.3.4.1 and in detail in chapter 4.4.2.1.2.2.

3.2.6.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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

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

The variations in IEFs between years are normally small. The IEFs for solid fuels, however, are considerably more variable than for other fuel types due to the variable supply of energy gases from the iron and steel industry. As blast furnace gas has a much higher 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. As the production in the iron and steel industry was much lower in 2009 than 2008 and 2010, 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.

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 from biomass is not included in the sectoral total of GHG emissions, CO₂ from combustion of peat, blast furnace gas and “other fuels”

²³ Boström et al, 2004

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% and 100%, respectively, and thus account for the greater part of the aggregate uncertainties. Activity data uncertainties are assigned by expert judgements made by persons at the energy statistics department of Statistics Sweden. Emission factor uncertainties have been assigned by national experts on emissions from stationary combustion.

3.2.6.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

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

The time series for all revised data have been studied carefully in search for outliers and to make sure that levels are reasonable. Data has, when possible, been compared with information from companies’ legal environmental reports and/or other independent sources. Remarks in recent review reports from the UNFCCC have been carefully read and taken into account whenever time limits allow. The results are verified by calculating CO₂ emissions with the reference approach, and comparing results with the sectoral approach (see Annex 4).

During 2011, there was a study²⁴ 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

The emission factors for CO₂ from coke oven gas, blast furnace gas and steel converter gas used in submission 2011 were outdated and based on data from one single facility. In submission 2012, a time series of CO₂ emissions 1990-2010 from energy gases sold from this facility to two public electricity and heat production plants have been provided by the steel production facility. This emission data has been used in submission 2012, resulting in new, year specific implied emission factors. This recalculation resulted in an increase of CO₂ emissions in CRF 1.A.1.a.

²⁴ Eklund & Kanlén 2011

The effect of the recalculation in terms of CO₂ emissions in some selected years is shown in table 3-4 below; the magnitude of the change is quite similar for all years except in 1996 when the difference between submissions 2012 and 2011 is 665 Gg CO₂. We suspect that the energy data in 1996 might be somewhat erroneous, but original energy data is no longer available and the CO₂ emissions have been verified by the steel producing facility.

Table 3.4. Recalculation of CO₂ in CRF 1A1a, solid fuels, submission 2012 compared to submission 2011.

Year	1990	1995	2000	2005	2008	2009
Gg CO ₂	225	294	191	97	149	107

In earlier submissions, what was believed to be transmission losses of natural gas were reported in CRF 1.A.5.a. In the Centralized Review of submission 2011, Sweden received a “Saturday paper” concerning this issue, and a careful investigation of the activity data used in submission 2011 was performed. The investigation revealed that the activity data used in 1.A.5.a was misinterpreted and should in fact be allocated to CRF 1.A.1.a, as the gas reported was not lost but used by a power plant. It was also concluded that this data had been double-counted in CRF 1.A.1.a and 1.A.5.a for the years 2007-2009. In submission 2012, these errors have been corrected resulting in an increase in GHG emissions in CRF 1A1a with between 0 to 25 Gg per year in 1990-2006.

3.2.6.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

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

3.2.7.1 SOURCE CATEGORY DESCRIPTION

Refineries process crude oil into a variety of hydrocarbon products such as gasoline and kerosene. During the refining process, dissolved gases are separated, some of which may be leaked or vented during processing and consequently reported under CRF 1.B.2. There are five refineries in Sweden. Three of these refineries produce fuel products such as gasoline, diesel and heating oils. The other two refineries mainly produce bitumen products and naphthenic special oils. One facility has a catalytic cracker; two facilities have hydrogen production plants and four of the facilities have sulphur recovery plants. The 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. For the last three years, fuel consumption has remained nearly constant.

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 1A1b.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1A1b	CO ₂	X	X		T2	CS	Yes
	CH ₄				T2	CS	Yes
	N ₂ O				T2	CS	Yes

CS Country Specific. T2 Tier 2.

3.2.7.2 METHODOLOGICAL ISSUES

The statistics for CRF 1A1b are based on a total of seven plants with the Swedish Standard Industrial Classification 232, petroleum refining. Five of these companies are refineries and they use over 99 % of the energy within the sector and thereby give rise to most of the emissions. The other two plants are oil companies, mainly involved in production of lubricating grease, which means that they are working with products from refineries and therefore should be reported under refineries according to IPCC guidelines.

Activity data for the five refineries 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. As a result of a specific SMED study during 2006²⁵, data from ETS are used for four refinery plants for 2005 and later years. For the fifth plant data from environmental reports were used. In 2008 and later years, the quality of ETS data is considered to be very high for all five of the refineries, and thus this is the primary data source for the GHG inventory. Environmental reports are used for verification. For refinery gas, plant specific CO₂ emission factors reported to the ETS are used for 2008 and later, since they are considered to be more accurate than the older standard emission factor.

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.

²⁵ Backman & Gustafsson, 2006

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.

The implied emission factor for CO₂ for refinery gas is slightly lower for 2008-2009 when plant specific emission factors are used. However, as the national emission factor used for earlier years is based on information from the refineries, the decreasing IEF is considered to reflect actual technology improvements.

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 emission factor uncertainty is 5% and the activity data uncertainty is 10%. The assigned uncertainties are based on information directly from the facilities. They are updated regularly but not annually.

3.2.7.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

In general, the same QA/QC procedures are used for CRF 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.

3.2.7.5 SOURCE-SPECIFIC RECALCULATIONS

Minor corrections of data have been performed.

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

Most emissions in this sector arise from two plants belonging to one company, producing coke to be used in blast furnaces for production of iron. The plants are integrated into the iron and steel production industry. Other fuel combustion in manufacturing of solid fuels and all fossil fuel combustion in manufacturing of nuclear power are also included in CRF 1A1c. The trend is related to the amounts of iron and steel produced, and hence there was a dip in 2009. Apart from this, emissions in recent years are quite similar to the emissions in the 1990's.

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

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

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1A1c	CO ₂				T2	CS	Yes
	CH ₄				T2	CS	Yes
	N ₂ O				T2	CS	Yes

CS Country Specific. T2 Tier 2.

3.2.8.2 METHODOLOGICAL ISSUES

The methodology for estimating emissions from the iron and steel industry was thoroughly revised in submission 2010. Activity data is taken from environmental reports and CO₂ emissions are estimated from carbon balances calculated by the facilities' own experts. Emissions of N₂O, CH₄, NMVOC and CO are estimated with the general T2 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 new methodology is described in detail in the methodological issues section about CRF 2.C.1.2 (section 4.4.1.2.2.)

Activity data for nuclear power plants is collected from industrial energy statistics for 1990 - 1996 and 2000 - 2002 and from quarterly fuel statistics for 1997 - 1999 and from 2003 onwards. For more details on the surveys see Annex 2.

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. Consumption of liquid fuels has decreased since 2006 and the consumption of biomass is small and fairly constant. (Liquid fuels and biomass are, of course, not used in the coke ovens but in small facilities that are allocated to 1.A.1.c due to their ISIC classification).

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 2011, preliminary data was used for 2009 for one of the coking plants. In submission 2012, more accurate data became available and thus 2009 data was revised. The revision resulted in +24 Gg CO₂, +0.075 Gg NO_x and – 0.058 Gg SO₂ in 2009 compared to submission 2011.

3.2.8.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

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

3.2.9.1 SOURCE CATEGORY DESCRIPTION

The iron and steel industry is, together with the pulp and paper industry and the chemical industry, one of the most energy intensive industrial branches in Sweden. There are three primary steel works that base their production on iron ore pellets procuring either steel or iron powder. There are also 10 secondary steel plants producing steel based on scrap iron. In 2009, fuel consumption in the iron and steel industry fell sharply as a consequence of decreased production due to the global recession. In 2010, production and fuel consumption recovered to more “normal” levels. The Swedish iron and steel works produced 4.8 million tonnes of steel in total in 2010, which is 73% more than in 2009.²⁶ The trend of the fuel combustion is increasing slightly since 1990 due to higher production of iron and steel products.

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

²⁶ The Swedish Steel Producers' Association, 2010-09-26

Table 3.7. Summary of source category description, CRF 1.A.2.a.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1.A.2.a	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. T2 Tier 2. T3 Tier 3.

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

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

For companies with less than 10 employees the Tier 1 method is used, since current data does not allow the Tier 2 methods to be used. Emissions from companies with less than 10 employees are allocated to CRF 1.A.2.f because the model estimate of fuel consumption within small companies is only produced on an aggregate level and not separated by ISIC code.

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

Emissions reported from primary steel works and other iron and steel works are reported in both CRF 1A2a and in CRF 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).

3.2.9.2.1 Primary iron and steel works

In Sweden, there are two plants for integrated primary iron and steel production, i.e. basing their production on iron ore pellets. The integrated iron and steel production consists of material flows between coke oven, blast furnace and steel-works, and in one plant, rolling mill (see Figure 4.6 in section 4.4.1.1.2). Emissions from fuel combustion (oils, LPG and recovered energy gases, i.e. coke oven gas and blast furnace gas) used in the rolling mills and for in-house power and heat production is allocated to this sub-sector in accordance with the IPCC Guidelines. The allocation approach used in submission 2012 has been used since submission 2010.

Table 3.8. Allocation of fuel consumption and CO₂ emissions in 2009 from iron ore based iron and steel industry on different CRF codes.

CRF	Plant station	Fuel consumption 2010 (TJ)	CO ₂ emissions 2010 (Gg)
1A1c	Coke Oven	4 069	313
1A2a	Combustion in Rolling Mills + Power and Heat Production	4 407	950
1B1c	Flare in Coke Oven (COG)	109	5
2C1.2	Blast Furnace + Steelworks (including Flaring of BFG and LD-gas)	NA	2 346
Total			3 614

In previous submissions, transformation losses of energy in iron ore based iron and steel industry were reported under CRF 1.A.5.a for all years. During 2011, a SMED study²⁷ was made that concluded that the difference between energy (coal) inserted in the processes and the energy from combustion of the fuels produced (steel work gases) should be allocated to CRF 2.C.1, since the energy is lost as heat in blast furnace and steelwork processes. This approach has been implemented in submission 2012.

3.2.9.2.2 *Secondary iron and steel works*

Except for the primary iron ore based iron and steel works, this sector includes emissions from for instance electric arc furnaces plants, iron ore pellet plants and iron powder plants.

3.2.9.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

For the two largest facilities, the time series is very consistent as all data is based on information from these facilities, and they have checked that the calculated emission and energy data is accurate. For CRF 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 yearly 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 CRF 1.A.2.a is considerably lower in 2009 than in earlier years. See also section 4.4.1.2.2.

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

²⁷ Gustafsson, Lidén & Gerner , 2011

these fuels the activity data uncertainty is 5%. The CO₂ emission factor uncertainty is 20% for blast furnace gas and coke oven gas, and 5% for LPG.

3.2.9.4 SOURCE SPECIFIC QA/QC AND VERIFICATION

In general, the same QA/QC procedures are used for CRF 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.

3.2.9.5 SOURCE SPECIFIC RECALCULATIONS

In submission 2011, preliminary data was used for 2009 for one facility. In submission 2012, more accurate data became available and thus 2009 data was revised. The revision resulted in -24 Gg CO₂, +0.007 Gg NO_x and -0.027 Gg SO₂ in 2009 compared to submission 2011.

3.2.9.6 SOURCE SPECIFIC PLANNED IMPROVEMENTS

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

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

3.2.10.1 SOURCE CATEGORY DESCRIPTION

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

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

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 1.A.2.b.

CRF	Gas	Key Category Assessment 2010			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.

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.

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.f.

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. In 1999 there is a large jump in the time series due to increased consumed amounts of natural gas. This has been identified as a possible reporting error for one facility, but original raw data from 1999 is no longer available and hence revision is not possible.

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. In 1990, the largest contribution to the aggregate uncertainty arises from 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 2010.²⁸ This study showed no reasons for revisions in CRF 1.A.2.b.

3.2.10.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

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.

²⁸ Danielsson & Nyström, 2010

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%.

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 1.A.2.c.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1.A.2.c	CO ₂	X	X		T2	CS	Yes
	CH ₄				T2	CS	Yes
	N ₂ O				T2	CS	Yes

CS Country Specific. T2 Tier 2.

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 see Annex 2.

Generally, plants classified as ISIC Division 24 according to ISIC Rev.3²⁹ in the energy statistics are included in this sector, as recommended in IPCC 1996 Revised Guidelines.

For one of the largest facilities, including two plants, ETS data is the activity data source for 2008-2009. 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. As in other subcategories of CRF 1A2, 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.f.

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.

In 2011, a consistent time series of the CO₂ emission factor for this 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,

²⁹ United Nations Statistics Division, 2010

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, and thus the inconsistent time series used in submission 2011, where the “old” emission factor was used 1990-2007 and the considerably lower emission factors reported to ETS were used for 2008-2009, has now been corrected. 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.

3.2.11.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As for CRF 1A2a and 1A2b, time series consistency despite the changes in activity data source is discussed in Annex 2.

As mentioned above, fuel consumption in 2010 is higher than in 1990. However, since 2003 there is no distinct trend and the fuel consumption in 2009 was about 10% lower than in 2008, which reflects the decreasing demand for this sector in 2009. In 2010, fuel consumption increased to roughly the same level as in 2006-2007.

As noted by the ERT, the implied emission factors for “other fuels” are variable, especially in the early years. This is explained by the fact that municipal waste has occasionally been combusted within the chemical industry, and most years also “other non-specified fuels”. As these fuels have very different emission factors for 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 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 5% and the emission factor uncertainty is assumed to be 10% based on the variation in plant specific values. Activity data uncertainties are assigned by expert judgements by staff at the energy statistics department of Statistics Sweden.

3.2.11.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

In general, the same QA/QC procedures are used for CRF 1A2c as for 1.A.2.a–b described above.

In the development project in 2010³⁰ mentioned above, the activity data time series 1990-2008 for all fuel types and all facilities within the chemical industry

³⁰ Gustafsson, Nyström & Gerner, 2010

were thoroughly reviewed. Reported emissions and activity data in CRF 1 and 2 were analysed on plant level and verified against environmental reports and when necessary, the plants were contacted for explanations or complementary data.

3.2.11.5 SOURCE-SPECIFIC RECALCULATIONS

As mentioned above, the CO₂ emission factor for methane-based gas mixtures 2001-2009 was revised in submission 2012. The differences in CO₂ emissions compared to submission 2011 are shown in Table 3.11 below.

Table 3.11 Difference in CO₂ emissions submission 2012-2011, CRF 1.A.2c

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009
Gg CO ₂	+64	-71	-53	-129	-35	-110	-190	-34	-30

Carbide furnace gas was in earlier submissions erroneously allocated to liquid fuels. As the gas is a by product when carbides are produced from coke, the correct allocation is to solid fuels. This reallocation means that compared to submission 2011, minor emissions are moved from liquid fuels to solid fuels.

3.2.11.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

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

3.2.12.1 SOURCE CATEGORY DESCRIPTION

In 2010 there were 41 paper mill plants, 165 sawmills (production capacity >10 000 m³/year) and 41 pulp industry plants in Sweden. In total, they were producing 11.4 million tonnes of paper, 17.0 million m³ of sawn timber and 11.9 million tonnes of pulp.³¹ 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.

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 1.A.2.d

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1.A.2.d	CO ₂				T2	CS	Yes

³¹ The Swedish Forest Industries Federation, 2011
http://skogsindustrierna.org/web/Statistik_om_skogsindustri.aspx

	CH ₄				T2	CS	Yes
	N ₂ O				T2	CS	Yes

CS Country Specific. T2 Tier 2.

3.2.12.2 METHODOLOGICAL ISSUES

Emissions from processes in the Pulp, paper and print industry are reported under CRF 2D1 according to IPCC Guidelines. See chapter 4.5.

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.

As for CRF 1.A.2 in general, for companies with less than 10 employees the Tier 1 method is used, since current data does not allow the Tier 2 methods to be used. Emissions from companies with less than 10 employees are allocated to CRF 1A2f.

Emissions from combustion of sulphur lyes are presently not reported in CRF 1A2d as this activity has been considered as an industrial process.

3.2.12.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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

In recent years, the relative amount of biomass has increased and the relative amounts of liquid fuels, especially residential fuel oil, have decreased. One effect of the increasing share of biomass is that emissions of fossil CO₂ per TJ of total fuel consumption is decreasing. This is the reason behind the fact that fossil CO₂ emissions were lower in 2008 than in 2007, despite the fact that the fuel consumption was higher in 2008 than in 2007.

The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. 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 1A2d as for 1A1a and 1A2a–c described above.

3.2.12.5 SOURCE-SPECIFIC RECALCULATIONS

Minor corrections of data have been performed.

3.2.12.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

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

3.2.13.1 SOURCE CATEGORY DESCRIPTION

The food and drink industry is the fourth largest branch of industry measured as production value and number of employees. There are about 3200 companies, of which only around 650 have more than 10 employees.³² The largest number of companies and employees are found in the bakery industry, but the most energy intensive branch is the sugar industry which accounts for about 25% of the fuel consumption in 1A2e. Dairies, breweries, producers of refined vegetable fats and potato products are other industries with significant fuel consumption (around 7-12% each of the fuel consumption in 1.A.2.e). The fuel consumption varies between years. A slight decrease can be observed since 1990. In later years, liquid and gaseous fuels account for about 40-45% each of the total fuel consumption.

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 3.13. Summary of source category description, CRF 1.A.2.e

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1.A.2.e	CO ₂				T2	CS	Yes
	CH ₄				T2	CS	Yes
	N ₂ O				T2	CS	Yes

CS Country Specific. T2 Tier 2.

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. For more details on these surveys see Annex 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.f.

³² The Swedish Food Federation 2009-09-16

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. As for other categories in CRF 1.A.2, the IEFs are slightly variable between years due to variations in fuel mix. The uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7. In the early 1990's, 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

Minor correction of data has been performed.

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

3.2.14.1 SOURCE CATEGORY DESCRIPTION

This source category is by nature quite heterogeneous. Both stationary and mobile emission sources are included. The stationary sources included are combustion within ISIC 10-37 except from the branches separately reported in 1.A.2.a-1.A.2.e, and stationary combustion within all companies with less than 10 employees regardless of branch, and stationary combustion within the construction sector. The mobile emission sources included in this sector are off-road vehicles and working machinery used in the construction and manufacturing industry.

In terms of stationary fuel combustion and emissions, three branches of industry are dominating; non-metallic mineral production (ISIC 26), manufacturing of wood products (ISIC 20), and mining industry (ISIC 13). In ISIC 20, however, biomass fuels are dominating and hence the emissions of fossil 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.f in total, it has decreased slightly since 1990. Liquid and biomass fuels account for most of the decrease. For mobile combustion, i.e. off road vehicles and working machinery, fuel consump-

tion in 2010 was about 22% higher than in 1990 but the trend has been slightly variable.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.14.

Table 3.14. Summary of source category description, CRF 1.A.2.f

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1.A.2.f	CO ₂	X	X		T1,T2	CS	Yes
	CH ₄				T1,T2	CS	Yes
	N ₂ O	X			T1,T2	CS	Yes

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

3.2.14.2 METHODOLOGICAL ISSUES

For emissions from stationary combustion, the Tier 2 method is used with the following exception: For the construction industry and for companies with less than 10 employees the Tier 1 method is used, since current data does not allow the Tier 2 method to be used. Stationary fuel combustion in the construction sector is shown below (Table 3.15).

Table 3.15 Stationary fuel combustion in the construction sector, TJ.

Year	LPG	Domestic heating oil	Residual fuel oil	Natural gas
1990	46	5 051	420	39
1996	46	4 692	382	79
2000	46	4 621	382	40
2005	46	1 254	265	501
2006	46	1 329	272	507
2007	46	1 391	269	507
2008	92	1 440	263	498
2009	92	1 460	246	462
2010	141	1 686	148	542

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

Emissions from all companies with less than 10 employees are estimated and reported under CRF 1.A.2.f. Activity data are collected from Statistics Sweden³³.

³³ Statistics Sweden, EN20SM 1990-2010. See also Annex 2.

Emissions are minor and with current data not possible to separate on different industry sectors.

Emissions from stationary combustion in the construction industry are calculated with activity data from Statistics Sweden.³⁴ The methodology used for this sub-category is the same as for stationary combustion in the Other sector, see section 3.2.20.4.1. Activity data is basically from the annual energy balances, except for the latest emission year. However, the data in Table 3.15 differ slightly from the official energy balances due to use of slightly different calorific values especially for earlier years.

Since 2002, for one glassworks plant, it is no longer possible to separate combustion emissions of SO₂ from process emissions. The reason is that the facility has restructured its environmental report, and only reports emissions of SO₂ on an aggregate level. The median value for the share of process related SO₂ emissions to the total SO₂ emissions is 2 % for the years 1990 - 2001. Emission data reported in the plants environmental report are considered to be more accurate than emissions calculated from fuel combustion with standard emission factors. Thus for practical reasons, SO₂ and NO_x emission data available from environmental reports are reported in CRF 2A7. All other energy related emissions for this facility are reported in CRF 1A2F. For 2008 and later, activity data for the three plants within the cement production industry is taken from the EU ETS system.

Emissions from mobile combustion refer to off-road vehicles and other machinery including various mobile vehicles and machines as for example tractors, dumpers, cranes, excavators, generators, wheel loaders, sorting works, pump unit and any other mobile machine in industry that run on petroleum fuels. The model used to estimate emissions from off-road vehicles and other machineries is considered to correspond to Tier 2. The model is further explained in Annex 2.

3.2.14.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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

CO₂ from diesel and heating oils are the largest sources of uncertainty in GHG emissions within CRF 1.A.2.f. The activity data uncertainty for all heating oils within this sector is as high as 20% on an aggregate level, due to the fact that emissions from the construction sector and small industries are estimated with the Tier 1 method. The activity data uncertainty for diesel combusted in off- road vehicles and working machinery is 5%. The CO₂ emission factor uncertainty is 1%, whereas the CO₂ emission factor uncertainty for diesel is as high as 10%. This uncertainty

³⁴ Statistics Sweden, EN20SM 1990-2010. See also Annex 2.

estimate was assigned when the method for emission calculations for off-road vehicles and working machinery was revised in 2008, and it will most likely be updated in submission 2012.

3.2.14.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Generally, the same QA/QC procedures are applied for 1A2f as for other 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 3.2.20.4.1 below.

3.2.14.5 SOURCE-SPECIFIC RECALCULATIONS

Activity data for the construction sector has been revised for 2008-2009 following revisions of the annual energy balances. Compared to submission 2011, stationary fuel consumption in 1.A.2.f is 2.3% higher in 2008 and 1.5% higher in 2009. The difference in emissions is 92 and 56 Gg CO₂ equivalents respectively.

The methodology for estimating emissions from off-road vehicles and working machinery was revised in submission 2012. The revision did not imply an updated methodology, but aimed to simplify the use of the model and at the same time update some emission factors, activity data and the allocation of emissions to different sectors. Allocation of emissions from off-road vehicles and working machinery is based on a report by Flodström (et al)³⁵. This is the most recent inventory including an allocation of working machinery to sectors in Sweden.

Changes in emissions from off road vehicles and working machinery compared to submission 2011 due to updated activity data, emission factors and the sectoral allocation is shown in Table 3.16.

Table 3.16. Changes in emissions from off road vehicles and working machinery compared to submission 2011. A positive percentage shows an increase in emissions in submission 2012 and vice versa.

CRF	1990 CO ₂ eq.	2008 CO ₂ eq.	2009 CO ₂ eq.	1990 TJ	2008 TJ	2009 TJ
Total	0.25%	3.13%	4.71%	-6.49	1304.37	1997.47
1.A.2.f; Industry	-13%	-8%	-5%	1353	-133	-284
1.A.3.e; Other	85%	88%	89%	-619	-205	-8
1.A.4.b; Households	19%	43%	49%	-2810	-1859	-1300
1.A.4.c Farming	21%	202%	204%	1591	1854	1879
1.A.4.c Forestry	-12%	-3%	0%	478	1647	1711

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.

³⁵ Flodström et al 2004. Uppdatering av utsläpp till luft från arbetsfordon och arbetsredskap för Sveriges internationella rapportering.

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

3.2.15.1 SOURCE CATEGORY DESCRIPTION

Presently data are provided for a total of 41 airports with regular and/or chartered air traffic. The national government administers 19 of these airports, while the remaining 22 are private and/or administered by local government.³⁶ The traffic routed through governmental airports account for about 90 % of the total fuel consumption within the civil aviation sector.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.17.

Table 3.17. Summary of source category description, CRF 1.A.3.a.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1.A.3.a	CO ₂				T1	CS	Yes
	CH ₄				T2, M	D, M	Yes
	N ₂ O				T2, M	D, M	Yes

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

3.2.15.2 METHODOLOGICAL ISSUES

Sweden uses the Tier 1 method for CO₂ and Tier 2a for all other gases.

Emissions from aviation in agricultural and forestry sectors are currently reported together with domestic aviation. Emissions from military use of aviation fuels are reported under Other – mobile sources (CRF 1.A.5.b).

The emissions from aviation reported to the UNFCCC are estimated using both data on supply and delivery of petroleum products from Statistics Sweden (see Annex 2) together with fuel- and emission data from the Swedish Transport Agency (SCAA).

The Swedish Transport Agency (SCAA) publishes for 2010 information on aviation emissions from all Swedish airports with regular and chartered flights in annual environmental reports. Since from 2010 there is no separate reporting on emissions from governmental respectively private airports, instead a total is reported. SCAA include the traffic from a number of non-governmental airports in their estimates from 2005 and almost all Swedish airports from 2006.

The methodology for calculating national emissions is the same for all years. The fuel consumption and emissions published by the SCAA are calculated by the Swedish Defence Research Agency (FOI). FOI uses statistics on the number of flights between cities, type of aircraft, amount of fuel needed for different flights and emissions per fuel on specific flights based on data on aircraft performance during different phases of the flight and the distance between destinations.

To estimate fuel consumption and emissions from domestic landing and take-off (LTO) FOI uses two models – HARP (HAsselrot's Reviewed Pollutions) and

³⁶ Swedish Transport Administration.

PIANO (Project Interactive Analysis and Optimization). HARP is used for estimating national Times in Mode (TIM) and PIANO is used for calculating the fuel consumption and emissions. Due to the fact that the Swedish airports generally are smaller than international airports in other countries, taxi times are much shorter for domestic flights and climb-out and take-off times are often shorter as well. Hence traffic from Swedish airports needs less fuel and give rise to lower emissions compared to the International Civil Aviation Organization (ICAO) standards that the IPCC guidelines follow.³⁷ For international flights, ICAO standard taxi time has been used for the part of the LTO cycle occurring on international airports.³⁸

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

Emissions of CO₂ are based on fuel delivery statistics and national thermal values from Statistics Sweden and emission factors from the Swedish EPA. Quotas for distributing the CO₂ emissions to domestic and international LTO and cruise are based on information on CO₂ emissions from the Swedish Transport Agency.

For 1990-1994 there are no quotas available for distributing CO₂ emissions on domestic and international LTO and cruise. As a result are CO₂ emissions estimated as described by Figure 3.4.

³⁷ Gustafsson, 2005.

³⁸ Näs, 2005.

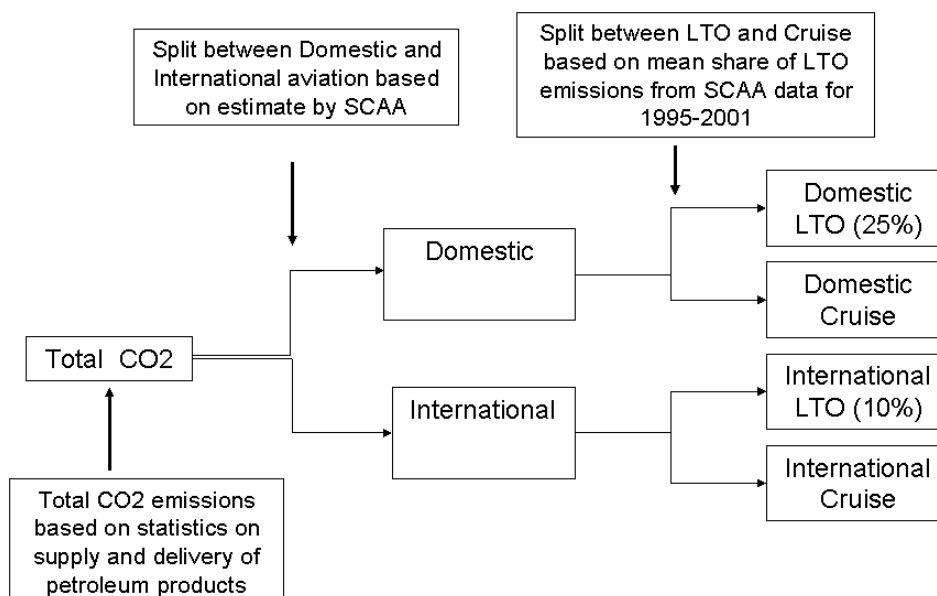


Figure 3.4. Model for estimating Domestic/International LTO/Cruise 1990-1994.

Due to the lack of activity data, all non-CO₂ emissions for 1990-1994 are calculated by SMED in cooperation with the SCAA. Emissions of CO are calculated by comparing the 1995 relationship between CO and CO₂ and using the same ratio (4.85 % of CO₂ emissions) for 1990-1994. Emissions of NO_x are calculated in a similar way. The ratio is relatively stable over the years and therefore the mean value of 1995-2004 (4.03 % of CO₂ emissions) is used for 1990-1994. Emissions of HC for 1990-1994 are calculated by extrapolation.

From 1995 and onwards, emissions of SO₂, NO_x, CO and HC are based on information from the SCAA and adjusted to match the delivered amount of aviation fuels. Emissions of NMVOC and CH₄ are estimated based on information on emissions of HC from the SCAA and emission factors from the IPCC guidelines.

N₂O emissions for LTO are estimated using information on the number of LTO cycles from the SCAA together with emission factors from IPCC. N₂O emissions for cruise are based on delivered amounts of fuel for cruise activities estimated by FOI, adjusted to be in line with fuel delivery statistics, together with emission factors according to the IPCC guidelines.

SCAA have received information on LTO emissions for 2001 and 2002 from 19 non-governmental airports and estimated CO₂ and NO_x emissions for all non-governmental airports based on this information. Adding together emissions of CO₂ and NO_x from both governmental and non-governmental airports provides a good estimate of the aviation emissions at national level. A comparison between these data and the ones calculated using the Tier 1 method shows good coherence with a variation of only 2-5 %.

In 2006, the Swedish Transport Agency (SCAA) responded to the governmental call to reduce response burden on statistical compilations. As a result, private

aviation as well as educational training flights and military are no longer covered in the SCAA reports on fuel consumption and emissions from aviation as from 2007. However, the fuel consumption and emission data estimated by FOI was already too low, since their model underestimate the flight route. The model estimates the fuel consumption based on the shortest distance between airports, which often is incorrect. The model also discounts extra fuel consumption due to "holding", e.g. when the airplane has to circulate above the airport before landing.

But as the fuel consumption estimated by FOI is adjusted to correlate with the statistics of the national fuel deliveries of jet kerosene and aviation gasoline for reporting to the UNFCCC, all emissions are consequently adjusted to correlate with these statistics. So the missing data from the private aviation as well as educational training flights is as a result adjusted to correlate with the supply in Sweden and is therefore included.

The emissions of NMVOC have decreased noticeably in the last years. The reason for this is that a specific type of airplane (MD-80/82), which is a major contributor to these emissions, is being phased out.

3.2.15.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

In order to maintain consistency with the time-series the estimation procedures have been developed as described above. However, due to the 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 uncertainty analysis tables are presented in Annex 7 and a general description of the uncertainties is presented in section 1.7.

3.2.15.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

3.2.15.5 SOURCE-SPECIFIC RECALCULATIONS

Incorrect activity and emission data was used in submission 2011. This was due to the problem with exclusion of private aviation as well as educational training flights and military in the calculations of fuel consumption and emissions executed by SCAA (Swedish Transport Agency). The data has been corrected and adjusted to correspond to actual fuel consumption.

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

3.2.16.1 SOURCE CATEGORY DESCRIPTION

Road transport is the single largest source category contributing to the total national greenhouse gas emissions (excluding LULUCF) in Sweden, all years. It includes several vehicle categories: Passenger cars, Light duty vehicles, Heavy duty vehicles and Mopeds & Motorcycles. Gasoline is the most common fuel used for road transports in 2010, but since 2002 emissions of CO₂ from gasoline has steadily been reduced mainly due to the increased number of diesel powered passenger cars and the introduction of biofuels.

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.b.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1.A.3.b	CO ₂	X	X		T1	CS	Yes
	CH ₄		X		M, T1	CS, M	Yes
	N ₂ O				M, T1	CS, M	Yes

CS Country Specific. T1 Tier 1. M Model.

3.2.16.2 METHODOLOGICAL ISSUES

Emissions of CO₂ and SO₂ from road traffic are based on statistics on supply and delivery of petroleum products (see Annex 2), in accordance with the IPCC Guidelines Tier 1. Emissions of CO₂ from combustion of gasoline and diesel are based on thermal values from SPI³⁹ and country-specific emission factors from Statistics Sweden and the Swedish EPA as shown in Appendix 1.

Prior to submission 2007, emissions of SO₂ from diesel and gasoline were based on the maximum allowed sulphur content of different environmental classes. Data on maximum allowed sulphur content was provided by SPI. As from submission 2007, emissions of SO₂ are based on the actual sulphur content for the different environmental classes of petrol and diesel fuel. The data on actual sulphur content, provided by Swedish Transport Administration (STA), is based on estimates made by VTI⁴⁰ for the years 1990-2001, and on fuel analysis from SPI from 2001 and onwards.

The amount of gasoline and the emissions of CO₂ and SO₂ from the use of gasoline by "Bifuel E85/petrol" and "Bifuel CNG" vehicles are reported under "Pas-

³⁹ Swedish petroleum institute. www.spbi.se

⁴⁰ Swedish Road- and Transport Research Institute. www.vti.se

senger cars” and the fuel type ”gasoline”. The rest of the emissions generated by ”Bifuel E85/petrol” and ”Bifuel CNG” vehicles are estimated under respectively vehicle category.

CO₂ and SO₂ from natural gas and biofuels are estimated using statistics on deliveries for natural gas, biogas, ethanol and FAME. The thermal value and emission factor for CO₂ from ethanol have changed as from submission 2012 and have also been adjusted for 1990-2009⁴¹. This results in a decrease of the CO₂ emissions by 1.48 % for all years. The thermal value and emission factor for FAME, as well as for natural gas, have been provided by the SEPA. Emissions of CO₂ from biogas, ethanol (including ethanol admixture) and FAME are reported as biomass and not included in the national totals.

Emissions of all other substances are provided by the Swedish Transport Administration, STA. The STA has since 2004 (submission 2006) used the EU road traffic emission model ARTEMIS (Assessment and Reliability of Transport Emission Models and Inventory Systems) to estimate emission from road traffic, but as from 2010 (submission 2012) the STA employs the newly updated road traffic emission model HBEFA 3.1 instead.

HBEFA 3.1 is the most recent version of HBEFA which dates from January 2010 and is a fusion between ARTEMIS and earlier models of HBEFA. The most prominent difference in the new model is the inclusion of the latest exhaust emission control technology (Euro V and Euro 4/5 with a particle filter). All emission factors have also been renewed and there has been an update of the vehicle fleet, the composition of the fuel and the current traffic work. There has also been an update of the road map based on the new speeding system for 2010⁴².

The HBEFA 3.1 model has been used to calculate most emissions. In the material from HBEFA, emissions of N₂O and CH₄ from HDV and passenger cars running on Ethanol, Natural gas and Biogas are missing. These are calculated separately.

Data from the HBEFA 3.1 model is separated by fuel type and four vehicle types: Passenger cars, Light commercial vehicles, Heavy-duty vehicles (including bus) and Mopeds & Motorcycles. Estimated fuel consumption per fuel and vehicle type is used to proportionally allocate national fuel statistics over those categories.

Emissions of CH₄, N₂O, NO_x, CO and NMVOC are according to HBEFA 3.1 data adjusted for military transport.

The fuel consumption and CO₂ emissions estimated by the STA differ slightly from those reported to the UNFCCC. 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. An overview of the two different objectives is presented in Table 3.19.

⁴¹ Fridell et al. 2010. ”Uppdatering av klimatrelaterade emissionsfaktorer”.

⁴² Swedish Transport Administration (STA). Leverans av data till klimatrapportering 2012, vägtrafik. 2011

Table 3.19. 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.

As from submission 2011, emissions of CH₄ and N₂O from ethanol used by passenger cars and HDV (Heavy Duty Vehicles) are estimated. The emissions are based on an implied emission factor derived from activity data and emissions from gasoline and AD from HBEFA 3.1.

As from submission 2012 additionally emissions of CH₄ and N₂O from natural gas and biogas are also estimated, using statistics on deliveries of natural gas and biogas. The emission factors used originate from a report published by Paulrud, Fridell and Strippel (2009)⁴³. These emissions are not provided by either ARTEMIS or HBEFA 3.1 (except in ARTEMIS where emissions of CH₄ from CNG were calculated).

Military transport emissions are reported under CRF 1A5b to be in accordance with the IPCC Guidelines, except for Military road transport which is included in the road traffic emissions estimated by HBEFA 3.1. To subtract and separate emissions from military transport from emissions from civil road transport, emissions from HBEFA 3.1 for each vehicle type are reduced by an amount equal to the weight of the fuel consumption reported by the Swedish Armed Forces relative to the fuel consumption from national statistics allocated to civil road transport, according to:

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

A = Military transport emissions

B = Total HBEFA emissions

C = Total fuel consumption National Statistics

D = Military fuel consumption Swedish Armed Forces

E_i = HBEFA emissions per vehicle type

3.2.16.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Activity data for natural gas and ethanol is available from 1990, while reliable activity data for biogas exists from 1996 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).

⁴³ Paulrud, Fridell Strippel. Uppdatering av klimatrelaterade emissionsfaktorer. IVL report 2nd edition 2009

A passenger car that goes through MOT in the beginning of 2009 has driven the most part during 2008. If the development of traffic is without interruption this issue is not a problem for the calculations. However, if a sudden event occurs, such as a drop in the economy as seen recently it will not be shown as clearly in the development of vehicle mileage as in statistics on fuel consumption. One example is for example the calculations of N₂O which is actually increasing slightly despite a decreasing fuel consumption overall.

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

3.2.16.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

3.2.16.5 SOURCE-SPECIFIC RECALCULATIONS

The change of road vehicle emission model from ARTEMIS to HBEFA 3.1 resulted in revised emissions for all emissions except CO₂ and SO₂, since these are based on statistics of fuel deliveries in Sweden. The change in emissions of CH₄ and N₂O can be seen in figure 3.5 and figure 3.6. The difference between the two emission models with regard to methane emissions arise from cold starts estimations as a result of the new cold start model. The reason for the difference in levels of emissions of N₂O between ARTEMIS and HBEFA 3.1 also lies in the new cold start model in HBEFA 3.1. The increase for HBEFA 3.1 for the last years that cannot be seen in ARTEMIS depends on that that HBEFA 3.1. is later updated and also include measurements on the latest technology with exhaust aftertreatment equipment on HDV.

Further information on the effects from the change of road emission model can be found in Annex 3.

A minor part of the allocation of gasoline and diesel oil to road traffic was affected by a revision of the methodology to estimate emissions from off-road vehicles and working machinery.

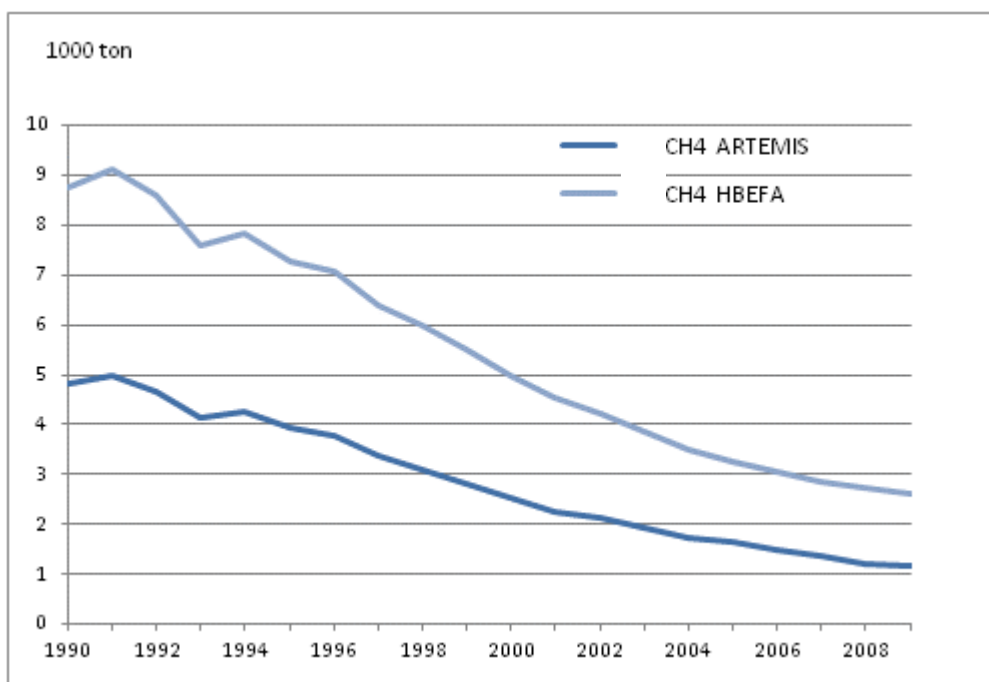


Figure 3.5 Emissions of CH₄ estimated by ARTEMIS and HBEFA.

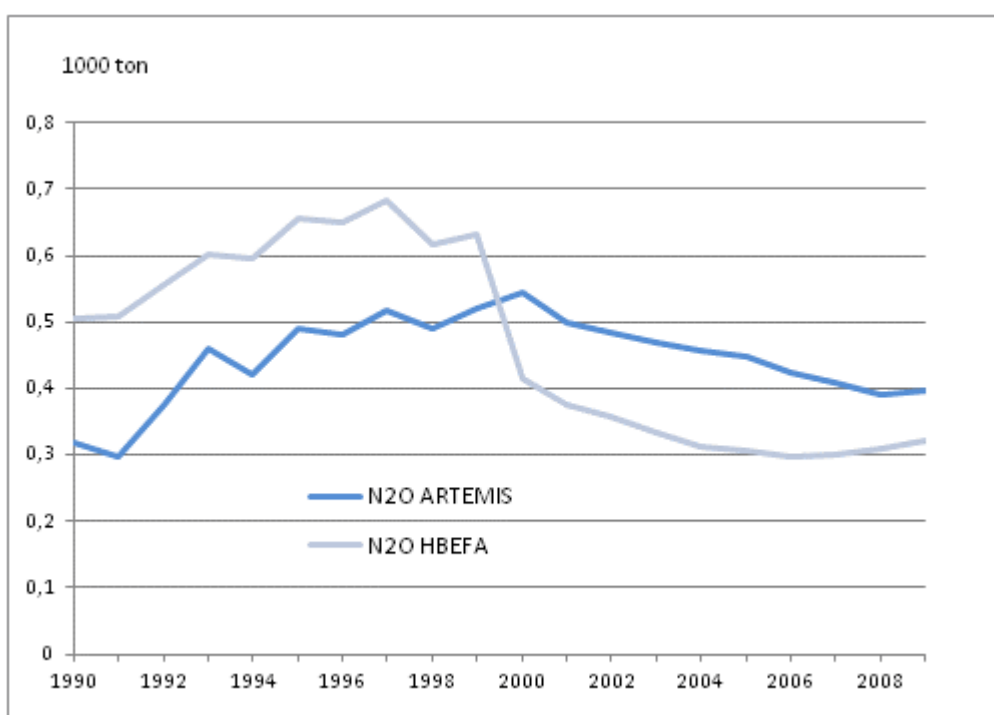


Figure 3.6. Emissions of N₂O estimated by ARTEMIS and HBEFA.

The thermal value and emission factor for ethanol have changed as from submission 2012 and consequently also for all the years 1990-2009. This results in a decrease of the CO₂ emissions by 1.48 % for all years.

As from the resubmission of 2011, emissions of CH₄ and N₂O from ethanol used by passenger cars and HDV (Heavy Duty Vehicles) are estimated. The calculations are based on an implied emission factors for gasoline and AD from HBEFA 3.1. The activity data for ethanol is based on the ethanol used in E85 cars and HDV and the ethanol mixed into gasoline (~5 %) is not included. The emissions of CH₄ and N₂O from this ethanol is included in the emissions from gasoline.

As from submission 2012 additionally emissions of CH₄ and N₂O from natural gas and biogas are also estimated, using statistics on deliveries of natural gas and biogas. The emission factors used originate from a report published by Paulrud, Fridell and Strippel (2009)⁴⁴. These emissions were neither calculated in ARTEMIS nor in HBEFA 3.1 (except for emissions of CH₄ from CNG in ARTEMIS).

Correction of previous minor erroneous data also occurs.

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 Railways (CRF 1.A.3.c)

3.2.17.1 SOURCE CATEGORY DESCRIPTION

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.20.

Table 3.20. Summary of source category description, CRF 1.A.3.c.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1.A.3.c	CO ₂				T1	CS	Yes
	CH ₄				T1	CR, CS	Yes
	N ₂ O				T1	CR, CS	Yes

CS Country Specific. CR CORINAIR. T1 Tier 1.

The majority of all railway traffic in Sweden runs on electricity. Only a small part runs on other fuels i.e. diesel fuel. According to IPCC's guidelines emissions related to the use of electricity for railway should not be included in this sector. Production of electricity is accounted for in CRF 1A1A, regardless of where it's consumed.

3.2.17.2 METHODOLOGICAL ISSUES

The Tier 1 method is used. Information on emissions from railways is provided by the Swedish National Rail Administration, as estimates on the amount of diesel

⁴⁴ Paulrud, Fridell Strippel. Uppdatering av klimatrelaterade emissionsfaktorer. IVL report 2nd edition 2009

consumed as well as estimates on emissions of CO₂, SO₂, NO_x, NMVOC, CH₄, CO, HC and N₂O.

Emission estimates are calculated based on the estimated diesel consumption together with emission factors from three different sources. Emission factors used for calculating CO₂ emissions are supplied by the Swedish Petroleum Institute⁴⁵, whereas emission factors used for NO_x and CO estimates are provided by the Swedish Transport Agency. Remaining emissions are calculated based on default emission factors from EMEP/CORINAIR.

3.2.17.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Overall, the emissions for CRF 1.A.3.C is consistent over time and associated with low uncertainties. The estimate of diesel consumption is based on fees paid by the rail operators and is considered to be of very high quality.

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

3.2.17.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

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

3.2.17.5 SOURCE-SPECIFIC RECALCULATIONS

Corrections of previous minor erroneous data have been made.

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 Navigation (CRF 1.A.3.d)

3.2.18.1 SOURCE CATEGORY DESCRIPTION

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

⁴⁵ www.spi.se August 2005

CO₂ emissions from navigation does not show any particular trend, but fluctuates over time.

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 1.A.3.d.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1.A.3.d	CO ₂	X	X		T1	CS	Yes
	CH ₄				T1	CR, CS	Yes
	N ₂ O				T1	CR, CS	Yes

CS Country Specific. CR CORINAIR. T1 Tier 1.

3.2.18.2 METHODOLOGICAL ISSUES

Emissions from national navigation are estimated using Tier 1.

Emissions from domestic navigation are calculated based on the amount of fuels that are purchased and consumed in Sweden.⁴⁶ Emissions from fuels that are purchased in Sweden but used abroad are reported separately as international bunker emissions. The allocation of emissions from navigation is summarized in Table 3.22.

Table 3.22. Reporting of emissions from navigation, according to the Good Practice Guidance.

Fuel bought in	Traffic between Swedish harbours	Traffic between Swedish and international harbours	Traffic between two international harbours
Sweden	Domestic, 1A3d	International bunkers, 1C	International bunkers, 1C
Other country	Not included	Not included	Not included

Emissions from gas/diesel oil and residual fuel oils, for 1990-2002, are calculated using emission factors from a SMED study from 2004⁴⁷. Emissions for 2003 and 2004 have been estimated using emissions factors for 2002 while emissions for 2005 and later years have been calculated using emissions factors provided by the Swedish Maritime Administration (SMA). The emission factors provided by the SMA are based on the mentioned study by SMED.

Emissions of CO₂ and SO₂ from leisure boats are calculated based on estimated gasoline consumption together with thermal values and emission factors which are the same as for civil road traffic. Emissions of NO_x, NMVOC, CH₄, CO and N₂O are all based on estimated gasoline consumption together with emission factors from CORINAIR for gasoline.

⁴⁶ Statistics Sweden EN31SM

⁴⁷ Cooper and Gustafsson, 2004.

Emissions of NO_x, NMVOC, CH₄, CO and N₂O from leisure boats also depend on the ratio between 2-stroke and 4-stroke engines. The estimated ratios between the two are based on a study by Statistics Sweden⁴⁸ from 2005. The study indicates that there is a larger share of 4-stroke engines in 2004 than in 1990. Based on the assumption that the move towards a larger number of 4-stroke engines has been gradual between since 1990, the ratio for each year between 1990 and 2004 has been estimated by interpolation. From 2005 and onwards, the ratio between 2- and 4-stroke engines is assumed to be the same as for 2004.

The Swedish Maritime Administration also report emissions from domestic navigation. These can however not be compared with emissions from the Swedish national inventory since the former include emissions from the whole Baltic Sea region.

3.2.18.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Fuel consumption 1990-2009 reported in submission 2011 to UNFCCC for domestic navigation, based on energy statistics from Statistics Sweden's, shows fluctuations for which it has been difficult to find natural explanations Figure 3.7.

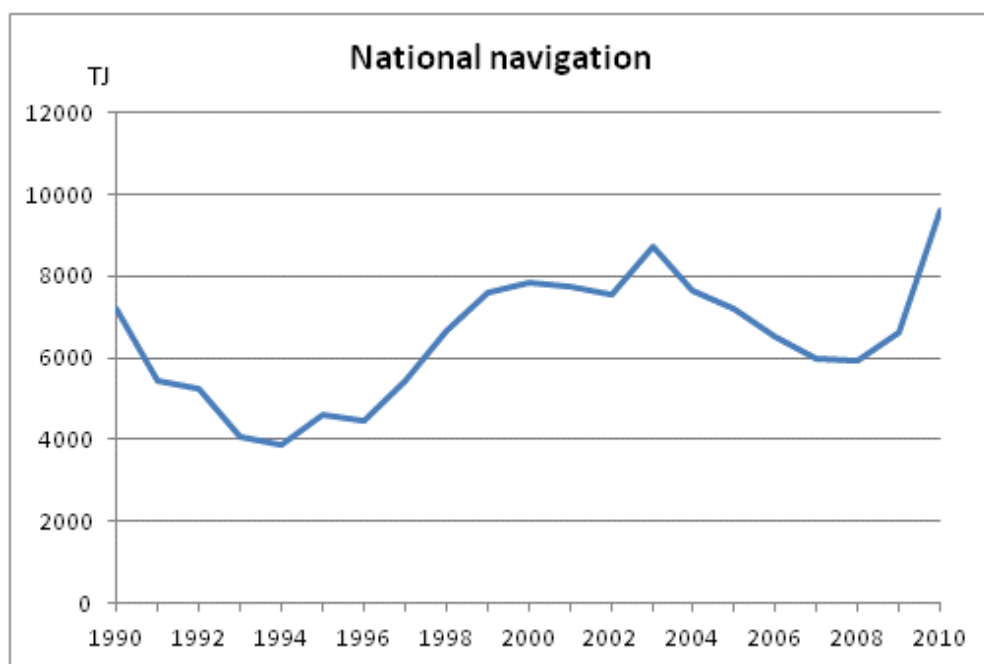


Figure 3.7. Fuel consumption by national navigation

As a result fuel consumption by national and international navigation has been studied in a SMED study⁴⁹. Fuel data in the Monthly fuel, gas and inventory statistics, which is used as activity data for estimating emissions for national navigation and international maritime bunkers, has been analyzed. The fuel data is collected

⁴⁸ Statistics Sweden, 2005.

⁴⁹ Eklund et al. 2011. Emissions from navigation and fishing including international bunkers

from oil companies and other sellers who have stocks of petroleum products and coal. The survey also collects stock data from companies with a large consumption of oil in the manufacturing industries and energy industries. The population consists of approximately 70 companies, and all of them are included in the survey.

In 1993, 24 companies reported fuel amounts for domestic navigation and 15 companies reported amounts for international maritime bunkers. During the period 1993-2010 many companies have been closed or taken over by larger companies. In 2010, very few companies remained – only eight companies reported fuel amounts for Domestic navigation or International maritime bunkers. With such a small population, it was possible to study each company carefully. Suppliers of significant quantities of bunker oil ($\sim 100\,000\text{ m}^3 - 2\,000\,000\text{ m}^3$) have been examined more closely.

The response from the companies was very good and produced reliable information. Data on domestic and international bunker fuel in the Monthly fuel, gas and inventory statistics have been found to be of good quality. As a consequence of that VAT is applied on national fuel consumption, but not on international bunkers, all respondents to the survey are able to separate these fuel amounts with high accuracy. Fuels used for domestic and international navigation have been separated correctly and in line with IPCC Guidelines.

The fuel consumption in 2010 for national navigation has increased noticeably since 2009. The data has been verified and is correct according to reported amounts of fuel deliveries. Note that the amount of fuel used by national navigation is relatively small compared to the total amount of fuel for navigation, including international navigation (bunkers).

3.2.18.4 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 prior to the publishing of statistics on fuel purchased. In addition to this, the consumption of every type of fuel in the last year is checked and compared with previous years. If large variations are discovered for certain fuels, responsible staff is contacted for an explanation. IEFs are calculated per fuel, substance and CRF-code and checked against the emission factors to make sure that no calculation errors have occurred when emissions were computed.

3.2.18.5 SOURCE-SPECIFIC RECALCULATIONS

The total amount of delivered diesel (excluding FAME) for mobile combustion is first allocated to those subsectors for which accurate and precise information on diesel consumption is available, whereof one is “off-road vehicles and working machinery”. The remaining amount of the total delivered diesel is allocated to subsectors where the estimated diesel consumption is more uncertain. These subsectors are fisheries, domestic navigation, and civil road traffic.

As the model for estimating emissions from off-road vehicles and working machinery has been updated for all years (1990-2009), this will consequently also affect the emissions from national navigation.

3.2.18.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

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

3.2.19.1 SOURCE CATEGORY DESCRIPTION

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.23.

Table 3.23. Summary of source category description, CRF 1.A.3.e.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1.A.3.e	CO ₂				T2	CS	Yes
	CH ₄				T2	M	Yes
	N ₂ O				T2	M	Yes

CS Country Specific. T2 Tier 2. M Model.

Emissions reported under CRF 1.A.3.e refer to emissions from off-road vehicles and working machinery including various mobile vehicles and machinery as for example refrigerating plant, wheel loader, lawn movers, excavators, trimmers, snow blowers and other mobile machine that run on liquid fuels.

3.2.19.2 METHODOLOGICAL ISSUES

The model used to estimate emissions from off-road vehicles and other machineries is considered to correspond to Tier 2. The model is further explained in Annex 2. Emissions from off-road vehicles and other machinery are also reported under CRF 1.A.2.f, 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.f	Mobile machineries in industry that run on petroleum fuels, as for example tractors, dumpers, cranes, excavators, generators, wheel loaders, sorting works, pumpunits etc.
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.
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.f.

3.2.19.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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

3.2.19.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

3.2.19.5 SOURCE-SPECIFIC RECALCULATIONS

The methodology for estimating emissions from off-road vehicles and working machinery was revised in submission 2012, see section 3.2.14.5. The revision did not imply an updated methodology but aimed to simplify the use of the model and at the same time update some emission factors, activity data and the allocation of emissions to different sectors. Allocation of emissions from off-road vehicles and working machinery is based on a report by Flodström (et al)⁵⁰. This is the most recent inventory including an allocation of working machinery to sectors carried out in Sweden

Changes in emissions from off road vehicles and working machinery compared to submission 2011 due to updated activity data, emission factors and the sectoral allocation is shown in

⁵⁰ Flodström et al 2004. Uppdatering av utsläpp till luft från arbetsfordon och arbetsredskap för Sveriges internationella rapportering.

Table 3.25 .The emissions of N₂O have changed noticeably between submission 2011 and submission 2012 due to the use of an incorrect emission factor for some working machinery in submission 2011. It has now been updated.

Table 3.25. Changes in emissions from off road vehicles and working machinery compared to submission 2011. A positive percentage shows an increase in emissions in submission 2012 and vice versa.

CRF	1990 CO2 eq.	2008 CO2 eq.	2009 CO2 eq.	1990 TJ	2008 TJ	2009 TJ
Total	8	114	170	-6	114	170
1.A.2.f; Industry	37	122	126	478	122	126
1.A.3.e; Other	-234	-150	-105	-2810	-150	-105
1.A.4.b; Households	137	154	156	1591	154	156
1.A.4.c Farming	119	4	-8	1353	4	-8
1.A.4.c Forestry	-51	-16	0	-619	-16	0

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

3.2.20.1 SOURCE CATEGORY DESCRIPTION

The heated area was 135 million m² in 2009. More than one third of this area consists of schools. Since 1990, the total consumption of fuels for heating of premises has decreased significantly due to the increased use of district heating. In the early 1990s, the total annual fuel consumption in this sector was around 35,000 TJ, around year 2,000 it had decreased to about 20,000 TJ, and in 2010 it was around 13,000 TJ. Liquid fuels account for most of the decrease, and in recent years, natural gas is the most common fuel followed by domestic heating oil and wooden fuels. Over 90% of the area was heated with district heating in 2009. The corresponding share in 1990 was about 55%.

Emissions from mobile combustion used in commercial and institutional activities are included in residential (CRF 1.A.4.b), as it is currently not possible to separate mobile combustion in these two categories from one another.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.26.

Table 3.26. Summary of source category description, CRF 1.A.4.a.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1.A.4.a	CO ₂	X	X		T1	CS	Yes
	CH ₄				T1	CS	Yes
	N ₂ O				T1	CS	Yes

CS Country Specific. T1 Tier 1.

3.2.20.2 METHODOLOGICAL ISSUES

For stationary combustion within CRF 1.A.4.a, all activity data is on national level by fuel type and estimated emissions are therefore considered to correspond to Tier 1. 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 3.2.20.4.1 and in Annex 2.

3.2.20.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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

3.2.20.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

In submission 2005 and earlier, there were large uncertainties in estimation models and allocation methods for fuel in the other sectors and CRF 1.A.2.f, construction. In 2005, a study was performed by SMED, aiming at identifying and analyzing the methods and models applied for each sub-sector and determine whether they were in line with the IPCC guideline recommendations.⁵¹ 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.b⁵². Due to these recalculations there are obvious inconsistencies between the national energy balances and the national emission inventory data. Furthermore, all fuels proved to be correctly allocated on stationary and mobile combustion. In the Swedish air emission inventory, that means that all diesel oil and gasoline reported under Other sectors in the energy balances are used by mobile combustion, while all the other fuels are related to stationary combustion.

⁵¹ Gustafsson, et al. 2005.

⁵² Paulrud et al. 2005.

3.2.20.4.1 Activity data for stationary combustion in other sectors

For stationary combustion within the Other sectors, the only complete and readily available activity data source is the energy balance. Table 3.27 below shows the consumption of different fuels in 2009 in the different sub-categories within the other sector, and those parts of CRF 1.A.2.f where the energy balance is also used, e.g. construction and small industrial facilities.

Table 3.27. Excerpt from energy balance sheet. Fuel consumption in 2009, TJ

Subsector	Bio-mass	LPG	Domestic heating oil	Residual fuel oils	Natural gas	Gas works gas
Agriculture, fisheries, 1A4c	6 800	100	3 500	200	500	-
Forestry, 1A4c	-	0	500	300	0	-
Small industrial plants, 1A2f	-	200	1 100	600	200	..
Construction, 1A2f	-	100	1 500	200	500	-
Service, 1A4a	1 800	2 300	3 100	0	3 100	300
Residential, 1A4b	49 700	200	6 700	0	3 000	400

In 2008 all available methods to estimate emissions from stationary combustion in other sectors were overhauled in a SMED study⁵³. The main problem is still that the timeline for the GHG inventory is too short for using final data for other sectors and construction for the latest year. All available alternatives have specific problems including higher uncertainties etc discussed in the study. The method that was considered to give the best data was using annual energy balances for all years when available, and for the latest year make a model estimate of fuel combustion that adjusts the amounts from the year before with the trend in the preliminary quarterly fuel statistics, as exemplified for 2007 in the equation below:

**Estimate 2007 = Annual statistics 2006* preliminary quarterly fuel statistics 2007/
quarterly fuel statistics 2006**

Since emissions for the most recent years are based on this model estimate, uncertainties are a bit higher for this year. Emissions for the most recent years will be revised in next submission when annual statistics are available.

Since 2002, and in particular since 2004, the consumption of biomass fuels has increased in this sector. This is partly explained by the general shift from liquid to biomass fuels in recent years. However, a data check performed in 2009 showed that the data for biomass use in the commercial/institutional sector in the energy balances might not be complete. Further investigations were planned to submission 2011, but this issue was not prioritised since no suitable alternative or complementary data sources were found.

⁵³ Lidén and Gerner, 2008

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

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

3.2.20.5 SOURCE-SPECIFIC RECALCULATIONS

As indicated in the previous section, activity data has been revised for all fuels for years 2008 and 2009. The greenhouse gas emissions in submission 2012 was 32 Gg CO₂ equivalents lower in 2008 and 69 Gg lower in 2009 compared to submission 2011.

3.2.20.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

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

3.2.21.1 SOURCE CATEGORY DESCRIPTION

In this category both stationary and mobile combustion occur. Stationary combustion of fuels within residential decreased by around 50% between 1990 and 2008, mainly due to a continuous increase in district heating use. Most of this change occurred before 2006; however, the use of heating oils is still decreasing while combustion of wood, wood chips and pellets has increased in recent years. 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.

Mobile combustion in CRF 1A4a is included in this sector, as it is currently not possible to separate mobile combustion in these two sectors from one another. Emissions from mobile combustion refer to emissions from off-road vehicles and other machinery including various mobile vehicles and machines as for example tractors, lawn movers, snow mobiles, forklifts, trimmers, chainsaws and forklifts.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.28.

Table 3.28. Summary of source category description, CRF 1.A.4.b.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1.A.4.b	CO ₂	X	X		T1,T2	CS	Yes
	CH ₄	X	X		T1,T2	CS	Yes
	N ₂ O		X		T1,T2	CS	Yes

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

3.2.21.2 METHODOLOGICAL ISSUES

For stationary combustion, all activity data is on national level by fuel type and estimated emissions are therefore considered to correspond to Tier 1.

For stationary combustion, the main data source is the annual energy balances. One- and two-dwellings statistics, Holiday cottages statistics and Multi-dwellings statistics are used as a complementary data source to get more details on biomass combustion. Biomass fuel consumption for heating residences are surveyed on the three most common combustion technologies: boiler, stoves and open fire places. Since 1998 biomass activity data is separated on wood logs, pellets/briquettes and wood chips/saw dust. Historical biomass data has been estimated by inter- and extrapolation.

Estimation models and allocation methods for fuel in the Other sectors as discussed in section 3.2.20 and use of preliminary data for stationary combustion in other sectors as discussed in section 3.2.20 also applies to CRF 1.A.4.b.

The model used to estimate emissions from off-road vehicles and other machineries is considered to correspond to Tier 2. The model is further explained in Annex 2.

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 Tier 1 methodology with indata 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 indata 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 3.2.20. 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 as described in section 3.2.21.2.

3.2.21.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

See section 3.2.20.4

3.2.21.5 SOURCE-SPECIFIC RECALCULATIONS

Following revisions of the energy balances, the activity data for stationary combustion within 1.A.4.b was revised for all fuels 2008-2009. Compared to submission 2011, greenhouse gas emissions are 36 Gg lower in 2008 and 82 Gg lower in 2009. The methodology for estimating emissions from off-road vehicles and working machinery was revised in submission 2012 (see section 3.2.19.5). Changes in emissions compared to submission 2011 due to updated activity data, emission factors and the sectoral allocation is shown in Table 3.29.

Table 3.29. Changes in emissions from off road vehicles and working machinery compared to submission 2011. A positive percentage shows an increase in emissions in submission 2012 and vice versa.

CRF	1990 CO ₂ eq.	2008 CO ₂ eq.	2009 CO ₂ eq.	1990 TJ	2008 TJ	2009 TJ
Total	0.25%	3,13%	4,71%	-6,49	1304,37	1997,47
1A2f; Industry	-13%	-8%	-5%	1353	-133	-284
1A3e; Other	85%	88%	89%	-619	-205	-8
1A4b; Households	19%	43%	49%	-2810	-1859	-1300
1A4c Farming	21%	202%	204%	1591	1854	1879
1A4c Forestry	-12%	-3%	0%	478	1647	1711

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.

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

3.2.22.1 SOURCE CATEGORY DESCRIPTION

This category includes emissions from stationary combustion for heating purposes and mobile combustion in off-road vehicles and working machinery within agriculture and forestry, and fishing vessels. The structure of the agricultural sector in Sweden is described in chapter 6.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.30.

Table 3.30. Summary of source category description, CRF 1.A.4.c.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1.A.4.c	CO ₂	X			T1,T2	CS	Yes
	CH ₄		X		T1,T2	CS	Yes
	N ₂ O				T1,T2	CS	Yes

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

3.2.22.2 METHODOLOGICAL ISSUES

For stationary combustion, all activity data is on national level by fuel type and estimated emissions are therefore considered to correspond to Tier 1.

For stationary combustion, activity data is 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 3.2.20, and use of preliminary data for stationary combustion in other sectors as discussed in section 3.2.20.4.1 also applies to CRF 1.A.4.c.

The model used to estimate emissions from off-road vehicles and other machineries is considered to correspond to Tier 2. The model is further explained in Annex 2.

Emissions from Fisheries, CRF 1.A.4.c, were first reported in submission 2006. The estimated fuel consumption is based on a survey on energy consumption within the fishing industry by Statistics Sweden⁵⁴ together with data on the Swedish fishing fleets' total installed effect in kW from the Swedish Board of Fisheries. The estimate on fuel consumption provided by Statistics Sweden refer to 2005, and for the previous and following years the fuel consumption is estimated by adjusting the 2005 value according to the development in total installed effect. The emissions factors used to estimate emissions from Fisheries are based on a SMED study from 2005⁵⁵, 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.

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

3.2.22.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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

The sharp increase in use of biomass in 2003 is due to a revision in submission 2009, where improved data was used for 2003 and later years. There is no information available to improve data from 2002 and earlier years. Emissions in 1990 are

⁵⁴ Statistics Sweden, 2006 ENFT0601.

⁵⁵ Cooper et al., 2005a.

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

3.2.22.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

See section 3.2.20.4

3.2.22.5 SOURCE-SPECIFIC RECALCULATIONS

Following revisions of the energy balances, the activity data for stationary combustion within 1A4c was revised for all fuels 2008-2009. Compared to submission 2011, greenhouse gas emissions are 12 Gg lower in 2008 and 12 Gg higher in 2009.

The methodology for estimating emissions from off-road vehicles and working machinery was revised in submission 2012 (see section 3.2.19.5). Changes in emissions compared to submission 2011 due to updated activity data, emission factors and the sectoral allocation is shown in Table 3.31.

Table 3.31. Changes in emissions from off road vehicles and working machinery compared to submission 2011. A positive percentage shows an increase in emissions in submission 2012 and vice versa.

CRF	1990 CO ₂ eq.	2008 CO ₂ eq.	2009 CO ₂ eq.	1990 TJ	2008 TJ	2009 TJ
Total	8	114	170	-6	114	170
1.A.2.f; Industry	37	122	126	478	122	126
1.A.3.e; Other	-234	-150	-105	-2810	-150	-105
1.A.4.b; Households	137	154	156	1591	154	156
1.A.4.c Farming	119	4	-8	1353	4	-8
1.A.4.c Forestry	-51	-16	0	-619	-16	0

The emissions of N₂O have changed noticeably between submission 2011 and submission 2012 due to the use of an incorrect emission factor for some working machinery in submission 2011. It has now been updated.

3.2.22.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

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

3.2.23.1 SOURCE CATEGORY DESCRIPTION

In submission 2012, no emissions are reported in this sector. The reason is that emissions and energy losses reported here in previous submissions have been reallocated to other sectors (1.A.1.a and 1.A.d). Previously, transformation losses of energy within the integrated iron and steel industry were allocated to CRF 1A5a,

but a study made in 2011 showed that the energy should be allocated to CRF 2.C.1 as it is lost as heat in the production processes in blast furnaces and steel works.⁵⁶ Emissions from use of natural gas that was believed to be pressure levelling losses were also reported in CRF 1.A.5.a in previous submissions. However, detailed studies of the underlying activity data revealed that the data had been misinterpreted and was in fact representing combustion of natural gas for heat production in gas works, and thus it should be reallocated to CRF 1.A.1.a. See also section 3.2.6.5.

3.2.23.2 METHODOLOGICAL ISSUES

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3.2.23.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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3.2.23.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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3.2.23.5 SOURCE-SPECIFIC RECALCULATIONS

See source category description, section 3.2.23.1.

3.2.23.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

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

3.2.24.1 SOURCE CATEGORY DESCRIPTION

CRF 1A5b includes emissions from military transports. Emissions from military transports have decreased over the years 1990-2008 due to a decrease in activity. However in 2009 the Swedish military increased its consumption jet kerosene compared to 2008, but in 2010 it went back down again (from 77,894 m³ to 48,692 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 3.32.

Table 3.32. Summary of source category description, CRF 1.A.5.b.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1.A.5.b	CO ₂		X		T1	CS	Yes
	CH ₄				T1	CS	No, see Annex 5
	N ₂ O		X		T1	CS	No, see Annex 5

CS Country Specific. T1 Tier 1.

⁵⁶ Gustafsson, Lidén & Gerner, 2010

3.2.24.2 METHODOLOGICAL ISSUES

Emissions from military transport are based on data on fuel consumption including all military activities and are considered to correspond to Tier 1. Fuel consumption from some more administrative military activities, such as the Swedish Defence Material Administration (FMV), the Swedish Fortification Department (FORTV), the Swedish Defence Research Agency (FOI) and the National Defence Radio Institute (FRA), are not included in the calculations.

A special estimation for the use of FAME was conducted by the military for the years 1999-2001. 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). Hence, estimates are considered to be both Tier 1 and Tier 2. Emissions from military aviation are based on an average of LTO and cruise emission factors. Emissions from military navigation are estimated using emission factors from civil navigation. Emissions from the use of diesel oil by military stationed abroad is reported under Multilateral operations, CRF 1.C.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:

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

A = Military transport emissions

B = Total HBEFA emissions

C = Total fuel consumption National Statistics

D = Military fuel consumption Swedish Armed Forces

E_i = HBEFA emissions per vehicle type

3.2.24.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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

3.2.24.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source specific procedures have been made.

3.2.24.5 SOURCE-SPECIFIC RECALCULATIONS

The change of the road vehicle emission model ARTEMIS to HBEFA 3.1 have resulted in revised emissions of CH₄ and N₂O from military road traffic.

3.2.24.6 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 gas works gas, storage and handling of oil in refineries, depots and gasoline distribution, and natural gas transmission and distribution.

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

3.3.1.1 SOURCE CATEGORY DESCRIPTION

There are no coalmines in Sweden and hence no fugitive emissions from coalmines occur.

Flaring of coke oven gas from the coke oven is reported in CRF 1.B.1.c since submission 2004. Since submission 2010, flaring of blast furnace gas in the blast furnace and steel converter gas in the steel converter are reported under CRF 2.C.1. CRF 1.B.1 is not really designed to include flaring, but since CRF 1B2 only refers to liquid and gaseous fuels, it is not possible to report flaring of coke oven gas in CRF Table 1.B.2. The amounts of flared gas vary considerably between years, and in 2009 it was unusually high, resulting in increasing emissions in CRF 1.B.1. According to environmental reports⁵⁷, coke oven gas is flared when the production is temporarily stopped because of urgent needs of reparation of equipment or other maintenance measures.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 3.33.

⁵⁷ SSAB, 2008 and 2009

Table 3.33. Summary of source category description, CRF 1.B.1.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1.B.1	CO ₂				T3	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

SO₂ emissions from quenching and extinction at coke ovens are reported in CFR 1B1b.

3.3.1.2 METHODOLOGICAL ISSUES

The estimation of emissions from flaring of coke oven gas is included in the carbon balance calculations and other plant specific calculations made in cooperation with the two facilities, see section 4.4. Data concerning SO₂ emissions from quenching and extinction at coke ovens are obtained directly from the operators of the two facilities.

3.3.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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

3.3.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

See section 4.4.1.2.2

3.3.1.5 SOURCE-SPECIFIC RECALCULATIONS

Thanks to improved in-data for 2009 from one of the facilities, CO₂ emissions have been revised for that year. The difference compared to submission 2011 is -0.2 Gg CO₂.

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), fugitive emissions from transmission and distribution of gas works gas (1.B.2.a.5), fugitive emissions from transmission and distribution of natural gas (1.B.2.b.2 and 1.B.2.b.3), and flaring of liquid fuels (1.B.2.c.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 3.34.

Table 3.34. Summary of source category description, CRF 1.B.2.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
1.B.2	CO ₂	X	X		T1, T2, T3	D, CS, PS	Yes
	CH ₄	X	X		CS, T1, T2	D, CS, PS	Yes
	N ₂ O				T1, T2	CS	Yes

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

3.3.2.2 METHODOLOGICAL ISSUES

3.3.2.2.1 Hydrogen production plants at refineries, CRF 1.B.2.A.1

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

Both CO₂ and non-CO₂ emissions are estimated using the Tier 2 method. Activity data as consumed amount of fuels (butane gas and naphtha, respectively for the two plants) and CO₂ emissions are taken from the company's report to the EU ETS system. Non-CO₂ emissions are calculated with this plant specific activity data. National emission factors are used for butane, whereas national emission factors for "other petroleum fuels" are used for naphtha due to lack of specific emission factors for this fuel.

3.3.2.2.2 Transport, CRF 1B2A3

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 from submission 2010 and onwards. 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, 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 tankers is available.

3.3.2.2.3 Refining/Storage, CRF 1.B.2.A.4

Sweden estimates both CO₂ and non CO₂ emissions by using the Tier 2 method. The Tier 2 method requires data at plant level and Sweden uses data provided by the refineries in their annual environmental reports. However, for CH₄ emissions, the IPCC Tier 2 equals a mass-balance estimate, whereas Sweden uses a country specific (CS) method (see below). Emissions are reported from catalytic cracking (CO, SO₂, NOX), desulphurisation (SO₂) and from the storage and handling of oil (NMVOC, CH₄). Catalytic cracking occurs at one plant in Sweden. CO emissions from catalytic cracking are calculated as:

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

Due to some operational problems at the plant the total emissions of CO were high for 1997 and 1998 compared to other years.

The emissions of SO₂ from desulphurisation increased in year 2006 compared to previous years due to operational disturbances at one facility.

Fugitive emissions of NMVOC and CH₄ from refineries include emissions from the process area as well as emissions from the refinery harbours when loading tankers. The estimates of NMVOC are mainly based on reported data from the facilities' environmental reports and older reports from the Swedish EPA^{58, 59, 60, 61} and Statistics Sweden⁶². 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 3.35, reported NMVOC emissions as well as activity data can be seen. 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 reported fugitive NMVOC 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 even from these plants. The reported emissions of CH₄ are very uncertain due to limited measurements. In Table 3.35, the reported emissions of CH₄ and also activity data can be seen.

⁵⁸ Swedish EPA, 1990.

⁵⁹ Swedish EPA, 1994a.

⁶⁰ Swedish EPA, 1994b.

⁶¹ Swedish EPA, 1995.

⁶² Statistics Sweden. 1996 Emissions to air in Sweden of volatile organic compounds (VOC) 1988 and 1994.

Table 3.35. Throughput of crude oil in refineries and estimated fugitive emissions of NMVOC and CH₄ (Mg) reported in CRF 1.B.2.A.4.

Year	Throughput of crude oil Mg	Total emissions of NMVOC Mg	Total emissions of CH ₄ Mg
1990	17 330 000	14 408	460
1995	19 430 000	7 643	400
2000	20 253 120	11 568	577
2005	19 919 968	7 691	399
2006	20 050 576	8 269	425
2007	17 706 518	8 877	417
2008	20 420 061	8 578	447
2009	19 669 472	8 779	438
2010	20 278 888	8 924	469

In submission 2009, emissions from combustion of cracker coke in refineries earlier reported in CRF 1A1b were reallocated to CRF 1.B.2.A.4 to be in line with the IPCC guidelines. This is based on a recent study performed by SMED⁶³. The cracking reactions produce some carbonaceous material (referred to as *coke*) that deposits on the catalyst and very quickly reduces the catalyst reactivity. The catalyst is regenerated by burning off the deposited coke. Hence the combustion is not carried out for energy purposes and thus the emissions should not be reported in CRF 1.A.

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 SPI⁶⁴. The calculations are based on the amount of product handled in the depots. The calculations cover 1990 – 2010 and are based on methods given by Concawe 85/54⁶⁵ for the years 1990-2006 and on Concawe 03/07⁶⁶ for 2007 and onwards. More than 30 depots have been considered during later years. Gas recovery systems and the recovered amount of gas have been considered in the calculations. For five depot areas the reported NMVOC emissions are based on emission measurements in the depot areas and not on calculations based on the amount product handled in the depots. The reporting of measured emissions instead of calculated emissions are based on recommendations from SPI⁶⁷. For years with missing data, interpolation between years with available data has been used for estimates. Handled amounts of gasoline and fugitive emissions of NMVOC from depots and gasoline stations are presented in Table 3.36.

⁶³ 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

⁶⁴ Per Brännström, 2010, personal communication

⁶⁵ Concawe, 1986, Hydrocarbon emissions from gasoline storage and distribution systems, Report No 85/54.

⁶⁶ Concawe Report No. 3/07, Air pollutant emission estimation methods for E-PRTR reporting by refineries

⁶⁷ Per Brännström, 2010, personal communication

The calculation of fugitive NMVOC emissions from gasoline distribution, 1990-2010 (Table 3.36), is based on methods given by Concawe⁶⁸, 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 stations⁶⁹. The basic assumptions are presented in Table 3.37.

Table 3.36. Handled and distributed amount of gasoline and estimated fugitive emissions of NMVOC (Gg) from storage at depots and at gasoline stations reported in CRF 1.B.2.a.5.

Year	Volume of gasoline m ³	Fugitive emissions of NMVOC at depots Gg	Fugitive emissions of NMVOC at gasoline stations Gg
1990	5 189 807	2.48	13.3
1995	5 239 592	1.93	3.06
2000	5 116 795	2.07	3.07
2005	5 116 408	2.31	3.07
2006	5 089 367	2.47	3.05
2007	5 038 847	2.35	3.02
2008	4 980 296	2.53	2.99
2009	4 793 299	2.41	2.88
2010	4 602 776	2.21	2.76

Table 3.37. Assumptions for calculating fugitive emissions from the handling and distribution of gasoline.

Parameter	Assumption
Density of gasoline	730 kg/m ³ 1990 - 1996 750 kg/m ³ 1997 -
Distribution of gasoline to gas stations	0.16 % of distributed volume
Spill	0.01 % of distributed volume
Filling of car tanks	0.18 % of filled volume
Measures at distribution to gas station	90 % Efficiency of measures
Measures at filling cars	70 % Efficiency of measures

The measures at distribution and filling were introduced over a period of time from 1991-1994, to the extent presented in Table 3.38. The amount of gasoline sold at large and small gas stations, respectively, was assumed to be 50/50 for the years 1990-1994. Data on the distributed amounts of gasoline (Table 3.36) is taken from the HBEFA3.1 road emission model. The model is based on a bottom-up approach considered to be Tier 2. The model is described in detail in Annex 2.

⁶⁸ Concawe, 1986, Hydrocarbon emissions from gasoline storage and distribution systems, Report No 85/54.

⁶⁹ Andersson, 2000.

Table 3.38. Fraction of gasoline stations with technical measures installed.

Year	Large gas stations >2000 m ³	Small gas stations
1990	0%	0%
1991	50%	0%
1992	75%	25%
1993	100%	75%
1994 -	100%	100%

3.3.2.2.5 *Transfer losses of gas works gas, CRF 1.B.2.A.5*

Transmission losses of gas works gas are reported from the producers of gas works gas to Statistics Sweden and published in Statistics on the delivery of gas products (and also reported as “losses” in the annual energy balances). At present, the emissions from these losses are calculated with the same emission factors that are used for stationary combustion, although they are reported as fugitive emissions. The allocation to CRF 1B2A5 is according to the 2006 IPCC Guidelines.

3.3.2.2.6 *Natural gas transmission, CRF 1.B.2.B.3*

Sweden has estimated fugitive methane and carbon dioxide emissions from natural gas transmission in a manner consistent with the IPCC Good Practice Guidance. Default emission factors of 2.90×10^{-3} Gg methane per year and per kilometre of transmission pipeline and 1.6×10^{-5} Gg carbon dioxide per year and per kilometre of transmission pipeline from Table 2.16 in the IPCC Good Practice Guidance has been used. The methane emission factor is the largest in the range given in Table 2.16 and reflects the use of mostly reciprocating compressors. Since at least one reciprocating compressor is used in the Swedish gas transmission network this emission factor has been used.

Activity data as kilometre of transmission pipeline has been obtained only for 1996⁷⁰ (320 km) and for 2008^{71,72}, (620 km). For years before 1996 the pipeline length has been estimated to be of the same length as in 1996 and for 2009 and 2010 the length has been estimated to be of the same length as in 2008. The latter assumption is based on information from one of the operators⁷³ of the network saying that there has been no extension of the transmission network between 2008 and 2010. For years between 1996 and 2008 the activity data has been estimated by interpolation.

⁷⁰ Technical description of the Swedish natural gas distribution system, Swedish gas center, Report SGC 088, June 1997

⁷¹ Distributionsformer för biogas och naturgas i Sverige, Grontmij – för Svenska Gasföreningen, november 2009

⁷² Tredje inre marknads paketet för el och naturgas – Fortsatt europeisk harmonisering – betänkande av Nya el- och gasmarknadsutredningen, Statens offentliga utredningar, SOU 2010:30, 2010

⁷³ Phone conversation 2011-10-10. Sigvard Trönell (E on)

Figure 3.8 shows total emissions of CH₄ and CO₂ as CO₂ equivalents for the years 1990 - 2010.

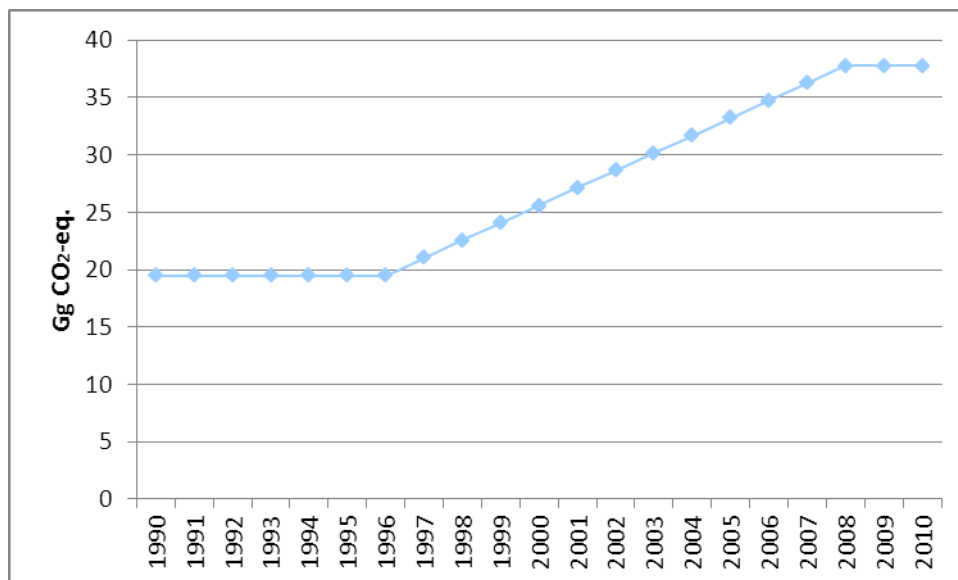


Figure 3.8 Total emissions of CH₄ and CO₂ as CO₂-equivalents reported in CRF 1.B.2.B.3.

3.3.2.2.7 Natural gas distribution, CRF 1.B.2.B.4

Sweden has estimated fugitive methane emissions from natural gas distribution in a manner consistent with the IPCC Good Practice Guidance. A default emission factor of 6.15×10^{-4} Gg per year and per kilometer of distribution mains has been used. The used emission factor is an average of the upper and lower default emission factors given in the IPCC Good Practice Guidance, Table 2.16.

The main extension phase of the Swedish natural gas distribution network ended in 1990. Since then there has been a reduced expansion in stages. Activity data as kilometer of distribution mains has been obtained only for 1996⁷⁰ (2,050 km) and for 2008^{71, 72} (2,600 km). For years before 1996 the pipeline length has been estimated to be of the same length as in 1996. For years between 1996 and 2008 the activity data has been estimated by interpolation. The network length in 2009 has been estimated to be 2610 km and in 2010 it has been estimated to 2,620 km. The latter estimates are based on information from one of the operators⁷³ of the distribution network saying that the network has been extended with approximately 20 km between the end of 2008 and the end of 2010. Since the operator could not estimate the extension per year the expansion has been estimated as 10 km per year.

Figure 3.9 shows total emissions of CH₄ and CO₂ as CO₂ equivalents for the years 1990 - 2010.

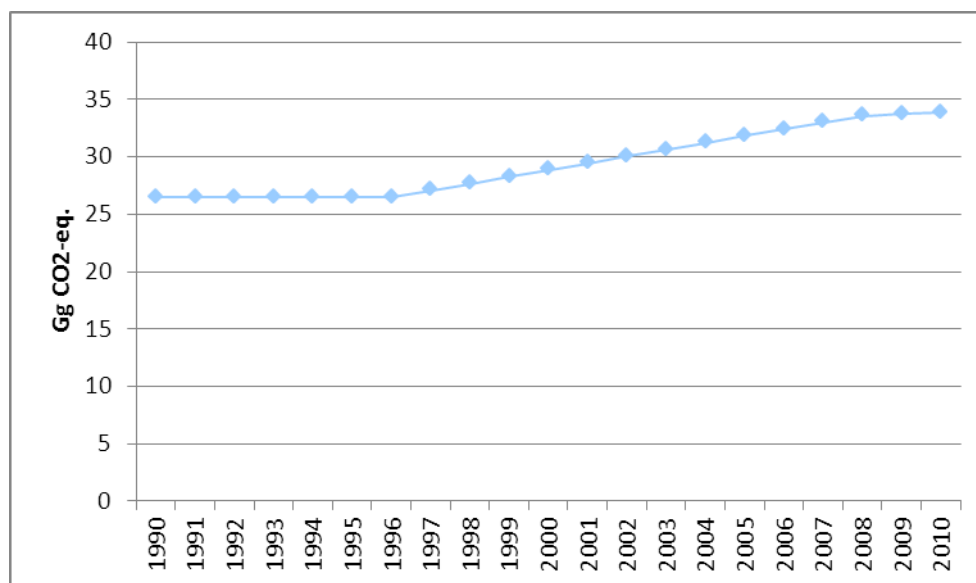


Figure 3.9 Total emissions of CH₄ and CO₂ as CO₂-equivalents reported in CRF 1.B.2.B.4.

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

In submission 2010, emissions from venting of oil were reported using the Tier 1 approach and default emissions factors from the 2000 Good Practice Guidance. For emissions of CH₄ and CO₂, the maximum values of the default EF are chosen to avoid any risk of underestimating the emissions. In submission 2011, an analysis was carried out⁷⁴ which indicated that the emissions from venting are most probably included in other categories of fugitive emissions; mainly in CRF 1.B.2.A.4 but possibly partly in 1.B.2.C.2. Hence, it was concluded that the emissions reported in 1.B.2.C.1. in submission 2010 were double counted, and in submission 2011 emissions from venting of oil are reported as IE (in 1.B.2.A.4 and 1.B.2.C.2.) Venting of natural gas or combined venting of oil and gas are presumed to be not occurring, however, if occurring, they are included in the emission data gathered from environmental reports as described in section 3.3.2.2.3.

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

Flaring of liquid fuels was estimated and reported for the first time in the Swedish inventory in submission 2005. Data includes flaring of refinery gases at four refineries and one chemical industry, and flaring of LPG at three iron and steel plants and one pulp industrial plant. Emissions in this CRF category varies quite widely between years due to large variations in the amount of refinery gases that needs to be flared each year. Data has been collected directly from the plant operators. For the years 2005 and later, data from the EU ETS system has been used when possi-

⁷⁴ Jerksjö 2011

ble. Data from the EU ETS system are verified against data from environmental reports and vice versa. In submission 2010 EU ETS data was analyzed carefully. It was concluded that the notation key for flaring of natural gas (NE in earlier submissions) could be changed, since no such flaring could be found in the EU ETS data and all plants that might be flaring are included in the EU ETS. There is a slight possibility that some flaring of natural gas is reported included in the flaring of liquid fuels. Because of this the notation key IE is used rather than NO, referring to emissions reported under CRF 1.B.2.C.2.1 Oil.

3.3.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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

3.3.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

3.3.2.5 SOURCE-SPECIFIC RECALCULATIONS

- The time series in CRF 1.B.2.A.4 for fugitive CH₄ emissions from refineries was revised in submission 2012. The emissions from one plant that refines about 50% of the crude oil in Sweden were before submission 2012 estimated as approximately 0.5 % of the total fugitive hydro carbon emissions. This estimate was based on information from the company. In submission 2012 the company was contacted again and their new estimate is that 5% of the total hydrocarbon emissions are CH₄. CH₄ emissions from this plant have been revised for the whole time series using this new percentage. Furthermore, fugitive CH₄ emissions from two other refineries from which the CH₄ emissions not have been estimated before submission 2012 were estimated also as 5% of the total hydro carbon emissions. For the remaining refineries in Sweden the CH₄ emissions are reported as in the facilities' environmental reports. The revision resulted in an increase of CH₄ emissions in CRF 1.B.2.A.4 of 106% (0.24 Gg) in 1990, 70% (0.18 Gg) in 2008 and 73% (0.19 Gg) in 2009, all compared to submission 2011. The emissions were probably underestimated in previous submissions and this revision aimed to improve the quality of the reported data, but the reported emissions are still considered to be very uncertain due to limited measurements.
- A new road emission model, HBEFA 3.1A, has been used in submission 2012 for calculating the distributed amounts of gasoline. The new model

uses a more sophisticated method to calibrate the modelled fuel consumption with the national fuel statistics and should therefore yield more realistic results. The model estimates around 10% lower amounts of used gasoline than the previous model. The revision resulted in a decrease of NMVOC emissions in CRF 1.B.2.A.5 of 7% (1.2 Gg) in 1990 and 5% (0.3 Gg) in 2008 and 2009, all compared to submission 2011.

- As described in section 3.2.11.2, year specific CO₂ emission factors for methane-rich gas mixtures used in the chemical industry have been developed in submission 2012. This also affects the emissions of CO₂ in CRF 1.B.2.c.2, as some of the gas is flared. Compared to submission 2011, the CO₂ emissions in CRF 1.B.2.c.2 increased with 4% in 2001 and decreased with between 2 and 8% each year 2002-2007.
- Fugitive CH₄ and CO₂ emissions from transmission of natural gas have been estimated by using the default method in the IPCC good practice guidance. The emissions of CH₄ were estimated by Sweden for the first time in the resubmission of 2011 and the CO₂ emissions in submission 2012. The trend shows increasing emissions from 1990 to 2010 and the emissions as CO₂ equivalents have been estimated to be 19 Gg in 1990 and 38 Gg in 2010.
- Fugitive CH₄ emissions from distribution of natural gas have been estimated by using the default method in the IPCC good practice guidance. The emissions were estimated by Sweden for the first time in the resubmission of 2011. The trend shows increasing emissions from 1990 to 2010 and the emissions as CO₂ equivalents have been estimated to be 26 Gg in 1990 and 34 Gg in 2010.

3.3.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4 Industrial processes (CRF sector 2)

4.1 Overview of sector

For Sweden the most important industries within the industrial sector has historically been base industries such as mining, iron and steel industry and pulp and paper industry. Other important industries when considering emissions of greenhouse gases from industrial processes include the cement industry, primary aluminium production, consumption of fluorinated greenhouse gases and some processes in the chemical industry.

Greenhouse gas emissions from the industrial processes sector have increased 511 Gg CO₂ equivalents from 6,330 Gg CO₂ equivalents in 1990 to 6,841 Gg CO₂ equivalents in 2009, an increase of 8.1% (

Figure 4.1). The trend is mainly affected by increased emissions of HFCs (+845 Gg CO₂ equivalents) and CO₂ (+417 Gg CO₂ equivalents), but also in decreased emissions of N₂O (-500 Gg CO₂ equivalents) and PFCs (-219 Gg). In

Figure 4.1 it can be seen that in 2010, CO₂ is by far the largest contributor among the greenhouse gases in this sector, accounting for 78% of the GHG emissions. Emissions of HFCs are the second largest greenhouse gas in 2010, accounting for 12.4% of the sector emissions.

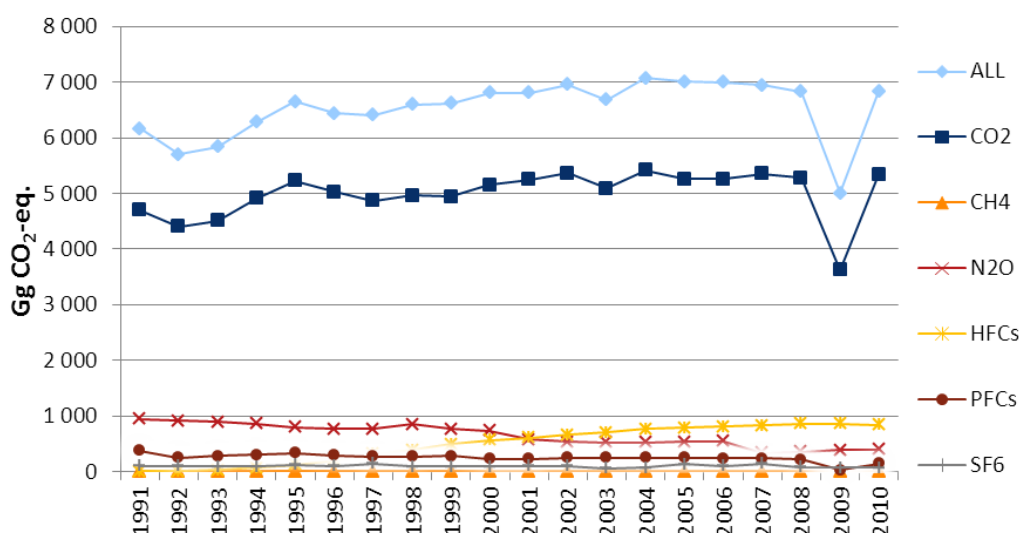


Figure 4.1. Total emissions of all greenhouse gases calculated as CO₂ equivalents from CRF 2 Industrial processes.

Among the industries in this sector, metal production (CRF 2.C) is the largest contributor in 2010, accounting for 3,326 Gg CO₂ equivalents or 48.6% (Figure 4.2). In Figure 4.2 it can be seen that there was a sharp decrease in greenhouse gas emissions from metal production (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 gases to this sector 2010 is mineral products (CRF 2.A) with 2,077 Gg CO₂ equivalents, or 30.4% of the sector emissions. Compared to 1990 there is an increase in greenhouse gas emissions from mineral products of about 20.6% (Figure 4.2), mainly due to increased production of lime and clinker.

For chemical industry (CRF 2.B), greenhouse gas emissions have decreased with 511 Gg CO₂ equivalents since 1990 and amounted to 458 Gg CO₂ equivalents in 2010. The reduction is closely linked to N₂O emissions from nitric acid production.

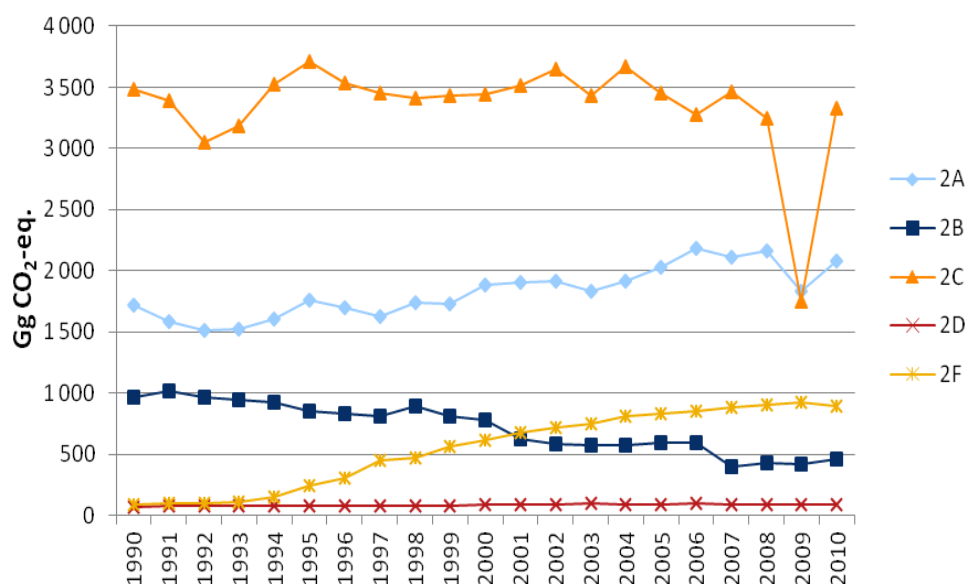


Figure 4.2. Total emissions of all greenhouse gases calculated as CO₂ equivalents from the different Industrial processes sub-sectors.

2A Mineral products. 2B Chemical industry. 2C Metal production. 2D Other production. 2F Consumption of Halocarbons and SF₆.

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. No production of halocarbons or SF₆ (CRF 2.E) occurs in Sweden. The consumption of fluorinated greenhouse gases (CRF 2.F) has increased substantially, 803 Gg CO₂ equivalents, 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.

Process emissions from pulp and paper in other production (CRF 2.D) do not contribute significantly to the emissions of greenhouse gases in Sweden. Table 4.1

shows the impact of recalculations reported in submission 2012 for GHG emissions by sector and sub-sectors for 1990, 1995, 2000 and 2005-2009. The recalculations are mainly due to new information on process-related CO₂ emissions, in the chemical industry, other (CRF 2.B.5) and revised information on estimations of fluorinated greenhouse gases (CRF 2.F). More detailed descriptions of the recalculations are found under sector specific sections below.

Table 4.1. Impact of recalculations of GHG emissions submission 2012 in the industrial processes sector.

Impact of recalculations submission 2012 (Gg CO ₂ eq.)							
CRF	2A	2B	2C	2D	2F	Total CRF 2	% CRF 2
1990	0	8	3	NA	0	12	0.2%
1995	NA	8	3	NA	6	17	0.3%
2000	0	22	3	NA	3	28	0.4%
2005	2	24	3	NA	-14	16	0.2%
2006	3	37	3	NA	-17	25	0.4%
2007	3	41	3	NA	-32	15	0.2%
2008	1	41	-2	NA	-45	-5	-0.1%
2009	0	43	1	NA	-65	-21	-0.4%

0: value less than 0.5. NA: no recalculation is performed.

4.2 Mineral products (CRF 2.A)

Reported emissions include estimates for cement production (2.A.1), lime production (2.A.2), limestone and dolomite use (2.A.3) soda ash use (2.A.4), asphalt roofing (2.A.5), road paving with asphalt (2.A.6), and other (2.A.7). In the source category other (2.A.7), glass production (2.A.7.1), non-iron ore mining and dressing plants, glass and mineral wool production, LECA production and production of roofing tiles, bricks and ceramics are included. Until 1998 also emissions from battery manufacturing are included in code 2.A.7.

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 kton. Emissions from cement production stem both from combustion of fuels and raw materials used in the processes. Emissions arising from fuel combustion are, with the exception of NO_x, reported in the energy sector (CRF 1.A.2.f). 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. Process related CH₄ and N₂O emissions from cement production are not occurring according to the IPCC Guidelines and thus reported as not applicable (NA).

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.2.

Table 4.2. Summary of source category description, CRF 2.A.1.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.A.1	CO ₂				T2	PS	Yes
	CH ₄				NA	NA	NA
	N ₂ O				NA	NA	NA

T2 Tier 2. PS Plant-specific.

4.2.1.2 METHODOLOGICAL ISSUES

In line with the Good Practice Guidance Tier 2 methodology, plant-specific CO₂ emission estimations in Sweden are based on clinker production and include emissions from by-pass dust and cement kiln dust (CKD) as well as emissions from organic carbon of raw meal.

For 1990-2004, information from the company on CO₂ emissions is based on clinker production and default EF from GHG protocol, CKD correction factor and organic carbon in raw meal.

CO₂ = Production of cement clinker (Gg) * 0.525 (Gg CO₂/ Gg clinker, i.e. default value in the GHG-protocol) * CKD correction factor+ CO₂ 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 website⁷⁵. 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.

Facts about the GHG protocol

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

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

The protocol for CO₂ emissions from the production of cement (WBCSD CSI, version 2.0) can be found on: <http://www.ghgprotocol.org>

⁷⁵ <http://www.ghgprotocol.org>. 2005-10-20.

From 2005, the company reports plant-specific data on CO₂ emissions to the EU ETS. The CO₂ emissions are based on production of clinker and CaO content of clinker, but also include CO₂ contained in released non-recycled dust (CKD and by-pass) as prescribed by the national guidelines for reporting to the EU ETS⁷⁶. In addition, CO₂ emissions from organic carbon of raw meal are estimated using information from the company for 2004.

Table 4.3 shows information on clinker production, total CO₂ emissions from clinker production, for year prior to 2005 the calculated emissions from CKD and the resulting CKD correction factor, and CO₂ emission from organic carbon content of raw meal.

Table 4.3. Amount of produced clinker and associated CO₂ from specific sources.

Year	Clinker Production	Total CO ₂ emissions	CO ₂ from Clinker (from 2005 incl. CKD)	CO ₂ from CKD	CKD correction factor	CO ₂ from organic carbon content of raw meal
	Gg	Gg	Gg	Gg		Gg
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	1 341	1 313	IE	NA	28
2006	2 660	1 470	1 439	IE	NA	30
2007	2 493	1 365	1 337	IE	NA	28
2008	2 644	1 425	1 395	IE	NA	30
2009	2 305	1 287	1 260	IE	NA	26
2010	2 454	1 350	1 322	IE	NA	28

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. They include emissions from fuel combustion as well as from industrial processes. Due to the use of a large variety (within and between years) of waste fuels there is a lack of correct emission factors for the energy sector (1.A.2.f), and thus all emissions are reported in this source category as process emissions. Reported emissions are decreasing over time since 1990.

Data on SO₂ emissions from cement production has been obtained directly from the company or from the environmental reports. Reported emissions are decreasing over time since 1990.

⁷⁶ Lyberg, A., Cements, Personal communication, September 2011

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 $\pm 2\%$ and the uncertainty of the emission factor for CO₂ is judged to be $\pm 5\%$.

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 Gg CO₂/Gg clinker produced) is used together with CKD correction factor and CO₂ emissions from organic carbon of raw meal. Since 2005, CO₂ emissions are taken from EU ETS (including CKD) and CO₂ emissions from organic carbon of raw meal are added. This means that different methods are used over time. In Figure 4.3 it can be seen that CO₂ IEF for total emissions from clinker production show larger variations after the introduction of EU ETS data as data source.

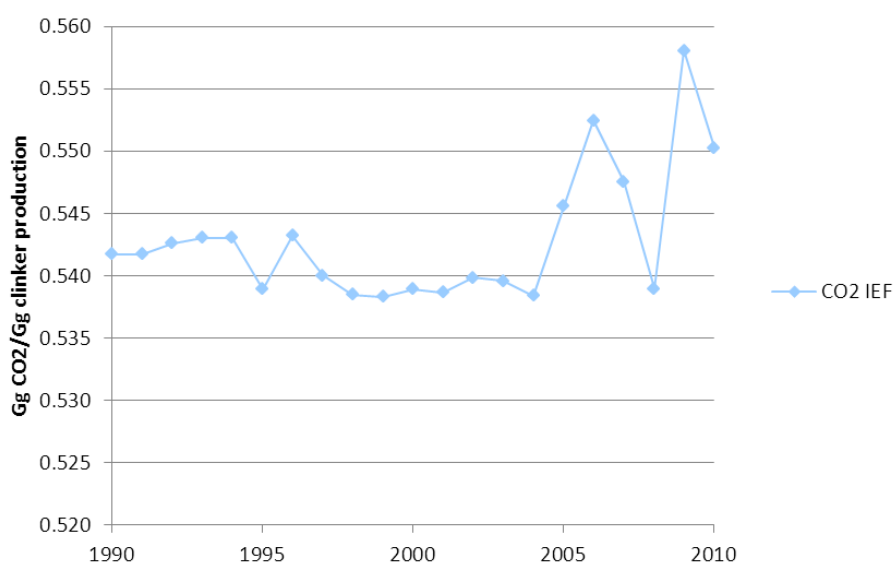


Figure 4.3. CO₂ IEF for total emissions from clinker production 1990-2010

4.2.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

In response to previous review recommendations, discussions with the cement producers have been finalized and it has been concluded that CO₂ emissions from dust are included in the estimations for the whole time-series (see methodological issues above). In Table 4.3 above information on clinker production, emissions from production, the calculated emissions from CKD and the resulting CKD correction factor are presented. Compared to the 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 are low or nearly non-existent.

Moreover, the implied emission factor for total CO₂ emissions 2005-2010 (average 0.5428 Gg CO₂/Gg clinker produced) is somewhat higher than the IPCC

Guidelines default value (0.5071 Gg CO₂/Gg produced clinker) and among the highest of the reporting Parties of the Convention. This is due to higher CaO content in clinker (data for 2008 and 2009 shows a variation in CaO content between 63.9 to 67.6%) compared to IPCC Guidelines default value (64.6%), but also because emissions from the organic carbon content of raw meal and CKD are included in the Swedish estimates whereas these sources are not included in the IPCC Guidelines default value.

To follow the Good Practice Guidance Tier 2 method, information shall also include the CaO content of the clinker and data on non-carbonate feeds to kilns. The cement production company reports the CaO content of the clinker to be approximately 65 %.

4.2.1.5 SOURCE-SPECIFIC RECALCULATIONS

In the previous submission, CO₂ emissions from the use of limestone for flue gas purification in one energy industry plant 2009 were double counted, i.e. reported in this source category as well as in CRF 2A3. In this submission, those emissions have been correctly deleted from this source category. Due to this recalculation emissions in 2009 were reduced with 2.8 Gg CO₂.

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 dolomite 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 steadily since 1990 from about 400 Gg to about 700 Gg in 2010. In 2009 there was a large decrease in lime production due to an economic recession in the EU. CO₂ is emitted during lime production through calcination of the calcium carbonate (CaCO₃) in limestone, or through the decomposition of dolomite (CaCO₃·MgCO₃). Process related CH₄ and N₂O are not emitted during lime production and thus report 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.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.A.2	CO ₂				D	D	Yes
	CH ₄				NA	NA	NA
	N ₂ O				NA	NA	NA

D Default.

4.2.2.2 METHODOLOGICAL ISSUES

4.2.2.2.1 CO₂ (Gg)

The emissions of CO₂ from the production of lime are based on activity data by type of lime, i.e. on produced amounts of quicklime, hydraulic lime and dolomitic lime, and corresponding EFs and purity of the limestone from the 2006 IPCC Guidelines. As CO₂ emissions also depend on the production process, the methods for collecting activity data and estimating CO₂ emissions are described by data source (i.e. the sugar industry, the pulp and paper industry and other production of lime) below.

4.2.2.2.1.1 Sugar industry

For determining activity data and emissions of CO₂ within the sugar industry, the amounts of limestone for the production of quicklime are used. The quantities are obtained directly from the sugar producing company 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% of CaCO₃.

In the production of sugar, lime is used for purification of the juice. Lime is added to the raw juice and some impurities are precipitated. In the carbonisation step CO₂ is bubbled through the juice and most of the remaining lime is precipitated as CaCO₃. The precipitated “limestone” is sold and used within agricultural activities. Information from the company gives that around 88% of the lime used was precipitated as CaCO₃. For later years this share has increased and in 2009 more than 94% of the lime used is precipitated to CaCO₃.

In earlier submissions the whole amount of lime produced and used within the sugar industry was reported as activity data without taking into account that a large amount of the produced lime is precipitated as CaCO₃ in the carbonation process. Since submission 2010, only the part of CaO which is not recovered as CaCO₃ is reported as activity data.

In Table 4.5 the used amounts of limestone, the amounts of produced lime and emitted CO₂, the precipitated CaCO₃, and the reported activity data and CO₂ emissions from lime production within the sugar industry is presented.

Table 4.5. Limestone used, amount of produced lime and emitted CO₂, precipitated CaCO₃ and reported activity data and CO₂ emissions from lime production within the sugar industry

Year	Used amounts of lime-stone	Amount of lime produced	CO ₂ from lime production	Precipitated share of lime	Precipitated amount of lime	Reported Activity Data (lime)	Reported CO ₂ emissions
	Gg	Gg	Gg	%	Gg	Gg	Gg
1990	94.7	51.4	40.4	87.5%	45.0	6.4	5.0
1995	76.4	41.5	32.6	87.5%	36.3	5.2	4.1
2000	70.0	38.0	29.9	87.5%	33.3	4.8	3.7
2005	60.9	33.1	26.0	92.0%	30.4	2.6	2.1
2006	68.1	37.0	29.1	92.0%	34.0	3.0	2.3
2007	48.6	26.4	20.7	91.3%	24.1	2.3	1.8
2008	57.3	31.1	24.4	94.4%	29.4	1.7	1.4
2009	55.8	30.3	23.8	94.1%	28.5	1.8	1.4
2010	43.3	23.5	18.5	94.1%	22.1	1.4	1.1

4.2.2.2.1.2 Pulp and paper industry

In response to previous review recommendations, since the 2011 submission, detailed data on the quantities of lime used as make-up lime in the pulp and paper industry, and quantities of limestone and dolomite used for production of make-up lime, have been obtained from the Swedish Lime Association and The Swedish Lime Industry from 1995⁷⁷.

Based on 2006 IPCC Guidelines, the purity of the limestone is set to 95% for the production of lime within the pulp and paper industry. The corresponding figure for dolomite is 100%. For the years before 1995, the amounts of make-up lime consumed are estimated using the average ratio between the quantity of make-up lime used and kraft pulp produced for the period 1995 – 2009 and corresponding production data for 1990 – 1994. Earlier information on the need for make-up lime has indicated that it would be less than 20 kg per Mg pulp. New information from a small number of Swedish pulp and paper industries shows that the need may vary considerably, from less than 10 kg per Mg to over 30 kg per Mg⁷⁸. The data used in submission 2011 gives an average need (1995 – 2008) of 20 kg make-up lime per Mg kraft pulp (Table 4.6) and can therefore be considered reliable to use to estimate the need for make-up lime to the pulp industry for years before the 1995. Similarly, the amount of CO₂ emitted is estimated for 1990 – 1994 by using the average ratio between emitted CO₂ and used amounts of make-up lime for the period 1995 – 2008. The used amount of Make-up lime was very low in 2009 which led to a reduced amount of emitted CO₂ in 2009 compared to previous years.

⁷⁷ Swedish Lime Association and The Swedish Lime Industry, Svenska Kalkföreningen, personal communication

⁷⁸ Håkan Sbtripple, IVL Swedish Environmental research Institute, personal communication

Table 4.6. Produced amounts of kraft pulp, IEF (Make-up lime used per produced amounts of kraft pulp), IEF (CO₂ emitted per produced make-up lime) and reported activity data and CO₂ emissions from make-up lime production for the pulp and paper industry

Year	Produced amounts of kraft pulp	Reported Activity Data (Make-up lime)	IEF (Make-up lime/kraft pulp)	Reported CO ₂ emissions	IEF (CO ₂ /Make-up lime)
	Gg	Gg	Gg/Gg	Gg	Gg/Gg
1990	5 944	118.7*	0.020**	88.5*	0.7457**
1995	6 377	119.4	0.019	89.0	0.7458
2000	7 557	138.1	0.018	103.0	0.7457
2005	7 784	172.0	0.022	128.3	0.7456
2006	7 828	156.5	0.020	116.7	0.7455
2007	7 835	188.6	0.024	140.7	0.7457
2008	7 635	164.7	0.022	122.8	0.7458
2009	7 299	116.9	0.016	87.2	0.7458
2010	7 462	169.4	0.023	126.4	0.7458

* estimated

** average ratio for 1995 – 2009

4.2.2.2.1.3 Other production of lime

For all other production of quicklime, hydraulic lime and dolomite (mainly used in iron and steel production), detailed data from 1990 are obtained from the Swedish Lime Association⁷⁹. To avoid double counting of emissions, activity data for produced quicklime, hydraulic lime and dolomite 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%. The produced amounts of quick lime and dolomitic lime in conventional lime mills was very low in 2009 which led to a reduced amount of emitted CO₂ in 2009 compared to previous years.

⁷⁹ Swedish Lime Association, Svenska Kalkföreningen, personal communication

Table 4.7. Produced amounts of quick lime and dolomitic lime, emitted CO₂ and IEF (CO₂ emitted per produced quick lime and dolomitic lime) in conventional lime mills.

Year	Reported Activity Data (quick lime and dolomitic lime, excluding lime in sugar and pulp industry)	Reported CO ₂ emissions (excluding emissions in sugar and pulp industry)	IEF (CO ₂ /quick lime + dolo- mitic lime)
	Gg	Gg	Gg/Gg
1990	264.3	201.1	0.7609
1995	258.4	196.4	0.7599
2000	403.9	306.0	0.7576
2005	495.6	375.6	0.7578
2006	543.7	412.1	0.7581
2007	530.5	402.6	0.7590
2008	541.4	409.6	0.7566
2009	400.6	301.6	0.7528
2010	529.6	398.6	0.7527

4.2.2.2.2 SO₂ (Gg)

The emissions of SO₂ from 1990 have been estimated for production of quick lime. The estimations from quick lime production were calculated using emission factors presented in environmental reports by one of the producers⁸⁰. The emission factor provided by the lime producer is substantially higher for 2008 and 2009 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.

Emissions of SO₂ from quick lime production intended for the pulp and paper industry are not included in the estimates reported in CRF 2.A.2.

4.2.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty for activity data is ± 2% and the uncertainty of the emission factor for CO₂ is ± 5%. The time-series are considered accurate, consistent and complete.

4.2.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The activity data reported in 2.A.2 have been compared with national statistics from Statistics Sweden in line with the Good Practice Guidance Tier 2⁸¹.

The comparison (Figure 4.4) shows that national statistics are more irregular but for most years the coherence is good. The differences are especially high in 1998, 1999 and from 2003 and onwards. The national statistics are based on national surveys mainly aiming at collecting data for economic statistics. In these surveys not all facilities are included and for those the produced amounts are estimated, which might lead to over- or underestimations of, in this case, produced

⁸⁰ Nordkalk, <http://www.nordkalk.com>

⁸¹ Statistics Sweden. Data from the Industrial production database: www.scb.se

amounts of lime. That 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 Industry⁸² is used as data source.

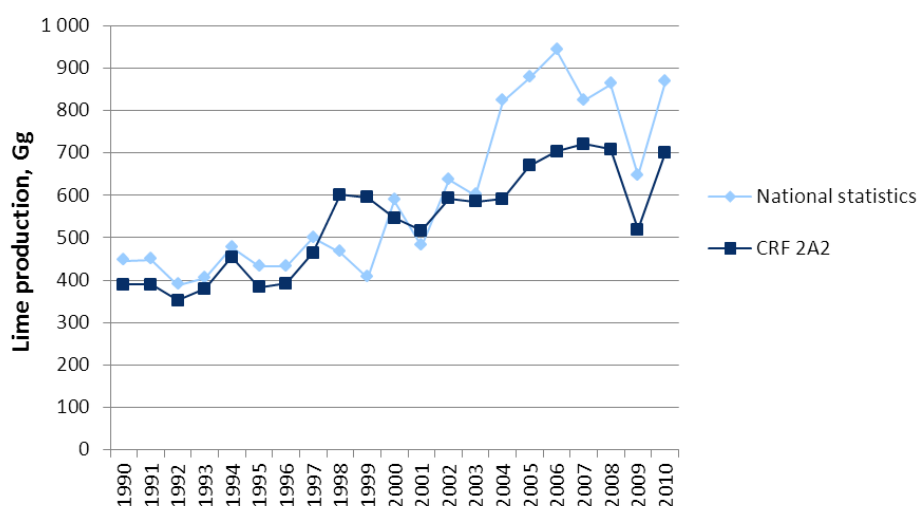


Figure 4.4. National total on produced amount of lime according to data from Statistics Sweden and reported data in CRF 2.A.2.

Quick lime is also produced and used within carbide production. According to the IPCC Guidelines, CO₂ emissions arising from this lime should be reported under CRF 2B4, together with other CO₂ emissions from carbide production. It is not known whether this lime is included in the national statistics in Figure 4.4, but it is most likely not.

4.2.2.5 SOURCE-SPECIFIC RECALCULATIONS

Emissions of CO₂ have been recalculated 1990-1994 and 2000-2007 due to a minor error in the previous calculations, resulting in increased emissions up to 0.1 Gg.

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

4.2.3.1 SOURCE CATEGORY DESCRIPTION

Limestone and dolomite are used in various processes in Sweden such as cement production, lime production, carbide production, iron sinter production (further described in 2.C.1.3), steel and other metal production, production of clay-based products, glass wool and mineral wool production, glass production, flue gas purification in energy industries and production of chemical products. The use of lime-

⁸² Swedish Lime Association and The Swedish Lime Industry, Svenska Kalkföreningen, personal communication

stone and dolomite in these processes gives rise to emissions of CO₂. However, not all CO₂ emissions from the use of limestone and dolomite are reported in this source category (see methodological issues below). Process-related CH₄ and N₂O are not emitted during limestone and dolomite use and thus reported as not applicable (NA). The largest contributor of CO₂ emissions in this source category is the iron sinter production. Three facilities (owned by one company) in the north of Sweden produce iron sinter. The use of dolomite in iron sinter production is on average about 80-120 Gg, while the use of limestone was introduced 1999 and has since increased over time to reach the highest use of about 100 Gg in 2010.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.8.

Table 4.8. Summary of source category description, CRF 2.A.3.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.A.3	CO ₂				CS	D	Yes
	CH ₄				NA	NA	NA
	N ₂ O				NA	NA	NA

D Default. CS Country Specific

4.2.3.2 METHODOLOGICAL ISSUES

This source category comprises of activity data, CO₂ emissions from the use of limestone and dolomite within facilities producing iron sinter, glass wool and mineral wool, chemical products, but also use of limestone and dolomite for flue gas purification in energy industries.

CO₂ emissions from the use of limestone and dolomite in the production of cement (2.A.1), lime (2.A.2) and carbide (2.B.4) are reported in corresponding CRF source categories in accordance with the IPCC Guidelines. According to the IPCC Guidelines, all other emissions of CO₂ from the use of limestone and dolomite should be reported as process emissions from limestone and dolomite use in CRF 2.A.3. Since the Centralized review of submission 2004 the ERT has repeatedly recommended Sweden to follow the guidelines. Since the CO₂ emissions from limestone and dolomite are small in some source categories it is not considered to be good practice to spend resources obtaining underlying data to separate these emissions.

Sweden has chosen to not include in 2.A.3 (but in corresponding categories):

- CO₂ emissions from the use of limestone and dolomite in primary and secondary production of steel (2.C.1.1, 2.C.1.2),
- CO₂ emissions from the use of limestone and dolomite in other metal production (2.C.5),
- CO₂ emissions from the use of limestone and dolomite in production of clay based products (2.A.7) and

- CO₂ emissions from the use of limestone and dolomite in glass production (2.A.7.1).

In the case of limestone and dolomite use within the production of glass, the reallocation of CO₂ emissions from 2.A.3 to 2.A.7.1 is due to recommendations from the EC (European Commission) Internal review in 2009. Emissions of CO₂ from use of limestone and dolomite for the production of clay based products are reported in 2.A.7. This is due to the fact that emissions originating from the use of limestone and dolomite seldom are separately reported in the ETS, but rather reported together with other carbon containing raw materials.

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. The calculations are made by applying the IPCC Guidelines default emission factors for limestone and dolomite⁸³.

Formulas for CO₂ emissions from limestone and dolomite:

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

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

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

In Table 4.9 the use of limestone and dolomite, and corresponding CO₂ emissions, for glass production (2A7.1), primary (2C1.2) iron and steel production and other metal production (2.C.5) are presented for 2005-2010. In relation to the amounts reported in 2.A.3 (Table 4.10), the yearly amounts not included in 2.A.3 represents around 35% of the total use of limestone and dolomite in Sweden 2005 – 2010.

⁸³ IPCC. Revised 1996 Guidelines for National Greenhouse Gas Inventories: Reference Manual section 2.5.2

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

Year	2A7.1		2A7-clay based products		2C1.1		2C1.2		2C5	
	AD, Gg	CO ₂ , Gg	AD, Gg	CO ₂ , Gg	AD, Gg	CO ₂ , Gg	AD, Gg	CO ₂ , Gg	AD, Gg	CO ₂ , Gg
2005	68	31.7	*	*	*	*	84	36.1	5	2.1
2006	73	33.7	*	*	*	*	84	36.1	4	1.8
2007	72	33.6	*	*	*	*	72	30.9	5	2.3
2008	73	33.7	*	*	*	*	89	38.1	4	1.8
2009	55	25.5	*	*	*	*	57	24.5	4	1.7
2010	66	30.8	*	*	*	*	67	28.6	6	2.5

* not possible to separate CO₂ from limestone/dolomite for included facilities

Table 4.10. Used amounts of limestone and dolomite and corresponding CO₂ emissions reported i 2A3.

	Total 2A3 Activity data (limestone and dolomite)	Total 2A3 CO ₂	CO ₂ Iron sinter production	CO ₂ Energy industries (flue gas desulphurisation)	CO ₂ Other mineral products (glass wool and mineral wool)	CO ₂ Other chemical industry
	Gg	Gg	%	%	%	%
1990	194	90.4	42.2	11.5	26.1	20.1
1995	214	100.2	54.1	14.2	17.9	13.8
2000	245	113.3	67.4	9.5	15.1	8.0
2005	248	115.8	70.3	15.6	9.6	4.5
2006	235	109.2	65.0	18.4	10.9	5.7
2007	261	121.7	70.2	14.8	9.8	5.1
2008	284	130.7	73.8	11.5	10.0	4.7
2009	223	104.4	70.0	13.7	9.3	6.9
2010	294	135.1	75.4	10.4	9.2	5.0

The emissions have increased during the reporting period due to higher limestone and dolomite use in the production of ore-based iron pellets. This increase is however softened by a decrease in the use within the mineral and glass wool industry and the chemical industry. Decreased emissions from the glass wool industry are partly due to an increased use of recycled materials and thereby less need for limestone and dolomite for raw glass wool production. During 2009 the used amounts of limestone and dolomite was lower compared to previous year due to the economic recession.

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

4.2.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty for activity data is $\pm 7\%$ and the uncertainty of the emission factor for CO₂ is $\pm 5\%$. The time series are considered accurate, consistent and complete. It is however possible that there are small facilities using (insignificant amounts of) limestone and dolomite which perhaps are not included in the Swedish inventory.

4.2.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed. For facilities part of the EU ETS, data on CO₂ emissions should however be used for verification of calculated CO₂ emissions using the IPCC default values.

4.2.3.5 SOURCE-SPECIFIC RECALCULATIONS

CO₂ emissions from flue gas purification in one facility have been added from 2005 due to information from the EU ETS. The flue gas purification in this facility was probably introduced in 1999-2000, but no information has been acquired to confirm this. The recalculation resulted in an increase in CO₂ emissions of about 1-3 Gg.

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 Soda ash use (CRF 2.A.4)

4.2.4.1 SOURCE CATEGORY DESCRIPTION

Soda ash is used in the production of glass wool, moist snuff and chemicals i.e. detergents, and until 2004 also in flue gas desulphurisation at energy plants. Soda ash is also used in production of glass (2A7.1). Soda ash is not produced in Sweden. The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.11.

Table 4.11. Summary of source category description, CRF 2.A.4.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.A.4	CO ₂				CS	D	Yes
	CH ₄				NA	NA	NA
	N ₂ O				NA	NA	NA

D Default. CS Country Specific

4.2.4.2 METHODOLOGICAL ISSUES

In 2004 a study was carried out to collect data on soda ash use and calculate CO₂ emissions.⁸⁴ From this study it became clear that no production of soda ash occur

⁸⁴ Nyström. 2004. SMED-report: CO₂ from the use of soda ash.

in Sweden, and is hence reported as NO in the CRF. Activity data consists of soda ash use from ten plants within several areas:

- production of glass wool, moist snuff and chemicals
- until 2004, in flue gas desulphurisation at energy plants

As for the use of limestone and dolomite, the emissions and activity data concerning use of soda ash within the glass industries have been reallocated to 2.A.7.1 due to recommendations from the EC Internal review in 2009. This reallocation reduces the reported CO₂ emissions by approximately 50% in the early 1990s and by over 90% for the last years. The reason for the large effect on reported emissions in later years is due to large changes in the use of soda ash in one chemical industry. This industry spent during the early 1990s considerable amounts of soda ash, and has since 1997 sharply reduced their consumption. In the beginning of the new millennium the soda ash used for manufacturing at this industry is bound in products, and thus no CO₂ is emitted.

Activity data for the use of soda within water treatment and moist snuff production, by others than the dominant manufacturer, has been estimated based on information from expert organisations⁸⁵ and the dominant snuff manufacturer. The emissions are calculated by applying the IPCC Guidelines default emission factors for soda ash for all activity data:

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

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

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

4.2.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty for activity data is $\pm 7\%$ and the uncertainty of the emission factor for CO₂ is $\pm 5\%$. The time series is consistent and complete for the major plants, but it has to be noted that some facilities using small amounts of soda ash might be missing in the inventory.

4.2.4.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.2.4.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

⁸⁵ The Swedish Chemicals Agency (KemI), www.kemi.se

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.

4.2.5 Asphalt roofing (CRF 2.A.5)

4.2.5.1 SOURCE CATEGORY DESCRIPTION

Since the end of the 1990's there have only been two companies in Sweden producing asphalt-saturated felt. Production and emission data provided by the manufacturers have been used for developing emission factors for estimations of the NMVOC emissions. No measurements or estimations on CO emissions have been performed by the industry and are consequently reported NE, not estimated, for the whole time-series. The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.12.

Table 4.12. Summary of source category description, CRF 2.A.5.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.A.5	CO ₂				NA	NA	NA

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

4.2.5.2 METHODOLOGICAL ISSUES

Data on the total Swedish production of asphalt-saturated felt was provided by the producing companies. Emission factors for asphalt roofing manufacture are presented in EMEP/CORINAIR Emission Inventory Guidebook.⁸⁶ These are based on studies performed during the 1970s in the USA and presented by EPA.⁸⁷ As stated in the guidebook, the level of uncertainty regarding the suggested emission factors is high, and it is recommended that better factors should be developed and used.

After contact with the industry, emission factors based on measurements and calculations made by the manufacturers were developed before submission 2005 for estimating the NMVOC emissions from the Swedish production of asphalt-saturated felt (Table 4.13)⁸⁸.

⁸⁶ EMEP/CORINAIR Emission Inventory Guidebook: <http://reports.eea.eu.int/EMEP/CORINAIR4/en>

⁸⁷ 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.

⁸⁸ Danielsson, H. 2004. SMED report: Investigation on the occurrence of emissions from asphalt roofing in Sweden.

Table 4.13. Estimated emissions of NMVOC from manufacturing of asphalt-saturated felt (CRF 2A5) in Sweden 1990 – 2010.

Year	NMVOC emissions from asphalt roofing, 2A5 Mg
1990	77.7
1995	98.6
2000	111.1
2001	112.9
2002	109.2
2003	101.1
2004	113.7
2005	139.7
2006	132.7
2007	142.4
2008	138.6
2009	103.1
2010	105.4

The NMVOC emissions from the production of asphalt-saturated felt originate from the felt saturation and coating processes and from leakage from the asphalt storage tanks, the latter being the dominating source. For the calculation of the NMVOC emissions, separate emission factors were used, 0.068 kg/Mg and 1.56 kg/Mg, respectively. The emission factors are based on measurements/estimations from 2003 and 1997. Previously reported notation keys for activity data have been changed from NE to C.

4.2.5.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The time-series are consistent

4.2.5.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.2.5.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.2.5.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

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

4.2.6.1 SOURCE CATEGORY DESCRIPTION

Large changes have occurred in asphalt paving technology over the last decade, with a gradual change towards use of water-based emulsions instead of solvent-containing bitumen solutions. Industry representatives estimated that the naphtha content in the solutions used for road paving was on average 23 % in 2002 and 33

% in 2010. In this inventory, only NMVOC emitted in the process of paving the roads is included. The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.14.

Table 4.14. Summary of source category description, CRF 2.A.6.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.A.6	CO ₂				NA	NA	NA

4.2.6.2 METHODOLOGICAL ISSUES

Estimates for the early 1990s are taken from investigations and inventories made in the early 1990s. Data for the years 2002 – 2010 has been calculated based on information from the asphalt producers on the average amount of solvent (naphtha) in the mixtures used for road paving. The producers have also provided figures on the total amount of road paving mixtures delivered in Sweden. It is assumed that all solvents in the solvent-based bitumen are emitted when used. Emissions of NMVOC reported for the years in mid- and late 1990s were interpolated (Table 4.15). In the calculations no emissions from imported solvent-based bitumen are used. The amount of imported solvent-based bitumen is most likely very small. In 2005 the emission of NMVOC was very high due to the fact that a heavy storm ruined many roads in southern Sweden. These roads needed to be restored quickly and solvent-based bitumen was used for this purpose.

Table 4.15. Emissions of NMVOC 1990–2010 from road paving with asphalt.

Year	NMVOC from road paving with asphalt Mg
1990	6 200
1995	3 800
2000	1 170
2005	1 230
2006	750
2007	935
2008	855
2009	341
2010	256

4.2.6.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The time-series is consistent.

4.2.6.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.2.6.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.2.6.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.2.7 Other (CRF 2.A.7)

4.2.7.1 SOURCE CATEGORY DESCRIPTION

Specified sub-categories under this heading are “Glass production (2.A.7.1)”, “Non-Iron ore mining and dressing”, “Glass and mineral wool production”, “Battery manufacture” and “Light expanded clay aggregate (LECA), roofing tile, brick, and ceramics production”. The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.16.

Table 4.16. Summary of source category description, CRF 2.A.7.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.A.7	CO ₂				CS	CS, D	No, see Annex 5
	CH ₄				NA	NA	NA
	N ₂ O				NA	NA	NA

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

4.2.7.1.1 Glass production, CRF 2.A.7.1

In Sweden there is one facility for float glass production, one for container glass and several small facilities for manual glass production. Emissions of CO₂ from the use of limestone and soda ash in glass production are from submission 2010 and onwards reported in 2.A.7.1. In earlier submissions CO₂ from the use of limestone and of soda ash in glass productions were reported under 2.A.3 and 2.A.4, respectively. From the float glass production, the total emissions of SO₂ and NO_x from the glass furnace are allocated to 2.A.7.1 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).

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

The only emissions reported for the non-iron ore mining and dressing are, in this submission, NO_x released from use of explosives. Also CO is emitted but no data concerning the CO emissions are available and the time series 1990 – 2010 is thus reported NE. Estimated emissions from combustion of fuels are included in the Energy sector (CRF 1).

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

Glass and mineral wool production occurs at three facilities run by two companies. Before 2004 there were four facilities but one closed down during 2003.

4.2.7.1.4 *Battery manufacturing, CRF 2.A.7*

One battery producer of NiCd-batteries previously used iso-propanol in their processes, which gave rise to emissions of NMVOC. The process was changed in 1998 and, since then, no NMVOC emissions occur from this source.

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

In this sub-code under 2.A.7 Sweden report 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 totally six facilities the years 1990-2008 and from totally five facilities from 2009 and onwards since one facility closed down during 2008. One of the facilities is dominating in CO₂ emissions. All CO₂ emissions from raw material used are reported in 2.A.7.

4.2.7.2 METHODOLOGICAL ISSUES

Specified sub-categories under this heading are, "Non-Iron ore mining and dressing", "Glass and mineral wool production", "Glass production", "Battery manufacture" and "Light expanded clay aggregate (LECA), roofing tile, brick, and ceramics production".

4.2.7.2.1 *Glass production, CRF 2.A.7.1*

Emissions of CO₂ from the use of limestone and from the use of soda ash in glass production are reported in CRF 2.A.7.1 together with CO₂ emissions from other carbon containing raw material. Of the reported total CO₂ emissions in 2.A.7.1, approximately 44% is caused by the use of soda ash and 55% 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 Gg 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 Gg, yearly.

The process-related SO₂ emissions from container and float glass production are reported for the period 1990 – 2010 in CRF 2.A.7. The reported NO_x emissions originate from the production of float glass. Data has been provided directly by the companies or collected from their environmental reports.

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

Data on NO_x emissions from use of explosives within the non-iron ore mining industry are reported 2002 – 2010, but for the years 1990 – 2001 no information is presently available. Data on NO_x emissions are collected from the companies' environmental reports to the authorities.

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

Within mineral wool production, the limestone and dolomite used cause process emissions of CO₂ which are allocated to CRF 2.A.3 according to the IPCC Guidelines. For some years however (1990-1995 and 1998-1999), blast furnace slag was used in the process causing CO₂ emissions as well. These emissions are reported in CRF 2.A.7. Activity data on the slag consumption has been obtained for the mentioned years from the mineral wool producers. The emission factor is 0.04 Gg CO₂ /Gg slag based on that the slag contains 1 % carbon and the CO₂ emissions are calculated by using the formula:

$$\text{Emissions of CO}_2 \text{ (Mg) from use of slag} = \text{Slag (Mg)} * 0.01 * (\text{C content}) * 44/12$$

For glass and mineral wool production, the time series of NMVOC emissions is based on data received from the companies directly or as reported in environmental reports together with earlier total estimates. The emissions of NMVOC consist of formaldehyde and phenol.

4.2.7.2.4 *Battery manufacture, 2.A.7*

NMVOC emissions from battery manufacture for the period 1990-1998 are compiled from data presented in the companies' environmental reports. The process has changed and no emissions of NMVOC occur after 1998.

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

Activity and emissions data for LECA production 1990 - 2004 is retrieved directly from the production plant, split into emissions from clay and emissions from additives (limestone and other carbon containing material). From 2005 and onwards, the equivalent data is acquired through the ETS and the Swedish LECA producer's annual report.

For roofing tile, brick and ceramics production, activity and emission data from 2005 and onwards is acquired through the ETS. The data in the ETS does not always separate between emissions from limestone/dolomite use and CO₂ emissions from other carbon containing raw material (i.e. from the clay and other carbonates used) needed for the production. In order to as far as possible report an accurate

total process-related CO₂ emission for the facilities included in this 2.A.7 sub-code, Sweden have chosen to report all CO₂ emissions in 2.A.7.

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

As activity data reported in this 2.A.7 sub-code produced amounts of LECA is reported due to lack of activity data for remaining facilities. The implied emission factor may vary somewhat from one year to another because of the specific composition of limestone, clay and additives with different carbon contents. In 2007, the C-content in one of the additives for LECA production was unusually high which has resulted in comparatively high CO₂-emissions for that year. The use of limestone and other additives in LECA production has declined in favour of clay which today contributes to about 88 % of all process related CO₂ emissions from LECA production. The facility producing LECA corresponds to around 75% of yearly reported CO₂ emissions in this 2.A.7 sub-code.

4.2.7.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainties of the direct CO₂ emissions in 2A7 are considered to be $\pm 7\%$ based on expert judgements.

4.2.7.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.2.7.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.2.7.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.3 Chemical industry (CRF 2.B)

Sources covered in the reporting are nitric acid production (2.B.2), carbide production (2B4) and other (2B5), which include a large variety of processes in the chemical industry. No ammonia production (2.B.1) or adipic acid production (2B3) occurs in Sweden.

4.3.1 Ammonia production (CRF 2.B.1)

4.3.1.1 SOURCE CATEGORY DESCRIPTION

There is an annual production of about 5 Gg of ammonia in Sweden, according to United Nation statistics⁸⁹. This ammonia is however not intentionally produced, but is a by-product in one chemical industry producing various chelates and chelat-

⁸⁹ UN. Commodity Production Statistica Database. Department of Economic and Social Affairs, Statistics Division,. As referred in FCCC Synthesis and Assessment report 2002 Part I.

ing agents, such as EDTA, DTPA and NTA⁹⁰. Emissions from this industry are included in CRF code 2B5. Ammonia production, 2.B.1, is thus reported as NO in the CRF-tables.

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

4.3.2.1 SOURCE CATEGORY DESCRIPTION

Production of nitric acid has taken place at three facilities in Sweden during 1990-2000. One of these was shut down 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 4.17.

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

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources Estimated
		Level	Trend	Qualitative			
2.B.2	CO ₂	X	X		NA	NA	NA
	CH ₄	X	X		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 the produced amount of nitric acid, has 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. Since two plants have been shut down, it is no longer possible to acquire this information. Calculations have therefore been made based on production statistics and an assumed emission factor (Table 4.18). The assumed emission factor of 7 kg/Mg for 1991 - 1993 is based on the calculated emission factors for 1990 and 1994 and is in line with the default factors for nitric acid production presented in Table 4.7 in IPCC Good Practice Guidance.

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. However, this information is confidential.

⁹⁰ Kindbom, 2004. SMED report: Investigation on the occurrence of ammonia production in Sweden. 2004-05-11.

Table 4.18. Activity data, emission factors and emissions for N₂O for nitric acid production

Year	Production of nitric acid Gg	Calculated EF (1990 and 1994- 2010),kg/Mg	Emissions of N ₂ O, Gg
1990	374	7.02	2.63
1991	395	7.00*	2.77
1992	380	7.00*	2.66
1993	369	7.00*	2.58
1994	377	6.62	2.50
1995	417	5.48	2.29
1996	400	5.48	2.19
1997	390	5.56	2.17
1998	400	6.10	2.44
1999	383	5.58	2.14
2000	430	4.80	2.06
2001	282	5.48	1.55
2002	263	5.41	1.42
2003	258	5.39	1.39
2004	257	5.37	1.38
2005	264	5.37	1.42
2006	272	5.42	1.47
2007	249	3.16	0.788
2008	266	3.26	0.866
2009	243	4.05	0.983
2010	257	3.92	1.01

*Emission factors have been assumed

4.3.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty for activity data is $\pm 2\%$ and the uncertainty of the emission factor for N₂O is $\pm 5\%$. The time-series is consistent. The fluctuations in the calculated total EF for N₂O 1994 – 2000 (Table 4.18) 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. 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 have been reduced compared to previous years. During 2009 the production of nitric acid was lower compared to previous years and also lower than in 2010. The increase of the N₂O emission factor

between 2008 and 2009 is due to that the N₂O reduction catalysts were not used during 2009. In 2010 the catalysts were used again but not during all months of the year, which probably is the reason for the higher emission factor in 2010 compared to 2007 and 2008.

4.3.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.3.2.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.3.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.3.3 Carbide production (CRF 2.B.4)

4.3.3.1 SOURCE CATEGORY DESCRIPTION

Silicium carbide production does not occur in Sweden but calcium carbide is produced at one facility. All process-related CO₂ emissions from the industry are included in the code 2.B.4.2. The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.19.

Table 4.19. Summary of source category description, CRF 2.B.4.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.B.4	CO ₂				D	PS	Yes

D Default. PS Plant-specific.

4.3.3.2 METHODOLOGICAL ISSUES

To cover all sources of CO₂ from the production of calcium carbide, estimates of emissions from the production of quick lime, from the reduction of quick lime to calcium carbide and CO₂ from use of calcium carbide have been made. In the tables and text below the estimated CO₂ emissions to be reported in CRF 2B4.2 are presented.

4.3.3.2.1 CO₂ emissions from quick lime production

In order to estimate the CO₂ emissions from the first step of the production of calcium carbide, the amount of limestone used for quick lime production is used as activity data together with the default emission factor from Revised 1996 IPCC Guidelines, 0.44 Mg CO₂/Mg limestone used. During the time period 1990 – 2010 the facility has for some years produced all quick lime that has been used in the

production while in other years large amounts of quick lime has been bought from other producers of quick lime. Thus, the CO₂ emission varies between years as can be seen in Table 4.20.

Table 4.20. Limestone used for quick lime production and associated CO₂ emissions to be reported in CRF 2.B.4.2.

Year	Limestone used for quick lime production, Gg	CO ₂ from quick lime production, Gg
1990	96	42
1995	79	35
2000	64	28
2005	75	33
2006	23	10
2007	69	30
2008	61	27
2009	9	4
2010	51	22

4.3.3.2.2 CO₂ emissions from calcium carbide production

Calcium carbide is produced in an electric arc furnace at high temperature, 2000 – 3000 °C. Quick lime, 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 quick lime to calcium carbide, data on produced amounts of calcium carbide, share of gas flared and default emission factor in IPCC Guidelines are used. Since there only is one producer of calcium carbide in Sweden the produced amounts are reported as confidential, C.

Table 4.21. Share of flared carbide oven gas and associated CO₂ emissions to be reported in CRF 2.B.4.2, 1990 – 2010.

Year	Carbide oven running time / Flaring time, %	CO ₂ from the reduction of CaO to CaC ₂ , Gg
1990	6%	4
1995	7%	4
2000	14%	6
2005	15%	7
2006	13%	6
2007	10%	4
2008	8%	4
2009	10%	3
2010	9%	3

4.3.3.2.3 CO₂ emissions from use of calcium carbide

In Revised 1996 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 the CO₂ emission from use of calcium carbide only the amount of calcium carbide for acetylene production and the use within the country has to be taken into account. Information from the calcium carbide producer in Sweden indicates that one third of the calcium carbide is used for acetylene production. Assuming that imported and exported amounts of acetylene have the same utilisation it is possible to reasonably well estimate the CO₂ emissions originating from acetylene use. Yearly statistics on imported and exported amounts from 1998 and onwards are available from Statistics Sweden⁹¹. Amounts used for acetylene production for earlier years are estimated. The default emission factor presented in the Revised 1996 IPCC Guidelines, 1.1 Mg CO₂/Mg calcium carbide use, has been used for the estimations.

Table 4.22. Amount of calcium carbide used for acetylene production, and CO₂ emissions from acetylene use reported in CRF 2.B.4.2.

Year	Amount of calcium carbide for acetylene production, Gg	CO ₂ from use of acetylene, Gg
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

4.3.3.2.4 Time series reported in CRF 2.B.4. 2

In table 4.23, the total CO₂ emission for some years in the time series reported in submission 2012 is presented. Since there is only one producer of calcium carbide in Sweden production statistics are reported as confidential, C. The total reported CO₂ emissions in CRF 2.B.4.2 are based on:

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

⁹¹ www.scb.se

Table 4.23. Time series reported in CRF 2.B.4 2.

Year	Produced calcium carbide, Gg	CO ₂ emissions from production and use of calcium carbide, Gg
1990	C	54.2
1995	C	45.5
2000	C	40.8
2005	C	49.6
2006	C	24.2
2007	C	43.4
2008	C	40.2
2009	C	11.7
2010	C	31.6

4.3.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As can be seen in Table 4.23, CO₂ emissions for 2006 and 2009 are much lower compared to surrounding years. For 2006 a minor part of the quick lime needed for production of calcium carbide were produced at the facility, the remaining part was bought from external producers. The sharp decrease of the CO₂ emission in 2009 is due to that the lime kiln was only operating during the last quarter of the year. Consequently, most of the quick lime used for calcium carbide production in 2009 was bought from external lime producers.

4.3.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.3.3.5 SOURCE-SPECIFIC RECALCULATIONS

Revised national statistics regarding import and export of calcium carbide gives revised CO₂ emissions for the years 2000, 2001, 2005- 2009. The recalculations leads to a decrease in CO₂ emissions less than 1 ‰ each year.

4.3.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.3.4 Other (CRF 2.B.5)

4.3.4.1 SOURCE CATEGORY DESCRIPTION

This sub-category includes various chemical industries, such as sulphuric acid production, the pharmaceutical industry, production of base chemicals for plastic industry, various organic and inorganic chemical productions and other non specified chemical production, which are not covered elsewhere. Approximately 70 larger industrial facilities are included in the emission estimates. Emissions of 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.5 should be reported in CRF 3C (e.g. pharmaceutical industries), but as it has been difficult to make the distinction clear between process emissions and solvent use, all NMVOC emissions from these facilities have been included in CRF 2B5.

Emission time-series for GHG are relatively stable. There is a slight drop in emissions of GHG in 2009 compared to 2008 e.g. due to lower production of carbon black. In addition, CH₄-emissions decreased in 1999 due to a much lower production at one facility and N₂O-emissions increased in 1999 due to the fact that one facility within "Pharmaceutical industry" reported higher emissions that year.

The SO₂ emissions reported in 2B5 decreased dramatically in 2004 in comparison to earlier years. This is due to that in December 2004 one facility for production of viscose staple fibre was shut down. The yearly 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.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.24.

Table 4.24. Summary of source category description, CRF 2.B.5.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.B.5	CO ₂				CS	PS	Yes
	CH ₄				CS, D	PS, D	Yes
	N ₂ O				CS	PS	Yes

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

4.3.4.2 METHODOLOGICAL ISSUES

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. A total of approximately 70 facilities are included. In the IPCC Guidelines, methods for estimating CH₄ emissions for several chemical products are presented and consequently the CRF Reporter is divided on those products (2.B.5.1-5). Since several plants in Sweden produce several chemicals products each but report emissions aggregated by plant, it is not possible to report emissions in accordance with the suggested split in the CRF Reporter. In Sweden, since submission 2006 the emissions are thus presented allocated to six separate branch categories: sulphuric acid production, pharmaceutical industry, production of base chemicals for plastic industry, organic chemical production, inorganic chemical production and other non-specified chemical production.

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 (11 g CH₄/kg production). Due to data confidentiality, emissions are included under 2.B.5 (Other inorganic chemical production).

4.3.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Based on expert judgements, the uncertainties of collected emissions of CO₂, CH₄ and N₂O are as follows: $\pm 50\%$, $\pm 100\%$ and $\pm 125\%$, respectively.

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

4.3.4.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

In addition, 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 Sweden⁹². Emissions reported in the environmental reports were compared to plant-specific data in the GHG inventory, significant discrepancies were investigated, and recommendations were provided on feasible improvements for submission 2011 as well as recommendations on further investigations⁹³.

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

4.3.4.5 SOURCE-SPECIFIC RECALCULATIONS

- Complete time series of CO₂ emissions from two facilities producing inorganic chemicals have been added in submission 2012. One of these facilities was contacted to obtain estimated process-related CO₂ emissions. The other facility presented a time-series for process-related CO₂ emissions in their 2010 environmental report. The added emissions lead to an average increase of CO₂ emissions in CRF 2.B.5 of 15% 1990-1999 (8 Gg), 46% (23 Gg) 2000-2005 and 75% 2006-2009 (40 Gg), see Figure 4.5.
- A complete time series of CH₄ emissions from one facility producing PVC have been estimated. The estimate is based on the facilities own measurements. The added emissions lead to an increase of CH₄ emissions less than 1% in CRF 2B5.

⁹² Gustafsson, T., Nyström, A-K., Gerner, A. Riktad kvalitetskontrollstudie av utsläpp från kemiindustrin i Sveriges internationella rapporter. SMED report 2010.

⁹³ Most recommendations on further investigations refer to the energy sector

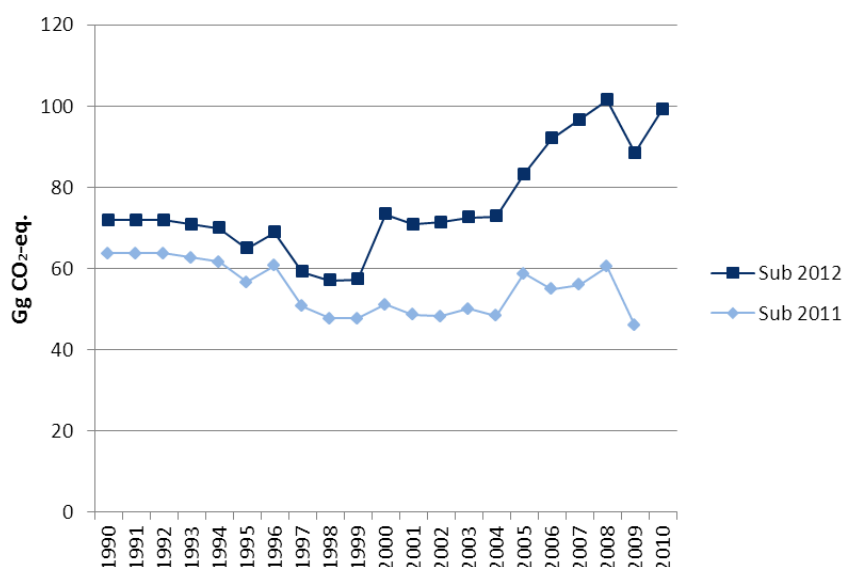


Figure 4.5. Reported CO₂ emissions in CRF 2.B.5 submission 2011 and submission 2012.

4.3.4.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.4 Metal production (CRF 2.C)

All sub-categories are covered in the estimates, i.e. 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.5), which consists of estimates for one large non-ferrous smelter plant and one metal recycling plant.

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

4.4.1.1 SOURCE CATEGORY DESCRIPTION

In Sweden, there are three primary iron and steel facilities and about ten secondary steel plants equipped with electric arc furnaces. In total, there are approximately 20 different facilities included in the different estimates. Processes occurring besides the primary processes and secondary steel production are rolling mills, pickling and other steel-related processes. From submission 2009 and onwards, emissions from two major iron ore mines and three facilities producing pellets in Sweden are reported in 2C1.3 (reallocated from previous reporting in 2.A.7). Emissions from a sinter producing facility are also included until 1995, when the production closed down.

Process emissions arising from reducing agents in the primary steel works and secondary iron and steel works are reported in CRF 2.C.1. As the plants also generate emissions from fuel combustion (CRF 1.A.1c 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.

In the Swedish inventory, emissions from primary iron and steel production and secondary steel production are reported separately and fed into the CRF Reporter under 2.C.1.2 Pig iron and 2.C.1.1 Steel, respectively. This enables process emissions from the two integrated iron and steel production plants in Sweden to be reported together (2.C.1.2 Pig iron), and thus not introducing further sources of uncertainty due to additional data handling.

The GHG emission trend 1990-2008 is rather stable with some minor inter-annual variations. However, the economic recession in 2009 had a great effect on the production volumes of iron and steel in Sweden and thus the emissions 2009 are significantly reduced. In 2010 the emissions are back at the same level as before 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 4.25.

Table 4.25. Summary of source category description, CRF 2.C.1.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.C.1	CO ₂	X	X		CS, T2	PS	Yes
	CH ₄				CS	PS	No, see Annex 5
	N ₂ O				NA	NA	NA

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

4.4.1.1.1 Secondary steel production, CRF 2.C.1.1

The 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.1.1. Reported CO₂ emissions also include emissions from the use of limestone and dolomite in secondary steel industry.

In submissions prior to submission 2010, the reported CO₂ emissions in CRF 2C1.1 included data from nine plants in 1990-2003 and eight plants from 2004, since one plant was shut down in 2004. From submission 2010 another two secondary steel industries are included in the reported CO₂ time series. Also another four plants with process related NO_x and/or NMVOC emissions are included in this sector. These plants do not produce steel, and hence do not emit CO₂.

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

4.4.1.1.2 Primary iron and steel production, CRF 2.C.1.2

In Sweden there are three producers of primary iron and steel, i.e. the basis of their production is iron ore pellets. Two plants produce pig iron and steel as part of their integrated coke ovens, blast furnaces and steel converters. The primary purpose of the use of coal and coke in the blast furnace is to secure oxidation and act as reducing agents, and the associated emissions are thus to be reported as industrial processes from iron and steel production in CRF 2.C.1, according to the IPCC Guidelines and Good Practice Guidance. The third plant produces iron sponge and iron powder.

4.4.1.1.3 Iron ore mining, dressing, sintering and iron ore pellets production, CRF 2.C.1.3

Emissions of CO₂ from the use of limestone and dolomite within the production of ore based iron pellets are reported in CRF 2.A.3. Estimated emissions from combustion of fuels are included in the Energy sector (CRF 1).

Emissions considered in CRF 2.C.1.3 are CO₂ from the use of bentonite and organic binder, SO₂ from the sulphur content in the ore and NO_x emitted as a result of the use of explosives. The use of mining explosives also causes emissions of carbon monoxide, CO⁹⁴.

4.4.1.1.4 CO₂ emissions reported in Coke, CRF 2.C.1.4

Emissions of CO₂ from the production of coke are reported in CRF 1.A.1.c and emissions of CO₂ from the use of coke in blast furnaces are reported in CRF 2.C.1.2 in line with the IPCC Guidelines.

4.4.1.1.5 CO₂ emissions reported in Other, CRF 2.C.1.5

No emissions of CO₂ reported in this sector.

4.4.1.2 METHODOLOGICAL ISSUES

4.4.1.2.1 Secondary steel production, CRF 2.C.1.1

In most cases, data from the Swedish enquiry for the Swedish national allocation plan (NAP) for the EU ETS could be used for the years 1998-2002. Data for 1990-1997 and 2003-2004 has been collected directly from the plants. From 2005, the equivalent data are acquired from the ETS, from the facilities environmental reports and through contacts with the companies.

Data in the ETS includes information concerning carbon bound in products, slag, etc, but also other sources for process related CO₂ emissions. Prior to submission 2010, these other emissions were not included for all facilities. Estimates of these missing CO₂ emissions were performed using ETS data for 2005 – 2008 and production data for years before 2005. All CO₂ emissions presented for the facilities in ETS 2005 – 2010 are included in 2C1.1 in submission 2012.

⁹⁴ Wieland, M.S. 2004.

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

For non-CO₂ emissions, the companies' environmental reports are the main source of information. NO_x, NMVOC and SO₂ emissions emitted from electric arc furnaces are reported in 2C1.1. NO_x emissions may also arise from pickling and NMVOC emissions from rolling mills. These sources are also included in the estimates.

4.4.1.2.2 Primary iron and steel production, CRF 2.C.1.2

4.4.1.2.2.1 Production of iron powder

The emissions of CO₂ are calculated using the Good Practice Guidance method Tier 2. Plant-specific data on emissions from carbon-containing input materials such as coke and anthracite and also specific carbon-contents of output iron and by-products are used for all years. From 2005, ETS data is used and 1990-2004, information has been 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.1.2. The remaining amounts of natural gas used by the facility are considered as energy-related and the corresponding emissions are reported in the Energy sector (CRF 1.A.2.a). To be consistent with calculations of emissions from production of pig iron, limestone used in the production is included in the emissions from the production of iron powder in CRF 2.C.1.2. Activity data reported is produced amount of direct-reduced iron (iron sponge).

4.4.1.2.2.2 Production of primary pig iron and steel

As a response to recommendations from UNFCCC expert review teams, since submission 2010, Sweden uses the recommended Tier 2 method according to the IPCC Guidelines, to base the calculations of CO₂ emissions 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; coke⁹⁵, pig iron⁹⁵, steel, tar, sludge, slag, etc. The remaining carbon contents are accounted for as CO₂ emissions:

⁹⁵ If put in stock or sold externally

$$CO_2 \text{ emissions}_{TotalCRF1and2} = \left[\sum_i (MI_i * C_i) - \sum_p (MO_p * C_p) \right] * 44/12$$

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 4.6 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 as fuel or flared. Some steel is treated in the rolling mills where LPG and different oils are used as fuel.

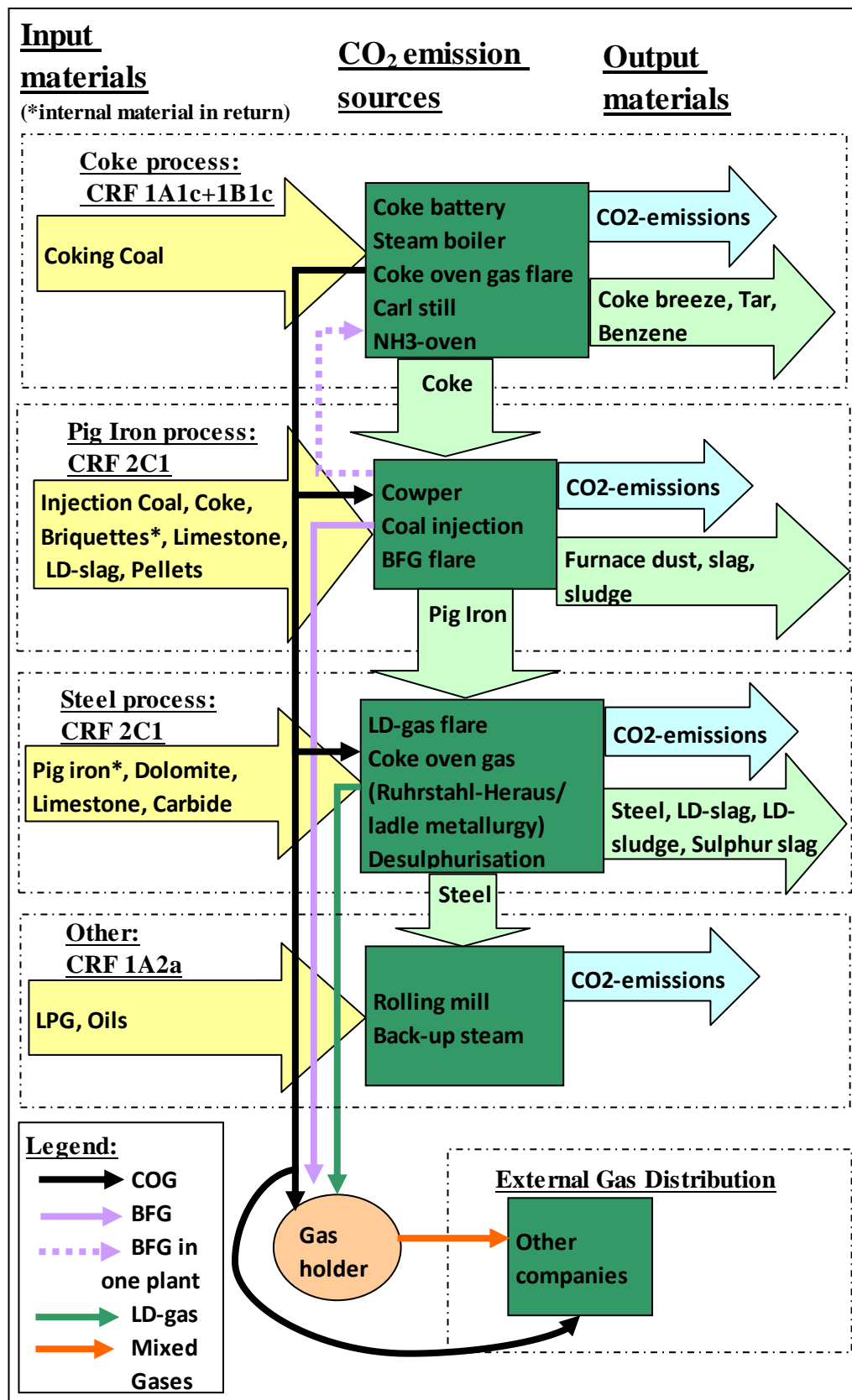


Figure 4.6. Carbon flow chart of integrated primary iron and steel plants in Sweden

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 not in accordance with the 1996 Guidelines as they fall under the category “Auto-producers⁹⁶”, but in line with the 2006 IPCC Guidelines⁹⁷ where allocation of emissions from delivered gases is described. Sweden has chosen to follow the 2006 IPCC Guidelines in this case as they are more in line with the emission reporting for the annual environmental reports and the EU ETS reporting.

During the whole process from raw material to final product, emissions of CO₂ are released. The allocation of both plants total CO₂ emissions on plant stations and consequently CRF sub-sector is based on detailed mass-balances (Table 4.26).

Table 4.26. CO₂ emission allocation 2010 in integrated primary iron and steel production (excluding external gas distribution).

CRF	Plant station	CO ₂ emissions 2010 (Gg)
1.A.1.c	Coke Oven	313
1.A.2.a	Combustion in Rolling Mills + Power and Heat Production	950
1.B.1.c	Flare in Coke Oven (COG)	5
2.C.1.2	Blast Furnace + Steelworks (including Flaring of BFG and LD-gas)	2346
Total		3614

According to the IPCC Guidelines, emissions of CO₂ from the use of limestone should be reported separately as process emissions from limestone and dolomite use in CRF 2.A.3. Since the Centralized review from submission 2004 the ERT has repeatedly recommended Sweden to follow the guidelines. As the CO₂ emissions from limestone and dolomite are small (<1 per cent of the plants total CO₂ emissions) it is not considered to be good practice to spend resources obtaining underlying data to separate these emissions. Hence Sweden choose to include these CO₂ emissions in CRF 2.C.1.2.

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.1.2) are taken from the environmental reports. Amounts of

⁹⁶ See IPCC Guidelines: Reporting instructions 1.3

⁹⁷ See 2006 IPCC Guidelines: Volume 3: Industrial Processes and Product Use, Box 1.1 (page 1.8)

pig iron produced 1990-2002 were obtained directly from both plants, together with total CO₂ emissions 1990-2002 for one of the plants. For the other plant, CO₂ emissions 1990-2002 are calculated using its pig 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.1.2) are based on the plant specific average distributions 2003-2007.

Consumed amounts of different energy gases and other fuels 1990-2002 are derived by applying the Good Practice Guidance surrogate method using the average values 2003-2007 and the CO₂ emissions as the surrogate parameter. Activity data reported in CRF Reporter in CRF 2C1.2 is produced amount of primary pig iron.

Emissions of CH₄, N₂O, NMVOC and CO are not reported in the plants' environmental reports. In the Swedish inventory these emissions are instead estimated from consumed amounts (including flared amounts) of energy gases multiplied by country-specific emission factors (see Appendix 1). 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.1.2, whereas emissions of N₂O are assumed to be not applicable (NA) in this sub-category, in accordance with the IPCC Guidelines. Emissions of NO_x and SO₂ are based on detailed plant information from the environmental reports.

4.4.1.2.3 Iron ore mining, dressing, sintering and iron ore pellets production, CRF 2.C.1.3

Data on production statistics as well as on 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. No data concerning the CO emissions is available and the time series is thus reported NE.

4.4.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The largest implication on the national total uncertainties from this category stems from uncertainties in CO₂ emissions in primary iron and steel production (CRF 2C1.2); based on expert judgement by SMED expertise the estimated uncertainty is ±5%. It should be noted however, that total emissions of CO₂ from iron and steel production, including energy related emissions, are likely to deem lower uncertainty estimates.

There is an obvious decrease in CO₂ IEFs since 1990 (Table 4.27) for primary pig iron and steel production, from 0.80 Gg CO₂/kton iron in 1990 to 0.55 Gg CO₂/kton pig iron in 2009. This is due to the undertaking of several energy efficiency measures, e.g. increased temperature in the blast furnaces and increased recycling of energy gases and by-products⁹⁸, leading to decoupling between CO₂ emissions and primary pig iron production in Sweden. Table 4.27 indicates an

⁹⁸ ENET-Steel, 2007.

increase of IEF in year 2010 compared to previous years, this is mainly due to performed repair works of the LD-gas holder at one plant.

The CO₂ IEF is overall significantly lower than the Tier 1 default emission factor (1.35 Gg CO₂/kton pig iron produced) presented in 2006 IPCC Guidelines Table 4.1. This is partly due to that a large share of the energy gases produced at one of the plants is distributed to other companies (as described above) and thus not accounted for in iron and steel production. Adding CO₂ from all the external gas distribution (though some gas is COG) would lead to an IEF in 2008 of 1.21 Gg CO₂/kton pig iron produced and thus considered to be reasonable with regard to the IPCC Guidelines default.

Table 4.27. CO₂ implied emission factors (IEF) for primary pig iron production

Year	CO ₂ IEF (Gg CO ₂ /kt primary pig iron produced)
1990	0.80
1995	0.78
2000	0.70
2005	0.58
2006	0.57
2007	0.56
2008	0.58
2009	0.55
2010	0.68

4.4.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

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

4.4.1.5 SOURCE-SPECIFIC RECALCULATIONS

2.C.1.1

CO₂ emissions from one facility have been corrected for 2008 and 2009. Carbon bound in product and scrubber sludges are excluded.

2.C.1.2

In submission 2011, preliminary data on CO₂ was used for 2009 for one of the primary pig iron and steel plants. In submission 2012, more accurate data became available and thus 2009 data was revised. The revision in submission 2012 of 2009 data resulted in an increase of 2.12 Gg CO₂ compared to submission 2011.

2.C.1.3

The time series for CO₂ has been updated. Now it includes both CO₂ from the use of organic binders as well as from the use of bentonite.

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

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- Iron and steel production. The production of iron silicide has decreased sharply since 2005, and since 2008 there is no production at all. This leads to ending of the emissions of CH₄ from 2008. Production of ferrosilicon leads to larger emissions of SO₂ compared to production of ferrochromium. From 2005 the production of ferrosilicon has been much reduced and from 2008 no ferrosilicon is produced. This leads to a distinct decrease in SO₂ emissions in later years. The economic recession in 2009 had a great effect on the production volumes of ferroalloys in Sweden and thus the emissions 2009 are significantly reduced.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.28.

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

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.C.2	CO ₂				T2	PS	Yes
	CH ₄				D	D	Yes
	N ₂ O				NA	NA	NA

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

4.4.2.2 METHODOLOGICAL ISSUES

CO₂ emissions within the production of ferroalloys are plant specific (in line with Tier 2), and are calculated based on the consumed amount of reducing agents (Tier 1a⁹⁹), i.e. electrodes and coke (and in 2003 coal) and their specific carbon contents. Input data is also the amount of carbon bound in produced ferroalloys. The common distribution of carbon in the incoming and outgoing materials is:

⁹⁹ <http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch2wb2.pdf>

Coke	+	Electrodes	→	Ferroalloys	+	Emissions	+	Particles
95%	+	5%	→	10%	+	89.5%	+	0.5%

To verify the emissions reported by the plant, emissions are calculated based on activity data on coal, coke, electrodes and the amount of carbon in produced ferroalloys and:

- emission factors and thermal values used for stationary combustion for coke and coal and information from the company that the electrodes contain 90 % carbon.
- IPCC default factors for coal, coke and electrodes¹⁰⁰.

The used formula is:

$$CO_2 \text{ (Mg)} = \text{Coke (Mg)} \times EF \times \text{Thermal value} + \text{Coal (Mg)} \times EF \times \text{Thermal value} \\ + \text{Electrode (Mg)} \times C\text{-content} \times \frac{44}{12} - CO_2 \text{ in produced ferroalloy (Mg, plant data)}$$

where 44/12 are the molecule weights of CO₂ and carbon. As can be seen in Table 4.29, there are differences in the plant specific data and emissions based on Swedish default EF and emissions estimated with IPCC Guidelines default values. The differences are due to the fact that - according to the company - the carbon content of the coke may vary from one year to another.

The total amount of carbon in the produced ferroalloys is presented in

Table 4.30, and is calculated based on the carbon content in coke, coal, electrodes and dust by the company. The amount of carbon in the produced ferroalloys varies between 0.1 % and 7 %. This carbon is reported under CRF 1.AD.10 - coke and coal. CH₄ emissions from production of FeSi alloys are reported from submission 2010 and calculated based on FeSi alloy production (Tier 2¹⁰¹)

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.

¹⁰⁰ IPCC. Revised 1996 Guidelines for National Greenhouse Gas Inventories: Reference Manual, Table 2.12.

¹⁰¹ 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Table 4.8

Table 4.29. 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.

Year	Plant specific data, Gg CO ₂	Swedish values, Gg CO ₂	IPCC default values, Gg CO ₂
1990	243	244	263
1995	265	274	295
2000	240	266	287
2005	225	214	231
2006	220	209	225
2007	220	188	203
2008	194	164	177
2009	48	48	52
2010	107	96	104

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

Year	Carbon in ferroalloys, Gg
1990	8.4
1995	8.7
2000	9.5
2005	8.0
2006	8.3
2007	8.4
2008	7.4
2009	1.8
2010	4.0

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.

Time-series are considered to be consistent.

4.4.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

As presented in Table 4.29 verification of CO₂ emissions reported by the plant is obtained as calculated Swedish default values give similar results.

4.4.2.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed. Reported activity data, which in earlier submissions were represented by used amounts of reducing agents, are in submission 2012 reported as amounts of carbon in used quantities of reducing agents.

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 halls. One of the potlines includes 56 closed prebake cells (CWPB), each of 150 kA. The other plant consisted of 262 cells and, until the beginning of 2008, operated three prebake cells and 259 open cells with Söderberg anodes (VSS). The Söderberg anodes were produced in an electrode pulp factory at the facility.

In 2008 a project was started to convert all Söderberg ovens to ovens with prebake cells. By the end of December 2009, 120 of a total of 262 cells had been converted to the prebake technology and the conversion to prebake cells continued under 2010. All pot-lines operating the Söderberg technology were shut-down by December 2008. At the end of 2010 113 converted prebake ovens were in operation.

The shutdown of Söderberg ovens explains the very large decline in PFC emissions in 2009 (- 85% compared to 2008) (Figure 4.7). Also the reported CO₂ has declined in 2009 relative to previous years. The relatively stable implied emission factor (

Table 4.32) provides the explanation that the reduced CO₂ emissions are due to reduced aluminium production in 2008 and 2009. The cold winter in 2010 resulted in high power input to the anodes, thus leading to high emissions of PFCs. There has also been some disruption with power outage as a result. This has had an impact on the operation and, inter alia, resulted in intermittent operation and increased number of anode effects.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.31.

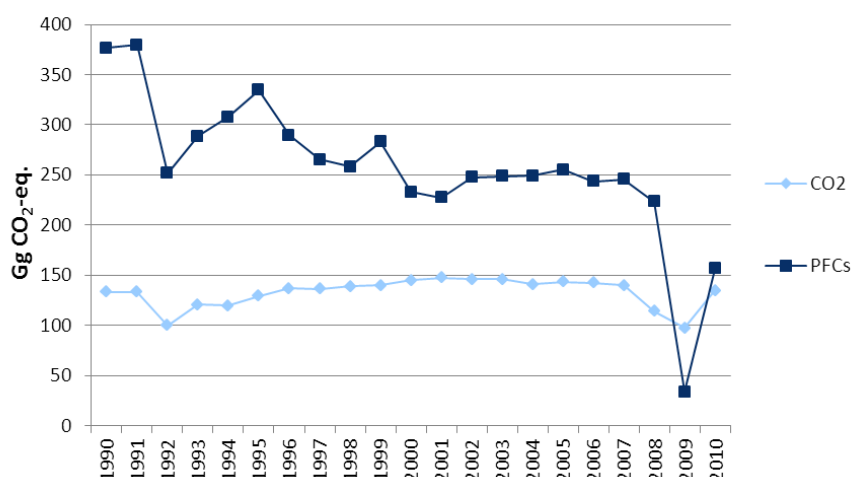


Figure 4.7. Time series for CO₂ and PCF emissions from aluminium production, CRF 2C3.

Table 4.31. Summary of source category description, CRF 2.C.3.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.C.3	CO ₂				T2	PS	Yes
	CH ₄				NA	NA	No, see Annex 5
	PFCs		X		T2	D	Yes

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

4.4.3.2 METHODOLOGICAL ISSUES

Primary aluminium is in Sweden produced in one facility, where the prebaked process is used. The time series of emissions compiled for primary aluminium production include emissions of CO₂, PFCs, NO_x, CO, NMVOC and SO₂. Reported production statistics and emissions data are based on information in the environmental reports or received directly from the company.

Reported emissions of NO_x are calculated from production statistics using emission factors defined by Swedish EPA¹⁰². NMVOC emissions are calculated from reported emissions of tar, assuming that 70 % of the tar is emitted as NMVOC¹⁰². CO emissions were for the first time reported in submission 2008 and are for 2002 - 2008 as reported in the company's environmental reports. For the period 1990 - 2001, the CO emissions are calculated based on production statistics and emission factors provided by the company as also for the SO₂ emissions during 1990 - 2005. For later years SO₂ emissions data are based on environmental reports published by the company.

Emission data for CO₂ from the production of primary aluminium 2002 - 2009 are derived through measurements and reported directly by the plants, whereas the emissions for 1990-2001 are calculated based on the mass of coal elements (an-

¹⁰² Ahmadzai, H. Swedish EPA. Personal communication. 2000.

odes) such as electrodes, coke etc. and the amount of carbon that is bound in soot. The formula used for CO₂ (Mg) for 1990-2001 is:

$$\text{Mass anodes (100\% C)} \times \frac{44}{12} \times (1 - 0.257^*)$$

* Mass CO₂ bound in soot and rest anodes in 2002

The value for carbon bound in soot and rest anodes (0.257) is based on the reported value for 2002 and has been about the same also in subsequent years (0.234 – 0.282).

For the years from 2002 and onwards the emissions reported by the plant have been verified by also collecting data on amount coal elements used and then calculating the emissions based on the equation above. The results are very comparable.

Due to the fact that the carbon bound in soot is not included in the reported CO₂ emissions in 2C3, the IEF (implied emission factor) values in the Swedish inventory (given as Mg CO₂/ Mg Al produced) are lower than the IPCC Guidelines default emission factors for prebaked and Söderberg (1.8 and 1.5 Gg CO₂/Gg produced Al) (

Table 4.32).

The two different processes for aluminium production, prebaked (CWPB) and Söderberg (VSS), have substantially different emission factors for PFCs. Estimates of emissions are based on the number of ovens and the number and duration of anode effects. This activity data is considered to be of good quality.

Table 4.32. Implied emission factor for CO₂ for the production of aluminium.

Year	Aluminium production Gg	Emissions of CO ₂ Gg	IEF Gg CO ₂ /Gg 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

Activity data used for the PFC emission calculations, anode effects in min/oven day and production statistics, were provided by the company, and specified for the prebaked and Söderberg processes. The reported emissions and calculated Implied Emission Factors are presented in Table 4.33.

Table 4.33. Activity data, emissions of C₂F₆, CF₄ and calculated IEF for aluminium production.

Year	Al production, CWPB, Gg	Al production, VSS, Gg	Total emissions, C ₂ F ₆ Mg	Total emissions, CF ₄ Mg	Calculated IEF			
					CWPB kg C ₂ F ₆ /Mg	VSS kg C ₂ F ₆ /Mg	CWPB kg CF ₄ /Mg	VSS kg CF ₄ /Mg
1990	23.4	72.9	3.05	53.66	0.0443	0.0276	0.3444	0.6255
1995	22.8	71.2	2.29	48.25	0.0106	0.0287	0.0827	0.6510
2000	23.0	78.1	1.57	33.58	0.0059	0.0184	0.0460	0.4165
2005	23.6	78.9	1.66	36.93	0.0022	0.0204	0.0171	0.4629
2006	23.6	78.1	1.59	35.21	0.0024	0.0196	0.0188	0.4453
2007	23.3	76.5	1.61	35.54	0.0026	0.0202	0.0205	0.4583
2008	29.6	52.0	1.83	31.74	0.0223	0.0226	0.1737	0.5113
2009	69.7	0.0	0.56	4.36	0.0080	0.0000	0.0625	0.0000
2010	96.1	0.0	2.62	20.36	0.0272	0.0000	0.2118	0.0000

4.4.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As can be seen in Table 4.33 the IEFs show a downward trend from 1990 to 2007, especially so for CF₄. This reflects the company's ongoing work aiming to reduce the time and frequency of the anode minutes. For 2008 it can be seen that the IEF for C₂F₆ as well as for CF₄ from the prebake ovens are higher compared to 2007. According to the company the reason for this is due to initial start up problems with the new prebake ovens. The IEF for 2009 indicates less start up problems of new prebake ovens in 2009.

As described earlier (Figure 4.7) is the sharp decline in PFC emissions in 2009 caused by the closure of all Söderberg ovens in 2008.

The reported time series are considered to be consistent.

4.4.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.4.3.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.4.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.4.4 SF₆ used in aluminium and magnesium foundries (CRF 2.C.4)

4.4.4.1 SOURCE CATEGORY DESCRIPTION

In Sweden, four magnesium foundries use SF₆ as a cover gas. No SF₆ is used in aluminium foundries (CRF 2.C.4.1) as far as known, and thus reported as not occurring (NO). The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.34.

Table 4.34. Summary of source category description, CRF 2.C.4.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.C.4	SF ₆				D	D	Yes

D Default.

4.4.4.2 METHODOLOGICAL ISSUES

The total amount of SF₆ used annually in the magnesium foundries (CRF 2.C.4.2) is reported as emissions, according to the IPCC Guidelines and Good Practice Guidance. Data is obtained from companies using SF₆.

4.4.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Estimated uncertainty in SF₆ emissions is judge by SMED to be ±40%. Time series are considered to be consistent.

4.4.4.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

In response to questions raised during the 2011 submission 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.

4.4.4.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

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 Other metal production (CRF 2.C.5)

4.4.5.1 SOURCE CATEGORY DESCRIPTION

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 4.35.

Table 4.35. Summary of source category description, CRF 2.C.5.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.C.5	CO ₂				D	PS	Yes

D Default. CS Country Specific.

4.4.5.2 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 the amounts of coke, coal, limestone, plastics and other raw material used in the production. The company directly reports these activity as well as carbon content in slag products. The emissions from coal and coke are calculated based on national thermal values (TV) and emission factors (EF). IPCC default value is used for CO₂ emissions from limestone. The equation used for the smelter is:

$$\begin{aligned}
 CO_2 (Mg) = & Coke (Mg) \times EF \times Thermal\ value + Coal (Mg) \times EF \times Thermal\ value \\
 & + Limestone (Mg) \times 0.97 \times \frac{44.0098}{100.0892} + C\ in\ raw\ material\ and\ plastics (Mg) \times \frac{44}{12} \\
 & - Slag (Mg) \times 0.0002 \times \frac{44}{12}
 \end{aligned}$$

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. 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.

4.4.5.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Time-series are considered to be consistent.

4.4.5.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Both plants in this category report their emissions in yearly environmental reports. For the one plant included in the EU-ETS the reported activity data and emissions are analysed and compared to EU-ETS data. Where EU ETS data is judged to be

appropriate and in line with the Good Practice Guidance, it is applied. More information on QC activities related to EU ETS is included in Annex 8.1.

4.4.5.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.4.5.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.5 Other production (CRF 2.D)

Other production covers emissions from the pulp and paper industry (2.D.1) as well as estimates from the production of food and drink (2.D.2). Emissions of fossil CO₂ are not estimated for this sector. According to the IPCC Guidelines Reference Manual, emissions of fossil CO₂ from this sector are not likely.

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

4.5.1.1 SOURCE CATEGORY DESCRIPTION

The pulp and paper industry in Sweden is an important source of industrial process emissions. 42 individual pulp and paper facilities are included in the reported emissions, as well as two manufacturers of cardboard. One of these facilities shut down during 2008 and during 2009 another two plants closed down their pulp and paper production. The Kraft process (sulphate) dominates in Sweden but there are also emissions from four sulphite and 16 CTMP (Chemo Thermo Mechanical Pulp) or TMP (Thermo Mechanical Pulp) facilities reported in CRF 2.D, 1990 - 2010.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.36.

Table 4.36. Summary of source category description, CRF 2.D.1.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.D.1	CO ₂				NA	NA	NA
	CH ₄				CS	CS	Yes
	N ₂ O				CS	CS	Yes

CS Country Specific.

4.5.1.2 METHODOLOGICAL ISSUES

Reported emissions from the pulp and paper industry are primarily based on information about production and emissions in the companies' environmental reports. The industrial organisation within this sector has, for several years, cooperated

closely with its members in developing sector-specific methods of measuring and calculating emissions, which have resulted in high quality emissions data. The reported emissions of NMVOC do not include terpenes.

The Swedish definition of process emissions includes the combustion of spent cooking liquor which gives rise to emissions of N_2O and CH_4 . The cooking liquor contains organic compounds and chemicals and is combusted to recover Na and S, but also to utilise the energy in the cooking liquor. The recovered Na and S (as Na_2CO_3 and Na_2S) are recycled and used in the process again. In submission 2008 and earlier, due to technical reasons, these emissions were reported in CRF 2.G. From submission 2008 and onwards, N_2O and CH_4 are reported in 2D1.

The estimated process emissions of CO_2 from quick lime production within this industry are allocated in CRF 2.A.2.

4.5.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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

4.5.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.5.1.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.5.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

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

4.5.2.1 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 4.37.

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

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.D.2	CO ₂				NA	NA	No, see Annex 5
	CH ₄				NA	NA	NA
	N ₂ O				NA	NA	NA

4.5.2.2 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 amount¹⁰³ together with figures on import and export¹⁰⁴. NMVOC emissions from beer production are based on the Swedish annual total production of beer^{105 106}.

Note that data for beer for 2010 was not updated in time for the finalization of the 2012 submission, and thus data for 2009 was used. NMVOC emissions originating from the production of liquors, bread, sugar, yeast, margarine and solid cooking fat, coffee roasters and animal feeds are all based on statistics available at Statistics Sweden's website. For the NMVOC emission estimates, emission factors presented in Table 4.38 were used. Emissions of CO₂ are not estimated but are believed to be minor or of biogenic origin.

¹⁰³ Systembolaget. Försäljningsstatistik. <http://www.systembolaget.se/>

¹⁰⁴ Statistics Sweden. Data from the Yearbook of Agricultural Statistics 2010 including Food Statistics. <http://www.scb.se/>

¹⁰⁵ Carlsberg Sweden. <http://www.carlsberg.se>

¹⁰⁶ Bryggeriföreningen. <http://sverigesbryggerier.se>

Table 4.38. NMVOC emission factors for the reported production activities in CRF 2.D.2 - Food and drink.

Production activity	Emission factor	Unit	Reference
Wine	0.8	kg/1000 litres	107
Beer	0.35	kg/1000 litres	107
Liquors	0.6	kg/1000 litres	EF based on emission and activity data from one producer, 2001 107
Bread (sponge dough)	8	kg/Mg	107
Bread (white)	4.5	kg/Mg	107
Bread (whole meal and light rye)	3	kg/Mg	107
Bread (dark rye)	0	kg/Mg	107
Cakes	0.1	kg/Mg	107
Biscuits	0.1	kg/Mg	107
Breakfast cereals	0.1	kg/Mg	107
Sugar	10	kg/Mg	108
Yeast	18	kg/Mg	107
Margarine and solid cooking fats	10	kg/Mg	107
Coffee roasting	0.55	kg/Mg	107
Animal feed	0.1	kg/Mg	107

4.5.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The time series is consistent.

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

No source-specific recalculations have been performed.

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.

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

Production of halocarbons and SF₆ does not occur in Sweden.

¹⁰⁷ EMEP/CORINAIR Emission Inventory Guidebook: <http://reports.eea.eu.int/EMEPCORINAIR4/en>

¹⁰⁸ Finnish Environment Institute, 2001. Revised Finnish Non Methane Volatile Organic Compound Emissions- Time series for the years 1998-1999 with Information on the Emissions Sources and Calculation Methods.

4.7 Consumption of Halocarbons and SF₆ (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 second largest source in 2010 is foam blowing (XPS-foam), followed by electrical equipment and aerosols. All remaining sources are comparatively small emitters of fluorinated greenhouse gases.

All sub-categories are covered in the estimates except solvents (2.F.5), due to varying and in-consistent information. According to the information available, solvents are estimated to only contribute a very minor share of the emissions of halocarbons, but it has not been possible to quantify the amount.

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

Table 4.39. Overview of submitted actual emissions data, Gg CO₂ equivalents.

CRF	Category	1990	1995	2000	2005	2006	2007	2008	2009	2010
F1	Refrigeration and air conditioning equipment	5	125	431	671	716	755	783	799	786
F2	Foam blowing	NA	NA	111	87	74	54	51	40	32
F3	Fire extinguishers	NA	NA	5	6	6	6	8	6	6
F4	Aerosols/Metered dose inhalers	1	7	22	29	24	26	26	25	27
F5	Solvents	NE	NE	NE	NE	NE	NE	NE	NE	NE
F6	Other use of ODS substitutes	NO	NO	NO	NO	NO	NO	NO	NO	NO
F7	Semiconductor manufacture	NA	11	8	NO	NO	NO	NO	NO	NO
F8	Electrical equipment	81	95	32	28	22	29	28	44	31
F9	Other	2	3	8	14	12	9	8	8	8

In estimating the actual 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). 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. Based on an earlier inventory model on actual emissions of fluorinated greenhouse gases in Sweden covering the time period 1990-1999¹⁰⁹, in 2005, the model was updated and refined e.g. concerning the calculations from the accumulated bank¹¹⁰. The model takes into consideration changes in accumulated amounts each year resulting from additional amounts of HFC, PFC and SF₆ imported and used within

¹⁰⁹ 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.

¹¹⁰ Kindbom, K. 2005. Revision of Methodology and Estimated Emissions of Fluorinated greenhouse Gases in Sweden. Report Series SMED Nr 16 2005, www.smed.se

the country, as well as the decline in accumulated stock caused by exports or emissions from operating systems. In 2011, a SMED study¹¹¹ was carried out to analyze 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 analyze 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. The model is described in more details in Annex 3:1.

Due to a recurring one year lag of updating of the data from the Products Register from the Swedish Chemicals Agency, data on bulk import and export in 2009 are updated. This results in revised data on actual emission estimates from stationary refrigeration and air-conditioning equipment (2.F.1) and from electrical equipment (2.F.8) for 2009 due to the calculation system (as described in Annex 3:1).

4.7.1 Refrigeration and air conditioning equipment (2.F.1)

4.7.1.1 SOURCE CATEGORY DESCRIPTION

Emissions of HFCs and PFCs from heat pumps, stationary air-conditioning, mobile air-conditioning, refrigeration and freezing equipment are included in this category. Emissions of SF₆ from refrigeration and air conditioning equipment are not applicable (NA) in Sweden. The most important source of greenhouse gases to the category is emissions of HFC-134a from air-conditioning in cars. It can be seen in Table 4.39 that emissions of HFCs and PFCs from this source category has increased from 5 Gg CO₂ equivalents 1990 to 756 Gg CO₂ equivalents 2010. 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, however, the emissions of HFCs are lower compared to 2009, mainly due to reduced use of HFC-134a in other stationary refrigeration 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 4.40.

Table 4.40. Summary of source category description, CRF 2.F.1.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.F.1	HFCs	X	X		CS, T2	CS, D	Yes
	PFCs				CS	CS, D	Yes
	SF ₆				NA	NA	NA

D Default. CS Country Specific. T2 Tier 2.

¹¹¹ 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.

4.7.1.2 METHODOLOGICAL ISSUES

Input data for the calculation of actual emissions consists of information from various sources; the Swedish Chemicals Agency, equipment producers and importers. Table 4.41 presents values for chemical charge, lifetime and emission factors for the applications used in the Swedish inventory. They are based on information from the equipment producers and IPCC default values. In the recent SMED study¹¹², 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.

Table 4.41. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of HFCs or PFCs used in calculations of actual emissions in Sweden. Intervals given indicate changes between 1990 and the last inventory year used in the calculations.

Application	Fluorinated substances	Lifetime**	Amount installed /unit, kg	Emissions at manufacturing	Emissions per year during use	Remained in product at disposal	Emissions at disposal
Household fridges and freezers	HFCs	20	0.1	2%	1%	90%	5%
Heat pumps	HFCs	20→15	5→1	1%	10→1%	90%	5%
Other refrigeration and air conditioning equipment	HFCs PFC-218	15	*	3.5	7→3.6%	90%	5%
Refrigerated transport	HFCs	10	10→6	4.5%	30→7%	90%	15%
Mobile air-conditioning, lorries	HFCs	6	1.2	1%→0.5%	15→10%	90%	15%
Mobile air-conditioning, cars	HFCs	11	0.8→0.7	1%→0.5%	15→7.5%	90%	15%
Mobile air-conditioning, buses	HFCs	12	7	1%→0.5%	10%	90%	15%

* 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 source "other stationary refrigeration". The

¹¹² 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.

chemicals concerned are HFC-23, HFC-32, HFC-125, HFC-134a, HFC-143a, HFC-152a and PFC-218 (C₃F₈). In addition, it was discovered in the recent SMED study that imported air-air heat pumps were prefilled with the refrigerant (R410A), and thus not included in the bulk import statistics from the Swedish Chemicals Agency.

Due to that data are derived from source-independent national statistics in the Product Register, as well as from some end users, it is currently impossible to correctly fill in the CRF background data table asking for domestic, commercial and industrial applications. Consequently, industrial refrigeration as well as stationary air-conditioning have been reported as included elsewhere (IE) and the emissions are included in commercial refrigeration in CRF table 2(II) F.

4.7.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The largest contribution to the total national emission uncertainty from this category stem from HFCs from mobile air conditioner and other refrigeration. Based on SMED expert judgement AD and EF uncertainty are $\pm 10\%$ and $\pm 40\%$ for mobile air conditioner, and $\pm 25\%$ and $\pm 50\%$ for other refrigeration.

Data in the category is of varying quality, but generally considered, by expert judgment, to be of medium quality and is usually better for the later years than for the earlier years of the inventory. The time-series are calculated using the same methodology for all years and are thus considered to be consistent.

4.7.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Estimates have been checked with trade associations KYS (Kylbranschens Samarbetsstiftelse) and SVEP (Svenska Värmepumpföreningen) and with experts at the Swedish EPA¹¹³. 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.

As HFCs from mobile air-conditioning in cars is the most influential sub-source in the category, its underlying factors are compared to IPCC default values and differences are analysed (Table 4.42). The values for car air-conditioner life-time, charge and annual leakage were chosen based on information in IPCC Guidelines and Good Practice Guidance. The values for EF for production, remaining at decommissioning and share recovered are attained from the Swedish car manufacture Volvo and in cooperation with experts at the Swedish EPA.

¹¹³ Swedish EPA . Ujfalusi, Bernekorn , and Björsell. Personal communication.

Table 4.42. Comparison of IPCC default factors and Swedish factors for MAC in cars.

Parameter	1996 IPCC/ update GPG	Swedish factors	Comment
Lifetime (y)	12/12	11	OK
Charge (kg)	0.8	0.8	OK
Annual leakage (%/year)	10-30/10-20	15-10	OK
EF _{production} (%)	4-5/0.5	1-0.5	OK
Remaining at de- commissioning (%)	75/40	90	High; We assume that there is continuous maintenance and refilling of the equip- ment
Share recovered (%)	0/0	85	OK according to ex- perts at Swedish EPA

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 2009 were updated. It mainly affected emissions of HFC-134a and HFC-152 in commercial refrigeration and in total, emissions was reduced about 10 Gg CO₂ equivalents.

2.IIA.F.1.2 Commercial Refrigeration:

- New information on heat pumps was collected in the recent SMED study enabling the model to deduct the proper amounts of chemicals for heat pumps from the overall bulk import statistics, and thus reallocate some amounts of chemicals to/from other stationary refrigeration. It resulted in minor changes of HFCs emissions all years of about $\pm 1-5$ Gg CO₂ equivalents.
- In addition, some errors in the calculations were corrected. Previously exported chemicals were erroneously included in the bulk import statistics 2005-2009. The correction resulted in reduced emissions of 5-10 Gg CO₂ equivalents.

2.IIA.F.1.6 Mobile Air-Conditioning:

In the previous submission, emissions of HFC-134a from non-refill containers were calculated for 1998-2009. As non-refill containers of HFC-134a have not been used in Sweden since 2006 due to new legislations recalculations have been performed for 2007-2009. This recalculation resulted in reduced emissions of HFC-134a of 11-32 Gg CO₂ equivalents.

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 (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 applicable (NA). Emissions of HFCs peaked in year 2000 and has since 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 4.43.

Table 4.43. Summary of source category description, CRF 2.F.2.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.F.2	HFCs				CS	PS	Yes
	PFCs				NA	NA	NA
	SF ₆				NA	NA	NA

CS Country Specific. PS Plant-specific.

4.7.2.2 METHODOLOGICAL ISSUES

Data is obtained from the producer on the used amount of HFC-134a and HFC-152a, emissions at production as well as the exported amount of chemicals in products each year. The use of HFCs in this application started in 1996. The company has also provided algorithms to calculate leakage of HFC-134a and HFC-152a during the product lifetime (Table 4.44).

Table 4.44. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of HFCs used in calculations of actual emissions in Sweden.

Application	Fluorinated substances	Lifetime**	Amount installed /unit, kg	Emissions at manufacturing	Emissions per year during use	Remained in product at disposal	Emissions at disposal
Foam blowing (XPS)	HFCs	> 12	*	35%	Declining	\$	<76%***

* Top-down calculations

** Lifetime means the average expected lifetime of a product, not the 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 leached from the prod-

ucts. Beside annual losses from products over time, the reported Swedish emissions in the CRF tables contain emissions from manufacturing.

More detailed information on the methodological issues for foam blowing is presented in Annex 3:4.

4.7.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

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 2 method given in the Good Practice Guidance, see Annex 3:4.

4.7.2.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

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 extinguishers (2.F.3)

4.7.3.1 SOURCE CATEGORY DESCRIPTION

HFC may be used as extinguishing medium in fixed fire extinguishing systems. In Sweden, emissions of HFCs from fire extinguishers are reported since 1997. Emissions of PFCs and SF₆ for the category are not applicable (NA).

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.45.

Table 4.45. Summary of source category description, CRF 2F3.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2F3	HFCs				CS	CS	Yes
	PFCs				NA	NA	NA
	SF ₆				NA	NA	NA

CS Country Specific.

4.7.3.2 METHODOLOGICAL ISSUES

All imports of HFCs to be installed in fire extinguishers are registered at the Swedish Chemicals Agency. From 2001, the use of HFC-227ea in fire extinguishers has been introduced in Sweden. Data has been obtained from the companies supplying such systems (Table 4.46).

Table 4.46. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of HFCs used in calculations of actual emissions in Sweden.

Application	Fluorinated substances	Lifetime**	Amount installed /unit, kg	Emissions at manufacturing	Emissions per year during use	Remained in product at disposal	Emissions at disposal
Fire extinguishing	HFCs	30	*	0.5%	2% / 0.1%***	95%	1%

* Top-down calculations

** Lifetime means the average expected lifetime of a product, not the designed technical lifetime from its first commissioning.

*** HFC-227ea 0.1 %, other HFCs 2 %.

4.7.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties are mainly associated with the exported amounts, which are relatively large.

The time series are calculated using the same methodology for all years and are thus consistent.

4.7.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.7.3.5 SOURCE-SPECIFIC RECALCULATIONS

In the previous submission, emissions of HFC-227ea were erroneously reported as not applicable (NA) 2009. In this submission, about 0.1 Gg CO₂ equivalents were reported. In addition, emissions of HFC-134a and HFC-125 2005 were corrected due to new information on imported amounts of chemicals. It resulted in minor reduction of emissions (about 0.04 Gg CO₂ equivalents).

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/metered dose inhalers (2.F.4)

4.7.4.1 SOURCE CATEGORY DESCRIPTION

HFC may be used as propellant gas in aerosols, but also as the actual product e.g. in cleaning sprays. In asthma medication inhalers, HFC-134a (norflurane) is some-

times used as propellant gas. Emissions of PFCs and SF₆ for the category are not applicable (NA).

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.47.

Table 4.47. Summary of source category description, CRF 2.F.4.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.F.4	HFCs				CS, T2	D	Yes
	PFCs				NA	NA	NA
	SF ₆				NA	NA	NA

D Default. CS Country Specific. T2 Tier 2.

4.7.4.2 METHODOLOGICAL ISSUES

Emission estimates cover technical aerosols as well as metered dose inhalers. The estimates consist of emissions from production of technical aerosols at one facility, and emissions from the use of imported technical aerosols and metered dose inhalers containing HFCs. The contribution from metered dose inhalers is relatively small, but has increased in later years.

The aerosol manufacturer provided information on the used amount of HFC-134a as well as emissions from production, and exported amounts of HFC-134a in products. Table 4.48 present the assumptions on product lifetime, emissions at manufacturing and disposal as well as remaining HFC in product at disposal.

For metered dose inhalers, statistics on the numbers of sold inhalers was received from the Swedish retailer for medical products, Apoteket. Information concerning the content of HFC in the inhalers was provided by the Swedish Medical Products Agency.

Table 4.48. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of HFCs used in calculations of actual emissions in Sweden.

Application	Fluorinated substances	Lifetime**	Amount installed /unit, kg	Emissions at manufacturing	Emissions per year during use	Remained in product at disposal	Emissions at disposal
Aerosols/ MDI	HFCs	2	*	NA	50%	50%	100%

* Top-down calculations

** Lifetime means the average expected lifetime of a product, not the designed technical lifetime from its first commissioning.

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

Emissions of HFC-134a have been recalculated for 2007 and 2008 due to new information from the Swedish retailer for medical products, Apoteket, on medication inhalers containing norflurane. Emissions increased by about 0.5 Gg CO₂ equivalents.

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 (2.F.5)

Efforts have been made to find national information concerning this sub-category but it has so far not been possible to establish what amounts may be used. A few users were contacted and they provided information that their use of solvents containing PFCs is very limited or non-existent. The company that was said to sell the solvent in Sweden denied doing so. Emissions from solvents are consequently reported as NO, not occurring.

4.7.6 Other applications using ODS substitutes (2.F.6)

No other applications are covered in the Swedish inventory.

4.7.7 Semiconductor manufacture (2.F.7)

4.7.7.1 SOURCE CATEGORY DESCRIPTION

HFC, PFC and SF₆ are used in the semiconductor manufacturing process. Semiconductor manufacture has in recent years occurred on a commercial scale at only one facility in Sweden. Previously one more facility was located in Sweden, but production was moved abroad. During 2004 the production in the only facility left was also closed down.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.49.

Table 4.49. Summary of source category description, CRF 2.F.7.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.F.7	HFCs				T1	D	Yes
	PFCs				T1	D	Yes
	SF ₆				T1	D	Yes

D Default. T1 Tier 1.

4.7.7.2 METHODOLOGICAL ISSUES

Information concerning the annually used amounts of various fluorinated substances has been provided by the company, and as far as possible been compared to information from the Products Register at the Swedish Chemicals Agency. Emissions are calculated by using the Good Practice Guidance Tier 1 method (top-down calculations) using an average expected lifetime of 1 year.

4.7.7.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Emission estimates are judged to be of good quality. The quality of activity data is usually better for the later years than for the earlier years of the inventory. The time series are calculated using the same methodology for all years and are thus consistent.

4.7.7.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Cross-references with the Products Register at the Swedish Chemicals Agency could not be made for later years, since the level of detail in the Products Register was insufficient.

4.7.7.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed.

4.7.7.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.7.8 Electrical equipment (2.F.8)

4.7.8.1 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 applicable (NA) for this category.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.50.

Table 4.50. Summary of source category description, CRF 2.F.8.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2F8	HFCs				NA	NA	NA
	PFCs				NA	NA	NA
	SF ₆				CS, D	CS, PS	Yes

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

4.7.8.2 METHODOLOGICAL ISSUES

The larger part of annual SF₆ emissions in earlier years originated from the manufacture of GIS (Table 4.52), where emissions in 1995 and 1997 peak due to a leaking valve in 1995 and to rebuilding and accidental leakages in 1997. The 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 4.51), as well as the share of products that are exported from the country, which exceeds 90 % of the production.

Table 4.51. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of SF₆, used in calculations of actual emissions in Sweden. Intervals given indicate changes between 1990 and the last inventory year used in the calculations.

Application	Fluorinated substances	Lifetime**	Amount installed /unit, kg	Emissions at manufacturing	Emissions per year during use	Remained in product at disposal	Emissions at disposal
Electrical insulation and GIS manufacture	SF ₆	30	*	12→1.5 %	0.6→0.5 %	#	NA

* Top-down calculations

** Lifetime means the average expected lifetime of a product, not the designed technical lifetime from its first commissioning.

Estimated lifetime at least 30 years, NE.

Emissions from installed amounts of SF₆ for insulation purposes in operating systems have previously contributed less to the actual annual emissions. In 2001-2002, a questionnaire was sent out to power companies from the trade association Swedenergy¹¹⁴ (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 Mg and an annual leakage rate of 0.6 % (equals the amount replaced from the questionnaire) and these were used as input data in the inventory. For later years, data on replaced amounts of SF₆ in operating systems results in a calculated annual leakage rate of 0.5 % (Swedenergy and power distribution companies).

Table 4.52. Calculated emissions and accumulated stock of SF₆ for electrical equipment.

Year	Emissions from GIS manufacture SF ₆ Mg	Annual losses SF ₆ Mg	Accumulated stock Mg	Total emissions SF ₆ Mg
1990	3.0	0.4	65.7	3.4
1995	3.5	0.5	76.0	4.0
2000	0.7	0.6	107.9	1.3
2005	0.5	0.7	143.0	1.2
2006	0.2	0.7	148.7	0.9
2007	0.4	0.8	162.9	1.2
2008	0.3	0.9	173.4	1.2
2009	0.9	0.9	185.2	1.8
2010	0.3	1.0	202.6	1.3

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 (about 15-21 per cent). Sources of SF₆ emissions that are covered in the calculations are the use in semi-conductor manufacture, in production of sound-proof windows, in magnesium foundries, in the production of gas-insulated switchgear and as insulation in electrical equipment. Information from the Products Register did not indicate that any areas of use have not been covered and are missing from the calculations.

For all sources, except as insulation in electrical equipment, the levels of annual 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

¹¹⁴ Swedenergy. Matz Tapper. Personal communication. 2005.

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).

4.7.8.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The quality of activity data is usually better for the later years than for the earlier years of the inventory. The time series are calculated using the same methodology for all years and are thus consistent.

4.7.8.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.7.8.5 SOURCE-SPECIFIC RECALCULATIONS

Due to updated information from the Swedish producer of gas-insulated switch-gear, a minor recalculation of SF₆ emissions 2009 were carried out (emissions were reduced about 2 Gg CO₂ equivalents).

4.7.8.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.7.9 Other (2.F.9)

4.7.9.1 SOURCE CATEGORY DESCRIPTION

The estimated emissions from the use of SF₆ in jogging shoes and in sound-proof windows are reported in CRF 2.F.9. No production of SF₆-containing shoes occurs in Sweden.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 4.53.

Table 4.53. Summary of source category description, CRF 2.F.9.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
2.F.9	HFCs				NA	NA	NA
	PFCs				NA	NA	NA
	SF ₆				CS	CS, D, PS	Yes

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

4.7.9.2 METHODOLOGICAL ISSUES

For jogging shoes, a more or less rough estimate has been made. It has not been possible to obtain any national data, so a Norwegian estimate was scaled to the

Swedish population.¹¹⁵ According to the results from a study performed in early 2004¹¹⁶ a phasing out of SF₆ and replacement with PFC-218 was started in 2003. The lifetime for shoes is set to 8 years in the national model (Table 4.54).

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 4.54). These estimates vary considerably between manufacturers, from 5-50 %. The reason for the increase in emissions in later years is the lifetime and the associated time lag for emissions originating from disposal. Calculating a weighted average of the emission factor at production results in a national figure in the order of 30 %, which is in line with the point estimate of 33 % given in the Good Practice Guidance.

Table 4.54. Typical values on equipment lifetimes, amounts of chemical per unit and emission factors for different applications of PFCs or SF₆, used in calculations of actual emissions in Sweden. Intervals given indicate changes between 1990 and the last inventory year used in the calculations.

Application	Fluorinated substances	Lifetime**	Amount installed /unit, kg	Emissions at manufacturing	Emissions per year during use	Remained in product at disposal	Emissions at disposal
Sound proof windows	SF ₆	30	*	5-50%##	1%	#	NA
Jogging shoes	SF ₆ PFC-218	8	*	NA	NA	100%	25%

* Top-down calculations

** Lifetime means the average expected lifetime of a product, not the designed technical lifetime from its first commissioning.

Estimated lifetime at least 30 years, NE.

Different emissions at different production units.

4.7.9.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The quality of activity data is usually better for the later years than for the earlier years of the inventory. The time series are calculated using the same methodology for all years and are thus consistent.

4.7.9.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

4.7.9.5 SOURCE-SPECIFIC RECALCULATIONS

In the previous submission, actual emissions of PFCs from stocks of jogging shoes were reported as not estimated (NE) 2003-2009. Under the assumption that the emissions only occur during disposal of the jogging shoes (see Table 4.54), in submission 2012 the correct notation key not applicable (NA) has been applied.

¹¹⁵ Weholt, Ø. 1999. Materialströmsanalys av SF₆. Beräkning av potentiellt og faktisk utslipp over tid

¹¹⁶ Kindbom, K. and Skårman, T. 2004. Nya scenarier för fluorerade växthusgaser. U952, Swedish EPA.

4.7.9.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

4.8 Consumption of Halocarbons and SF₆ Potential Emissions (CRF 2.F.P)

4.8.1 Potential emissions

Data on bulk imports and exports are obtained from the Products Register hosted by the Swedish Chemicals Agency, which did not register these substances until 1995. Estimates of potential emissions for imports and exports were, however, made for all years in the time series, 1990-2004 in a special study in 2005¹¹⁷. The method of estimating potential emissions for the following years was made accordingly.

Due to the recurring one year lag of updating of the data from the Products Register from the Swedish Chemicals Agency, data on bulk import and export in 2009 are updated. This results in revised data on potential emissions for 2009.

4.9 Other, CRF 2G

Not applicable for Sweden.

¹¹⁷ Kindbom, K. 2005. Revision of Methodology and Estimated Emissions of Fluorinated greenhouse Gases in Sweden. Report Series SMED Nr 16 2005.

5 Solvent and other product use (CRF sector 3)

5.1 Overview of sector

This chapter describes emissions from solvents and other product use. Use of solvents and products containing solvents result in emissions of non-methane volatile organic compounds (NMVOC), which is regarded as an indirect greenhouse gas as it over a period of time will oxidise to CO₂ when emitted to the atmosphere.

Estimates reported in this sector include emissions from paint application (CRF 3A), degreasing and dry-cleaning (CRF 3.B), chemical products, manufacture and processing (CRF 3C) and other solvent use (CRF 3.D.5). Other use of N₂O (CRF 3D4) includes evaporative emissions of N₂O arising from other types of product use. This includes N₂O emissions from anaesthesia and aerosol cans.

Emissions of total greenhouse gases from the solvent and other product use sector (CRF 3) have decreased by 6 % from 332 Gg CO₂ equivalents in 1990 to 311 Gg CO₂ equivalents in 2010 (see Figure 5.1). The decline can largely be explained by a reduction in the use of solvents in CRF 3A (paint application) due to a shift to water-based paints, which contain a smaller fraction of solvents compared to solvent-based paints.

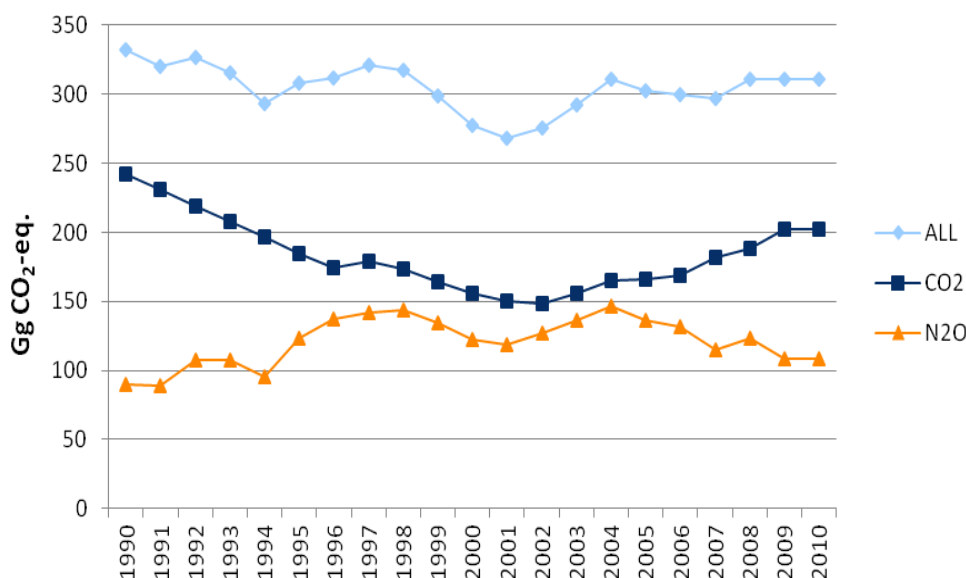


Figure 5.1. Total emissions of all greenhouse gases calculated as CO₂ equivalents from CRF 3 Solvent and Other product use.

CO₂ emissions in CRF 3A (paint application) have decreased by 67 % from 94 Gg CO₂ equivalents in 1990 to 31 Gg CO₂ equivalents in 2010 (Figure 5.2). The largest source of CO₂ emissions from solvents in CRF sector 3 is CRF 3D (other). CO₂

emissions in CRF 3D have increased by 23 % from 138 Gg CO₂ equivalents in 1990 to 170 Gg CO₂ equivalents in 2010.

CRF 3D (other) also consists of N₂O emissions from CRF 3D4 (other use of N₂O). The use of N₂O has increased with 20% from 90 Gg CO₂ equivalents in 1990 to 109 Gg CO₂ equivalents in 2010.

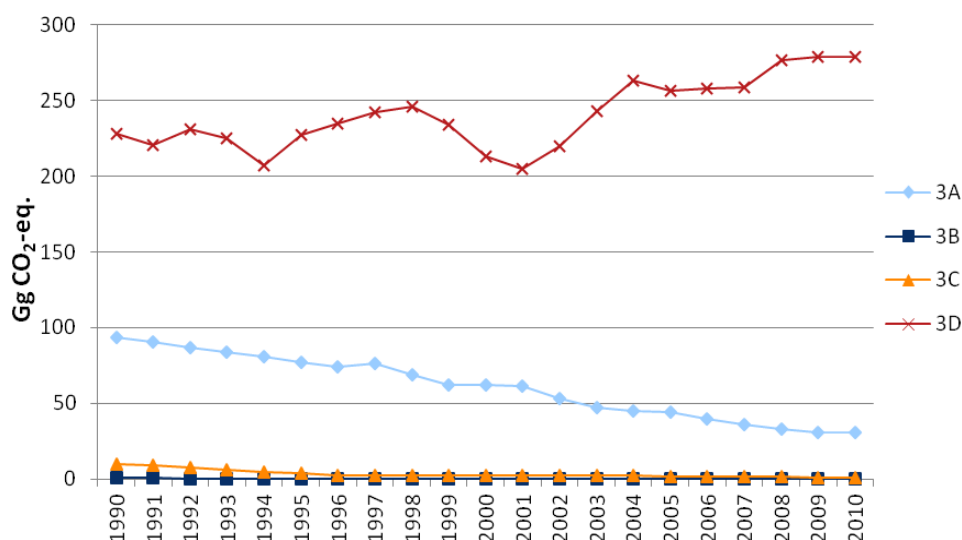


Figure 5.2. Total emissions of all greenhouse gases calculated as CO₂ equivalents from the different Solvent and Other product use sub-sectors. 3A - Paint application. 3B - Degreasing and dry-cleaning. 3C - Chemical products, manufacture and processing. 3D - Other.

Table 5.1 shows the impact of recalculations reported in submission 2012 for GHG emissions by sector and sub-sectors for 1990, 1995, 2000 and 2005-2009. Detailed descriptions of the recalculations are found under sector specific sections below.

Table 5.1. Impact of recalculations of GHG emissions submission 2012 in the Solvent and Other product use sector.

Impact of recalculations submission 2012 (Gg CO ₂ eq.)						
CRF	3A	3B	3C	3D	Total CRF 3	% CRF 3
1990	NA	NA	NA	NA	NA	NA
1995	NA	NA	NA	NA	NA	NA
2000	NA	NA	NA	NA	NA	NA
2005	0	NA	NA	0	0	0.0%
2006	0	NA	0	0	0	0.1%
2007	-3	0	0	14	11	3.8%
2008	-2	0	0	18	16	5.3%
2009	-5	0	0	21	16	5.3%

0: value less than 0.5 Gg. NA: no recalculation is performed.

The model used for estimating the CO₂ and NMVOC emissions reported in sector 3 is described in detail in Annex 3.3.

5.2 Paint application (CRF 3.A)

5.2.1 Source category description

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

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), are presented in Table 5.2.

Table 5.2. Summary of source category description, CRF 3A.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
3.A	CO ₂				CS	CS	Yes

CS Country Specific.

5.2.2 Methodological issues

All activity data from 1995 has been obtained from the Products register at the Swedish Chemicals Agency. Emissions from 1988 are taken from a time series that was compiled in a special study concerning NMVOC emissions, carried out by SMED in 2002¹¹⁸. The emissions for 1990-1994 have been interpolated based on the information from the late 1980's and known data for 1995.

5.2.3 Uncertainties and time-series consistency

The reported time series are considered to be consistent, except for last year (2010) where data for previous year (2009) has been reported. This procedure has been raised by the ERT several times. The reason of procedure is due to the fact that activity data from the Product Register is not official at the time data is needed to be able to perform the calculations and report in a timely manner.

5.2.4 Source-specific QA/QC and verification

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

5.2.5 Source-specific recalculations

Due to the recurring one year lag of updating of the data from the Product Register from the Swedish Chemicals Agency and the use of moving average for compiling the NMVOC and CO₂ time series in subsector 3A, the reported emissions for 2007 - 2009 were updated in submission 2012. A minor correction has been performed in the calculation model for emission year 2006 and consequently the reported emissions for 2004 - 2006 have been recalculated (Table 5.1).

¹¹⁸ Kindbom, K., Boström, C-Å., Skårman, T., Gustafsson, T. and Talonpoika, M. 2003. Estimated Emissions of NMVOC in Sweden 1988-2001.

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 Degreasing and Dry cleaning (CRF 3.B)

5.3.1 Source category description

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

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), are presented in Table 5.3.

Table 5.3. Summary of source category description, CRF 3B.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
3.B	CO ₂				CS	CS	Yes

CS Country Specific.

5.3.2 Methodological issues

All activity data from 1995 has been obtained from the Products Register at the Swedish Chemicals Agency. Emission data for 1988 is based on reported quantities of tetrachloroethylene from the Swedish Chemicals Agency. After 1995 also other substances for degreasing and dry cleaning are included. Of the total amount of NMVOC used within CRF 3B these “non tetrachloretylene” substances contribute approximately 30%. As not only tetrachloroethylene is included in the time series after 1995, the NMVOC emissions reported 1988 is recalculated using a correction factor based on the proportion of other NMVOCs of the total NMVOC for 1995 (tetrachloroethylene plus 30 %). Emissions between 1990 and 1994 have been interpolated based on the information from the late 1980’s and known data for 1995. The solvents used within CRF 3B includes a lower carbon share compared to the solvents used in the other sub-codes within CRF 3.

5.3.3 Uncertainties and time-series consistency

The reported time series are considered to be consistent, except for last year (2010) where data for previous year (2009) has been reported. This procedure has been raised by the ERT several times. The reason of procedure is due to the fact that activity data from the Product Register is not official at the time data is needed to be able to perform the calculations and report in a timely manner.

5.3.4 Source-specific QA/QC and verification

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

5.3.5 Source-specific recalculations

Due to the recurring one year lag of updating of the data from the Product Register from the Swedish Chemicals Agency and the use of moving average for compiling the NMVOC and CO₂ time series in subsector 3B, the reported emissions for 2007 - 2009 are updated in submission 2012 (Table 5.1).

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 Chemical products, Manufacture and Processing (CRF 3.C)

5.4.1 Source category description

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

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), are presented in Table 5.4.

Table 5.4. Summary of source category description, CRF 3C.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
3.C	CO ₂				CS	CS	Yes

CS Country Specific.

5.4.2 Methodological issues

The category includes emissions from car manufacturing, paint industry and from rubber industry. Emissions from car manufacturing contribute by approximately 50%, paint industry by 30 % and rubber industry by 20 % of the reported emissions in CRF 3C. Emission data for car manufacturing has been compiled from environmental reports for 1990 and data for 1991-1994 has been interpolated. For paint industry emission data for 1990-1994 has been taken from the old time series given in a special study concerning NMVOC emissions, carried out by SMED in 2002¹¹⁸. Emission data for the rubber industry is known for 1988¹¹⁸ and data for 1990-1994 have been interpolated based on the information from the late 1980's and known data for 1995.

5.4.3 Uncertainties and time-series consistency

The reported time series are considered to be consistent, except for last year (2010) where data for previous year (2009) has been reported. This procedure has been raised by the ERT several times. The reason of procedure is due to the fact that

activity data from the Product Register is not official at the time data is needed to be able to perform the calculations and report in a timely manner.

5.4.4 Source-specific QA/QC and verification

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

5.4.5 Source-specific recalculations

Due to the recurring one year lag of updating of the data from the Product Register from the Swedish Chemicals Agency and the use of moving average for compiling the NMVOC and CO₂ time series in subsector 3C, the reported emissions for 2007 - 2009 were updated in submission 2012. New activity data has been obtained from the Swedish Chemicals Agency for emission year 2008 concerning rubber industry and consequently emissions for 2006-2008 have been recalculated (Table 5.1).

5.4.6 Source-specific planned improvements

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

5.5 Other (CRF 3.D)

5.5.1 Source category description

All data concerning solvents, NMVOC and CO₂, are reported in CRF 3D5. CRF 3D5 includes solvents sold to the printing industry, for preservation of wood, to leather industry and to textile industry. The code also includes solvents used by other industries not reported separately, and solvents for domestic use. In CRF 3D4 sold amounts and use of N₂O are reported. Due to confidentiality, data for 3D1 - Use of N₂O for Anaesthesia and 3D3 - N₂O from Aerosol cans cannot be reported separately.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), are presented in Table 5.5.

Table 5.5. Summary of source category description, CRF 3D.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
3.D	CO ₂				CS	CS	Yes
3.D	N ₂ O				CS	CS	Yes

CS Country Specific.

5.5.2 Methodological issues

Solvents used in printing industry, for preservation of wood, in leather industry and in textile industry have been estimated separately. The code also includes solvents used by other industries not reported separately, and also solvents for domestic use.

The printing industry contributes by 8 %, preservation of wood 1 %, leather and textile industry < 1 % and general solvent use 90 % of the total reported emissions in CRF 3D. Emission data for 1988 is known for most industries included in CRF 3D and in most cases the emissions for 1990-1994 have been interpolated based on information from the late 1980's and known data for 1995.

There are two companies in Sweden selling 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 - 2008). The time series of use of N₂O in Sweden are reported in Other use of N₂O (3D4) since no background data is available to separate between the source categories Use of N₂O for Anaesthesia (3D1) and N₂O from Aerosol cans (3D3). Consequently CRF codes 3D1 and 3D3 are both reported as IE. Activity data for the latest year, 2009, is not yet official and hence Sweden has chosen to report data from 2008 also for 2009. Data for 2009 will be updated in the next submission.

5.5.3 Uncertainties and time-series consistency

The reported time series are considered to be consistent, except for last year (2010) where data for previous year (2009) has been reported. This procedure has been raised by the ERT several times. The reason of procedure is due to the fact that activity data from the Product Register is not official at the time data is needed to be able to perform the calculations and report in a timely manner. The emissions for the printing industry have increased in later years due to introduction of two new solvent products.

5.5.4 Source-specific QA/QC and verification

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

5.5.5 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 3D4 for 2009 is updated in submission 2012.

Due to the recurring one year lag of updating of the data from the Product Register from the Swedish Chemicals Agency and the use of moving average for compiling the NMVOC and CO₂ time series in subsector 3D5, the reported emissions for 2007 - 2009 are updated in submission 2012 (Table 5.1). Minor corrections have been performed in the calculation model for CRF 3D5 Other, other non-specified use of solvents, for emission year 2004, 2005, 2008. The corrections affect the reported emissions from year 2002 - 2008. For printing industry new activity data has been obtained from the Swedish Chemicals Agency for emission year 2008 and consequently emissions for 2006 - 2008 have been recalculated.

5.5.6 Source-specific planned improvements

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

6 Agriculture (CRF sector 4)

6.1 Overview of sector

In sector four only emissions of nitrous oxide (N₂O) and methane (CH₄) are reported. Carbon dioxide emissions from agriculture are reported under other sectors. Carbon dioxide from working vehicles are reported in the energy sector and carbon dioxide from liming of agricultural land are reported in the LULUCF sector. Sweden's inventory includes emissions from enteric fermentation, manure management and agricultural soils. Rice cultivation, burning of savannas or burning of agricultural residues does 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 those remaining are growing larger. Livestock farmers predominately engage in milk production and the main crops grown in Sweden are grain and fodder crops.¹¹⁹ The decrease of agricultural land area has continued since Sweden joined the European Union in 1995 and the acreages of land for hay and silage has increased. Organic farming has increased from 3 % of the arable land area in 1995 to 16 % in 2009.¹²⁰

The total greenhouse gas (GHG) emissions from sector four have decreased by 13 % since 1990, from 9,065 Gg CO₂ equivalents to 7,873 Gg CO₂ equivalents (Figure 6.1). In Figure 6.2 the largest emissions in this sector are nitrous oxide from nitrogen circulation in agricultural land (CRF 4D).

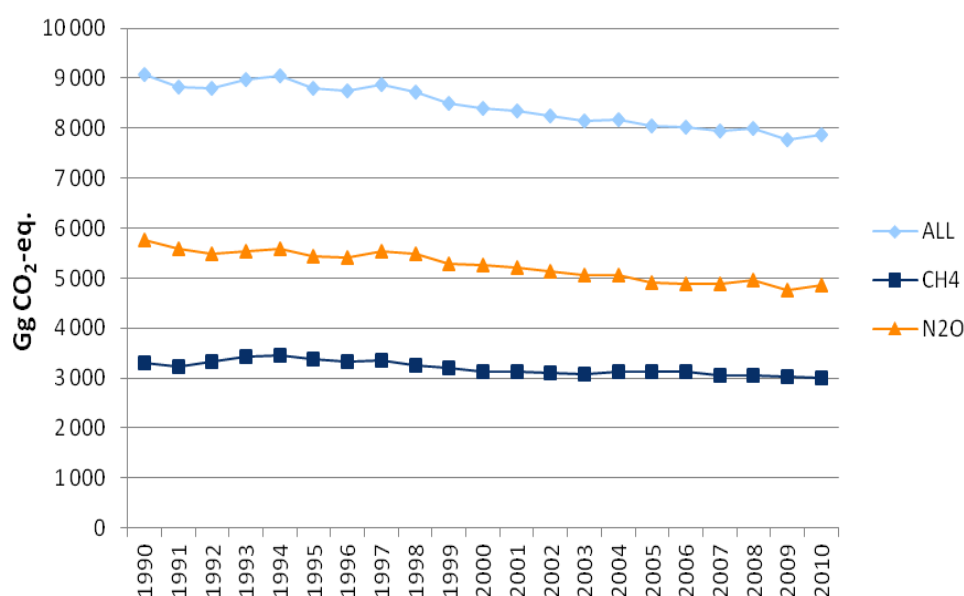


Figure 6.1. Total emissions of all greenhouse gases calculated as CO₂ equivalents from CRF 4 Agriculture.

¹¹⁹ Ministry of the Environment, 2001.

¹²⁰ Swedish Board of Agriculture, [www.jordbruksverket.se](http://jordbruksverket.se), <http://miljomal.nu>

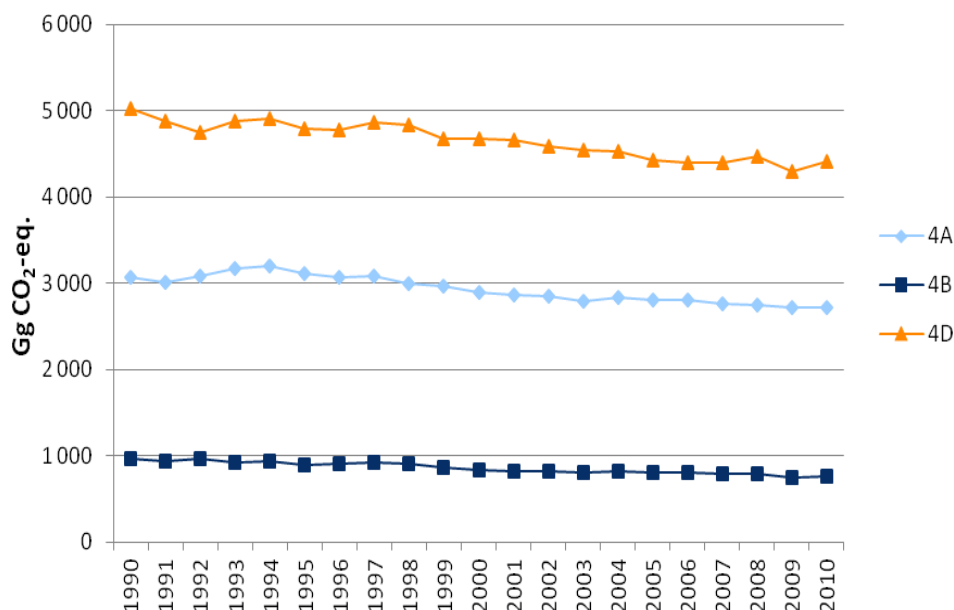


Figure 6.2 Total emissions of all greenhouse gases calculated as CO₂ equivalents from the different agricultural sub-sectors. There are no emissions from 4.C or 4.E-G.

Table 6.1 shows the impact of recalculations reported in submission 2012 for GHG emissions by sector and sub-sectors for 1990, 1995, 2000 and 2005-2009. The recalculations are mainly due to revised MCF for liquid manure and updated data for average nitrogen leaching from agricultural soils. More detailed descriptions of the recalculations are found under sector specific sections below.

Table 6.1. Impact of recalculations of GHG emissions submission 2012 in the agricultural sector.

Impact of recalculations submission 2012 (Gg CO ₂ eq.)								
CRF	4.A	4.B	4.D.1	4.D.2	4.D.3	4.D.4	Total CRF 4	% CRF 4
1990	12	-111	10	7	-90	0	-172	-1.9%
1995	12	-153	-15	7	-223	0	-372	-4.1%
2000	12	-145	-22	7	-91	0	-238	-2.8%
2005	15	-163	-30	9	-180	0	-348	-4.1%
2006	18	-156	-45	11	-195	-13	-379	-4.5%
2007	21	-160	-45	9	-175	-1	-351	-4.2%
2008	24	-152	-35	11	-153	16	-290	-3.5%
2009	27	-158	-35	12	-226	-42	-422	-5.2%

0: value less than 0.5.

Livestock is the main contributor to greenhouse gas emissions from agriculture. In Table 6.2 all the livestock subgroups used in the calculations are presented. Mink and foxes are minor contributors to greenhouse gas emissions and are not included in the inventory due to a lack of well-founded emission factors.

Table 6.2. Livestock subgroups used in the calculations.

Categories according to IPCC Guidelines	Sub-categories Enteric Fermentation	Sub-categories Methane from manure management	Sub-categories N ₂ O from manure management	Sub-categories N ₂ O from grazing animals
Dairy Cattle (**)	Dairy cows	Dairy cows	Dairy cows	Dairy cows
Non-Dairy Cattle (**)	Beef cows	Beef cows	Beef cows	Beef cows
	Other cattle	Growing animals (12-24 months)	Growing animals (12-24 months)	Growing animals (12-24 months)
		Calves > 6 months	Calves > 6 months	Calves > 6 months(*)
		Calves < 6 months	Calves < 6 months	Calves < 6 months(*)
Swine	Swine	Sows	Sows	NO
		Boars	Boars	
		Pigs for meat production	Pigs for meat production	
		Piglets	Piglets	
Sheep	Sheep	Sheep	Sheep	Sheep
Goats	Goats	Goats	Goats	Goats
Horses (***)	Horses	Horses	Horses	Horses
Poultry	Poultry	Poultry	Laying hens (**)	NO
			Chickens (**)	
			Slaughter Chickens (****)	
Other (*****)	Reindeer	NO	NO	Reindeer

(*) The age distribution of calves is accomplished by using standard values.

(**) Farm Register. (***) Statistics Sweden. (****) Swedish Poultry Meat Association. (*****) Sametinget (The Sami Parliament of Sweden).

The Farm Register provides the main basis for agricultural statistics in Sweden. The Register is administered by the Swedish Board of Agriculture and Statistics Sweden and provides annual information on the total number of animals of different categories on Swedish farms¹²¹. The information on livestock refers to the situation prevailing in mid-June of that year and thus is considered to be equivalent to a one-year average. Most of the information on livestock numbers comes from the Farm Register, but the distribution of calves (older and younger than 6 months respectively) is model-assisted: 60 % are assumed to be younger than 6 months and the rest are assumed to be over 6 months old.

Concerning horses, the Farm Register gives an underestimation of the number of horses because only horses on farms are included. I.e. not horses for leisure activities. However, a separate survey¹²² estimated total number of horses in Sweden in 2010 and 2004, these estimates are used in the calculations instead. The number of slaughter chickens (mean number of chickens kept during the year) is provided by the Swedish Poultry Meat Association. This estimate is generally higher than the

¹²¹ Swedish Board of Agriculture, JO 20-series.

¹²² Swedish Board of Agriculture, 2011

estimate given by the Farm Register, which on the other hand is considered to be too low.

6.2 Enteric Fermentation (CRF 4.A)

6.2.1 Source category description

The animal husbandry sub-sector is an important sector influencing GHG emissions from agriculture in Sweden. Livestock farming, including farmyard manure management, is the major source of CH₄ emissions. From the total emission of CH₄ about 85 % derives from enteric fermentation from cattle. The total numbers of livestock in Sweden in 1990-2010 are presented in Table 6.6 and Figure 6.3.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), are presented in Table 6.3.

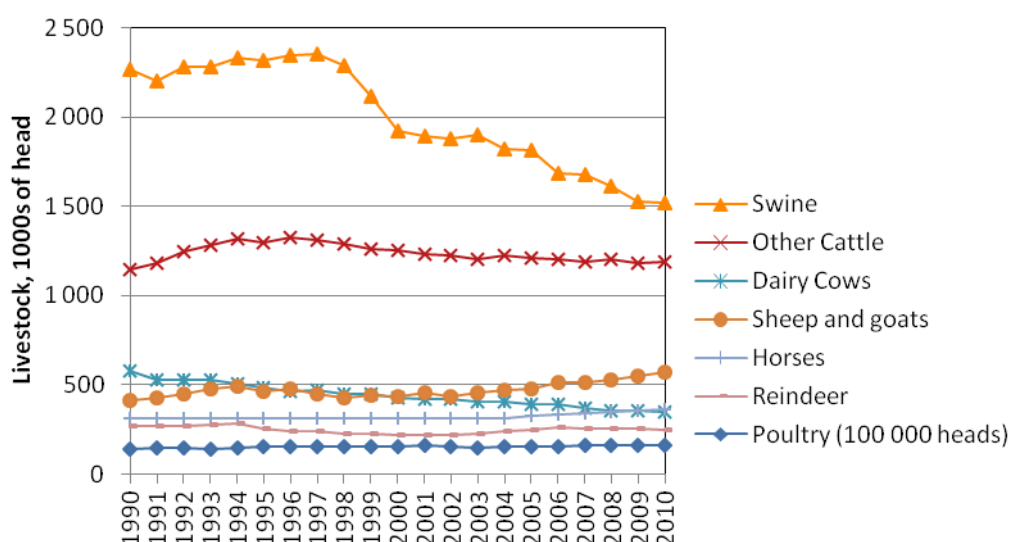


Figure 6.3. Livestock in Sweden 1990-2010, 1000s of head.

Table 6.3. Summary of source category description, CRF 4.A.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
4.A	CH ₄	X	X		CS, T1, T2	CS, D	Yes

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

6.2.2 Methodological issues

6.2.2.1 EMISSION FACTORS, METHANE

The livestock population (Table 6.6) in each category is multiplied by an emission factor and the total emission is calculated as:

$$emissions = \sum_i population_i * EF_i$$

Emission factors (EF_i) for the significant cattle subgroups are national. For reindeer, where the IPCC Guidelines do not provide default values, an emission factor is calculated according to the IPCC Guidelines methodology using a Finnish value of gross energy requirements.¹²³ For emissions from swine, sheep, goats and horses the IPCC default values are used. Statistics on livestock categories are presented in Table 6.2. A national methodology based on feed energy requirements expressed as metabolisable energy¹²⁴ is used in the Swedish inventory to estimate emission factors for dairy cows, beef cows and other cattle. For dairy cows during the lactation we first calculate the metabolisable energy (MJ/day) from the energy requirements for maintenance and lactation. The calculation steps for average milk production are given in Table 6.5. It is a weighted mean for cows included and not included in the official control activity. The metabolisable energy is then used to estimate digestible energy, and from this the emission of methane is calculated using the methane conversion rate.

The calculations for dairy cows were revised some years ago¹²⁵. The emission factors for other cattle groups were also re-evaluated, using the same methodology¹²⁵. The conclusion led to a decision to use the emission factor, 50 kg CH₄/head and year, a value close to the Good Practice Guidance default value for non-dairy cattle (48 kg CH₄/head and year). Due to the recommendation of the ERT during the in-country visit in Sweden in 2007, CH₄ emission factors for beef cows and reindeers were revised to 78.0 kg CH₄/head and year and 19.9 kg CH₄/head and year, respectively. The following is a review of the different stages in the calculation for dairy cows. Metabolisable energy (MJ/day) is calculated using the formula from Spörndly 1999:

Lactation period:

$$\text{Metabolisable energy (MJ/day)} = 1.11 \times (62 + \text{Milk Production/day} \times 5) - 13.6$$

Dry period:

$$\text{Metabolisable energy (MJ/day)} = 62 + 13$$

Metabolisable energy is then converted to digestible energy using the formula¹²⁶:

$$\text{Metabolisable energy (\% of digestible energy)} = 83.2 + 2.53 \times L - 0.045 \times G - 0.184 \times Rp$$

¹²³ Statistics Finland, 2007

¹²⁴ Lindgren, 1980; Murphy, 1992; Bertilsson, 2002.

¹²⁵ Bertilsson, 2001.

¹²⁶ Lindgren, 1980.

Methane conversion rate of digestible energy is calculated using the formula¹²⁷:

$$\text{Methane conversion rate (\% methane of digestible energy)} = 15.7 - 0.030 \times \text{SK} - 1.4 \times \text{L}$$

Where L is the total feed intake expressed as multiples of maintenance energy. G is the share of coarse feed and Rp is the crude protein content in the food expressed as percentage of total food consumption in dry matter (dm). SK is the digestibility of the feed (% of gross energy). All used constant for the different years are given in Table 6.4. Finally, the actual emission of methane is estimated with the formula:

$$\text{Emission of methane (Kg/day)} = (\text{Digestible energy} \times \text{Methane conversion rate}) / 55.65$$

The Swedish method resembles the one used by IPCC. The main difference is that Sweden uses metabolisable energy in the calculations as opposed to gross energy intake. Furthermore, the energy loss caused by methane emissions is calculated as a fraction of digestible energy. This fraction is in turn determined by total feed intake and digestibility of the feed. IPCC instead express energy in methane as a constant fraction of gross energy in feed.

Table 6.4. Constants used for estimating methane from dairy cattle.

Year	Dry cows				During lactation			
	L	G	Rp	SK	L	G	Rp	SK
1990	1.2	80.1	14	69	3.0	55	16	69
1995	1.2	80.1	14	69	3.2	55	16	69
2000	1.2	80.1	14	69	3.5	55	16	69
2005	1.2	80.1	14	69	3.5	55	16	69
2006	1.2	80.1	14	69	3.5	55	16	69
2007	1.2	80.1	14	69	3.5	55	16	69
2008	1.2	80.1	14	69	3.5	55	16	69
2009	1.2	80.1	14	69	3.5	55	16	69
2010	1.2	80.1	14	69	3.5	50	17	69

For the year 2010 this resulted in an emission of 393 g of methane per day for milk cows during the lactation period. The lactation period is estimated to 305 days per year. For cows during the non-lactation period the value does not change between years and is estimated to 201 g of methane per day. The final emission from milk cow per head and year is then calculated from the emission during the lactation and the non-lactation period.

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

¹²⁷ Lindgren, 1980.

For this we use the formulas:

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

Methane conversion rate (Y_m) = $CH_4/\text{head}/\text{year} \times 55.65 / (GE \times 365)$

The default values in the IPCC Guidelines are used for the less significant animal groups¹²⁸ and for these groups the development of a national emission factor has not been given priority. The emission factors used for dairy cattle and other animal groups are collected in Table 6.7.

Table 6.5. Number of dairy cows and average milk production.

Year	Dairy cows in country, number of head(*)	Dairy cows in the official control activity, number of head (**)	Produced milk per head in official control activity, kg/head/yr (**)	Produced milk per head, not in official control activity (**)	Average milk production per head, kg/yr (***)
1990	576 000	421 780	7 319	5 330	6 786
1991	528 000	388 860	7 376	5 280	6 824
1992	526 000	367 452	7 376	5 400	6 780
1993	525 000	376 126	7 740	5 600	7 133
1994	509 000	383 124	8 011	6 100	7 538
1995	482 000	390 146	8 083	6 200	7 724
1996	466 000	382 511	8 033	6 150	7 696
1997	468 000	380 760	8 209	6 250	7 844
1998	449 000	380 567	8 298	6 258	7 987
1999	449 000	378 623	8 377	6 300	8 051
2000	428 000	368 350	8 537	6 430	8 243
2001	418 000	360 364	8 742	6 627	8 450
2002	417 000	354 801	8 784	6 665	8 468
2003	403 000	346 133	8 794	6 750	8 506
2004	404 000	332 367	8 994	6 750	8 596
2005	393 000	332 367	8 994	6 750	8 648
2006	388 000	318 986	9 283	6 750	8 832
2007	369 646	298 865	9 412	6 750	8 902
2008	357 194	293 939	9 322	6 750	8 867
2009	356 776	285 246	9 486	6 750	8 937
2010	348 095	275 715	9 468	6 750	8 903

(*) Farm Register, (**) Swedish Dairy Association. (***) Calculated value.

¹²⁸ According to current estimations, "other animal groups" produce less than 10 % of the total methane that results from enteric fermentation.

Table 6.6. Population size of different animal groups (1000s heads).

Year	Dairy cows	Non-Dairy Cattle			Swine				Sheep		Horses	Goats		Other	Poultry		
	Dairy Cows	Beef Cows	Growing animals (12-24 months)	Calve	Sow (****)	Pig for meat production	Piglet	Boar	Sheep	Lamb	Horse (*)	Goat (***)	Kid (****)	Reindeer	Laying hen (*****)	Chicken	Slaughter Chicken (**)
1990	576	75	543	524	221	1 276	758	8.6	162	244	316	2.9	1.4	271	6 522	2 200	5 500
1991	528	98	543	537	219	1 239	736	8.3	168	251	316	3.2	1.6	271	6 222	2 600	5 833
1992	526	136	565	548	225	1 283	763	8.3	180	267	316	3.5	1.8	271	6 222	2 200	6 333
1993	525	154	549	581	241	1 272	756	7.9	189	282	316	3.5	1.8	280	5 922	1 900	6 333
1994	509	165	561	592	241	1 264	815	8.2	196	288	316	3.5	1.8	284	6 022	2 200	6 833
1995	482	157	596	542	237	1 300	768	7.6	195	266	316	3.5	1.8	253	6 222	1 800	7 083
1996	466	164	617	543	273	1 303	765	6.9	203	266	316	3.5	1.8	241	5 822	2 200	7 250
1997	468	169	614	530	269	1 313	764	5.8	195	247	316	3.5	1.8	239	5 822	1 900	7 833
1998	449	170	611	509	255	1 293	733	4.8	187	234	316	3.5	1.8	227	5 522	2 200	7 833
1999	449	165	600	499	220	1 239	651	4.2	194	244	316	3.5	1.8	227	5 722	2 200	7 833
2000	428	167	589	500	202	1 146	566	4.2	198	234	316	3.5	1.8	221	5 822	1 700	7 917
2001	418	166	573	494	212	1 089	586	3.9	208	244	316	3.5	1.8	221	5 822	1 700	8 708
2002	417	169	553	499	208	1 096	574	3.4	197	229	316	3.5	1.8	220	4 822	1 500	8 833
2003	403	165	527	512	204	1 127	567	3.9	210	238	316	3.7	1.8	229	4 622	1 500	8 668
2004	404	172	539	514	192	1 095	528	3.1	220	246	316	3.7	1.8	239	5 122	1 600	8 752
2005	393	177	527	508	185	1 085	538	2.7	222	249	323	3.7	1.8	251	5 222	1 700	8 387
2006	388	178	530	496	184	1 002	492	2.6	244	262	331	3.7	1.8	261	4 611	1 600	8 892
2007	370	186	516	489	179	1 015	480	2.5	242	267	339	3.7	1.8	255	5 428	1 753	8 925
2008	357	196	513	492	167	974	465	2.4	251	273	347	3.7	1.8	257	5 656	1 649	8 975
2009	357	192	502	488	158	943	426	2.4	254	287	355	3.7	1.8	252	5 381	1 898	8 533
2010	348	197	513	479	154	937	427	2.3	273	292	363	3.7	1.8	250	6 191	1 647	8 565

Most data from the Farm register, Swedish Board of Agriculture and Statistics Sweden. (*) Estimated number of horses 2010, by Statistics Sweden. (**) Swedish Poultry Meat Association. (***) Data on goats were available until 1992, this data have been extrapolated. (****) Between 1995 and 1996 there was an increase in number of sows by 13 %. The reason for this sudden increase is that as from this year also uncovered gilts are included in this group. (*****) Including a small fraction of turkeys.

Table 6.7. Methane from animals, used emission factors.

Livestock subgroups	Kg CH ₄ / head/year	Method
Dairy cows in 1990, average milk production 6786 kg/yr/head	120.3	1
Dairy cows in 2010, average milk production 8909 kg/yr/head	132,0	1
Beef cows	78	4
Growing animals (12-24 months)	50	4
Calves	50	4
Swine	1.5	2
Sheep	8	2
Goats	5	2
Horses	18	2
Poultry	No fermentation assumed	
Reindeer	19.9	2

(1) The emission factor is related to milk production and calculated from Spörndly, 1999 and Bertilsson, 2001.

(2) IPCC Guidelines. (3) Statistics Finland, 2007, Tier 2. (4) Bertilsson, 2001.

6.2.3 Uncertainties and time-series consistency

Between 1995 and 1996 there was an increase in the number of sows by 13 %. The reason for this sudden increase is that as from this year also uncovered gilts are included in this group. When no estimate on number of horses exists before 2004, this value is used for all preceding years. From 2010 there was a minor change in the values of the share of coarse feed and the crude protein content in dairy cow food (see Table 6.4).

6.2.4 Source-specific QA/QC and verification

The time series for the different populations and milk production is checked for consistency. Emission estimates and methods are reviewed yearly by external national experts.

6.2.5 Source-specific recalculations

The whole time series for number of horses has been updated with the results from a new survey carried out by the Swedish board of agriculture.

6.2.6 Source-specific planned improvements

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

6.3 Manure Management (CRF 4.B)

6.3.1 Source category description

Include emission of methane and nitrous oxide from manure management. The summary of the latest key category assessment, methods and EF used, and informa-

tion on completeness, i.e. if any sources are not estimated (NE), are presented in Table 6.8.

Table 6.8. Summary of source category description, CRF 4.B.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
4.B	CH ₄				T1, T2	CS, D	Yes
	N ₂ O	X	X		T1, T2	CS, D	Yes

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

6.3.2 Methodological issues

Statistics on manure management and the use of manure and fertilisers are collected biannually by Statistics Sweden¹²⁹. Data on stable periods (Table 6.9) and manure management systems (Table 6.10, Table 6.11 & Table 6.12) originate from this survey. Since dairy cows are often stabled at night and spend time in the stables during milking, the data on stable periods for this animal category is combined with an assumption that 38 % of its manure was produced in the stable during the grazing period. The Swedish Board of Agriculture publishes data on manure production from cattle and swine as well as on nitrogen production from most of the animal subgroups included in the inventory¹³⁰. Data on dairy cows for different levels of milk productivity are presented in Table 6.13. As productivity has increased during the reporting period, the data in Table 6.13 is used for interpolating an accurate mean value for each reporting year in the inventory. The values for manure production and nitrogen production in each of the other animal groups are given in Table 6.14 and Table 6.15, respectively. The data for manure and nitrogen production are estimated values per head, year and box. That is, the production if one hypothetically assumes that an animal of a specific animal category would stay in the box for a year. Total yearly production per animal category is then estimated by multiplying these values with number of animal in mid June according to the farm register. Naturally the number of animals in the different categories/age classes will vary somewhat during a year. However, we use the value from the farm register as an approximation of the annual average. Due to more intense swine production, the yearly production for sows and pigs for meat production were updated in 2001. All emission factors used in the calculations are presented in Table 6.16.

¹²⁹ Statistics Sweden, MI 30-series.

¹³⁰ Swedish Board of Agriculture, 1993; and Swedish Board of Agriculture, 2001; Swedish Board of Agriculture, 1995; Swedish Board of Agriculture, 2000. The given values are calculated according to the model STANK – the official model for input/output accounting on farm level in Sweden (Linder, 2001).

Table 6.9. Stable periods for cattle, months.

Year	Dairy cows	Beef cows	Steers and bulls	Heifers	Calves	Sheep, horses, goats	Rein-deer	Poultry, Swine
1990	7.2	6.2	7.6	6.5	7.8	6	0	12
1995	7.2	6.2	7.6	6.5	7.8	6	0	12
2000	7.2	5.8	7.6	6.1	7.6	6	0	12
2005	(*) 6.9	(*) 5.4	(*) 7.9	(*) 5.5	(*) 7.3	6	0	12
2006	6.9	5.4	7.9	5.5	7.3	6	0	12
2007	(*) 7.2	(*) 5.2	(*) 8.3	(*) 5.7	(*) 8.0	6	0	12
2008	7.2	5.2	8.3	5.7	8.0	6	0	12
2009	(*) 7.1	(*) 5.5	(*) 8.7	(*) 5.8	(*) 8.1	6	0	12
2010	7.1	5.5	8.7	5.8	8.1	6	0	12

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

Table 6.10. Waste management systems, fraction of liquid systems.

Year	Dairy cattle	Other cattle	Pigs for meat production	Other swine	Sheep, goats, horses, reindeer	Poultry
1990	0.23	0.17	0.44	0.44	0	0.25
1991	0.23	0.17	0.44	0.44	0	0.25
1992	0.23	0.17	0.44	0.44	0	0.25
1993	0.29	0.22	0.58	0.58	0	0.25
1994	0.29	0.22	0.58	0.58	0	0.25
1995	0.31	0.23	0.63	0.63	0	0.25
1996	0.31	0.23	0.63	0.63	0	0.25
1997	(*) 0.33	(*) 0.16	(*) 0.8	(*) 0.24	0	0.25
1998	0.33	0.16	0.8	0.24	0	0.25
1999	(**) 0.39	(**) 0.14	(**) 0.82	(**) 0.26	0	0.25
2000	0.39	0.14	0.82	0.26	0	0.25
2001	(***) 0.44	(***) 0.15	(***) 0.86	(***) 0.31	0	0.25
2002	0.44	0.15	0.86	0.31	0	0.25
2003	(****) 0.46	(****) 0.14	(****) 0.88	(****) 0.38	0	0.25
2004	0.46	0.14	0.88	0.38	0	0.25
2005	(*****) 0.50	(*****) 0.15	(*****) 0.87	(*****) 0.33	0	0.25
2006	0.50	0.15	0.87	0.33	0	0.25
2007	(*****) 0.55	(*****) 0.14	(*****) 0.94	(*****) 0.47	0	0.25
2008	0.55	0.14	0.94	0.47	0	0.25
2009	(*****) 0.58	(*****) 0.18	(*****) 0.94	(*****) 0.61	0	0.25
2010	0.58	0.18	0.94	0.61	0	0.25

(*) Statistics Sweden, 1998. (**) Statistics Sweden, 2000b. (***) Statistics Sweden, 2002b. (****) Statistics Sweden, 2004. (*****) Statistics Sweden, 2006. (*****) Statistics Sweden 2008, (*****) Statistics Sweden 2010. Other values are standard values, or interpolated /extrapolated.

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

Year	Dairy cattle	Other cattle	Pigs for meat production	Other swine	Sheep, goats	Reindeer	Horses	Poultry
1990	0.52	0.32	0.54	0.45	0.5	0	0.48	0.55
1991	0.52	0.32	0.54	0.45	0.5	0	0.48	0.55
1992	0.52	0.32	0.54	0.45	0.5	0	0.48	0.55
1993	0.46	0.27	0.40	0.31	0.5	0	0.48	0.55
1994	0.46	0.27	0.40	0.31	0.5	0	0.48	0.55
1995	0.44	0.26	0.35	0.26	0.5	0	0.48	0.55
1996	0.44	0.26	0.35	0.26	0.5	0	0.48	0.55
1997	0.41	0.33	0.17	0.65	0.5	0	0.48	0.55
1998	0.41	0.33	0.17	0.65	0.5	0	0.48	0.55
1999	0.35	0.31	0.18	0.67	0.5	0	0.48	0.55
2000	0.35	0.31	0.18	0.67	0.5	0	0.48	0.55
2001	0.31	0.26	0.13	0.58	0.5	0	0.48	0.55
2002	0.31	0.26	0.13	0.58	0.5	0	0.48	0.55
2003	0.27	0.24	0.11	0.51	0.5	0	0.48	0.55
2004	0.27	0.24	0.11	0.51	0.5	0	0.48	0.55
2005	0.23	0.20	0.05	0.44	0.5	0	0.48	0.55
2006	0.23	0.20	0.05	0.44	0.5	0	0.48	0.55
2007	0.20	0.22	0.06	0.41	0.5	0	0.48	0.55
2008	0.20	0.22	0.06	0.41	0.5	0	0.48	0.55
2009	0.16	0.20	0.05	0.32	0.5	0	0.48	0.55
2010	0.16	0.20	0.05	0.32	0.5	0	0.48	0.55

Table 6.12. Waste management systems, fraction of deep litter systems (categorised as “other” in the CRF-tables).

Year	Dairy cattle	Other cattle	Pigs for meat production	Other swine	Sheep, goats, reindeer	Horses	Poultry
1990	0.01	0.08	0.02	0.11	0	0.02	0.20
1991	0.01	0.08	0.02	0.11	0	0.02	0.20
1992	0.01	0.08	0.02	0.11	0	0.02	0.20
1993	0.01	0.08	0.02	0.11	0	0.02	0.20
1994	0.01	0.08	0.02	0.11	0	0.02	0.20
1995	0.01	0.08	0.02	0.11	0	0.02	0.20
1996	0.01	0.08	0.02	0.11	0	0.02	0.20
1997	0.01	0.08	0.02	0.11	0	0.02	0.20
1998	0.01	0.08	0.02	0.11	0	0.02	0.20
1999	0.01	0.09	0.01	0.07	0	0.02	0.20
2000	0.01	0.09	0.01	0.07	0	0.02	0.20
2001	0.00	0.12	0.01	0.12	0	0.02	0.20
2002	0.00	0.12	0.01	0.12	0	0.02	0.20
2003	0.01	0.14	0.01	0.11	0	0.02	0.20
2004	0.01	0.14	0.01	0.11	0	0.02	0.20
2005	0.01	0.16	0.01	0.22	0	0.02	0.20
2006	0.01	0.16	0.01	0.22	0	0.02	0.20
2007	0.01	0.17	0.00	0.12	0	0.02	0.20
2008	0.01	0.17	0.00	0.12	0	0.02	0.20
2009	0.01	0.16	0.01	0.07	0	0.02	0.20
2010	0.01	0.16	0.01	0.07	0	0.02	0.20

Table 6.13. Manure and nitrogen production from dairy cows.

Animal groups	Manure kg dm/day/head	Nitrogen kg/year/head
Dairy Cows (Milk production 6,000 kg/yr)	5.75	97
Dairy Cows (Milk production 8,000 kg/yr)	6.07	117
Dairy Cows (Milk production 10,000 kg/yr)	6.19	137

Table 6.14. Manure production from other animal groups.

Animal groups	Manure production, kg dm/day
Beef cows (*)	2.64 (in stable); 3.64 (during grazing)
Growing animals (12-24 months)	2.6
Calves > 6 months	1.12
Calves < 6 months	0.69
Sows	0.74 (1990-2001); 0.793 (as from 2002)
Boars	0.52
Pigs for meat production	0.42
Piglets	0.05

Swedish Board of Agriculture, 1993. Swedish Board of Agriculture, 1995. Swedish Board of Agriculture, 2001.

Table 6.15. Nitrogen production from other animal groups.

Animal groups	Nitrogen kg/year/head, 1990-2001	Comment	Updated values on nitrogen prod. used for 2002 - 2008, kg/ year/head	Comment
Beef cows	63			
Growing animals 12-24 months	47			
Calves > 6 months	28			
Calves < 6 months	28			
Sows	18.5		22.5	
Boars	13			
Pigs for meat pro- duction	9.5	2.5 prod. cycles/ year	10.8	3 prod. cycles / year
Piglets	0.5		0.5	
Sheep	13	Ewes incl. 1.5 lambs		
Lambs	0			
Goats	13	Does incl. 1.5 kids		
Kids	0			
Horses	50	Mean value for all animals		
Laying hens and turkeys	0.64			
Chickens	0.28	2.5 prod. cycles/ year		
Slaughter Chickens	0.29	6.5 prod. cycles/ year		
Reindeer*	10			

Values are calculated according to the STANK model (Swedish Board of Agriculture)

* Data from Statistics Finland

Table 6.16. Emission factor manure management

Manure management	Emission factor for CH ₄	
MFC solid manure(*)	1 % of B ₀	1
MFC liquid manure(*)	3.5 % of B ₀	5
MFC deep litter(*)	39 % of B ₀	1
Dairy Cattle - volatile solid (VS)	1 937 kg VS/animal/yr	3
Dairy Cattle - B ₀ (**)	0.24 m ³ CH ₄ /kg VS	1
Dairy Cattle - Emission per animal	16 kg CH ₄ /animal/yr	7
Non-Dairy Cattle – volatile solid (VS)	625 kg VS/animal/yr	3
Non-Dairy Cattle – B ₀	0.17 m ³ CH ₄ /kg VS	1
Non-Dairy Cattle – emission/animal (***)	5.6 kg CH ₄ /animal/yr	4
Swine – volatile solids (VS)	110 kg VS/animal/yr	3
Swine - B ₀ **	0.45 m ³ CH ₄ /kg VS	1
Swine – emission per animal (***)	3 kg CH ₄ /animal/yr	4
Sheep – emission	0.19 kg CH ₄ /animal/yr	1
Goats – emission	0.12 "	1
Horses – emission	1.40 "	1
Poultry – emission	0.08 "	1
Manure management	Emission factor for N ₂ O	Note
Waste Management System	% N ₂ O-N of N-supply	
Liquid manure	0.1	1
Solid manure	2	1
Deep litter	2	1

(*)MCF = Methane Conversion Factor. (**) B₀ = maximum methane producing capacity for manure. (***) Weighted value – more than one animal category. (1) IPCC Guidelines. (2) National, Dustan 2002. (3) National – STANK. (4) Calculated – 2002. (5) National, Rodhe et al. 2008.

6.3.2.1 4.B(a). METHANE (INCLUDING EXCRETION FROM GRAZING ANIMALS)

The Good Practice Guidance Tier 2 methodology for estimating methane from manure management, including excretions from grazing animals, is applied for cattle and swine, and the corresponding Tier 1 methodology is used for other animal groups¹³¹. The formula for the emission factor for livestock group “i”, according to the Good Practice Guidance Tier 2 methodology is:

$$emissionfactor_i = VS_i * B_{0i} * 0.67 * \sum_{jk} MCF_{jk} * MS_{ijk}$$

where VS_i is the volatile substance excreted per year, B_{0i} is the maximum methane producing capacity for manure produced by an animal within the livestock group, MCF_{jk} is a conversion factor for methane production, given a manure management

¹³¹ According to current estimations, cattle and swine produce about 85-90% of the total methane emissions from manure management.

system j, where grazing animals are considered as one of the systems, and a climate region k. MS_{ijk} is the fraction of animal manure handled using manure system j in climate region k.

The B_{0i} and MCF factors used are the default values in the Good Practice Guidance, except for the revised MCF for liquid manure, where the value of 3.5 % is used. This value was developed by Rodhe et al. 2008 and is considered to be more appropriate for Swedish conditions. The values reported in the CRF tables are sometimes aggregated after the calculation has been carried out for more specific animal groups. Hence the implied emission factor for “other cattle” will depend not only on different manure management systems and stable periods over the years, but also on the relative composition of the different subgroups. The implied emission factor therefore varies between the reported years.

The Swedish Board of Agriculture provides data from a national database on manure production from cattle and swine¹³². Information on waste management systems is collected from the surveys published in the biannual statistical report on the use of fertilisers and animal manure in agriculture¹³³ and the interpolated values are used for the intermediate years. Three manure management systems are considered apart from grazing animals: liquid systems (Table 6.10), solid storage (Table 6.11) and deep litter (Table 6.12) (sometimes categorised as “other” in the national inventory). National estimates of stable periods for cattle are collected from the statistical report on use of fertilisers and animal manure in agriculture¹³⁴. This information has been available biannually since 1997. Before 1997, the data are extrapolated to 1990. When looking on the trends for the implied emission factor (IEF) there is a distinct increase for both non-dairy and dairy cattle. For non-dairy cattle this is caused by a decreased use of solid manure systems and an increased use of deep litter systems, which has a higher methane conversion factor. For dairy cattle the use of solid systems has also decreased but here the use of liquid systems has increased instead.

6.3.2.2 4.B(b). NITROUS OXIDE

The methodology for estimating N_2O from manure management is in accordance with the IPCC Guidelines Tier 2 methodology; it is based on emission factors from the IPCC Guidelines in combination with national activity data. The emissions from different manure management systems are calculated as:

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

where N_T is the number of head of livestock in category T in the country, NEX_T is the annual average excretion of N per head of category T in the country, $GrazPe-$

¹³² Swedish Board of Agriculture, 1993. Swedish Board of Agriculture 1995. Swedish Board of Agriculture 2001. The given values are calculated according to the model STANK – “Stallgödselnäring i kretslopp” the official model for input/output accounting on farm level in Sweden (Linder, 2001). STANK is currently being evaluated in a study launched by The European Commission.

¹³³ Statistics Sweden, MI 30-series.

¹³⁴ Statistics Sweden, MI 30-series.

riod_T is the grazing period in days for livestock category T, $\text{MS}_{(T,S)}$ is the fraction of total annual excretion for each livestock category T managed in manure management system S in the country. For Dairy cattle the time spent in the stable at nights and for milking during grazing is excluded from GrazPeriod.

Data on nitrogen production has been derived by the Swedish Board of Agriculture (Table 6.13, Table 6.14 and Table 6.15). Stable period and manure management systems are the same as used in the methane calculations (Table 6.9, Table 6.10, Table 6.11 and Table 6.12).

The emission factors are described in Table 6.17. In the CRF tables, where some animal subgroups are aggregated, the implied emission factors (IEFs) may change over the years, depending on the relative size of the respective subgroups aggregated.

6.3.3 Uncertainties and time-series consistency

Due to more intense swine production, the nitrogen production for sows and pigs for meat production were updated in 2002.

6.3.4 Source-specific QA/QC and verification

Activity data are checked for consistency. Emission estimates and methods are reviewed yearly by external national experts.

6.3.5 Source-specific recalculations

The MCF for liquid manure has been revised. A study by Rodhe et al. 2008 investigated the emissions of methane and nitrous oxide from cattle slurry storage. This report in English is a summary of a more detailed report available only in Swedish. In another survey the same authors examined emissions from swine slurry. This confirmed the results for cattle when the emissions from swine and cattle were similar. In submission 2012 this new knowledge is applied in the inventory and the MCF for cattle and swine is revised to 3.5 %. This is a conservative interpretation of the results from the surveys that generally showed on an even lower value. The EF for nitrous oxide was not changed although the surveys indicated that the used EF also is too high. However, the survey showed on large variation and no ensured result could be concluded.

The whole time series for number of horses has been updated with the results from a new survey carried out by the Swedish board of agriculture.

The whole time series for number of slaughter chickens has been updated due to an updated estimation method.

6.3.6 Source-specific planned improvements

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

6.4 Agricultural Soils (CRF 4.D)

Emissions of nitrous oxide from agricultural soils are presented under CRF 4.D.1 to CRF 4.D.4. When the subsectors represent relatively different processes they are divided in separate paragraphs and also treated independently in the key categories analyses. Table 6.17 gives an overview of all emission factors used in this sector.

Table 6.17. Emission factor for N₂O from soils

Direct emissions from soils	Emission factor % N ₂ O-N of N-supply	Note
Mineral fertiliser	0.8	1
Manure	2.5	1
Crop residue	1.25	2
N-fixing Crops	1.25	2
Manure during grazing	2	2
Background emission due to cultivation	Kg N ₂ O-N/ha/yr	
Cultivation of Histosols	8	2
Cultivation of Mineral Soils	0.5	1
Indirect emissions from soils		
Deposition of N from Swedish agriculture	1 % of emitted N	2
Leached nitrogen	2.5 % of leaching	2

(1) National, Klemedtsson, 2001. (2) IPCC Guidelines.

6.4.1 Direct Soil Emissions (CRF 4.D.1)

6.4.1.1 SOURCE CATEGORY DESCRIPTION

The category includes the direct emission of nitrous oxide from soils. In terms of magnitude the most important emissions are from animal manure applied to soils followed by cultivation of histosols and from the use of synthetic fertilisers, respectively. Also included in this category are emissions from nitrogen fixing crops and crop residues. In this category Sweden also includes emission from sewage sludge used as fertilisers. The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), are presented in Table 6.18.

Table 6.18. Summary of source category description for the entire category CRF 4.D.1.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
4.D.1	N ₂ O	X	X		CS, T1, T1a, T1b, T2	CS, D	Yes

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

6.4.1.2 METHODOLOGICAL ISSUES

6.4.1.2.1 *Emission factors*

For estimating direct soil emissions, the Good Practice Guidance encourages parties to use country-specific emission factors for N₂O from agricultural fields, where possible. A suggested alternative is to use factors from other countries with comparable management and climatic conditions. In order to update the information from research, a literature study was carried out, requested by the Swedish EPA¹³⁵. The study includes documented N₂O emission measurements carried out in Sweden and in other countries in northern Europe and in Canada. The results show that there is limited data available. It was for example not possible to develop different emission factors for added nitrogen to mineral or organic soils. Best data availability was found for the use of synthetic fertilisers on mineral soils. Here the emissions of N₂O-N were between 0 and 0.8 % of added nitrogen. However, when the emissions are caused by other processes than newly added fertiliser, a correlation between added nitrogen and emitted nitrogen was not always apparent. For example, the amount of fertiliser used on cereals did not affect the magnitude of emitted N₂O. Thus, a method was suggested where the emissions are divided into two parts, one is dependent on fertiliser use and the other is a constant background emission. When the use of synthetic fertiliser on grass lands increased the emissions with some 0.8 % of added nitrogen an emission factor of 0.8 % was suggested for the use of synthetic fertiliser on all agricultural land. A lower value than the IPCC Good Practice Guidance default value of 1.25 % for mineral fertiliser nitrogen has also been suggested in a synthesis of literature data¹³⁶. The background emission from mineral soils was suggested to be 0.5 kg N₂O-N/ha/year (section 6.4.4). For the use of animal manure the study concluded that there are even less data available and the emissions according to different surveys varied between 0.6 % and 8 % of added nitrogen. Using a regression model an emission factor of 2.5 % was suggested. The study also suggested country specific emission factors for background emission from organic soils and from indirect emissions of N₂O from atmospheric deposition and nitrogen leaching. These emission factors were however not adopted in the inventory as they were considered to be too unreliable. Instead IPCC default factors were used. A summary of all emission factors applied for 4.D is given in Table 6.17.

6.4.1.2.2 *Emission of ammonia*

The calculations of ammonia emissions from the agricultural sector are mainly built on data collected through Statistics Sweden's field investigation among farmers. The calculation methods have been developed by the Swedish EPA and Statistics Sweden in collaboration with the Swedish Board of Agriculture and the Swedish Institute of Agricultural and Environmental Engineering¹³⁷. The calculations

¹³⁵ Klemedtsson, 2001.

¹³⁶ Løgreid and Aastveit, 2002.

¹³⁷ Swedish Environmental Protection Agency 1997

have been made by Statistics Sweden since 1990 at national and regional levels. Regional results are published from 2005 at the web-site of Statistics Sweden¹³⁸. The results from 1990-1994 are not comparable with these from 1995-2007, due to changed questionnaire in Statistics Sweden's field investigation among farmers and updated methods for calculating the emissions.

In short the calculations are made as follows:

$$\begin{aligned} A &= (V + L + S) \\ V &= D \times N \times P \times F(v) \\ L &= D \times N \times P \times (1 - F(v)) \times F(l) \\ S &= D \times N \times P \times (1 - F(v)) \times (1 - F(l)) \times F(s) \end{aligned}$$

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)

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 animal¹³⁹

N = production of nitrogen, kg, per type of animal, year and handling¹⁴⁰

P = stable period¹⁴¹

F(v) = emission of nitrogen through stable ventilation, % of total nitrogen content in stable manure¹⁴².

F(l) = emission of nitrogen during storing, % of total nitrogen content in stable manure after ventilation losses¹⁴³.

F(s) = emission of nitrogen during spreading, % of ammonium nitrogen content in stable manure after ventilation and storing losses¹⁴⁴.

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 farmers¹⁴⁵. Ventilation-, storage- and spreading-losses originate from a data calculating program (called STANK) from Swedish Board of Agriculture and from Swedish Institute of Agricultural and Environmental Engineering., Table 6.20 and Table 6.21 give an overview of the emission factors used in the calculations.

¹³⁸ Statistics Sweden 2007

¹³⁹ Swedish Board of Agriculture 2008 and other sources

¹⁴⁰ Swedish Board of Agriculture 1995; Swedish Board of Agriculture 2000; Swedish Board of Agriculture 2001

¹⁴¹ Statistics Sweden 2008

¹⁴² Swedish Board of Agriculture 2005

¹⁴³ Swedish Institute of Agricultural and Environmental Engineering 2002

¹⁴⁴ Swedish Institute of Agricultural and Environmental Engineering 2002

¹⁴⁵ Statistics Sweden, 2008

Table 6.19. Nitrogen losses caused by ventilation in stables, % of Total-N.

Type of animal	Solid-manure	Deep litter	Liquid manure	Semisolid manure	Urine
Cattle	4	20	4	4	4
Swine	10	25	14	10	10
Laying hens	10	35	10		
Chickens	10	20	10		
Slaughter chickens			10		
Horses	4	15			
Sheep	4	15			

Table 6.20. Nitrogen losses caused by ammonia emission during storage of manure, % of total-N.

Type of manure, handling	Type of animal					
	Cattle	Swine	Laying hens/chickens	Slaughter chickens	Horses	Sheep
Solid manure	20	20	12		25	25
Semisolid manure	10	10				
Liquid manure, uncovered						
Filled from underneath	6	8	8			
Filled from above	7	9	9			
Liquid manure, covered						
Filled from underneath:						
Roof	1	1	1			
floating crust	3	4	4			
other	2	2	2			
Filled from above:						
roof	1	1	1			
floating crust	4	5	5			
other	3	3	3			
Urine, uncovered						
Filled from underneath	37	37				
Filled from above	40	40				
Urine, with cover						
Filled from underneath:						
roof	5	5				
floating crust	17	17				
other	10	10				
Filled from above:						
roof	5	5				
floating crust	20	20				
other	12	12				
Deep litter manure	30	30	20	5		33

Table 6.21. Nitrogen losses caused by ammonia emission during spreading of manure (% of total-N).

Season/ Spreading method	Spreading strategy and tillage timing	Solid manure	Urine	Liquid manure
Early spring/late winter				
Broadcast	Spread on frozen ground	20	40	30
Trailing hoses			30	20
Spring				
Broadcast	Immediately	15	8	10
	Mulching within 4 h	33	14	15
	Mulching within 5-24 h	50	20	20
	Spread on pasture	70	35	40
	Spread on grain		11	20
Trailing hoses	Immediately		7	5
	Mulching within 4 h		14	8
	Mulching within 5-24 h		20	10
	Spread on pasture		25	30
	Spread on grain		10	15
Shallow injection	Spread on pasture		8	15
Early summer, summer				
Broadcast	Spread on pasture	90	60	70
	Spread on grain		10	20
Trailing hoses	Spread on pasture		40	50
	Spread on grain		10	7
Shallow injection	Spread on pasture		15	30
Early autumn				
Broadcast	Immediately	20	15	5
	Mulching within 4 h	35	23	18
	Mulching within 5-24 h	50	30	30
	No mulching	70	45	70
Trailing hoses	Immediately		10	3
	Mulching within 4 h		18	9
	Mulching within 5-24 h		25	15
	No mulching		30	40
Late autumn				
Broadcast	Immediately	10	10	5
	Mulching within 4 h	15	15	8
	Mulching within 5-24 h	20	20	10
	No mulching	30	25	30
Trailing hoses	Immediately		4	3
	Mulching within 4 h		11	4
	Mulching within 5-24 h		18	5
	No mulching		25	15

6.4.1.2.3 4.D.1.1 Nitrous oxide from synthetic fertilisers

Emissions from fertilisers are calculated as:

$$emissions = N_{FERT} \times (1 - Frac_{GASF}) \times EF \times 44 / 28$$

where N_{FERT} is the total amount of fertiliser nitrogen consumed annually, and $Frac_{GASF}$ is the fraction that volatilises as ammonia. Statistics on sales of fertilisers, recalculated into nitrogen quantities, are published annually by Statistics Sweden¹³⁴. The estimated emissions are based on amount of nitrogen in mineral fertilisers sold in Sweden excluding the nitrogen lost as ammonia (Table 6.22). The proportion of nitrogen lost as ammonia ($Frac_{GASF}$) differs between different types of fertilisers. The values used are from the EMEP/EEA emission inventory guidebook 2009 and calculated using the mean spring temperature of 5.9 degrees centigrade (Table 6.23). In Table 6.22 sold quantities of ammonia-emitting products are shown, which directly explains variations in the $Frac_{GASF}$ between different years.

Table 6.22. Sold quantity of ammonia emitting fertilisers and nitrogen in sludge used as fertilizers.

Year	N in sold fertilisers, tonnes	Ammonium Nitrate, AXAN, N26, N27, N28, tonnes of product	N-solution, tonnes of product	Urea, tonnes of product	NPK, tonnes of N	NP, tonnes of N	NK, tonnes of N	Proportion of emitted fertiliser-N ($Frac_{GASF}$)	Sludge, tonnes of N.
1990	224 500	225 387	10 089	5 932	64 600	11 000	0	0.0084	(**) 1 180
1991	208 600	237 612	6 498	4 683	52 100	11 000	3 700	0.0082	1 180
1992	178 400	179 234	8 837	2 980	45 400	8 500	3 000	0.0083	1 180
1993	207 200	200 004	5 257	3 501	46 100	9 800	3 300	0.0083	1 180
1994	216 400	167 150	7 820	3 061	55 900	12 300	3 000	0.0087	(**) 1 433
1995	198 300	182 486	11 193	1 955	51 050	13 451	2 912	0.0089	(*) 2 304
1996	192 300	158 613	5 949	1 474	48 000	14 000	2 500	0.0078	2 304
1997	204 600	175 558	4 399	1 104	51 500	15 900	2 300	0.0076	2 304
1998	205 600	209 463	2 631	889	53 723	14 286	2 033	0.0076	(*) 2 027
1999	179 200	166 077	3 111	745	50 092	14 619	1 746	0.0079	2 027
2000	189 400	205 869	3 772	655	51 600	11 400	2 200	0.0075	(*) 1 758
2001	196 900	235 495	2 036	553	54 000	11 300	3 000	0.0075	1 171
2002	174 400	189 709	638	446	49 800	9 900	2 000	0.0078	593
2003	180 100	238 828	1 083	382	53 900	10 600	2 200	0.0077	692
2004	176 800	240 553	4 928	475	54 500	11 900	1 800	0.0083	796
2005	161 500	273 036	3 364	519	59 000	8 400	1 600	0.0092	1 053
2006	160 300	267 754	3 164	225	57 800	8 500	1 800	0.0091	1 322
2007	167 100	285 064	0	271	61 100	5 300	2 000	0.0087	1 322
2008	186 500	360 415	13	235	71 029	3 931	1 805	0.0091	2 481
2009	(***) 142 400	298 882	67	1 088	43 600	2 000	1 100	0.0094	2 205
2010	168 000	348 691	0	1 002	52 800	2 600	1 400	0.0091	2 205

Statistics on fertilisers from Swedish Board of Agriculture, 2011 and Statistics Sweden, 2011.

(*) Statistics Sweden 1997b and Statistics Sweden 2001. (**) from Statistics Sweden 1992 and Statistics Sweden 1995. Other values are expert judgements. (***) The decrease in 2009 is due to an overconsumption in 2008 due to a dropped tax on fertilisers

Table 6.23. Fraction of nitrogen for different fertiliser types that is lost as ammonia

Fertiliser	Lost as ammonia (% of N)
Ammonium Nitrate, AXAN, N26, N27, N28	0.9
N-solution	6.3
Urea	12.7
NPK	0.9
NP	1.4
NK	0.9
Sludge	30

6.4.1.2.4 4.D.1.2 Nitrous oxide from animal manure applied to soils

To calculate the N₂O from animal manure, the default methodology according to the IPCC Guidelines is used combined with national estimates of N content in manure (section 6.3.2) and a national estimation of ammonia-N emissions. The formula is:

$$emissions = \sum_T N_T \times Nex_T \times (365 - GrazPeriod_T) / 365 \times (1 - Frac_{GASM}) \times EF \times 44 / 28$$

where GrazPeriod_T is the grazing period in days and (365-GrazPeriod_T)/365 is the fraction of manure deposited during the stable period. Frac_{GASM} and Frac_{GASG} are national values of the fractions of ammonia-N emissions from animal manure (Table 6.24). The fractions are estimated by Statistics Sweden and the Swedish EPA¹⁴⁶. The estimates are model-based and take into account many factors that influence gas emissions (see 6.4.1.2.2).

Table 6.24. Ammonia-N emissions from manure, fraction.

	1995	1997	1999	2001	2003	2005	2007	2008	2009	2010
Stable manure (FracGASM)	0.33	0.33	0.33	0.33	0.33	0.32	0.33	0.33	0.33	0.33
Manure from grazing animals ("FracGASG")	0.12	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08

Statistics Sweden, MI 37-series.

6.4.1.2.5 4.D.1.3 N₂O from N-fixing crops in pure stands and in temporary grass

Nitrogen fixation crops are pasture grounds with features of clover, leguminous crops (cooking and fodder peas, preserved peas, vetches, field beans etc). This nitrogen fixation by leguminous plants is a part of the nitrogen circulation in agricultural soils and the corresponding N₂O emissions are included in the inventory. Data derives from national estimates of nitrogen fixation, which account for regional differences, in combination with the Good Practice Guidance's default emission factor for direct N₂O emissions.

¹⁴⁶ Statistics Sweden, MI 37-series.

The formula is stated:

$$emissions = \sum_{crop, county} Area_{crop, county} \times NfixingAmount_{crop, county} \times EF \times 44 / 28,$$

The total production of the respective crops is given by multiplying the cultivated area, according to the Farm Register, by standard yield. The reason for using standard yields instead of actual yields in the calculations is that the time series becomes more consistent and not drastically effected by stochastic events like extreme weather conditions. Estimated standard yields for different crops are published annually by the Swedish Board of Agriculture/Statistics Sweden and are a function of crop yields estimated by surveys conducted over the last 15 years¹⁴⁷ (Table 6.29 and Table 6.30).

Areas are given in Table 6.26, Table 6.27 and Table 6.28. To estimate nitrogen fixation from the atmosphere, a model according to Høgh-Jensen has been used since submission 2006¹⁴⁸. The model covers fixation from root and stubble as well as transmission to other plants. It has been adapted to account for Swedish conditions¹⁴⁹ and has also been used by others such as the Swedish Board of Agriculture. According to the model the amount of fixed nitrogen is estimated as a part of the total amount of nitrogen in the plant's biomass. This part varies depending on the kind of leguminous plant, the age of the pasture, the number of harvests and, to some extent, the fertilised amount of fertiliser applied.

6.4.1.2.6 4.D.1.4 N₂O from crop residue

For the estimation of N₂O from crop residues we also use standard yields instead of actual yields in the calculations. To estimate N₂O from nitrogen circulation in crop residues, the methodology recommended in the Good Practice Guidance is used combining national activity data on removed residues and other parameters, such as nitrogen content, at crop level with the Good Practice Guidance's default emission factor for direct N₂O emissions. The data on crop residues builds on a one-time study from 1997¹⁵⁰ on how straw and tops from different crops are used. The formula used for the calculations is:

$$emission = \sum_{crop} yield_{crop} \times area_{crop} \times Fracresidues_{crop} \times FracN_{crop} (1 - Fracresiduesremoved_{crop}) \times EF \times 44 / 28,$$

Yield is the standard yield, Fracresidues are the crop residues as a fraction of the harvest, FracN is the fraction of nitrogen in crop residues and Fracresiduesremoved is the fraction of crop residues that is removed according to a field survey¹⁵¹ from 1997. When calculating N-circulation in residues from cereal crops, national factors for recalculation from harvest to crop residue and the corresponding N-content

¹⁴⁷ Statistics Sweden, 2002e.

¹⁴⁸ Høgh-Jensen et al. 2004.

¹⁴⁹ Frankow-Lindberg, 2005.

¹⁵⁰ Statistics Sweden, 1999.

¹⁵¹ Statistics Sweden, 1999.

based on national measurement data are used¹⁵². For other crops, a combination of national factors and IPCC default values was used¹⁵³. All factors used for calculating N input with crop residues are given in Table 6.25. Areas of different crops used in the calculations are stated in Table 4.26, Table 6.27 and Table 6.28. Standard yield¹⁵⁴ of different crops used in the calculations is presented in Table 6.29 and Table 6.30.

Table 6.25. Data used for calculating nitrogen input in crop residues.

Crop	Fraction of crop residues removed (ResiduesRemoved)	Fraction of N in crop residues, per cent of dm (FracN)	Fraction residues in relation to harvest, (FracResidues)	Dry matter content, fraction
Winter wheat	0.06	0.51	0.87	0.85/0.86
Spring wheat	0.06	0.44	0.96	0.85/0.86
Winter rye	0.09	0.60	1.08	0.85/0.86
Winter barley	0.23	0.51	0.87	0.85/0.86
Spring barley	0.12	0.77	0.83	0.85/0.86
Oats	0.12	0.73	0.89	0.85/0.86
Mixed grain	0.18	0.67	0.98	0.85/0.86
Triticale	0.06	0.60	1.08	0.85/0.86
Sugar beets	0.09	2.25	0.66	0.85
Winter rape	0.02	1.07	0.47	0.91
Spring rape	0.02	1.07	0.47	0.91
Winter turnip rape	0.02	1.07	0.47	0.91
Spring turnip rape	0.02	1.07	0.47	0.91
Table potatoes and Potatoes for starch prod.	0	1.10	0.40	0.20
Temporary grass	0	1.30	0.25	0.84
Temporary grass for seed	0.49	1.30	0.94	0.84
Green fodder	0	1.30	0.25	0.84
Pasture ground	0	1.30	0.40	0.67
Peas, Peas for fodder and brown beans	0.02	1.42	1.50	0.85
Peas for conservation	0	1.42	1.50	0.85

Adolfsson, R. 2005.

¹⁵² Mattson, 2005.

¹⁵³ Adolfsson, R. 2005.

¹⁵⁴ Statistics Sweden, 2002e.

Table 6.26. Areas of different crops used in the calculations (hectares).

Year	Winter wheat	Spring wheat	Winter rye	Winter barley(*)	Spring barley	Oats	Mixed grain	Triticale(**)
1990	320 120	29 595	73 460	-	492 027	387 823	32 628	-
1991	225 330	33 387	43 239	-	490 896	364 272	40 337	-
1992	233 678	36 647	34 597	-	454 097	360 859	47 420	-
1993	271 818	32 581	46 390	-	420 437	321 961	35 330	35 330
1994	212 095	39 722	38 957	29 536	443 489	341 415	25 421	42 526
1995	222 304	39 076	39 693	26 220	427 115	278 322	27 124	44 577
1996	292 170	42 392	33 558	22 061	446 503	283 588	34 230	61 694
1997	299 594	44 588	29 416	15 272	467 628	315 465	30 247	66 473
1998	359 024	39 021	34 617	15 949	429 011	311 467	26 972	66 751
1999	209 641	65 777	24 507	11 883	470 104	305 658	33 022	32 586
2000	353 201	48 364	34 533	12 997	398 227	295 544	45 328	40 728
2001	354 495	44 670	34 403	9 577	387 922	278 174	25 370	39 642
2002	285 249	54 350	24 395	6 386	410 456	295 002	22 623	30 809
2003	364 058	47 290	24 366	6 345	362 127	279 808	25 235	44 661
2004	349 823	53 585	24 402	5 268	392 006	229 696	18 697	52 195
2005	295 325	59 430	21 386	5 356	373 208	200 122	18 857	50 292
2006	317 603	43 333	23 454	5 691	309 444	206 055	17 430	55 406
2007	323 182	38 367	24 716	8 274	318 407	207 909	15 317	53 914
2008	311 632	49 915	27 581	10 396	395 367	227 588	15 955	49 287
2009	326 838	48 297	36 633	18 278	351 878	196 038	17 050	53 571
2010	331 805	68 184	24 228	17 928	300 847	164 386	19 150	36 231

Statistics from the Farm Register. (*) Before 1994, statistics on winter barley and spring barley revised as one crop. (**) Before 1993, statistics on Triticale was included in mixed grain.

Table 6.27. Areas of different crops used in the calculations (hectares).

Year	Sugar beets	Winter rape	Spring rape	Winter turnip rape	Spring turnip rape	Table potatoes	Potatoes starch prod.
1990	38 502	84 598	44 203	9 068	30 035	27 305	8 866
1991	47 963	75 724	41 046	8 089	26 362	28 269	8 807
1992	51 287	51 364	56 519	3 145	26 366	30 414	8 791
1993	51 287	74 460	46 203	2 455	22 370	27 815	8 469
1994	53 353	46 035	53 033	1 746	27 647	25 449	7 539
1995	57 518	56 084	23 311	1 587	23 661	27 630	7 371
1996	59 223	21 737	18 976	811	23 869	27 577	9 060
1997	60 459	22 888	19 475	1 787	19 432	26 732	9 081
1998	58 737	23 159	16 705	1 470	13 238	25 133	8 567
1999	59 881	19 626	31 273	1 206	23 784	24 422	8 391
2000	55 484	24 870	12 112	1 395	9 791	23 610	9 293
2001	54 834	19 900	13 591	857	10 425	23 776	8 460
2002	54 820	31 219	21 943	1 899	12 408	23 142	8 589
2003	50 100	23 352	26 670	817	7 734	21 923	8 617
2004	47 625	37 496	36 715	1 244	8 343	23 015	8 656
2005	49 182	34 997	38 578	1 460	7 116	22 081	8 372
2006	44 184	47 638	35 148	1138	6 270	20 212	7 966
2007	40 682	50 341	33 044	1 117	3 341	20 330	8 032
2008	36 778	61 860	24 359	834	2 453	19 590	7 293
2009	39 782	67 841	29 245	282	2 150	19 706	7 252
2010	37 950	71 836	35 695	496	2 207	19 842	7 361

Table 6.28. Areas of different crops used in the calculations (hectares).

Year	Tempo- rary grass	Tempo- rary grass for seed	Green forage	Pasture ground	Peas incl fodder	Peas for conser- vation (*)	Brown beans (*)	Total area arable land (**)
1990	727 590	10 753	39 698	190 503	32 742	-	-	3 100 906
1991	696 069	10 418	33 509	239 818	23 327	-	-	3 092 557
1992	708 384	8 791	2 896	292 825	14 059	-	-	3 084 551
1993	748 094	7 863	23 137	314 458	8 720	-	-	3 074 825
1994	757 000	8 241	23 000	314 666	6 598	-	-	3 070 068
1995	766 776	7 907	23 695	276 927	11 959	8 578	709	3 064 679
1996	750 085	7 854	22 268	247 369	17 713	8 821	690	3 059 172
1997	746 832	8 470	24 443	234 677	32 742	9 028	921	3 055 165
1998	742 068	9 013	21 935	221 418	49 150	8 524	938	3 046 475
1999	760 227	8 165	21 867	198 091	30 053	8 752	872	3 031 311
2000	760 227	8 465	21 867	198 091	27 892	8 525	835	3 026 101
2001	750 200	10 300	26 400	179 400	29 928	8 862	756	3 018 561
2002	759 419	12 439	32 387	181 604	31 959	8 909	717	3 009 116
2003	769 200	12 306	31 748	164 100	28 942	9 121	767	3 006 553
2004	770 412	12 329	35 715	164 359	33 116	9 318	767	2 998 488
2005	803 920	12 847	39 628	192 670	31 285	8 874	707	2 979 035
2006	816 400	15 151	42 463	206 270	26 180	8 954	646	2 968 123
2007	831 390	14 276	46 482	190 400	19 198	8 824	535	2 963 706
2008	870 740	14 260	44 619	183 380	17 414	7 343	498	2 964 346
2009	888 800	13 969	54 442	178 210	24 705	8 791	521	2 966 270
2010	894 470	14 818	57 069	172 780	36 084	9 368	658	2 964 187

(*) Before 1995 statistics on peas & beans were aggregated. (**) Data from the national forest inventory

Table 6.29. Standard yield of different crops used in the calculations, total weight (including water), kg/hectare.

Year	Winter wheat	Spring wheat	Winter rye	Winter barley (*)	Spring barley	Oats	Mixed grain	Triticale	Sugar beets	Winter rape
1990	5 818	4 918	4 195	-	3 911	3 866	3 305	5 818	44 843	2 748
1991	5 929	4 948	4 242	-	3 947	3 872	3 323	5 929	45 272	2 758
1992	6 040	4 979	4 288	-	3 982	3 879	3 341	6 040	45 701	2 767
1993	6 151	5 009	4 335	-	4 018	3 885	3 359	6 151	46 130	2 776
1994	6 207	5 012	4 398	-	4 036	3 869	3 359	6 207	46 446	2 777
1995	6 262	5 014	4 461	-	4 053	3 853	3 360	6 262	46 762	2 777
1996	6 393	5 078	4 600	-	4 103	3 882	3 394	5 434	46 985	2 752
1997	6 477	5 151	4 705	-	4 153	3 897	3 421	5 505	46 838	2 735
1998	6 592	5 021	5 010	-	4 136	3 714	3 336	5 603	46 686	2 681
1999	6 503	5 017	5 103	-	4 153	3 710	3 342	5 528	46 637	2 638
2000	6 446	5 059	5 204	-	4 137	3 658	4 431	6 446	46 300	2 609
2001	6 408	5 134	5 348	-	4 168	3 685	4 517	6 408	46 249	2 607
2002	6 351	5 176	5 448	-	4 204	3 747	3 976	6 351	46 416	2 634
2003	6 376	5 265	5 561	-	4 266	3 823	4 045	6 376	46 626	2 717
2004	6 231	5 227	5 526	-	4 245	3 853	4 049	6 231	46 661	2 789
2005	6 196	5 282	5 567	-	4 248	3 880	4 064	6 196	46 389	2 887
2006	6 169	5 201	5 515	-	4 201	3 870	4 036	6 196	47 193	3 027
2007	6 128	5 042	5 561	-	4 184	3 869	4 027	6 128	47 990	3 147
2008	6 184	4 966	5 580	5 177	4 280	3 997	3 245	4 849	49 129	3 214
2009	6 210	4 804	5 626	5 408	4 266	3 967	3 292	5 044	51 703	3 300
2010	6 268	4 585	5 711	5 460	4 320	4 016	3 305	5 060	52 920	3 423

Swedish Board of Agriculture, Statistics Sweden, JO 15-series. (*) Until 2008 no standard yields was produced. The value for winter rye was used as an approximation.

Table 6.30. Standard yield of different crops used in the calculations, total weight (inc. water), kg/hectare.

Year	Spring rape	Winter turnip rape	Spring turnip rape	Table potatoes	Potatoes for starch prod.	Temporary grass	Green fodder
1990	1 777	1 821	1 587	29 194	36 045	7 490	5 000
1991	1 762	1 804	1 578	29 769	36 502	7 120	5 000
1992	1 746	1 787	1 570	30 343	36 958	6 010	5 000
1993	1 731	1 770	1 562	30 918	37 415	5 933	5 000
1994	1 715	1 747	1 558	31 409	37 585	5 856	5 000
1995	1 699	1 724	1 555	31 900	37 754	5 779	5 000
1996	1 679	1 682	1 542	31 817	37 651	5 702	5 000
1997	1 680	1 622	1 533	31 832	37 613	5 625	5 000
1998	1 607	1 523	1 420	34 910	39 706	5 548	5 000
1999	1 657	1 474	1 431	35 598	40 665	5 471	5 000
2000	1 720	1 471	1 451	35 146	40 401	5 394	5 000
2001	1 809	1 444	1 483	34 608	40 268	5 317	5 000
2002	1 910	1 390	1 511	33 866	39 812	5 240	5 000
2003	2 008	1 415	1 553	33 436	39 368	5 010	5 000
2004	2 062	1 440	1 573	32 461	38 530	5 010	5 000
2005	2 141	1 496	1 596	31 536	38 426	4 840	5 000
2006	2 175	1 586	1 590	30 976	38 367	4 450	5 000
2007	2 214	1 655	1 583	30 493	37 982	5 030	5 000
2008	2 217	1 709	1 534	29 857	37 315	4 863	5 000
2009	2 184	1 755	1 479	29 470	36 985	4 807	5 000
2010	2 144	1 811	1 428	29 374	37 020	4 889	5 000

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

6.4.1.2.7 4.D.1.5 Background emissions of N_2O from cultivation of organic soils

The background emissions from organic soils vary with different crops¹⁵⁵. They are considered to be higher from ploughed soils than from pasture or temporary grass lands¹⁵⁶ and the suggested emission factors are 1 and 6 kg N_2O -N ha⁻¹, respectively. The IPCC Guidelines' default value is however implemented in the inventory since a Swedish/Finnish research group concluded that not enough data exists to generate different emission factors for different management and soil types¹⁵⁷. The area of organic soils has only been estimated intermittently. The latest survey in 2009 concluded that approximately 5 % of the total area of arable land consists of organic soils¹⁵⁸. That fraction has then been used for all years, assuming that the area of organic soils relative the total area of arable land stays constant over time.

¹⁵⁵ Klemetsson, 2001.

¹⁵⁶ Klemetsson, 2001.

¹⁵⁷ Klemetsson et al., 1999.

¹⁵⁸ Berglund, Berglund & Sohlenius, 2009

6.4.1.2.8 4.D.1.6 N_2O from sludge used as fertiliser

N_2O from sewage sludge used as fertiliser is a part of the N_2O emissions from agricultural soils and may be reported, according to the Good Practice Guidance, if sufficient information is available. This emission was included for the first time in the inventory for submission 2006. The activity data used is given in Table 6.22. Out of the total amount of nitrogen emitted, 70 % is assumed to emanate from direct emissions and 30 % from indirect emissions. The emission factor used for the direct emissions is 1.25 % of the nitrogen in the sewage sludge. The corresponding value for the indirect emissions is 1 %. The IPCC Guidelines' default factor for ammonia emissions from fertilisers is used to differentiate between direct and indirect emissions. Statistics on the use of sludge have been collected intermittently by Statistics Sweden and the Swedish EPA from sewage treatment plants (Table 6.22). The emissions are calculated as:

$$emissions = \sum_i F_{Ri} \times N_{SEWAGESLUDGE} \times EF_i \times 44/28,$$

F_{Ri} is the fraction of N emitted as direct/indirect emissions and EF_i is the corresponding emission factor. The direct emissions from sewage sludge have been reported as an optional category in the CRF and the indirect emission is reported under CRF category 4.D.3.1.

6.4.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Two related parameters are the amount of nitrogen in sold fertiliser, estimated by the sales statistics, and the nitrogen in used fertilisers, estimated from interviews with farmers. Sales statistics are collected annually by the Swedish board of agriculture and Statistics Sweden¹⁵⁹. 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 1980s¹⁵⁹. The estimated nitrogen content in sold products has for most years been somewhat higher. The two estimates should be about the same, at least in the long run. The difference may be due to storage and/or the fact that estimation methods are affected by different error types. The sales statistics also contain quantities sold for use outside the agricultural sector and are therefore expected to result in a higher figure. The user statistics provide valuable information about the use of fertilisers in different crops and regions, but the sales statistics are considered to give a more accurate estimate of total use. Therefore, the latter have been used in the GHG inventory. Another advantage of the sales statistics is that they are updated annually.

Statistics on the use of sewage sludge have been published irregularly and in different reports, but a time series has been created through interpolation/extrapolation and certain assumptions. The quality of data has increased over time and data for the latest years is of satisfactory quality.

¹⁵⁹ Statistics Sweden, MI 30-series.

6.4.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Activity data are checked for consistency. Emission estimates and methods are reviewed yearly by external national experts.

6.4.1.5 SOURCE-SPECIFIC RECALCULATIONS

Statistics Sweden has newly started to publish standard yields also for temporary grass. Before this was done the time series for temporary grass was built on another method compared other crops. From the new data together with a literature study of old values a new time series has been constructed that is now harmonized with the time series for the other crops.

Data for crop yields for peas and broad beans has been updated for the years 2007-2009.

New calculations from Statistics Sweden for nitrogen and phosphorus balances for agriculture has resulted in revised values for the years 2007-2009 for FracGASM, both for the stable and grazing period.

Due to new data from Statistics Sweden the variable $N_{fixingAmount_{crop, county}}$ has been updated for all eight counties and all nitrogen fixing crops for the year 2009 (see 6.4.1.2.5).

6.4.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

6.4.2 Pasture, Range and Paddock Manure (CRF 4.D.2)

6.4.2.1 SOURCE CATEGORY DESCRIPTION

N_2O emissions from nitrogen excreted during grazing. Calculations are carried out according to the methodology in the IPCC Guidelines. Nitrogen lost as ammonia is considered as well and builds on national estimates of ammonia emissions from grazing manure. The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), are presented in Table 6.31.

Table 6.31. Summary of source category description for the entire category CRF 4.D.2.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
4.D.2	N_2O	X	X		T2	CS, D	Yes

CS Country Specific. T2 Tier 2. D Default.

6.4.2.2 METHODOLOGICAL ISSUES

For N_2O emissions from N excreted on permanent pastures the default emission factor of 2 % N_2O -N/kg nitrogen excreted is used for all animal groups. This is probably an overestimation of the emission when the nitrogen lost as N_2O is likely

to be lower in cold climates as in Sweden. However, very scarce information is available and until better empiric data is available the IPCC default EF will be used. The emissions are calculated as:

$$emissions = \sum_T N_T \times Nex_T \times GrazPeriod_T / 365 \times (1 - Frac_{GASG}) \times EF$$

N_T is the number of animals of type T in the country, Nex_T is the N-excretion of animals of type T , $GrazPeriod_T$ is the grazing period for animals of type T , $Frac_{GASG}$ is ammonia-N emissions (fraction) and EF is the emission factor. The nitrogen production for the different animal groups is presented in Table 6.13 and Table 6.15.

Table 6.32. Waste management systems, fraction of manure deposited on Pasture, Range and Paddock.

Year	Dairy cattle	Other cattle	Pigs for meat production	Other swine	Sheep, Goats	Reindeer	Horses	Poultry
1990	0.25	0.42	NO	NO	0.50	1.00	0.50	NO
1995	0.25	0.44	NO	NO	0.50	1.00	0.50	NO
2000	0.25	0.46	NO	NO	0.50	1.00	0.50	NO
2005	0.26	0.49	NO	NO	0.50	1.00	0.50	NO
2006	0.26	0.49	NO	NO	0.50	1.00	0.50	NO
2007	0.25	0.47	NO	NO	0.50	1.00	0.50	NO
2008	0.25	0.47	NO	NO	0.50	1.00	0.50	NO
2009	0.25	0.46	NO	NO	0.50	1.00	0.50	NO
2010	0.25	0.46	NO	NO	0.50	1.00	0.50	NO

6.4.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The time-series is consistent.

6.4.2.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Activity data are checked for consistency. Emission estimates and methods are reviewed yearly by external national experts.

6.4.2.5 SOURCE-SPECIFIC RECALCULATIONS

The whole time series for number of horses has been updated with the results from a new survey carried out by the Swedish board of agriculture.

Owing to new data from Statistics Sweden¹⁶⁰ the values for fraction of nitrogen that volatilizes as NH_3 and NO_x from manure management and grazing manure are updated.

¹⁶⁰ Statistics Sweden, 2011

6.4.2.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

6.4.3 Indirect Emissions (CRF 4.D.3)

6.4.3.1 SOURCE CATEGORY DESCRIPTION

Includes indirect emissions from soils. In generally the Good Practice Guidance default emission factors are used. The Good Practice Guidance stresses the lack of knowledge on a global scale and the extreme variability in the suggested emission factors and parties are not encouraged to use national values unless rigorously documented and previewed country-specific values have been developed. However, values for losses of nitrogen as ammonia (see 6.4.1.2.2) and nitrogen leakage are national. The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), are presented in Table 6.33.

Table 6.33. Summary of source category description for the entire category CRF 4.D.3.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
4.D.3	N ₂ O	X	X		CS, T1a	CS, D	Yes

CS Country Specific. T1 Tier 1. D Default.

6.4.3.2 METHODOLOGICAL ISSUES

6.4.3.2.1 4.D.3.1 Atmospheric deposition

The formula for estimating the emissions is:

$$emissions = (N_{fert} \times Frac_{GASF} + N \times Nex \times Frac_{GASM} + N \times Nex \times Frac_{GASG}) \times EF \times 44/28$$

N_{fert} is the nitrogen supply by mineral fertiliser and $Frac_{GASF}$ is the corresponding N fraction emitted as ammonia, calculated from sold quantities of different fertilisers and CORINAIR. $N \times Nex$ is the total amount of nitrogen excreted from animals, combined with national estimates of $Frac_{GASM}$, the fraction of nitrogen from animal manure emitted as ammonia, and " $Frac_{GASG}$ ", the fraction of manure from grazing animals emitted as ammonia (see 6.4.1.2 for explanations on the calculations of $Frac_{GASM}$ and $Frac_{GASG}$)

6.4.3.2.2 4.D.3.2 Nitrogen Leaching and Run-off

The national estimate of nitrogen leaching is estimated by the SLU and calculated from the SOILNDB model¹⁶¹, which is a part of the SOIL/SOILN model¹⁶¹. This

¹⁶¹ Johnsson, 1990; Swedish EPA, 2002.

simulation model was developed during the 1980s in order to describe nitrogen processes in agricultural soils¹⁶². Since then the model has been elaborated and tested on data from controlled leaching experiments, and these tests show that the model estimates leaching from soil with good precision¹⁶³. By using national data on crops, yields, soil, use of fertiliser/manure and spreading time, the leaching is estimated for 22 regions. These regions are based on similarities in agricultural production areas.

For calculating nitrogen leaching in the inventory, the average N leaching per hectare, calculated by the SOILNDB model, is multiplied by the total Swedish area of agricultural soil. The estimated indirect N₂O emission is stated:

$$emissions = area \times leachfactor \times EF \times 44 / 28$$

To estimate the implied FracLEACH, which is required as additional information in CRF 4D for each reporting year, the leached nitrogen, according to the national model, is divided by the sum of nitrogen in fertilisers and animal production. This quotient varies between 0.20 and 0.25, which is relatively close to the IPCC Guidelines' default value of FracLEACH (0.3).

6.4.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The average nitrogen leaching from agricultural soils, the leach factor, has been estimated by Swedish University of Agricultural Sciences for the years, 1995, 1999, 2005 and 2009 to 21, 21, 18, 18 kg/ha respectively. 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 decrease between 1999 and 2005 is believed to mainly be dependent on an increase in the area of catch crops. But an increased awareness of the eutrophication problem also lead to changed fertilising patterns. No estimate of uncertainty is done, but the used method is considered to be the best available in Sweden, taking many relevant factors with an impact on nitrogen leaching into account. Since statistics on the use of fertilisers and manure are produced every other year,¹⁶⁴ the estimates can be updated at most every second year. However, due to economic reasons, the data has been published intermittently.

6.4.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Activity data are checked for consistency. Emission estimates and methods are reviewed yearly by external national experts.

¹⁶² Johnsson et al., 1987.

¹⁶³ Swedish EPA, 2002b.

¹⁶⁴ Statistics Sweden, NA 30-series; Statistics Sweden, MI 30-series.

6.4.3.5 SOURCE-SPECIFIC RECALCULATIONS

The total area of agricultural land has changed for all years. As a consequence of the method used by SLU for calculating agricultural land the estimates of the five most recent years change for every new submission (see 7.2.2.1).

Data for average nitrogen leaching from agricultural soils has been updated (see 6.4.3.3)

6.4.3.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

6.4.4 Other (CRF 4.D.4)

6.4.4.1 SOURCE CATEGORY DESCRIPTION

Under CRF 4.D.4 Sweden report a background emission from agricultural soils. The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), are presented in Table 6.34.

Table 6.34. Summary of source category description for the entire category CRF 4.D.4.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
4.D.4	N ₂ O	x	X		CS	CS	Yes

CS Country Specific.

6.4.4.2 METHODOLOGICAL ISSUES

Based on a study of national emission factors¹⁶⁵, a background emission from the cultivation of mineral soils have been included with the national emission factor of 0.5 kg N₂O-N ha⁻¹. The total area of mineral soils is calculated as total area of arable land minus the area of organic soils.

6.4.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The estimated emission is strongly dependent on estimated total area of agricultural land. This classification is performed by the Swedish National Forest Inventory (NFI¹⁶⁶). In total the sample consists of approximately 30 000 sample plots. However, only one fifth are investigated yearly. As a consequence of this the accuracy will increase retroactively until the whole five year cycle is completed. The estimate for the last year will only be based on 6 000 sample plots, and then the accuracy gradually increases until the whole five year cycle is completed. That is, the number of sample plots for one, two, three, four and five years old data is 6 000, 12 000, 18 000, 24 000 and 30 000, respectively. However, to reduce the variation

¹⁶⁵ Klemetsson, 2001.

¹⁶⁶ Ranney et al., 1987

that sometimes arise for the most recent years due to sampling errors the estimates of the areas are calculated as a running average for the last five years (see 7.2.2.2).

6.4.4.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

6.4.4.5 SOURCE-SPECIFIC RECALCULATIONS

Values for area of total agricultural land and organic soil are updated (see 7.2.2.1).

6.4.4.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

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

7.1 Overview of LULUCF

Sweden reports carbon stock changes and greenhouse gas emissions from Forest land, Cropland, Grassland and Settlements and associated land-use transfers¹⁶⁷. These land use categories are considered managed. Except for a small area used for peat extraction, Wetlands and Other land are considered unmanaged and only areas of these categories are reported. The reporting also includes N₂O emissions associated with nitrogen fertilization of Forest land, N₂O emissions due to land conversions to cropland, CO₂, emissions associated with liming and N₂O as well as CH₄ emissions from biomass burning.

In 2010 the net removal from the Land Use, Land-Use Change and Forestry LULUCF-sector was estimated to ca 34,055 Gg CO₂. The net removal decreased slightly from 2009 to 2010 by ca 1,693 Gg CO₂. The long-term trend with decreasing net removals in living biomass is mainly due to an increase in harvest rates.

The gross removal originating from tree growth in Sweden shows an increasing trend and lies currently around 120 M m³sk (approx. 160 Mtons CO₂ per year). The harvest is also increasing but the annual fluctuations are large. In 2010 the gross harvest was approximately 90 M m³sk.

Since Submission 2010 Sweden reports data and supplementary information for the Kyoto Protocol including emission/removals for activities under article 3.3 (Afforestation, Reforestation and Deforestation) and for Forest management under article 3.4. In 2010 changes in carbon pools for afforestation, reforestation and deforestation together constituted a source of 1,965 Gg CO₂ and Forest management represented a removal of 37,001 Gg CO₂. The supplementary information required for the reporting under the Kyoto Protocol is found in the NIR part II (Chapter 11).

Forest is the major land-use category in Sweden. The total forest area (FAO definition) is about 28 million hectares. The productive forests (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 23 million hectares¹⁶⁸.

Harvest of trees is more or less restricted to productive forests and the unrestricted productive forest area has decreased since 1990, as a result of the estab-

¹⁶⁷ Sweden uses random sampling methodology to estimate land-use and land-use transfers. The reporting is based on 30 000 permanent sample plots inventoried by the Swedish National Inventory of Forests (RIS). The permanent sample plots have been re-inventoried at intervals of 5-10 years and the land-use of each is described from the year of the first inventory and every year thereafter. The land-use of years between inventories has been interpolated. This means that a full record of plots comprise 30 000 plots whereas the latest year is only represented by 6 000 plots. Therefore, estimates of the five most recent years are re-calculated in each submission. From submission 2012 data for inventory cycles without a full record to 2010 are extrapolated, see Figure 7.5. Both the extrapolation and the re-calculation is made to improve the accuracy of estimates.

¹⁶⁸ Swedish University of Agricultural Sciences, 2011

lishment of nature reserves. Increased demand for forest products has led to a continuous increase in felling during the reported period peaking at 2005 (due to wind throws originating from a severe storm), while the growth rate only increased moderately. However, harvest statistics indicate an high demand of forest products in recent years with quite large fluctuations between years. It should be noted that from the base year and onwards, the reported growth is larger than the drain – defined as harvest and self mortality.

The land use and land-use change matrices (Table 7.1a-b) is based on about 6000 (1990-2010) and 30000 sample plots (1990-2006), respectively¹⁶⁹. Due to a five-year inventory cycle we can only provide a full record of data 1990-2006. Note that only the area in Table 7.1b corresponds to the reported area in the CRF-tables (year 2006) while Table 7.1a might deviate somewhat because it is based on a smaller sample. Forest land is the most important land-use category. The gross and net conversions indicate that conversions from Forest land to Settlements are frequent.

Table 7.1a¹⁷⁰ Land Use Categories 1990, 2010 and gross and net land use transfers 1990-2010 (based on about 6000 permanent sample plots inventoried 1985-2010). The carbon stock of Forest land in the mountain area¹⁷¹ (915 000 ha) is not monitored in the field and changes in the carbon pools for this area are not reported.

Area [1000 ha]	“From” Year 1990	“To” Year 2010					
		Forest Land	Crop- Land	Grass- Land	Wet- land	Settle- ments	Other Land
Forest land	28571	28220	1	38	131	158	23
Cropland	2872	69	2666	70	0	67	0
Grassland	541	87	38	410	0	6	0
Wetlands	7305	437	0	0	6754	0	114
Settlements	1695	82	13	9	17	1568	5
Other land	4237	187	0	0	47	0	4002
Sum after transfers		29081	2718	528	6950	1800	4144

¹⁶⁹ The reason for reporting two land use matrixes is mainly because it is mandatory to report a land use matrix 1990-2010 and because the accuracy increases when using a full record of sample plots.

¹⁷⁰ Table 7.1a is put together based on a request from the ERT in the centralized review (Subm 2009).

¹⁷¹ Löfgren, 1998

Table 7.1b Land Use Categories 1990, 2006 and gross and net land use transfers¹⁷² 1990-2006 (based on about 30 000 permanent sample plots inventoried 1983-2010).

Area [1000 ha]	"From"	"To" Year 2006					
	Year 1990	Forest Land	Crop-Land	Grass-Land	Wet-land	Settle-ments	Other Land
Forest land	28245	27954	3	24	76	149	39
Cropland	3099	83	2899	44	4	68	0
Grassland	506	41	44	398	3	12	6
Wetlands	7269	164	0	3	6993	8	100
Settlements	1703	68	22	6	8	1587	12
Other land	4337	33	0	2	37	1	4265
Sum after transfers		28343	2968	477	7120	1826	4423

The largest carbon stocks are found in the living biomass and soil organic carbon pools on Forest land, and the largest annual stock change is the change in the living biomass pool (Figure 7.1 and 7.2). A net removal of CO₂ due to increases in the living biomass pool is reported for every year during the period.

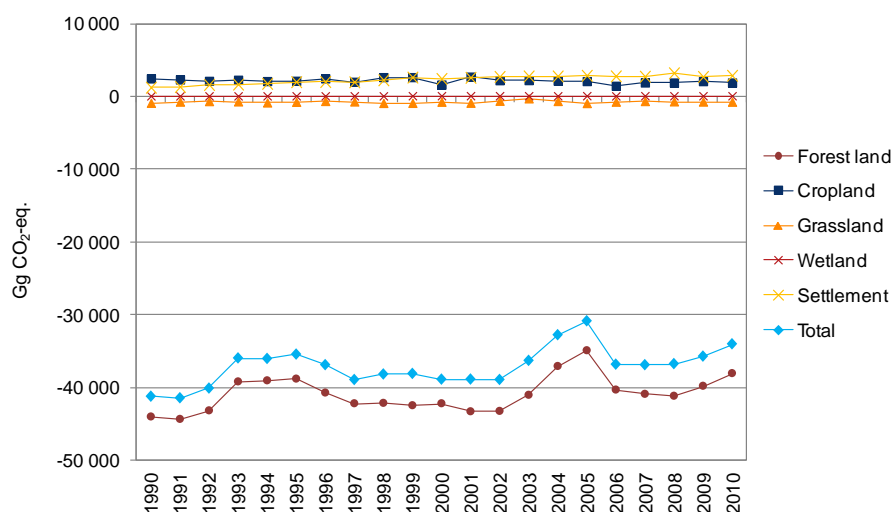


Figure 7.1. Net emissions/removals of GHG in the LULUCF sector from different land-use categories and total net removals for the LULUCF-sector

Both the dead organic matter pool and the soil organic carbon pool have resulted in net removals during most years of the reported period. Some soils act as sources whereas others act as sinks. The major source is the emissions from drained organic soils (Histosols) on Forest land and on Cropland. An area of about 4.4 Mha of the Forest land was considered as Histosols 2010 and ca 20 % (approx. 1 M ha) of the Histosols can be assumed to be drained. The Cropland area on Histosols is estimated to approx. 145 kha (2010) and all of that area is drained. The area is decreasing since the total Cropland area (the average trend) in Sweden is decreasing, leading to a trend towards decreased emissions from Cropland. The decrease in

¹⁷² The carbon stock of Forest land in the mountain area (915 000 ha) is not monitored in the field and changes in the carbon pools for this area are not reported.

area is mainly due to conversion to Forest land and Settlements. Conversion from and to Grassland do also occur.

There has been considerable variation between submissions for specific years in the soil organic carbon pool on mineral soils. These variations are partly caused by random variation in the sample. Since the total pool is huge and the changes in the pool comparatively small the numbers are sensitive to random variation when small changes are multiplied by large areas. It should be noted that a change of 0.1% in the pool is equivalent to more than 3,000 Gg CO₂. The variation between years has been reduced after the introduction of a new method for extrapolation of data on plot basis (first time used and described as a recalculation in Submission 2011). Variation between submissions may still be substantial. We expect that this variation will decrease with time when more plots are re-inventoried.

Stämmer detta?? Är det inte nytt iom sub 2012? /Maria som inte har full koll på detta

Emissions of CO₂, N₂O and CH₄ from i) direct N₂O emissions from nitrogen fertilization, ii) N₂O emissions from disturbance associated with land-use conversion to Cropland, iii) CO₂ emissions from agricultural lime application, and iv) GHG-emissions from biomass burning are quite limited in Sweden. The total emission shows no obvious trend but instead a quite stable emission less than 0.3 Mton CO₂-equivalents every year during the period 1990-2010. Among the categories, the largest emissions originate from liming. Sweden does not report N₂O emissions from drainage of soils. A summary of emissions/ removals is found in Tables 7.2 a and 7.2 b.

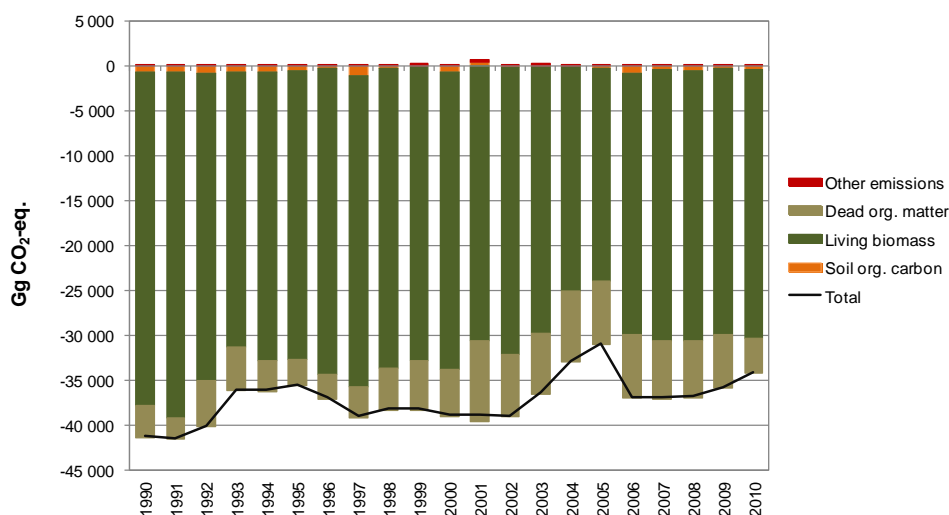


Figure 7.2. Net removals/emissions of GHG in the LULUCF sector from different carbon pools.

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

Table 7.2a. Summary of net removals (-)/emissions (+) in living biomass (LB), dead organic matter (DOM) and soil organic carbon (SOC) per land use category.

7.2 a	Net removals (minus=removal) [Mt CO ₂]															
	Forest land				Cropland				Grassland				Wet- land SOC	Settlement		
	LB	DOM	SOC		LB	DOM	SOC		LB	DOM	SOC			LB	DOM	SOC
			Min.	Org.			Min.	Org.			Min.	Org.				
1990	-36,8	-3,6	-12,9	9,2	0,1	0,0	0,1	2,1	-0,5	-0,4	-0,3	0,2	0,0	0,1	0,3	0,8
1991	-38,3	-2,4	-13,0	9,2	-0,1	0,0	0,2	2,1	-0,4	-0,4	-0,3	0,2	0,0	0,1	0,4	0,9
1992	-34,1	-5,2	-13,0	9,2	-0,1	0,0	0,1	2,1	-0,3	-0,3	-0,3	0,2	0,0	0,2	0,4	1,0
1993	-30,4	-4,9	-13,1	9,2	-0,1	0,0	0,1	2,1	-0,4	-0,3	-0,3	0,2	0,0	0,0	0,5	1,1
1994	-31,6	-3,7	-13,1	9,2	-0,1	0,0	-0,1	2,0	-0,5	-0,3	-0,3	0,2	0,0	0,0	0,5	1,2
1995	-31,7	-3,3	-13,1	9,2	-0,2	0,0	0,1	2,0	-0,4	-0,3	-0,3	0,2	0,0	0,0	0,6	1,3
1996	-33,7	-3,1	-13,2	9,2	-0,1	0,0	0,3	2,1	-0,3	-0,3	-0,3	0,2	0,0	0,0	0,6	1,4
1997	-34,1	-3,8	-13,6	9,2	-0,1	0,0	-0,1	2,0	-0,3	-0,3	-0,3	0,2	0,0	-0,2	0,7	1,5
1998	-32,8	-5,1	-13,6	9,3	-0,1	0,0	0,5	2,1	-0,6	-0,3	-0,3	0,2	0,0	0,0	0,7	1,5
1999	-32,3	-6,1	-13,5	9,4	-0,1	0,0	0,5	2,1	-0,6	-0,3	-0,2	0,2	0,1	0,2	0,8	1,6
2000	-32,2	-5,9	-13,6	9,4	-0,4	0,0	-0,2	2,0	-0,4	-0,3	-0,3	0,2	0,1	-0,1	0,8	1,8
2001	-29,6	-9,6	-13,6	9,4	-0,3	0,0	0,7	2,1	-0,6	-0,3	-0,3	0,2	0,1	-0,1	0,9	1,9
2002	-31,5	-7,7	-13,6	9,4	-0,2	0,0	0,1	2,0	-0,3	-0,3	-0,3	0,2	0,1	-0,2	0,9	2,0
2003	-29,4	-7,5	-13,6	9,4	-0,2	0,0	0,2	2,0	0,0	-0,3	-0,3	0,2	0,1	-0,2	0,9	2,1
2004	-24,3	-8,6	-13,6	9,4	-0,4	0,0	0,3	2,0	-0,3	-0,3	-0,4	0,2	0,0	-0,1	0,9	2,0
2005	-23,0	-7,8	-13,6	9,4	-0,3	0,0	0,1	2,0	-0,6	-0,2	-0,4	0,2	0,1	0,0	0,9	2,0
2006	-28,3	-7,7	-13,8	9,4	-0,6	0,0	-0,2	2,0	-0,4	-0,2	-0,4	0,2	0,0	0,1	0,8	1,9
2007	-29,5	-7,1	-13,8	9,5	-0,4	0,0	0,1	2,0	-0,3	-0,2	-0,4	0,2	0,1	0,1	0,8	1,9
2008	-30,0	-7,0	-13,8	9,5	-0,4	0,0	0,1	1,9	-0,3	-0,3	-0,4	0,2	0,1	0,5	0,8	1,9
2009	-29,0	-6,6	-13,8	9,5	-0,4	0,0	0,2	2,1	-0,4	-0,2	-0,3	0,2	0,1	0,0	0,8	1,9
2010	-29,3	-4,5	-13,8	9,5	-0,4	0,0	0,1	2,0	-0,4	-0,2	-0,3	0,2	0,1	0,2	0,8	1,9

Table 7.2b. Summary of net emissions (+)/removals (-) in living biomass (LB), dead organic matter (DOM) and soil organic carbon (SOC) and other sources. The total LULUCF removals are expressed as CO₂-equivalents.

7.2 b Year	Total carbon pool changes [Mt CO ₂]			Other emissions [Mt substance]						Total LULUCF [Mt CO ₂ -eq]
				Fert. 5 (I)	To CL 5 (III)	Liming 5 (IV)	Biomass burning 5 (V)			
	LB	DOM	SOC	N ₂ O	N ₂ O	CO ₂	CO ₂	CH ₄	N ₂ O	
1990	-37,2	-3,6	-0,7	1,9E-04	7,5E-05	1,7E-01	IE	8,2E-05	5,6E-07	-41,3
1991	-38,6	-2,3	-0,7	1,1E-04	9,3E-05	1,3E-01	IE	7,6E-05	5,3E-07	-41,5
1992	-34,4	-5,2	-0,8	7,6E-05	9,4E-05	1,1E-01	IE	7,7E-05	5,3E-07	-40,1
1993	-30,8	-4,8	-0,6	6,7E-05	1,2E-04	1,3E-01	IE	8,0E-05	5,5E-07	-36,0
1994	-32,2	-3,5	-0,6	5,9E-05	1,3E-04	1,6E-01	IE	7,6E-05	5,3E-07	-36,1
1995	-32,3	-3,0	-0,5	6,9E-05	1,4E-04	1,7E-01	IE	7,7E-05	5,3E-07	-35,5
1996	-34,1	-2,8	-0,2	6,2E-05	1,4E-04	1,9E-01	IE	8,2E-05	5,6E-07	-36,9
1997	-34,7	-3,5	-1,1	4,9E-05	1,6E-04	1,7E-01	IE	4,2E-04	2,9E-06	-39,0
1998	-33,5	-4,7	-0,2	5,0E-05	1,6E-04	1,3E-01	IE	2,2E-05	1,5E-07	-38,2
1999	-32,9	-5,6	0,1	6,5E-05	1,6E-04	1,6E-01	IE	1,4E-04	9,7E-07	-38,1
2000	-33,1	-5,3	-0,7	6,4E-05	1,8E-04	1,6E-01	IE	1,4E-04	9,7E-07	-38,9
2001	-30,6	-9,0	0,5	5,4E-05	1,9E-04	1,4E-01	IE	1,4E-04	9,9E-07	-38,9
2002	-32,1	-7,0	0,0	3,7E-05	2,0E-04	1,3E-01	IE	2,3E-04	1,6E-06	-39,0
2003	-29,8	-6,8	0,1	4,4E-05	2,1E-04	1,3E-01	IE	2,9E-04	2,0E-06	-36,3
2004	-25,1	-8,0	0,0	5,5E-05	2,1E-04	1,2E-01	IE	2,6E-04	1,8E-06	-32,8
2005	-23,8	-7,2	-0,2	8,2E-05	2,2E-04	1,2E-01	IE	2,4E-04	1,6E-06	-30,9
2006	-29,2	-7,1	-0,7	8,8E-05	2,3E-04	9,1E-02	IE	5,8E-04	4,0E-06	-36,9
2007	-30,2	-6,5	-0,4	1,2E-04	2,3E-04	1,2E-01	IE	1,1E-04	7,9E-07	-36,9
2008	-30,2	-6,4	-0,4	1,6E-04	2,4E-04	1,0E-01	IE	6,3E-04	4,3E-06	-36,8
2009	-29,8	-6,0	-0,2	1,5E-04	2,3E-04	9,8E-02	IE	1,3E-04	8,6E-07	-35,7
2010	-30,0	-3,9	-0,4	2,1E-04	2,3E-04	9,1E-02	IE	3,4E-05	2,3E-07	-34,1

7.2 Description of categories 5A, 5B, 5C, 5D, 5E and 5F

7.2.1 Characteristics of categories

A summary of the key categories under the LULUCF-sector is found in Table 7.3. In the LULUCF-sector CO₂ emissions/removals for Forest land, Cropland, Grassland and Settlements are considered key-categories for reporting of carbon stock changes in the CRF-categories 5A, 5B, 5C and 5E. Sweden uses Tier 2 and 3 methodologies and country-specific emissions factors. Land under 5D (except for a small area used for peat extraction) and 5F are considered unmanaged and not reported. The reported land under 5D refers to quite limited emissions from peat extraction. Emissions from categories 5I, 5III, 5IV and 5V are reported. For some of these categories it is not possible to separate emissions into land use categories since emissions are based on the total amount used (nitrogen fertilisation) or sold (liming). Category 5III is considered key-category (included in 5B Cropland N₂O) Category 5II, Non-CO₂ emissions from drainage of soils and wetlands, is not reported.

7.2.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

7.2.2.1 THE SWEDISH NATIONAL INVENTORY OF FORESTS

The Swedish National Inventory of Forests (RIS¹⁷³) consists of the Swedish National Forest Inventory (NFI¹⁷⁴) and The Swedish Forest Soil Inventory (MI¹⁷⁵). The NFI and the MI are integrated in the same sample design, using the same permanent sample plots. However, the sampling interval of the soil inventory is longer since processes in the soil are much slower than in the living biomass.

The plots associated to the NFI are re-inventoried every fifth year and the plots associated to the MI are re-inventoried every tenth year. Moreover, top soil cores are only taken at every second sample plot and deeper soil horizons are only sampled on every fourth sample plot. The reported data of changes in the living biomass and dead wood pools are based on the NFI-measurements and changes in the litter and soil organic carbon pools are based on the MI-measurements.

The NFI is an annual, systematic, cluster-sample inventory of Sweden's forests (Figure 7.3 and 7.4). Each year roughly a thousand survey sample clusters are inventoried in the field. One third of the clusters are temporary and two thirds are permanent. Only permanent sample plots are used for the UNFCCC reporting. The clusters are distributed all over the country in a pattern that is denser in the southern part of than in the northern part of the country. The clusters (tracts) are square-shaped with sample plots along each side. Each cluster consists of four to eight sample plots, depending on geographical region. Each year, about 6000 permanent survey sample plots are inventoried in the field. On each circular sample plot, with a radius usually of 10 or 20 m, information is collected about the trees, the stand and the site. The main focus of the NFI is on monitoring forests for timber production and environmental protection.

¹⁷³ Swedish University of Agricultural Sciences, 2005

¹⁷⁴ Ranneby et al., 1987

¹⁷⁵ Swedish University of Agricultural Sciences, <http://www-markinventeringen.slu.se/>

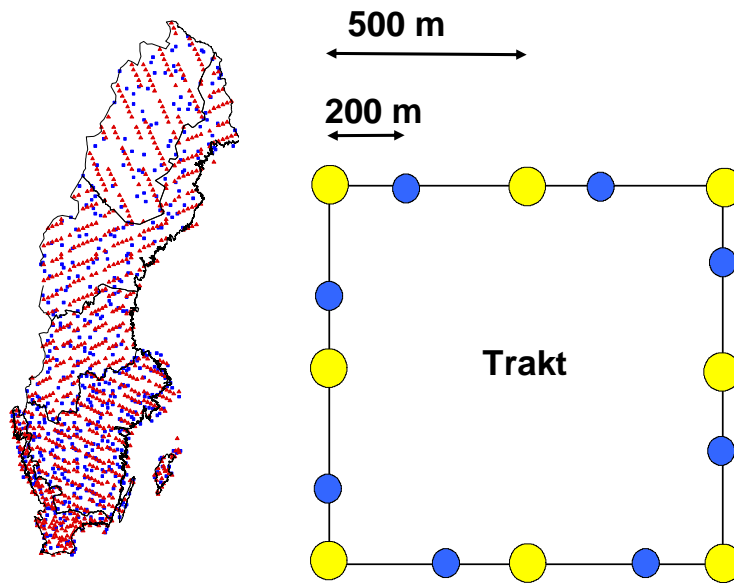


Figure 7.3 Covering whole Sweden, each year a permanent sample grid (red) is re-inventoried and a temporary sample grid (blue) is inventoried. To be able to trace both gross and net land use transfers, only permanent sample plots are used in the reporting. When estimating changes of e.g. C, the accuracy is also higher using permanent then when using temporary sampling plots. Each red dot represents a cluster of sample plots (Trakt) and within Trakt the yellow plots are used for the inventory while the blue plots are used for validation of harvests (estimates on up to one year old stumps).

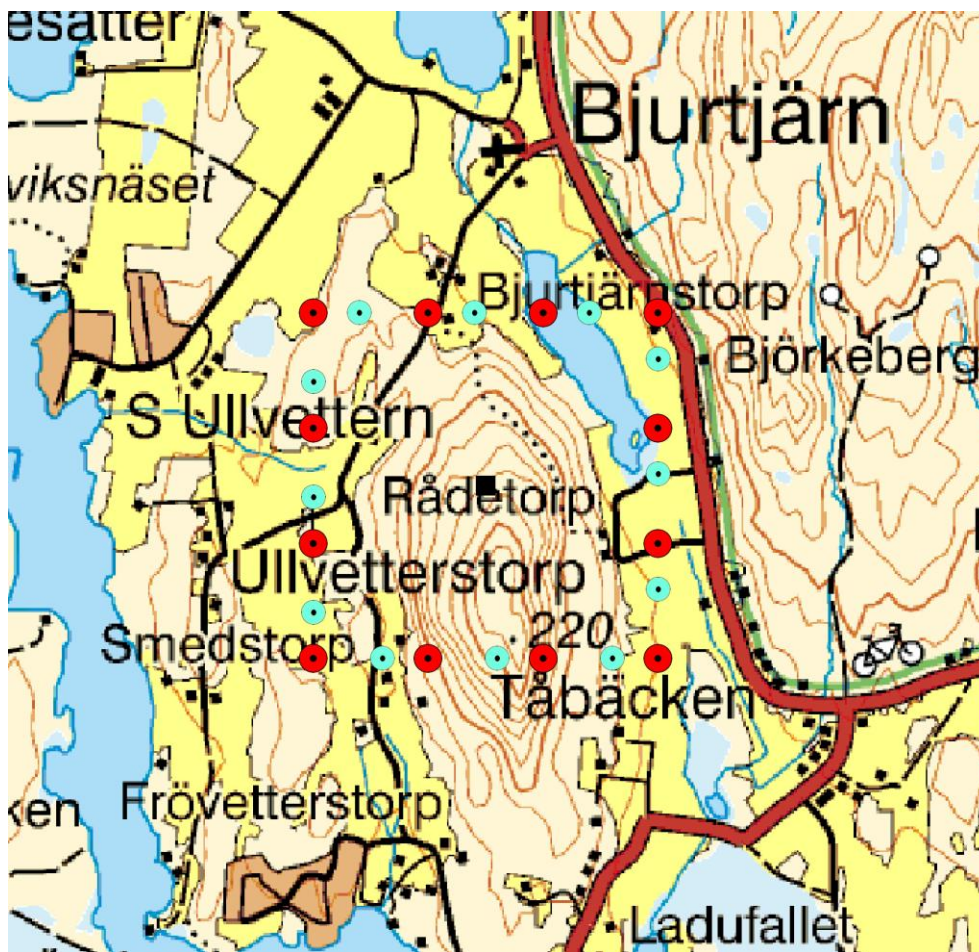


Figure 7.4 The sample plots (red) are covering all relevant land use. On the example above, plots are located on e.g. Forest land, Cropland, Wetlands and some plots are divided into more than one land use category. On the plots, measurements are made to estimate standing biomass of trees. If at the next 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 analyzed for C concentration and other properties. Litter is partly estimated using data from the plot and partly modeled. Observe that the shape of tracts differs by county. An additional sample (blue) is used for estimates of harvests.

The soil inventory uses the 10-m radius sampling plot. A number of variables are recorded including general site variables, the soil and humus type and the litter and different soil layers are sampled for further laboratory analysis. The O, H or A horizon are sampled using an augur. The mineral soil is sampled in different layers according to the distance from the soil surface and to some extent depending on the soil type. From 2003 and onwards the soil sampling has been harmonized with an ongoing European inventory, i.e. Biosoil¹⁷⁶ and soil samples are taken at fixed depths.

¹⁷⁶ <http://biosoil.jrc.it/>

7.2.2.2 SAMPLE BASED ESTIMATIONS

The sample frame consists of a map covering the whole land and fresh water area of Sweden. A sea archipelago zone where islands covered by vegetation might occur is also included in the frame (but no sea area is reported). The frame is divided into 31 strata (i.e. representing counties) and a specific number of sample units are sampled per stratum. Each cluster (tract) of sample plots is assumed to be the sample unit. The inventoried area of a tract is given a specific area weight and will consequently represent a larger area. The weighing is generated so that the sum of all represented areas will be equal to the total county area.

The land use of whole plots or parts of plots may change by time but the total tract area will always represent the same area. At the county level, the reported value of a change in a carbon pool (for example a change in the living biomass pool for the land use category Forest land remaining Forest land) will be estimated by a ratio estimator¹⁷⁷. 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 2006 and consequently only 24000, 18000, 12000 and 6000 sample plots are available for the estimates of 2007, 2008, 2009 and 2010, respectively. When five years have proceeded since 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 five most recent reporting years are re-calculated and revised in each submission.

Since the random variation of the samples largely affects the estimates of areas and carbon stock changes for the four most recent years (as also noted in the annual review reports), Sweden now extrapolates each of the five sample series using the running average for the five years previous to the actual year, to enlarge the data set for each reported year. As illustrated in Figure 7.5 the years after the last inventory year is calculated using the running average for each sample series. The effect of the extrapolation levels out “strange” area and carbon stock variations evolving from the randomness of the sampling as exemplified in Figure 7.5.

¹⁷⁷ Thompson, 1992

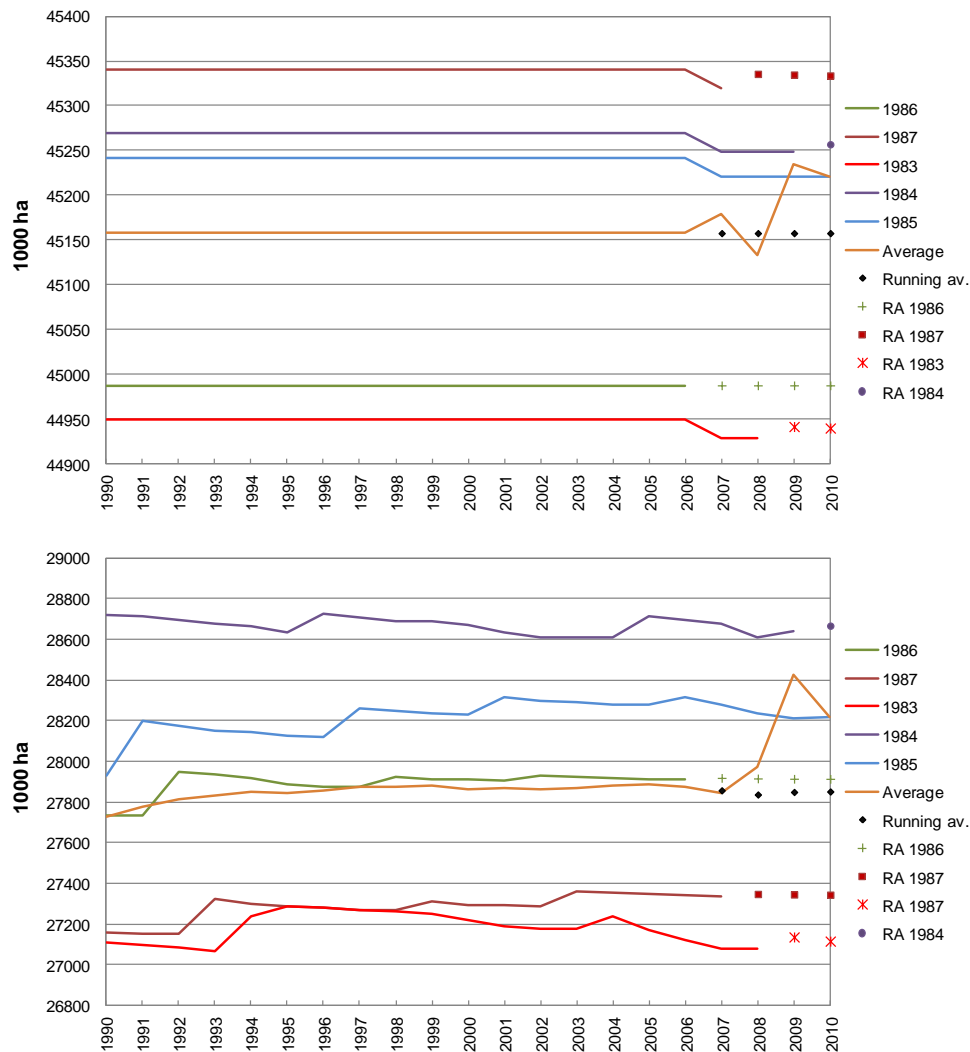


Figure 7.5 The upper panel shows the total area of Sweden with (R average) and without (average) the extrapolated numbers, continuous lines represents measured and interpolated values and dots represents extrapolated values. The lower panel shows the area of Forest land remaining Forest land with (R average) and without (average) the extrapolated numbers, continuous lines represents measured and interpolated values and dots represents extrapolated values.

Sweden reports “human induced” carbon changes only, where “human induced” has the interpretation of “managed”, i.e. the biomass stock change on unmanaged land are set to zero. However, the “actual” stock on unmanaged land is considered when calculating stock changes after conversions between unmanaged and managed land and vice versa. This is possible since trees are inventoried on almost any land. All areas, managed or unmanaged, are reported.

7.2.2.3 THE LULUCF-REPORTING DATABASE

The reporting database is based on permanent sample plots inventoried by RIS. In total, around 40000 permanent sample plots were distributed during the period 1983-1987. Plots without a full record have been removed from the reporting data-

base and therefore the number of sample plots has been reduced by about 25 % to around 30 000.

The permanent sample plots representing all land and fresh-water areas have been re-inventoried at intervals of 5-10 years (from 2003 in a five-year cycle). Land-use of each plot (or sub-plot for plots divided in two or more land use classes) is described from the year of the first inventory and every year thereafter. The land-use of years between inventories has been interpolated by linear interpolation (see Table A.3.2.1 in Annex 3:2). Biomass pools for years between inventories are also linearly interpolated.

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

Until 2005 information of the exact time of a land use transfer was not recorded by the NFI. Therefore, land-use transfers between 1990 and 2005 are assumed to occur at a random year between two consecutive inventories. From the inventory year 2006 and onwards the year of conversion is assessed in field. Every plot that is converted to another land-use category is reported for 20 years in the land-use transfer class. After 20 years the plot will be reported in the class to which it was transferred. If a second land-use conversion occurs within the 20 years, the counting starts all over again and the second transfer is reported for 20 years in the land-use transfer class as in the first example. In the reporting database it is possible to trace some of the land-use transfers that occurred up to 20 years before 1983 and consequently it is possible to decide how many years a sample plot has belonged to a certain land-use category and what land-use category it was converted from already at the start of the reporting period (1990). Consequently, several land use transfer categories include areas already before 1990. The IPCCs “20 year default rule” has vast influence on reported figures. One example is the fact that large carbon pools are accumulated in the conversion category Cropland converted to Forest already before the base year. After twenty years, parts of these land areas are reported as Forest remaining Forest. Consequently a loss of carbon will be reported under Cropland to Forest for and the corresponding removal is instead reported under Forest remaining Forest. To some extent, the continuously transfer of land use between categories and the five-year inventory cycle average out such events.

The FAO definition of Forest land was introduced in 1998. Until 1998 Forest land was assessed based on the national definition of Forest land. Therefore, land-use categories have to be re-determined for the period 1990-1997. There are two main types of redetermination cases which are handled as follows:

1. If the land-use category for a sample plot was registered as Forest land at the first inventory after 1997 and the national land-use category (see Table 7.4) had been the same at all earlier inventories since 1990, the plot are assumed to have always belonged to the land-use category Forest land.
2. If the land-use category was registered as Forest land at the first inventory after 1997 and the national land-use category (see Table 7.4) had changed since 1990, the first land-use category are assumed to remain

until the year of conversion. If at consecutive inventories after that, the land-use category belonged to the same land-use category, the plot is assumed to belong to the category Forest land all years after the year of conversion.

Two types of inconsistently classified land-use transfers have been identified and corrected:

1. Inconsistency over time in applying land-use category definitions.
2. Inconsistency in delineating borders between plots divided into more than one land-use category.

One example of the first type is when at different inventories, the land-use category of a sample plot has been classified as Forest land at the first inventory, as Wetland at the next inventory and then again as Forest land at the third inventory without traces of human activities. A case like this is corrected so that the land-use category is assumed to be Forest land on all three occasions. Another example of the first type is when a recreation forest close to a city has been converted from Settlements (section 7.2.3.1, national land-use category 13, “Urban land”) to Forest land and the new land-use category consists of old trees. This has been corrected so the land-use is assumed as Forest land on both occasions. One example of the second type is when the delineation of a divided plot, representing more than one land-use category, has been changed at the re-inventory due to personal judgments rather than due to actual changes. These land-use changes should not be registered as land use changes and have been corrected by keeping the newer delineation, usually if the assumed incorrect new delineation deviates approximately less than 0.75 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.

7.2.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories

Sweden has defined Forest land according to the Global Forest Resources Assessment (FAO/FRA) 2005¹⁷⁸. Forest land is land with a tree crown cover (or equivalent stocking level) of more than 10 percent at maturity, with a minimum area of 0.50 hectare and the trees should be able to reach a minimum height of 5 m at maturity *in situ*. However, there are two small discrepancies between the FRA 2005 definition and the definition implemented in the Swedish inventory.

¹⁷⁸ Food and Agriculture Organization of the United Nations, 2004

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

CRF	Gas	Key Category Assessment 2010			Method	EF
		Level	Trend	Qualitative		
5A	CO ₂ ^{1,3}	X	X		T1, T2, T3	CS
	N ₂ O				T1 (5I, 5V)	D (5I, 5V)
	CH ₄				T1 (5V)	D (5V)
5B	CO ₂ ²	X	X		T1, T2, T3, T1 (5IV)	CS, D (5IV)
	N ₂ O		X		T1 (5III)	D (5III)
5C	CO ₂ ³	X			T1, T2, T3	CS
	N ₂ O				T1 (5V)	D (5V)
	CH ₄				T1 (5V)	D (5V)
5D	CO ₂				T2	CS
5E	CO ₂	X	X		T1, T2, T3	CS

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

In the Swedish inventory permanent forest roads (width>5m) are not considered Forest land, and no minimum width to constitute Forest land is considered (note that the strict terms of Decision 11/CP.7 does neither mention the minimum width nor the forest roads¹⁷⁹). All Forest land is considered managed, i.e. even protection of forests in reserves is considered as management. Cropland is defined as regularly tilled agricultural land and all Cropland is assumed managed. Grassland is defined as agricultural land that is not regularly tilled and all Grassland is assumed managed. Generally, Wetlands is assumed unmanaged and is defined as mires and areas saturated by fresh water. However, ca 10 000 ha of the Wetland area is used for peat extraction and therefore assumed managed. Settlements are defined as infrastructure components such as roads and railways, power lines within forests, municipality areas, gardens and gravel pits. All Settlements are assumed managed. Other land is defined as impediments (waste land) and most of the mountain area in northwest Sweden. All Other land is assumed unmanaged. Land-use categories are monitored within the Swedish National Forest Inventory (NFI¹⁸⁰).

7.2.3.1 THE CONNECTION BETWEEN NATIONAL AND REPORTED LAND USE CATEGORIES

The reported land use categories are based on 16 national land use categories monitored by the Swedish National Inventory of Forests (RIS). For example in year 2000 the area of Forest land, according to the definition of forest described above, was estimated to 27 414 000 ha. This corresponds to 22 749 000 ha Productive Forest land (national category 01), 1 678 000 ha Mire (04), 520 000 ha Rock Surface (05), 268 000 ha Sub alpine Coniferous Woodland (06), 376 000 ha High

¹⁷⁹ FCCC/CP/2001/13/Add.1, p 58

¹⁸⁰ Ranney et al., 1987

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

Table 7.4 National Land Use Categories, their connection to the UNFCCC Land Use Categories and their potential importance for carbon reporting. A=all land is considered FAO Forest land, B=large areas are considered FAO Forest land. Observe that this example is based on both temporary and permanent sample plots. Thus, the total area is not comparable with reported areas.

National Land Use Category	UNFCCC/KP-Land Use Category	Carbon Stock In Living Biomass of Trees [T gram] Year 2000	Area [1000 ha] Year 2000	Additional Explanation
Productive Forest land (01)	F	1047	22749	Land which hosts a potential yield of stem-wood exceeding one cubic metre per hectare and year (A).
Grazing Land (02)	G	5.7	494	Not regularly cultivated.
Arable Land (03)	C	1.5	3052	Regularly cultivated
Mire (04)	W	35.6	4588	Land which hosts a potential yield of stem-wood lower than one cubic metre per hectare and year (B).
Rock Surface (05)	O	16.4	896	Rocky or stony areas. (B)
Sub alpine Coniferous Woodland (06)	F	8.2	307	Land-zone usually located between (01) and (07). (A)
High Mountain (07)	O	Low	3010	Usually unstocked or sparsely stocked. (B)
Climatic Impediment (08)	O	0.7	48	Usually located in flat terrain in northern Sweden. (B)
Road and Railroad (09)	S	0.5	445	For permanent use. Not only roadway and rail but also other connected areas as embankments and ditches.
Power line Within Forest (10)	S	0.2	145	Minimum width 5 m, otherwise Productive Forest land (01)
Protected Area, Nature Reserve (11)	(F)	Medium	3967	This land use category was left out 2003 and is thereafter included in the remaining land use categories.
Military Impediment (12)	S	Low	69	Could not be inventoried for security or safety reasons.
Urban Land (13)	S	Low	1185	Settlements of many different kinds.
Other land (14)	S	2.1	115	Different kinds of land that is not covered by Other land use categories. Examples: gravel pits, halting places and slalom slopes
Water (not sea) (15)	W	0	4009	Lakes, rivers, creeks, canals, pounds etc. Minimum width of 2 m.
Sea (16)	-	-	-	To check if the total land area is constant.
Total		1118	45080	

7.2.3.2 CONSISTENCY IN REPORTING LAND USE CATEGORIES

The NFI has monitored land-use categories in a reasonably consistent way since 1983. Based on permanent sample plots, it is possible to trace both gross and net

land-use transfers from 1983 and onwards. On Forest land, it is also possible to determine former land-use (i.e. Cropland or Grassland) before the base year (1990). All land areas are included in the field inventory except high mountains and urban land. These latter land-use categories are only inventoried for area by remote sensing. It is assumed that their relative importance for the Swedish carbon budget is negligible.

A few historical inconsistencies in the land-use category assessment have been identified and corrected. Before year 2003, protected areas ("Protected Area, Nature Reserve"; section 7.2.3.1) were not regularly inventoried. From 2003 and onwards this areas are included in other land-use categories. Usually there are data from at least one field inventory of "protected areas" before 1990, but sometimes no data are available. If no data are available, the change in carbon pools in former "protected areas" is assumed to be zero from 1990 to 2002. From 2003 potential changes will be reported based on field inventory data. The FRA 2005 definition of Forest land was introduced in the field inventory in 1998 and therefore land-use categories in earlier inventories has been re-determined. A description on the treatment of former protected areas, re-determination of land-use categories and the methodology for correcting inconsistencies in the land-use category assessment are described in more detail in the methodology section.

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

7.2.4.1 LIVING BIOMASS

The reported carbon pool changes refer to the biomass of all living trees with a height of at least 1.3 m. Thus, small trees, shrubs and other vegetation, such as herbs are not included in the figures. Both above-ground and below-ground biomasses are reported. Above-ground 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 volume¹⁸¹. Broad-leaved species constitute most of the remaining 8 %. Below-ground biomass is defined as living biomass below stump height (1 % of tree height) down to a root diameter of 2 mm (fine roots, <2 mm, are operationally defined as belonging to the dead organic matter pool or in the soil organic carbon pool). The living biomass pool is reported for all land-use categories assessed in the field inventory.

7.2.4.2 DEAD ORGANIC MATTER

The dead organic matter pool includes the carbon pools dead wood and litter. Dead wood is defined as fallen dead wood, 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 and a length of at least 1.3 m. Dead wood of stumps with corresponding roots are reported for Forest land remaining Forest land (and Forest management under the Kyoto Proto-

¹⁸¹ Swedish University of Agricultural Sciences, 2004

col), while fallen dead wood and snags are reported for all relevant land-use categories. Litter includes all non-living biomass not classified as dead wood, lying dead, in various states of decomposition above the mineral or organic soil. This includes the litter, 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.

7.2.4.3 SOIL ORGANIC CARBON

The soil organic carbon pool on forest land and grassland includes all carbon in the mineral soil below the litter, fomic and humic layers in mineral soils and all organic carbon in soils classified as Histosols¹⁸². The carbon pool considered is soil organic carbon down to a depth of 0.5 m measured from top of the mineral soil or, alternatively, from the soil surface when the soil is classified as a Histosol.

7.2.5 Emissions of N₂O, CO₂ and CH₄, CRF 5(I), 5(II), 5(III), 5(IV) and 5(V)

7.2.5.1 DIRECT N₂O EMISSIONS FROM N FERTILIZATION, CRF 5(I)

To increase the forest production, some middle aged or older forest stands on mineral soils are occasionally fertilized. In 1990, the fertilized forest area was estimated to 69 200 ha¹⁸³. Since then, the annual fertilized area has decreased to about 20 000 ha in 1997-2004. In 2010, this area had increased to about 80 000 ha. The underlying data (areas) are based on an annual questionnaire sent to approximately 150 large-scale forest companies and constitute Official Statistics of Sweden collected by the Swedish Forest Agency. Large-scale forestry are defined as forest companies with more than 10 employees or owners of more than 5000 ha Forest land., contributes with 98.5 % of fertilizer related emissions of N₂O. Consequently, small-scale forestry is assumed to contribute with approximately 1.5 % of the emissions. To estimate the total annual emission, area figures are multiplied with normal average amount of fertilizer N spread per hectare. The normal average amount N spread per hectare is obtained from companies that are carrying out the fertilization in practice (there are only a few companies in this business).

7.2.5.2 N₂O EMISSION FROM DRAINAGE OF SOILS, CRF 5(II)

According to UNFCCC (decision 13/CP.9), reporting emissions of nitrous oxide from drainage (N₂O-direct $N_{drainage}$) is optional. One reason for that is the limited understanding of the processes controlling the emissions. No N₂O emissions from drainage of soils will be reported this year, but some preliminary studies indicate that reliable methods may be available in a few years.

¹⁸² Food and Agriculture Organization of the United Nations, 1994.

¹⁸³ National Board of Forestry, 2004

7.2.5.3 N₂O EMISSIONS FROM DISTURBANCE ASSOCIATED WITH LAND-USE CONVERSION TO CROPLAND, CRF 5(III)

Due to more intensive soil management on Cropland, the transfer of other land-use to Cropland is usually associated with a temporary increase in the mineralization of organic matter. Part of the released N may be converted to N₂O through denitrification. Land converted to Cropland is reported as belonging to the conversion class for twenty years (if no secondary conversion occurs). The accumulated area converted from Forest land to Cropland during 20 years has been up to 5 000 ha and the area converted from Grassland to Cropland is now around 55 000 ha. The area of other land-use conversions to Cropland is negligible.

7.2.5.4 CARBON FROM AGRICULTURAL LIME APPLICATION, CRF 5(IV)

Lime is used for soil improvement in both agriculture and horticulture to mitigate acidification that is caused by the export of biomass, acidifying fertilizers and acid rain. The reported figures are based on quantities sold for agricultural and horticultural purposes plus lime from sugar mills and steel production. The quantities are separated into dolomite (CaMg(CO₃)₂) and limestone (CaCO₃), where dolomite and Mg-lime are reported as dolomite and all other categories are reported as limestone. All categories are supposed to contain 100 % dolomite/limestone except residual lime from sugar production which is assumed to contain 65 % limestone due to a water content of approximately 35 %. The accuracy of estimates of the sold quantities is assumed to be high and constitutes Official Statistics of Sweden¹⁸⁴. Separate default IPCC emission factors are used for limestone and dolomite, respectively.

7.2.5.5 N₂O, CH₄ AND CO₂ FROM BIOMASS BURNING, CRF 5(V)

Forest fires are very rare in Sweden. Wildfires have been monitored by the Swedish Rescue Services Agency since 1996¹⁸⁵ and the area of wildfires has varied from 400 to 6400 ha yr⁻¹. Controlled burning after clear-cutting to improve regeneration of trees is monitored by a full record from 1990 and onwards (Swedish Forest Agency). Controlled burning for nature conservation is monitored from 2006. In recent years, an area of approximately 300-3000 ha is annually burned after clear cutting and 100-2000 ha is now annually burnt for nature conservation. The Swedish Rescue Services Agency reports the annual area of wildfires for three different land categories: "Forest", "Sparsely covered by trees" and "No tree cover". The definition of "Forest" almost corresponds to the national definition of productive forest. "Sparsely covered by trees" are areas sparsely covered by trees such as mires, forest in the mountain area and parks. "No tree cover" is land with no trees such as agricultural land, open areas but also some mires. The assumed former stock on burned areas is based on estimates of above-ground living and dead biomass inventoried by the NFI by matching national definitions to the definition by the Swedish Rescue Services Agency. The area of wildfires is probably slightly

¹⁸⁴ Statistics Sweden, 2004

¹⁸⁵ Swedish Rescue Services Agency, 2004

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.

7.3 Methodological issues

7.3.1 CRF-tables 5A, 5B, 5C, 5D, 5E and 5F

7.3.1.1 BASE METHODOLOGY

Sweden reports emission/removals from carbon pools mainly according to the IPCC stock change method. The stock change method is combined with a sample-based inventory design which makes it possible to estimate errors of the estimates. The Swedish National Inventory of Forests (RIS¹⁸⁶) has monitored the most relevant carbon pools since 1983. A particular advantage with the Swedish NFI is that it has been undertaken using permanent sample plots, on all land use categories, which makes it possible to monitor both gross and net land-use conversions for the six land-use categories in a consistent and transparent manner (for further details, see Annex 3:2).

7.3.1.2 METHODOLOGY LIVING BIOMASS CRF 5A, 5B, 5C, 5D, 5E AND 5F

A national methodology (Tier 3) is used. The above-ground biomass per fractions is estimated by applying Marklund's¹⁸⁷ biomass functions to trees on permanent sample plots of the NFI¹⁸⁸. The below-ground biomass is estimated by using Peterssons and Ståhl's¹⁸⁹ biomass functions on biomass data from the same trees as for the above-ground biomass. The conversion factor 0.49 is used to convert biomass to carbon¹⁹⁰. 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.

7.3.1.3 METHODOLOGY DEAD ORGANIC MATTER CRF-TABLES 5A, 5B, 5C, 5D, 5E AND 5F

A national methodology (Tier 3) is used to estimate the dead organic matter pool. The pool includes different sub-pools (dead wood, litter and the organic soil horizon) that are estimated slightly differently.

The inventory of dead wood began in 1994 for northern Sweden and from 1995 for the whole country. The carbon content in dead wood was calculated using conver-

¹⁸⁶ Swedish University of Agricultural Sciences, 2005

¹⁸⁷ Marklund, 1987 and 1988

¹⁸⁸ Ranney et al., 1987

¹⁸⁹ Petersson and Ståhl, 2006

¹⁹⁰ National Board of Forestry, 2000

sion factors from volume per decay class to biomass for the species Norway spruce and Scots pine. The volume is measured by the NFI. Below-ground 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 carbon dioxide equivalents 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)– consequently, 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 volume¹⁹¹ and stump and root biomass¹⁹² applied to sample trees representing the standing stock of Swedish forests. The decay of stump systems is modelled¹⁹³ by simple decomposition functions. The described methodology is consistently used during the reported period. Emissions from stump systems before 1990 are considered by similar methodology (1853-1989). Sweden is discussing options to improve the accuracy of estimates in future reporting¹⁹⁴.

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 above-ground dead wood. Litter fall is calculated using empirical functions based on tree stand properties and litter fall for deciduous species by biomass functions based on leaf biomass. This fraction of litter is regarded as an annual pool. The remaining part of this pool after one year is included in the O horizon and thus measured by the soil inventory. The fine litter (< 2 mm) is estimated by sampling the O or H horizon sample which is taken on an area basis, weighed and analysed for carbon content (for further details, see , see Annex 3:2).

7.3.1.4 METHODOLOGY SOIL ORGANIC CARBON CRF 5A, 5B, 5C, 5D, 5E AND 5F

The soil organic carbon pool is estimated using different approaches depending on the land use. For Forest land and Grassland on mineral soils, estimates are based on repeated soil sampling in combination with pedotransfer functions. For organic forest and grassland soils the changes are based on emission factors and area estimates of different sub-categories. For Cropland the ICBM model^{195,196} is used to predict changes in the soil organic carbon stock on mineral soils and an estimation of the subsidence to calculate the change on organic soils.

¹⁹¹ Näslund 1947

¹⁹² Petersson and Ståhl, 2006

¹⁹³ Melin et al., 2009)

¹⁹⁴ Petersson and Melin, 2010; Melin et al., 2010)

¹⁹⁵ the Introductory Carbon Balance Model

¹⁹⁶ Andrén & Kätterer, 2001

7.3.1.4.1 Forest land and Grassland on mineral soils CRF 5A and 5C

The method is a Tier 3 method. The estimates are based on repeated measurements on the NFI plots of several variables. The basic function used to determine the amount of carbon in a soil layer is based on the amount of carbon in a certain soil layer and the fraction of fine earth. The amount of fine earth is dependent on the bulk density and amount of gravel, stones and boulders in the soil (for further details, see Annex 3:2).

7.3.1.4.2 Forest land and Grassland on organic soils CRF 5A and 5C

The method is a Tier 2 method. Changes in the organic carbon pool are calculated as the difference between annual below ground litter input and the heterotrophic respiration. Annual litter production is derived from the National Forest Inventory and the emission factors for drained and undisturbed organic forest soils are based on studies from Sweden and Finland (for further details, see Annex 3:2).

7.3.1.4.3 Cropland on mineral soils CRF 5B

The method to estimate the carbon balance of agricultural soils is a Tier 3 method. The carbon changes in the mineral soil are calculated based on data from eight agricultural production regions using the model ICBM-region. The ICBM model is described in Andrén & Kätterer¹⁹⁷. 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 texture¹⁹⁸ (for further details see Annex 3:2).

7.3.1.4.4 Cropland on organic soils CRF 5B

The method to estimate the carbon balance of organic agricultural soils is a Tier 2 method. A national emission factor for cropland on organic soils is used to calculate the mean annual carbon loss per cm soil subsidence. The emission factor is modified according to crop type. The relative area proportion of the different crop types and the total area of organic soils under agricultural production were estimated in a national survey¹⁹⁹. Compared to earlier estimated and reported areas the area is now essentially smaller (for further details see Annex 3:2). The area has been linked to the changes in total cropland area so that decreasing cropland area proportionally affects the area of cropland on organic soils²⁰⁰ (for further details see Annex 3:2).

¹⁹⁷ Andrén & Kätterer, 2001.

¹⁹⁸ Eriksson 1997, 1999

¹⁹⁹ Berglund and Berglund, 2009

²⁰⁰ In previous submissions a small discrepancy in the area of organic soils reported for cropland remaining cropland in the LULUCF sector and the area of cultivated organic soils reported in the agriculture sector was detected (ERT, centralised review Subm 2009). In this submission the consistency has been improved and areas have been estimated as described in the text.

7.3.1.5 METHODOLOGY FOR DEAD ORGANIC MATTER AND SOIL ORGANIC CARBON FOR CONVERSION BETWEEN LAND-USE CLASSES CRF-TABLES 5A.2.1-5, 5B.2.1-5, 5C.2.1-5, 5D.2.1-5, 5E.2.1-5 AND 5F.2.1-5 CROPLAND ON ORGANIC SOILS CRF 5B

The method to estimate the emission/removals in the DOM – and the SOC pools associated with land use changes is a Tier 2 method. In general (except for dead wood and coarse litter) the carbon stock changes associated with conversion of lands is estimated using an emission/removal factor is used in combination with the areal change in land-use for further details see Annex 3:2).

7.3.1.6 CO₂ EMISSION FROM MINERALIZATION WHEN EXTRACTING PEAT CRF 5D

The method used to estimate CO₂ emission from peat extraction areas is a Tier 1 approach. A limited area of Wetlands (10000 ha) used for peat extraction is considered managed and reported under Wetlands remaining Wetlands. The reported CO₂ emissions refer to mineralization when extracting peat for fuel and agricultural purposes. The emitted CO₂ [Mton•yr⁻¹] is calculated as the product of the extracted area and an emission factor (for further details see Annex 3:2).

Peat extraction is only ongoing on part of the production area. The peat extraction is usually proceeding many years on the same production area until this area is closed down and restored. Former managed peat land is usually restored by saturation by water or by conversion to Forest land. The water saturation will probably stop most carbon mineralization and Wetlands converted to Forest land is reported under Wetlands converted to Forest land (for further details see Annex 3:2).

7.3.2 CRF 5(I), 5(II), 5(III), 5(IV) and 5(V)

7.3.2.1 DIRECT N₂O EMISSIONS FROM N FERTILIZATION, CRF 5(I)

A Tier 1 methodology is used and the reported figures refer to $N_2O_{direct\ fertilizer}$ (of N). All fertilization is assumed to occur on Forest land remaining Forest land²⁰¹. In year 1990 nitrate of lime (Ca(NO₃)₂) was the dominant fertilizer but thereafter the fertilizer have been based on 50 % NO₃-N and 50 % NH₄-N. The reported annual $N_2O_{direct\ fertilizer}$ [Gg•yr⁻¹] is calculated as the product of the applied amount and the emission factor (for further details see Annex 3:2).

7.3.2.2 N₂O EMISSIONS FROM DRAINAGE OF SOILS, CRF 5(II)

Not reported (optional).

²⁰¹ 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.

7.3.2.3 N₂O EMISSIONS FROM DISTURBANCE ASSOCIATED WITH LAND USE CONVERSION TO CROPLAND, CRF 5(III)

A Tier 1 methodology is used. The reported annual N₂O emission from disturbance associated with land use conversion to Cropland (N_2O_{conv} [Gg•yr⁻¹]) is calculated according to equation 3.3.15 in IPCC GPG for LULUCF (IPCC²⁰²) (for further details see Annex 3:2).

7.3.2.4 CARBON FROM AGRICULTURAL LIME APPLICATION, CRF 5(IV)

Methodology level Tier 1-2 is used for reporting carbon emissions from liming. The reporting is based on consumption studies²⁰³ and all liming is assumed to occur on Cropland remaining Cropland. The reported annual carbon emission from agricultural lime application (C_{lime} , [Gg•yr⁻¹]) is calculated as the product of the applied lime and the emission factors (see Annex 3:2 for further details).

7.3.2.5 EMISSIONS FROM BIOMASS BURNING, CRF 5(V)

A Tier 1 methodology and IPCC default emission factors are used. All land categories are monitored but the reported emission is assumed to occur only on Forest land remaining Forest land and on Grassland remaining Grassland. Calculations are based on the amount of biomass per area, burned area and emission factors (for further details see Annex 3:2).

7.4 Uncertainties and time series consistency

7.4.1 Uncertainties

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. A summary of uncertainties is found in Table 7.5.

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 could also arise from missing or overlapping pools. Systematic errors are subjectively judged with help from experts and from default error values according to IPCC²⁰⁴.

²⁰² Intergovernmental Panel on Climate Change, 2003

²⁰³ Statistics Sweden, 2004

²⁰⁴ Intergovernmental Panel on Climate Change, 2003

Table 7.5 Estimated annual net emissions/removals and their corresponding uncertainty (2•relative “standard error”). For categories Living biomass, Dead organic matter and Soil organic carbon, standard errors are based on random sampling. For other categories, standard errors refer to biases that are assumed. Assuming GWP=1 for CO₂, 310 for N₂O and 21 for CH₄, the uncertainty level for the total net removal is estimated to 28 %. Combined uncertainties are calculated according to IPCC, minus=removal

Category	Emission/Removal [Gg•yr ⁻¹]			2-Relative Standard [%]		
	CO ₂	N ₂ O	CH ₄	CO ₂	N ₂ O	CH ₄
Living biomass	-30007	-	-	24	-	-
Dead organic matter	-3878	-	-	50	-	-
Soil organic carbon	-400	-	-	35	-	-
Direct N fertilization, 5 (I)	-	0.212	-	-	50	-
Drainage of soils, 5 (II)	-	NE	-	-	NE	-
Conversion Cropland, 5 (III)	-	0.231	-	-	100	-
Agricultural lime application, 5 (IV)	91	-	-	50	-	-
Biomass burning, 5 (V)	-	0.000	0.034	-	75	75
All	-34194	0.443	0.034	28	80	75

7.4.2 Living biomass, CRF 5A, 5B, 5C, 5D, 5E and 5F

The estimated accuracy of the living biomass pool depends mainly on the sample design of the NFI. Results from the control inventory of the NFI indicate that measurement errors, registration errors and errors caused by the instruments (callipers) could be assumed to be close to zero. Potential bias induced by incorrectly specified models and an unrepresentative derivation data are ignored. Estimates for reporting years 1990-2006 are based on approximately 30000 sample plots and with a corresponding estimated relative standard error of 12%. Estimates for reporting years 2007, 2008, 2009 and 2010 are based on measurements on approximately 24000, 18000, 12000 and 6000 sample plots, respectively, combined with extrapolated data. We believe that this extrapolation increases the accuracy substantially but to be on the sure side, to avoid a potentially risk of systematic errors, we gradually update extrapolated data using data from re-measured sample plots (see Annex 3:2 for further details).

7.4.3 Dead organic matter, CRF 5A, 5B, 5C, 5D, 5E and 5F

Estimates of dead organic matter are based on sampled data from the litter pool and dead wood pool from the NFI and the MI. The sample error for the entire dead organic matter pool is calculated similarly to the living biomass calculation and is given in Table 7.5. There is probably a small error in the estimates of dead wood due to incorrect measured volumes and due to errors connected to the conversion from volume to carbon. Coarse litter is calculated as 15 % of the dead wood. The error of this proportion might be large since the knowledge of the relation between the amount of dead wood and coarse litter is poor. Compared to submission 2011 accuracy has improved since the reported figures now are based on more repeated measurements of permanent sample plots. For changes in carbon in the O-horizon the measurements are based on samples from 1993-1998 (first inventory) and from

2003-2008 (second inventory), while dead wood measurements are from the period 1995 to 2010. We are now also basing the estimate on interpolated values for years between inventories. The accuracy will increase in the future when more data from repeated measurements will be accessible.

One of the major difficulties in reporting changes in DOM and SOC is that the pool is very large and the changes small in comparison to the pool. As seen in figure 7.6 the reported changes are considerable in terms of carbon and they do have an impact on the national carbon budget. However, the annual changes are still only in the order of a few % of the pool and can hardly be detected in the 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.

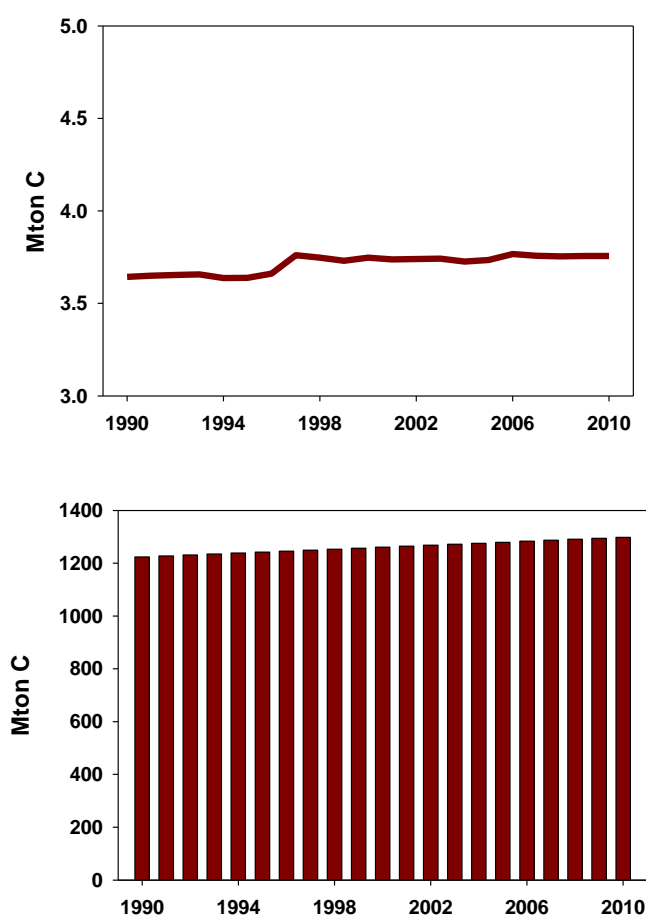


Figure 7.6 The reported change in soil carbon on mineral soils (upper panel) and the corresponding stock (lower panel) for Forest remaining Forest in the current submission.

7.4.4 Soil organic carbon, CRF 5A, 5B, 5C, 5D, 5E and 5F

The sample error for the soil organic carbon pool is calculated similarly to the living biomass calculation and is given in Table 7.5. The problems associated to the estimates of changes in the soil carbon pool is of the same nature as the ones described for the dead organic matter pool above, and significant improvements are

expected when the proportion of repeated measurements will increase. Another problem associated to our methodology is the risk of systematic errors in the sampling and analysis of data. Since there are rather small changes in large pools even a small systematic error may cause a trend in the material. From 2003 the sampling methods of soil samples have been changed compared to earlier inventories in order to avoid subjective judgments in sampling, e.g. regarding determination of soil horizon boundaries. This might give rise to problems of comparability between inventories, but should improve the quality of the data by reducing future risks of systematic errors.

Significant efforts are made to check data and to remove possible sources of error in the field data collection. The uncertainty in activity data (area) for CO₂ emission from drained forest land is judged to 25 % and errors in the emission factor to 25 % as well. The uncertainty in activity data (area) 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 300 %. The high error of the EF is based on the fact that i) the variation between different emission factors is significant²⁰⁵, and ii) the underlying data of the EF does not perfectly match the target population^{206,207}.

7.4.5 Other CO₂ emissions, CRF 5(IV) and 5(V)

The reported CO₂ emission from agricultural lime application is based on consumption studies and the design is regarded as a total inventory with no random error. The error due to activity data is probably small and the reason for this is high quality data on quantities of limestone and dolomite sold. It is assumed that the error due to the use of incorrect emission factors used might be quite large. The reported uncertainty is based on a default error coefficient from IPCC²⁰⁸.

Uncertainties from biomass burning arise from the errors in the estimated area that is burned and in the emission factors used. The emitted amounts per area unit depend on the biomass stock before the fire and the proportion of this biomass that actually is burned. The error of the estimated burned area is probably quite small but the knowledge of emitted amount per area is quite poor. The reported uncertainty is based on a default error coefficient from IPCC.

7.4.6 N₂O and CH₄ emissions, CRF 5(I), 5(III) and 5(V)

Generally for all N₂O and CH₄ emissions, the error in activity data is small compared to the error due to errors associated to the emission factors. 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

²⁰⁵ Statistics Sweden, 2002

²⁰⁶ Kasimir-Klemmedtsson et al., 2000

²⁰⁷ Sund et al., 2000

²⁰⁸ Intergovernmental Panel on Climate Change, 2003

error that is much larger than 25 %. Based on this information a total error of 50 % for N₂O emissions from N-fertilization is suggested.

The accuracy of estimates of N₂O emissions from disturbance associated with land-use conversion to Cropland 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. The uncertainty level is based on this reasoning and on IPCC default values (IPCC).

According to the points raised in the discussion above on uncertainties in CO₂ emissions from biomass burning, the uncertainty of N₂O and CH₄ emissions from biomass burning are assumed to be 75 %, (Managing uncertainties: A.1.4).

7.4.7 Completeness

It is assumed that all categories have been reported only once. This is ensured by using only one source of information for the land area representation of carbon pools.

Sweden reports carbon stock changes in all carbon pools and all other emissions for mandatory categories considered managed (Forest land, Cropland, Grassland, Settlements and a small area of Wetland used for peat extraction). The notation key “NO” is used when there is no observed occurrence for a certain category (i.e. uncommon land use changes). 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 methods. In the latter case either gains or losses are reported “IE”. The notation key “NA” is used when the reported activity does not result in emissions/removals. This notation key is also used for emissions/removals from unmanaged land. The notation key “NE” is only used for categories not estimated because they are currently optional to report. Harvested wood products are not reported (optional) and factoring out has not been considered.

7.4.8 Time series consistency and verification

The time series of change in carbon stock for the living biomass pool is 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 extrapolates data in the beginning of the period and this because the inventory did not begin until the mid 1990th. Due to a relative high sampling error, a trend is reported and it is quite difficult to match emissions/removals from dead wood to the correct year. The dead wood pool constitutes a net removal and this could partly be explained by the fact that an increasing amounts of dead wood and snags have been left after harvest, however, no proper validation has been made.

The time series of the dead organic matter pool is consistently measured since 1993 with only minor changes in sampling methodology. The soil organic carbon

has been sampled annually since 1993. In 2003 a revision of sampling methodology was made to harmonize sampling with international monitoring programs. Studies on the effects of these changes in sampling have not revealed any systematic differences with respect to soil carbon pool estimates. The time series for dead organic matter and soil organic carbon in forests have been compared to results from two process-oriented models. Models and measurements agreed well in estimation of the soil carbon pool and in the direction of change, but there were small changes with respect to the rate of change between the models and the measurements²⁰⁹.

7.5 QA/QC

7.5.1 Quality assurance

The quality assurance system of the data collection within RIS used for the UNFCCC and Kyoto reporting has been described by the Swedish University of Agricultural Sciences²¹⁰ and a detailed description of routines is under development. 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. For this submission, quality assurance has been carried out in an internal review by experts at SLU. A national review has been carried out by representatives for the Swedish Forest Agency and Swedish Board of Agriculture.

7.5.2 Quality control

An internal quality control has been performed following level Tier 1, (Table 5.5.1 in Good Practice Guidance 2003).

For reported activity data, descriptions of definitions, description of underlying models, description of sampling design and emission factors used were studied and no errors were found. This was also valid for descriptions of land areas, eventual transcription errors and references. Both calculations and units of estimates were cross checked and judged as reasonable. Original data from the NFI constitute official statistics of Sweden and were not checked. All data (and methodologies used) is archived by the SLU.

7.6 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 7.2.2.2. Small

²⁰⁹ Ortiz C. et. al. 2009.

²¹⁰ Karlton, E. et. al.. 2005.

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 sale statistics, information on biomass burning or emission factors related to land-use change).

The fourth category is when the methods have been improved.

In the current submission, the living biomass pool (also valid for areas per land use category), land use areas and areas subject to land use transfers have been recalculated for the years 2006-2010 to improve accuracy and each estimate are now based on 6000 more sample plots and incomplete inventory cycles have been extrapolated to 2010, see also section 7.2.2.2. Minor corrections of single plots have been made and that is why also small deviations from former submissions occur also for years 1990-2006. The effect of this annual recalculation on Living biomass on Forest land remaining forest land is illustrated in figure 7.7.

The pools dead organic matter and soil organic carbon on mineral soils on Forest land remaining forest land and Grassland-remaining-Grassland have been recalculated for the whole time series from 1990 to 2010 due to introduction of more re-inventoried sample plots.

Recalculations occur also for non-carbon pools due to slightly adjustments in activity data (areas), but these re-calculations are very small and have no practical influence on the accounting. Due to recalculated estimates of areas, emissions from disturbance associated with land use conversion to Cropland (5III) have been updated. Some rounding errors have been corrected (general for both carbon and non-carbon pools). Observe that, to avoid double counting, CO₂ emissions from wild-fires and controlled burning are now reported included in carbon stock changes in living biomass. If reported, the CO₂ emissions from burning would only have been 0.01 Mton CO₂ eq for year 2010 and consequently the correction is only made for consistency reasons.

The recalculations are summarized in Table 7.6.

Table 7.6a and b. Recalculations of carbon stock changes and other emissions between submission 2011 and submission 2012 in the LULUCF-sector. Positive numbers indicate an increase in emissions and negative numbers indicate an increase in removals (or a decrease in emissions for categories 5I to 5V).

7.6 a Difference between Submission 2011 and 2012 [Mt CO ₂]					
Year	Forest land	Cropland	Grassland	Wetland	Settlement
1990	3,39	-0,06	0,18	0,04	0,03
1995	3,84	0,01	0,12	0,05	-0,11
2000	2,15	-0,01	0,13	-0,04	-0,37
2005	5,43	0,09	0,05	-0,04	-0,23
2006	-1,59	-0,14	0,34	0,04	-0,41
2007	-2,63	-0,01	0,02	-0,04	-0,16
2008	-1,42	0,09	-0,22	-0,05	-1,09
2009	6,17	0,09	-0,14	-0,05	-0,10

7.6 b	Total carbon pool changes [M ton CO ₂]			Other emissions [M ton substance]						Total	
				Fert.	To CL	Liming	Biomass burning				
				5 (I)	5 (III)	5 (IV)	5 (V)				
	Year			N ₂ O	N ₂ O	CO ₂	CO ₂	N ₂ O	CH ₄	[M ton CO ₂ -eq]	[%]
	LB	DOM	SOC								
1990	-0,87	3,16	1,20	-0,06	-0,02	0,00	NA	0,00	0,00	3,44	-0,87
1995	-0,76	3,52	1,14	-0,02	-0,04	0,00	NA	0,00	0,00	3,83	-0,76
2000	-0,62	1,57	1,11	-0,02	-0,05	0,00	NA	0,00	0,00	2,09	-0,62
2005	-0,67	5,03	1,03	-0,03	-0,07	0,00	NA	0,00	0,00	5,31	-0,67
2006	-6,17	3,66	0,86	-0,03	-0,08	0,00	NA	-0,01	0,00	-1,85	-6,17
2007	-9,10	5,25	1,09	-0,04	-0,07	0,00	NA	0,00	0,00	-2,73	-9,10
2008	-8,79	5,00	0,97	-0,05	-0,08	0,00	NA	-0,01	0,00	-2,88	-8,79
2009	1,68	2,84	1,42	-0,05	-0,08	0,00	NA	0,00	0,00	5,85	1,68

0 equals value less than 0.5.

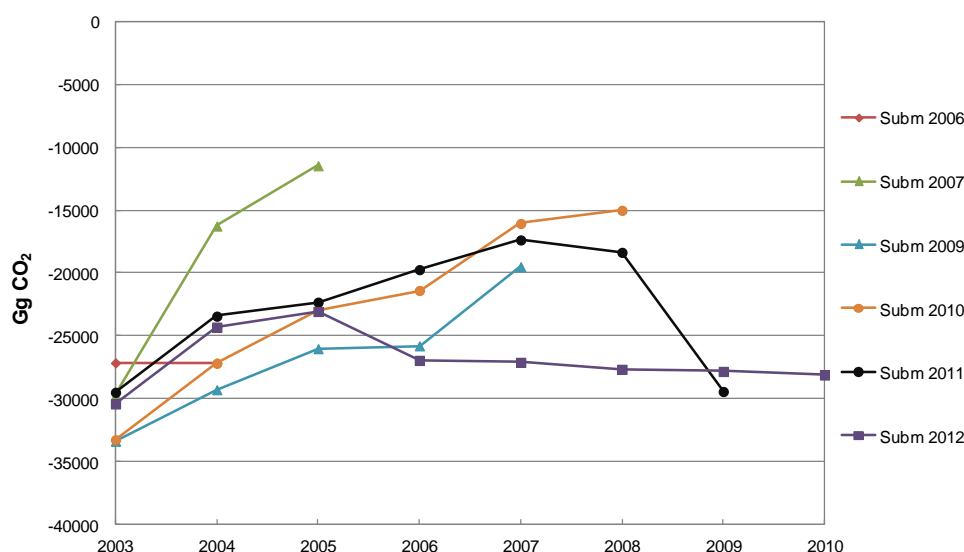


Figure 7.7 Reported living biomass on Forest land remaining forest land (5A1) according to different submissions. The values (the five latest reported years) are continuously recalculated (due to a resubmission, submission 2008 correspond to submission 2009).

7.7 Coming improvements

7.7.1 Informal reporting of HWP

On informal basis, Sweden reports emissions/removals from Harvested Wood Products (HWP) using the Production Approach (PA) as described in the IPCC 2006 Guidelines (IPCC, 2006). Thus, emissions from HWP are estimated as changes in the carbon pool of HWP in use originating from Swedish forests.

A Tier 3 model was used. Calculations were made using different life-lengths per product category, and inflow of new paper products was calculated using different data from different steps along the refinement chain: pulp for paper in Tier 3a and primary paper products in Tier 3b (Table 7.7).

Input data originated from FAO (FAOSTAT) and national data sources; National Board of Forestry, SDC, Statistics Sweden, and Swedish Forest Industries Federation. The data used concerned production and trade of raw material and primary products and covered different length of time. Data about harvested round wood and sawn wood for instance covered 1850-2010.

The model calculates net-emissions of CO₂ by estimating differences in the size of the HWP-carbon pool between years. Equation 12.1 in IPCC 2006 Guidelines was used. Separate calculations were made for different product categories: sawn wood, wood based panels, and paper products. A HWP-carbon pool for a certain year was estimated by adding an inflow of new products to, and subtracting an outflow (decay) of consumed products from the pool of previous year. The difference between the years was translated into CO₂ emissions or CO₂ uptake.

Inflow was calculated by adding primary products made from exported raw material of domestic origin such as round wood, chips and pulp, to domestically produced products of domestic origin. Domestic production from imported raw material was excluded at each step along the refinement chain. Production of primary paper products based on recovered paper is excluded since domestically collected recovered paper might originate from imported paper. Excluding recovered paper also ensures that carbon in paper is not calculated as inflow more than once.

A first-order decay was assumed, i.e. it is proportional to the size of the carbon pool, and is calculated using half-life (number of years until 50% is consumed) as input variable.

Half-times for sawn wood, wood based panels and paper products were set to 35, 25 and 2 years respectively, which corresponds to agreements from the climate meeting in Cancún, and to 15, 15 and 1 year, respectively, which have been used in previous NIR (Table 7.7).

In Tier 3a, calculations were made where the inflow of paper products was based on data on pulp. Pulp for paper originating from domestic forests is eventually turned into paper and according to the production approach it does not matter where the paper is produced or consumed as long as the pulp originates from domestic forests. In Tier 3b, calculations were based on semi-finished paper. Using paper should probably be more uncertain than using pulp. Paper production is preceded of more steps in the refinement chain, and adjustments for recovered paper and other material must be made. Thus, using paper as data source makes the calculations more complicated than using pulp.

The net-emission of CO₂ varied between -5.5 and -0.3 Mton during 1990-2010, using the shorter life times, and between -9.6 and -2.7 using the longer life-times (Figure 7.8). The difference between using pulp or paper was rather large since 2007 and onwards, which might be due to uncertainties in data of recovered paper, adjustments for added compounds in the production process of paper, and a storage effect of pulp.

Sweden considers the results from the Tier 3 model using inflow of pulp and half times 35, 25 and 2 years as most reliable. The half-lives of wooden products in Sweden have been estimated based on statistics and estimations of the development of the building stock in Sweden. The half-life turned out to be about 20 years and since Sweden is a net-exporter of end products such as wooden one-family houses, the true half-life should exceed 20 years. Thus 35 and 25 years should be closer to the truth than 15 years.

Table 7.7. Half-lives and inflow data used in the calculations of HWP

Method	Data	Half-life (decay) [years]			
		Sawn wood	Wood based panels	Pulp	Paper
Tier 3, a I	CS, FAO	15	15	1	-
Tier 3, a II	CS, FAO	35	25	2	-
Tier 3, b I	CS, FAO	15	15	-	1
Tier 3, b II	CS, FAO	35	25	-	2

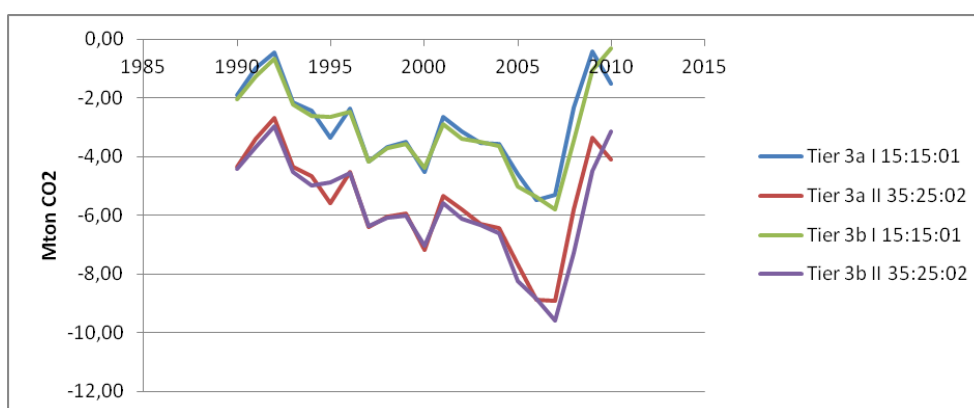


Figure 7.8 Net emissions of CO₂ from the HWP-carbon pool originating from Swedish forests during 1990-2010, calculated with different decay rates and different inflow data (see text).

8 Waste (CRF sector 6)

8.1 Overview of sector

In this sector, the most important emissions of greenhouse gases are those of CH₄ from solid waste landfills, CRF 6.A. Minor categories are the subcategories of wastewater handling, CRF 6.B, from where N₂O and CH₄ are reported. Emissions of CO₂, NO_x, SO₂ and NMVOC are reported from waste incineration, CRF 6.C. No emissions are reported in CRF 6.D.

For all greenhouse gases together, the trend over the last ten years has been a constant reduction of emissions (Figure 8.1). For CH₄, the trend can be explained by decreasing quantities of organic waste deposited at landfills. Also, the quantities of recovered landfill gas were increasing until from 1990 until 2003. For N₂O 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. CO₂ from waste incineration is a small source of greenhouse gases and contributes to the total greenhouse gas emissions in 2010 with 6 %.

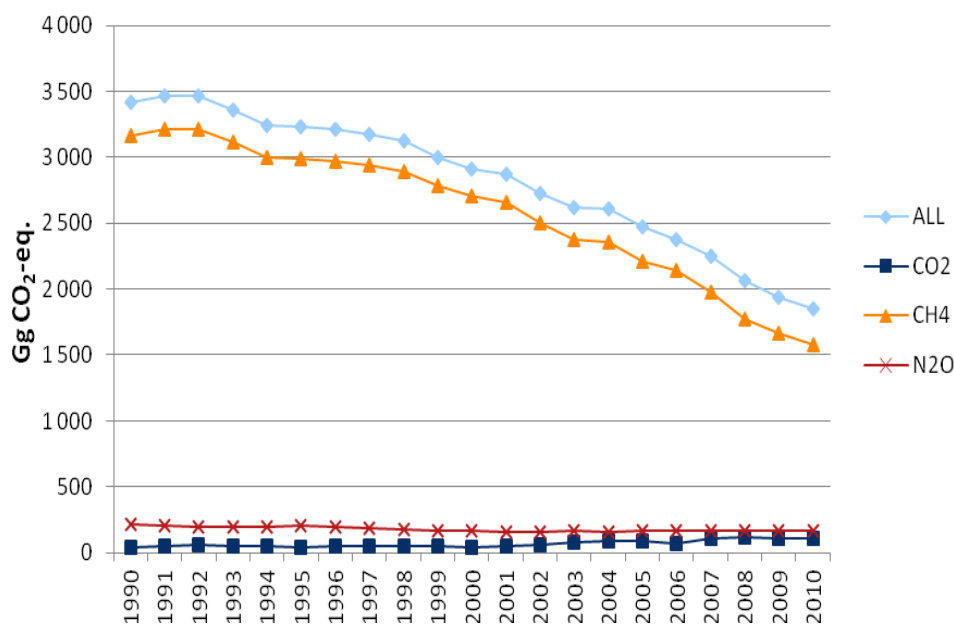


Figure 8.1. Total emissions of all greenhouse gases calculated as CO₂ equivalents from CRF 6 Waste.

Figure 8.2 shows that greenhouse gas emissions from the Waste sector (CRF 6) largely come from solid waste disposal on land (CRF 6A). CH₄ in sub-sector 6.A represents between 84.2 % and 67.4 % of totally reported greenhouse gases in the Wastewater sector during the period 1990 – 2010.

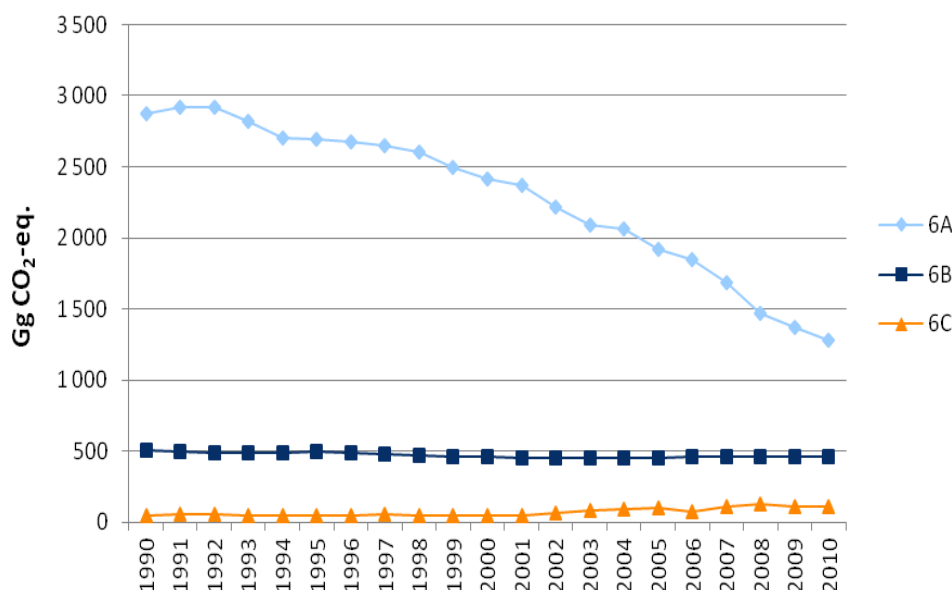


Figure 8.2. Total emissions of all greenhouse gases calculated as CO₂ equivalents from the different Waste sub-sectors.

Table 8.1 shows the impact of recalculations reported in submission 2012 for GHG emissions by sector and sub-sectors for 1990, 1995, 2000 and 2005-2009. The recalculations are mainly due to new data for protein consumption in human sewage (CRF 6.B.2.2). More detailed descriptions of the recalculations are found under sector specific sections below.

Table 8.1. Impact of recalculations of GHG emissions submission 2012 in the waste sector.

Impact of recalculations submission 2012 (Gg CO ₂ eq.)					
CRF	6.A	6.B	6.C	Total CRF 6	% CRF 6
1990	NA	NA	NA	NA	NA
1995	NA	NA	NA	NA	NA
2000	NA	NA	NA	NA	NA
2005	NA	NA	NA	NA	NA
2006	NA	1	NA	1	0.0%
2007	NA	2	NA	2	0.1%
2008	NA	3	NA	3	0.2%
2009	NA	3	NA	3	0.2%

0: value less than 0.5. NA: no recalculation is performed.

8.2 Solid waste disposal on land (CRF 6.A)

Waste management in Sweden has been developed considerably over the past twenty years. Legislation, such as the implementation of EU directives and national tax policies in the waste management field, has forced and encouraged investments in new technical solutions and waste treatment methods. There has been a comprehensive extension of the treatment capacity of Swedish incineration plants for

household waste (with energy recovery) and development of waste management practices other than solid waste disposal on land (landfilling).

Since Sweden is a country with a developed mining and quarrying industry, mining waste is by far the most dominating single waste category in generation of waste and landfilling. In year 2008, 93.2 % of the landfilled waste (or 59.1 Mt of 63.4 Mt) was mining waste.

In the 1990s, the amount of deposited waste (other than mining waste) decreased significantly. This is especially notable for household waste (in Sweden also referred as “Municipal waste”), which is the largest contributor of greenhouse gases of all waste categories. Only 1.0 % of the generated household waste was deposited in 2010 which can be compared with 43.8 % in 1990. The remaining part of the generated household waste in 2010 was either incinerated (48.7 %), recycled (35.7 %) or treated biologically (13.5 %).

Depositing has become an expensive waste management solution for disposal of waste. Since January 1st 2000, there is taxation on depositing, currently 435 SEK²¹¹ per ton of waste liable to taxation. Another important change is the implementation of the national prohibitions on the landfilling of burnable and organic wastes in the 9-10 §§ of the Landfill Ordinance (2001:512). The landfilling of 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.

In the end of 2008 a new EU regulation for deposition came into force and since then the number of landfills for municipal waste has decreased significantly in Sweden from 140 active landfill sites in 2007 to only 80 in 2008 according to the trade association Avfall Sverige – Swedish Waste Management. The number of active landfills for municipal waste was 76 in 2010.

In year 2010, landfill gas was extracted at 57 landfills²¹² whereof 40 were active landfills. According to a survey²¹³, the production of biogas in Sweden in 2010 was totally 1 387 GWh (or 99.5 Gg in methane). 21.5 % of the produced biogas was produced at landfills. The biogas production (collected gas) on landfills decreased by 41.2 % from 2003 to 2010, since the amounts of deposited organic waste has decreased significantly the past years, due to the implementation of waste treatment policies.

Biogas from landfills is mainly used for heating but also for production of electricity. Currently, none of this gas is used as vehicle fuel because of the difficulties to upgrade the gas to sufficient quality. About 12 % of the biogas produced (collected gas) at landfills was flared in 2010.

Sweden is reporting emissions of methane for CRF 6.A.1 (managed waste disposal sites). For CRF 6.A.2 (unmanaged waste disposal sites), Sweden is reporting

²¹¹

²¹² Avfall Sverige / Swedish Waste Management 2011

²¹³ Swedish Energy Agency, 2011

NO (not occurring), since there are no known unmanaged disposal sites for organic waste or municipal solid waste in use²¹⁴.

The responsibility for landfills to have permission or to report the landfill to the authorities, has been regulated in Sweden since 1969, which is why unmanaged (or illegal) landfills are very uncommon.

Sweden has some problems related to the subject unmanaged waste: *littering*. This occurs in particular around recycling stations. Other kinds of littering of organic waste that are occurring in Sweden are the disposal of smaller amounts of garden waste from households in the nature or that residuals from animals are disposed of where they are hunted. When littering is discovered however, the clean-up is to be performed or paid for by the operator responsible. If the responsible operator cannot be found, the relevant municipality has a responsibility to perform the clean-up of the site.

8.2.1 Managed waste disposal on land (CRF 6.A.1)

8.2.1.1 SOURCE CATEGORY DESCRIPTION

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 8.2.

Table 8.2. Summary of source category description, CRF 6.A.1.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources estimated
		Level	Trend	Qualitative			
6.A	CO ₂				NA	NA	NA
	CH ₄	X	X		T2	CS, D	Yes
	N ₂ O				NA	NA	NA

CS Country Specific. T2 Tier 2. D Default.

8.2.1.2 METHODOLOGICAL ISSUES

The decrease in deposited waste quantities reduces the potential of methane emissions from landfills. Figure 8.3 shows the methane emissions calculated by the IPCC default model and the IPCC First Order Decay (FOD) model respectively.

²¹⁴ Nygren, 2010

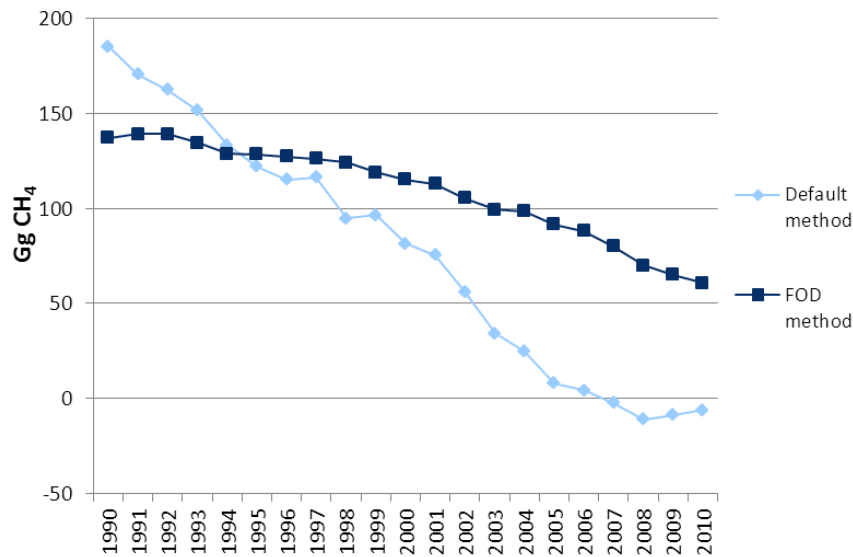


Figure 8.3 Emission of methane from Swedish landfills 1990-2010, estimated by the two IPCC methodologies, (Gg CH₄).

The two methods are not really comparable. According to the default model, there is a rapid decrease that immediately follows the decrease in deposited waste. By using this model, the annual landfill gas potential is calculated, rather than the actual gas emissions. The gas emission value for 2010 is negative (-5.9 Gg) since the quantity of recovered gas exceeds the landfill gas potential for waste deposited the same year.

The FOD model, on the other hand, uses a time factor representing the delay in methane production, which results in a slower decrease of emitted methane. The estimates of the FOD model are used in the Swedish National GHG Inventory. In Table 8.3, the estimates from the FOD model and the deposited amount of municipal solid waste (MSW) are presented.

Table 8.3 Methane emission from Swedish landfills according to IPCC Default and FOD methods. Deposited MSW*, sludges and total (excl. mining waste), 1990-2005

Year	Gas emissions Default method Gg CH ₄	Gas emissions FOD method Gg CH ₄	Deposited MSW* in 1000 tonnes	Deposited sludge from wastewater handling and pulp industry in 1000 tonnes	Total deposited waste (excl. mining waste)** in 1000 tonnes
1990	185	137	2 323	1 400	5 563
1991	170	139	2 223	1 262	5 161
1992	162	139	2 203	1 174	4 977
1993	151	134	2 199	1 086	4 824
1994	133	129	2 166	860	4 547
1995	122	128	1 974	850	4 330
1996	115	127	1 856	880	4 145
1997	116	126	1 842	975	4 203
1998	95	124	1 678	700	3 868
1999	96	119	1 756	620	3 853
2000	81	115	1 529	587	3 720
2001	76	113	1 488	514	3 488
2002	56	105	1 338	341	3 006
2003	34	99	1 034	223	2 688
2004	25	98	810	113	2 380
2005	8	92	541	58	2 067

* Includes household and similar waste, park and garden waste, industry- and non-industry specific waste (organic fractions), construction and demolition waste (organic fraction).

** Includes household and similar waste, park and garden waste, industry- and non-industry specific waste (organic and inorganic fractions), construction and demolition waste (organic and inorganic fractions) and sludge from wastewater handling and pulp industry.

Table 8.4 Methane emission from Swedish landfills according to IPCC Default and FOD methods, deposited solid waste (containing Degradable Organic Carbon), sludges (containing DOC) and total (incl. mining waste), 2006-2009

Year	Gas emissions Default method Gg CH ₄	Gas emissions FOD method Gg CH ₄	Deposited solid waste (containing DOC)* in 1000 tonnes	Deposited industrial effluent sludges and common sludge* in 1000 tonnes	Total deposited waste (excl. mining waste)* in 1000 tonnes	Total deposited mining waste* in 1000 tonnes
2006	4	88	1 250	180	4 143	61 820
2007	-2	80	994	144	4 260	60 450
2008	-11	70	739	108	4 376	59 080
2009	-8	65	739	108	4 376	59 080
2010	-6	61	739	108	4 376	59 080

* Activity data and statistics for 2006 and 2008 are from Swedens reporting to the Commission according to the Waste Statistic Regulation. Activity data for 2007, 2009 and 2010 are interpolated/extrapolated values.

8.2.1.2.1 National application to IPCC First Order Decay (FOD)

The method used for estimating methane emissions from municipal solid waste is the Tier 2 methodology, the IPCC First Order Decay model, with a slightly differ-

ent 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 assumption²¹⁵ 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 2010.

8.2.1.2.1.1 Methane potentials

IPCC values for gas potentials are used for the different fractions of household waste, as well as garden waste. As noted above, these values are somewhat higher than Swedish estimates, but lie within a reasonable interval.

The IPCC gives no gas potential for deposited sludge (already treated, for example, by rotting) from wastewater treatment. The content of Degradable Organic Carbon (DOC) in sludge from wastewater treatment is approximately 7 percent.²¹⁶ The gas potential of the sludge is reduced by 50 % because it is treated.²¹⁷ By using formulas given in Good Practice Guidance the gas potential can be calculated to 24 kg/tonnes of sludge.

For wastewater sludge from the pulp industry, a national value of 45 kg methane/tonnes of waste is used.²¹⁸ Gas potentials in waste from the food industry are presented in section 8.2.1.

8.2.1.2.1.2 Recovered gas

Since gas recovery can be of importance for the final emissions of methane, Good Practice Guidance recommends formulas that subtract the recovered gas from the produced gas. In Sweden the first plant for biogas extraction from landfills was started in 1983. The business has increased until 2003 when gas was recovered in 72 plants. Since 2008, about 58 gas plants are in operation, and the amount of re-

²¹⁵ Statistics Sweden, 2005

²¹⁶ Recounted from RVF, 1996.

²¹⁷ Sweco Viak, 2000.

²¹⁸ Swedish EPA, 1993.

covered gas is now decreasing because of the dramatic reduction of deposition of organic waste. Information on recovered gas (in energy units) is provided by Avfall Sverige and converted to quantity (in tonnes) by Statistics Sweden (Table 8.5).

Table 8.5 Recovered methane from landfill gas, tonnes.

Year	Recovered gas
1982	0 ¹
1983	NE ²
1990	12 000 ³
1991	12 210 ³
1992	14 430 ³
1993	20 800 ⁴
1994	27 500 ⁴
1995	30 000 ⁴
1996	30 000 ⁵
1997	30 000 ⁵
1998	30 000 ⁵
1999	33 000 ⁵
2000	34 000 ⁵
2001	32 400 ⁵
2002	35 947 ⁵
2003	36 449 ⁵
2004	30 135 ⁵
2005	29 418 ⁵
2006	24 567 ⁶
2007	24 553 ⁶
2008	26 979 ⁶
2009	24 240 ⁶
2010	21 439 ⁶

1) No gas recovery. 2) 1st plants started. 3) Swedish EPA/RVF. 4) RVF, 1996c. 5) RVF, 1997-2006. 6) Avfall Sverige (Swedish Waste Management), 2007-2011

The table below shows quantities of produced energy from landfill gas and how much that is flared in Sweden. The energy is used for production of electricity and for heating.

Table 8.6 Energy recovery and flaring at landfills in Sweden, MWh²¹⁹.

Year	2004	2005	2006	2007	2008	2009	2010
Energy recovery	370 000	340 000	282 200	290 100	310 800	294 240	262 200
of which is used for production of electricity	25 000	20 000	20 800	22 600	23 700	17 400	20 400
Flaring	50 000	70 000	60 200	52 100	65 100	43 600	36 600
Total	420 000	410 000	342 400	342 200	375 900	337 840	298 800

8.2.1.2.1.3 Other parameters

The Methane Correction Factor for modern Swedish landfills is equal to one (1.0) (Table 8.7). Waste management was centralised during the 1970s. Before 1980, landfills were smaller and presumably less compact. Information that helps establish the MCF factor (cover material, mechanical compacting and levelling of waste) is missing. For calculations before 1980 the IPCC default value 0.6 was used.

The IPCC default value 50 % is used for the methane content in landfill gas (F) (Table 8.7). The value of DOC_F 0.5 has been chosen according to IPCC methodology.

The oxidation factor is estimated to be 10 %, and the half-life of the methanogenesis is 7.5 years.²²⁰ The choice of the half-life factor has also been motivated by the rather wet climate conditions in Sweden ($MAP/PET > 1$), and that the 2006 IPCC Guidelines recommends the default value of 7 for such climate conditions.

Table 8.7 Other used parameters in the methane emission calculations.

Parameter	Value	Motivation
MCF - 1979	0.6	IPCC Default
MCF 1980 -	1	Well managed(*)
F	50 %	IPCC Default
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 1975.²²¹ An assumption is therefore made that before 1976, 37 % of all deposited household waste was burned.

²¹⁹ Avfall Sverige (Swedish Waste Management)

²²⁰ Börjesson, 2000

²²¹ Swedish EPA, 1983.

8.2.1.2.2 WASTE STATISTICS IN SWEDEN, 1980 - 2005

The Swedish EPA made the first national survey in Sweden in 1980, collecting data on deposited waste (only for household waste and similar). Statistics Sweden collected similar data in 1985, 1990 and 1994. Since 1994, the Swedish Waste Management (former RVF) has carried out an annual survey on deposited waste. Thus, household waste is the best documented waste category, with high quality data available since 1980. Household waste is also the most important category for methane production in landfills. Statistics on deposited sludge from households and park and garden waste are available since 1990. Standard values on fractions of deposited household waste from 1970 and 1975 are also available at the Swedish Waste Management.

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).

8.2.1.2.3 WASTE STATISTICS IN SWEDEN, 2006 AND ONWARD

The Regulation of the European Parliament and the Council No 2150/2002 of 25 November 2002 on waste statistics (hereafter referred to as “the Waste Statistics Regulation” or “WStatR”) contains rules for the reporting of waste statistics to the 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 for the different types of waste according to EWC-Stat. 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 on land, CRF 6A”.

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 and 2008. No waste statistics on landfilling are compiled for the intermediate years by SEPA.

In 2010, a study²²² was carried out in order to analyze possibilities to use the reported waste data to WStatR for the calculations of CH₄ from solid waste landfills. The study recommended implementation of WStatR-data from reference year 2006 and onwards. The advantages of WStatR-data in relation to waste statistics for 1980-2005 are mainly that:

- WStatR-data uses more specific and better developed 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 is containing Degradable Organic Carbon) were chosen, and the DOC content of the chosen waste categories was investigated by analyzing the statistical source material in cooperation with waste experts. Interpolations and extrapolations have been made for the intermediate years.

8.2.1.2.4 WASTE CATEGORIES, 1980-2005

8.2.1.2.4.1 Household waste, sludge and garden waste

Table 8.8 summarizes the available statistics on household waste, sludge from waste water treatment and garden waste. Interpolation is used for the intermediate years. Before 1990, park/garden waste and sludge from households are assumed to be directly proportional to the population, with the same proportion as in 1990.

²²² Edborg, Stenmarck, Sundquist & Szudy, 2010

Table 8.8 Deposited household waste, sludge and garden waste (1000 tonnes).

Year	Household waste (and similar)	Sludge from waste water treatment, wet weight	Garden waste
1980 ¹	1 450	..	..
1985 ²	1 040	..	..
1986 ³	1 020	..	..
1988 ⁴	1 080	..	..
1990 ⁵	1 400	900	70
1994 ⁶	1 380	610	80
1995 ⁷	1 200	540	60
1996 ⁸	1 110	470	70
1997 ⁸	1 150	455	50
1998 ⁹	1 020	490	45
1999 ¹⁰	972.5	490	45
2000 ¹¹	869.5	345	53
2001 ¹²	880	330	44
2002 ¹³	820	215	40
2003 ¹⁴	575	155	33
2004 ¹⁵	380	102	0*
2005 ¹⁶	210	58	0*

1) Swedish EPA, 1983. 2) Statistics Sweden, 1988; RVF. 3) RVF, 1988. 4) RVF, 1990. 5) Statistics Sweden, 1992. 6-16) RVF, 1996-2006.

* Included in household waste from reference year 2004. ** Estimate

The composition of household waste has been investigated in many studies over the years. Ohlsson²²³ presents a historic overview of Swedish investigations, the first of which was carried out in 1977. The time series indicates a rather constant composition of components, except the paper content, which declines during the 1990s. The chosen composition²²⁴ for 1990 and 1995 are presented in Table 8.3. The composition in the years between the surveys is interpolated. It should be pointed out that this type of analysis contains an unknown variation, and the source of error may be large. Ohlsson also shows that different studies may differ greatly in methods and results.

In 2005, another overview of household waste composition was published.²²⁵ Different fractions of household waste from southern Sweden have been analysed with the same methodology in 3 different years (1997, 2000 and 2004), see further in Table 8.9.

²²³ Ohlsson, 1998 and REFORSK, 1998

²²⁴ Ohlsson, 1998

²²⁵ RVF, 2005

Table 8.9. Content of Swedish household waste, %.

	1990	1995	1997	2000	2004
A, Paper and textiles	33	28	23	25	18
B, Garden/park waste, and diapers	14	14	14	11	13
C, Food waste	40	40	41	39	43
D, Wood	1	1	1	1	1

In Sweden the section of the Ordinance prohibiting the deposition of organic waste as landfill was implemented on January 1st 2005. The waste treatment plants need permissions in order to deposit organic waste.

The impact of the new legislation on the DOC content of deposited household waste has not been investigated and documented, but the waste composition and DOC content of the of deposited household waste has probably changed since the analysis from 2004. Separation of organic fractions made by the households should lead to a decrease of the DOC content. The organic fractions are treated by composting and anaerobic digestion. Organic fractions (and other fractions) from the mixed waste generated by households and companies are also separated at waste treatment plants before landfilling.

8.2.1.2.4.2 Industrial waste

As noted above, statistics on deposited industrial waste are not divided into organic waste categories. Special studies of organic waste are considered to be the most important information sources of industrial waste categories. In 2004 a study on deposition of organic waste was carried out by Profu and financed by the Swedish EPA.²²⁶ 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;²²⁷ the waste groups found to generate methane in landfills are presented in Table 8.10.

The most important subgroup here is sludge from the pulp industry and the other 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.

²²⁶ Profu, 2004.

²²⁷ Swedish EPA, 1993

Table 8.10 Organic industrial waste, early 1990s (Swedish EPA, 1993).

Waste category	Produced quantity, 1000 tonnes/yr	Deposited fraction, %	Deposited quantity, 1000 tonnes/yr	Gas potential, Mm ₃ CH ₄ /yr
Sludge from pulp industry	1000	50	500	31.5
Carcasses	8	35	2.8	0.63
Waste from slaughter houses	40	5	2	0.45
Sludge from slaughter-houses	45	8	3.6	0.28
Entrails	30	5	1.5	0.09
Manure from slaughter-houses	10	5	0.5	0.03
Draff	5.5	0.5	0.0275	0.03
Waste from sugar beet industry	100	0.5	0.5	0.02
Waste from potato industry	46	0.5	0.23	0.01
Returned bread	13	3	0.39	0.11
Mycelia waste	2	1	0.02	0.01
Scrows waste	5.5	100	5.5	0.8
Waste from fishing industry		50	0	0.5
Whey	1 000	0	0	0
Tinned foods industry	53	50	26.5	1.55
Total:				
Sludge from pulp industry			500	31.5
Other			43.6	4.5

Data on deposited sludge from the pulp industry is available from a survey carried out annually from 1994 up to year 2000 by the Swedish EPA. In 2004, data on deposited sludge from the pulp industry is taken from the Swedish Forest Industries Federation. Data for the intermediate years have been interpolated. The reports contain detailed information on waste and waste treatment for each pulp and paper producer. Intermediate values (1991-1993) have been interpolated (Table 8.11).

Table 8.11 Values of deposited wastewater sludge from the pulp industry, wet weight.

Year	Quantity 1000 tonnes/year
1990	500 ¹
1994	250 ²
1995	310 ³
1997	520 ⁴
1998	210 ⁵
1999	130 ⁶
2000	242 ⁷
2001	184 ⁸
2002	126 ⁸
2003	68 ⁸
2004	10,5 ⁹
2005	0 ⁹

1) Swedish EPA, 1993. 2) Swedish EPA, 1995. 3) Swedish EPA, 1996b. 4) Swedish EPA, 1998b. 5) Swedish EPA, 1999. 6) Swedish EPA, 2000. 7) Swedish EPA, 2001. 8) Value interpolated no similar survey carried out. 9) Swedish Forest Industries Federation.

A study on organic industry-specific waste was published in 1996²²⁸. In accordance with the report, the deposited waste categories are presented in Table 8.12. The gas potentials were calculated by Sweco Viak.

Table 8.12 Organic Industrial Waste 1996.

Waste category	Deposited quantity, 1000 tonnes/yr	Gas potential, Mm3 CH ₄ /yr
Waste from slaughter houses	22.5	0.88
Waste from potato and vegetable industries	11.5	0.64
Total:	34	1.52

Swedish EPA, 1996

The final gas potential is used as gas potentials in the methane calculations for 1996 and later. By using the two reports, values are interpolated between 1990 and 1996.

In addition to the gas potentials from these industries, the gas potentials for paper and cardboard waste from industries, which is not included in the referred reports, have to be added. Information on these gas potentials is extracted from a survey ("Waste from the manufacturing and minerals extraction industries in 1998") made by the Swedish EPA and Statistics Sweden.²²⁹ In 1998, about 6,000 tonnes of paper and wrapping material were deposited. This quantity is added each year to the industrial waste already noted.

²²⁸ Swedish EPA, 1996

²²⁹ Statistics Sweden, 2000

8.2.1.2.4.3 Composition of deposited waste

Table 8.13 illustrates the estimated composition of deposited waste (excl. mining waste) 1990-2005.

Table 8.13 Composition of deposited waste, percent.

Year	Paper	Food	Plastic	Glass	Textile	Napkins	Sludge from waste water	Sludge from pulp industry	Wood	Other inert	Other organic
1990	7.1	13.5	2.1	0.6	0.7	1.3	16.2	9.0	0.3	34.9	14.3
1991	7.4	14.6	2.2	0.7	0.8	1.5	15.5	9.0	0.3	34.5	13.6
1992	7.5	15.4	2.3	0.7	0.8	1.5	15.1	8.5	0.3	34.2	13.7
1993	7.5	16.1	2.4	0.7	0.8	1.6	14.5	8.0	0.4	34.1	14.0
1994	7.7	17.2	2.6	0.8	0.9	1.7	13.4	5.5	0.4	35.8	14.2
1995	6.8	15.8	2.4	0.7	0.8	1.6	12.5	7.2	0.3	36.9	15.1
1996	6.3	15.9	2.3	0.7	0.8	1.5	11.3	9.9	0.3	36.1	14.8
1997	5.6	16.0	2.5	0.7	0.8	1.6	10.8	12.4	0.3	35.5	13.8
1998	5.4	15.6	2.4	0.7	0.8	1.5	12.7	5.4	0.3	41.0	14.2
1999	5.2	15.0	2.3	0.7	0.8	1.5	12.7	3.4	0.3	40.7	17.5
2000	5.4	13.5	2.5	0.8	0.7	1.2	9.3	6.5	0.2	45.5	14.6
2001	5.8	14.2	2.7	0.8	0.8	1.2	9.5	5.3	0.2	45.2	14.4
2002	6.3	15.5	2.9	0.9	0.9	1.3	7.2	4.2	0.2	46.9	13.8
2003	5.0	13.0	2.3	0.7	0.7	1.1	5.8	2.5	0.1	55.4	13.5
2004	2.8	10.4	1.8	0.4	0.4	0.9	4.3	0.4	0.1	63.1	15.5
2005	1.9	7.8	1.2	0.2	0.2	0.6	2.8	0.0	0.1	72.2	13.0

8.2.1.2.5 Used statistics on deposited waste, 1952-2010

8.2.1.2.5.1 Used statistics 1952-2005

Table 8.14 – 8.15 shows the activity data 1952-2005 used in the calculations of methane emissions from solid waste disposal on land.

Table 8.14 Overview over used statistics on deposited waste and interpolated/-extrapolated values: Solid waste.

Year	Standard value: Household waste/citizen (kg)	Fraction deposited household waste	Fraction of burned household waste on landfills	Deposited household waste and similar, 1000 tonnes	Deposited park and garden waste, 1000 tonnes	Deposited organic industrial waste(**), 1000 tonnes	Deposited industrial waste (not industry specific), organic fraction(**), 1000 tonnes	Deposited construction and demolition waste, organic fraction(**), 1000 tonnes
1952	290	76%	37%	992	58	56	207	63
1953	290	76%	37%	998	59	56	211	64
1954	290	76%	37%	1005	59	56	215	66
1955	290	76%	37%	1012	59	56	220	68
1956	290	76%	37%	1018	60	56	226	70
1957	290	76%	37%	1024	60	56	232	71
1958	290	76%	37%	1030	60	56	234	73
1959	290	76%	37%	1035	61	56	239	75
1960	290	76%	37%	1041	61	56	250	77

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

Year	Standard value: Household waste/ citizen (kg)	Fraction deposited household waste	Fraction of burned household waste on landfills	Deposited household waste and similar, 1000 tonnes	Deposited park and garden waste, 1000 tonnes	Deposited organic industrial waste(**), 1000 tonnes	Deposited industrial waste (not industry specific), organic fraction(**), 1000 tonnes	Deposited construction and demolition waste, organic fraction(**), 1000 tonnes
1961	290	76%	37%	1049	62	56	260	78
1962	290	76%	37%	1056	62	56	272	80
1963	290	76%	37%	1064	62	56	280	82
1964	290	76%	37%	1072	63	56	301	83
1965	290	76%	37%	1079	63	56	316	85
1966	290	76%	37%	1088	64	56	325	87
1967	290	76%	37%	1096	64	56	330	89
1968	290	76%	37%	1105	65	56	345	90
1969	290	76%	37%	1114	65	56	349	92
1970	290	76%(*)	37%	1122	66	56	364	94
1971	290	76%	37%	1126	66	56	369	96
1972	290	76%	37%	1129	66	56	372	97
1973	290	66%	37%	984	66	56	391	99
1974	290	66%	37%	987	67	56	406	101
1975	290	66%(*)	37%(*)	990	67	56	409	103
1976	290	66%	30%	1109	67	56	452	116
1977	290	66%	22%	1229	67	56	483	131
1978	290	58%	15%	1186	67	56	517	145
1979	290	58%	7%	1292	68	56	593	162
1980			0%	1450(*)	68	56	628	177
1981				1400	68	56	632	179
1982				1300	68	56	627	182
1983				1200	68	56	551	158
1984				1100	68	56	579	161
1985				1040(*)	68	56	595	163
1986				1020(*)	68	56	602	165
1987				1050	69	56	615	168
1988				1080(*)	69	56	624	170
1989				1240	70	56	630	172
1990				1400(*)	70(*)	56	622	175
1991				1390	72	57.1	567	137
1992				1390	75	58.2	554	126
1993				1390	77	59.3	558	115
1994				1380(*)	80(*)	60.3	564	82
1995				1200(*)	60(*)	61.4	571	82
1996				1110(*)	70(*)	62.5	536	78
1997				1150(*)	50(*)	62.5	495	85
1998				1020(*)	45(*)	62.5	477	73
1999				972.5(*)	45(*)	62.5	580	96
2000				869.5(*)	53(*)	62.5	473	71
2001				880(*)	44(*)	62.5	439	62
2002				820(*)	40(*)	62.5	370	45
2003				575(*)	33(*)	62.5	323	40
2004				380(*)	0(***)	62.5	321	47
2005				210(*)	0(***)	62.5	231	37

(*) Taken from statistical sources. Other values are interpolated or extrapolated.

(**) Estimate. (***) Included in household waste from reference year 2004.

Table 8.15 Overview over used statistics on deposited waste and interpolated/extrapolated values: Sludge, wet weight.

Year	Deposited sludge from waste water treatment, 1000 tonnes	Deposited sludge from pulp industry, 1000 tonnes
1952	748	500
1953	753	500
1954	759	500
1955	764	500
1956	768	500
1957	772	500
1958	777	500
1959	781	500
1960	786	500
1961	791	500
1962	797	500
1963	803	500
1964	809	500
1965	814	500
1966	821	500
1967	827	500
1968	834	500
1969	840	500
1970	847	500
1971	849	500
1972	852	500
1973	855	500
1974	857	500
1975	860	500
1976	862	500
1977	865	500
1978	867	500
1979	869	500
1980	871	500
1981	872	500
1982	873	500
1983	874	500
1984	875	500
1985	876	500
1986	881	500
1987	885	500
1988	890	500
1989	895	500
1990	900(*)	500(*)
1991	800	462
1992	750	424
1993	700	386
1994	610(*)	250(*)
1995	540(*)	310(*)
1996	470(*)	410(*)
1997	455(*)	520(*)
1998	490(*)	210(*)
1999	490(*)	130(*)
2000	345(*)	242(*)
2001	330(*)	184
2002	215(*)	126.3

Year	Deposited sludge from waste water treatment, 1000 tonnes	Deposited sludge from pulp industry, 1000 tonnes
2003	155(*)	68
2004	102(*)	10.5(*)
2005	58(*)	0(*)
2005	58(*)	0(*)

(*) Taken from statistical sources. Other values are interpolated or extrapolated.

8.2.1.2.5.2 Used statistics 2006-2010

Table 8.16 shows waste statistics for 2006-2010 used in the calculations of methane emissions from solid waste disposal on land. It also shows estimated DOC content for each waste category.

Table 8.16. Overview over used statistics* 2006-2010 on deposited waste and interpolated/extrapolated values, 1000 tonnes, and estimated DOC content, percent.

EWC-Stat code	Description of waste categories	2006 ^(*)	2007	2008 ^(*)	2009	2010	DOC content
03.1	Chemical deposits and residues	C	C	176.946	176.946	176.946	2
03.2	Industrial effluent sludges: <u>Dry matter</u>	11.914	11.247	10.580	10.580	10.580	9
05.	Health care and biological wastes: <u>Hazardous</u>	C	C	0.004	0.004	0.004	8
05.	Health care and biological wastes	C	C	0.010	0.010	0.010	8
07.2	Paper and cardboard wastes	38.977	20.636	2.296	2.296	2.296	36
07.5	Wood wastes	C	C	1.840	1.840	1.840	40
07.6	Textile wastes	0.228	0.600	0.972	0.972	0.972	24
09A	Animal and vegetal wastes (excl. 09.11 & 09.3)	11.548	8.803	6.058	6.058	6.058	15
09.11	Animal waste of food preparation and products	0.303	0.323	0.343	0.343	0.343	15
09.3	Animal faeces, urine and manure	0.372	0.224	0.075	0.075	0.075	9
10.1	Household and similar wastes	203.821	161.904	119.986	119.986	119.986	18
10.2	Mixed and undifferentiated materials	482.743	352.592	222.442	222.442	222.442	3,1
10.3	Sorting residues	311.483	259.721	507.599	507.599	507.599	2,5
11A	Common sludges (excl. dredging spoils): <u>Dry matter</u>	26.383	19.762	13.140	13.140	13.140	28
		1 137.					
Total, wet weight		1 429.239	920	846.601	846.601	846.601	

* Waste statistics for 2006 and 2008 are from Swedens reporting to the Commission in accordance to the Waste Statistic Regulation. Waste statistics for 2007, 2009 and 2010 are interpolated/extrapolated values.

C: Confidential

8.2.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Because of the simplifications in the used top-down model and the difficulties in estimating many of the parameters, the estimated emissions in the waste sector are uncertain. The time dependency in methane production makes the model estimate further dependent on assumptions of waste management from earlier years. The uncertainty is highest in 1990 and then decreases, mainly due to better and more frequent activity data on household waste during the 1990s. The section of the Ordinance prohibiting deposition of organic waste as landfill was implemented on January 1st 2005. It has led to higher uncertainties since the data on DOC has not been updated during the last years to cover the changes. The DOC from the year 2005 is probably overestimated.

IPCC Guidelines suggest that the error in estimated methane generation potential may be about 15 % given high quality data and 50 % given poor data on methane generation, per ton of waste. The uncertainty in statistics on deposited waste may be 10 %, if the waste is weighted, or more than 200 % if the data quality is poor. The errors in estimated methane recovery will probably be small, according to the Good Practice Guidance. Given these standard uncertainty ranges and applying the simple error propagation formula, a total error of estimated methane emissions of about 20 % would be achievable, in the best case, given high quality data.

According to Good Practice Guidance there is some extra uncertainty in the methane generation rate constant [-40 %, 300 %], and in the oxidation factor, if oxidation is assumed. An assessment of the confidence interval for the Swedish methane estimate from landfills would be around 50-60 % for 2005. Swedish waste statistics 2005 on household waste, in particular, are of high quality, but the estimates are still dependent on lower quality data and extrapolations from earlier years. Furthermore, statistics on different waste fractions in household waste, and especially industrial waste, are still of lower quality. The quality of parameters based on IPCC default values may also be low, since they rely on older research, and data from Swedish on-site measurements is not yet extensive enough for verification.

The time series in the waste sector are calculated consistently and in line with the Good Practice Guidance. When statistics are not produced annually, interpolation and extrapolation have been necessary tools for imputation.

8.2.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

8.2.1.4.1 Quality Assurance and Quality Control

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

8.2.1.4.2 *Verification of data and reducing compiling errors*

Statistics Sweden and the IVL has on behalf of the Swedish EPA scrutinized the activity data (quantities of deposited; household waste, park and garden waste, sludge from waste water treatment) used for calculations. The accuracy in these activity data is judged to be good.

8.2.1.5 SOURCE-SPECIFIC RECALCULATIONS

No recalculations have been made in CRF 6A that has any influence on the emissions. A small adjustment has been made of "Annual MSW at the SWDS" (background information) for the years 2006-2009, because plastic waste has been excluded since it is considered to have no or little impact on generation of landfill gas.

8.2.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

8.3 Waste water handling (CRF 6.B)

Sweden is reporting data on emissions of nitrous oxide (N₂O) and methane (CH₄) for the sectors Industrial Wastewater, CRF 6.B.1 and Domestic and Commercial Wastewater, CRF 6.B.2.

8.3.1 Industrial, domestic and commercial wastewater (CRF 6.B.1 and CRF 6.B.2)

8.3.1.1 SOURCE CATEGORY DESCRIPTION

In Sweden, internal wastewater treatment is practised in some industries (see further in section 8.3.1.2.1.2 Industries with internal wastewater treatment). These plants are situated both by the coast and in the inland.

There are 500 municipal wastewater treatment plants in Sweden with treatment capacity for more than 2,000 personal equivalents. 95 % of the wastewater is treated mechanically, chemically and biologically. In some larger plants, or plants with sensitive recipients, special nitrogen treatment is performed. These wastewater treatment plants also receive wastewater from industries without internal wastewater treatment.

In addition, there are also a number of smaller plants or private plants of varying standard.²³⁰ There are also approximately 1.3 million people in Sweden not connected to any wastewater treatment plant.

Considerable quantities of heat and bioenergy are recovered from sewage and wastewater.²³¹ Anaerobic wastewater treatment and anaerobic digestion of sludge

²³⁰ Swedish EPA & SMED, 2003

²³¹ Ministry of the Environment, 2001.

is practised in Sweden and generates methane for production of electricity, heating, vehicle fuel and for local gas distribution networks. Some of the methane is flared.

The estimations of emissions (leakage) of nitrous oxide and methane from the wastewater treatment processes and sludge treatment processes need further improvements. However, some improvements have been made in submission 2011 by calculating and reporting emissions of CH₄ from wastewater treatment (Industrial Wastewater, CRF 6B1a, and Domestic and Commercial Wastewater, CRF 6B2a). Also emissions of CH₄ from sludge treatment (Domestic and Commercial Wastewater, CRF 6B2b) are calculated and reported.

According to a survey²³² by the Swedish Energy Agency on biogas production and utilization, the production of biogas in Sweden in 2010 was 1 387 GWh (or 99.5 Gg in methane) to be compared with 1 285 GWh (or 92.2 Gg in methane) in 2005²³³. In 2010, 44 % of the produced energy from biogas was produced at wastewater treatment plants (anaerobic digestion of sludge). The biogas production at wastewater treatment plants increased by 9.8 % from 2005 to 2010. Approximately 9.4 % of the biogas produced at wastewater treatment plants was flared in 2010.

The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), is presented in Table 8.17.

Table 8.17. Summary of source category description, CRF 6.B.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources Estimated
		Level	Trend	Qualitative			
6.B	CO ₂				NA	NA	NA
	CH ₄	X			CS, D, T1	CS, D	Yes
	N ₂ O				CS	D	Yes

CS Country Specific. T1 Tier 1. D Default.

8.3.1.2 METHODOLOGICAL ISSUES

8.3.1.2.1 Nitrous oxide (N₂O)

National activity data on nitrogen in discharged wastewater from municipal wastewater treatment plants and industries are used, in combination with a model estimating nitrogen in human sewage from people not connected to municipal wastewater treatment plants.

The general formula to calculate the emissions is:

$$(N_{Industry} + N_{WastewaterTreatmentPlants} + PROTEIN * Nr_{People} * 0.16) * EF * 44 / 28$$

²³² Swedish Energy Agency, 2011

²³³ Swedish Energy Agency, 2007

where $N_{\text{WastewaterTreatmentPlants}}$ and N_{Industry} are the nitrogen in discharged wastewater from municipal wastewater treatment plants (including industries without internal wastewater treatment) and other industries (with internal wastewater treatment) respectively. IPCC's default emission factor, 1 % N_2O-N/N , is used as emission factor (EF) for the discharges from all three sources (Wastewater treatment plants, Industries and unconnected households).

IPCC Guidelines suggest an emission factor of 1% (N_2O-N/kg sewage N discharged sewage effluent) for sewage nitrogen that enters rivers and estuaries (Good Practice Guidance, Table 4.18), while the N_2O emissions associated with sewage treatment and land disposal are considered to be negligible. There is no Swedish research that will motivate a national emission factor concerning discharged sewage nitrogen.

8.3.1.2.1.1 Wastewater treatment statistics and activity data related to nitrous oxide emissions in Sweden

According to Swedish environmental protection law, all municipal wastewater treatment plants designed for more than 2,000 person equivalents, including industry, need to report their discharges in legal environmental reports delivered to their supervision agency. Statistics are published every other year by the Swedish EPA.²³⁴

For industrial wastewater handling, Sweden has better data on discharges in tonnes than in cubic metres and therefore has chosen to publish data of discharges of nitrogen in tonnes. Discharges in tonnes are more relevant than in cubic meters because large quantities of the waste water output reported in the environmental reports are actually cooling water and not process water. It is less confusing for the reporting companies to report the quantity/quantities of their discharges of various substances in *tonnes* instead of in *cubic metres*.

The statistics on discharges of nitrogen exclude municipal wastewater treatment plants designed for less than 2,000 person equivalents. These were surveyed in 1999, and were found to represent about 6 % of the total discharged nitrogen, which is compensated for using a "1.1 factor" in the above formula.

The statistics also exclude approximately 1.3 million people in rural areas, who are not connected to municipal wastewater treatment. Until submission 2009, Sweden estimated this population to almost 1 million people. The new estimate is based on new data²³⁵ for 1995, 2000 and 2005. The mean of these data is approx. 1 264 000 people, which is rounded up to 1.3 million people in the calculations to compensate for suspected underestimation for year 1995. Sweden cannot see any national trend or variations over the years that are significant enough to apply in the calculations, since the data for 1995 (1 205 686 people) is likely an underestimation, and 2000 (1 296 757 people) and 2005 (1 291 299 people) are very similar.

²³⁴ Statistics Sweden, MI 22 SM, Swedish EPA and SMED.

²³⁵ Statistics Sweden MI 11 SM 0701, Korrigerad version

However, the nitrogen from these people is accounted for in the formula as well, through the model estimate of nitrogen production.

National values for protein consumption are used and are available in time series. Previously a constant value was used.

8.3.1.2.1.2 Industries with internal wastewater treatment

The formula is: $N_{Industry} * EF * 44 / 28$

The sector covers; pulp and paper industry, oil refineries, chemical industry, iron and steel industry, food manufacturing industry, manufacturing of wood products and mining and quarrying industry.

Table 8.18 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), tonnes.

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	..	109	..	..	..
2001	3 014	..	..	..	..	..	..	..	..	..	..
2002	3 169	68	..	268	..	72	..	3	..	..	..
2003	3 162	..	..	..	..	..	..	..	..	..	..
2004	3 039	30	..	224	..	54	..	11	2	6	451
2005	3 222	..	..	..	..	..	..	..	..	..	..
2006	3 200	39	..	144	..	74	..	17	2	3	496
2007	2 825	..	..	..	..	..	..	..	..	..	..
2008	2 830	26	256	139	807	68	89	27	2	2	480
2009	2 600	..	..	..	..	..	..	..	..	..	..
2010	2 590	..	..	..	..	..	..	..	..	..	..

Source: NV 4657, NV 4434, NV 4657, NV 4924, NV 4987, NV 5114, Swedish Forest Industries Federation, .MI 22 SM, Swedish EPA and SMED

8.3.1.2.1.3 Municipal wastewater treatment plants

The formula is: $N_{WastewaterTreatmentPlants} * EF * 44 / 28$

$N_{\text{WastewaterTreatmentPlants}}$ is magnified by 10 %, in order to compensate for wastewater from small treatment plants, not included in the statistics.

Table 8.19 Discharges of nitrogen from large municipal wastewater treatment plants (from treatment of domestic, commercial and industrial waste water), tonnes.

Year	Municipal wastewater treatment plants
1990	26 200
1992	25 310
1995	25 940
1998	21 376
2000	18 977
2002	18 036
2004	17 779
2006	18 347
2008	18 433

Source: MI 22 SM, Swedish EPA and SMED

8.3.1.2.1.4 Households not connected to municipal wastewater treatment plants

The formula is: $(PROTEIN * Nr_{\text{People}} * 0.16) * EF * 44 / 28$

PROTEIN is the annual per capita consumption per person/year, Nr_{People} is the number of people not connected to municipal wastewater treatment plants, and 0.16 is the fraction of nitrogen in proteins (Table 8.20).

Table 8.20. Protein consumption in Sweden, g/person/day

Year	Protein consumption g/person/day
1980	87
1985	86
1990	89
1995	89
2000	97
2003	101
2004	102
2005	102
2008	111
2009	110

Source: The Swedish yearbook of agricultural statistics 2007 & 2011

8.3.1.2.2 Methane (CH_4)

8.3.1.2.2.1 Methane emissions from wastewater treatment

Sweden has previously reported NE (not estimated) for methane emissions from wastewater handling. This has been changed in submission 2011.

CRF 6B1a, Industrial wastewater, Wastewater

The majority of the facilities in Sweden are using aerobic processes, where no CH_4 is supposed to be generated because of the use of aeration in the wastewater treatment process. In 2010, there were only five (5) facilities using anaerobic wastewater treatment processes in Sweden. These facilities were in the pulp industry and food industry.

For methane emissions from industries with internal wastewater treatment, Sweden has chosen a national method to estimate the emissions based on data availability. According to wastewater treatment expertise²³⁶, the loss of CH_4 in the energy recovery process should be within the range of 2 - 5 %. This factor can be combined with data on energy recovery from the anaerobic processes.

In 2010, 114 GWh²³⁷ (or 8.2 Gg CH_4) was recovered. By using the upper value (5 %) of the leakage factor to ensure a conservative estimate, the emission of CH_4 is calculated to 0.43 Gg for 2010.

Data on energy recovery from anaerobic processes are available for 2005-2010. For 1990-2004 no data are available and therefore the data for 2005 was extrapolated for these years. The estimate of the loss of CH_4 in the energy recovery process (5 %) is used for all years.

CRF 6B2a, Domestic and Commercial Wastewater, Wastewater

When analyzing the sector CRF 6B2a in Sweden it is necessary to divide the sector into three sections:

- a) Large wastewater treatment plant (treatment capacity: more than 2 000 pe)
- b) Small wastewater treatment plants (treatment capacity: 25 -2000 pe)
- c) Population not connected to wastewater discharge system

a) In Sweden, all large wastewater treatment plants are using aerobic wastewater treatment processes. No CH_4 is supposed to be generated because of the use of aeration in the wastewater treatment process.

²³⁶ Ek, 2010

²³⁷ Swedish Energy Agency, 2011

b) For small wastewater treatment plants, the situation is at the moment not well enough investigated and therefore Sweden is using the IPCC Good Practice Guidance method (Page 5.15 Box 5.1 Check method):

$$WM = P \times D \times SBF \times EF \times FTA \times 365 \times 10^{-12} \quad \text{where}$$

WM = Annual CH₄ emission per country, from domestic wastewater (Tg)

P = Population of country or urban population for some developing countries (person)

D = Organic load in biochemical oxygen demand per person (g BOD/person/day),
overall default = 60 g BOD/person/day

SBF = Fraction of BOD that readily settles, default = 0.5

EF = Emission factor (g CH₄/g BOD), default = 0.6

FTA = Fraction of BOD in sludge that degrades anaerobically, default = 0.8

Activity data on population connected to small wastewater treatment plants (700 000 people) is derived of background data from a survey from 2010 on treatment methods and sewage networks in Swedish municipal waste water treatment plants. A report²³⁸ was published in 2011.

c) For population not connected to wastewater discharge system, the following applies:

1.) The sludge in the wastewater (SBF = Fraction of BOD that readily settles) is collected and transported to anaerobic digestion plants located at larger wastewater treatment plants²³⁹. It is covered and reported in section CRF 6B2b (sludge treatment).

2.) CH₄ emissions from the remaining wastewater are likely to be NO (not occurring) or negligible. The waste water is rich in oxygen, and for biological processes to occur the water must not be too cold.²⁴⁰ Sweden has a rather cold climate with an average annual temperature of 4.8 (°C) 1991-2005. At the moment Sweden does not²⁴¹ have any written references to support this statement and therefore emissions are estimated by using the default Check method (as for 'b') above).

The activity data (population not connected to wastewater discharge system) is the estimate based on data²⁴² for 1995, 2000 and 2005 (1 300 000 people).

²³⁸ Brånvall & Svanström, 2011

²³⁹ Ek, 2010

²⁴⁰ Ibid

²⁴¹ Ek & Szudy, 2011

²⁴² Statistics Sweden MI 11 SM 0701, Korrigerad version

8.3.1.2.2.2 Methane emissions from sludge treatment

CRF 6.B.1.b, Industrial wastewater, Sludge

The European Union Waste Statistics Regulations (EC 2150/2002), also called WStatR, came into force in November 2002. It requires all Member States to provide data to the European Commission every two years on the generation and treatment of waste and on the number and capacities of waste management facilities. In this context, waste treatment covers incineration, recovery and disposal. Sweden has so far, as a Member State of the European Union, reported official national statistics on waste to the Commission for the years 2004, 2006 and 2008.

The inventory work and the data collection for WStatR has provided Sweden's national waste experts with valuable information on existing waste management practices in Sweden. Since the WStatR by definition shall cover 100 % of the generated waste in all sectors and incineration, recovery and disposal of waste, it is considered a reliable data source.

Both environmental reports and questionnaires have been used as data sources. All companies which perform waste treatment activities need permits and also to compile an annual environmental report. These environmental reports have been read by a team of waste experts for the purpose of finding waste data for WStatR.

The conclusions²⁴³ on the subject are that no activities such as anaerobic digestion of sludge from industrial wastewater treatment have been found during the inventory. Therefore Sweden is reporting "NO" (not occurring) for *emissions* and *recovery* for *6B1: sludge treatment*.

CRF 6.B.2.b, Domestic and commercial wastewater, Sludge

A study²⁴⁴ conducted by SWECO on behalf of Stockholm Water Authority (Stockholm Vatten) on two wastewater treatment plants in Stockholm shows that this leakage is between 4 % and 7 % of the gas production for these plants. If these plants are representative for all 135 wastewater treatment plants that apply anaerobic digestion in Sweden year 2010, then a national methane emission estimates can be calculated by combining this factor with data on energy recovery from the anaerobic sludge treatment.

In 2010, 614 GWh²⁴⁵ (or 44.0 Gg CH₄) was recovered. By using the upper value (7 %) of the leakage factor to ensure a conservative estimate the emission of CH₄ is calculated to 3.32 Gg for 2010.

²⁴³ Memo "Occurrence of treatment of sludge by anaerobic digestion in Swedish industries", Statistics Sweden, 2011 "

²⁴⁴ "Metanförsluster vid avloppsreningsverken i Henriksdal och Bromma", Stockholm Vatten, 2004

²⁴⁵ Swedish Energy Agency, 2011

Data on energy recovery from anaerobic sludge treatment are available for 2005-2010. For 1990-2004 no data are available and therefore the data for 2005 was extrapolated for these years. The estimate of the loss of CH₄ in the energy recovery process (7 %) is used for all years.

8.3.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Because of the simplifications in the used top-down model and the difficulties in estimating many of the parameters, the estimated emissions in the waste sector are uncertain.

The statistics of discharges from municipal wastewater treatment plants are biased from sources of inaccuracy such as under coverage, non-response or no observations and sample errors “within” the treatment plants. No objective methods of calculating accuracy measures have been developed, but data on nitrogen is considered to have a margin of inaccuracy of well under 10 % at national level. The inaccuracy in the emission factor is estimated to be at least 50 %, according to Good Practice Guidance. This results in an overall inaccuracy exceeding 50 % annually, and more for years where activity data have been extrapolated.

For methane emissions, both national methods and default methods are used. For the activity data “energy recovery” for the early years with no observations, a 50 % uncertainty is assumed, while for the recent years with actual observations a 10 % uncertainty is assumed. The uncertainty of the emission factor “leakage” is assumed to be the same for all years (40 %). All of these estimates are expert judgements.

For the activity data “population connected to small wastewater treatment plants” and “population not connected to wastewater treatment plants” the uncertainty for the early years is judged to be higher (10 %, expert judgement) than for the recent years (5 %, IPCC default). The uncertainty of the emission factor (Equation 5.6 in Good Practice Guidance) “Check method” is based on expert judgements and assumed to be high (65 %).

The time series in the waste sector are calculated consistently and in line with the Good Practice Guidance. When statistics are not produced annually, interpolation and extrapolation have been necessary tools for imputation.

8.3.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

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

8.3.1.5 SOURCE-SPECIFIC RECALCULATIONS

Recalculations have been made for N₂O from 6.B.2.2 Human sewage, since new data are available for protein consumption for the years 2008 and 2009. The new data has an impact on emission years 2006-2009. The recalculations has led to

increasing emissions of N₂O (2.9 %-7.8 %) from category 6B2.2. Human sewage in submission 2012.

8.3.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

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

8.4 Waste incineration (CRF 6.C)

8.4.1 Source category description

Emissions from incineration of hazardous waste, and in later years also MSW and industrial waste, from one large plant are reported in CRF 6.C. Emissions from other MSW incineration plants combusting waste for energy purposes are included in CRF 1. The summary of the latest key category assessment, methods and EF used, and information on completeness, i.e. if any sources are not estimated (NE), are presented in Table 8.21.

Table 8.21. Summary of source category description, CRF 6.C.

CRF	Gas	Key Category Assessment 2010			Method	EF	All sources Estimated
		Level	Trend	Qualitative			
6.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.

8.4.2 Methodological issues

For the whole waste category, the methodology and time series consistency are in line with the Good Practice Guidance.

Emissions from incineration of hazardous waste, and in later years also MSW and industrial waste, from one large plant are reported in CRF 6.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 and NO_x are measured continuously in the fumes at the plant. In 2003 capacity was increased substantially at the plant by taking one new incinerator into operation. The new incinerator incinerates a mixture of MSW, industrial waste and hazardous waste. As a consequence of increased capacity, the emissions from 2003 are increased compared to earlier years. Only a minor part (less than 0.5 %) of the total amount of MSW incinerated for energy purposes in Sweden are incinerated in the facility included in 6.C. All other emissions from incineration of MSW are reported in CRF 1.

Emissions reported are CO₂, CH₄, N₂O, NO_x, SO₂ and NMVOC. The CO₂ emission of biogenic origin of the MSW fraction of the waste, has since 2003 (when the incineration capacity increased dramatically, in order to treat MSW)

been estimated using published information²⁴⁶. Total amounts of incinerated waste as well as the amount of incinerated municipal waste have been obtained by the company. Also the total CO₂ emissions from incineration of waste are as reported by the company. In a report published by the Swedish Waste Management Association (2003)²⁴⁶ the information is given that approximately 70 % of the emitted CO₂ from incineration of municipal waste have biogenic origin. For the estimates we have assumed the same carbon content in hazardous, industrial and MSW waste.

According to information from the facility, occasional measurements concerning CH₄ and N₂O have been performed. The company reports CH₄ emission around 1.1 Mg for 2008. This information, together with information of incinerated amounts of waste 1990 until 2007, has been used for estimating a complete time series for emissions of CH₄ in CRF 6C. In submission 2010 also N₂O from waste incineration is reported for the whole time series 1990 – 2008. The estimates are based on occasional measurements of the N₂O concentrations in the flue gas made by the company together with information on yearly flue gas volumes 2003 - 2009. For 1990 until 2002 the volumes are not known and for these years the flue gas volumes have been estimated using the average of the ratios between volumes and incinerated amounts of waste for 2003 to 2008. Activity data and emission factors used for the CH₄ and N₂O estimates are presented in Table 8.22.

Table 8.22. Activity data and emission factors used for estimations of CH₄ and N₂O emissions in CRF 6.C.

Year	Total amounts of incinerated waste	Flue gas volume	N ₂ O	CH ₄
	Gg	1000 m ³	EF, g/1000 m ³	IEF, kg/Gg
1990	30	220 674*	15.00	7.73**
1995	33	240 637*	15.00	7.73**
2000	28	205 778*	15.00	7.73**
2001	31	228 934*	15.00	7.73**
2002	33	240 887*	15.00	7.73**
2003	122	789 438	15.00	7.73**
2004	130	881 100	15.00	7.73**
2005	126	1 099 338	15.00	7.73**
2006	122	902 039	15.00	7.73**
2007	140	915 032	15.00	7.73**
2008	146	1 189 691	15.00	7.73
2009	162	1 107 410	15.00	5.32
2010	115	1 007 061	15.00	7.84

* = estimated volume

** = IEF for 2008 used for estimations 1990 - 2007

²⁴⁶ The Swedish Association of Waste Management. RVF rapport 2003:12 (in Swedish). Förbränning av avfall. Utsläpp av växthusgaser jämfört med annan avfallsbehandling och annan energiproduktion.

8.4.3 Uncertainties and time-series consistency

In Revised 1996 IPCC Guidelines no information concerning uncertainties for CO₂, CH₄ and N₂O can be found. In 2006 IPCC Guidelines is stated that if a default value for emission factor is used the uncertainty has been estimated to be ± 100 percent or more and the uncertainty for plant specific activity data is $\pm 5\%$. 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 $\pm 100\%$ 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 $\pm 10\%$. Due to lack of other information the emissions data uncertainty for CO₂ and CH₄ are set to $\pm 10\%$.

As can be seen in Table 8.20 the implied emission factor (IEF) varies slightly between 2008 and 2009. Reported emissions are based on continuous measurements and the reason for the variation between 2008 and 2009 can be explained by a variation in the composition of the incinerated waste.

8.4.4 Source-specific QA/QC and verification

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

8.4.5 Source-specific recalculations

No source-specific recalculations have been performed.

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.

9 Other

Not applicable for Sweden.

10 Recalculations and improvements

Since the last submission, recalculations of GHG emissions for several years have been carried out throughout the inventory. The recalculations are due to comments and implemented recommendations from the national and international review teams in the on-going progress to make the inventory be fully in line with the IPCC Guidelines and the Good Practice Guidance. The recalculations include new methods, emission factors, thermal values and activity data. Some recalculations are due to errors in earlier inventories detected during the work with the present inventory.

10.1 Explanations and justifications for recalculations

The explanations and justifications for the recalculations made in this submission since the submission by October, 2011, together with descriptions on their implications for the emission levels, are given in the sector specific chapters.

10.2 Implications for emission levels

This section provides a general description for each sector of the major recalculations made. The implications for emission levels of GHG emissions by sector are presented in Table 10.1. In section 10.3 the implications for emission trends are presented.

10.2.1 Energy, CRF 1

In the energy sector, recalculations have been made for all GHG in the entire time series 1990-2009. Reallocation of combustion of natural gas in gasworks has been reallocated from CRF 1A5a to 1A1a, and fugitive CO₂ emissions from transmission of natural gas have been estimated for the first time. In 2008 and 2009 the recalculations are largely caused by revised activity data in the other sector CRF (1A4a, 1A4b, 1A4c) and parts of Manufacturing Industries and Construction, other (1A2f/Stationary). The methodology for estimating emissions from off-road vehicles and working machinery has been slightly adjusted, which implies minor recalculations. A few emission factors have been revised, e.g. CO₂ emissions from steelwork gases used in CRF 1A1a and CH₄ and N₂O for biomass in mobile combustion.

10.2.2 Industrial processes, CRF 2

In Industrial processes, CRF 2, new information on process-related CO₂ emissions, in the chemical industry, other (CRF 2B5) and revised information on estimations of fluorinated greenhouse gases (CRF 2F) led to revised emission estimates.

10.2.3 Solvents and other products use, CRF 3

Update of the Swedish Chemicals Agency data 2007-2009 effecting Solvents and other product use (CRF 3A and 3D) results in minor increase of GHG emissions.

10.2.4 Agriculture, CRF 4

The whole time series for number of horses has been updated with the results from a new survey carried out by the Swedish Board of Agriculture.

The MCF for liquid manure has been revised. A study by Rodhe et al. 2008 investigated the emissions of methane and nitrous oxide from cattle slurry storage.

The whole time series for number of slaughter chickens has been updated due to an updated estimation method.

Statistics Sweden has recently started to publish standard yields also for temporary grass. From the new data together with a literature study of old values a new time series has been constructed that is now harmonized with the time series for the other crops.

New calculations from Statistics Sweden for nitrogen and phosphorus balances for agriculture has resulted in revised values for the years 2007-2009 for FracGASM, both for the stable and grazing period.

Owing to new data from Statistics Sweden²⁴⁷ the values for fraction of nitrogen that volatilizes as NH_3 and NO_x from manure management and grazing manure have been updated.

Data for average nitrogen leaching from agricultural soils has been updated.

There are new estimates for total area of agricultural land for the most recent five years. The reason is the method used by SLU for estimating agricultural where number of sample plots increase with new submissions (see 7.2.2.1).

10.2.5 LULUCF, CRF 5

A major part of the large differences in the total removals from 2006 and onwards is the result of the annual update of the reporting data base, which results in recalculated data in the carbon pools (mainly Living biomass for all categories) from 2006 to 2009. The difference is also due to the recalculation of individual sample series using extrapolation as described in section 7.2.2.2.

10.2.6 Waste, CRF 6

No recalculations have been made in CRF 6A that has any influence on the emissions. A small adjustment has been made of "Annual MSW at the SWDS" (background information) for the years 2006-2009, because plastic waste has been excluded since it is considered to have no or little impact on generation of landfill gas.

Recalculations have been made for N_2O from 6B2.2 Human sewage, since new data are available for protein consumption for the years 2008 and 2009. The new data has an impact on emission years 2006-2009. The recalculations has led to increasing emissions of N_2O (2.9 %-7.8 %) from category 6B2.2. Human sewage in submission 2012.

²⁴⁷ Statistics Sweden, 2011

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

Table 10.1. Recalculations of GHG emissions between submission 2012 and submission 2011 by CRF sector.

Recalculation difference														
Year	Total (excl LULUCF)		CRF 1		CRF 2		CRF 3		CRF 4		CRF 5		CRF 6	
	Gg CO ₂ eq.	%	Gg CO ₂ eq.	%	Gg CO ₂ eq.	%	Gg CO ₂ eq.	%	Gg CO ₂ eq.	%	Gg CO ₂ eq.	%	Gg CO ₂ eq.	%
1990	264	0.4%	425	0.8%	12	0.2%	0	0.00	-172	-1.9%	3 463	-8%	0	0.0%
1991	75	0.1%	262	0.5%	12	0.2%	0	0.00	-199	-2.2%	4 288	-9%	0	0.0%
1992	-5	0.0%	226	0.4%	11	0.2%	0	0.00	-242	-2.7%	1 915	-5%	0	0.0%
1993	147	0.2%	437	0.8%	15	0.3%	0	0.00	-305	-3.3%	2 959	-8%	0	0.0%
1994	68	0.1%	389	0.7%	14	0.2%	0	0.00	-334	-3.6%	3 819	-10%	0	0.0%
1995	116	0.2%	470	0.9%	17	0.3%	0	0.00	-372	-4.1%	3 798	-10%	0	0.0%
1996	488	0.6%	843	1.4%	18	0.3%	0	0.00	-374	-4.1%	3 140	-8%	0	0.0%
1997	88	0.1%	404	0.7%	18	0.3%	0	0.00	-334	-3.6%	2 881	-7%	0	0.0%
1998	26	0.0%	301	0.6%	19	0.3%	0	0.00	-294	-3.3%	2 929	-7%	0	0.0%
1999	57	0.1%	266	0.5%	18	0.3%	0	0.00	-227	-2.6%	1 141	-3%	0	0.0%
2000	59	0.1%	269	0.5%	28	0.4%	0	0.00	-238	-2.8%	2 064	-5%	0	0.0%
2001	203	0.3%	443	0.9%	28	0.4%	0	0.00	-268	-3.1%	-178	0%	0	0.0%
2002	47	0.1%	309	0.6%	27	0.4%	0	0.00	-288	-3.4%	2 071	-5%	0	0.0%
2003	-25	0.0%	266	0.5%	24	0.4%	0	0.00	-314	-3.7%	3 435	-9%	0	0.0%
2004	-269	-0.4%	38	0.1%	23	0.3%	0	0.00	-330	-3.9%	3 605	-10%	0	0.0%
2005	-207	-0.3%	125	0.3%	16	0.2%	0	0.00	-348	-4.1%	5 354	-15%	0	0.0%
2006	-10	0.0%	342	0.7%	25	0.4%	0	0.00	-379	-4.5%	-1 865	5%	1	0.0%
2007	-196	-0.3%	127	0.3%	15	0.2%	11	0.0	-351	-4.2%	-2 730	8%	2	0.1%
2008	29	0.0%	304	0.7%	-5	-0.1%	16	0.1	-289	-3.5%	-2 899	9%	3	0.2%
2009	-323	-0.5%	102	0.2%	-21	-0.4%	16	0.1	-422	-5.2%	5 890	-14%	3	0.2%

10.3 Implications for emission trends

The total emissions of GHG have changed for all inventory years due to the recalculations. Below a more detailed description is presented of implications for emission trends due to recalculations of the base year emissions and the last recalculated year's emissions. Note that this section does not include implications for emission trends in the LULUCF sector. In Table 10.2 it can be seen that compared to the estimated assigned amounts, the base year emissions in submission 2012 are about 717 Gg CO₂ equivalents higher.

Table 10.2. Difference between Assigned Amount and Base Year emissions submission 2012 by GHG, excluding LULUCF

GHG	Assigned Amount (Gg CO ₂ eq.)	Base Year* emissions Submission 2012 (Gg CO ₂ eq.)	Difference between Base Year emissions Submission 2012 and Assigned Amount (Gg CO ₂ eq.)
CO ₂	56 301.08	56 890.29	589.21
CH ₄	6 719.22	7 049.88	330.66
N ₂ O	8 534.73	8 326.21	-208.53
F-gases	596.61	602.23	5.62
Total	72 151.65	72 868.61	716.96

*1995 for F-gases and 1990 for other GHG emissions (excluding LULUCF)

Based on submission 2012, the estimated GHG emissions in Sweden decreased by 9.1% between the base year (72,869 Gg CO₂ equivalents) and 2010 (66,232 Gg CO₂ equivalents). In Table 10.3 it can be seen that in submission 2011 the trend from the base year to 2009 shows a 17.3% decrease. It can also be seen that the recalculation of GHG emissions in submission 2012 increased the downward trend between the base year and 2009 by 621 Gg CO₂ equivalents or 0.8 % points compared to submission 2011.

Table 10.3. Impact on emission trends (base year to 2009) due to recalculations of GHG emissions between submission 2012 and submission 2011 by GHG, excluding LULUCF

Trend Base Year* to 2009						
GHG	Submission 2011		Submission 2012		Difference between submission 2012 and submission 2011	
	Gg CO ₂ eq.	%	Gg CO ₂ eq.	%	Gg CO ₂ eq.	% points
CO ₂	-10 025	-17.7%	-10 227	-18.0%	-202	-0.3
CH ₄	-1 700	-24.1%	-1 772	-25.1%	-72	-1.1
N ₂ O	-1 304	-15.6%	-1 581	-19.0%	-277	-3.3
F-gases	453	75.9%	382	63.5%	-71	-12.4
Total	-12 576	-17.3%	-13 197	-18.1%	-621	-0.8

*1995 for F-gases and 1990 for other GHG emissions (excluding LULUCF)

10.4 Recalculations and other changes made in response to the review process

As the inventory time cycle in Sweden is planned for a national independent review of the inventory, submission 2011 is already compiled in mid-October 2010. The preliminary result of the centralized review in 2010, taking place in September, can thus only be taken into account as minor recalculations and changes in response to the review process. In Table 10.4 the recalculations and other changes in data and in the NIR made in response to the UNFCCC review process are described briefly and referenced to relevant sections to the NIR. Table 10.5 describes the Expert Review team recommendations for submission 2009 and earlier not yet implemented in the Swedish inventory and the reasons for that together with possible implementation plans.

Table 10.4. Recalculations and other changes made in response to the UNFCCC review process.

Review ²⁴⁸	Sector	Paragraph and recommendation in report (shortened)	Actions as a result of ERT recommendations
Submission 2006	General	12. In the NIR provided more methodological detail so that the relationship between activity data (AD), emission factors (EFs) and equivalent parameters and emission estimates was clear, and if the reasons for apparent outliers or anomalies in implied emission factors (IEFs) had been easier to understand. This would have reduced the number of questions and requests for background material during the review. The ERT recommends that the accessible style of the NIR be retained, but that more use is made of tabular and graphic material, and annexes to convey the methodological detail.	Several measures are in place to enable further review of data. E.g. IEFs are compared to IPCC defaults in CRF 2C1.2 and CRF 2F.
submission 2007/2008, (Submission	General	10, (24). The LULUCF sector requires improved descriptions of country circumstances and the approaches to estimating emissions and removals. One area where transparency could be improved is the use	The description of the LULUCF sector has continuously been improved since submission 2008 with information concerning the national circumstances. Information on the use of EU ETS data in the Swedish GHG inven-

²⁴⁸ FCCC/IRR/2006/SWE, FCCC/ARR/2008/SWE, FCCC/ARR/2009/SWE and FCCC/ARR/2010/SWE. The draft Annual Review Report for the 2011 submission has not been available in time for implementation in submission 2012.

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

2010)		of EU ETS data in the national GHG inventory, in the description of the national system.	tory has continuously been improved since submission 2008. See section 1 and 3 and 4 and Annex 2 (1.1.10), and Annex 8:1. Further information will be added as needed in future submissions.
Submission 2007/2008	General	83. Include information on the commitment period reserve.	Information is included in section 12.5.
Submission 2009, (Submission 2010)	General	8, (6, 13). Provide information in CRF table 7 as presented in Annex 1 to the NIR for the purpose of completeness.	Included in submission 2011.
Submission 2009, (Submission 2010)	General	19, (18). Extend the information on its national system to include the specific responsibilities of the organizations participating in SMED and consultants who assist the Swedish EPA in the inventory preparation.	Information on the national system is revised and updated in submission 2011 and in submission 2012, see section 1.2 and 1.3
Submission 2009, (Submission 2010)	General	20, (19). Total emission estimates used for the key category analysis were not the same as those reported in the NIR, CRF tables and the background tables (appendix 20B to the NIR). Perform the key category analysis correctly and report it in the next annual submission.	The key category analysis is subject to QA and QC activities before delivered to the UNFCCC but they were not fully applied in the resubmission of 2009 due to limited time.
Submission 2009	General	21. Extend its overall uncertainty analysis to include the LULUCF sector. Perform uncertainty analysis taking correlations between gases or categories into account in the next annual submission.	Uncertainty estimates for LULUCF are included in submission 2011. IPCC Tier 1 does not allow correction of correlations between activity data when used for estimating several GHG (e.g. CO ₂ , CH ₄ and N ₂ O based on fuel combustion). The activity data uncertainty is thus applied in several cells in the IPCC Table 6.1 calculations leading to underestimations of total emissions.
Submission 2009	General	23. Provide information on QA applied to data from EU ETS.	Information on the use of EU ETS data in the Swedish GHG inventory has continuously been improved since submission 2008. See section 1 and 3 and 4 and Annex 2 (1.1.10) and Annex 8:1. Further information will be added as needed in future submissions.

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

Submission 2009	General	24. Improve transparency by providing more precise and detailed explanations of methodologies, AD and EFs used as well as relevant category-specific QA/QC activities in cases Sweden uses AD from different sources for a single category, country-specific EFs, or methods that are not explicitly explained in the Revised 1996 IPCC Guidelines or the IPCC good practice guidance.	More information is included in submission 2011.
Submission 2009	General	28. (a) If recommendations identified during the previous review cannot be implemented, the Party should clearly explain the reasons;	Fulfilled through table 10.5
Submission 2009	General	28 (d) The implementation of QA/QC procedures needs to be improved to avoid calculation errors and inconsistency between the CRF tables and the NIR;	Sweden's internal handling plan for deliverables between contracting agency SMED and Swedish EPA have been revised in order to enable more time for internal QA/QC routines. Further efforts will be continuously made in future submissions in order to improve QA/QC procedures. Improvements will be reported in coming NIRs.
Submission 2009	General	88. In the SIAR enhance the availability of the required public information mentioned above and ensure that rejected transactions are terminated, and should report, in its next annual submission, on these two identified issues.	See complete response in Annex 6
Submission 2009	General	89. Include correct information on its commitment period reserve in its next annual submission.	Correct information on the commitment period reserve is included in section 12.5.
Submission 2009	General	90. Report any changes in its national system in accordance with section I.F of the annex to decision 15/CMP.1.	The information on the national system is revised and updated in submission 2011 and submission 2012, see section 1.2 and 1.3

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

Submission 2009	General	91. Report in its next annual submission any changes in its national registry in accordance with section I.G of the annex to decision 15/CMP.1.	Appropriate information is provided in submission 2011
Submission 2010	General	11, 14. Continue to include emission estimates from civil aviation, industrial wastewater and domestic and commercial wastewater raised by the ERT in the list of potential problems.	Addressed in submission 2012, see section 3.2.15 and section 8.3.1.
Submission 2010	General	21. Use the results of uncertainty analysis to prioritize improvements in the inventory for its next annual submission.	Since the 2011 submission, a Tier 2 key category analysis is performed, taking into account uncertainty estimates. The Tier 2 analysis is used when prioritizing resources and efforts for improving the inventory (see section 1.2.3) together with other input such as international reviews and national peer review.
Submission 2006	Energy	23, 37. Categories not estimated	Fugitive emissions of CH ₄ from transport of crude oil are estimated in submission 2010 and added to CRF 1B2a iii Transport, whereas CO ₂ emissions in the same category is considered to be not estimated (NE) in Sweden (see NIR 3.3.2). 1B2c Flaring: In submission 2010, all emissions are estimated. All plants where flaring occurs are part of the EU ETS system, and according to this data no flaring of natural gas occurs. If natural gas is included in the "burning gas" sometimes reported to the EU ETS, the emissions are estimated but reported as IE (in flaring of liquid fuels).

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

Submission 2007/2008	Energy, Industrial processes, Waste	19, 32, 80. Categories not estimated	1B2c Flaring: In submission 2010, all emissions are estimated. All plants where flaring occurs are part of the EU ETS, and according to this data no flaring of natural gas occurs. If natural gas is included in the "burning gas" sometimes reported to the EU ETS, the emissions are estimated but reported as IE (in flaring of liquid fuels). CH ₄ from Carbon Black added in CRF 2B5 all years (see NIR 4.3.4)
Submission 2006	Energy	24. Institutionalize system-level checks to minimize the risk of missing plants or data in its future submissions.	The emissions from stationary combustion are calculated with activity data from a sample survey (thoroughly described in Annex 2). SMED internal QC procedures are in place to minimize error in compilation and data handling. The procedures will be continuously improved also in future submission.
Submission 2006	Energy	32 Methodology for Iron and steel industry	Addressed in submission 2010. Emissions have been revised for all years and reported in accordance with IPCC Guidelines (see NIR section 4.4.1)
submission 2006	Energy	34. Improve explanations on fluctuating trend for fugitive emissions of refinery gas in Petroleum refining	Text in NIR section 3.3.2 clarified in submission 2010
submission 2006	Energy	36. The allocation of fuel between civil aviation and aviation bunkers is not transparently described in the NIR, especially for the period 1990–1994.	A more detailed description is provided in NIR submission 2010 section 3.2.15
submission 2007/2008	Energy	27. The CO ₂ IEF for diesel decreased due to the change in the mix of the different types of diesel in Sweden. The ERT recommends that Sweden provide explanations in its next NIR, together with the specific carbon content values of Swedish MK1 and MK3 diesel.	In submission 2010, these specific carbon content values are shown in Appendix 20.
submission 2007/2008	Energy	30. The ERT recommends that Sweden provide specific information in its next NIR on how technology improvements influence the CH ₄ EFs from biomass burning.	In submission 2010, extensive information on this issue is included in NIR Annex 2. Very detailed information is provided in Paulrud et al, 2005: Methane emissions from residential biomass combustion. This report can be provided to the ERT if requested.

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

Submission 2009	Energy	32. Report emissions from some categories were reported as "NE", such as CO ₂ , CH ₄ and N ₂ O from venting of oil and gas and flaring of gas for all years.	Emissions from venting are considered to be included in other subsectors in 1.B.2 (see section 3.3.2.2). Flaring of natural gas is probably not occurring, but if occurring, it is included in flaring of oil.
Submission 2009	Energy	44. Clearly describe recalculations for off road vehicles and machinery made with the logic for making the revisions in the NIR in its next annual submission.	In submission 2011 there are no recalculations on this category. All recalculations made in other categories are clearly described in the NIR and in the CRF.
submission 2007/2008	Energy and Industrial processes	28, 29, 33, 35, 36. Sweden uses a CS-method to estimate and allocate CO ₂ emissions from pig iron production, not in line with the good practice guidance as this method allocates all CO ₂ emissions to the output (i.e. the blast furnace), rather than using an input based CO ₂ calculation method.	Addressed in submission 2010. Emissions have been revised for all years and reported in accordance with IPCC Guidelines (see NIR section 4.4.1)
Submission 2009, (Submission 2010)	Energy	38, (42). Investigate how distribution of marine distillate fuels and residual fuel oils between domestic and international navigation data corresponds to the definition of international and domestic marine transport in IPCC and explain large inter-annual variations.	Fuel data in the Monthly fuel, gas and inventory statistics, which is used as activity data for estimating emissions for national navigation and international maritime bunkers, has been analyzed in a SMED study (Eklund et al. 2011. Emissions from navigation and fishing including international bunkers). It has been found to be of good quality and fuels used for domestic and international navigation have been separated correctly and in line with IPCC Guidelines.
Submission 2010	Energy	33. Provide information and improve the transparency on the amount of fuel consumed in construction.	A table showing fuel consumption in the construction sector has been included in section 3.2.14.2
Submission 2010	Energy	34. For the largest iron and steel plants include explanatory information on the accuracy of AD and the consistency of the time series of data, and ensure the accuracy of its reporting without compromising the consistency of the time series of data.	Information is included in sections 3.2.9.2.1 and 4.4.1.2.2

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

Submission 2010	Energy	35. Investigate the reliability of the different sources of information, use appropriate and consistent sources of data for NCVs for its next submission, and provide the justification and reasoning for revising the previously used NCVs.	Explanations are provided in Annex 2.
Submission 2010	Energy	37. Provide explanatory information on the rationale for recalculations.	Explanations are provided in the section "Source specific recalculations" for those CRF categories where recalculations have been made in the current submission.
Submission 2010	Energy	43. Report correct notation key for CO2 emissions from solid fuels use in agriculture/forestry/fisheries	The notation key is "NO" for 2001 and onwards which is correct since no solid fuels have been used in this category since 2000.
Submission 2010	Energy	44. Provide information in the NIR on the fluctuating trend (e.g. large inter-annual changes) in the CO2 IEFs of other fuels for public electricity and heat production.	Information is provided in the section "Uncertainties and time-series consistency" (section 3.2.6.3)
Submission 2010	Energy	46. For civil aviation explain in more detail the method used to estimate the AD for 2008.	The estimation of CO2 from civil aviation is based on the data on supply and delivery of petroleum products from Statistics Sweden. Non-CO2 emissions are based on information from the SCAA and adjusted to match the delivered amount of aviation fuels (see NIR section 3.2.15)
Submission 2010	Energy	48. Explain the approach and method used to estimate fugitive emissions from distribution of oil products.	Explanations are provided in section 3.3.2.2
submission 2007/2008	Industrial processes	37. Inconsistency in IEF since 2005 is not explained in the NIR. Sweden is encouraged to provide the time series for the content of calcium oxide (CaO) in clinker to validate the single average value (65%) for the whole period.	Addressed in submission 2010. Before 2005 the company used the default EF 0.525 for the estimates. From 2005, CO ₂ emissions are based on analysis on the CaO content in the clinker. Data from 2008 and 2009 show a CaO content variation between 63.9 to 67.6%. See NIR 4.2.1.
submission 2007/2008	Industrial processes	38. The ERT recommends that Sweden improves the transparency of the reporting of the methodology used to estimate the CO ₂ removals in the pulp and paper industry.	Addressed in submission 2010. Reported data is revised in submission 2010. The revised time series affects reported activity data as well as CO ₂ emission data. See NIR section 4.5.1

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

submission 2007/2008	Industrial processes	40. The ERT encourages Sweden to correct and improve its reporting in the NIR, and to improve the transparency of the applied approach by adding an allocation table of the annual amounts of limestone used and emissions for each category.	Reported data in 2A3 is revised in submission 2010. An allocation table is added in the NIR and activity and emission data is provided for 2005 - 2008. See NIR section 4.2.3
Submission 2009	Industrial processes	46. Correct the discrepancy between figures in CRF and NIR.	Figures are correctly reported in submission 2011 as better SMED internal QC procedures are in place to minimize discrepancy between figures in CRF and NIR.
Submission 2009, (submission 2010)	Industrial processes	48, (54) Continue the discussion with the cement producing company and improve the CO ₂ estimates as appropriate.	Addressed in submission 2012, see NIR section 4.2.1.4
Submission 2009	Industrial processes	49. Complete the planned revision of methods and explain the new methods for pulp and paper industry in a transparent manner in the next annual submission.	Addressed in submission 2010, see NIR section 4.2.2
Submission 2009, (submission 2010)	Industrial processes	50, (62) Implement planned improvements in Limestone and dolomite use – CO ₂ with regards to transparency and allocation of emissions.	Addressed in submission 2010, see NIR section 4.2.3
Submission 2009	Industrial processes	52. Implement planned improvements in Iron and steel production and provides a transparent explanation of the revised estimation methods as well as the reallocation of emissions from the energy sector to this category. Include in the NIR a brief discussion on the results of the carbon balance checks.	Addressed in submission 2010. Emissions have been revised for all years and reported in accordance with IPCC Guidelines (see NIR section 4.4.1).
Submission 2009	Industrial processes	53. Clearly explain this in more detail in the NIR if it continues reporting CO ₂ from limestone use in iron and steel production.	Addressed in submission 2010, see NIR section 4.4.1
Submission 2009	Industrial processes	54. Make efforts to estimate the emissions from foam blowing that are not estimated currently, and include them in the next annual submission.	Data from the manufacturers is considered to be complete, see NIR section 4.7.2.

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

Submission 2009	Industrial processes	55. Calculate and include CO ₂ emissions from the use of calcium carbide using the default EF presented in the Revised 1996 IPCC Guidelines unless there is evidence showing that the calcium carbide produced is not used in the country.	Addressed in submission 2011, see NIR section 4.3.3
submission 2006	Agriculture	52. Break in time series 1995	Addressed in submission 2010. In the footnote to Table 6.6 an explanation to this is added.
submission 2006	Agriculture	54. Background data on enteric fermentation for cattle in CRF tables not consistent with calculations.	Addressed in submission 2010. The Background data this is referring to is not used in the actual calculations. The paragraph concerning the method for the calculations of enteric fermentation has been revised.
submission 2006	Agriculture	61. Sweden does not provide sufficient information in the NIR about the volatilization ratios of ammonia (NH ₃) and nitrogen oxide (NO _x) from the use of synthetic fertilizers and the application of animal manure.	A new paragraph named "Emission of ammonia" was added to NIR in submission 2011 to clarify this issue.
Submission 2007/2008	Agriculture	44. Provide detailed information in its NIR on the assumptions and national conditions supporting the calculation/selection of EFs (e.g. N ₂ O emissions from manure management and from agricultural soils).	The NIR has been updated with additional information about this.
submission 2007/2008	Agriculture	46. The ERT recommends that Sweden re-examine the preparation of table 4.B(b) to ensure that it accounts for all N excretion for the estimation of N ₂ O from manure management and for the quantification of N input for manure applied to soils and excretion on pasture range and paddock (table 4.Ds1). The ERT also recommends that Sweden ensure that its QA/QC procedures provide for accurate and correct completion of CRF tables in the agricultural sector.	This was due to a miscount that resulted in some incorrect activity data in submission 2009. It did, however, not affect the estimate of the actual emissions. This was corrected in submission 2010.
Submission 2007/2008	Agriculture	47. Revise this N-excretion rate in accordance with the conditions it is reporting for the number of pigs, that is, number of animals produced (including rotations) or number of average livestock at a given time.	The reference day for the estimation of number of pigs is the first of June. This should approximately be the average number of pigs for an arbitrary time of year.
Submission 2007/2008	Agriculture	48. Encourage Sweden to clarify the decrease in the IEF for solid storage from 0.0197 kg N ₂ O-N/kg N in 1990 to 0.0192	In CRF this value is constantly 0.02 for all reporting years.

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

		kg N ₂ O-N/kg N in 2006 and indicate which management systems underlie the IEF of 0.02 kg N ₂ O-N/kg N in the category other.	
submission 2007/2008	Agriculture	51. The ERT recommends that Sweden ensure the consistency of information between CRF tables 4.B(b) and 4.D	In table 4.B (b) the total amount of nitrogen excreted is given. In table 4.D the amount of nitrogen directly lost as ammonia is subtracted from the total amount and the remaining amount is used as activity data for release of nitrous oxide.
submission 2007/2008	Agriculture	52. Sweden does not provide sufficient information in the NIR on the volatilization ratios of ammonia (NH ₃) and nitrogen oxide (NO _x) from the use of synthetic fertilizers, and the application of animal manure.	A new paragraph named "Emission of ammonia" was added to NIR in submission 2011 to clarify this issue.
Submission 2009	Agriculture	58. Following the recommendations from previous reviews, the ERT recommends that Sweden improve transparency by providing additional information on how the EFs are calculated for tier 2 methods.	Additional information about the country specific EF has been included in the NIR for submission 2010.
Submission 2009	Agriculture	59. Further details on how the EF for dairy cattle is developed.	This has been clarified in submission 2011.
Submission 2009	Agriculture	60. Provide further documentation to explain the trend in emissions for manure management and the changing IEF.	The trend is explained in the beginning of section 6, Agriculture.
Submission 2009	Agriculture	63. Provide further information in the NIR on the appropriateness for Swedish conditions of the factors: country-specific EFs of 0.8 and 2.5 per cent kg N ₂ O-N/kgN for nitrogen from synthetic fertilizer and nitrogen from manure applied to soils, respectively.	This has been clarified in submission 2011.
Submission 2009	Agriculture	64. Further explanation be provided in the NIR of the appropriateness of the use of this country-specific EF (pasture, range and paddock manure is 0.016 kg N ₂ O-N/kg N and unfertilized pastures/grasslands is based on a value in the range of 0.002–0.01 kg N ₂ O–N/kg N).	Sweden has now changed the EF for pasture, range and paddock manure to the IPCC default value of 2%.
Submission 2010	Agriculture	66. Use the notation key "NO" in accordance with the IPCC good practice guidance in particular in CRF table 4.D.	This has been corrected in submission 2011

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

Submission 2010	Agriculture	67. improve the transparency of its reporting and include all relevant information on the country-specific EFs and methodologies used in the NIR, in particular for estimating N ₂ O emissions from agricultural soils.	The NIR has been updated with additional information in submission 2011.
Submission 2010	Agriculture	69. Include in the NIR and in the CRF tables additional information e.g. on milk yield per cow, digestibility of feed and gross energy intake, in order to improve the transparency.	This has been adjusted in submission 2011
Submission 2010	Agriculture	70. For CH ₄ from manure management include explanations for the fluctuations and the increasing IEF trends.	This information is included in the NIR since submission 2011
Submission 2010	Agriculture	72. Account for the average livestock population of all growing animal species, namely piglets	This information can be found in Table 6.6
Submission 2010	Agriculture	73. For direct soil N ₂ O emissions, include further explanations regarding country-specific EFs.	This information can now be found in the paragraph "Emission factors" under "Direct Soil Emissions (CRF 4.D.1)"
Submission 2010	Agriculture	75. For N ₂ O from pasture, range and paddock manure, provide consistent information in the NIR and in the CRF tables, and transparent explanations of the relevant corrections and changes made.	The paragraph in the NIR has been updated and a new table included in submission 2012
Submission 2010	Agriculture	76. For N ₂ O emissions from atmospheric deposition, include all relevant information on country-specific methodologies in the NIR, and provide well-documented explanations with regard to all country-specific EFs and parameters used.	A new paragraph regarding the emissions of ammonia from fertilisers and manure (and by that, $Frac_{GASM}$ and $Frac_{GASG}$) has been included in the NIR.
Submission 2010	LULUCF	20. Perform key category analysis at a more disaggregated level of categories, and as a result revise its key categories for activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol, for its next annual submission and explain in the NIR how it plans to use the key category analysis to prioritize improvements in the inventory.	Sweden performed the analysis on the level suggested by the ERT.
Submission 2010	LULUCF	82. Consider using the category other land to adjust the annual fluctuations in its total land area.	Sweden has started investigating how the estimates could be improved using complementary methods for the last reporting years. In this submission the inconsistency in total area as well as other categories has been solved using extrapolation for sample series

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

			ending earlier than 2010. See section 7.2.2.2.
Submission 2010	LULUCF	86. The ERT noted that there were some errors in the NIR, especially in the references related to the figures and tables provided in the NIR and recommended Sweden to improve the consistency of the reporting within the NIR, enhance its QC procedures and correct such errors in its next annual submission.	This has been checked and corrected in submission 2011.
Submission 2010	LULUCF	87. The ERT recommended that Sweden provide in its NIR more information on the drivers of the emission trends and their impact on the annual carbon stock changes, in order to improve the transparency of the reporting and facilitate the review of the inventory of the Party's next annual submission.	This was implemented in Submission 2011.
Submission 2010	LULUCF	88. The ERT noted that there is an inconsistency between the reported area of land converted to forest land and the area subject to the afforestation/reforestation activities reported under Article 3, paragraph 3, of the Kyoto Protocol and recommended that Sweden revise the method used to identify the relevant area and ensure the consistency of its reporting under the Convention and under the Kyoto Protocol, thus improving the transparency and accuracy of its reporting.	Sweden has started investigating how the estimates could be improved using complementary methods for the last reporting years. In this submission the inconsistency has been solved using extrapolation for sample series ending earlier than 2010. See section 7.2.2.2. However since AR and D areas are aggregated since 1990 and the area accumulation of land converted to Forest land starts earlier these are not comparable per se.
Submission 2009	LULUCF	59. Improve its approach for determining land-use change in order to report a consistent time series of annual land-use change matrices, as is suggested in the IPCC good practice guidance for LULUCF.	Sweden has increased the transparency in the description of methods used in the inventory in accordance with IPCC GPG.
Submission 2009	LULUCF	55. Improve the transparency of its inventory by providing all the necessary documentation and information in its future submissions, in accordance with the IPCC good practice guidance for LULUCF.	Sweden has increased the transparency in the description of methods used in the inventory in accordance with IPCC GPG.

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

Submission 2007/2008	LULUCF	70. Clarify in the NIR whether annual land-use change data are used to produce the estimates and report a consistent time series of these annual land-use change data in accordance with the IPCC good practice guidance for LULUCF.	Now clearly addressed in NIR
Submission 2007/2008	LULUCF	54. The ERT encourages the Party to improve the completeness of its reporting in its future annual submissions by providing estimates and relevant information for categories that are not estimated.	Sweden's reporting of LULUCF is now complete except for categories that are currently not mandatory to report.
submission 2007/2008	LULUCF	55. The ERT recommends that Sweden improve the transparency of its inventory by providing all the necessary documentation and information in its future submissions, in accordance with the IPCC good practice guidance for LULUCF.	Figures have been introduced to make it easier for the reviewer to follow the quite complicated sample design use. The text is continuously improved. See NIR section 7.3.1. Estimators are moved to Annex to NIR.
submission 2007/2008	LULUCF	56. The ERT recommends that Sweden consider the use of notation keys NO or IE either for gains or losses when the stock change method is applied.	Sweden is following this advice from submission 2010.
Submission 2007/2008	LULUCF	60. The total area of organic soil reported in the LULUCF sector does not match the area of cultivated organic soils reported in the agriculture sector (CRF table 4.Ds1).	In submission 2010, the reporting of total cropland areas in the agriculture sector (CRF 4) has been revised to be consistent with the reporting in the LULUCF sector. The area of cultivated organic soils still differ due to differences in data sources. The full correction is introduced in submission 2011.
Submission 2007/2008	LULUCF	63. Sweden reports a net carbon increase for the living biomass (except 1991) and dead organic matter pools for all years. The ERT recommends that Sweden provide an explanation for this trend in its next NIR in order to improve the transparency of its reporting.	The transparency in describing this issue has improved in submission 2010. See NIR section 7.1.
Submission 2007/2008	LULUCF	66. With the exception of the years 2002, 2003 and 2005 Sweden reports a net carbon increase in living biomass associated with land-use change from forest land to grassland. The ERT recommends that Sweden provide an explanation for the outlined trend in its next NIR.	The transparency in describing this issue has improved in submission 2010. See NIR section 7.1.

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

Submission 2007/2008	LULUCF	67. With the exception of the years 1992 and 2006, Sweden reports a net carbon increase in living biomass associated with land-use change from forest land to settlements. To improve the transparency, the ERT recommends that Sweden provide an explanation for the outlined trend in its next NIR.	The transparency in describing this issue has improved in submission 2010.
submission 2007/2008	LULUCF	68. Sweden has not been able to separate emissions from organic and mineral soils (CRF table 5 (III)). The ERT recommends that Sweden improve its methodology in order to be able to report the two soil categories separately.	Categories are reported separately in submission 2010.
Submission 2006	LULUCF	69. Improve consistency in the CRF tables by correcting the errors.	Corrected.
Submission 2006	LULUCF	70. Estimate CO ₂ emissions from land converted to wetland.	Addressed in submission 2010. No longer reported unmanaged.
Submission 2006	Waste	75. The ERT recommends that Sweden provide further information on the utilization of gas recovery in its next NIR.	From submission 2008, the use of recovered gas is described in NIR.
Submission 2006	Waste	79. The ERT recommends that Sweden use the notation key "not estimated" ("NE") for CH ₄ emissions from wastewater treatment, instead of "included elsewhere" ("IE"), in CRF table 6.B.	From submission 2010, the notation key NE is reported for CH ₄ emissions from wastewater treatment (sludge). In submission 2011, by following the recommendations of ERTs Saturday paper, emission estimates has been reported for CH ₄ emissions from wastewater treatment (wastewater). This is further described in the NIR section 8.3.1.2.2.1
Submission 2006	Waste	76. Measure CH ₄ and N ₂ O emissions from hazardous waste incineration periodically on-site.	Addressed in submission 2010, see NIR section 8.4
Submission 2007/2008	Waste	73. CO ₂ emissions from solid waste disposal on land could be better reported using the notation key NO.	From submission 2010, the notation key NO is reported for CO ₂ emissions.
Submission 2007/2008	Waste	74. CH ₄ emissions from wastewater treatment have been reported as NE	In submission 2011, by following the recommendations of the ERT, emission estimates has been reported for CH ₄ emissions from wastewater treatment (wastewater). This is further described in the NIR section 8.3.1.2.2.1

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

submission 2007/2008	Waste	75. The ERT recommends that Sweden change the notation key from IE to NE for the emissions from sludge resulting from treatment during the wastewater handling process.	In submission 2011, emission estimates has been reported for CH ₄ emissions from wastewater treatment (sludge).
Submission 2007/2008	Waste	74. Attempt to estimate CH ₄ emissions from wastewater treatment as part of the general assessment for "NE" categories and to provide the background data on industrial wastewater in CRF table 6.B.	CH ₄ emissions from wastewater treatment (wastewater and sludge) are estimated in submission 2011. This is further described in the NIR section 8.3.1.2.2.2.
Submission 2007/2008	Waste	76. Clarifications on methodology Wastewater handling needed in NIR	In submission 2010, justifications have been made in NIR section 8.3.2 (See section 8.3.1.2.1 in NIR submission 2011)
Submission 2007/2008	Waste	80. CH ₄ and N ₂ O emissions from waste incineration are reported as 'NE'. The ERT recommends that Sweden calculate these emissions (however insignificant) using IPCC default EFs, rather than wait for the outcome of actual measurements.	Estimates of N ₂ O and CH ₄ emissions are included in submission 2010. See NIR section 8.4
Submission 2009	Waste	81. Clarify about unmanaged landfill sites throughout the time series from 1990 to 2007 and provide more information on managed and unmanaged landfill sites in Sweden.	In NIR submission 2011, more information is provided on the matter. This is further described in the NIR section 8.2
Submission 2009	Waste	82. Confirm which Tier is used in CH ₄ from Solid waste disposal on land and if necessary correct this information.	Tier 3 was changed to Tier 2 in submission 2010.
Submission 2009	Waste	83. Give more and updated information on the amount of landfill gas recovered that was used for energy and was flared.	More information was provided in NIR 2011. This is further described in the NIR section 8.2.1.2.1.2
Submission 2009	Waste	85. Provide some additional information about the lower value in 2006 for CO ₂ emissions from waste incineration.	Information is provided in section 8.4. Data are direct measurements from the facilities flue gases and are considered to be correct.

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

Submission 2010	Waste	<p>99. Continue to estimate and report the CH₄ emissions from industrial, domestic and commercial wastewater and sludge, ensure consistency between the information reported in the NIR and that in the CRF tables and include all necessary information (e.g. category description, methodological issues, uncertainty and time-series consistency, recalculations and planned improvements) in order to improve the transparency.</p> <p>Provide information on the rationale for using the notation keys to report on wastewater handling</p>	<p>Sweden has improved the reporting of CH₄ emissions from industrial, domestic and commercial wastewater and sludge in submission 2010 (resubmission) and further more in submission 2011. Emissions and methodologies are presented and described in the CRF-tables and in NIR.</p>
Submission 2010	Waste	<p>100. Consider using time-dependent AD on protein consumption (e.g. statistics from the Food and Agriculture Organization of the United Nations) to further improve the accuracy.</p>	<p>Since submission 2011, Sweden is using existing time series data on protein consumption from the Swedish yearbook of agricultural statistics.</p>

Table 10.5. Recommendations from the UNFCCC review process not yet implemented in the Swedish inventory.

Review ²⁴⁹	Sector	Paragraph and recommendation in report (shortened)	Rationale for not yet adapting ERT recommendation and possible improvement plan
Submission 2007/2008	Energy	79.The ERT recommends that only one value (e.g. 25 kg CO ₂ /GJ) be used for all years for incinerated municipal waste in order to maintain time-series consistency and consistency with reporting on incineration in category 1.A.	A study performed in 2009 ²⁵⁰ addressed this issue. It was concluded that there is not enough evidence to revise the emission factor for years prior to 2003, and SEPA decided not to revise the emission factor at all. We are aware of this issue and our ambition is to improve this emission factor in future submissions.
Submission 2009, (Submission 2010)	Energy	31, 36, 39, (39). The ERT reiterates the recommendation made by the previous review that Sweden investigates the cause of the difference between the data reported to the IEA and that reported to the UNFCCC.	An study ²⁵¹ was carried out in 2010. The recommendations from that study have not fully been implemented in the inventory, as described in Annex 4 (Reference approach). A study on this issue will be made in 2011/2012 which will hopefully result in reduced discrepancies and/or more complete explanations to the existing differences. The results will be included in submission 2013.
Submission 2009	Energy	32. Report emissions from some categories were reported as "NE", such as the CH ₄ and N ₂ O emissions from mobile military use of biomass (FAME) for the years 1999 to 2001, CO ₂ from oil transport for all years,	In submission 2011 all categories for which IPCC default methodologies exist are estimated. There are no emission factors available to estimate CH ₄ and N ₂ O emissions from mobile military use of biomass for the years 1999 to 2001 but emissions are expected to be minor. Sweden lack information on CO ₂ emissions from oil transport and there is no IPCC default methodology for CO ₂ from oil transport using tanker ships.
Submission 2009	Energy	35. The ERT reiterates the recommendation made by the previous review that Sweden reconciles the differences between the reference approach and the sectoral approach.	Data and methodology for the reference approach have been studied during 2010 and 2011. There are, however, still quite large differences between the reference approach and the sectoral approach for some years. A study on this issue will be made in 2011/2012 which will hopefully result in reduced discrepancies and/or more complete explanations to the existing differences. The results will be included in submission 2013.

²⁴⁹ FCCC/IRR/2006/SWE, FCCC/ARR/2008/SWE and FCCC/ARR/2009/SWE and FCCC/ARR/2010/SWE. The draft ARR for the 2011 submission has not been available in time for implementation in submission 2012.

²⁵⁰ Paulrud, Fridell Strippel, 2009

²⁵¹ Hedlund & Lidén, 2010

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

Submission 2010	Energy	38. Provide correct information in the documentation box of CRF table 1.A related to discrepancies between the reference and sectoral approaches. Investigate difference between the reference and sectoral approaches associated with solid fuels by properly separate fugitive emissions and emissions from fuel combustion in the industrial processes sector.	A study on this issue will be made in 2011/2012 which will hopefully result in reduced discrepancies and/or more complete explanations to the existing differences. The results will be included in submission 2013.
submission 2007/2008	Industrial processes	41. For CO ₂ and N ₂ O from solvent and other product use, Sweden reported identical emission estimates for 2005 and 2006 in its 2008 submission. The ERT recommends that Sweden improve its data collection procedures in order to estimate final emissions in a timely manner.	Not implemented but addressed in NIR Annex 3.3. We intend to make special arrangements for data collection for submission 2014 in order to avoid using preliminary data in that submission.
Submission 2010	Industrial processes	59. Allocate CO ₂ emissions from limestone and dolomite used in iron and steel production to limestone and dolomite use category.	Not implemented, but addressed in NIR section 4.4.1.2.
Submission 2009, (Submission 2010)	Industrial processes	56. (63) Report CH ₄ and N ₂ O from combustion of cooking liquor in the pulp, paper and print category under the energy sector, in accordance with the Revised 1996 IPCC Guidelines.	This will be addressed in the coming submissions, but addressed in NIR section 4.5.1.
Submission 2007/2008	LULUCF	75. The ERT reiterates the recommendation from the previous review that Sweden improve its methodology (to separate emissions from organic and mineral soils (CRF table 5 (III))) in order to be able to report the two soil categories separately in future submissions.	Currently we do not have appropriate information on exactly on which land these changes occur. Therefore the emissions are reported aggregated.
Submission 2007/2008	LULUCF	69. The ERT noted that Sweden may be underestimating the C stock increase in living biomass and recommends that Sweden verify differences in IEF compared to Finland and Norway and make revisions if necessary.	Comparing IEF may not tell the whole story. The annual harvest may differ significantly between years in and between countries. Therefore the difference may not be seen as exceptional.
Submission 2009	LULUCF	57. Report the subcategory mire under grassland, further distinguishing between managed and unmanaged land subcategories.	Grasscovered mires are always saturated with water and therefore reported under Wetlands.
Submission 2006	Waste	77. Account for CO ₂ emission only from non-biogenic waste incineration sources according to the IPCC Good Practice Guidelines.	This will be addressed in the coming submissions.

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

Submission 2007/2008	Waste	72. Include information on time series for industrial organic waste in order to provide a more complete picture of municipal solid waste AD.	No data are available, which has been further described in the NIR of submission 2011. See NIR section 8.2.1.2.2.
Submission 2007/2008	Waste	78. Include information on biogenic fraction of incinerated municipal waste in its next NIR, and update and validate this value regularly as the biogenic fraction of incinerated municipal solid waste varies over time. It is good practice to assume that the composition of incinerated municipal solid waste is similar to that of generated municipal solid waste (IPCC good practice guidance, page 5.28).	This will be addressed in the coming submissions.

10.5 Major changes in methodological descriptions

Table 10.6. Documentation of major changes in methodological descriptions compared to previous year NIR.

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	DESCRIPTION OF METHODS	RECALCULATIONS	REFERENCE
	Please tick where the latest NIR includes major changes in methodological descriptions compared to the previous year NIR	Please tick where this is also reflected in recalculations compared to the previous year CRF	If ticked please provide some more detailed information for example related to sub-category, gas, reference to pages in the NIR, etc
Total (Net Emissions)			
1. Energy			
A. Fuel Combustion (Sectoral Approach)			
1. Energy Industries	X	X	See NIR 3.2.6.2, 3.2.6.5, 3.2.1.7
2. Manufacturing Industries and Construction		X	See NIR 3.2.11, 3.2.14
3. Transport	X	X	See NIR 3.2.15-16 and 3.2.18
4. Other Sectors	X	X	See NIR 3.2.21-22
5. Other	X	X	See NIR 3.2.24
B. Fugitive Emissions from Fuels			
1. Solid Fuels			
2. Oil and Natural Gas	X	X	See NIR 3.3.2.2.6 and 3.3.2.2.7
2. Industrial Processes			
A. Mineral Products	X	X	See NIR 4.2.1-4.2.3
B. Chemical Industry			

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

C. Metal Production			
D. Other Production			
E. Production of Halocarbons and SF6			
F. Consumption of Halocarbons and SF6	X	X	See NIR 4.7
G. Other			
3. Solvent and Other Product Use			
4. Agriculture			
A. Enteric Fermentation			
B. Manure Management	X		See NIR 6.3.5
C. Rice Cultivation			
D. Agricultural Soils	X		See NIR 6.4.3.3
E. Prescribed Burning of Savannas			
F. Field Burning of Agricultural Residues			
G. Other			
5. Land Use, Land-Use Change and Forestry		X	See NIR 7.6 is an overview of all recalculations in CRF 5
A. Forest Land	X	X	See NIR 7.2.2.2, 7.4.2 and 7.6
B. Cropland	X	X	See NIR 7.2.2.2, 7.4.2 and 7.6
C. Grassland	X	X	See NIR 7.2.2.2, 7.4.2 and 7.6
D. Wetlands	X	X	See NIR 7.2.2.2, 7.4.2 and 7.6
E. Settlements	X	X	See NIR 7.2.2.2, 7.4.2 and 7.6
F. Other Land	X	X	See NIR 7.2.2.2, 7.4.2 and 7.6
G. Other			
6. Waste			

SWEDISH ENVIRONMENTAL PROTECTION AGENCY
National Inventory Report Sweden 2012

A. Solid Waste Disposal on Land			
B. Waste-water Handling		X	See NIR 8.3.1.5
C. Waste Incineration			
D. Other			
7. Other (as specified in Summary 1.A)			
Memo Items:			
International Bunkers			
Aviation			
Marine			
Multilateral Operations			
CO2 Emissions from Biomass			

NIR Chapter	DESCRIPTION		REFERENCE
	Please tick where the latest NIR includes major changes in descriptions compared to the previous year NIR		If ticked please provide some more detailed information for example reference to pages in the NIR

PART 2: SUPPLEMENTARY INFORMATION REQUIRED UNDER ARTICLE 7, PARAGRAPH 1

11 KP-LULUCF

11.1 General information

Sweden provides supplementary information under Article 7 of the Kyoto Protocol (KP) for the Land Use, Land-Use Change and Forestry sector. This information requested is further specified in Decision 15/CMP.1, 16/CMP.1 and IPCC GPG for LULUCF (IPCC²⁵²).

Emissions/ removals originating from the activities Afforestation and Reforestation (AR) and Deforestation (D) are quite uncommon in Sweden (Table 11.1 and 11.2). The accumulated AR and D-areas always increase by time when estimates are based on the full set of inventory plots. However, if based only on re-measured plots, for the most recent years this might not always be the case. This is due to the five-year inventory cycle, where the estimates for the five recent years are based on a decreasing number of plots. To avoid a risk of an incorrect decrease in AR and D area and to improve the accuracy of estimates, inventory cycles without a full record to 2010 are extrapolated (see 7.2.2.2 and Figure 7.5). Areas under ARD are accumulated and therefore extrapolations are based the trend of the five years previous to the actual year, while extrapolation for area under Forest management(FM) and living biomass for all Art. 3.3 and 3.4 activities are based on a running average of the five years previous to the actual year. There are several options to make this extrapolation 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 of between being enough to reduce random variation and be reasonably up to date. Each submission, data for the five recent years 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 six in IPCC 2003 GPG describes that extrapolation is valid to improve estimates for years with missing data. Without extrapolation, due to this explained sampling randomness from estimates based on different number of sample plots, the estimated area under AR would have decreased between 2008 and 2009 and between 2009 and 2010. The same would have been valid for the area of D between 2009 and 2010. Comments by reviewers to report a constant total area and increasing areas under D (and normally under AR), made Sweden introduce extrapolation. The methodology has also the advantage to improve the accuracy of estimates. The only potential disadvantage is the challenge to trace back extrapolated carbon of living biomass to land use from 1990 and onwards.

Sweden has elected the activity Forest management (FM) under Article 3.4 of the Kyoto Protocol (KP). The KP-reporting of FM and AR harmonize (areas) with the UNFCCC-reporting of Forest land and land converted to Forest land. Due to a slow growth rate in boreal forests, land under AR will not be considered har-

²⁵² Intergovernmental Panel on Climate Change, 2003

vested during the first commitment period²⁵³ and these juvenile forests are not fertilized. Therefore, direct N₂O emissions from N fertilization and emissions from forest fires are reported only under FM. Forest fires –both natural and wildfires– are uncommon and, this far, has not been registered on ARD-land. N₂O emissions from disturbance associated with land use conversion from Forest land to Cropland are reported under D. N₂O emissions from drainage of soils are not reported (voluntary). Liming is assumed to only occur on agricultural land and is not reported under the KP.

Table 11.1 The accumulated area under activities AR, D and FM .

[M ha]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
AR	0.02					0.11	0.12	0.13	0.14	0.15	0.17	0.19	0.21	0.22	0.23	0.23	0.23	0.23	0.23	0.24	
D	0.01					0.12	0.14	0.15	0.16	0.16	0.17	0.18	0.19	0.19	0.20	0.21	0.21	0.21	0.21	0.21	
FM	28.23					28.13	28.12	28.10	28.09	28.09	28.09	28.10	28.13	28.18	28.24	28.28	28.31	28.31	28.31	28.31	

Table 11.2 Emissions / removals (minus), CO₂ [Mton] from reported carbon pools in AR, D and FM for the third year in the commitment period (2010).

[Mton]	Above ground biomass	Below ground biomass	Dead wood	Litter	Soil organic carbon
AR	-0.53	-0.18	-0.01	-0.26	0.18
D	0.60	0.20	0.00	0.98	0.99
FM	-21.4	-7.24	-6.92	3.13	-4.57

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 7). The estimates of emissions/ removals and areas are based on permanent sample plots inventoried by the Swedish National Inventory of Forests covering all land and fresh water areas. A major difference from the UNFCCC reporting is that the carbon pool living biomass is separated into above ground and below ground living biomass and that the dead organic matter pool is separated into dead wood and litter in the reporting under the KP. Only emissions/ removals on land under the activities AR, D and FM are reported under the KP. ARD land is accumulated from 1990 using permanent sample plots covering all land and fresh water areas. Changes in carbon pools on ARD-land are reported for years 2008-2010. Land under FM is accumulated from 1990 and changes in carbon pools are reported on such land 2008-2010.

²⁵³ The concept "harvest" is important when a party claims to offset emissions from land under harvested AR-land (e.g. FCCC/KP/CMP/2005/8/Add.3 p.6) but no definition of "harvest" has been found. So Sweden assumes that "harvest" refers to emissions at final felling and such AR-land is not expected to exist in Sweden during the first commitment period.

Sweden has elected commitment period accounting for LULUCF for the first commitment period.

11.1.1 Definitions of forest and any other criteria

For reporting purposes under the Kyoto Protocol, Forest land is defined, according to the FAO definition, as land with a tree crown cover (or equivalent stocking level) of more than 10 %, an area of more than 0.5 ha and a minimum height of 5 m. Both crown cover and height refers to maturity *in situ*, and consequently, Forest land could temporary be unstocked due to human intervention such as final felling. Normally such land is regenerated within a few years and Forest land is not considered 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.

All Forest land is assumed managed. Thus, the definition of Forest land and the assumption that all Forest land is managed are consistent with reporting under the UNFCCC. The underlying data are also consistent for the whole reporting period. In fact, the area of Forest land under the UNFCCC reporting should equal the sum of the areas subject to activities Forest management and Afforestation/ Reforestation under the Kyoto Protocol (this far all land under Afforestation/ Reforestation has secondary classification Forest management and none under Deforestation).

The definition of Forest land is consistent with former reporting 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.

Under the Kyoto Protocol it is central to distinguish between definitions of land use categories, activities and spatial assessment units (Figure 11.1). The definition of Forest land has a minimum area but this is not the case for activities. For Sweden the spatial assessment unit is a permanent sample plot (radius 10 m) and since this plot could be delineated into more than one land use category, deforestation close to 0 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.

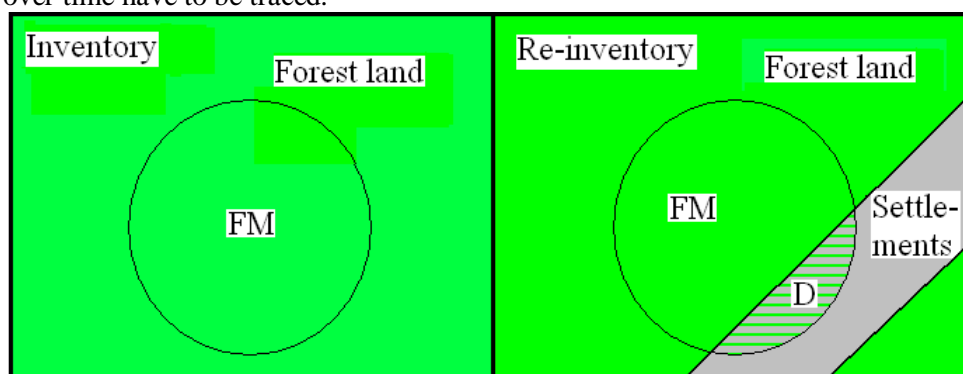


Figure 11.1) Example distinguishing the concepts of land use category, activities under the Kyoto Protocol, and spatial assessment unit in the Swedish sample based inventory: At the first inventory, only the land use category Forest land exist in an area but at the re-inventory part of the Forest land has been deforested to the land use category Settlements. Activities under the Kyoto Protocol are estimated using area based sampling by circular sampling plots (the spatial assessment unit). At the first inventory, the whole plot represents the activity Forest management (FM) but at the re-inventory the plot represent the activities FM and Deforestation (D), respectively. Observe that both land use categories and activities have definitions but Sweden has no minimum area limit set for estimating activities.

11.1.2 Elected activities under Article 3, paragraph 4, of the Kyoto Protocol

For the accounting of LULUCF-activities under article 3.4 during the first commitment period, Sweden has elected Forest management (FM). FM is defined as activities on Forest land.

11.1.3 Description of how the definitions of each activity under Article 3.3 and each elected activity under Article 3.4 have been implemented and applied consistently over time

Sweden defines Deforestation (D) as land use conversions from Forest land (all forest land area is regarded managed) to Cropland, Grasslands or Settlements (all land under these three categories are assumed managed). Afforestation/ Reforestation (AR) is defined as land use conversions in the opposite direction (Figure 11.2). Land use categories are strictly defined (see NIR chapter 7.2.3) 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 11.3). If the land use of a sample plot or part of a sample plot is assessed as converted between consecutive inventories the exact year of the conversion is estimated from properties on the sample plot (site, stand and vegetation properties). This method has been used since 2006. For the years 1990-2006, the conversion year between consecutive inventories is randomly assumed. AR on former Cropland, Grasslands and Settlements are connected with an active human decision. Normally regeneration is following shortly after the land conversion. All AR land is by national legislation considered as Forest land and the same definition of Forest land is used in the For-

estry act (1979:429 2 § 1.) as for the UNFCCC reporting. The activity Forest management (FM) is assumed occurring on all land fulfilling the forest definition (see 11.1.1). If land is subject to AR (or D), this land may have secondary classification FM. Land could only be reported under one activity or none (to avoid double counting).

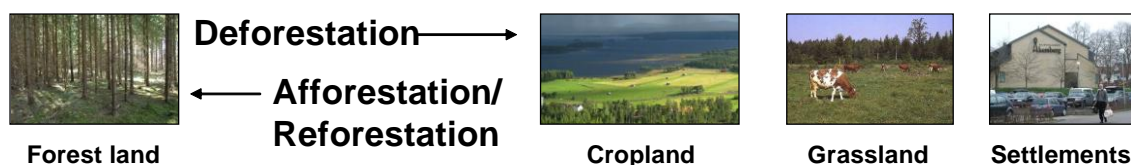


Figure 11.2) D is defined as land use conversions from Forest land (managed) to another managed land use class (all Cropland, Grasslands and Settlements are assumed managed). AR are defined as land use conversions in the opposite direction (C, G or S to F).

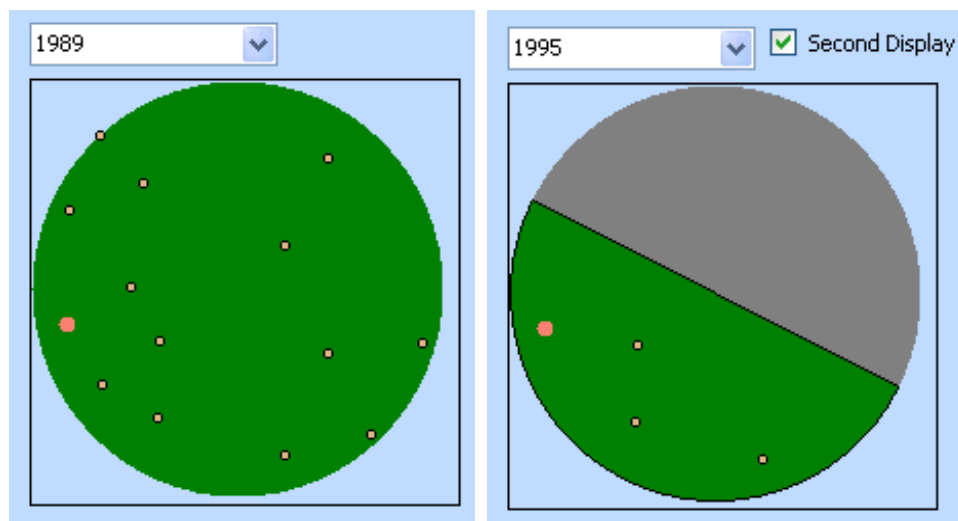


Figure 11.3) The figure shows data for a specific sample plot in the Swedish LULUCF-database. The individual tree biomass on approximately 30 000 permanent sample plots are matched to land use and traced back to before the base year in a consistent way. Applying area based sampling all 30000 permanent sample plots represents the whole land and fresh water area in Sweden and carbon stock changes are estimated using the stock change method on these plots. Part of this specific plot was 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.

11.1.4 Descriptions of precedence conditions and/or hierarchy among Article 3.4 activities, and how they have been consistently applied in determining how land was classified.

Precedence conditions are: D, AR and FM since FM is the only activity elected under article 3.4. Land under Deforestation (D) cannot leave this category. This is basically also valid for land under AR – except after D. Land under Afforestation/Reforestation (AR) usually has secondary classification FM (always if reported under Forest land remaining Forest land or conversion to Forest land under the UNFCCC). Theoretically, land under Deforestation can have secondary classifica-

tion FM (if reported under Forest land remaining Forest land or conversion to Forest land under the UNFCCC) but this far such land does not exist. . Land areas under FM that are naturally degraded can leave the category until 2008 (but not during the commitment period) and is not reported under the KP (usually reported as Forest land converted to Wetland or Other land under the UNFCCC). Deforested land can leave FM at any time from 1990 and onwards category and these land areas are then reported under D. Land associated with the activities reported (AR, D and FM) is accumulated from end of 1989 and onwards, and changes in carbon pools and other emissions on these land areas are reported during the commitment period.

11.2 Land-related information

11.2.1 Spatial assessment unit used for determining the area of the units of land under Article 3.3

The “Spatial assessment unit”, which is the same as for the UNFCCC-reporting, is used to determine the area of accounting for ARD. The “Spatial assessment unit” is defined as the minimum area used to detect a land use conversion.

Sweden monitors land use transfers based on field measurements using circular sample plots (radius 10 m). If any part of a plot is converted from one land use category to another, it can be detected. Thus, the “Spatial assessment unit” will be a sample plot part and activities down to an area of 0 m² could be detected. The same “Spatial assessment unit” has consistently been used in both the UNFCCC and the KP-reporting (Figure 11.1).

11.2.2 Methodology used to develop the land use matrix

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

The Swedish National Forest Inventory covers all land and fresh water areas before the base year and onwards on sample plots with a fixed position (permanent sample plots). This makes it possible to consistently trace both gross and net land use transfers over time.

11.2.3 Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations

Sweden uses a geographical boundary encompassing units of land (Reporting method 1) and has adopted approach 3 (Table 4.2.2 in GPG LULUCF 2003) for reporting emissions/ removals under article 3 of the KP (Figure 11.4). In practice a sample frame of approximately 30000 permanent sample plots is covering all relevant managed land in Sweden (see NIR chapter 7). The sample frame is divided

into about 30 strata and the distance between sample units within stratum is based on autocorrelation. A five-year inventory cycle is used and each year about 6000 sample plots are inventoried over the whole country. Each sample plot has an identification code and a registered geographical position. 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 11.4).

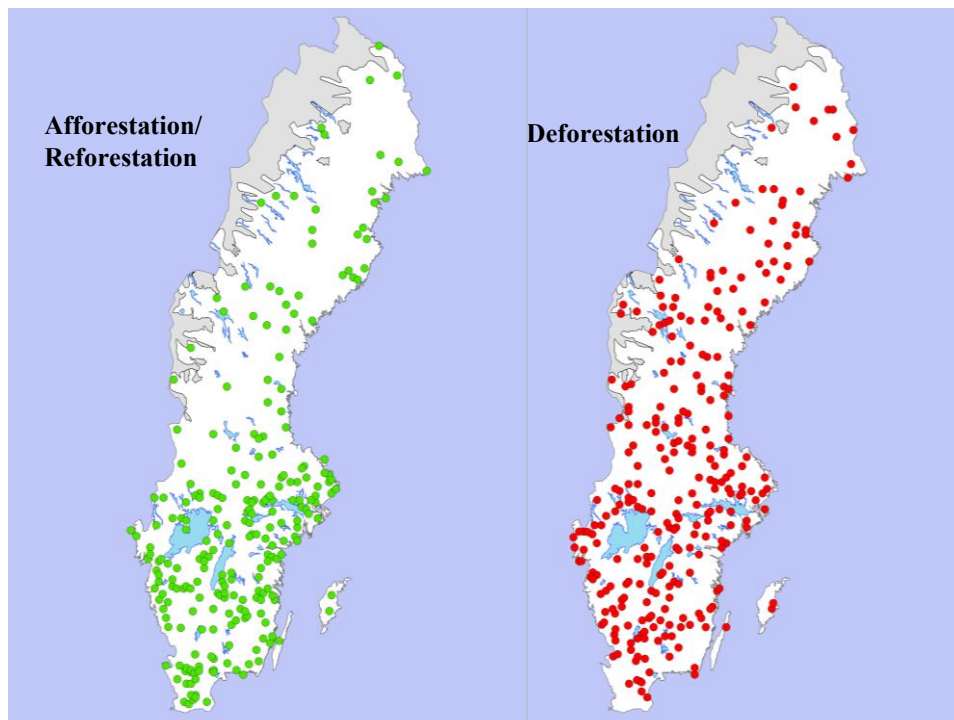


Figure 11.4) The location of sample plots partly or completely reported under ARD in Sweden (1990-2010).

11.3 Activity-specific information

11.3.1 Methods for carbon stock change and GHG emission and removal estimates

In most cases, methodologies, models and assumptions under the KP-reporting are consistent with the UNFCCC-reporting. This chapter focuses on discrepancies.

11.3.1.1 DESCRIPTION OF THE METHODOLOGIES AND THE UNDERLYING ASSUMPTIONS USED

11.3.1.1.1 Carbon pools

The living biomass pool changes is estimated in exactly the same way as under the UNFCCC reporting using the stock change method and area based sampling (See 7.3.1.2 + NIR Annex 3:2). However, the living biomass is reported separately for above-ground and below-ground biomass, respectively.

The dead wood, litter and soil organic pools are calculated using the same methods as for the UNFCCC-reporting (See 7.3.1.3-4 + Annex 3:2) using the area distribution associated with the reported activities under the Kyoto protocol (ARD and FM).

All methods used for FM is Tier 3 whereas methods for Litter, Dead wood and Soil organic carbon for ARD is Tier 2.

11.3.1.1.2 Other emissions

Emissions associated with direct N₂O emissions from N fertilization in forests (TABLE 5(KP-II)1) are estimated in the same way as under the UNFCCC (see 7.2.5.1). The estimates are based on activity data and emission factors with no information of the actual geographical distribution of fertilizer used. The fertilization is strictly regulated by the Forestry act and Sweden assumes that no fertilizer is applied in young forests. Therefore all emissions are assumed to occur under the activity FM and none under AR and the reported figure under “Forest Land remaining Forest Land“ (UNFCCC, TABLE 5(I)) should correspond to the reported figure under FM (TABLE 5(KP-II)1)). It should be noted that fertilization is very restricted in Sweden. The annual fertilized area is expected to increase in the coming years but to cover less than 0.5 % of the total area of Forest land.

In line with the UNFCCC-reporting (TABLE 5(II)), N₂O emissions from drainage of soils (TABLE 5(KP-II)2) are not reported. The justification for omitting the emission is found in section 11.3.1.2.

The reporting of N₂O emissions from disturbance associated with land-use conversion to Cropland (TABLE 5(KP-II)3) are only relevant for the activity D and is reported. The reported figure should be similar to the figure reported under “2.1 Forest land converted to Cropland” (UNFCCC, TABLE 5(III)) and discrepancies arise only from a different accumulations of land between the two reporting's (see activities).

All forest fires (TABLE 5(KP-II)5) are reported under FM and this figure should correspond to the figure reported under Forest land (UNFCCC, TABLE 5(V)). Forest fires may occur in all kinds of forests but no fires have been registered by the National Forest Inventory on land reported under activities AR.

11.3.1.1.3 Activities

Kyoto Protocol activity areas are accumulated from the base year and onwards and, normally, do not leave the class. For the UNFCCC-reporting converted land stays in the conversion class for twenty years and is thereafter reported under the land use category it was converted to. The twenty-year accumulation of land under the UNFCCC-reporting may begin long before the base year and is therefore not suitable to, for example, compare D under the Kyoto Protocol with Forest land con-

verted to Cropland, Grassland or Settlements. Using conversions from Forest land as a “proxy” for D has lead to several misunderstandings when assessing the outcome of the UNFCCC and the KP reporting.

11.3.1.2 JUSTIFICATION WHEN OMITTING ANY CARBON POOL OR GHG
EMISSIONS/REMOVALS FROM ACTIVITIES UNDER ARTICLE 3.3 AND
ELECTED ACTIVITIES UNDER ARTICLE 3.4

Sweden accounts for all carbon pools (above-ground biomass, below-ground biomass, litter, dead wood and soil organic carbon). This is also valid for all non-carbon pool emissions except nitrous-oxide emissions from drainage of soils under FM (Table 5(KP-II)2). These emissions is optional to report since the available methods to estimate the emissions is not accurate enough (IPCC 2003 GPG, Appendix 3a.2).

11.3.1.3 INFORMATION ON WHETHER OR NOT INDIRECT AND NATURAL
GHG EMISSIONS AND REMOVALS HAVE BEEN FACTORED OUT

Sweden argues that the issue of “factoring out” was solved during negotiations with the cap for FM. A footnote of par. 7 of decision 16/CMP1 “recognizes that the intent of the appendix to the annex to decision 16/CMP.1 is to factor out the effects described in paragraph 7 (a)–(c) of these guidelines for the first commitment period”). So Sweden has indirectly “factored out” 7 (a)-(c) by the cap for FM but no direct “factoring out” has been made. Moreover, sound science for a direct “factoring out” does not exist and no methodology has been adopted.

11.3.1.4 CHANGES IN DATA AND METHODS SINCE PREVIOUS SUBMISSIONS
(RECALCULATIONS)

The uncertainty of estimates increases by decreasing number of sample plots and Table 11.3 illustrate the need of annual recalculations of the most recent years to increase the accuracy. In the current submission, the living biomass pool and activity areas have been recalculated for the most recent years to improve accuracy and each estimate are now based on 6000 more measured sample plots. The consequence of this re-calculation is an increased carbon net removal in living biomass for recent years. To avoid an increasing uncertainty of estimates by decreasing number of sample plots Sweden has now introduced extrapolation for inventory cycles without a full record of sample plots until 2010.

Table 11.3 The accumulated area under activities AR, D and FM and the approximate number of sample plots each estimate is based on (partly extrapolated plots inside brackets), presented by submission. Last three rows express the difference between submissions due to recalculations.

Submission	1990	·	·	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
2011														
AR [M ha]	0.02	·	·	0.12	0.14	0.15	0.16	0.19	0.21	0.22	0.25	0.29	0.29	-
D [M ha]	0.01	·	·	0.14	0.15	0.16	0.17	0.18	0.19	0.20	0.21	0.24	0.27	-
FM [M ha]	28.24	·	·	28.12	28.11	28.10	28.09	28.09	28.10	28.04	28.08	28.41	29.20	-
No. of plots (10 ³)	30	·	·	30	30	30	30	30	30	24	18	12	6	-
2012														
AR [M ha]	0.02	·	·	0.12	0.13	0.14	0.15	0.17	0.19	0.21	0.22	0.23	0.23	0.24
D [M ha]	0.01	·	·	0.14	0.15	0.16	0.16	0.17	0.18	0.19	0.19	0.20	0.21	0.21
FM [M ha]	28.23	·	·	28.12	28.10	28.09	28.09	28.09	28.10	28.13	28.18	28.24	28.28	28.31
No. of plots (10 ³)	30	·	·	30	30	30	30	30	30	30	(30)	(30)	(30)	(30)
Difference between Submission 2012 and 2011														
AR [M ha]	0.00	·	·	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.03	-0.06	-0.06	-
D [M ha]	0.00	·	·	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.04	-0.06	-
FM [M ha]	-0.01	·	·	-0.01	-0.01	0.00	0.00	0.00	0.00	0.09	0.10	-0.17	-0.92	-

Estimates of carbon stock changes for ARD activities are very uncertain. The major reason for this uncertainty is that ARD activities represents a relatively small area every year which means that they are very uncommon (2-5 plots a year can be attributed to AR or D) relative the sample intensity (Table 11.4). The extrapolations seem to have reduced the uncertainty a lot and we expect even more stable estimates when recalculated estimates are based on the full record of approximately 30 000 sample plots. Estimates for FM are now quite certain since they are partly based on extrapolated data. As for AR we expect even more stable estimates after recalculations. However, the uncertainty will most probably not influence on the accounting since the net removal from FM is much larger than the net emission from ARD, thus it will be possible to offset net emissions from ARD by the net removal from FM and further claim credits from FM limited by the cap (2.13 Mtons CO₂ per year).

Table 11.4 Emissions / removals (minus), [Mton CO₂] from reported carbon pools in AR, D and FM per submission

Activity	Carbon pool	2008 Subm. 2010	2008 Subm. 2011	2008 Subm. 2012	2009 Subm. 2011	2009 Submi. 2012	2010 Submi. 2012
AR	Above ground biomass	-1.10	-0.86	-0.54	-0.64	-0.53	-0.53
	Below ground biomass	-0.36	-0.28	-0.18	-0.22	-0.18	-0.18
	Dead wood	-0.03	-0.02	-0.02	-0.02	-0.02	-0.01
	Litter	-0.39	-0.32	-0.25	-0.32	-0.26	-0.26
	Soil organic carbon	0.31	0.22	0.17	0.22	0.17	0.18
	Total	-1.58	-1.27	-0.83	-0.98	-0.82	-0.80
D	Above ground biomass	0.47	1.38	1.03	0.78	0.86	0.60
	Below ground biomass	0.16	0.45	0.35	0.26	0.28	0.20
	Dead wood	0.00	0.00	0.00	0.00	0.00	0.00
	Litter	0.92	1.09	0.92	1.23	0.95	0.98
	Soil organic carbon	0.84	1.10	0.94	1.25	0.96	0.99
	Total	2.38	4.03	3.24	3.52	3.05	2.76
FM	Above ground biomass	-11.6	-15.7	-21.7	-22.3	-19.8	-21.4
	Below ground biomass	-4.23	-5.42	-7.57	-7.46	-8.51	-7.24
	Dead wood	-2.23	-9.70	-9.15	-7.38	-8.75	-6.92
	Litter	-1.24	-1.45	2.88	-1.47	2.90	3.13
	Soil organic carbon	0.68	-5.82	-4.55	-5.99	-4.56	-4.57
	Total	-18.6	-38.1	-40.1	-44.6	-38.7	-37.0

11.3.1.5 UNCERTAINTY ESTIMATES

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

Table 11.5 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	25	-	-
	Dead organic matter	50	-	-
	Soil organic carbon	35	-	-
	Direct N fertilization, 5 (I)	-	50	-
	Biomass burning, 5 (V)	-	75	75
AR	Living biomass	29	-	-
	Dead organic matter	70	-	-
	Soil organic carbon	35	-	-
D	Living biomass	82	-	-
	Dead organic matter	70	-	-
	Soil organic carbon	35	-	-
	Conversion Cropland, 5 (III)	-	100	-

11.3.1.6 INFORMATION ON OTHER METHODOLOGICAL ISSUES

There are currently no methods identified that needs further clarification than those already explained.

11.3.1.7 THE YEAR OF THE ONSET OF AN ACTIVITY, IF AFTER 2008

The onset of activities follows IPCC GPG for LULUCF (IPCC²⁵⁴) and no activity has been set on after 2008.

11.4 Article 3.3

11.4.1 Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2012 and are direct human-induced

Sweden defines D as land use conversions from Forest land (all managed) to Cropland, Grasslands or Settlements (all land under these three categories are assumed managed). AR is defined as land use conversions in the opposite direction (Figure 11.2). Land use categories are strictly defined (see NIR chapter 7.2.3) 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 (see chapter 7 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

²⁵⁴ Intergovernmental Panel on Climate Change, 2003

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 2012 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 exact year of conversion is estimated from properties on the sample plot (site, stand and vegetation properties). This is valid from 2006. Until 2006, the conversion year between consecutive inventories is randomly distributed.

11.4.2 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation

Final felling is a natural step in the rotation cycle of forestry. Also storms may result in large areas of felled trees (wind-throws). If final felling or disturbances as storms have been identified between two consecutive inventories this is not enough to classify the plot as D. However, if for instance a new road, a power line or other land use preceding the definition of forest is located on the former Forest land, then 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.

11.4.3 Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested

About 200 000 ha²⁵⁵ Forest land is annually losing its forest cover as a natural step in the forest rotation cycle. The position and status of every sample plot that has lost forest cover is known but D is not reported until confirmed (see 11.4.2). The geographical position and area of all final fellings on Forest land are monitored by detection of changes using the remote sensing system ENFORMA²⁵⁶. Each land owner has to apply to the Forestry Agency before harvest and in that regard, state whether the removal of trees is a natural step in the forest rotation cycle or harvest followed by a permanent land use change (D).

²⁵⁵ Swedish University of Agricultural Sciences, 2010

²⁵⁶ Olsson et al, 2005

11.5 Article 3.4

11.5.1 Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human induced

The activity FM is assumed to occur on all Forest land and land areas with first classification FM is reported under Article 3.4 FM. Land reported under AR usually has secondary classification FM. Land under activity FM is accumulated from 1990 but could leave this category for D at any time. Before 2008 (but not during the commitment period), land under FM could leave this category by natural degradation to Wetland or Other land and is then not reported at all. This IPCC-rule has no practical significance for reported removals/ emissions. The area under FM is quite stable and all land use categories, including Forest land, are consistently monitored in field since 1983. Therefore it is possible to trace back all land use categories and land use conversions to at least 1990. "Human induced" is assumed equivalent with "managed" and all Forest land is assumed managed. Most forest biomass is actively managed for timber and pulp production and remaining forest biomass is managed for nature conservation. The definition used coincides with definition of Forest land according to the Forestry act (1979:429).

11.5.2 Information relating to Cropland Management, Grazing Land Management, and Revegetation, if elected, for the base year

Sweden has not elected these activities.

11.5.3 Information relating to Forest Management

The net removal from living biomass is important for the total net removal reported under FM. The net removal from living biomass is the result from growth and drain and is sensitive to the demand of forest products from the forest industry.

11.6 Other information

11.6.1 Key category analysis for Article 3.3 activities and any elected activities under Article 3.4

A qualitative key category analysis has been made (IPCC GPG for LULUCF (IPCC²⁵⁷), p 5.38-5.40). Carbon dioxide emissions/ removals from Activities For-est management, Afforestation/ Reforestation and Deforestation were considered key-categories (CO₂). Every key-category is estimated using Tier 2 and 3. Emissions from non-carbon pools are very restricted under the KP. These are not considered as key categories and reported using Tier 1. Under the UNFCCC, part of 5III N₂O emissions from land use conversions to Cropland corresponds to D from Forest to Cropland. However, this category was not identified as key-category

²⁵⁷ Intergovernmental Panel on Climate Change, 2003

because most of the emissions under the UNFCCC refer to land use conversions from Grasslands to Cropland and due to a “conservative” high assumed uncertainty (100%). Sweden will follow up this emission carefully in the future (Tier 1) and we will compare the probably overestimated uncertainty with neighbouring countries using similar methodology. Sweden base the key-category analysis on a higher disaggregation level than suggested (GPG 2003, Table 5.4.4), because the key-category analysis is made per land use and gas (as suggested by reviewers). Since Sweden uses higher tier for all key-categories under the KP, Sweden has no immediately plan to improve the inventory (LULUCF). However, the key-category analysis is useful for monitoring potential changes in emission/removal trends.

11.7 Information relating to Article 6

Information relating to Article 6 is provided in Annex 6:1 and 6:3.

12 Information on accounting of Kyoto units

12.1 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 2011 containing the information required in paragraph 11 of the annex to decision 15/CMP.1 and adhering to the guidelines of the SEF has been submitted to the UNFCCC Secretariat electronically in document "SEF_SE_2012_1_13-45-42 10-1-2012".

12.2 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 2011 containing the information required in paragraph 11 of the annex to decision 15/CMP.1 and adhering to the guidelines of the SEF has been submitted to the UNFCCC Secretariat electronically. See document "SEF_SE_2012_1_13-45-42 10-1-2012.xls"

12.3 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 2011-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 2010 reporting period, pursuant of 15/CMP.1 annex I.E paragraphs 13 & 14. Refer to Separate Electronic Attachment "SIAR Reports 2011-SE v 1.0.xls" Worksheet R3.
15/CMP.1 annex I.E paragraph 15:	No non-replacements occurred during the 2011 reporting period, pursuant of 15/CMP.1 annex I.E paragraph

Annual Submission Item	Party provided content
List of non-replacements	<p>15.</p> <p>Refer to Separate Electronic Attachment "SIAR Reports 2011-SE v 1.0.xls" Worksheet R4.</p>
<p>15/CMP.1 annex I.E paragraph 16:</p> <p>List of invalid units</p>	<p>No invalid units exist as at 31 December 2011, pursuant of 15/CMP.1 annex I.E paragraph 16.</p> <p>Refer to Separate Electronic Attachment "SIAR Reports 2011-SE v 1.0.xls" Worksheet R5.</p>
<p>15/CMP.1 annex I.E paragraph 17:</p> <p>Actions and changes to address discrepancies</p>	<p>In order to improve reliability of the processing of reconciliation requests sent by the ITL, and also to improve the accuracy of the information sent back in our replies, the handling of reconciliation messages in Greta 5.1 is upgraded. Due to the complexity of the previous implementation and the conceptual simplicity of the requirements, it was decided to completely replace it with a new brand new implementation utilising the new SAM service.</p> <p>In Greta 5.2(integrated in Greta 5.3) a new message flow was introduced. In Q3 2009, the UNFCCC raised a change request to alter the message flow for external transfers. The new message flow introduces an additional step that marks the transaction and unit blocks as proposed in the acquiring registry until the acquiring registry has confirmed acceptance of the unit blocks and the ITL has completed the transaction.</p> <p>The purpose of the additional step is to ensure that a registry cannot transfer units received by external transfer until the ITL have completed the transaction.</p> <p>The new message flow will help reduce the number of discrepant transactions in production.</p>

12.4 Publicly accessible information

Annual Submission Item	Party provided content
<p>15/CMP.1 annex I.E</p> <p>Publicly accessible information</p>	<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 – http://www.energimyndigheten.se/en/International/Instruments/EU-ETS---Implementation-in-Sweden/EUETS/Reports/</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 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: http://www.energimyndigheten.se/en/International/Instruments/EU-ETS---Implementation-in-Sweden/EUETS/Reports/SUS-Report-Tool/</p> <p>JI projects in Sweden (Paragraph 46)</p> <p>Note that no Article 6 (Joint Implementation) project is reported as conversion to an ERU under an Article 6 project, as this did not occur in the specified period.</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.</p> <p>Article 10 of EU Regulation 2216/2004/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>Note that no Article 6 (Joint Implementation) project is reported as conversion to an ERU under an Article 6 project, as this did not occur in the specified period..</p>
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<p>15/CMP.1 annex I.E</p> <p>Publicly accessible information</p>	<p><u>Paragraph 47e</u> Sweden does not perform LULUCF activities and therefore does not issue RMUs</p> <p><u>Paragraph 47g</u> 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> 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> 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> <p><u>Paragraph 47k</u> There is no previous commitment period to carry ERUs, CERs, and AAUs over from.</p>
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12.5 Calculation of the commitment period reserve (CPR)

12.5.1 Assigned Amount

The assigned amount pursuant to Article 3, paragraphs 7 and 8, has been calculated in accordance with the annex to decision 13/CMP.1. Sweden's base year is 1990 and the Party has chosen 1995 as the base year for HFCs, PFCs and SF₆. Sweden's quantified emission limitation is 92 per cent as included in Annex B to the Kyoto Protocol. As Sweden is part of the European Community, whose Member States will meet their reduction commitment jointly in accordance with Article 4 of the Kyoto Protocol, Sweden's quantified emission limitation is 104 per cent. Sweden's assigned amount is calculated based on the Party's Article 4 commitment.

In response to inventory issues identified during the review of the Initial Report, Sweden submitted revised estimates of its base year inventory, which resulted in a recalculation of the assigned amount. Based on the revised estimates for Sweden's base year emissions – 72 152 Gg CO₂ eq. equal to 72 151 646 tonnes CO₂ eq. – the

assigned amount is calculated to be 375 189 Gg CO₂ eq. equal to 375 188 559 tonnes CO₂ eq.

12.5.2 Commitment Period Reserve (CPR)

According to the annex to decision 11/CMP.1 (paragraph 6), “Each Party included in Annex I shall maintain, in its national registry, a commitment period reserve which should not drop below 90 per cent of the Party’s assigned amount calculated pursuant to Article 3, paragraphs 7 and 8, of the Kyoto Protocol, or 100 per cent of five times its most recently reviewed inventory, whichever is lowest.”

Sweden’s original commitment period reserve was based on 90 percent of assigned amount. However in the centralized review of submission 2009 the ERT pointed out that the option “100 per cent of five times its most recently reviewed inventory” gave a lower CPR. The CPR in submission 2009 was therefore recalculated to the amount of 100 per cent of five times the national total not including LULUCF (in 2007 reported in submission 2009 to be 65 412 Gg CO₂ eq. equal to 65 412 113 tonnes CO₂ eq.) resulting in a CPR of 327 061 Gg CO₂ eq. equal to 327 060 565 tonnes CO₂ eq.

In submission 2012 the CPR is calculated from “100 per cent of five times its most recently reviewed inventory”. The national total not including LULUCF (in 2010 reported in submission 2012) is 66 232 Gg CO₂ eq. equal to 66 232 370 tonnes CO₂ eq. The CPR is then 331 162 Gg CO₂ eq. equal to 331 161 849 tonnes CO₂ eq.

12.6 KP-LULUCF accounting

Sweden reports and accounts for activities under article 3.3 and the activity Forest management under article 3.4 of the Kyoto protocol. Detailed descriptions on definitions of activities and carbon pools as well as methods for the quantification of emissions and removals related to these activities can be found in chapter 11 of the NIR. For 2010 the activities under article 3.3 constituted a net source of 2.0 Mtons CO₂. Forest management under article 3.4 constituted a removal of 37 Mtons CO₂. After offsetting the article 3.3 source the remaining removal from Forest management constitutes 35 Mtons CO₂. However, final accounting quantity for 2010 is limited by the cap to 2.13 Mtons CO₂. It may be noted that Sweden has elected commitment period accounting. The referred figures represent only 2010.

13 Information on changes in national system

There has been no changes to the national system since last submission.

14 Information on changes in national registry

Reporting Item	Party provided content
15/CMP.1 annex II.E paragraph 32.(a) Change of name or contact	No changes of name or contact
15/CMP.1 annex II.E paragraph 32.(b) Change of cooperation arrangement	No change of the cooperation arrangement occurred during the 2011 reporting period.
<p>Software Changes</p> <p>Upgrade of the GRETA software</p> <p>A new software version has been developed, Greta 5.1, 5.2 and 5.3. The scope of the new versions was to develop software that was further more compatible with the UNFCCC Data Exchange Standard (DES ver. 1.1.7 and the Commission Registry Regulation (No 2216/2004, No 916/2007 and 994/2008) and to improve the performance of the registry software a number of architectural improvements have been implemented in version 5.1, 5.2 and 5.3. This has brought improvements in relation to Registry performance, reliability and scalability.</p> <p>Before implementation the new software versions were thoroughly tested. The tests were performed by the developers, DECC, the Working Group A (a working group consisting of Greta-licensees (NL, SE, IE UK and NO)) and finally through an acceptance test with the CITL. Sweden upgraded the Greta software from version 4.3 to version 5.1 in production environment on Jan 13th 2011 and from 5.1 to 5.3 on Nov 10th 2011. Greta version 5.2 was not implemented in production environment but the improvements and new functionality were included in 5.3.</p> <p>The improvements and functions implemented in the new software version are:</p> <p>The Greta Version 5.1 release includes:</p> <ul style="list-style-type: none"> • Manual Selection for Surrender <p>In order to enable operators to select specific unit blocks for surrender, a manual selection screen similar to that for Propose Transfer has been implemented. This will provide operators greater control over the units that are surrendered.</p> <ul style="list-style-type: none"> • Simplification to the Compliance Process <p>The Surrender and Emissions Proposal functions have been altered to enable the user to select the account/installation using the widely used “select legal entity” and “select account” process.</p>	

- Rewrite of Reconciliation Processing

In order to improve reliability of the processing of reconciliation requests sent by the ITL, and also to improve the accuracy of the information sent back in our replies, it was decided to upgrade the handling of reconciliation messages in Greta. Due to the complexity of the previous implementation and the conceptual simplicity of the requirements, it was decided to completely replace it with a new brand new implementation utilising the new SAM service.

- Security Fixes

- Cross Site Scripting – The RedirectUrl parameter passed to the login page is now ignored. This reduces the chance of phishing attacks. This change has been implemented for the Greta login page and the reporting services login page.
- Auto Complete – The form inputs within the Greta application now contain the AutoComplete attribute. Setting AutoComplete to “off” causes browsers to not cache the values entered into input boxes.
- Marking Cookies as HttpOnly – This helps prevent malicious scripts from accessing information contained in cookies.

- Maintenance bug fixes raised from support

- Reporting services updates

The Greta Version 5.2 release includes:

- Transaction Finalisation (New message flow)

In Q3 2009, the UNFCCC raised a change request to alter the message flow for external transfers. The new message flow introduces an additional step that marks the transaction and unit blocks as proposed in the acquiring registry until the acquiring registry has confirmed acceptance of the unit blocks and the ITL has completed the transaction.

- Account Confidentiality Service

In order to comply with the Registry Regulations regarding confidentiality of Account Representative contact data, a new windows service (AMI) has been introduced to ‘correct’ confidential data displayed on Europa.

- Maintenance Fixes

- Bug fixes
- High priority fixes from earlier version

- Security Enhancements

- Session Locking
- Ability to Rejected Blacklisted (stolen) units
- Dual approval for RA transactions
- User logon audit trail
- Generic error on logon failure
- Updates to the Security Guide

The Greta Version 5.3 release includes:

- Security Enhancements

<ul style="list-style-type: none"> • Data Migration Enhancements To aid in the migration of data to the CSEUR, the following changes have been made in GRETA: <ul style="list-style-type: none"> ○ Company Registration Number is now mandatory for organisations ○ Installation Telephone Numbers 1 & 2 • Out of hours lock The Out of Hours Lock feature has been added to Greta 5.3. When selected, 'Out of Hours Lock' will suspend access to the registry outside of the defined office hours. All users without the "suspend access" permission that try to use the registry out-of-hours will be denied access. • Trusted Accounts The Trusted Accounts feature has been added to Greta 5.3. Its aim is to further enhance the security of the registry by ensuring secondary checks are made on transactions to accounts that do not belong to the transferring account's trusted account list. • Maintenance Fixes High Priority bug fixes are included in this release. 	
15/CMP.1 annex II.E paragraph 32.(d) Change of conformance to technical standards	No change in the registry's conformance to technical standards occurred for the 2011 reporting period.
15/CMP.1 annex II.E paragraph 32.(e) Change of procedures	No changes were made to the procedures to prevent and/or resolve discrepancies during the 2011 reporting period.
15/CMP.1 annex II.E paragraph 32.(f) Change of Security	<ul style="list-style-type: none"> • In the spring of 2011 were automatic (through tools Nessus and Acunetix) and manual (by security experts from outside consultant) vulnerability and penetration testing (such as black box) performed in and to the SE registry and its IT environment in order to identify potential security flaws. Based on the results was an implemented improvement in the IT environment upon which iterations of tests was conducted to an acceptable level of safety achieved. New tests are being implemented every time changes are made in the SE registry's IT environment. • Requirements for electronic ID cards on the (so called smart card or hard electronic identification, electronic ID, which requires card reader and chip card and authentication password)

	<p>was introduced in March 2011 for all domestic account representatives of the SE registry.</p> <ul style="list-style-type: none"> • Limitations on the registry's opening hours during certain periods in order to improve the coverage of events in the SE registry and shorten the response time in relation to any breach of security was introduced, starting in December 2010. • Enhanced scrutiny of account applications to the SE registry (called KYC on the model used by financial institutions) was introduced in 2011 in order to capture the account holders with dubious purposes of trading. • Internal risk analysis was conducted in spring 2011 in order to identify risk factors. • The Swedish Security Service educated the staff of the SE registry in dignitary protection, espionage, terrorism and protective security. • The Swedish Energy Agency has developed and installed a "script" in the software for the SE registry as an alarm for any transaction exceeding a certain volume. The script was that the authority could identify stolen allowances from the Austrian registry and stop them from being passed on to additional accounts in the European registry system for emissions trading. • To reduce the risk of individual employees with sensitive system privileges would be used for intrusion into the system matured account-keeping authority personal contact details for the external use of functional mailboxes and group phone numbers. • All internal access to the SE registry was limited to merely administrators appointed by the Swedish Energy Agency and defined at the European Commission and the UNFCCC. • Increased usage of encrypted information in the communication with other Member States and the European Commission. • Participation in the preparation of new legislation at national and EU level to improve security in the EU ETS.
15/CMP.1 annex II.E	No change in publicly available information occurred

paragraph 32.(g) Change of list of publicly available information	during the reporting period.
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	No change of the registry internet address occurred during the 2011 reporting period.
15/CMP.1 annex II.E paragraph 32.(i) Change of data integrity measure	No change of data integrity measures occurred during the 2011 reporting period.
15/CMP.1 annex II.E paragraph 32.(j) Change of test results	As below.
<u>Test Plan and Test Report</u> The following test plans and test results for version 5.1, 5.2 and 5.3 of the Greta registry software have been included in Annex 6: - GRETA test plan and report for Version 5.1, 5.2 and 5.3 - Release notes for Version 5.1, 5.2 and 5.3	
Previous Annual Review recommendations for the National Registry <i>FCCC/ARR/2010/SWE</i>	
<i>ERT recommendation:</i> No recommendations to address	

15 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 CMP 15: § 23 och § 24.

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 with 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 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.

The Swedish research activities, as indicated in Chapter 8 of Swedens National Communication Report 5 (NC 5), 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. Sweden's focus on increased use of bioenergy, both through increased domestic production but also through increased imports in particular from develop-

ing countries, has meant that 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 NC5 of such efforts in the areas of technology transfer, knowledge building and support for adaptation measures. In addition, Sweden contributed multilateral aid in addition to our commitments by additional financial support to the special climate change Fund and least developed countries fund.

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.

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 reflect the external effect of carbon dioxide emissions and the market failure.

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 CO₂ emissions a cost have been imposed on environmentally harmful technologies such as fossil fuel based heat- and electricity production and industries.

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.

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 time period. 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 and Sweden is keen on launching a demonstration project in this area. In the long term Sweden have the ambition to participate in the field of multilateral research collaborations

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 7 of NC 5. 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.

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 5). *Inter alia*, through;

- support for research programmes on renewable energy technologies coordinated by Asian Institute of technology,
- education on sustainable energy technology in partnership with universities in Uganda, Mozambique, Ethiopia and Tanzania,
- support for photovoltaic technologies for energy services to rural areas in Zambia.

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.

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16.2 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
CO ₂	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
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
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
SCAA	Swedish Civil Aviation Authority
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
SO ₂	Sulphur dioxide
SPI	Swedish Petroleum 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