National Inventory Report Sweden 2024: Annexes

Greenhouse Gas Emission Inventories 1990-2022

Submitted under the United Nations Framework Convention on Climate Change

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1 Annex 1: Key Categories

Key Categories (including and excluding LULUCF) are presented below and in section 1.5 of the NIR.

1.1 Description of methodology used for identifying key categories

The analysis has been made for the base year and the latest year using the approach 1 and approach 2 levels and trend assessment according to the methods described in the 2006 IPCC guidelines. The approach 1 method assesses the impacts of various source/sink categories on the level and the trend of the national emission inventory. The approach 2 method includes information on uncertainties.

In the approach 1 analysis key categories are the aggregated categories that together contribute up to either 95% of the level or 95% of the overall contribution to trend of all greenhouse gas emissions in Sweden. In the approach 2 analysis, information about the sources' uncertainties is also included in the analysis. Approach 2 key categories are those that add up to 90% of the contribution to level and trend in the national inventory.

The analysis is performed for all direct greenhouse gases, i.e. CO_2, CH_4, N_2O, HFCs, PFCs and SF_6, with all emissions converted to CO_2-eq.

1.1.1 Approach 1 level assessment

The contribution of each source or sink category to the total national inventory level is calculated as:

$$L_{x,t} = \left|E_{x,t}\right| / \sum_{y} \left|E_{y,t}\right|$$

Lx,t= level assessment for source or sink x in latest inventory year (year t).
│Ex,t│ = absolute value of emission or removal estimate of source or sink category x in year t
∑│Ey,t│= total contribution, which is the sum of the absolute values of emissions and removals in year t calculated using the aktregation level chosen by the country for key category analysis. Because both emissions and removals are entered as absolute values, the total contribution/level can be larger than a country's total emissions minus removals.

Key categories are those that, when summed together in descending order of magnitude, add up to 95% of the sum of all $L_{x,t}$.

1.1.2 Approach 1 trend assessment

For the latest inventory year (year t), the trend assessment is calculated for each source or sink category and each GHG. If inventory data are available for both the base year and year t the trend assessment is calculated as (in accordance with the 2006 IPCC guidelines):

$$T_{x,t} = \frac{|E_{x,0}|}{\sum_y |E_{y,0}|} = \left| \left[\frac{(E_{x,t} - E_{x,0})}{|E_{x,0}|} \right] - \frac{\left(\sum_y E_{y,t} - \sum_y E_{y,0} \right)}{\left| \sum_y E_{y,0} \right|} \right|$$

$T_{x,t}$= trend assessment of source or sink category *x* in year *t* as compared to the base year (year 0)

$|E_{x,0}|$ = absolute value of emission or removal estimate of source or sink category *x* in year 0

$E_{x,t}$ and $E_{x,0}$ = real values of estimates of source or sink category *x* in years *t* and 0, respectively

$\sum E_{y,t}$ and $\sum E_{y,0}$ = total inventory estimates in years *t* and 0, respectively

If there is no base year emission for a given category the trend assessment is instead calculated as:

$$T_{x,t} = \left| E_{x,t} / \sum_y |E_{y,0}| \right|$$

1.1.3 Approach 2 level and trend assessments

When the information from the approach 1 key categories analysis is combined with the outcome from the uncertainty analysis, it results in an approach 2 key category analysis. IPCC encourages inventory compilers to use this approach if possible. It will provide additional insight into the reasons why particular categories are *key* and will assist in prioritizing activities to improve inventory quality and reduce overall uncertainty. The level and trend assessment including uncertainty is calculated as:

$$LU_{x,t} = (L_{x,t} \times U_{x,t}) \quad , \quad TU_{x,t} = (T_{x,t} \times U_{x,t})$$

Where $L_{x,t}$ and $T_{x,t}$ are the results from the approach 1 level and trend analysis, respectively. $U_{x,t}$ is the category percentage uncertainty in year *t* calculated as described in Annex 7. The key categories are those that add up to 90% of the sum of all $LU_{x,t}$ or 90% of the contribution to trend and $TU_{x,t}$, respectively, when ranked by decreasing order of magnitude.

1.2 Results

The results of the year 2022 key category analysis are summarized in Tables A1.1 to A1.8 and include level and trend assessments with or without LULUCF according to both Approach 1 and 2. Emissions of CO_2 from gasoline and diesel combustion in passenger cars (CRT 1.A.3.b.i) together with emissions of CO_2 from Public Electricity and Heat Production:Other Fuels (CRT 1.A.1.a) are the top three sources in 2022 in the approach 1 level assessment excluding LULUCF (Table A1.1). Together they contribute with 25% of the national total and are also the top three emission categories when including LULUCF (Table A1.2).

In 2022, 66 key categories in terms of trend have been identified, excluding LULUCF (Table A1.3). The Energy Sector (CRT 1) contributes with the majority of the key categories (42).

The category with the most significant change, excluding LULUCF, since 1990 is CO_2 from combustion of liquid fuels in the residential sector (1.A.4.b). This source contributes to 10.9% of the explanation of the overall trend. Other categories with significant decreasing trends are combustion of diesel oil and gasoline from road transport as well as combustion of other fuels from Public Electricity and Heat Production (CRT 1.A.1.a).

Trend assessment including LULUCF identified 56 key categories, of which Forest land remaining forest land (4.A.1) has the by far largest impact and explains 56.4% of the observed trend 1990-2022 (Table A1.4).

The approach 2 level and trend assessments (Table A1.5 to Table A1.8) result in higher priority of categories with high uncertainties in sources or sinks compared to the approach 1 assessments. Generally, emissions from the agriculture, waste and LULUCF sectors.

Table A1.1. Key Category Analysis approach 1 Level Assessment, excluding LULUCF.

Table A1.1. KCA approach 1,level, excl LULUCF IPCC Source Category	Substance	Year 2022 emissions or removals (kt CO_2-eq)	Level Assessment Year 2022	Key Source Level in 2022
1 A 3 b i Road Transportation, Cars: Gasoline	CO2	5047.98	11,16%	1
1 A 3 b i Road Transportation, Cars: Diesel oil	CO2	3148.10	6,96%	2
1 A 1 a Public Electricity and Heat Production:Other Fuels	CO2	3101.18	6,85%	3
1 A 3 b iii Road Transportation, Heavy duty trucks: Diesel oil	CO2	2789.51	6,16%	4
2 C 1 Iron and Steel Production	CO2	2520.96	5,57%	5
3 A 1 Non-dairy cattle	CH4	1619.62	3,58%	6
1 A 1 a Public Electricity and Heat Production: Solid Fuels	CO2	1609.68	3,56%	7
3 A 1 Dairy cattle	CH4	1240.85	2,74%	8
1 A 3 b ii Road Transportation, Light duty trucks: Diesel oil	CO2	1208.80	2,67%	9
1 A 2 g vii Off-road vehicles and other machinery: Liquid Fuels	CO2	1114.02	2,46%	10
1 A 4 c Agriculture/Forestry/Fisheries: Liquid Fuels	CO2	836.41	1,85%	11
2 F 1 Refrigeration and air conditioning	HFCs	785.82	1,74%	12
3 D a 1 Inorganic N fertilizers	N2O	769.78	1,70%	13
1 A 2 a Iron and Steel: Solid Fuels	CO2	616.69	1,36%	14
3 D a 6 Cultivation of organic soils (i.e. histosols)	N2O	604.36	1,34%	15
1 A 2 g viii Other: Liquid Fuels	CO2	595.19	1,32%	16

Table A1.1. KCA approach 1,level, excl LULUCF IPCC Source Category	Substance	Year 2022 emissions or removals (kt CO_2-eq)	Level Assessment Year 2022	Key Source Level in 2022
1 A 2 a Iron and Steel: Liquid Fuels	CO2	555.19	1,23%	17
1 A 2 d Pulp, Paper and Print: Liquid Fuels	CO2	545.33	1,21%	18
5 A 1 Managed waste disposal sites	CH4	509.09	1,13%	19
1 A 3 d Domestic Navigation: Gas/Diesel Oil	CO2	438.80	0,97%	20
1 A 1 c Manufacture of Solid fuels and Other Energy Industries: Solid Fuels	CO2	372.36	0,82%	21
1 A 4 b Residential: Liquid Fuels	CO2	366.27	0,81%	22
3 D a 4 Crop residues applied to soils	N2O	360.22	0,80%	23
1 A 3 e Other Transportation: Total	CO2	353.76	0,78%	24
1 A 3 a Domestic Aviation: Jet Kerosene	CO2	298.64	0,66%	25
1 A 4 a Commercial/Institutional: Liquid Fuels	CO2	291.10	0,64%	26
3 D a 2 a Animal manure applied to soils	N2O	285.19	0,63%	27
2 C 7 Other	CO2	257.02	0,57%	28
1 A 4 a Commercial/Institutional: Gaseous Fuels	CO2	224.85	0,50%	29
2 C 2 Ferroalloys production	CO2	196.72	0,43%	30
5 D 1 Domestic wastewater	N2O	184.93	0,41%	31
3 A 4 Horses	CH4	179.17	0,40%	32
2 C 3 Aluminium production	CO2	174.66	0,39%	33

Table A1.1. KCA approach 1,level, excl LULUCF IPCC Source Category	Substance	Year 2022 emissions or removals (kt CO_2-eq)	Level Assessment Year 2022	Key Source Level in 2022
1 A 3 d Domestic Navigation: Residual Oil	CO2	168.04	0,37%	34
3 D b 2 Nitrogen leaching and run-off	N2O	166.30	0,37%	35
1 A 2 a Iron and Steel: Gaseous Fuels	CO2	150.22	0,33%	36
1 A 2 e Food Processing, Beverages and Tobacco: Gaseous Fuels	CO2	130.15	0,29%	37
3 A 2 Sheep	CH4	128.50	0,28%	38
3 B 1 Non-dairy cattle	CH4	125.56	0,28%	39
3 G Liming	CO2	122.44	0,27%	40
5 C 1 Waste Incineration	CO2	111.22	0,25%	41
1 A 1 a Public Electricity and Heat Production: Peat	CO2	107.26	0,24%	42
1 A 2 e Food Processing, Beverages and Tobacco: Liquid Fuels	CO2	102.32	0,23%	43
1 A 1 a Public Electricity and Heat Production: Biomass	N2O	94.80	0,21%	44
1 A 3 b ii Road Transportation, Light duty trucks: Gasoline	CO2	85.04	0,19%	45
3 A 4 Raindeer	CH4	84.11	0,19%	46
3 D b 1 Atmospheric deposition	N2O	83.52	0,18%	47
1 A 2 b Non-ferrous metals: Liquid Fuels	CO2	83.26	0,18%	48
1 A 4 c Agriculture/Forestry/Fisheries: Domestic Heating Oil	CO2	82.73	0,18%	49
1 A 3 b iv Road Transportation, Motorcycles: Gasoline	CO2	81.74	0,18%	50

Table A1.1. KCA approach 1,level, excl LULUCF IPCC Source Category	Substance	Year 2022 emissions or removals (kt CO_2-eq)	Level Assessment Year 2022	Key Source Level in 2022
2 H 1 Pulp and paper	N2O	80.34	0,18%	51
3 B 1 Dairy cattle	CH4	79.58	0,18%	52
3 B 1 Non-dairy cattle	N2O	78.52	0,17%	53
1 A 1 b Petroleum refining: Liquid Fuels	CO2	C	C	C
2 A 1 Cement Production	CO2	C	C	C
2 B 10 Other	CO2	C	C	C
1 A 1 a Public Electricity and Heat Production: Liquid Fuels	CO2	C	C	C
1 A 2 f Non-metallic minerals: Solid Fuels	CO2	C	C	C
2 A 2 Lime Production	CO2	C	C	C
1 A 2 g viii Other: Solid Fuels	CO2	C	C	C
1 A 2 c Chemicals: Liquid Fuels	CO2	C	C	C
1 A 2 f Non-metallic minerals: Liquid Fuels	CO2	C	C	C
1 A 2 f Non-metallic minerals: Other Fuels	CO2	C	C	C
2 D 1 Lubricant use	CO2	C	C	C
1 A 1 b Petroleum refining: Gaseous Fuels	CO2	C	C	C
2 D 3 Other	CO2	C	C	C
1 A 2 f Non-metallic minerals: Gaseous Fuels	CO2	C	C	C

Table A1.1. KCA approach 1,level, excl LULUCF IPCC Source Category	Substance	Year 2022 emissions or removals (kt CO_2-eq)	Level Assessment Year 2022	Key Source Level in 2022
1 A 1 a Public Electricity and Heat Production: Gaseous Fuels	CO2	C	C	C
1 A 2 c Chemicals: Gaseous Fuels	CO2	C	C	C

Table A1.2. Key Category Analysis approach 1 Level Assessment, including LULUCF.

Table A1.2. KCA approach 1, level, incl LULUCF IPCC Source Category	Substance	Year 2022 emissions or removals (kt CO2-eq)	Level Assessment Year 2022	Key Source Level in 2022
4 A 1 Forest land remaining forest land	CO2	-39490.06	38,45%	1
4 G Total HWP from domestic harvest	CO2	-8391.68	8,17%	2
1 A 3 b i Road Transportation, Cars: Gasoline	CO2	5047.98	4,91%	3
1 A 3 b i Road Transportation, Cars: Diesel oil	CO2	3148.10	3,07%	4
1 A 1 a Public Electricity and Heat Production:Other Fuels	CO2	3101.18	3,02%	5
4 B 1 Cropland remaining cropland	CO2	2823.22	2,75%	6
1 A 3 b iii Road Transportation, Heavy duty trucks: Diesel oil	CO2	2789.51	2,72%	7
2 C 1 Iron and Steel Production	CO2	2520.96	2,45%	8
4 E 2 1 Forest land converted to settlements	CO2	2209.51	2,15%	9
3 A 1 Non-dairy cattle	CH4	1619.62	1,58%	10
1 A 1 a Public Electricity and Heat Production: Solid Fuels	CO2	1609.68	1,57%	11
3 A 1 Dairy cattle	CH4	1240.85	1,21%	12
1 A 3 b ii Road Transportation, Light duty trucks: Diesel oil	CO2	1208.80	1,18%	13
1 A 2 g vii Off-road vehicles and other machinery: Liquid Fuels	CO2	1114.02	1,08%	14
4 A Drained organic soils	N2O	1022.78	1,00%	15
1 A 4 c Agriculture/Forestry/Fisheries: Liquid Fuels	CO2	836.41	0,81%	16
2 F 1 Refrigeration and air conditioning	HFCs	785.82	0,77%	17

Table A1.2. KCA approach 1, level, incl LULUCF IPCC Source Category	Substance	Year 2022 emissions or removals (kt CO2-eq)	Level Assessment Year 2022	Key Source Level in 2022
3 D a 1 Inorganic N fertilizers	N2O	769.78	0,75%	18
4 C 2 1 Forest land converted to grassland	CO2	731.11	0,71%	19
1 A 2 a Iron and Steel: Solid Fuels	CO2	616.69	0,60%	20
3 D a 6 Cultivation of organic soils (i.e. histosols)	N2O	604.36	0,59%	21
1 A 2 g viii Other: Liquid Fuels	CO2	595.19	0,58%	22
1 A 2 a Iron and Steel: Liquid Fuels	CO2	555.19	0,54%	23
1 A 2 d Pulp, Paper and Print: Liquid Fuels	CO2	545.33	0,53%	24
4 C 1 Grassland remaining grassland	CO2	-532.23	0,52%	25
5 A 1 Managed waste disposal sites	CH4	509.09	0,50%	26
1 A 3 d Domestic Navigation: Gas/Diesel Oil	CO2	438.80	0,43%	27
1 A 1 c Manufacture of Solid fuels and Other Energy Industries: Solid Fuels	CO2	372.36	0,36%	28
1 A 4 b Residential: Liquid Fuels	CO2	366.27	0,36%	29
4 A 2 4 Settlements converted to forest land	CO2	-364.80	0,36%	30
3 D a 4 Crop residues applied to soils	N2O	360.22	0,35%	31
1 A 3 e Other Transportation: Total	CO2	353.76	0,34%	32
4 E 2 2 Cropland converted to settlements	CO2	325.27	0,32%	33
1 A 3 a Domestic Aviation: Jet Kerosene	CO2	298.64	0,29%	34
1 A 4 a Commercial/Institutional: Liquid Fuels	CO2	291.10	0,28%	35

Table A1.2. KCA approach 1, level, incl LULUCF **IPCC Source Category**	**Substance**	**Year 2022 emissions or removals (kt CO2-eq)**	**Level Assessment Year 2022**	**Key Source Level in 2022**
4 D 1 1 Peat extraction remaining peat extraction	CO2	288.60	0,28%	36
3 D a 2 a Animal manure applied to soils	N2O	285.19	0,28%	37
2 C 7 Other	CO2	257.02	0,25%	38
4 A Drained organic soils	CH4	250.74	0,24%	39
4 E 1 Settlements remaining settlements	CO2	-249.80	0,24%	40
1 A 4 a Commercial/Institutional: Gaseous Fuels	CO2	224.85	0,22%	41
2 C 2 Ferroalloys production	CO2	196.72	0,19%	42
5 D 1 Domestic wastewater	N2O	184.93	0,18%	43
4 B Drained organic soils	CH4	182.08	0,18%	44
3 A 4 Horses	CH4	179.17	0,17%	45
2 C 3 Aluminium production	CO2	174.66	0,17%	46
1 A 3 d Domestic Navigation: Residual Oil	CO2	168.04	0,16%	47
3 D b 2 Nitrogen leaching and run-off	N2O	166.30	0,16%	48
1 A 1 b Petroleum refining: Liquid Fuels	CO2	C	C	C
2 A 1 Cement Production	CO2	C	C	C
2 B 10 Other	CO2	C	C	C
1 A 1 a Public Electricity and Heat Production: Liquid Fuels	CO2	C	C	C
1 A 2 f Non-metallic minerals: Solid Fuels	CO2	C	C	C

Table A1.2. KCA approach 1, level, incl LULUCF IPCC Source Category	Substance	Year 2022 emissions or removals (kt CO2-eq)	Level Assessment Year 2022	Key Source Level in 2022
2 A 2 Lime Production	CO2	C	C	C
1 A 2 g viii Other: Solid Fuels	CO2	C	C	C
1 A 2 c Chemicals: Liquid Fuels	CO2	C	C	C
1 A 2 f Non-metallic minerals: Liquid Fuels	CO2	C	C	C
1 A 2 f Non-metallic minerals: Other Fuels	CO2	C	C	C
2 D 1 Lubricant use	CO2	C	C	C
1 A 1 b Petroleum refining: Gaseous Fuels	CO2	C	C	C

Table A1.3. Key Category Analysis approach 1 Trend Assessment, excluding LULUCF.

Table A1.3. KCA, approach 1, trend, excl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO2-eq)	Year 2022 emissions or removals (kt CO2-eq)	Contribution to Trend	Key Source Trend
1 A 4 b Residential: Liquid Fuels	CO2	6211.59	366.27	10,85%	1
1 A 3 b i Road Transportation, Cars: Diesel oil	CO2	524.25	3148.10	8,54%	2
1 A 1 a Public Electricity and Heat Production:Other Fuels	CO2	524.33	3101.18	8,40%	3
1 A 3 b i Road Transportation, Cars: Gasoline	CO2	11993.59	5047.98	7,79%	4
5 A 1 Managed waste disposal sites	CH4	3846.51	509.09	5,86%	5
1 A 4 a Commercial/Institutional: Liquid Fuels	CO2	2612.33	291.10	4,15%	6
1 A 3 b ii Road Transportation, Light duty trucks: Diesel oil	CO2	173.72	1208.80	3,33%	7
1 A 1 a Public Electricity and Heat Production: Solid Fuels	CO2	4230.90	1609.68	3,27%	8
2 C 1 Iron and Steel Production	CO2	2636.63	2520.96	2,57%	9
2 F 1 Refrigeration and air conditioning	HFCs	4.65	785.82	2,37%	10
3 A 1 Non-dairy cattle	CH4	1418.93	1619.62	2,18%	11
1 A 2 g viii Other: Liquid Fuels	CO2	2061.61	595.19	2,17%	12
1 A 1 a Public Electricity and Heat Production: Peat	CO2	1150.05	107.26	1,89%	13
1 A 2 d Pulp, Paper and Print: Liquid Fuels	CO2	1785.65	545.33	1,78%	14
1 A 2 g vii Off-road vehicles and other machinery: Liquid Fuels	CO2	987.32	1114.02	1,48%	15
1 A 3 b ii Road Transportation, Light duty trucks: Gasoline	CO2	833.91	85.04	1,35%	16
2 B 2 Nitric Acid Production	N2O	695.63	5.53	1,32%	17

Table A1.3. KCA, approach 1, trend, excl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO2-eq)	Year 2022 emissions or removals (kt CO2-eq)	Contribution to Trend	Key Source Trend
1 A 3 b iii Road Transportation, Heavy duty trucks: Diesel oil	CO2	3820.09	2789.51	1,10%	18
1 A 3 e Other Transportation: Total	CO2	1051.53	353.76	0,95%	19
2 C 3 Aluminium production	PFCs	510.94	34.43	0,88%	20
1 A 2 e Food Processing, Beverages and Tobacco: Liquid Fuels	CO2	596.36	102.32	0,84%	21
1 A 3 d Domestic Navigation: Gas/Diesel Oil	CO2	257.30	438.80	0,84%	22
1 A 1 c Manufacture of Solid fuels and Other Energy Industries: Solid Fuels	CO2	300.32	372.36	0,55%	23
3 D a 1 Inorganic N fertilizers	N2O	934.88	769.78	0,53%	24
1 A 4 a Commercial/Institutional: Gaseous Fuels	CO2	86.09	224.85	0,52%	25
1 A 2 d Pulp, Paper and Print: Solid Fuels	CO2	264.58	4.29	0,50%	26
1 B 2 a Oil	CO2	254.82	0.00	0,49%	27
1 A 2 a Iron and Steel: Gaseous Fuels	CO2	25.21	150.22	0,41%	28
1 A 3 a Domestic Aviation: Jet Kerosene	CO2	658.13	298.64	0,36%	29
3 D a 4 Crop residues applied to soils	N2O	402.38	360.22	0,32%	30
1 A 4 c Agriculture/Forestry/Fisheries: Solid Fuels	CO2	157.08	0.00	0,30%	31
1 A 3 b i Road Transportation, Cars: Gasoline	CH4	160.96	8.79	0,28%	32
3 A 1 Dairy cattle	CH4	1810.70	1240.85	0,28%	33
2 C 3 Aluminium production	CO2	132.86	174.66	0,27%	34
1 A 1 a Public Electricity and Heat Production: Biomass	N2O	10.83	94.80	0,27%	35

Table A1.3. KCA, approach 1, trend, excl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO2-eq)	Year 2022 emissions or removals (kt CO2-eq)	Contribution to Trend	Key Source Trend
5 C 1 Waste Incineration	CO2	43.85	111.22	0,25%	36
3 D a 2 a Animal manure applied to soils	N2O	319.67	285.19	0,25%	37
3 B 1 Non-dairy cattle	CH4	68.55	125.56	0,25%	38
2 C 7 Other	CO2	275.78	257.02	0,25%	39
3 A 4 Horses	CH4	159.06	179.17	0,24%	40
1 A 2 a Iron and Steel: Solid Fuels	CO2	849.67	616.69	0,23%	41
3 D a 5 Mineralization/immobilization associated with loss/gain of soil organic matter	N2O	0.00	72.51	0,22%	42
1 A 3 b i Road Transportation, Cars: Gasoline	N2O	118.23	6.18	0,21%	43
1 A 1 a Public Electricity and Heat Production:Other Fuels	N2O	19.08	76.90	0,20%	44
3 A 2 Sheep	CH4	102.31	128.50	0,19%	45
1 A 3 b i Road Transportation, Cars: Diesel oil	N2O	0.13	61.14	0,19%	46
1 A 3 b iii Road Transportation, Heavy duty trucks: Diesel oil	N2O	12.35	68.17	0,18%	47
5 D 1 Domestic wastewater	N2O	200.65	184.93	0,17%	48
1 A 3 b iv Road Transportation, Motorcycles: Gasoline	CO2	39.15	81.74	0,17%	49
1 A 4 c Agriculture/Forestry/Fisheries: Liquid Fuels	CO2	1400.47	836.41	0,16%	50
1 A 3 d Domestic Navigation: LNG	CO2	0.00	52.33	0,16%	51
2 C 2 Ferroalloys production	CO2	227.58	196.72	0,16%	52
1 A 1 b Petroleum refining: Liquid Fuels	CO2	1777.89	C	C	C

Table A1.3. KCA, approach 1, trend, excl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO2-eq)	Year 2022 emissions or removals (kt CO2-eq)	Contribution to Trend	Key Source Trend
2 A 1 Cement Production	CO2	1271.95	C	C	C
2 B 10 Other	CO2	514.02	C	C	C
1 A 1 a Public Electricity and Heat Production: Liquid Fuels	CO2	1277.00	C	C	C
1 A 2 g viii Other: Solid Fuels	CO2	98.42	C	C	C
1 A 2 f Non-metallic minerals: Solid Fuels	CO2	1141.51	C	C	C
1 A 2 f Non-metallic minerals: Other Fuels	CO2	0.00	C	C	C
1 A 1 a Public Electricity and Heat Production: Gaseous Fuels	CO2	485.58	C	C	C
2 A 2 Lime Production	CO2	331.60	C	C	C
1 A 1 b Petroleum refining: Gaseous Fuels	CO2	0.00	C	C	C
1 A 2 f Non-metallic minerals: Liquid Fuels	CO2	625.45	C	C	C
2 D 1 Lubricant use	CO2	157.87	C	C	C
1 A 2 f Non-metallic minerals: Gaseous Fuels	CO2	65.28	C	C	C
1 A 2 c Chemicals: Solid Fuels	CO2	100.86	C	C	C

Table A1.4. Key Category Analysis approach 1 Trend Assessment, including LULUCF.

Table A1.4. KCA, approach 1, trend, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Year 2022 emissions or removals (kt CO_2-eq)	Contribution to Trend	Key Source Trend
4 A 1 Forest land remaining forest land	CO2	-53249.07	-39490.06	56,36%	1
1 A 3 b i Road Transportation, Cars: Diesel oil	CO2	524.25	3148.10	3,05%	2
1 A 1 a Public Electricity and Heat Production:Other Fuels	CO2	524.33	3101.18	3,00%	3
1 A 3 b i Road Transportation, Cars: Gasoline	CO2	11993.59	5047.98	2,62%	4
4 B 1 Cropland remaining cropland	CO2	2681.33	2823.22	2,29%	5
1 A 3 b iii Road Transportation, Heavy duty trucks: Diesel oil	CO2	3820.09	2789.51	2,02%	6
2 C 1 Iron and Steel Production	CO2	2636.63	2520.96	1,99%	7
4 E 2 1 Forest land converted to settlements	CO2	2241.11	2209.51	1,76%	8
3 A 1 Non-dairy cattle	CH4	1418.93	1619.62	1,34%	9
1 A 3 b ii Road Transportation, Light duty trucks: Diesel oil	CO2	173.72	1208.80	1,18%	10
1 A 2 g vii Off-road vehicles and other machinery: Liquid Fuels	CO2	987.32	1114.02	0,92%	11
1 A 4 b Residential: Liquid Fuels	CO2	6211.59	366.27	0,90%	12
3 A 1 Dairy cattle	CH4	1810.70	1240.85	0,88%	13
4 A Drained organic soils	N2O	1014.93	1022.78	0,82%	14
2 F 1 Refrigeration and air conditioning	HFCs	4.65	785.82	0,79%	15
1 A 1 a Public Electricity and Heat Production: Solid Fuels	CO2	4230.90	1609.68	0,75%	16
4 C 2 1 Forest land converted to grassland	CO2	418.84	731.11	0,65%	17

Table A1.4. KCA, approach 1, trend, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Year 2022 emissions or removals (kt CO_2-eq)	Contribution to Trend	Key Source Trend
4 G Total HWP from domestic harvest	CO2	-5006.61	-8391.68	0,61%	18
3 D a 1 Inorganic N fertilizers	N2O	934.88	769.78	0,58%	19
1 A 4 c Agriculture/Forestry/Fisheries: Liquid Fuels	CO2	1400.47	836.41	0,55%	20
4 C 1 Grassland remaining grassland	CO2	-559.47	-532.23	0,47%	21
1 A 2 a Iron and Steel: Solid Fuels	CO2	849.67	616.69	0,45%	22
3 D a 6 Cultivation of organic soils (i.e. histosols)	N2O	880.73	604.36	0,43%	23
1 A 2 a Iron and Steel: Liquid Fuels	CO2	830.77	555.19	0,39%	24
1 A 3 d Domestic Navigation: Gas/Diesel Oil	CO2	257.30	438.80	0,39%	25
1 A 1 c Manufacture of Solid fuels and Other Energy Industries: Solid Fuels	CO2	300.32	372.36	0,31%	26
4 A 2 4 Settlements converted to forest land	CO2	-30.39	-364.80	0,31%	27
4 E 2 2 Cropland converted to settlements	CO2	100.05	325.27	0,31%	28
3 D a 4 Crop residues applied to soils	N2O	402.38	360.22	0,28%	29
4 D 1 1 Peat extraction remaining peat extraction	CO2	75.29	288.60	0,27%	30
5 A 1 Managed waste disposal sites	CH4	3846.51	509.09	0,27%	31
1 A 4 a Commercial/Institutional: Liquid Fuels	CO2	2612.33	291.10	0,24%	32
3 D a 2 a Animal manure applied to soils	N2O	319.67	285.19	0,22%	33
1 A 4 a Commercial/Institutional: Gaseous Fuels	CO2	86.09	224.85	0,21%	34
2 C 7 Other	CO2	275.78	257.02	0,20%	35

Table A1.4. KCA, approach 1, trend, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Year 2022 emissions or removals (kt CO_2-eq)	Contribution to Trend	Key Source Trend
4 A Drained organic soils	CH4	255.41	250.74	0,20%	36
4 E 1 Settlements remaining settlements	CO2	-29.90	-249.80	0,20%	37
1 A 2 d Pulp, Paper and Print: Liquid Fuels	CO2	1785.65	545.33	0,18%	38
1 A 2 g viii Other: Liquid Fuels	CO2	2061.61	595.19	0,18%	39
1 A 3 a Domestic Aviation: Jet Kerosene	CO2	658.13	298.64	0,17%	40
2 C 2 Ferroalloys production	CO2	227.58	196.72	0,15%	41
2 C 3 Aluminium production	CO2	132.86	174.66	0,15%	42
3 A 4 Horses	CH4	159.06	179.17	0,15%	43
1 A 2 a Iron and Steel: Gaseous Fuels	CO2	25.21	150.22	0,15%	44
5 D 1 Domestic wastewater	N2O	200.65	184.93	0,14%	45
1 A 1 b Petroleum refining: Liquid Fuels	CO2	1777.89	C	C	C
2 A 1 Cement Production	CO2	1271.95	C	C	C
2 B 10 Other	CO2	514.02	C	C	C
2 A 2 Lime Production	CO2	331.60	C	C	C
1 A 2 g viii Other: Solid Fuels	CO2	98.42	C	C	C
1 A 1 a Public Electricity and Heat Production: Liquid Fuels	CO2	1277.00	C	C	C
1 A 2 f Non-metallic minerals: Other Fuels	CO2	0.00	C	C	C
1 A 2 c Chemicals: Liquid Fuels	CO2	424.22	C	C	C

Table A1.4. KCA, approach 1, trend, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Year 2022 emissions or removals (kt CO_2-eq)	Contribution to Trend	Key Source Trend
1 A 2 f Non-metallic minerals: Solid Fuels	CO2	1141.51	C	C	C
2 D 1 Lubricant use	CO2	157.87	C	C	C
1 A 1 b Petroleum refining: Gaseous Fuels	CO2	0.00	C	C	C

Table A1.5. Key Category Analysis approach 2 Level Assessment, excluding LULUCF.

Table A1.5. KCA, approach 2, level, excl LULUCF IPCC Source Category	Substance	Year 2022 emissions or removals (kt CO_2-eq)	Combined uncertainty in 2022 (%)	Contribution to Level in 2022 with Uncertainty	Key Source Level in 2022 (Approach 2)
3 D a 1 Inorganic N fertilizers	N2O	769.78	80.2	7,73%	1
3 D a 6 Cultivation of organic soils (i.e. histosols)	N2O	604.36	85.1	6,45%	2
1 A 1 a Public Electricity and Heat Production:Other Fuels	CO2	3101.18	15.7	6,08%	3
3 A 1 Non-dairy cattle	CH4	1619.62	25.5	5,17%	4
3 D b 1 Atmospheric deposition	N2O	83.52	400.5	4,19%	5
2 F 1 Refrigeration and air conditioning	HFCs	785.82	38.4	3,78%	6
3 D a 4 Crop residues applied to soils	N2O	360.22	82.5	3,72%	7
3 B Indirect N2O emissions	N2O	72.50	400.5	3,64%	8
5 A 1 Managed waste disposal sites	CH4	509.09	55.9	3,57%	9
3 A 1 Dairy cattle	CH4	1240.85	20.6	3,21%	10
1 A 3 b i Road Transportation, Cars: Gasoline	CO2	5047.98	5.0	3,16%	11
3 D b 2 Nitrogen leaching and run-off	N2O	166.30	151.3	3,15%	12
3 D a 2 a Animal manure applied to soils	N2O	285.19	80.2	2,86%	13
1 A 3 b i Road Transportation, Cars: Diesel oil	CO2	3148.10	5.1	2,01%	14
1 A 1 a Public Electricity and Heat Production: Solid Fuels	CO2	1609.68	9.9	2,00%	15
2 C 1 Iron and Steel Production	CO2	2520.96	6.0	1,89%	16

Table A1.5. KCA, approach 2, level, excl LULUCF IPCC Source Category	Substance	Year 2022 emissions or removals (kt CO_2-eq)	Combined uncertainty in 2022 (%)	Contribution to Level in 2022 with Uncertainty	Key Source Level in 2022 (Approach 2)
1 A 3 b iii Road Transportation, Heavy duty trucks: Diesel oil	CO2	2789.51	4.9	1,70%	17
3 D a 3 Urine and dung deposited by grazing animals	N2O	67.52	152.0	1,29%	18
5 D 1 Domestic wastewater	N2O	184.93	49.0	1,14%	19
3 A 4 Horses	CH4	179.17	40.3	0,91%	20
1 A 2 g vii Off-road vehicles and other machinery: Liquid Fuels	CO2	1114.02	6.3	0,88%	21
3 B 1 Non-dairy cattle	CH4	125.56	53.9	0,85%	22
1 A 3 b ii Road Transportation, Light duty trucks: Diesel oil	CO2	1208.80	5.1	0,77%	23
3 D a 5 Mineralization/immobilization associated with loss/gain of soil organic matter	N2O	72.51	82.5	0,75%	24
1 A 2 d Pulp, Paper and Print: Other Fuels	CO2	57.75	100.5	0,73%	25
1 A 4 b Residential: Biomass	CH4	54.54	100.5	0,69%	26
3 A 2 Sheep	CH4	128.50	40.3	0,65%	27
3 B 1 Dairy cattle	CH4	79.58	53.9	0,54%	28
1 A 3 b iii Road Transportation, Heavy duty trucks: Diesel oil	N2O	68.17	62.0	0,53%	29
1 A 4 b Residential: Biomass	N2O	39.59	100.5	0,50%	30
1 A 3 b i Road Transportation, Cars: Diesel oil	N2O	61.14	65.0	0,50%	31
1 A 2 a Iron and Steel: Liquid Fuels	CO2	555.19	7.1	0,49%	32
1 A 2 d Pulp, Paper and Print: Liquid Fuels	CO2	545.33	7.1	0,48%	33

Table A1.5. KCA, approach 2, level, excl LULUCF IPCC Source Category	Substance	Year 2022 emissions or removals (kt CO_2-eq)	Combined uncertainty in 2022 (%)	Contribution to Level in 2022 with Uncertainty	Key Source Level in 2022 (Approach 2)
3 D a 2 c Other organic fertilizers applied to soils	N2O	44.04	80.2	0,44%	34
1 A 4 b Residential: Liquid Fuels	CO2	366.27	9.3	0,43%	35
3 A 4 Raindeer	CH4	84.11	40.3	0,42%	36
3 B 3 Swine	CH4	62.72	53.9	0,42%	37
1 A 2 a Iron and Steel: Solid Fuels	CO2	616.69	5.4	0,42%	38
1 A 4 c Agriculture/Forestry/Fisheries: Liquid Fuels	CO2	836.41	3.8	0,40%	39
3 B 1 Dairy cattle	N2O	60.67	49.1	0,37%	40
1 A 1 a Public Electricity and Heat Production: Biomass	N2O	94.80	30.4	0,36%	41
3 B 1 Non-dairy cattle	N2O	78.52	36.2	0,36%	42
1 A 3 a Domestic Aviation: Jet Kerosene	CO2	298.64	9.2	0,34%	43
1 A 3 d Domestic Navigation: Residual Oil	CO2	168.04	15.8	0,33%	44
1 A 1 c Manufacture of Solid fuels and Other Energy Industries: Solid Fuels	CO2	372.36	7.1	0,33%	45
1 A 4 a Commercial/Institutional: Liquid Fuels	CO2	291.10	8.8	0,32%	46
1 A 4 c Agriculture/Forestry/Fisheries: Domestic Heating Oil	CO2	82.73	30.4	0,32%	47
1 A 4 a Commercial/Institutional: Gaseous Fuels	CO2	224.85	11.2	0,32%	48
1 A 3 e Other Transportation: Total	CO2	353.76	7.1	0,31%	49
1 A 1 b Petroleum refining: Liquid Fuels	CO2	C	C	C	C

Table A1.5. KCA, approach 2, level, excl LULUCF IPCC Source Category	Substance	Year 2022 emissions or removals (kt CO_2-eq)	Combined uncertainty in 2022 (%)	Contribution to Level in 2022 with Uncertainty	Key Source Level in 2022 (Approach 2)
1 A 2 f Non-metallic minerals: Other Fuels	CO2	C	C	C	C
2 D 1 Lubricant use	CO2	C	C	C	C
2 A 1 Cement Production	CO2	C	C	C	C
1 A 2 f Non-metallic minerals: Solid Fuels	CO2	C	C	C	C
2 B 10 Other	CO2	C	C	C	C

Table A1.6. Key Category Analysis approach 2 Level Assessment, including LULUCF.

Table A1.6. KCA, approach 2, level, incl LULUCF IPCC Source Category	Substance	Year 2022 emissions or removals (kt CO_2-eq)	Combined uncertainty in 2022 (%)	Contribution to Level in 2022 with Uncertainty	Key Source Level in 2022 (Approach 2)
4 A 1 Forest land remaining forest land	CO2	-39490.06	17.7	32,24%	1
4 G Total HWP from domestic harvest	CO2	-8391.68	30.4	11,76%	2
4 A Drained organic soils	N2O	1022.78	100.0	4,71%	3
4 B 1 Cropland remaining cropland	CO2	2823.22	28.6	3,72%	4
4 E 2 1 Forest land converted to settlements	CO2	2209.51	29.7	3,02%	5
3 D a 1 Inorganic N fertilizers	N2O	769.78	80.2	2,84%	6
3 D a 6 Cultivation of organic soils (i.e. histosols)	N2O	604.36	85.1	2,37%	7
1 A 1 a Public Electricity and Heat Production:Other Fuels	CO2	3101.18	15.7	2,23%	8
4 C 2 1 Forest land converted to grassland	CO2	731.11	60.0	2,02%	9
3 A 1 Non-dairy cattle	CH4	1619.62	25.5	1,90%	10
3 D b 1 Atmospheric deposition	N2O	83.52	400.5	1,54%	11
2 F 1 Refrigeration and air conditioning	HFCs	785.82	38.4	1,39%	12
3 D a 4 Crop residues applied to soils	N2O	360.22	82.5	1,37%	13
3 B Indirect N2O emissions	N2O	72.50	400.5	1,34%	14
5 A 1 Managed waste disposal sites	CH4	509.09	55.9	1,31%	15
3 A 1 Dairy cattle	CH4	1240.85	20.6	1,18%	16

Table A1.6. KCA, approach 2, level, incl LULUCF IPCC Source Category	Substance	Year 2022 emissions or removals (kt CO_2-eq)	Combined uncertainty in 2022 (%)	Contribution to Level in 2022 with Uncertainty	Key Source Level in 2022 (Approach 2)
1 A 3 b i Road Transportation, Cars: Gasoline	CO2	5047.98	5.0	1,16%	17
3 D b 2 Nitrogen leaching and run-off	N2O	166.30	151.3	1,16%	18
4 A Drained organic soils	CH4	250.74	100.0	1,15%	19
3 D a 2 a Animal manure applied to soils	N2O	285.19	80.2	1,05%	20
4 B Drained organic soils	CH4	182.08	100.0	0,84%	21
4 E 2 2 Cropland converted to settlements	CO2	325.27	49.8	0,75%	22
1 A 3 b i Road Transportation, Cars: Diesel oil	CO2	3148.10	5.1	0,74%	23
1 A 1 a Public Electricity and Heat Production: Solid Fuels	CO2	1609.68	9.9	0,73%	24
2 C 1 Iron and Steel Production	CO2	2520.96	6.0	0,70%	25
4 D 1 1 Peat extraction remaining peat extraction	CO2	288.60	50.0	0,66%	26
1 A 3 b iii Road Transportation, Heavy duty trucks: Diesel oil	CO2	2789.51	4.9	0,62%	27
4 C 1 Grassland remaining grassland	CO2	-532.23	20.1	0,49%	28
3 D a 3 Urine and dung deposited by grazing animals	N2O	67.52	152.0	0,47%	29
4 A 2 4 Settlements converted to forest land	CO2	-364.80	25.8	0,43%	30
5 D 1 Domestic wastewater	N2O	184.93	49.0	0,42%	31
3 A 4 Horses	CH4	179.17	40.3	0,33%	32
1 A 2 g vii Off-road vehicles and other machinery: Liquid Fuels	CO2	1114.02	6.3	0,32%	33

Table A1.6. KCA, approach 2, level, incl LULUCF IPCC Source Category	Substance	Year 2022 emissions or removals (kt CO_2-eq)	Combined uncertainty in 2022 (%)	Contribution to Level in 2022 with Uncertainty	Key Source Level in 2022 (Approach 2)
3 B 1 Non-dairy cattle	CH4	125.56	53.9	0,31%	34
1 A 3 b ii Road Transportation, Light duty trucks: Diesel oil	CO2	1208.80	5.1	0,28%	35
1 A 1 b Petroleum refining: Liquid Fuels	CO2	C	C	C	C
1 A 2 f Non-metallic minerals: Other Fuels	CO2	C	C	C	C
2 D 1 Lubricant use	CO2	C	C	C	C
2 A 1 Cement Production	CO2	C	C	C	C

Table A1.7. Key Category Analysis approach 2 Trend Assessment, excluding LULUCF.

Table A1.7. KCA, approach 2, trend, excl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Year 2022 emissions or removals (kt CO_2-eq)	Combined uncertainty in 2022 (%)	Contr.to Trend with Uncertainty	Key Source Trend (Approach 2)
5 A 1 Managed waste disposal sites	CH4	3846.51	509.09	55.9	20,27%	1
1 A 1 a Public Electricity and Heat Production:Other Fuels	CO2	524.33	3101.18	15.7	8,13%	2
1 A 4 b Residential: Liquid Fuels	CO2	6211.59	366.27	9.3	6,26%	3
2 F 1 Refrigeration and air conditioning	HFCs	4.65	785.82	38.4	5,64%	4
3 A 1 Non-dairy cattle	CH4	1418.93	1619.62	25.5	3,44%	5
1 A 3 b i Road Transportation, Cars: Diesel oil	CO2	524.25	3148.10	5.1	2,69%	6
3 D a 1 Inorganic N fertilizers	N2O	934.88	769.78	80.2	2,65%	7
1 A 3 b i Road Transportation, Cars: Gasoline	CO2	11993.59	5047.98	5.0	2,40%	8
1 A 1 a Public Electricity and Heat Production: Peat	CO2	1150.05	107.26	19.6	2,29%	9
1 A 4 a Commercial/Institutional: Liquid Fuels	CO2	2612.33	291.10	8.8	2,25%	10
1 A 1 a Public Electricity and Heat Production: Solid Fuels	CO2	4230.90	1609.68	9.9	2,00%	11
3 D b 1 Atmospheric deposition	N2O	91.46	83.52	400.5	1,91%	12
3 D a 4 Crop residues applied to soils	N2O	402.38	360.22	82.5	1,62%	13
3 D a 2 a Animal manure applied to soils	N2O	319.67	285.19	80.2	1,24%	14
3 D a 5 Mineralization/immobilization associated with loss/gain of soil organic matter	N2O	0.00	72.51	82.5	1,12%	15

Table A1.7. KCA, approach 2, trend, excl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Year 2022 emissions or removals (kt CO_2-eq)	Combined uncertainty in 2022 (%)	Contr.to Trend with Uncertainty	Key Source Trend (Approach 2)
3 B Indirect N2O emissions	N2O	91.63	72.50	400.5	1,08%	16
1 A 3 b ii Road Transportation, Light duty trucks: Diesel oil	CO2	173.72	1208.80	5.1	1,05%	17
2 C 1 Iron and Steel Production	CO2	2636.63	2520.96	6.0	0,95%	18
3 B 1 Non-dairy cattle	CH4	68.55	125.56	53.9	0,83%	19
1 A 2 d Pulp, Paper and Print: Liquid Fuels	CO2	1785.65	545.33	7.1	0,78%	20
1 A 3 b i Road Transportation, Cars: Gasoline	N2O	118.23	6.18	58.6	0,76%	21
1 A 3 b i Road Transportation, Cars: Diesel oil	N2O	0.13	61.14	65.0	0,74%	22
3 D a 6 Cultivation of organic soils (i.e. histosols)	N2O	880.73	604.36	85.1	0,72%	23
3 D a 3 Urine and dung deposited by grazing animals	N2O	67.26	67.52	152.0	0,71%	24
1 A 3 b iii Road Transportation, Heavy duty trucks: Diesel oil	N2O	12.35	68.17	62.0	0,70%	25
1 A 3 b i Road Transportation, Cars: Gasoline	CH4	160.96	8.79	39.9	0,70%	26
1 A 2 d Pulp, Paper and Print: Other Fuels	CO2	39.64	57.75	100.5	0,61%	27
3 D a 2 c Other organic fertilizers applied to soils	N2O	7.08	44.04	80.2	0,59%	28
3 A 4 Horses	CH4	159.06	179.17	40.3	0,59%	29
1 A 2 g vii Off-road vehicles and other machinery: Liquid Fuels	CO2	987.32	1114.02	6.3	0,57%	30
5 D 1 Domestic wastewater	N2O	200.65	184.93	49.0	0,53%	31
1 A 1 a Public Electricity and Heat Production: Biomass	N2O	10.83	94.80	30.4	0,50%	32

Table A1.7. KCA, approach 2, trend, excl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Year 2022 emissions or removals (kt CO_2-eq)	Combined uncertainty in 2022 (%)	Contr.to Trend with Uncertainty	Key Source Trend (Approach 2)
3 A 2 Sheep	CH4	102.31	128.50	40.3	0,48%	33
3 D b 2 Nitrogen leaching and run-off	N2O	236.08	166.30	151.3	0,47%	34
1 B 2 c Venting and flaring	CO2	73.48	0.01	50.9	0,45%	35
2 B 2 Nitric Acid Production	N2O	695.63	5.53	5.4	0,44%	36
1 A 2 g viii Other: Liquid Fuels	CO2	2061.61	595.19	3.1	0,42%	37
1 A 3 b ii Road Transportation, Light duty trucks: Gasoline	CO2	833.91	85.04	5.0	0,42%	38
1 A 3 e Other Transportation: Total	CO2	1051.53	353.76	7.1	0,42%	39
1 A 2 e Food Processing, Beverages and Tobacco: Liquid Fuels	CO2	596.36	102.32	7.1	0,37%	40
1 A 4 a Commercial/Institutional: Gaseous Fuels	CO2	86.09	224.85	11.2	0,36%	41
3 A 1 Dairy cattle	CH4	1810.70	1240.85	20.6	0,35%	42
1 A 3 b iii Road Transportation, Heavy duty trucks: Diesel oil	CO2	3820.09	2789.51	4.9	0,33%	43
2 C 3 Aluminium production	PFCs	510.94	34.43	5.4	0,29%	44
3 D a 2 b Sewage sludge applied to soils	N2O	4.91	22.01	80.2	0,28%	45
1 A 1 a Public Electricity and Heat Production:Other Fuels	N2O	19.08	76.90	22.2	0,27%	46
1 A 2 d Pulp, Paper and Print: Solid Fuels	CO2	264.58	4.29	8.6	0,26%	47
3 B 1 Non-dairy cattle	N2O	63.35	78.52	36.2	0,26%	48
1 A 1 b Petroleum refining: Liquid Fuels	CO2	1777.89	C	C	C	C

Table A1.7. KCA, approach 2, trend, excl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Year 2022 emissions or removals (kt CO_2-eq)	Combined uncertainty in 2022 (%)	Contr.to Trend with Uncertainty	Key Source Trend (Approach 2)
1 A 2 f Non-metallic minerals: Other Fuels	CO2	0.00	C	C	C	C
2 D 1 Lubricant use	CO2	157.87	C	C	C	C
1 A 2 f Non-metallic minerals: Solid Fuels	CO2	1141.51	C	C	C	C
1 A 2 c Chemicals: Other Fuels	CO2	2.83	C	C	C	C
2 A 1 Cement Production	CO2	1271.95	C	C	C	C
2 B 10 Other	CO2	514.02	C	C	C	C

Table A1.8. Key Category Analysis approach 2 Trend Assessment, including LULUCF.

Table A1.8. KCA, approach 2, trend, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Year 2022 emissions or removals (kt CO_2-eq)	Combined uncertainty in 2022 (%)	Contribution to Trend with Uncertainty	Key Source Trend (Approach 2)
4 A 1 Forest land remaining forest land	CO2	-53249.07	-39490.06	17.7	50,03%	1
4 A Drained organic soils	N2O	1014.93	1022.78	100.0	4,10%	2
4 B 1 Cropland remaining cropland	CO2	2681.33	2823.22	28.6	3,27%	3
4 E 2 1 Forest land converted to settlements	CO2	2241.11	2209.51	29.7	2,61%	4
1 A 1 a Public Electricity and Heat Production:Other Fuels	CO2	524.33	3101.18	15.7	2,35%	5
3 D a 1 Inorganic N fertilizers	N2O	934.88	769.78	80.2	2,33%	6
4 C 2 1 Forest land converted to grassland	CO2	418.84	731.11	60.0	1,95%	7
3 D a 6 Cultivation of organic soils (i.e. histosols)	N2O	880.73	604.36	85.1	1,82%	8
3 A 1 Non-dairy cattle	CH4	1418.93	1619.62	25.5	1,70%	9
2 F 1 Refrigeration and air conditioning	HFCs	4.65	785.82	38.4	1,51%	10
3 D b 1 Atmospheric deposition	N2O	91.46	83.52	400.5	1,31%	11
3 D a 4 Crop residues applied to soils	N2O	402.38	360.22	82.5	1,15%	12
3 B Indirect N2O emissions	N2O	91.63	72.50	400.5	1,08%	13
4 A Drained organic soils	CH4	255.41	250.74	100.0	1,00%	14
4 G Total HWP from domestic harvest	CO2	-5006.61	-8391.68	30.4	0,93%	15
3 A 1 Dairy cattle	CH4	1810.70	1240.85	20.6	0,90%	16

Table A1.8. KCA, approach 2, trend, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Year 2022 emissions or removals (kt CO_2-eq)	Combined uncertainty in 2022 (%)	Contribution to Trend with Uncertainty	Key Source Trend (Approach 2)
3 D b 2 Nitrogen leaching and run-off	N2O	236.08	166.30	151.3	0,90%	17
3 D a 2 a Animal manure applied to soils	N2O	319.67	285.19	80.2	0,89%	18
1 A 3 b i Road Transportation, Cars: Diesel oil	CO2	524.25	3148.10	5.1	0,78%	19
4 E 2 2 Cropland converted to settlements	CO2	100.05	325.27	49.8	0,76%	20
5 A 1 Managed waste disposal sites	CH4	3846.51	509.09	55.9	0,76%	21
4 D 1 1 Peat extraction remaining peat extraction	CO2	75.29	288.60	50.0	0,69%	22
1 A 3 b i Road Transportation, Cars: Gasoline	CO2	11993.59	5047.98	5.0	0,65%	23
4 B Drained organic soils	CH4	265.35	182.08	100.0	0,64%	24
2 C 1 Iron and Steel Production	CO2	2636.63	2520.96	6.0	0,60%	25
1 A 3 b iii Road Transportation, Heavy duty trucks: Diesel oil	CO2	3820.09	2789.51	4.9	0,49%	26
4 C 1 Grassland remaining grassland	CO2	-559.47	-532.23	20.1	0,48%	27
1 A 4 b Residential: Liquid Fuels	CO2	6211.59	366.27	9.3	0,42%	28
3 D a 3 Urine and dung deposited by grazing animals	N2O	67.26	67.52	152.0	0,41%	29
4 A 2 4 Settlements converted to forest land	CO2	-30.39	-364.80	25.8	0,40%	30
1 A 1 a Public Electricity and Heat Production: Solid Fuels	CO2	4230.90	1609.68	9.9	0,37%	31
5 D 1 Domestic wastewater	N2O	200.65	184.93	49.0	0,35%	32
3 B 1 Non-dairy cattle	CH4	68.55	125.56	53.9	0,30%	33

Table A1.8. KCA, approach 2, trend, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Year 2022 emissions or removals (kt CO_2-eq)	Combined uncertainty in 2022 (%)	Contribution to Trend with Uncertainty	Key Source Trend (Approach 2)
1 A 1 b Petroleum refining: Liquid Fuels	CO2	1777.89	C	C	C	C
1 A 2 f Non-metallic minerals: Other Fuels	CO2	0.00	C	C	C	C
2 D 1 Lubricant use	CO2	157.87	C	C	C	C

2 Annex 2: Detailed discussion of methodology and data for estimating emissions from fossil fuel combustion.

2.1 Sources for activity data in CRT 1A and parts of CRT 1B

Activity data used in the energy sector is mainly based on statistics on fuel consumption. In sections 1.1.1.-1.1.9 below, the various energy surveys, produced by Statistics Sweden on behalf of Swedish Energy Agency, are described. Other data sources are described in sections 1.1.10-1.1.13. These data sources, e.g. environmental reports and data reported to EU ETS, have a different purpose than official energy statistics. The main focus in these data sources is not fuel consumption but emissions. Nevertheless, they contain useful data on fuel consumption that in some cases is more complete than the energy surveys. For stationary combustion within the Other sector, activity data from the annual energy balances is used in order to ensure that all activities are covered and no activities are double counted. The energy balances are based on a number of surveys, which are all described below.

A number of activity data sources are used and the UNFCCC ERT (expert review team) has asked for the rationale for choosing a certain data source, an explanation of how these sources are deemed accurate or inaccurate, and how time series consistency is ensured. In Tables A2.1 and A2.2 below, the descriptions of the different data sources and reasons for the choice of certain data sources are summarized. More details are found in the following text.

Table A2.1. Summary of the main activity data sources used in the inventory for stationary combustion.

CRT	Main acticity data sources	Comments
1A2	Energy use in the manufacturing industry (ISEN), Quarterly fuel statistics (KvBr) and environmental reports.	1990-1996 and 2000-2002: ISEN. 1997-1999 and 2003 and onwards: KvBr.
1A2g + 1A4	Energy balances.	For the parts of 1A2g and 1A4 that are not covered by regular surveys.
1A1b and 1A2c	Emissions reported to EU ETS.	Parts of 1A2c since 2005/2008.
1A1c + 1A2a	Environmental reports	AD and CO_2 for the two integrated iron and steel plants (see annex 3.5).

Table A2.2. Summarized properties of activity data sources used in the inventory for stationary combustion.

Activity data source	Description	Comments
Energy use in manufacturing industry (ISEN)	Total survey of industrial facilities with 10 or more employees.	Data for year t finalized in February/March year t+2, which is too late for the inventory. Used as main AD source for 1A2 for earlier years.
Quarterly fuel statistics (KvBr)	Total survey for the energy sector, cut-off sample survey for manufacturing industry (ISEN is the sample frame)	Data for year t finalized in March year t+1. Several studies have shown that this data source is complete and consistent.
Emissions reported to EU ETS	Facilities included in the EU Emission trading scheme 2005-. Emission data is complete, activity data and/or NCVs not always reported.	The definition of "facility" is different from the one used in official energy statistics (KvBr or ISEN). Population definitions changes between trading periods. No standardization of fuel types.
Environmental reports	All operators whose activities have an impact on the environment are obliged to report environmental reports to the authority responsible for the emission permits.	Quality and completeness is very variable. Activity data is not always included. Most of the information is only available in text reports, which means that data cannot be processed in an automatized way.The reports are also used for verification and occasionally for plant specific NCV:s
Energy balances	Includes all supply and use of fuels and other energy types on aggregate levels.	See discussions in later sections.

In numerous development projects during the last ten years, several of them quoted in NIR section 3, different data sources have been compared and checked against each other, and in some of these projects industrial facilities have been contacted by phone or e-mail to verify data. Generally, the quarterly fuel statistics is considered to be more complete than the ISEN, because the industrial energy survey, at least in early years, does not include all back pressure power. Besides, the annual industrial energy survey is not ready in time for the GHG inventory.

A detailed comparison between the quarterly fuel statistics, the annual industrial energy survey show some differences between, but the differences did not indicate systematic errors in any of the surveys, and hence the quarterly fuel statistics is of sufficient quality[1].

Environmental reports are often a good source of emission data, but generally they do not contain sufficient activity data for the energy sector, and facilities with small emissions are not obliged to submit environmental reports. The EU-ETS system has very good coverage of the trading facilities, but presently it is not possible to use as main data source due to several reasons. Firstly, the database is not adapted to automatic data processing, and secondly, some facilities only report carbon balances. Furthermore, to produce correct estimates for the non-trading facilities,

[1] SCB, Förstudie om ökad samordning av tre energiundersökningar (2021)

one must be able to separate trading facilities from non-trading ones in the official energy statistics (KvBr or ISEN), and this is currently not possible due to different definitions of administrative units in the official energy statistics and the EU-ETS, respectively.

For the Other sector, energy balances are used because none of the underlying surveys covers all emission sources in the different sub-sectors, but in the energy balances, complementary calculations are made in order to obtain full coverage and avoid double counting. Data for CRT 1.A.4 has been verified against the underlying surveys described in section 2.1.3 -2.1.6 below, and the coherence was good for biomass fuels and oils, whereas the coverage of use of e.g. LPG was considered to be better in the energy balances.

2.1.1 Quarterly fuel statistics

Quarterly fuel statistics are used as follows:

- All years for data on stationary combustion in the CRT sector 1.A.1.a, parts of 1.A.c 1.A.2, with the exception of 1.A.2 for the years 1990-1996 and 2000-2002 (where ISEN is used) and for some undercodes in 1.A.2.g (where the Energy Balances is used).
- 1990-1996 for information on in-house (own-produced) fuels in CRT 1.A.1.b and 1.A.2 since the statistics on energy use in manufacturing industry did not cover own-produced fuels during these years.
- 2000-2002 for data on fuel combustion for back pressure power in CRT 1.A.2.c-e, both sold and consumed at the producing plant. This is due to that the Annual statistics on energy use in manufacturing industry (which is the main data source for industries 2000-2002) has been found not to cover fuel consumption for back pressure power.

Quarterly fuel statistics are carried out as a web-based sample survey. For the manufacturing industries, i.e. CRT 1.A.2, the statistical unit is equivalent to working unit[2]. In the public electricity and heat production sector, i.e. 1.A.1.a, the statistical unit is more aggregated for larger companies, which report all facilities in each municipality in one unit. In recent years, the survey includes around 850-900 units each year, of which just over 300 units belong to CRT 1.A.1.a. The sample to the quarterly fuel statistics is based on the sample for the annual statistics of energy use in manufacturing industry, except for electricity and heat production for which the quarterly fuel statistics is a total survey. Data are collected from all companies in electricity and heat production, all companies in the pulp and paper industry and all companies in the manufacturing industry with more than nine employees and annual fuel combustion of more than 325 tonne oil equivalents.

The survey should cover all fuel consumption, both own-produced and purchased fuels. However, in some cases it has been noted by the GHG inventory staff that

[2] A company may consist of several working units, that is could be located in several places (factories).

not all in-house fuels are covered. In those cases supplementary data has been collected to assure complete time series (section 1.1.9). In the survey form, respondents are also asked to specify whether fuels are used as raw materials or for energy purposes.

The sample frame is updated annually based on the latest results of the Energy use in manufacturing industry (ISEN). The response rate to the quarterly fuel statistics is almost 100% for ISIC 40 (that is, CRT 1.A.1.a) and about 90% for manufacturing industries. The non-respondents among the industries are often small companies, which means that much more than 90% of consumed energy is covered in responses to the survey. To compensate for companies not included in the sample and companies not responding to the survey, all fuel consumption is raised with a factor which is produced from information on the line of business, number of employees and business volume from the most recent year when the statistics on energy use in manufacturing industry was a total survey (as discussed above). By definition, the survey does not cover energy consumption in working units with less than ten employees. The energy consumption in these "small industries" is estimated with a calculation model based on an intermittent survey[3] and published in the energy balances. This estimate covers all industrial branches and the fuel consumption and emissions are reported under CRT 1.A.2.g.

The quarterly fuel statistics for each year are compiled and ready for use at approximately the end of March the following year. This gives enough time to process the data for the greenhouse gas inventory.

In the GHG inventory, data on plant level and by fuel type is used. The quarterly fuel statistics is not used in the inventory for the two largest plants within the iron and steel industry, see also section 3.2.9 of the NIR.

2.1.2 Annual statistics on energy use in manufacturing industry (ISEN)

The statistics on energy use in manufacturing industry (ISEN) is used for emissions from stationary combustion in the CRT sectors 1.A.1.b, 1.A.1.c and 1.A.2 for the years 1990-1996 and 2000-2002. The Quaternary statistics for these years did not include fuel consumption for back pressure power, because data on this activity was collected via a different survey (Electricity supply, district heating and supply of natural and gasworks gas (AREL)).

The energy use in manufacturing industry statistics is based on an annual survey of manufacturing companies. In 1990-1996, 2000 and from 2004, all companies with more than 9 employees are included. In 1997-1999 and in 2001-2003 it was

[3] In 2011, a survey of small industries was conducted as a "satellite survey" to the annual industrial energy statistics. The results are not published separately but included in the energy balances. The estimates for 2010 are used to calculate fuel consumption in later years.

conducted as a sample survey to companies with less than 50 and more than 9 employees, and as a total survey to all companies with more than 50 employees. In 1990-1996, only purchased fuels were surveyed but, since 1997, information on all fuel consumption has been collected.

The response rate to the energy use in manufacturing industry statistics in the years for which this survey is used in the GHG emission inventory was about 85%. To compensate for non-response, fuel consumption is weighted with a factor based on the line of business, number of employees and business volume. There is no adjustment for manufacturing industries with less than 10 employees. A special form is sent to electricity producing companies within manufacturing industries, where the amounts of fuels used for electricity production and manufacturing purposes are specified. All manufacturing industries with electricity production are included in the survey every year. In the inventory, all data used are on plant level and by fuel type. An overview of the Annual statistics on energy use in manufacturing industry used in the inventory for 1990-2002 is given in Table A2.3. For the early years, data was complemented with other data sources in order to compensate for quality problems mentioned above.

Table A2.3. Summarized properties of the Annual statistics on energy use in manufacturing industry used in the inventory.

Year	Type of survey	Coverage	Adjustments	Quality
1990-1996	Annual total survey to all companies with more than nine employees	Working units, purchased fuels, quantity and economic value of purchased fuels	Weighted to represent all companies with more than 9 employees	Not so good quality for quantity, good quality for economic value
1997-1999	Annual total survey to all companies with at least 50 employees and a stratified sample of companies with 10-49 employees	Working units purchased and own-produced fuels	Weighted to represent all companies with more than 9 employees	Good on national level and on coarse branch level, poor for single fuel types and single branches
2000	Annual total survey to all companies with more than nine employees	Working units, purchased and own-produced fuels	No adjustments	Excellent
2001-2002	Annual total survey to all companies with at least 50 employees and a stratified sample of companies with 10-49 employees	Working units, purchased and own-produced fuels	Weighted to represent all companies with more than 9 employees	Good

2.1.3 One- and two-dwelling statistics

One- and two-dwelling statistics are, together with holiday cottages statistics and multi-dwelling statistics, the main data sources for stationary biomass combustion in households in the energy balances, which in turn are used to calculate emissions from stationary combustion in households, CRT 1.A.4.b.

This sample survey is conducted every second or third year to collect data on the use of electricity and heat for a total of 7,000 one- and two-dwellings. The years in between, the energy use is modeled based on changes in temperature between the years. Until 1999, the survey has a random sample from a real estate assessment, which includes all dwellings with a value higher than 50,000 SEK (about 5,600 €). From 2000, all dwellings used as permanent dwelling are included in the sample. Every third year, a postal survey collects data from agricultural properties. The sample in this sector is 3,000 objects. Data is on national level by fuel type and considered to be of relatively good quality. To make sure that all emissions from households are included and that no double-counting occurs, activity data is taken from the annual energy balance sheets. However, the fuel consumption reported under the households category in the energy balance is based on the surveys described here.

2.1.4 Holiday cottages statistics

Holiday cottages statistics, together with one- and two-dwelling statistics and multi-dwelling statistics, is used to calculate emissions from stationary combustion in households, CRT 1.A.4.b. As described above, an aggregate from the energy balances is used as activity data for stationary combustion in CRT 1.A.4.b.

Holiday cottages are defined as residences with no permanent residents. Energy consumption in holiday cottages has been surveyed with large time intervals, i.e. in 1976, 2001 and 2012. In 2012, Statistics Sweden carried out a stratified sample survey to house owners, covering 4,500 of the 589,525 objects in the sample frame. The net sample, excluding over coverage, included 4,024 objects and the response rate was 44%. Because of difficulties regarding classification, houses with type codes other than recreational dwellings were also included in the sample frame. The questionnaire form used in 2012 was based on the one used in 2002. Results show that electricity and biomass combustion are the two predominating heating sources in holiday cottages, both in 2001 and 2011[4].

2.1.5 Multi-dwelling statistics

Multi-dwelling statistics, together with one- and two-dwelling statistics and holiday cottages statistics, is used to calculate emissions from stationary combustion of biomass in households, CRT 1.A.4.b.

[4] Statistic Sweden. ES 2012:03. Biomass consumption in holiday cottages accounted for about 6% of the total consumption of biomass in CRT 1A4b in 2001.

This is a sample survey carried out every second or third year, sent to the owners of 7,000 multi-dwelling buildings, covering the use of electricity and heat. For the years in between, the energy use is modelled based on changes in temperature between the years. The survey is based on a random sample from a real estate assessment. The real estate assessment includes all dwellings with an economic value higher than 50,000 SEK (about 5,600 €). Data is on national level by fuel type and of relatively good quality. Statistics on biomass consumption in multi-dwelling buildings was not included in the survey until 2001. However, the time series for 1.A.4.b indicates that this data gap does not lead to any significant under-estimation as biomass use in multi-dwellings is sparse compared to the consumption in one- and two-dwellings.

2.1.6 Premises statistics

Premises statistics are used to calculate emissions from stationary combustion in the commercial and institutional sector, CRT 1.A.4.a.

This survey is a sample survey carried out each second or third years, covering the use of electricity, heat and fuel combustion for heat production of about 8,000 premises. For the years inbetween, the energy use is modelled based on change in temperature between the years. Premises situated in an industrial area are not covered in the dataset. Some of these premises are covered in the Annual statistics on energy use in manufacturing industry as well as in the quarterly fuel statistics and are reported in Manufacturing Industries and Construction (CRT 1.A.2). To get full coverage, supplementary corrections are made for under or over coverage based on the assumption that these are distributed on over and under cover are as in the answers in the energy balance[5]. Data is on national level by fuel type and of relatively good quality. Statistics on biomass consumption in premises was not included in the survey until 2001.

2.1.7 Monthly fuel, gas and inventory statistics

Statistics on supply and delivery of petroleum products[6] has in previous submissions (up to submission 2019) been one of the main sources used to estimate the emissions from mobile combustion in NFR 1A2gii, 1A3a-e, 1A4b-c ii, and 1A4ciii. Data from the survey is used at a national level and by fuel type.

The survey is also the data source for stationary combustion of heating oils in households and premises reported in the energy balances, which is used as activity data source for CRT 1.A.4.a and 1.A.4.b, stationary. The data from the survey is

[5] Statistics Sweden EN20SM, 1990-2010, and Swedish Energy Agency (2011 and later)

[6] Monthly fuel, gas and inventory statistics. https://www.scb.se/en/finding-statistics/statistics-by-subject-area/energy/energy-supply-and-use/monthly-fuel-gas-and-inventory-statistics/

also used for reference approach in CRT 1Ab for all fuels except biomass, waste and peat

Data in the survey is collected from importers, producers, storage companies and distributors of energy products. Fuels collected are crude oil, petroleum products, biofuels and coal. The survey covers around 65 companies..

A revised version of the survey was introduced in 2018 (submission 2020) and some uncertainties regarding the quality of the statistics for diesel and gasoline were identified. This resulted in the use of an alternative data source for these fuels; the fuel suppliers' reports under the Swedish Fuel Quality Act.

2.1.8 The Swedish Fuel Quality Act

As the same oil companies covered by the monthly fuel, gas and inventory survey are obliged to collect and report fuel data under the "Swedish fuel quality act", this data source is used for diesel, gasoline and liquid biofuels as from 2018. The amount of diesel and gasoline collected and reported by the "Monthly fuel, gas and inventory" survey and the "Swedish fuel quality act" only differed around 1 percent for the 3-4 years preceeding the change of data source. So, despite the change of data source that took place in 2018, the activity data used is considered to be consistent and of good quality.

2.1.9 Statistics on the delivery of gas products

Statistics on the delivery of vehicles gas are used to estimate the emissions from natural gas and biogas from road transport (CRT 1.A.3.b). The statistics are based on the survey "Supply of vehicle gas", which is a monthly total survey and consists of approximately 30 companies and municipalities that supply vehicle gas to end customers[7].

A monthly questionnaire is sent to all companies in Sweden that deliver natural gas, biogas and gasworks gas (less than ten companies). Consumption purposes are specified in the survey. Results of this survey are published by Statistics Sweden[8].

2.1.10 Other statistics from Statistics Sweden

Data used in the inventory for stationary fuel consumption in the construction sector, in all companies with less than 10 employees (CRT 1.A.2.g) and stationary combustion in CRT 1.A.4.a-1.A.4.c is taken from the annual energy balances[9]. Data is on national level and by fuel type. Total consumption for these sectors is

[7] https://www.scb.se/en/finding-statistics/statistics-by-subject-area/energy/energy-supply-and-use/deliveries-of-natural-gas-and-biomethane-for-transport/

[8] Statistic Sweden; http://www.scb.se/sv_/Hitta-statistik/Statistik-efter-amne/Energi/Tillforsel-och-anvandning-av-energi/Leveranser-av-fordonsgas/Aktuell-pong/2013M09/

[9] Statistics Sweden EN20SM, 1990-2010, and Swedish Energy Agency (2011 and later)

checked against fuel deliveries, so that possible errors only occur in the allocation between these sectors.

Data on fuel consumption for the construction sector for 1990-2003 is based on a survey from 1985[10], adjusted according to the number of working hours for each year. The fuel consumption for the construction sector in 2004 and later is based on a survey from 2005[11]. Data on fuel consumption in the agricultural sector is based on two intermittent surveys, for gardening[12] and agriculture[13]. The first survey is a sample survey that collects data on energy use in greenhouses and has been carried out for 1990, 1993, 1996, 1999, 2002 and 2008. Data for intermediate years is estimated using number of working hours. The second sample survey collects data for energy use in the other parts of the agricultural business and has been performed for 1994, 2002 and 2007 (fuel consumption in households in the agricultural sector is not included here but is included in the one- and two-dwellings statistics). Data for intermediate years is estimated using annual changes in value added.

Fuel consumption in the forestry sector has been studied thoroughly in 1985 and 2007[14]. Estimates for the years before 2005 are upgraded from the 1985 study with available statistics on the annual felling volume 1990-1995 and from 1996 value added are used.

Fuel consumption in small companies (9 employees or less) reported in the annual energy balances is estimated using a model for the years 1990-2010. Fuel consumption for companies with 10-49 employees is taken from Annual statistics on energy use in manufacturing industry and the average use of fuel per employee is calculated. The two information sources are combined to estimate the fuel consumption in small companies. In 2012, the annual statistics on energy use in manufacturing industries (ISEN) for the reference year 2011 included a sample survey to small companies as well. The results were not published in ISEN but in the annual energy balance for 2011, which was published in 2013 and used in submission 2014 as activity data source for small enterprises.

2.1.11 EU Emission Trading System (ETS)

Data from the EU Emission Trading System (EU-ETS) is used, since submission 2007 and emission years 2005 and later, for oil refineries (CRT 1.A.1.b, 1.B.2.a and 1.B.2.C.2.1), as a SMED study during 2006[15] showed that this is the most

[10] Statistics Sweden, 1986

[11] Statistics Sweden, 2005

[12] Statistics Sweden JO36SM, 1991, 94, 97, 2000, 2003, 2006, 2010

[13] Statistics Sweden JO63SM, 1995, 2003, 2008

[14] ER 2007:15. Energianvändningen inom skogsbruket 2005

[15] Backman & Gustafsson, 2006

accurate data source for these facilities. In addition, EU-ETS data is used for the three cement producing facilities for 2008 and onwards, one plant in CRT 1.A.2.e for 2006 and one plant in CRT 1.A.2.c for 2008 and onwards, since the EU-ETS data contains more detailed information on fuel types for these facilities. EU-ETS data is also used for verification of other data sources, e.g. official energy statistics (KvBr or ISEN) and environmental reports. For example, official energy consumption statistics for large facilities within the chemical industry and the steel producing industry are regularly compared with ETS data, and if major differences should be discovered, further investigations are made. Furthermore, summed up plant-specific emissions allocated to the energy sector (CRT 1) and industrial processes (CRT 2) plants are compared to total emissions reported to the EU-ETS applying a cross-sectoral control tool which serves as QC procedure (see NIR section 1.3.5.1 for more detailed description). As mentioned above, for technical reasons, it is not possible to use EU-ETS data as major source of activity data for stationary combustion. Another reason not to use EU-ETS data for stationary combustion as the main data source is that in some facilities only some of the installations within the facility are included in the trading scheme, and the definition of which installations that should be included has changed between the first and second trading period.

Mass balances reported to EU-ETS for the two primary iron and steel works are used for allocation of emissions and energy flows in these plants (see annex 3.5).

2.1.12 Environmental reports

Data on fuel consumption in refineries, CRT 1.A.1.b, 1B.2.A.1, 1.B.2.A.4 and 1.B.2.C.2.1, is often collected from environmental reports in cases when the data sources mentioned above are not considered to be accurate. (This mostly applies to the years before 2005, when EU-ETS was introduced). For one refinery, environmental reports are the only data source for the years 2002-2007. Environmental reports are also an important data source for fuel consumption and emissions in chemical industries (CRT 1.A.2.c, 2.B.10.a). Though in later years, fuel consumption is taken from the Quarterly fuel statistics since it has shown to be complete. Data for the two largest integrated iron and steel works (1.A.1.c, 1.A.2.a, 1.B.1.b, 1.B.1.c, 2.C.1.b) are based on information from the companies' legal environmental reports. Environmental reports are also used for verification of the Quarterly fuel statistics data for some selected plants in the same way as ETS data is used.

2.1.13 Contacts with operators

For earlier years, i.e. 2005 and before, data on fuel consumption in refineries, CRT 1.A.1.b, and chemical industries, CRT 1.A.2.c, was in many cases collected by means of direct contacts with the operators, as activity data was not sufficiently covered in regular surveys or administrative sources. Operators are sometimes also contacted to verify or correct data that is suspected to contain errors. Since submission 2010, the largest iron and steel company has been involved in the improvements in methodology and data for these sectors (1.A.1.c, 1.A.2.a, 1.B.1.b, 1.B.1.c, 2.C.1.b). The methodology used is described in NIR section 3.2.9.

2.1.14 Data sources for navigation

The fuel consumption for national and international navigation, except for leisure boats, was in previous submissions (prior to submission 2019) based on the monthly survey on supply and delivery of petroleum products[16]. But it was problematic for the suppliers of fuel to separate the fuel supplied to national respectively international navigation. As the monthly survey of fuel supply statistics was revised[17], the fuel for national and international navigation was no longer split up in the survey. Instead, the result from the survey only show the total supply of fuel for national and international navigation in Sweden.

The fuel consumption for domestic navigation[18] is estimated by the Shipair model as from submission 2020. Shipair is developed by the Swedish meteorological and hydrological institute (SMHI). The Shipair model collects AIS data (Automatic Identification System), which is used by the ships to transmit identity and position information and shows how the ships move between Swedish ports. Information regarding the ships, such as size, engine power and type of vessel is also collected from different databases. This enables the Shipair model to estimate the energy consumption and the amount of fuel.

Beside the Shipair model, the energy consumption from domestic navigation is based on a survey of the largest shipping actors for national navigation, with the exception for cargo ships.[19] The survey asks for the fuel consumption by fuel type, since Shipair does not have information regarding which fueltype is used. The difference between the fuel consumption estimated by Shipair and by the survey, is assumed to be the fuelconsumption by cargo ships.

The consumption of LNG (liquid natural gas) by navigation was first included in submission 2021 for the year 2019. In submission 2022, data for 2018 and 2020 was added. The data is based on a survey, which took place in 2020, 2021, 2022 and 2023, aiming to map the consumption of LNG by both national and

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

[17] The revised monthly survey of fuel supply statistics was implemented in january 2018.

[18] Excluding leisure boats.

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

international navigation[20,21,22]. The emission factors for LNG are based on a study from 2020.[23]

The fuel consumption of international navigation is estimated as the difference between the total supply of fuel for navigation in the monthly survey of fuel supply statistics and the estimated energy consumption for national statistics.

2.1.15 Fuel allocation

Activity data for stationary combustion is based on fuels consumption at fuel type level and is for the GHG inventory aggregated into fuel groups according to Table A2.4.

Table A2.4. Fuel type allocation in submission 2024.

Activity Data Fuel Type	CRT Fuel Group
Domestic fuel oil, Residual fuel oil, LPG, Kerosene, Petroleum coke, Other petroleum fuels, Refinery gas, Fuel oil, Methane and fuel gases	Liquid Fuels
Natural gas & LNG	Gaseous Fuels
Coke oven gas, Blast furnace cas, LD-gas, Coking coal, Coke, Coal, Other solid fuels, Carbide furnace gas, Charcoal,	Solid Fuels
Fossil fraction of waste & Other non secified fossil fuels	Other fossil Fuels
Peat	Peat
Wood Fuels, Spent Liqour, Tall and Pitch Oil, Land fill gas, Other Biomass, Biogenic fraction of waste	Biomass

2.1.16 Other data sources for mobile combustion

Beside using statistics on supply and delivery of petroleum products[24], data reported according to the Swedish fuel quality act, data from the Shipair model (SMHI) and the survey of the largest shipping actors for national navigation, the following sources are used:

- Swedish Transport Administration (emission data for road traffic and railways),
- the Swedish Transport Agency (emission data for aviation),
- the Swedish Energy Agency,
- the Swedish Armed Forces (fuel consumption),
- the Swedish Biogas Association (consumption of biogas)
- and several official reports.

[20] Eklund, et al. 2020. Sjöfartens förbrukning av LNG.

[21] Eklund et al. 2021. Sjöfartens förbrukning av LNG 2020.

[22] Eklund et al. 2022. Sjöfartens förbrukning av LNG 2021.

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

[24] Monthly fuel, gas and inventory statistics. https://www.scb.se/en/finding-statistics/statistics-by-subject-area/energy/energy-supply-and-use/monthly-fuel-gas-and-inventory-statistics/

2.2 Net calorific values

Unless otherwise stated, NCVs for each fuel type are produced by Statistics Sweden based on information from energy surveys. All NCVs refer to net calorific values (NCV) as recommended by the IPCC Guidelines. All NCVs including references are enclosed in Table A2.6. Most NCVs are calculated on the basis of chemical qualities and are considered to be of good quality. When possible, the same NCVs are used in the Reference and Sectoral approaches. However, in the reference approach, it is normally not possible to use specific NCVs for each reporting company. Instead, the national NCVs recommended by the Swedish Energy agency, which are also used in the energy balances, are used for all parameters in the reference approach, which can cause minor differences between the reference and sectoral approaches. For some fuels, e.g. crude oil, NCVs are not provided by the Swedish Energy Agency. For these fuels, default values from IPCC 2006 Guidelines are used.

In the inventory, activity data for 1990-2006 on many fuel types are reported in tonne oil equivalents (toe), which is an energy unit. For these fuels the conversion factor of 41.87 GJ/toe is applied. In the energy surveys done by Statistics Sweden, these fuels are reported in mass unit/volume unit as well as the energy content (due to that the NCV often varies a lot for these fuel types). To facilitate data processing, Statistics Sweden calculates the energy content in toe from this information and the result is then used in the greenhouse gas inventory. This implies that the energy content of fuels concerned is very precise.

For 2007 and later years, energy data are taken directly from the Quarterly fuel statistics data bases, enabling the use of facility-specific NCVs in the GHG inventory without performing the calculation of toe. NCVs for 2007 and later years are considered to be of excellent quality. The time series is considered to be consistent, since the conversions to toe made 2006 and earlier, made use of the same information that is used to calculate energy amounts 2007 and onwards. The only difference is that prior to 2007, the energy statistics department made these calculations, and 2007 and later, the calculations are made by the GHG inventory staff.

Fuels that are standardized products, such as for instance residual fuel oil or liquefied petroleum gas (LPG) have calorific values that do not change between years. In submission 2010 some revisions were made. In earlier submissions, the NCV for biogas used for transports (this amount increases each year) was not known and therefore the NCV for natural gas was used for this fuel. In a SMED study[25] performed in 2009, a correct NCV for biogas was provided from the biogas

[25] Paulrud et al. 2010.

supplier AGA. The same study also resulted in revision of the NCVs for ethanol (new NCV taken from Handbook of Chemistry and Physics) and Fatty Acid Methyl Ester (FAME).

An overview of the NCVs used is shown in Table A2.5. For all mobile combustion, and for standard fuels for stationary combustion, national emission factors are used. For non-standard fuels, median, maximum and minimum NCVs are shown. Statistics are based on more than 100 observations unless otherwise stated in the remark column.

Table A2.5. Net Calorific Values (NCVs) used for 2022 in submission 2024.

Fuel type	Unit	Median	Min	Max	Remark
Blast furnace gas	GJ/1000m3	2.91	2.86	2.96	Less than 20 observations 1990-2022
Coke	GJ/tonne	28.04	27	28.08	Less than 20 observations 1990-2022
Coke oven gas	GJ/1000m3	17.51	17.39	17.92	Less than 20 observations 1990-2022
Coking coal	GJ/tonne	26.12	25.05	28.39	Less than 20 observations 1990-2022
Diesel Oil	GJ/m3	35.29	35.29	35.29	Stationary combustion
Domestic Heating Oil	GJ/m3	35.82	35.82	35.82	Stationary combustion
Kerosene	GJ/m3	34.34	34.34	34.34	Less than 20 observations 1990-2022
LNG	GJ/tonne	48.89	48.89	48.89	Less than 20 observations 1990-2022
LPG	GJ/tonne	46.04	46.04	46.05	
Landfill gas	GJ/1000m3	36.33	9	46.04	20-99 observations 1990-2022
Landfill gas	GJ/tonne	48.89	36	48.89	Less than 20 observations 1990-2022
Natural Gas	GJ/1000m3	39.6	39.6	39.6	Year specific NCV:s, www.ens.dk
Other biomass	GJ/m3	33.55	29.99	41.96	
Other biomass	GJ/tonne	32.94	5.6	38.16	20-99 observations 1990-2022
Other non specified	GJ/1000m3	6.47	6.47	6.47	Less than 20 observations 1990-2022
Other non specified	GJ/m3	27.61	21.67	33.55	Less than 20 observations 1990-2022

Fuel type	Unit	Median	Min	Max	Remark
Other petroleum fuels	GJ/m3	22.64	22.64	22.64	Less than 20 observations 1990-2022
Other petroleum fuels	GJ/tonne	42.62	41.18	44.07	Less than 20 observations 1990-2022
Other solid fuels	GJ/m3	31.32	31.32	31.32	Less than 20 observations 1990-2022
Peat	GJ/tonne	10.62	8.82	17.46	Less than 20 observations 1990-2022
Petroleum coke	GJ/tonne	35.29	35.29	35.29	Less than 20 observations 1990-2022
Residual Fuel Oil	GJ/m3	38.34	37.44	38.34	
Steel converter gas	GJ/1000m3	7.8	7.8	7.9	Less than 20 observations 1990-2022
Tall oil	GJ/m3	37.06	34.13	39.92	Less than 20 observations 1990-2022
Tall oil	GJ/tonne	37.56	36.72	39.38	Less than 20 observations 1990-2022
Waste	GJ/tonne	11.81	2.88	14.73	
Wooden fuels	GJ/m3	2.8	1.16	17.64	
Wooden fuels	GJ/tonne	17.28	6.67	18.72	
Gasoline	GJ/m^3	32.78			Mobile combustion, all sources
Biogas	GJ/1000 m^3	34.9			Mobile combustion, all sources
Diesel oil	GJ/m^3	*			Mobile combustion. Year specific NCV:s, see separate table
Marine gasoil	GJ/m^3	35.868			Navigation
Residual fuel oil	GJ/m^3	39.53			Navigation
Ethanol	GJ/m^3	21.20			Road traffic
ETBE	GJ/m^3	25.99			Road traffic
FAME	GJ/m^3	33.00			Road traffic
HVO	GJ/m^3	33.98			Road traffic
Aviation Gasoline	GJ/m^3	31.45			Aviation
Aviation Kerosene Fossil	GJ/m^3	35.28			Aviation
Aviation Kerosene bio	GJ/m^3	34.0			Aviation
Jet Gasoline	GJ/m^3	32.7			Aviation
Natural gas (CNG)	GJ/ 1000 m^3	39.6			Road traffic
LNG	GJ/ m^3	22.19			Navigation

Fuel type	Unit	Median	Min	Max	Remark
LBG	GJ/ m^3	21.55			Navigation

Note: refinery gas and petrochemical by product gases are reported in various units and plant specific NCV:s are used.

2.2.1 Liquid fuels

For diesel oil, the NCV used in the inventory shows a decreasing trend. In Sweden, this fuel type is separated into three different fuel classes; diesel of environmental classes (EC) 1-3. EC 1 has the best environmental qualities, for instance lower content on aromatic hydrocarbons. EC 1 also has a lower NCV. EC 3 affects the environment most and has a higher NCV.[26] In 1990, EC 3 was the most common type of diesel. Over the years, the use of environmental class 3 has decreased and instead environmental class 2 and 1 are more common. In the inventory, the mix of environmental class 1-3 used each year is taken into account when calculating a NCV, which is appropriate for each year. Year-specific NCVs for diesel are shown in Table A2.6.

Table A2.6. NCVs (NCV) for diesel except railways.

Years	NCV (GJ/m^3)
1990	35.82
1991	35.69
1992	35.55
1993	35.40
1994	35.43
1995	35.44
1996	35.36
1997	35.34
1998	35.33
1999-2000	35.31
2001-2006	35.29
2007-2022	35.28

NCVs for different oils (except oils used in navigation) are based on information from Drivkraft Sverige, which in turn is based on information from oil companies and is crosschecked with Swedish standards for calculating NCVs. NCVs for marine diesel oil, marine gas oil and residual fuel oil used for navigation are according to a SMED study in 2004.[27]

[26] https://drivkraftsverige.se/uppslagsverk/fakta/berakningsfaktorer/energiinnehall-densitet-och-koldioxidemission/ 2023-01-04

[27] Cooper & Gustafsson, 2004.

NCVs for refinery gases and other oils in refineries are specific for each operator and fuel. Data on consumption of fuels in tonne (or sometimes m^3) and corresponding NCVs are collected. Activity data for these fuels, used by refineries and chemical industries, is for 2007 and later mainly taken from the EU ETS system, and in most cases plant-specific NCVs of excellent quality are also reported and used in the GHG inventory. In other cases, NCVs from the environmental reports are used.

In submission 2010, the NCVs for gasoline, aviation kerosene and aviation gasoline were revised following a SMED Study. The conclusion of the study was that NCVs used for these fuels before submission 2010 were not well documented. NCVs according to the 2006 IPCC Guidelines are now used, since the NCVs used earlier for these fuels were concluded to be of questionable quality. There is no indication that carbon content or NCV for aviation kerosene and aviation gasoline sold in Sweden should differ from international standards. The properties of aviation fuels are normally the same in all countries, and hence it is appropriate to use the values recommended by IPCC. The NCV for gasoline is since submission 2010 from Drivkraft Sverige and relies on fuel analyses.[28]

The NCV for petroleum coke is based on information from consumers taken from the different energy surveys done by Statistics Sweden and is therefore considered to be of good quality. The NCV for diesel used for stationary combustion is according to SPI likely approximately the same mix of environmental classes as mobile diesel for each year. Using the same NCVs as for mobile diesel therefore gives correct time series.

In 1990-2010, naphtha was used as raw material for production of gas works gas. Since 2011, liquefied natural gas is used instead. However, the gas is mixed with air and the quality of the gas delivered to the transmission net (in terms of methane content and NCV) is stated to be similar to how it was before the change of feedstock[29]. Hence, the same NCVs and emission factors are used for gas works gas for 2011 as for earlier years. Since natural gas liquids are allocated to liquid fuels in the CRT reporter in table 1.Ab, we have chosen to allocate the gas works gas consumed in 2011 and onwards to liquid fuels also in the sectoral approach.

Solid fuels and peat

For coke oven gas, blast furnace gas and steel converter gas, the NCVs change between years, but there is no trend in the changes, only annual fluctuations due to the quality of used primary fuels each year. NCVs used in the inventory are based on annual information from the consumers (quite few) on actual energy content, and the quality of the NCV is considered to be very good.

[28] Paulrud et al. 2010

[29] Stockholm Gas, 2012

For carbon products such as coal and coke, it is difficult to establish the NCV due to lack of information on energy content in imported fuels. For 2007 and later years, NCVs reported from the consumers are used when available. Slightly more than half of the reported observations of combusted coal in the the Quarterly fuel statistics include specific NCVs. For coke, this share is about 75%.

Where no NCV is reported, the standard NCV provided from the Swedish Energy Agency is used. Hence, the NCVs used for 2007 and later are considered to be of high quality.

2.2.2 Gaseous fuels

Natural gas is a non-processed primary fuel, and hence the NCV changes between years, however without any trend. All natural gas consumed in Sweden is imported from Denmark, except for LNG which is imported from Norway and northern Europe.

Since submission 2019, Sweden uses the same NCVs for the natural gas imported from Denmark as reported in Denmarks National Inventory[30]. The NCVs used are shown in Table A2.7. The NCV used for LNG is based on values from the Swedish Energy Agency.

Table A2.7. Net calorific values (NCV) for natural gas, all consumption.

Years	NCV CNG (TJ/1000 m^3)	NCV LNG (TJ/1000 m3)
1990-1992	39	-
1993-1996	39.3	-
1997	39.6	-
1998	39.9	-
1999	40	-
2000	40.15	-
2001	39.97	-
2002	40.03	-
2003	39.94	-
2004	39.77	-
2005	39.67	-
2006	39.54	-
2007	39.59	-
2008	39.49	-
2009-2016	39.46	-
2017	39.62	-
2018	39.60	-
2019-2022	39.60	22.194

30 Energistyrelsen, 2021-12-06 (https://ens.dk/sites/ens.dk/files/CO2/standardfaktorer_for_2020.pdf)

2.2.3 Biomass

Data for 2006 and earlier for wood, black liquor, tall oil, landfill gas and other biomass, other petroleum fuels, other solid fuels and other not specified fuels, is reported to Statistics Sweden by surveyed consumers in toe, and the conversion factors are thereby set to 41.87 GJ/toe for these fuels. For 2007 and later years, this is true for CRT 1.A.4. For the other sectors, only black liquor is reported in toe. Other biomass is reported in several different units, e.g. tonne, m^3 or MWh, and NCVs are reported together with the quantity. These NCV:s are considered to be accurate.

The net calorific value for ethanol is provided by Drivkraft Sverige (formerly SPBI[31]) and is 21.2 GJ/m^3 or 26.9 MJ/kg. The net calorific values for ETBE (25.992 GJ/m^3) and HVO (33.984 GJ/m^3) are based on information from the Swedish Energy Agency[32]. The net calorific value for FAME (33 GJ/m^3) is based on a SMED report[33].

2.2.4 Other fuels

Data for waste and other not specified fuels is reported to Statistics Sweden through a survey to consumers in toe, and the conversion factors are thereby set to 41.87 GJ/toe for these fuels. In 2007 and later, waste was combusted within CRT 1.A.1.a only and the reporting unit was tonne. The NCVs for waste reported by the consumers are considered to be accurate, and thus these NCV:s were used for 2007 and later. For other not specified fuels the reporting units vary, and reported NCVs are used (sometimes, the fuel quantities are reported in an energy unit , e.g. MWh).

2.3 Emission factors

Emission factors for CO_2 and SO_2 depend on the content of carbon and sulphur in the fuels. For SO_2, the emissions also depend on how efficient the emission control in the plant is, for instance if scrubbers are used. For most fuels, the CO_2 emission factors do not change over the years. One exception is the emission factor for CO_2 from diesel oil. As discussed for NCV:s above (1.2.1), there are three environmental classes (EC) for diesel oil in Sweden, and the emission factor used each year reflects the mix of EC:s that year. Other exceptions are non-standard fuels that are by-products of industrial processes, such as e.g. blast furnace-, coke oven- and steel converter gas from the integrated iron and steel industry, refinery gases, and gases produced in the petrochemical industry. These gases are used as fuels, and their NCV:s and carbon content varies between years. From submission

[31] Swedish Petroleum and Biofuel Institute

[32] http://www.energimyndigheten.se/statistik/den-officiella-statistiken/statistikprodukter/varmevarden-och-densiteter/

[33] Paulrud, S, Fridell, E, Stripple, H, Gustafsson, T. 2010. *Uppdatering av klimatrelaterade emissionsfaktorer.* SMED report 92:2010

2017, also the emission factor for combustion of waste is variable in time for the 7 largest incineration plants in Sweden.

Other emission factors, e.g. for N_2O, CH_4, NMVOC, CO and NOx, depend on area of consumption and/or the used combustion technique. The efficiency of emission control in the plant is also important. Therefore, these emission factors change over the years as ovens, combustion technique and emission control used becomes better.

2.3.1 Overview of emission factors for greenhouse gases

Emission factors for CO_2, CH_4 and N_2O for selected years are shown in in Table A2.8 to Table A2.11. Many of the emission factors for stationary combustion are the same for all years, and hence only a few years are shown in the tables. For CH_4 and N_2O, the emission factors are only shown for stationary combustion as emissions of these gases from mobile combustion are estimated with model calculations and not as the product of fuel consumption and an emission factor. A complete list of emission factors for all fuels, years and substances can be found at the Swedish EPA website, including full references[34].

[34] http://www.naturvardsverket.se, search for “Beräkna utsläpp”,

Table A2.8. Emission factors for CO_2 (mobile combustion), kg/GJ for selected years.

Table A2.8. Emission factors for CO_2 (mobile combustion), kg/GJ for selected years								
Fuel type	**Sector**	**1990**	**2000**	**2005**	**2010**	**2015**	**2020**	**Source**
Aviation Gasoline	Domestic	70.00	70.00	70.00	70.00	70.0	70.0	Paulrud, Fridell, Stripple & Gustafsson, 2010
Aviation Kerosene fossil	Domestic	71.5	71.5	71.5	71.5	71.5	71.5	2006 IPCC GL
Aviation Kerosene bio	Domestic	71.5	71.5	71.5	71.5	71.5	71.5	2006 IPCC GL
Biogas	Bus	NO	NO	56.10	56.10	56.10	56.10	Danska energinet
Biogas (CBG)	Passenger Cars	NO	NO	56.10	56.10	56.10	56.10	Danska energinet
Biogas (LBG)	Navigation	56.35	56.35	56.35	56.35	56.35	56.35	Vad är energiinnehållet i naturgas, biogas och fordonsgas? - Energigas Sverige
Diesel Oil	Navigation/Shipping	74.26	72.2	72.2	72.2	72.2	72.2	Paulrud, Fridell, Stripple & Gustafsson, 2010 (1990-2005), Mawdsley, Jerksjö m.fl. 2021, "SMED memo 2021. CO2 emission factor for fossil diesel fuel" (1996->).
Marine gasoil	Fisheries	73.76	73,76	73,76	73,76	73,76	73,76	Helbig, Mawdsley et al. 2018
Diesel Oil	Railways	74.26	72.2	72.2	72.2	72.2	72.2	Paulrud, Fridell, Stripple & Gustafsson, 2010 (1990-2005), "SMED memo 2021. CO2 emission factor for fossil diesel fuel" (1996->).
Diesel Oil	Road traffic; all vehicles	74.26	72.2	72.2	72.2	72.2	72.2	Paulrud, Fridell, Stripple & Gustafsson, 2010 (1990-2005), Mawdsley, Jerksjö m.fl. 2021 "SMED memo 2021. CO2 emission factor for fossil diesel fuel" (1996->).
Diesel Oil	Small boats	74.26	72.2	72.2	72.2	72.2	72.2	Paulrud, Fridell, Stripple & Gustafsson, 2010 (1990-2005), Mawdsley, Jerksjö m.fl. 2021, "SMED memo 2021. CO2 emission factor for fossil diesel fuel" (1996->).
Diesel Oil	Working machinery; all sectors	74.26	72.2	72.2	72.2	72.2	72.2	Paulrud, Fridell, Stripple & Gustafsson, 2010 (1990-2005), Mawdsley, Jerksjö m.fl. 2021 "SMED

Table A2.8. Emission factors for CO_2 (mobile combustion), kg/GJ for selected years

Fuel type	Sector	1990	2000	2005	2010	2015	2020	Source
								memo 2021. CO2 emission factor for fossil diesel fuel" (1996->).
Marine gasoil	Navigation/Shipping	73.76	73.76	73.76	73.76	73.76	73.76	Helbig, Mawdsley et al. 2018
Gasoline	All sectors	72.0	72.0	72.0	72.0	72.0	72.0	Drivkraft Sverige
Natural Gas (CNG)	Road traffic	56.6	57.4	56.8	56.74	57.06	55.52	Energinet, www.ens.dk
Natural Gas (LNG)	Navigation	54.7	54.7	54.7	54.7	54.7	54.7	Hult & Winnes, IVL 2020

Table A2.9. Emission factors for CO_2 (stationary combustion), kg/GJ for selected years.

Table A2.9. Emission factors for CO_2 (stationary combustion), kg/GJ for selected years.

Fuel type	Sector	1990	2000	2005	2010	2015	2020	2021	2022	Source
Biogenic waste	Industry	94.3	94.3	94.3	NO	NO	NO	NO	NO	Mawdsley, I., Wisell, T., Stripple, H., Ortiz, C. 2016
Waste biogenic fraction	Power plants and district heating	60.37	60.37	60.37	60.37	56.45	58,54	58,54	51.35	Mawdsley, I., Wisell, T., Stripple, H., Ortiz, C. 2016; Swedish Waste Association
Waste fossil fraction	Power plants and district heating	33.95	33.95	33.95	33.95	38.45	38.83	38.83	42.45	Mawdsley, I., Wisell, T., Stripple, H., Ortiz, C. 2016; Swedish Waste Association
Blast furnace gas	Iron and steel production	274.45	274.45	228.82	301.9	326.9	307.5	310.3	328.59	Gustafsson, Lidén & Gerner, 2011
Charcoal	Small scale combustion	112	112	112	112	112	112	112	112	Boström et al. 2004a.
Coke	All consumption	103	103	103	103	103	103	103	103	2006 IPCC GL
Coke oven gas	Iron and steel production	44.36	44.16	41.57	44.81	52.09	46.47	45.16	48.00	Gustafsson, Lidén & Gerner, 2011
Coking coal	All consumption	90.7	93	93	93	93	93	93	93	Boström et al., 2004a
Diesel Oil	All consumption	74.26	72.2	72.2	72.2	72.2	72.2	72.2	72.2	Mawdsley I., Jerksjö M., Yaramenka K., Eklund V.2021. CO2 emission factor for fossil diesel fuel. SMED Memorandum 2021.
Domestic Heating Oil	All consumption	74.26	72.26	74.26	74.26	74.26	74.26	74.26	74.26	Swedish Petroleum and Biofuel Institute
Gas works gas	All consumption	52	52	52	52	56.6	56.6	56.6	56.6	Nyström & Cooper, 2005.
Kerosene	All consumption	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9	2006 IPCC GL
Landfill gas	All consumption	93	93	93	93	93	93	93	93	Helbig et al. 2018
LNG	All consumption	NO	NO	NO	NO	NO	56.5	56.5	56.5	Josefsson Ortiz et al. 2022.
LPG	All consumption	65.1	65.1	65.1	65.1	65.1	65.1	65.1	65.1	Mawdsley et al 2022b
Methane etc.	All consumption	55	50	52.7	49.7	57.3	49.4	46.7	47.21	Plant specific data
Natural Gas	All consumption	56.6	57.4	56.8	56.7	57.1	55.52	55.47	56.38	Energinet, www.ens.dk
Other biomass	All consumption	81	81	81	81	81	81	81	81	Mawdsley, I. et al. 2022.
Other non specified	All consumption	30	30	30	30	30	30	30	30	Mawdsley, I. et al. 2022.

Table A2.9. Emission factors for CO_2 (stationary combustion), kg/GJ for selected years.

Fuel type	Sector	1990	2000	2005	2010	2015	2020	2021	2022	Source
Other solid fuels	All consumption	70	70	70	70	70	70	70	70	Mawdsley, I. et al. 2022.
Peat	All consumption	105.2	105.2	105.2	105.2	105.2	105.2	105.2	105.2	Helbig et al. 2018
Petroleum coke	All consumption	100	100	100	100	100	100	100	100	Nyström & Cooper, 2005
Refinery gas	Refineries	59.3	59.3	59.3	56.2	52.5	68.04	72.5	69.40917	Nyström & Cooper, 2005. 2008 and later: plant specific data.
Residual Fuel Oil	All consumption	76.2	76.2	76.2	76.2	76.2	76.2	76.2	76.2	Paulrud et al. 2010
Tall oil	All consumption	76	76	76	76	76	76	76	76	Mawdsley, I. et al. 2022.
Waste fossil	Industry	33.95	33.95							2006 IPCC GL

Table A2.10. Emission factors for CH_4 (stationary combustion), kg/GJ for selected years.

Fuel type	Sector	1990	2000	2010	2015	2020	2021	2022	Source
Biogenic waste	Industry	0.02	0.02	NO	NO	NO	NO	NO	Boström et al., 2004a
Waste fossil and biogenic fraction	Power plants and district heating	0.02	0.005	0.005	0.005	0.005	0.005	0.005	Boström et al., 2004a
Blast furnace gas	Industry, power plants and district heating	0.001	0.001	0.001	0.001	0.001	0.001	0.001	2006 IPCC GL
Charcoal	Small scale combustion	0.2	0.2	0.2	0.2	0.2	0.2	0.2	2006 IPCC GL
Coke	Industry	0.001	0. 001	0. 001	0. 001	0.001	0.001	0.001	Boström et al., 2004a
Coke	Other consumption	0.004	NO	NO	NO	NO	NO	NO	Boström et al., 2004a
Coke oven gas	Industry, power plants and district heating	0.001	0.001	0.001	0.001	0.001	0.001	0.001	2006 IPCC GL
Coking coal	Industry, power plants and district heating	0.001	0.001	0.001	0.001	0.001	0.001	0.001	Boström et al., 2004a. Mawdsley, I. et al 2016
Coking coal	Other consumption	0.004	0.004	NO	NO	NO	NO	NO	Boström et al., 2004a. Mawdsley, I. et al 2016
Diesel Oil	Industry, power plants and district heating	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	Mawdsley, I. et al. 2022.
Domestic Heating Oil	Industry, power plants and district heating	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	Mawdsley, I. et al. 2022.
Domestic Heating Oil	Other consumption, small scale combustion	0.002	0.002	0.002	0.002	0.002	0.002	0.002	Boström et al., 2004a
Gas works gas	All combustion	0.001	0.001	0.001	0.001	0.001	0.001	0.001	Boström et al., 2004a
Kerosene	Industry, power plants and district heating	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	Mawdsley, I. et al. 2022
LPG	All combustion	0.001	0.001	0.001	0.001	0.001	0.001	0.001	Boström et al., 2004a
Landfill gas	Industry, power plants and district heating	NO	0.001	0.001	0.001	0.001	0.001	0.001	2006 IPCC GL

Table A2.10. Emission factors for CH_4 (stationary combustion), kg/GJ for selected years.

Fuel type	Sector	1990	2000	2010	2015	2020	2021	2022	Source
Methane etc.	Industry	0.0009	0.0009	0.001	0.001	0.001	0.001	0.001	Boström et al., 2004a
Natural Gas	All combustion	0.001	0.001	0.001	0.001	0.001	0.001	0.001	Boström et al., 2004a
Other biomass	Industry, power plants and district heating	0.01	0.01	0.01	0.01	0.01	0.01	0.01	Mawdsley, I. et al. 2022.
Other biomass	Other consumption, Agriculture	0.006	0.006	0.006	0.006	0.006	0.006	0.006	Helbig et al 2018
Other biomass	Other consumption, Other	0.09	0.09	0.09	0.09	0.09	0.09	0.09	Helbig et al 2018
Other non specified	Industry, power plants and district heating	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	NO	Mawdsley, I. et al. 2022
Other non specified	Other consumption	0.3	0.3	0.3	0.3	0.3	0.3	NO	Mawdsley, I. et al. 2022
Other petroleum fuels	Industry, power plants and district heating	0.002	0.002	0.002	0.002	0.002	0.002	0.002	Mawdsley, I. et al. 2022
Other solid fuels	Industry, power plants and district heating	0.004	0.004	0.004	0.004	0.004	0.004	0.004	Mawdsley, I. et al. 2022
Peat	Industry, Power plants and district heating	0.011	0.011	0.011	0.011	0.011	0.011	0.011	Mawdsley, I. et al 2016
Petroleum coke	Industry	0.001	0.001	0.001	0.001	0.001	0.001	0.001	Boström et al., 2004a
Refinery gas	Industry	0.001	0.001	0.001	0.001	0.001	0.001	0.001	2006 IPCC GL
Refinery oil	Industry	0.0008	0.0008	0.0008	0.0008	0.0008	NO	NO	Mawdsley, I. et al 2016
Residual Fuel Oil	Industry, power plants and district heating	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	Mawdsley, I. et al 2016
Residual Fuel Oil	Other consumption	0.003	0.003	0.003	0.003	0.003	0.003	0.003	Boström et al., 2004a
Steel converter gas	Industry, power plants and district heating	NO	0.001	0.001	0.001	0.001	0.001	0.001	2006 IPCC GL
Tall oil	Industry, power plants and district heating	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	2006 IPCC GL

Table A2.10. Emission factors for CH_4 (stationary combustion), kg/GJ for selected years.

Fuel type	Sector	1990	2000	2010	2015	2020	2021	2022	Source
Waste (non-biomass fr	Industry, Power plants and district heating	0.005	0.005	0.005	0.005	0.005	0.005	0.005	Mawdsley, I. et al. 2022
Wooden fuels	Households: Boilers: pellets	0.006	0.006	0.006	0.006	0.006	0.006	0.006	Mawdsley, I. et al 2016. Helbig et al 2018
Wooden fuels	Households: Boilers: wood chips	0.006	0.006	0.006	0.006	0.006	0.006	0.006	Mawdsley, I. et al 2016. Helbig et al 2018
Wooden fuels	Commercial/institutional, Households, Agriculture: Boilers: wood logs Traditional	0.088	0. 088	0. 088	0. 088	0.088	0.088	0.088	Mawdsley, I. et al 2016. Helbig et al 2018
Wooden fuels	Commercial/institutional, Households, Agriculture: Boilers: wood logs Modern	0.015	0.015	0.015	0.015	0.015	0.015	0.015	Mawdsley, I. et al 2016. Helbig et al 2018
Wooden fuels	Households: Open fire places	0.35	0.35	0.35	0.35	0.35	0.35	0.35	Mawdsley, I. et al 2016. Helbig et al 2018
Wooden fuels	Households: Stoves: pellets	NO	0.001	0.001	0.001	0.001	0.001	0.001	Mawdsley, I. et al 2016. Helbig et al 2018
Wooden fuels	Households: Stoves: wood chips	NO	0.099	NO	NO	NO	NO	NO	Mawdsley, I. et al 2016. Helbig et al 2018
Wooden fuels	Households: Stoves: wood logs Traditional	0.119	0. 119	0. 119	0. 119	0.119	0.119	0.119	Mawdsley, I. et al 2016. Helbig et al 2018
Wooden fuels	Households: Stoves: wood logs Modern	0.099	0.099	0.099	0.099	0.099	0.099	0.099	Mawdsley, I. et al 2016. Helbig et al 2018
Wooden fuels	Industry, power plants and district heating	0.011	0.011	0.011	0.011	0.011	0.011	0.011	Mawdsley, I. et al 2016. Helbig et al 2018
Wooden fuels	Commercial/institutional, Agriculture Boilers: pellets	0.06	0.06	0.06	0.06	0.06	0.06	0.06	Helbig et al 2019
Wooden fuels	Commercial/institutional, Agriculture Boilers: wood chips	0.06	0.06	0.06	0.06	0.06	0.06	0.06	Helbig et al 2019

Table A2.11. Emission factors for N_2O (stationary combustion) in kg/GJ for selected years.

Table A2.11. Emission factors for N_2O (stationary combustion) in kg/GJ for selected years.

Fuel type	Sector	1990	2000	2010	2015	2020	2021	2022	Source
Biogenic waste	Industry	0.004	0.004	NO	NO	NO	NO	NO	Boström et al., 2004a. Mawdsley, I. et al 2016
Biogenic waste	Power plants and district heating	0.005	0.004	0. 004	0. 004	0.004	0.004	0.004	Boström et al., 2004a. Mawdsley, I. et al 2016
Blast furnace gas	All consumption	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	Mawdsley & Stripple, 2014
Carbide furnace gas	All consumption	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	Mawdsley & Stripple, 2014
Charcoal	Small scale combustion	0.001	0.001	0.001	0.001	0.001	0.001	0.001	2006 IPCC GL
Coke	All consumption	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	Mawdsley & Stripple, 2014
Coke oven gas	All consumption	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	Mawdsley & Stripple, 2014
Coking coal	All consumption except pressurized fluidized bed	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	Mawdsley & Stripple, 2014
Coking coal	Pressurized fluidized bed	0.033	0.033	0.033	0.033	0.033	0.033	0.033	Mawdsley & Stripple, 2014
Domestic Heating Oil	All consumption	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	Mawdsley, I. et al 2022
Gas works gas	All consumption	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	Mawdsley & Stripple, 2014
Kerosene	All consumption	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	Mawdsley, I. et al 2016
LNG	All consumption	NO	NO	NO	NO	0.001	0.001	0.0001	Josefsson Ortiz, C. et al 2022
LPG	All consumption	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	Mawdsley & Stripple, 2014
Landfill gas	All consumption	NO	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	Mawdsley & Stripple, 2014
Methane etc.	Industry	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	Mawdsley & Stripple, 2014
Natural Gas	All consumption	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	Mawdsley & Stripple, 2014
Other biomass	All consumption	0.001	0.001	0.001	0.001	0.001	0.001	0.001	Mawdsley, I. et al 2022
Other non specified	Other consumption	0.004	0.004	0.004	0.004	0.004	0.004	NO	Mawdsley, I. et al 2022
Other non specified	Industry, Power plants and district heating	0.001	0.001	0.001	0.001	0.001	0.001	0.001	Mawdsley, I. et al 2022

Table A2.11. Emission factors for N_2O (stationary combustion) in kg/GJ for selected years.

Fuel type	Sector	1990	2000	2010	2015	2020	2021	2022	Source
Other petroleum fuels	All consumption	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	Mawdsley, I. et al 2022
Other solid fuels	All consumption	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	Mawdsley, I. et al 2022
Peat	All consumption	0.01	0.005	0.005	0.005	0.005	0.005	0.005	Boström et al., 2004a
Petroleum coke	All consumption	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	IPCC Guidelines 2006
Refinery gas	Industry	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	Mawdsley & Stripple, 2014
Refinery oil	Industry	0.0006	0.0006	0.0006	0.0006	0.0006	NO	NO	Boström et al., 2004a. Mawdsley, I. et al 2016
Residual Fuel Oil	All consumption	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	2006 IPCC GL
Steel converter gas	All consumption	NO	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	Mawdsley & Stripple, 2014
Tall oil	All consumption	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	Mawdsley et al. 2017 (2006 IPCC GL)
Waste (non-biomass fr	Industry	0.004	0.004	NO	NO	NO	NO	NO	Boström et al., 2004a. Mawdsley, I. et al 2016
Waste (non-biomass fr	Power plants and district heating	0.005	0. 004	0. 004	0.004	0.004	0.004	0.004	Boström et al., 2004a. Mawdsley, I. et al 2016
Wooden fuels	Industry	0.005	0.005	0.005	0.005	0.005	0.005	0.005	Boström et al., 2004a. Mawdsley, I. et al 2016
Wooden fuels	Power plants and district heating	0.003	0.003	0.003	0.003	0.003	0.003	0.003	Boström et al., 2004a. Mawdsley, I. et al 2016
Wooden fuels	Other consumption	0.004	0.004	0.004	0.004	0.004	0.004	0.004	2006 IPCC GL

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2.3.2 Stationary combustion

Emission factors depend on the type of fuel, and the type of plant and abatement equipment. Sine submission 2003 a series of development and revisions of emission factors were made and are summarised in table A2.12, including the latest revisions for submission 2023.

Table A2.12. Main revisions of emission factors for stationary combustion.

Submission	CRT	Emission factor revised	Fuel type	Reference
2003	All stationary, 1B	NMVOC	All fuel types	Kindbom et al., 2003
2006	All stationary	All emission factors	Most common fuel types	Boström et al. 2004
2011	All stationary, Mobile	CO_2, N_2O and CH_4	Gas works gas, natural gas, biogas, ethanol, FAME, gasoline, aviation gasoline and aviation kerosene, and the N_2O emission factor for petroleum (cracker) coke	Paulrud et al. 2010
2012	1A1a, 1A2c, 1B2	CO_2	Coke oven gas, blast furnace gas and steel converter gas, methane-based gas mixtures	
2014	All stationary	CO_2	Gas works gas	Jerksjö et al., 2013
2018	1A1, 1A2	CO_2, CH_4, N_2O, CO and SO_2	Several fuel types	Mawdsley, I., Stripple, H. 2017. Revision of emission factors for stationary combustion within the industrial sector, SMED Report No 7.
2019	All stationary	CO_2	Natural gas, peat and landfill gas	Energistyrelsen, 2018-11-26 (https://ens.dk/ansvarsomraader/co2-kvoter/stationaere-produktionsenheder/co2-rapportering-og-returnering) Helbig, T. Stripple, H., Hjort, A., Mawdsley, I. 2018. Uppdatering av emissionsfaktorer för CO_2 från torv och deponigas. SMED PM 2018-05-20.
2019	1A2	N_2O, CH_4, CO, SO_2,	Petroleum coke, coal, and domestic heating oil	

2019	1A4b	CH_4, CO and NMVOC	Wooden fuels	Helbig, T., Gustavsson, T., Kindbom, K. Jonsson, M. 2018. Uppdatering av nationella emissionsfaktorer för övrig sektor (CRT/NFR 1A4). SMED rapport no 13 2018.
2021	All stationary	All emission factors,	carbide furnace gas	Yaramenka, Yaramenka, K., Danielsson, H., Josefsson Ortiz, C., 2020, Improvements in reporting of emissions from carbide production. SMED report No 16 2020
2021	1A2f	CO_2	All fuels except biomass	Josefsson Ortiz, C. & Guban, P. 2020. Revidera AD och EF för Cementa för CO2-utsläpp. SMED PM.
2021	1A1b	SO_2	Several fuels	Yaramenka, K., Mawdsley, I., Kindbom, K., Josefsson Ortiz, C. 2020 Förbättring av utsäppsraportering från Sveriges raffinaderier – fokus på luftföroreningar och NEU. (Manuscript not yet published).
2022	All stationary	CO_2, SO_2	Diesel oil	Mawdsley I., Jerksjö M., Yaramenka K., Eklund V.2021. CO2 emission factor for fossil diesel fuel. SMED Memorandum 2021. Fridell, E., Mawdsley, I. & Eklund, V. 2021. Revised emission factors for shipping. SMED report no 15 2021. Agreement: 250-21-001.
2023	All stationary	CO_2, CH_4, N_2O, SO_2, NOx, NMVOC, and BC	Several fuels, focus on biomass and other fuel types	Mawdsley, I., Danielsson, H., Yaramenka, K., Josefsson Ortiz, C., Guban, P. 2022. Översyn av emissionsfaktorer inom stationär förbränning. SMED rapport nr 8. Avtal: 250-21-001.
2023	All stationary	CO_2	LNG	Josefsson Ortiz, C., Guban, P., Mawdsley, I., Yaramenka, K 2022. Updated CO2 emission factors for stationary combustion of LNG and blast furnace gases in Sweden. SMED rapport nr 7. Avtal 250-22-001.

In submission 2023, a major revision of CO_2, CH_4, N_2O, SO_2, NOx, NMVOC, and BC emission factors was made for several fuel types. The focus on the revision was on emission factors for biomass and other fuels, and to update factors with non transparent references[35]. As a result of this revision the following revisions were made:

- Emission factors for biogenic CO_2 from combustion of black liquor is updated from 96 to 105 kg/GJ,

[35] Mawdsley, I., Danielsson, H., Yaramenka, K., Josefsson Ortiz, C., Guban, P. 2022. Översyn av emissionsfaktorer inom stationär förbränning. SMED rapport nr 8. Avtal: 250-21-001.

- Emission factors fo CO_2 from combustion of wooden fuels, tall oil and other biomass was revised according to a more defined composition of the fuels. Wooden fuels from 96 to 105 kg/GJ, Tall oil from 75.3 to 76 kg/GJ and other biomass from 96 to 81 kg/GJ.
- Emission factors of other fuels were updated for CO_2, CH_4, N_2O, SO_2, NOx, NMVOC, and BC for other solid, other petroleum and other non specified fuels. CO_2 was revised for other soilid from 60 to 70 kg/GJ and for other non specified from 60 to 30 kg/GJ for all sectors. For CH_4 other solid, other non specified and other petroleum was revised, from 0.001 kg/GJ to 0.004 for other solid, 0.009 for other non specified and 0.002 for other petroleum for 1A1 and 1A2. For 1A4 CH_4 was revides for other non specified fuels from 0.001 to 0.3 kg/GJ.
- Emission factors that had the earlier referens “SEPA 1995” was revised for the fuel types (More details are found in Mawdsley et al. 2021):
    - Municipal waste for CH_4 in 1A2
    - Black liquor for N_2O, NMVOC, CO, NOx in all stationary CRT codes
    - Burning oil for CH_4 in all stationary CRT codes
    - Land fill gas for CH_4 in CRT 1A4, NOx in 1A2, NOx in 1A1a
    - Diesel oil for CH_4, NOx in all stationary codes
    - Gas/Diesel oil and residual fuel oil CH_4 for gas turbines
    - Gas/diesel oil for CH_4 and N_2O for all stationary codes
    - Residual fuel oil for CO (1A4), CH_4 (1A1a, 1A2) and N_2O (all CRT codes)
    - Kerosene for CH_4, CO_2 and N_2O for all stationary codes
    - Coke for CO_2 for all stationary codes
    - Refinery gas for CO for all stationary codes
    - Tall oil for CH_4 for all stationary codes
    - Wooden fuels for CH_4 and N_2O for 1A4

The largest effects are seen in N_2O emission in CRT 1A4 with an average decrease of 35%. The revision resulted in effets on the biogenic CO_2 emissions with an increase of 6-9 % in CRT 1A1, 1A2 and 1A4. Emissions of SO_2 decreased on average with 3-8% for CRT 1A1, 1A2 and 1A4. The corresponding decrease of CO was 4 and 6% for the stationary codes.

CO_2 emissions from combustion for stationary combustion (CRT 1A1a, b, c,1A2, 1A4) of LNG have been separated from natural gas in submission 2023. LNG occurs in the activity data from KvBr in the CRT/NFR codes 1A1a, 1A1b, 1A2a, 1A2b, 1A2c, 1A2d, 1A2e, 1A2f and 1A2g since emission year 2019. Most of the LNG is consumed by the industry sector in Sweden. The reported amounts of consumed LNG in KvBr were for 2019 around 13.5 % of the total reported natural gas. The share of consumed LNG in 2020 in 1A1 was 0.5 % and for 1A2 19 %.

The study presented a new emission factor for CO_2 and LNG of 56.5 kg/GJ and is used in the Swedish GHG-inventory for all years when LNG occurs. Other emissions originating from LNG combustion are suggested to have the same EF as natural gas (same as in submission 2022)[36].

As part of the QC activities, all national GHG emission factors used for stationary combustion are compared with the default values and confidence intervals given in the 2006 IPCC Guidelines. Most emission factors are found to be within the interval. There were, however, a few exceptions as described in Table A2.13.

Table A2.13. Emission factors outside the intervals given in the 2006 IPCC Guidelines.

Fuel type	CRT	GHG	EF (kg/GJ), low or high*	Explanation
Blast furnace gas	1A1a	CO_2	328,6 (high)	4)
Landfill gas	1A1, 1A2, 1A4	CO_2	93 (high)	
Waste	1A1a	CH_4	0.005 (low)	2)
Peat	1A1, 1A2	CH_4	0.011 (high)	1)
Wooden fuels	1A4	CH_4	Lower	5)
Residual fuel oil	1A4	N_2O	0.006 (high)	3)

* (low) indicates that national EF is lower than the lower limit of the confidence interval according to the guidelines, (high) indicates that it is higher than the upper limit.

Explanations:

1. The emission factors for peat are based on plant specific information[37].
2. The emission factor is based on facility specific information that indicates that the combustion in the Swedish plants is very effective which leads to lower emissions of CH_4[38].
3. The emission factor is based on a study from 2004[39]. Emission factors for N_2O for solid and gaseous fuels were reviewed and revised downwards in 2014[40], but liquid fuels were not prioritized this time.
4. The emission factor from the steel converter gases are at facility level.
5. Emission factors for wooden fuels have been updated and divided to a finer level in fuel type and combustion technology.

2.3.2.1 EMISSION FACTORS FOR CO_2 FOR COKE OVEN GAS, BLAST FURNACE GAS AND STEEL CONVERTER GAS

Emission factors for CO_2 for coke oven gas, blast furnace gas and steel converter gas for iron ore-based steel production are national and are used in a few public

[36] Josefsson Ortiz, C., Guban, P., Mawdsley, I., Yaramenka, K 2022. Updated CO2 emission factors for stationary combustion of LNG and blast furnace gases in Sweden. SMED rapport nr 7. Avtal 250-22-001.

[37] Mawdsley et al. 2016

[38] Boström et al., 2004

[39] Boström et al., 2004

[40] Mawdsley & Stripple, 2014

electricity and heat production plants. Since the 2010 submission, CO_2 emissions from coke production plants as well as from iron and steel production plants in the Swedish inventory are based on plant-specific carbon mass-balances.

The carbon mass-balances are made to control the flow of carbon and are based on the carbon content in incoming and outgoing materials:

Coke oven: coal + blast furnace gas
→ coke oven gas + coke + slag + tar + benzene

Blast furnace: coal + coke + iron pellets + limestone + briquettes
→ blast furnace gas + pig iron + slag + soot

Steel converter: crude iron + carbide
→ steel converter gas + crude steel + slag

The major part of these gases sold to companies in ISIC 40, i.e. CRT 1.A.1.a, is produced by one iron and steel production facility. This plant keeps a record of CO_2 emissions from the energy gases sold. In order to produce as good emission estimates as possible, these emissions are used together with energy amounts reported to the quarterly fuel survey. The emissions are, however, not separately calculated for the three different gases. Hence it is not considered relevant to calculate separate emission factors for each of the three gases, and thus an aggregate IEF is used.

A very minor part of the steel work gases used in CRT 1.A.1.a are produced by another facility not quoted above. For this facility, no data on CO_2 emissions from energy gases sold are available. The quality of the emission factor seems to be good for coke oven gas from 2001 and later on generally for steel converter gas. Unfortunately, carbon balances are not available prior to the years 2001. Hence the uncertainty of the values is higher for the years surrounding 1990 (about +/-10%) than for the years surrounding 2000 (about +/- 5%)[41].

2.3.2.2 EMISSION FACTORS FOR CO_2 FROM REFINERY GAS, PETROLEUM COKE AND CARBIDE FURNACE GAS

Emission factors for CO_2 from refinery gas, petroleum coke and carbide furnace used according to table A2.14[42].

Table A2.14. Emission factors on CO_2 for refinery gas and petroleum coke used since submission 2006.

Fuel type	CO_2 factor since submission 2006 Tonne CO_2/TJ
Refinery gas	59.3*
Petroleum coke	100

*for refinery gas, plant specific EFs are used for later years.

[41] Ivarsson, 2003.

[42] Paulrud et al. 2010

Plant-specific emission factors for CO_2 from refinery gas are used for 2008 and later years as they are readily available from the EU-ETS data, which is considered to be the most accurate data source in this respect. The implied average emission factor for refinery gas combusted in CRT 1.A.1.b in 2008 is slightly lower the one developed in submission 2006, and it is even lower in 2009 than 2008.

Carbide furnace gas is reallocated to CRT 2B5 as estimation of carbide furnace gas oxidation with one method increases accuracy, completeness and consistency of the data[43].

2.3.2.3 EMISSION FACTOR FOR CO_2 FROM METHANE-RICH GASES PRODUCED AND USED IN THE CHEMICAL INDUSTRY

In the petrochemical industry, considerable amounts of gas that is a by-product in various production processes are used for energy production. Flaring of this gas is also common. The gas is produced by one facility and used by a few other plants in the same municipality.

In ETS data for 2011 and later, there is sufficient information in ETS data and environmental reports to calculate plant specific emission factors for all facilities using this gas. A few facilities use the gas from the main producer, but some of them mix it with their own by-products and sometimes natural gas, which means that the emission factor is not exactly the same for all plants. This also implies that the emission factor for flared gas is not necessarily the same as the one for the gas combusted for energy production purposes.

In submission 2023, there was a reallocation of two facilities of one company between CRT 2 and 1.A. A developing study [44], where the company itself was involved, enabled the division of stationary and process based emissions. This reallocation of the stationary emissions of these two fascilites had lead to an increase of CO_2-emissions with around 14-20% between 1990 and 2012 and around 5% increase between 2013 and 2019 and in 2020 an increase of around 30%.

The emission factors shown in Table A2.15 are aggregate IEFs for all facilities using petrochemical by-product gases reported in CRT 1.A.2.c.

[43] Yaramenka, K., Danielsson, H., Josefsson Ortiz, C., 2020, Improvements in reporting of emissions from carbide production. SMED report No 16 2020

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

Table A2.15. Emission factor for CO_2 from methane rich gas in the petrochemical industry in submission 2024.

Year	IEF	Source
1990-2000	55.00	Plant-specific data
2005	52.70	Plant-specific data
2006	46.81	Plant-specific data
2007	57.00	Plant-specific data
2008	52.12	Plant-specific data
2009	56.85	Plant-specific data
2010	49.74	Plant-specific data
2011	51.83	Plant-specific data
2012	52.24	Plant-specific data
2013	61.44	Plant-specific data
2014	59.63	Plant-specific data
2015	57.28	Plant-specific data
2016	62.08	Plant-specific data
2017	61.74	Plant-specific data
2018	61.81	Plant-specific data
2019	58.55	Plant-specific data
2020	49.42	Plant-specific data
2021	46.73	Plant-specific data
2022	47.21	Plant-specific data

Annually, as a part of the QA/QC procedure, a cross-check of the emissions between CRT 1A1, 1A2, 1B and 2 is made in order to make sure that emissions are neither missing nor double counted in these CRT codes. The cross check is made against EU ETS and Environmental reports at fascility level.

2.3.2.4 EMISSION FACTORS FOR SO_2 AND NO_X FROM REFINERY OIL AND GAS

Emission factors for combustion of refinery gas and oil for NOx and SO_2 are from Yaramenka et al. 2020[45].

2.3.2.5 EMISSION FACTORS FOR COMBUSTION OF BIOMASS IN HOUSEHOLDS

For N_2O emission factors, no new measurement studies were carried out and no new information from the literature was found, and thus no adjustments were made. For NO_X emission factors, data from mainly six Swedish studies was used. The emission of NO_X for pellets varied between 30-80 mg/MJ and for wood logs between 20-120 mg/MJ.

The emission factors for CO are mainly based on measured emission data from Swedish residential biomass combustion experiments in the field as well as in the

[45] Yaramenka, K., Mawdsley, I., Kindbom, K., Josefsson Ortiz, C. 2020 Förbättring av utsäppsraportering från Sveriges raffinaderier – fokus på luftföroreningar och NEU. (Manuscript not yet published)

laboratory. The variation in CO emissions is usually large and the levels may sometimes be very high, especially from wood log combustion (up to 23,700 mg/MJ have been registered).

The fraction of methane in VOC (sum of methane and NMVOC) is approximately 20-40% by weight for pellet boilers and 30-70% by weight for wood boilers[46]. The emission factors used are based on data from measurements in Swedish residential biomass combustion experiments in the field as well as in the laboratory.

For SO_2 emission factors, an S-content of (0.01 wt% dry fuel) is applied, with the assumption that no sulphur is bound in the ash.

The emission factors used for Other biomass were in accordance with the emission factors revised for wooden combustion of Boiler - wood chips of revision in submission 2019. The revision of emission factors for Other biomass are presented in Table A2.16 [47].

Table A2.16. Emission factors for CH_4, N_2O, NOx, CO, NMVOC and SO_2 determined from small scale combustion of wood logs, pellets and wood chip using different combustion technologies. All data are presented as mg/MJ fuel.

Combustion technology	Fuel	Emission factor (average)					
		CH_4	N_2O	NO_X	CO	NMVOC	SO_2
Boilers Traditional	Wood logs	88	5	80	3842	552	10
Boilers Modern	Wood logs	15	5	80	1189	87	10
Boilers	Wood ships	6	5	80	430	59	10
Boilers	Pellets	6	5	65	339	17	10
Stoves Traditional	Wood logs	119	5	80	2371	199	10
Stoves Modern	Wood logs	99	5	80	1740	84	10
Stoves	Wood ships	*	*	*	*	*	*
Stoves	Pellets	1	5	65	208	4	10
Open fire places	Wood logs	350	5	80	4400	220	10
Open fire places	Wood chips	*	*	*	*	*	*
Open fire places	Pellets	*	*	*	*	*	*

2.3.2.6 EMISSION FACTORS FOR COMBUSTION OF BIOMASS IN THE COMMERCIAL/INSTITUTIONAL SECTOR AND AGRICULTURE/FORESTRY/FISHERY SECTOR

Emissions factors from small-scale stationary combustion of biomass in the commercial/institutional sector (CRT/NFR 1.A.4.a) and agriculture/forestry/fishery sector (CRT/NFR 1.A.4.c) for CH_4 , CO and NMVOC are found in Table A2.17.

[46] Johansson et al, 2004.

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

The calculations are based on technology-specific emission factors[48]. In order to apply these technology-specific emission factors, shares of fire wood, wood chips and wood pellets in total wood fuel amount were calculated per subsector and across the entire time series. As implemented for the household sector (CRT/NFR 1.A.4.b), emissions from fire wood are calculated by considering different shares of modern and traditional combustion units over time[49].

Table A2.17. Emission factors for CH_4, N_2O, CO and NMVOC determined combustion of wood logs, pellets and wood chip using different combustion technologies for commercial/Institutional sector and agricultural/Forestry/Fishery sector. All data are presented as mg/MJ fuel.

Combustion technology	Fuel	Emission factor (average) mg/MJ		
		CO	NMVOC	CH_4
Boilers	Pellet	339	17	6
Boilers	Wood chips	430	59	6
Boilers Traditional	Wood	3842	552	88
Boilers Modern	Wood	1189	87	15

2.3.2.7 EMISSION FACTORS FOR WASTE AND OTHER NON-SPECIFIED FUELS

The fuel category “other fuels” includes two types of fuels; fossil municipal/industrial waste and “other non-specified fuels”. The emission factors for CH_4 and N_2O from waste are from Boström et.al. 2004.

“Waste” is reported to the quarterly fuel statistics as one single fuel, but in the emission inventory, it has to be split into a fossil and a biogenic fraction. It was concluded that combustion of 1 GJ waste causes emissions of 94.3 kg CO_2, of which 33.95 kg is of fossil origin and 60.35 kg is biogenic. This implies that 36% of the CO_2 emissions are fossil, and as a rough assumption, both activity data and all emissions were allocated as 36% fossil and 64% biogenic. This means that for each of the fractions, the CO_2 emission factor is 94.3 kg/GJ[50].

The CO_2 emission factor for waste are from 2015 and later from the 8 largest incineration plants that report CO_2-emissions to the EU/ETS trading accounting. These emission factors are more accurate than the national one and are therefor since 2015 used from this source. These 8 largest plants stand for around 80% of all CO_2-emissions from waste incineration in this sector. The fraction of the fossil and biogenic part is found in table A2.18. For submission year 2024, emission years 2021 and 2022 were revised for waste. During submission 2023, data for

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

[49] Helbig, T. Kindbom, K. Jonsson, M. 2019. Uppdatering av nationella emissionsfaktorer för övrig sektor (CRT/NFR 1A4). SMED rapport no 12 2019

[50] Stripple et al., 2014

2020 was reused for the year 2021. This was revised based on new data that was made available for 2021. For 2021, the reference value was revised for the ^{14}C method[51] used because the previous reference value for the ^{14}C method was estimated to be too low compared to the ^{14}C in incineration.

Table A2.18. Emission factor for CO_2 from combustion of waste.

Year	CO_2, Fossil fraction	CO_2, Biogenic fraction	Fraction biogenic/fossil waste	CO_2, Total
2014	33.95	60.39	64/36	94.32
2015	38.45	56.45	59.5/40.5	94.9
2016	37.5	56.65	60.2/39.8	94.15
2017	35.46	60.47	63/37	95.93
2018	37.16	58.95	61.36/38.66	96.11
2019	38.02	59.40	60.97/39.03	97.42
2020	38.83	58.54	60.12/39.88	97.37
2021	42.10	51.43	54.99/45.01	93.53
2022	42.46	51.35	54.74/45.26	93.80

For "other non-specified fuels", the fossil fraction is assumed to be 100%[52]. The emission factor is 60 kg CO_2/GJ for "other non-specified fuels". This means that even small variations in the relative amounts of waste and other fuels respectively cause fluctuations in the IEF's between years.

2.3.2.8 EMISSION FACTORS FOR CO2 FROM SPENT LIQUIOR

Biogenic CO_2 emissions are included in the national total emissions of greenhouse gases reported to UNFCCC as a memo item, reported under the energy sector (CRT 1).

In submission 2023, the emission factor for CO_2 emissions was revised from 96 to 105 kg/GJ. All other emissions are still reported under IPPU (CRT 2) with revised emission factors according to the same study.

2.3.3 Mobile combustion

For all sectors regarding mobile combustion, country specific net calorific values and emission factors are used for CO_2 and SO_2. See tables above. The CO_2 emission factor for diesel was updated in submission 2022 for the years 1996-2019, which affects the emissions of CO_2 from several sectors, such as road traffic, navigation, railways, fishing and working machinery.

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

[52] RVF, 2003

Other emission factors used for mobile combustion calculations are either country-specific or default values from IPCC Guidelines and EMEP/EEA Guidebook 2013/2016/2019. These emission factors are described in greater detail in NIR section 3.2.

2.3.3.1 ROAD TRAFFIC (CRT 1.A.3.B)

The emissions of CH_4 and N_2O are estimated by the European road emission model HBEFA. In submission 2012, the emission factor for CO_2 from ethanol was revised as a result of revised NCV for ethanol[53].

In submission 2024, several updates have been made to the calculations for road traffic. Most notably, A-tractor cars were reallocated from working machinery to road traffic and now constitute a sixth vehicle category (See chapter 3.2.17.5 in the NIR for more details). Diesel A-tractor cars are assumed to have emissions similar to a Euro 3 passenger car without a particle filter, while gasoline A-tractor cars are assumed to have emissions similar to a Euro 2 passenger car. In both cases, a speed of 30 km/h are assumed.

2.3.3.2 RAILWAYS (CRT 1.A.3.C)

The emission factors for CH_4 and N_2O emissions from railways are from EEA Guidebook 2019 and are used for the whole time series and all types of railway engines.

2.3.3.3 NAVIGATION (CRT 1A3D)

The emission factors for CH_4, N_2O, NOx, CO, NMVOC and SO_2 for national and international navigation are analysed and, if needed, revised in every submission by the IVL Swedish Environmental Research Institute.

The emission factors for NO_x, NMVOC, NH_3, BC and particles for leisure boats were updated in submission 2023, for all fuel types. In submission 2022, the emission factors for NO_x (2005-2020) from diesel, marine gasoil and residual fuel oil were updated. The emission factor for SO_2 (1990-2020) from diesel was updated for the whole time series. The CO_2 emission factor for marine gasoil was revised in submission 2020[54].

2.3.3.4 PIPELINE TRANSPORT (CRT 1A3E)

The same national calorific values and emission factors are used as for stationary combustion of natural gas in CRT 1.A.4.a, to estimate the emissions of CO, NMVOC, NO_x and SO_2 from pipeline transport (CRT 1.A.3.e.i).

[53] Paulrud et al. 2010.

[54] Helbig et al. 2018.

2.3.3.5 FISHING (1A4C)

In submission 2013, the emission factor for SO_2 from marine gasoil used by fishing vessels (CRT 1.A.4.c) was revised to sync with domestic navigation (1.A.3.d). In submission 2022, the default fuel for fishing was changed from diesel oil to marine gasoil for the entire time series based on the result from a SMED study[55].

2.3.4 Fugitive emissions

Non-CO_2 emission factors used for calculations of fugitive emissions at refineries (hydrogen production in CRT 1.B.2.a.1, make-up coke combustion in CRT 1.B.2.a.4 and flaring in CRT 1.B.2.C.2.1) are partly the same as national factors for stationary combustion. In submission 2020, emission factors for fugitive emissions were revised[56]; summary of the currently used emission factors (for the most recent emission year, except for naphta, which was not used after 2011) is presented in Table A2.19. Emission factors for flaring and make-up coke combustion, if not marked as revised, are the same as emission factors for stationary combustion for emission year 1990, since abatement is assumed to be absent.

Table A2.19. Summary of emission factors used for calculation of fugitive emissions (CRT 1B), kg/GJ (for NMVOC from flaring of refinery gas –%).

CRT category	Fuel/ material	CH_4	N_2O	NMVOC	SO_2	CO	NO_x
.1.B.2.a.1	LNG / natural gas	0.001	0.0001	0.002	-	0.015	0.012*
	Refinary gas	0.001	0.0001	0.002	0.002	0.01	ER
	Naphta	0.003	0.0006	0.002	0.15	0.01	0.1
1.B.2.a.4	Make-up coke	0.001	0.0015	0.002	ER	ER	ER
1.B.2.C.2.1	Refinary gas	0.006	0.0005	0.5%*	0.005*	0.01	0.076
	LNG / natural gas	0.001	0.0001	0.002	-	0.01	0.06
	Hydrogen			-	-	-	0.1

ER – emission factors not used; emissions as specified in the facilities' environmental reports
*Revised in submission 2020, different from emission factor for stationary combustion

2.3.5 References for sections 2.1, 2.2 and 2.3

Backman, H., Gustafsson, T., 2006. Verification of activity data within the energy sector for reporting to the UNFCCC, EU Monitoring Mechanism, CLRTAP and the EU NEC Directive using data from the EU Emission Trading Scheme. SMED report 76:2006.

Boström, C, Flodström, E and Cooper D. 2004. Emissionsfaktorer för stationär förbränning. SMED report 3:2004

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

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

Cooper, D. and Gustafsson, T., 2004, Methodology for calculating emissions from ships: 2 Emission factors for 2004 reporting. SMED Report 5:2004.

Drivkraft Sverige
https://drivkraftsverige.se/uppslagsverk/fakta/berakningsfaktorer/energiinnehall-densitet-och-koldioxidemission/ 2023-01-04

Eklund, V., Helbig, T., Jerksjö, M., Jonsson, M. 2019. Analys och implementering av data från nya MåBra. PM 2019-09-30.

Eklund, V. Kellner, M. 2020. Sjöfartens förbrukning av LNG. SMED PM 2020.

Eklund, V., Kellner, M. 2021. Sjöfartens förbrukning av LNG 2020. SMED PM 2021.

Eklund, V., Kellner, M. 2022. Sjöfartens förbrukning av LNG 2021. SMED PM 2022.

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

EN0118 (2020). Transportsektorns energianvändning (inrikes sjöfart).

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

Energistyrelsen, 2021-12-06 (https://ens.dk/sites/ens.dk/files/CO2/standardfaktorer_for_2020.pdf)

ER 2007:15. Energianvändningen inom skogsbruket 2005

Fridell, E., Mawdsley, I. & Eklund, V. 2021. Revised emission factors for shipping. SMED report no 15 2021. Agreement: 250-21-001.

Gerner, 2011. Underlag för revidering av EF för CO_2 från bränngas. SMED Memorandum.

Gustafsson, Lidén and Gerner, 2011. Emissions from integrated iron and steel industry in Sweden. Model for estimation and allocation of energy consumption and CO_2 emissions for reporting to the UNFCCC. SMED report 97:2011.

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

Helbig, T. Kindbom, K. Jonsson, M. 2019. Uppdatering av nationella emissionsfaktorer för övrig sektor (CRT/NFR 1A4). SMED rapport no 12 2019

Helbig, T. Stripple, H., Hjort, A., Mawdsley, I. 2018. Uppdatering av emissionsfaktorer för CO_2 från torv och deponigas. SMED PM 2018-05-20.

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

Helbig, T., Fridell, E., Winnes, H., Mawdsley, I., Eklund, V. 2018. Uppdatering av emissionsfaktorer för CO_2 från diesel och EO1 för sjöfart. SMED PM 2018-08-15.

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

Hult, C. et al. 2020. Emission factors for methane engines on vehicles and ships. SMED Report No 8 2020.

Ivarsson, 2003. Improved statistics for SSAB, refineries and lime producers. SMED report 59:2003.

Jerksjö M., Gerner A., Wängberg I., 2013. Utveckling av metod för att beräkna emissioner av metan, övriga kolväten och koldioxid från naturgas-, biogas- och stadsgasnät i Sverige. (Method for estimating emissions of methane, NMVOC and CO_2 from pipeline distribution of natural gas, biogas and town gas in Sweden.) SMED Report no 121, 2013.

Johansson L, Leckner B, Gustavsson L, Cooper P, Tullin C, Potter A. 2004. Emission characteristics of modern and old-type residential boilers fired withwood logs and wood pellets. Atmospheric Environment 38, 4183-4195.

Josefsson Ortiz, C. & Guban, P. 2020. Revidera AD och EF för Cementa för CO2-utsläpp. SMED PM.

Josefsson Ortiz, C., Guban, P., Mawdsley, I., Yaramenka, K 2022. Updated CO2 emission factors for stationary combustion of LNG and blast furnace gases in Sweden. SMED rapport nr 7. Avtal 250-22-001.

Mawdsley, I & Stripple, H, 2014. Revision of N_2O emission factors for combustion of gaseous and solid fuels. SMED PM

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

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

Mawdsley I., Jerksjö M., Yaramenka K., Eklund V.2021. CO2 emission factor for fossil diesel fuel. SMED Memorandum 2021.

Mawdsley I. & Helbig T. 20201. Reporting of biomass in CRT tables and reallocation of emissions from spent liquor combustion. SMED Report No 8 2021

Mawdsley, I., Danielsson, H., Yaramenka, K., Josefsson Ortiz, C., Guban, P. 2022. Översyn av emissionsfaktorer inom stationär förbränning. SMED rapport nr 8. Avtal: 250-21-001.

Nyström, A-K & Cooper, D. 2005. Use of data from the EU emission trading scheme for reporting to EU Monitoring Mechanism, UNFCCC and CLRTAP. SMED report 74:2005.

Nyström, A-K & Skårman, T. 2006. Quality control of emitted NO_X and SO_2 in Swedish industries. SMED report 35:2006

Paulrud, S, Kindbom, K, Cooper, D, Gustafsson, T. 2005. Methane emissions from residential biomass combustion. SMED report 17 2005.

Paulrud, S, Kindbom, K, Gustafsson, T. 2006. Emission factors and emissions from residential biomass combustion in Sweden. SMED report 70:2006

Paulrud, S, Fridell, E, Stripple, H, Gustafsson, T. 2010. Uppdatering av klimatrelaterade emissionsfaktorer (Update of climate related emission factors, 2nd edition). SMED report 92:2010.

RVF, 2003. Förbränning av avfall. Utsläpp av växthusgaser jämfört med annan avfallsbehandling och annan energiproduktion. RVF rapport 2003:12

SCB, 2021. Förstudie om ökad samordning av tre energiundersökningar.

Skårman, T, Danielsson , H, Kindbom, K, Jernström, M, Nyström, A-K., 2008: Fortsättning av riktad kvalitetskontrollstudie av utsläpp från industrin i Sveriges internationella rapportering (Continued QC study of emissions from industrial plants the Swedish emission inventories). SMED report 36:2008.

Stockholm Gas, http://www.stockholmgas.se/ 2014.

Swedgas, https://www.swedegas.se/ 2014.

Swedish petroleum and biofuel institute, http://www.spi.se/produkter.asp?art=48 , 2005-10-17.

Statistic Sweden.ES 2012:03. Energy statistics for dwellings with no registered permanent resident (holiday homes) 2011 http://www.energimyndigheten.se/sv/Statistik/Slutlig-anvandning/Bostader-och-service/Fritidshus/

Statistic Sweden; http://www.scb.se/sv_/Hitta-statistik/Statistik-efter-amne/Energi/Tillforsel-och-anvandning-av-energi/Leveranser-av-fordonsgas/Aktuell-pong/2013M09/

Statistics Sweden EN20SM, 1990-2010. Årliga energibalanser (Annual energy balances) http://www.scb.se/statistik/EN/EN0202/2007I08/EN0202_2007I08_SM_EN20SM0904.pdf

Statistics Sweden, 1991, 94, 97, 2000, 2003, 2006, 2010. JO36SM: Trädgårdsräkningen (The Horticultural census). Unit for Agriculture, Forestry and Fishing Statistics.

Statistics Sweden, 1995, 2003, 2008. JO63SM: Consumption of diesel oil and fuel oil in agriculture and number of ciserns and storage capacity. Unit for Agriculture Structure.

Statistics Sweden, 1986. Report on fuel consumption in the construction and forestry sectors. Energy Statistics.

Statistics Sweden, 2005: Energy use in construction sector 2004, http://www.scb.se/statistik/_publikationer/EN0114_2004A01_BR_ENFT0501.pdf

Statistics Sweden, 2009: Inventering av industristatistiken (Inventory of the energy statistics)

Stripple, H, Sjödin, Å, Appelberg, I, Gerner, A, Sörme, L, Szudy, M, 2014. Revidering av emissionsfaktorer för växthusgaser för förbränning av sopor och träbränslen. (Revision of emission factors for greenhouse gases from combustion of waste and wooden fuels). Draft SMED report.

The Swedish Energy Agency http://www.energimyndigheten.se/statistik/den-officiella-statistiken/statistikprodukter/varmevarden-och-densiteter/

Swedish Environmental Protection Agency, http://www.naturvardsverket.se, search for “Beräkna utsläpp”.

SEPA, Swedish Environmental Protection Agency. 1995. Sverige mot minskad klimatpåverkan. Uppföljning av målen för utsläpp av växthusgaser 1994. Rapport 4459. Stockholm 1995.

Yaramenka, K., Kindbom, K., Helbig, T. 2019. Improvements in the reporting of fugitive emissions (CRT and NFR 1B), Phase II. SMED Report No 8 2019.

Yaramenka, K., Mawdsley, I., Kindbom, K., Josefsson Ortiz, C. 2020 Förbättring av utsäppsraportering från Sveriges raffinaderier – fokus på luftföroreningar och NEU. (Manuscript not yet published)

2.4 Allocation of fuels for mobile combustion

This section describes the allocation and distribution of the delivered amount of fuels on subsectors.

2.4.1 Gasoline

Data on the delivered amounts of gasoline at a national level is provided by the national statistics on supply and delivery of petroleum products for 1990-2017 and data reported under the Swedish fuel quality act is used for 2018-2022 (see section 2.1.7).

National sales of gasoline includes low blended ethanol and ETBE. To separate biofuel emissions from fossil fuel emissions, all ethanol and ETBE used by road traffic is reported as biomass under CRT 1.A.3.b. However, a small part of ETBE is considered fossil and the emissions of CO_2 from the fossil part are included in the national total of CO_2.

Ethanol has been used by buses since 1990, but low blended ethanol entered the market in the year 2000 and peaked in 2005. The gasoline sold at gas stations up to August 2021 was an admixture of about 95% gasoline and 5% ethanol. From the 1'st of August 2021, Sweden has increased the ethanol fraction to 10% and the total consumption of ethanol increased by 33% in the last year. The total amount of ethanol peaked in 2010 and includes, besides low blended ethanol, the volume of ethanol used by E85 vehicles and by ethanol buses.

The allocation of gasoline to different subsectors takes place in three steps and is illustrated in Figure A2.1 below.

1. In the first step, the low blended ethanol/ETBE in gasoline is subtracted from the total delivered amounts of gasoline at a national level.
2. In the next step, the gasoline consumption by domestic navigation, as well as the model estimated consumption by road traffic (HBEFA data) and off road vehicles (model estimated) is subtracted.
3. The remaining volume of gasoline is proportionally distributed to civil road traffic and to working machinery.

The gasoline consumption by road traffic is estimated by the European road vehicle emission model HBEFA (se section 2.5). The gasoline consumption by off-road vehicles (CRT 1.A.2.gvii, 1.A.3.eii, 1.A.4.aii, 1.A.4.bii and 1.A.4.cii) is estimated using a model based on a study carried out in 2008 (se section 1.6)[57].

[57] Fridell, Jernström & Lindgren, 2008

The consumption of gasoline by domestic navigation is dominated by leisure boats and is based on four different surveys[58]. The last three studies have only indicated different ranges for the fuel consumption, which has led to separate analyzes to determine the fuel consumption [59, 60, 61].

The consumption of gasoline in between the studies was estimated by interpolation based on the assessed consumption in each survey[62]. No domestic ferries or bigger ships run on gasoline.

Figure A2.2 shows a comparison between the total volume of fossil and biogenic gasoline through a top-down and bottom-up approach; where the top-down approach shows the total estimated gasoline consumption for all sectors while the top-down approach shows the total deliveries of gasoline. The difference is the residual, which is distributed proportionally to road traffic and off-road vehicles.

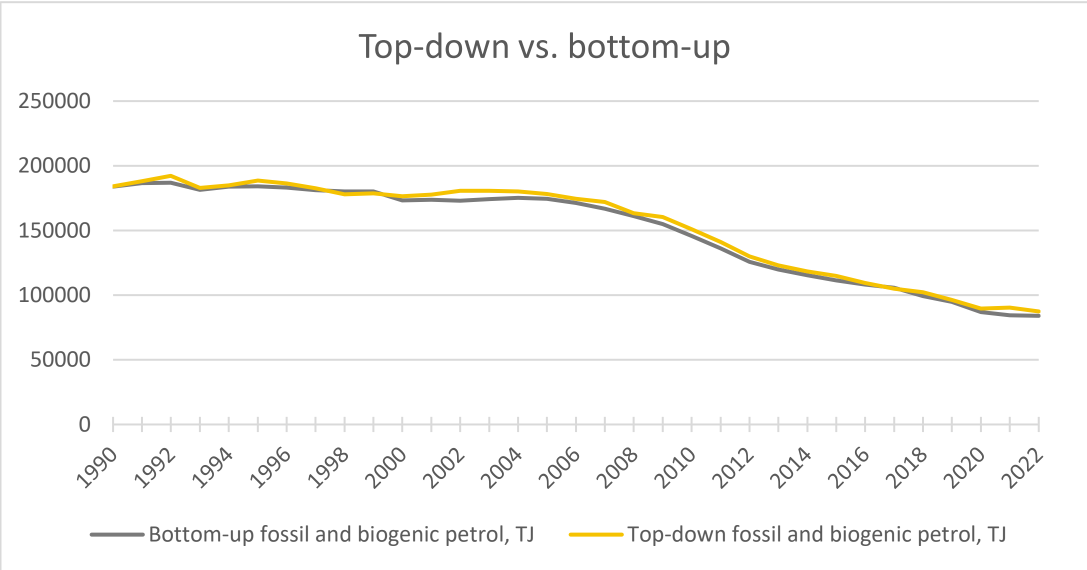

Figure A2.2. Bottom-up vs. top-down approach for petrol in submission 2024.

The approximate distribution of gasoline to subsectors in 2022 is shown in Figure A2.3. Civil road traffic accounts for almost all gasoline consumption, followed by off-road vehicles and other machinery. Gasoline consumption by domestic navigation is relatively low.

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

59 Gustafsson, 2005.

60 Eklund V. 2014.

61 Fridell, Mawdsley & Wisell.. SMED Report No 9 2017.

62 2005-2009, 2010-2014 and 2016-2020

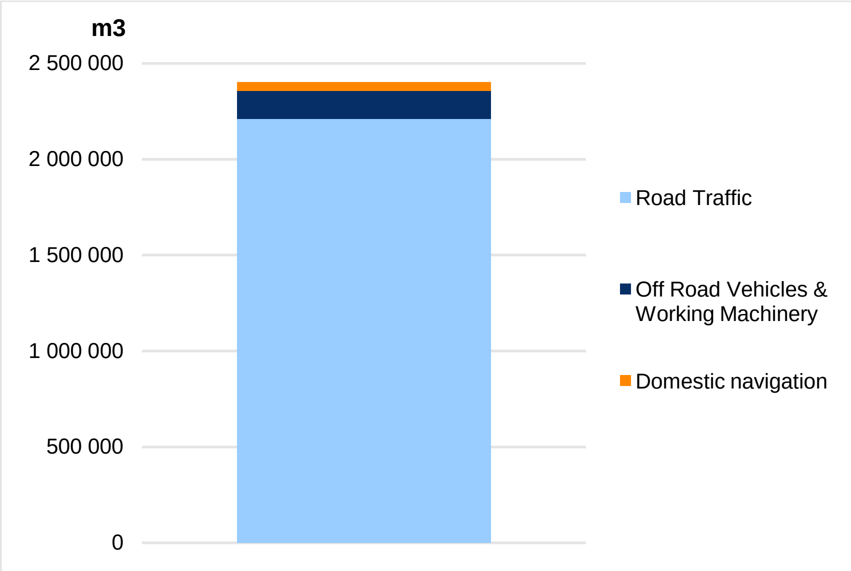

Figure A2.3. Distribution of gasoline by subsector in 2022.

2.4.2 Diesel

Data on the total amount of diesel oil delivered at a national level is provided by the statistics on supply and delivery of petroleum products for 1990-2017 while data reported under the Swedish fuel quality act is used for 2018-2022 (section 2.1.7). The use of diesel by international bunkers is specified as discussed in NIR section 3.2.2.

The diesel for national consumption is distributed to different subsectors following a three-step process.

1. *In the first step*, the diesel used for stationary combustion and the low blended FAME/HVO is subtracted from the total delivered amounts of diesel.
    - The total volume of HVO is reported as biomass under CRT 1.A.3.b, but a small part of FAME is considered to have a fossil origin and the emissions of CO_2 from the fossil part of FAME is included in the national emissions of GHG.
2. In the *second* step, the diesel consumption by road traffic (HBEFA data), off road vehicles (model estimated), railways, domestic navigation including leisure boats is subtracted.
3. *In the third and last step*, the remaining volume of diesel is proportionally distributed to road traffic and off-road vehicles. The allocation is made in proportion to the estimated consumption of diesel in each subsector. As of submission 2022, the fishing sector is no longer included in this step, since a SMED study in 2021[63] showd that the fuel used by the fishing fleet is domestic heating oil and not a diesel as was previously assumed.

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

The diesel estimate of each subsector is based on the sources according to table A2.20.

Table A2.20. Subsectors with a diesel consumption that is subtracted in the second step.

Subsector	CRT	Estimation of amount of diesel consumed
Road traffic	1A3b	HBEFA: road emission model
Working machinery	1A2gvii, 1A3eii, 1A4aii-1A4cii	Model for off road vehicles
Railway	1A3c	Survey by the Swedish Energy Agency
Domestic navigation	1A3d	Shipair (SMHI) and survey of fuel consumption for domestic navigation the Swedish Energy Agency.
Leisure boats	1A3d	SMED report, 2005. SMED PM, 2014. SMED Report No 9 2017

Just as for petrol, Figure A2.5 shows a comparison between the volume of fossil and biogenic diesel through a top-down and a bottom-up approach; where the top-down approach shows the total estimated consumption of diesel by all sectors while the top-down approach shows the total deliveries of diesel. The difference is the residual, which is distributed proportionally to road traffic and off-road vehicles. The discrepancy between the bottom-up approach and the top-down approach is bigger for diesel oil than for petrol, but has decreased since 2009.

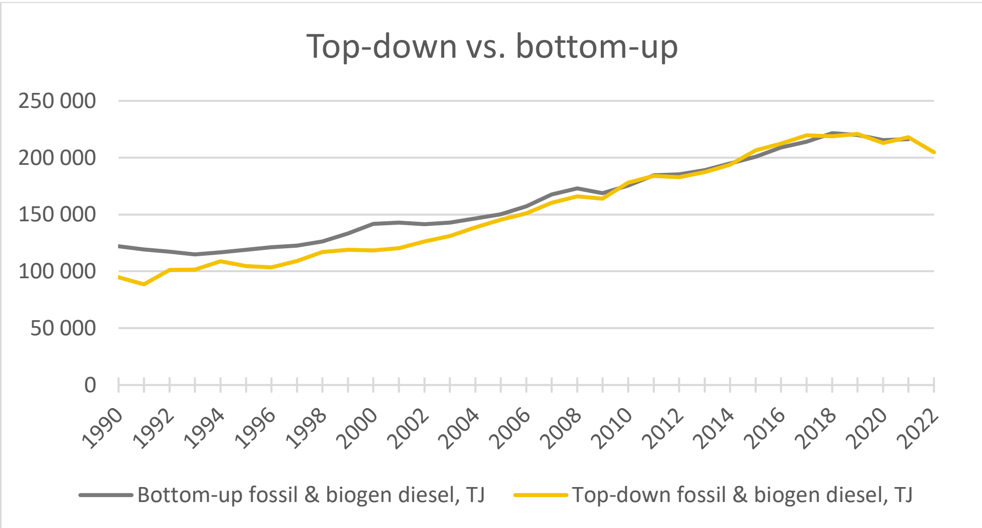

Figure A2.5. Bottom-up vs. top-down approach for diesel in submission 2024.

The diesel consumption by off-road vehicles and other machinery is estimated by a model, which is based on a SMED study from 2008[64], and was implemented in submission 2009. The model has been updated with new data and improved by each submission. See section 2.6 for more information.

[64] Fridell, Jernström & Lindgren 2008

The fuel consumption from domestic navigation[65] was before submission 2020 provided by the statistics on supply and delivery of petroleum products[66]. As from submission 2020, the energy consumption from domestic navigation is based on a model called Shipair, developed by the Swedish meteorological and hydrological institute (SMHI), and information collected from the largest shipping actors for domestic navigation[67]. See section 2.4.3 below for more information.

The consumption of diesel by recreational boats is based on four different surveys[68]. The last three studies have only indicated different ranges for fuel consumption, which has led to separate analyzes to determine the fuel consumption [69, 70, 71]. The consumption of diesel in between the studies was estimated by interpolation based on the assessed consumption in each survey[72].

Figure A2.6 shows the approximate distribution of the delivered amount of diesel oil in 2022. Just as for gasoline, diesel from civil road traffic accounts for most of the consumption. However, diesel from off-road vehicles and other machinery also contributes to a considerable amount (21%) of the total diesel consumption.

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65 Except for leisure boats.

66 Statistic Sweden. Monthly fuel, gas and inventory statistics. http://www.scb.se/sv_/Hitta-statistik/Statistik-efter-amne/Energi/Tillforsel-och-anvandning-av-energi/Manatlig-bransle--gas--och-lagerstatistik/

67 Eklund, V. et al. 2019. Analys och implementering av data från nya MåBra.

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

69 Gustafsson, 2005.

70 Eklund V. 2014.

71 Fridell, Mawdsley & Wisell.. SMED Report No 9 2017.

72 2005–2009, 2010–2014 and 2016-2020

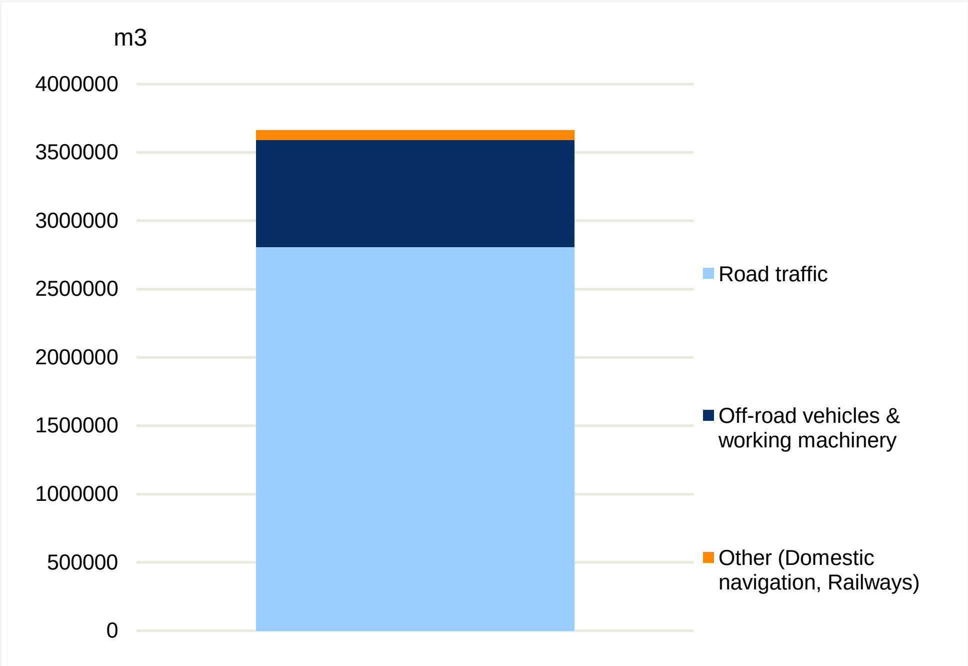

Figure A2.6. Distribution of diesel oil by subsector in 2022.

2.4.2.1 ENVIRONMENTAL CLASSES OF DIESEL OIL

Diesel oil is refined into three categories; so called environmental classes 1-3. These have been gradually introduced from 1991. Today, environmental class 1 (low sulphur) diesel is the only kind of diesel sold in Sweden [73].The shift in consumption of diesels of different environmental classes has had a significant impact on the emissions.

Table A2.21 shows the characteristics for environmental class 1-3 regarding NCVs and emission factors for CO_2. The transition in consumption from exclusively environmental class 3 diesels in 1990 to more or less exclusively environmental class 1 diesels today has contributed to a 3% decrease in CO_2 emissions from diesel.

Information on the diesel distribution on environmental classes has been collected from the former Swedish National Road Administration for the years 1990-1993 and from Statistics Sweden for 1994 and later years. Drivkraft Sverige has assisted with information regarding NCVs and emission factors for CO_2[74]. SMED has calculated yearly averages of NCVs and emission factors.

[73] The Swedish Transport Agency, https://www.transportstyrelsen.se/sv/vagtrafik/Miljo/Luftkvaliet-i-tatorter/Miljoklassade-branslen/.

[74] https://drivkraftsverige.se/ 2023-01-05.

Table A2.21. Impact from different environmental class diesel on NCV and emission factors for CO_2.

Diesel	NCV (GJ/m^3)	Emission factor CO_2 (tonne/TJ)	Weight 1990 (%)	Weight 2000 (%)	Weight 2013 (%)
Environmental class 1	35.28	72.2	0	94	99
Environmental class 2	35.28	72.2	0	0	0
Environmental class 3	35.82	72.2	100	6	1
Average 1990	35.82	72.2			
Average 2000	35.31	72.2			
Average 2010	35.28	72.2			
Average 2020	35.28	72.2			

2.4.3 Marine distillate fuels

Marine destillate fuels is a group name covering diesel oil and marine gasoil used for navigation. Emissions from these fuels are reported as gas/diesel oil in the CRT. The source for the activity data (AD) used for domestic navigation changed in submission 2020. In previous submissions, the AD was based on the monthly survey on supply and delivery of petroleum products[75]. As from submission 2020, the fuel consumption from domestic shipping is mainly based on a methodology called Shipair, which was developed by the Swedish meteorological and hydrological institute (SMHI). The Shipair model collects data from AIS (Automatic Identification System), which ships use to continuously transmit identity and position information. The AIS data shows how the ships move between Swedish ports. Information regarding the ships, such as size, engine power and type of vessel is also collected. This enables the Shipair model to estimate the amount of energy needed for the ships to move and the fuel consumption. Shipair makes an estimation of which fuel is used is based on IMO's fourth Greenhouse Gas Study (https://www.imo.org/en/ourwork/Environment/Pages/Fourth-IMO-Greenhouse-Gas-Study-2020.aspx), where Table 9 (Allocation algorithm for the main engine fuel type) describes how data from the IHS database can be used to select fuel type. When there is not enough IHS data to base fuel type on that, the assumption is made that ships over 6000 gross tons is assumed to run on residual fuel oil while ships under 6000 gross tons is assumed to run on marine gasoil.

Beside the Shipair model, the fuel consumption by domestic navigation is based on information collected from the largest shipping actors for national navigation, with the exception for cargo ships.[76] Information regarding the fuel consumption, by fuel type, is collected as the amount of marine gasoil estimated by Shipair needs to be split into marine gasoil, diesel, gasoline and biofuels. The difference between

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

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

the fuel consumption estimated by Shipair, is assumed to be marine gasoil used by cargo ships

The diesel consumption by leisure boats is based on four different surveys regarding leisure boats from 2004, 2010, 2015[77] and 2020 and three different studies by SMED[78]. Marine diesel oil for domestic navigation is discussed under the diesel section, 2.4.2. The statistics on marine distillate fuels are reported separately for domestic and international navigation and the split is based on the information provided by the respondents to the survey on supply and delivery of petroleum products.

The amount of marine destillate fuel used for domestic navigation and leisure boats (CRT 1.A.3.d) is shown in Figure A2.7. The stricter rules regarding the sulphur content in marine fuels, which took effect in January 2015, led to a shift from heavy oil fuel oil to lighter oil products with a lower sulphur content in 2015. But in 2018 there were a shift to heavy marine oils again but with a reduced sulphur content, so called "hybrid oils" and to LNG. However, in 2022 the consumption of LNG is decreasing due to higher gas prices. This can be seen in Figures A2.7 and A2.8 and A.2.9.

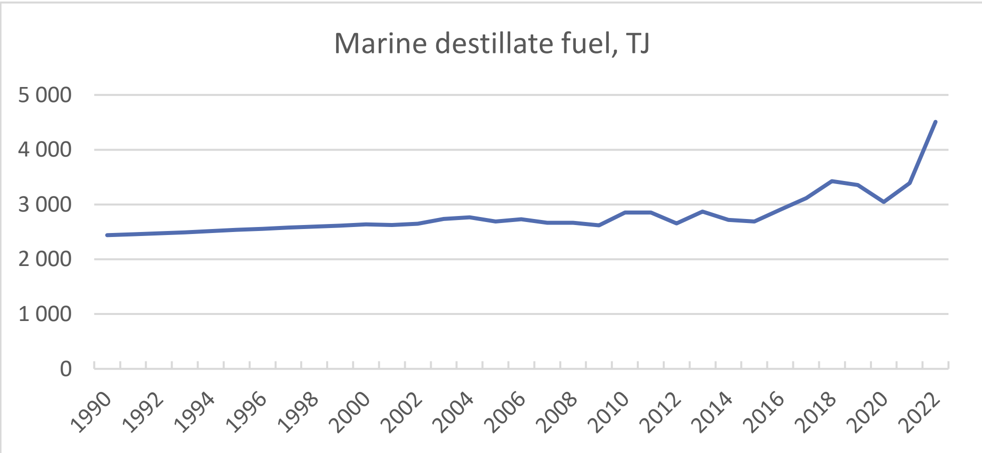

Figure A2.7. Consumption of diesel oil and marine gasoil used by domestic navigation (marine destillate fuel) 1990-2022.

[77] Statistics Sweden, 2005. Transportsstyrelsen. 2010. Transportstyrelsen 2015.

[78] Gustafsson, T. 2005. Eklund, V. 2014. Fridell, E., Mawdsley, I., Wisell T. 2017

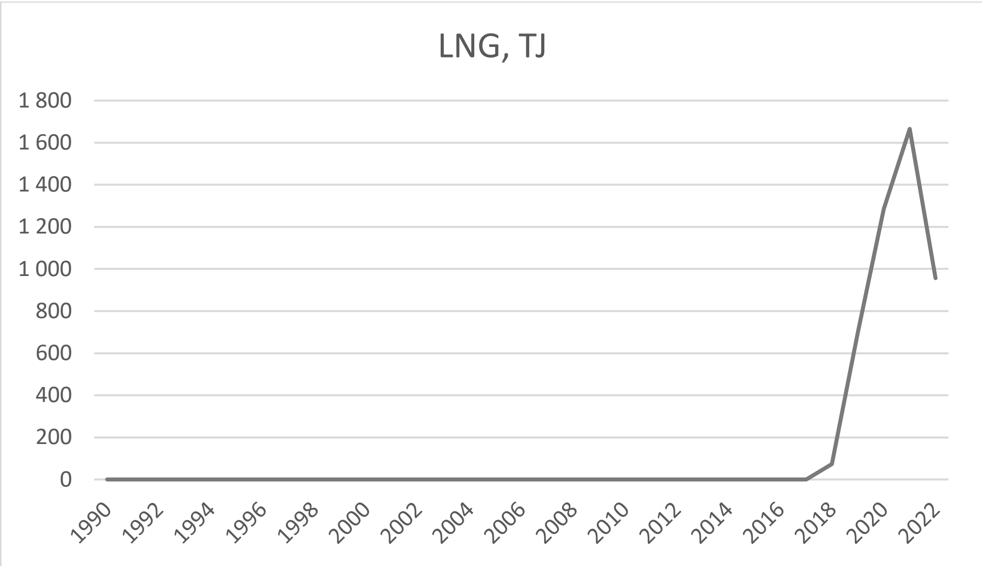

Figure A2.8. Consumption of LNG used by domestic navigation 1990-2022.

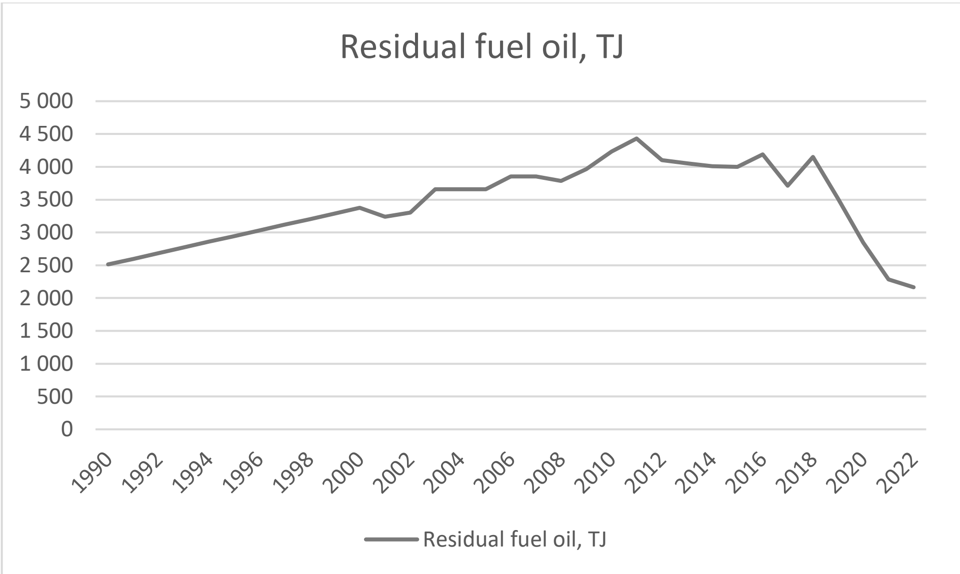

Figure A2.9. Consumption of marine Residual fuel TJ by domestic navigation for 1990-2022.

2.4.4 Residual fuel oils

As from submission 2020, the energy consumption from domestic shipping is mainly based on a methodology called Shipair and the fuel consumption by fuel type collected from the largest shipping actors for national navigation, with the exception for cargo ships.[79] See section 2.4.3 and figure A2.8 above for more information.

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

2.4.5 Jet kerosene, jet gasoline and aviation gasoline

All jet kerosene, biogenic jet kerosene, jet gasoline and aviation gasoline are assumed to be used for aviation. Delivered amounts of aviation fuels are provided at a national level by the statistics on supply and delivery of petroleum products (Section 2.1.7).

2.4.6 Natural Gas and biofuels

Other fuels used for transports are ethanol, FAME, natural gas, LNG and biogas. Ethanol and FAME are partly blended into gasoline and diesel and partly used in a more pure form in so-called flexifuel vehicles. Information on delivered amounts of ethanol and FAME are provided at a national level by the statistics on supply and delivery of petroleum products (Section 2.1.7). Data on delivered amounts of natural gas for transportation is provided by the statistics on delivery of gas products (Section 2.1.8). The LNG data is based on a survey[80], which was performed in 2020, 2021,2022 and 2023, aiming to map the consumption of LNG by both national and international navigation. Data on the consumption of biogas for 1996 -2008 is provided by the Swedish Biogas Association and by Statistics Sweden for 2009-2023. Data for 1990-1995 is not available.

2.4.7 References section 2.4

Gustafsson, T. 2005. Update of gasoline consumption and emissions from leisure boats in Sweden 1990-2003 for international reporting. SMED report 73 2005.

Eklund, V. 2014. Justering av småbåtars bränsleförbrukning. SMED PM 2014.

Eklund, V. et al. 2020. Sjöfartens förbrukning av LNG. SMED PM 2020.

Eklund, V., Helbig, T., Jerksjö, M., Jonsson, M. 2019. Analys och implementering av data från nya MåBra. PM 2019-09-30.

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

Fridell, E., Jernström, M., Lindgren,M., 2008. Arbetsmaskiner – Uppdatering av metod för emissionsberäkningar. SMED Report 2008.

Fridell E., Mawdsley I., Wisell T. 2017: Development of new emission factors for shipping. SMED Report No 9 2017.

Gustafsson, T. 2005. Update of gasoline consumption and emissions from leisure boats in Sweden 1990-2003 for international reporting. SMED report 73 2005.

Statistics Sweden, 2005: Båtlivsundersökningen 2004 (Leisure boats survey 2004).

Statistics Sweden, 2006: Energy consumption in the fishery sector 2005. Official Statistics of Sweden.

[80] Eklund, et al. 2020. Sjöfartens förbrukning av LNG.

Statistics Sweden. Monthly fuel, gas and inventory statistics. http://www.scb.se/sv_/Hitta-statistik/Statistik-efter-amne/Energi/Tillforsel-och-anvandning-av-energi/Manatlig-bransle--gas--och-lagerstatistik/

Transportsstyrelsen, 2010. Båtlivsundersökningen 2010 (Swedish leisure boat survey 2010). https://www.transportstyrelsen.se/batlivsundersokningen

Transportsstyrelsen, 2015. Båtlivsundersökningen 2015 (Swedish leisure boat survey 2015). https://www.transportstyrelsen.se/batlivsundersokningen

The Swedish Transport Agency, https://www.transportstyrelsen.se/sv/vagtrafik/Miljo/Luftkvaliet-i-tatorter/Miljoklassade-branslen/.

2.5 The HBEFA road model

The HBEFA (Handbook of Emissions Factors) emission model builds on the former ARTEMIS road model (used from submission 2006 to submission 2011). To a large extent, the two models are principally the same, since the HBEFA road model was developed from a merging of the ARTEMIS road model and the former version of HBEFA. 2.1. Since then the model ha undergone many updates and the most recent version named 4.2[81] was used for the first time in submission 2023.

HBEFA provides emission factors and calculates emissions for segments and sub-segments of six main vehicle categories - passenger cars (PC), light commercial vehicles (LCV), heavy goods vehicles (HGV), urban busses, coaches, and motorcycles including mopeds (MC). Segments are defined as groups of vehicles of similar size (e.g. light commercial vehicles with kerb weight less than 1305 kg and rigid trucks with weight between 14 and 20 tonnes) which are using the same type of fuel/technology (petrol, diesel, CNG/petrol, LNG, electricity, etc.), whereas sub-segments are defined as groups of vehicles of similar size, fuel/technology and emission concept (e.g. pre-Euro, Euro 1, 2, 3, etc.).

HBEFA calculates emissions separated into hot emissions, cold start emissions and evaporative emissions. An overview of the model structure with input and output parameters is given by Figure A2.9. The hot emission factors are calculated with the PHEM model[82] and are representative for typical European driving conditions.

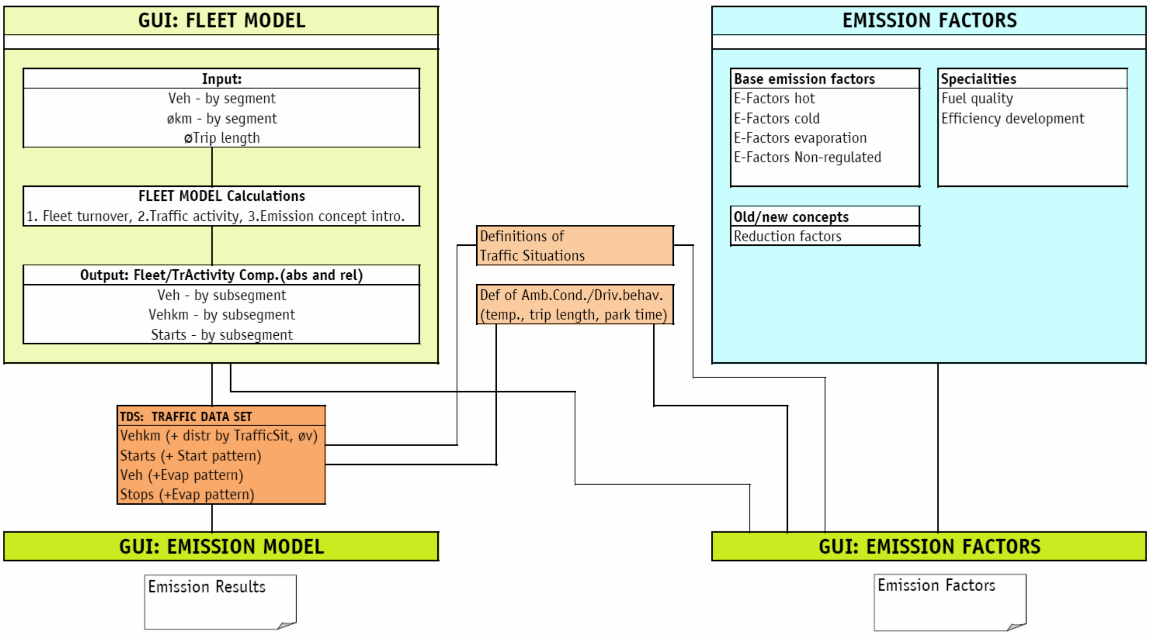

Figure A2.9. HBEFA model structure.

81 Infras, 2022

82 FVT, 2022

2.5.1 National fleet data

The Swedish vehicle fleet is in HBEFA described by means of the number of vehicles on segment level and age distributions on segment level derived from the Swedish national vehicle register.

For buses HBEFA distinguishes between two types of buses: urban buses, mainly used for urban driving, and coaches, mainly used for rural and motorway driving. Over the years different methods have been used to determine which HBEFA category each bus registered in Sweden should belong to. In the current method buses classified as Class I, Class II or Class A in the national register is considered to be Urban buses in HBEFA and Class III and class B buses are considered to be coaches.

In HBEFA, trucks are split into two main categories 1) rigid trucks and 2) articulated trucks/trucks with trailers. Since there is no information in the Swedish vehicle register on the use of trailers, this is described by means of so called vehicle transformation patterns in HBEFA. A transformation pattern defines the mileage distributions for each weight class, with and without trailer, respectively. The truck category "with trailer" is split further into different sizes of trailers expressed as the maximun permissible (i.e. weight range, e.g. 20-28 tonne) of the truck and trailer combination. The transformation patterns for Sweden were derived from traffic measurements on Swedish roads. Vehicle fleet data is shown in Figure A2.10.

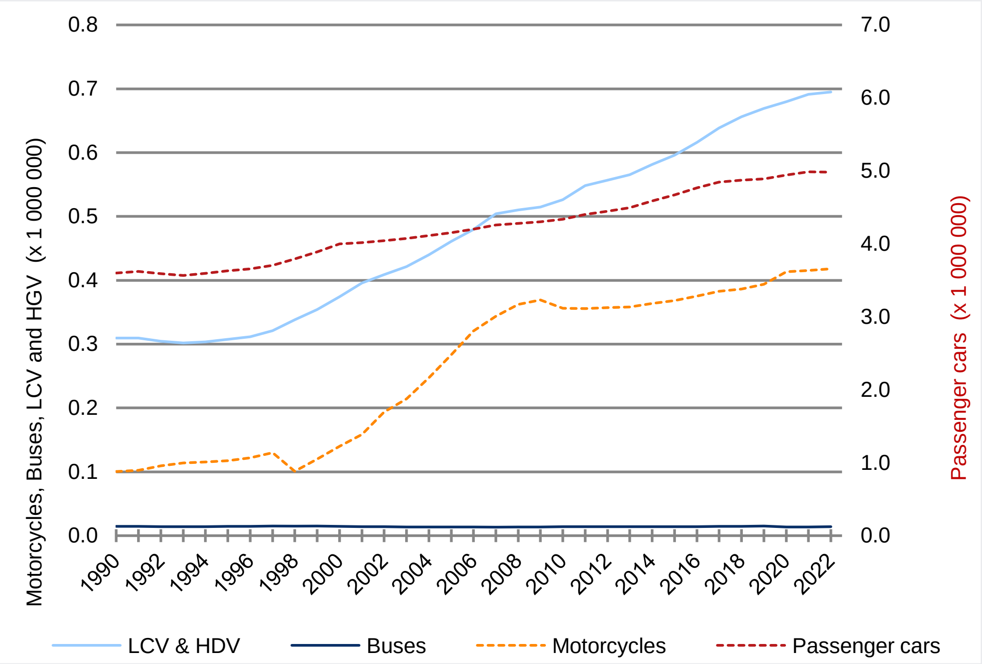

Figure A2.10. Vehicle fleet data by dec 31, numbers, 1990-2022 Statistics Sweden.

2.5.2 Traffic activity data

2.5.2.1 VEHICLE MILEAGES, LOADS, TRIP LENGTHS AND FUELS

The HBEFA model requires annual average vehicle kilometers travelled per vehicle category (Figure A2.11). The source used for this data later years is the official statistics on Vehicle mileage for swedish registered vehicles[83]. This statistics gives the total vehicle kilometers travelled in Sweden per vehicle catregory. For trucks the data takes into account the kilometers driven with foreign trucks in Sweden and the kilometers driven abroad with trucks registered in Sweden. For the other vehicle categories it is assumed that the total number of kilometers driven abroad by Swedish vehicles is the same as the total kilometers driven by foreign vehicles in Sweden, and thus these driving distances are considered to cancel each other out.

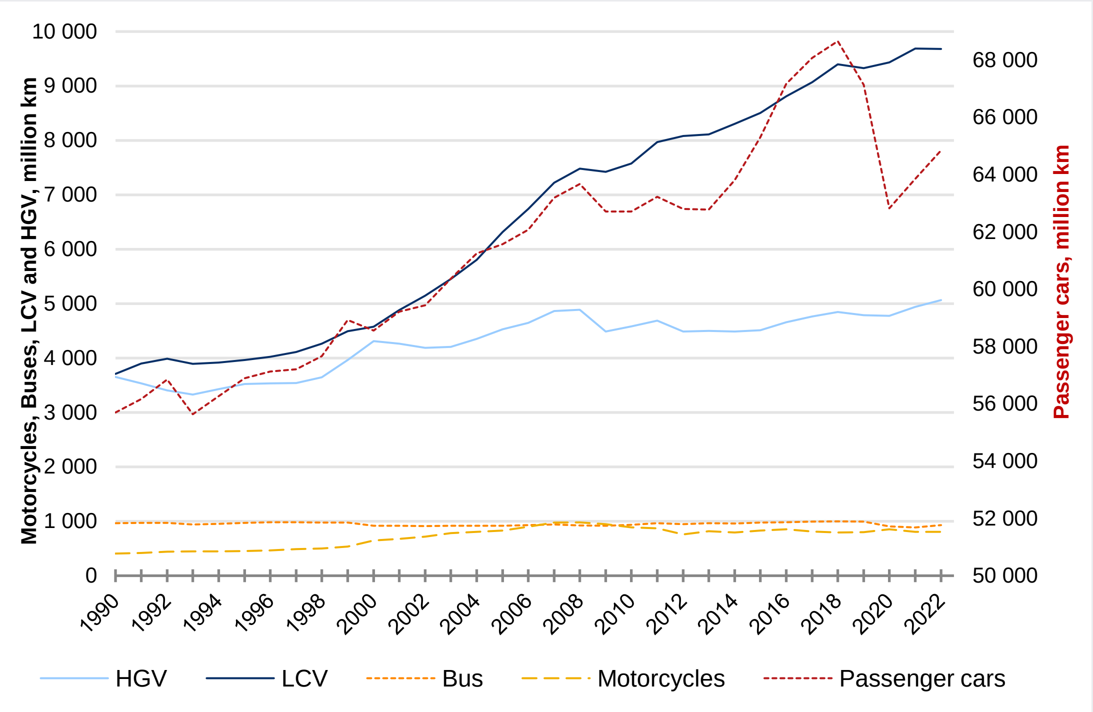

Figure A2.11. Vehicle mileages 1990-2022 according to HBEFA.

HBEFA also requires average annual driving distances per vehicle segments which is used to distribute the total vehicle kilometers travelled on the different segments. To do this, data on annual milage on a vehicle level is used. This data is provided by Trafikanalys and is based on yearly odometer readings within the Swedish inspection & maintenance (I/M) program[84]. This data is used for deriving both mileage per vehicle segment, and mileage as a function of vehicle age.

For heavy duty vehicles, HBEFA requires a distribution of load between empty (0% load), half-load (50% load), and fully loaded (100% load) vehicles by segment

[83] Trafikanalys, 2022

[84] Trafikanalys, 2011

and age. This data was derived from a major national survey on Swedish domestic road goods transport[85].

In order to estimate evaporative and cold start emissions, information on distributions of trip lengths and parking times, and on the seasonal and diurnal variation of ambient temperature is needed. Trip lengths and parking times can be derived from surveys, or from data from instrumented cars. For Sweden, an average trip length according to surveys is 12 km, and according to instrumented cars 7 km[86]. Instrumented cars provide the trip length from engine start to engine stop. Even if instrumented car data just represents a few vehicles and use in few families, this data set has been considered more representative than the survey data, since the information requested is the distance travelled from engine start to engine stop[87]. Thus, available instrumented vehicle data was used to estimate trip lengths and parking times in Sweden.

2.5.2.2 TRAFFIC SITUATIONS

The HBEFA model includes 369 traffic situations, i.e. combinations of road type, speed limit, area (rural and urban) and level of service. The level of service describes how disturbed the traffic is relative to undisturbed traffic and there are five different levels - 1) Free Flow, 2) Heavy Traffic, 3) Saturated 4) Stop and Go and 5) Heavy Stop and Go conditions (see Table A2.22). Furthermore, different level of road grade can be attributed to each traffic situation.

Table A2.22. Definition of the five classes of traffic conditions.

Class	Definition
Freeflow	Free flowing conditions, low and steady traffic flow. Constant and quite high speed. Indicative speeds: 90-120 km/h on motorways, 45-60 km/h on a road with speed limit of 50 km/h. LOS A-B according to HCM.
Heavy	Free flow conditions with heavy traffic, fairly constant speed. Indicative speeds: 70-90 km/h on motorways, 30-45 km/h on a road with a speed limit of 50 km/h. LOS C-D according to HCM.
Saturated	Unsteady flow, saturated traffic. Variable intermediate speeds, with possible stops. Indicative speeds: 30-70 km/h on motorways, 15-30 km/h on a road with speed limit of 50 km/h. LOS E according to HCM.
Stop + go	Stop and go. Congested flow, stop and go or gridlock. Variable and low speed and stops. Indicative speeds: 30-70 km/h on motorways, 15-30 km/h on a road with speed limit of 50 km/h. LOS E according to HCM.
Heavy stop+go	Heavily congested flow. Average speed range from 5.5 km/h to 7.2 km/h

[85] Hammarström and Yahya, 2000

[86] SNRA 1999

[87] André et al., 1999

Distributions of total vehicle kilometers travelled over the traffic situations have been produced for periods of two or three years since 1990. The method has changes slightly over the years and the work has been documented in reports available in Swedish. The most recent report describes the process used for producing a distribution for 2021[88].

Of all traffic situations in HBEFA, 200 were considered in Sweden in 2021. In those traffic situations, 62 different road categories were represented, for which the traffic condition "Free Flow" was predominant. In fact, as much as 96.7% of the overall vehicle kilometers travelled by passenger cars was characterised by free flow conditions. In Table A2.23 the ten most abundant HBEFA traffic situations for passenger cars are presented. 65% of the vehicle kilometers travelled with passenger cars in 2021 was allocated to 0% road gradient and 28% to ± 2% road gradient. For 2022 and 2023 the same distribution as for 2021 was used.

Table A2.23. The ten most common traffic situations in Sweden in 2021, and their share of the total vehicle mileage for passenger cars.

Description of traffic situations	Share of national vehicle kilometers travelletVehicle mileage
Rural / Motorway / 110 / Freeflow / 0%	8.8%
Rural / Trunk / 70 / Freeflow / 0%	7.2%
Rural / Trunk / 100 / Freeflow / 0%	6.3%
Rural / Trunk / 80 / Freeflow / 0%	5.7%
Rural / Trunk / 80 / Freeflow / ± 2%	4.3%
URB / Access / 40 / Freeflow / 0%	4.1%
Rural / Trunk / 70 / Freeflow / ± 2%	3.8%
Rural / Motorway / 120 / Freeflow / 0%	2.7%
Rural / Motorway / 110 / Freeflow / ± 2%	2.6%
Rural / Trunk / 100 / Freeflow / ± 2%	2.3%
Total	**47.9%**

2.5.3 Most recent updates

In submission 2024 the following updates were made

- Statistics describing the Swedish vehicle stock 2022 and its associated traffic activity were implemented in HBEFA.

- A fuel consumption calibration for light commercial vehicles, CNG/gasoline cars (calibration of both methane and gasoline consumption), and plug-in hybrids (calibration of both gasoline and electricity consumption). The updates were made because the consumption per kilometer for those vehicle categories appeared too low compared to what other countries use in the HBEFA and it was also low compared to

88 Ericsson et al (2022)

real-world consumption data and reported CO_2 over the WLTP and/or NEDC cycle.

- A new survival probability function for battery electric passenger cars was implemented in HBEFA.

- The vehice category A tractor cars was added to 1.A.3.b. This is a vehicle type unique for Sweden and can be described as a car or lorry with limited gearbox, limited max speed and reclassified as tractor. In previous submissions they were included in the non-road sctor.

2.5.4 References section 2.5

André, M., Hammarström, U. and Reynaud, I., 1999. Driving statistics for the assessment of pollutant emissions from road transport. INRETS Report LTE 9906. February 1999.

Ericsson, E., Persson, A., Nolinder, E., Vuorenmaa Berdica, K. (2022) Trafikarbetets fördelning på HBEFA-modellens trafiksituationer – Dokumentation av arbetet 2021-2022, WSP Advisory, 2022-10-05. (in Swedish)

FVT (Forschungs-gesellschaft für Verbrennungs-kraftmaschinen und Thermodynamik), 2022, https://www.fvt.at/em/en/simulation/phem.html

Hammarström, U. and Yahya, M.-R., 2000. Estimation of representative fuel factors for heavy lorries – Questionnaire survey. VTI Report 445 (in Swedish). www.vti.se/publikationer.

Infras 2022, HBEFA 4.2 Documentation of updates, https://www.hbefa.net/e/documents/HBEFA42_Update_Documentation.pdf

SNRA (1999) Initial study of driving patterns and exhaust emissions in urban areas and development of a method in order to measure changes in acceleration and speed around road junctions. Driving behaviour 1998. SNRA Publication 1999:137.

Trafikanalys, 2011. Reviderad modell för beräkning av körsträckor – nya data för vägtrafiken 1999-2009. PM 2011:4

Trafikanalys (2022) Vehicle mileage for Swedish Registered Vehicles. https://www.trafa.se/en/road-traffic/driving-distances-with-swedish-registered-vehicles/

2.6 Methodology for working machinery

Fuel consumption and emissions of NO_X, NMVOC, CH_4, CO and N_2O from working machinery are estimated with a model developed by SMED in 2008, considered to correspond to Tier 3. Working machinery in this context means mobile machinery with a combustion engine that is not used on roads, waterways or railways. Included are e.g. construction machinery, handheld garden machines and snow mobiles.

Emissions and fuel consumption are calculated in the model with the equations below:[89]

$$E = N \times Hr \times P \times Lf \times EF_{adj} \tag{1}$$

E = Emissions in kt
N = number of vehicles,
Hr = yearly running time in hours,
P = engine power in kW,
Lf = load factor, and
EF_{adj} =adjusted emission factors in g kWh^{-1} according to equation below (applied for larger off road vehicles and snow scooters).

$$EF_{adj} = EF_l \times CAF \times TAF \times DF \times FAF \tag{2}$$

EF_l = emission regulations according to EU legislation in g kWh^{-1},
CAF = adjustment factor for difference between regulation and value measured at certification,
TAF = adjustment factor for transient (i.e. difference between static test cycle and real use of the machine),
DF = adjustment factor for decline of the motor by increasing age, and
FAF = adjustment factor for difference between certification fuel and Swedish diesel of type "MK1".

All variables in the equations are described as vectors with data for every model year the last 25 years.

2.6.1 Emission factors

Emissions of CO_2 and SO_2 are estimated using the same emission factors as for diesel and gasoline used for road traffic and are considered to correspond to Tier 2. The emission factors for SO_2 and CO_2 are adjusted according to fuel specifications for each year.

Emission factors for diesel machinery with an installed engine power > 37 kW are based on the emission regulations according to the EU legislation. Emission factors for diesel machinery < 37 kW are taken from Corinair[90]. For gasoline driven smaller off-road vehicles and machinery, emission factors are taken from Winther

[89] Fridell, Jernström and Lindgren, 2008

[90] EEA. 2007

and Nielsen 2006.[91] These are based on certification measurements. Fuel consumption and emission factors for snow mobiles are also taken from Winther and Nielsen 2006, except the emission factors for hydrocarbons, carbon monoxide and particles, which are taken from USEPA (2005)[92].

2.6.2 Vehicle Stocks

The number of diesel machinery 37 – 560 kW of different types is mainly based on a bottom-up inventory for the year 2006. [93] In submission 2014 the model was updated[94] with new information on the number of machines for some of the diesel vehicles in the range of 37 kW – 560 kW. In this update also improved estimates of vehicle life time were obtained from the new data and are now used in the model. In submission 2018 the model was updated with sales data for some off-road vehicles for 2005-2016. The sales data was provided by the Swedish trade association for suppliers of mobile machines.[95] Sales data is from submission 2019 and onwards used annually for updating the model with number of new machinery.

Numbers of tractors per sector, model year and engine power interval are for most years taken from the Swedish vehicle register. The number of working machines >560 kW for earlier years are taken from a IVL study conducted on behalf of the Swedish Transport Agency[96]. The number of working machines < 37 kW are based on a bottom-up inventory for the year 2002[97]. The number of machines for other years are estimated on e.g. sales data provided by the Swedish trade association for suppliers of garden machinery, estimates of lifetime or set as unchanged from 2002. Different methods are used for different types of machines.

The number of snow mobiles and all-terrain vehicles (ATVs) is obtained from the Swedish vehicle register.

2.6.3 Other parameters

Yearly running time, engine power and the load factor in equation (1) above are taken from Wetterberg[98] and Flodström[99]. Load factors for some of the machines are from a IVL study made in 2015[100]. The fuel adjustment factor, FAF, and the certification adjustment factor, CAF, for larger vehicles in equation (2) are taken

[91] Winther, M., Nielsen, O.-K., 2006.

[92] USEPA. 2005.

[93] Wetterberg C, Magnusson R, Lindgren M, Åström S. 2007.

[94] Jerksjö, M. 2013.

[95] Eklund, V., Lidén, M., Jerksjö, M., 2017.

[96] Transportstyrelsen 2014

[97] Flodström, E., Sjödin, Å., Gustafsson, T. 2004.

[98] Wetterberg C, Magnusson R, Lindgren M, Åström S. 2007.

[99] Flodström, E., Sjödin, Å., Gustafsson, T. 2004.

[100] Jerksjö, M., Fridell, E., Wisell, T. 2015

from Lindgren (2007).[101] The TAF and DF factors are taken from the Non-road model[102].

2.6.4 Allocation to CRT sectors

The allocation of emissions from working machinery is mainly based on a report by Flodström (et al)[103]. This is the most recent Swedish inventory including an allocation of working machinery to the different CRT sectors. There has also been some changes of the allocation proposed in Flodström *et al.*, 2004. Most of these changes have been done by expert judgements in cases where the allocation did not seem to be accurate. In submission 2018, the allocation to CRT sectors was updated, as new information was received from the Swedish trade association for suppliers of mobile machines and from the vehicle register. Table A2.25 shows the emissions of CO_2 from fuels used by working machinery 2022, split by sector and fuel type.

Table A2.25. CO_2 emissions from fossil fuels used by working machinery 2022.

CRT sector	Category	Fuel type	CO_2 (%)
1A2g vii	Industry	Diesel	40%
1A4a ii	Commercial/institutional	Diesel	7%
1A4b ii	Residential	Diesel	1%
1A4c ii	Agriculture	Diesel	14%
1A4c ii	Forestry	Diesel	12%
1A2g vii	Industry	Gasoline	1%
1A4a ii	Commercial/institutional	Gasoline	3%
1A4b ii	Residential	Gasoline	7%
1A4c ii	Agriculture	Gasoline	1%
1A4c ii	Forestry	Gasoline	1%
1A3e ii	Other Transport	Diesel + Gasoline	13%
Total	**Total**	**Total**	**100%**

2.6.5 Most recent updates

In submission 2023, snow scooters and all-terrain vehicles have been separated into two different machine types in the model. Sweden has tried to obtain more precise information on e.g. annual operation hours and lifetime for both machine types but no reliable data was obtained so far. Therefore, all parameters for all-terrain vehicles are set to be equal to snow mobiles with the exception that all-terrain vehicles are assumed to run on 4-stroke engines only.

[101] Lindgren M. 2007.

[102] USEPA. 2010.

[103] Flodström, E., Sjödin, Å., Gustafsson, T. 2004.

The A-tractor, a modified regular car registered as a tractor with certain operation constraints (modified power train and maximum speed of 20 mph), was until submission 2024 part of the tractor segment within the national non-road mobile machine model. During submission 2024 these machines were moved to 1.A.3.b. Statistics Sweden also reviewed the tractor fleet throughout the time series which led to changes in the number of tractors included in the model. Moreover, all-terrain vehicles (ATV) registered as tractors were moved from the machine segment Tractors to the machine segment ATV which resulted in fewer diesel tractors in operation and a larger number of gasoline driven all-terrain vehicles in operation..

2.6.6 References section 2.6

40 CFR 89.112 - Oxides of nitrogen, carbon monoxide, hydrocarbon, and particulate matter exhaust emission standards. July 1st, 2013. Available at https://www.govinfo.gov/app/details/CFR-2013-title40-vol21/CFR-2013-title40-vol21-sec89-112

EEA. 2007. EMEP/CORINAIR Emission Inventory Guidebook - 2007. Technical report No 16 European Environment Agency, Copenhagen Denmark.

EEA (2016). EMEP/EEA air pollutant emission inventory guidebook 2016. https://www.eea.europa.eu/publications/emep-eea-guidebook-2016

EU Regulation 2016/1628 of the European Parliament and of the Council of 14 September 2016 on requirements relating to gaseous and particulate pollutant emission limits and type-approval for internal combustion engines for non-road mobile machinery. Available at https://eur-lex.europa.eu/eli/reg/2016/1628/2020-07-01

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

Flodström, E., Sjödin, Å., Gustafsson, T. 2004. Uppdatering av utsläpp till luft från arbetsfordon och arbetsredskap för Sveriges internationella rapportering. Rapportserie SMED och SMED&SLU Nr 2 2004.

Fridell, E., Jernström, M., Lindgren,M., 2008. Arbetsmaskiner – Uppdatering av metod för emissionsberäkningar. SMED report 39 2008.

Jerksjö, M., Fridell, E., Wisell, T. Non-Road Mobile Machinery Model – Updates 2015. IVL report C134

Mawdsley, I. Uppdatering av utsläpp från gräsklippning i Sveriges utsläppsrapportering. SMED report 29 2020.

Lindgren M. 2007. A methodology for estimating annual fuel consumption and emissions from non-road mobile machinery – Annual emissions from the non-road mobile machinery sector in Sweden for year 2006. Report – Environment, Engineering and Agriculture 2007:01. Department of Biometry and Engineering, SLU, Uppsala, Sweden.

Statistics Sweden, 2006: Energy consumption in the fishery sector 2005. Official Statistics of Sweden.

Szudy, M., Eklund, V., Bergström, J., Pihl-Karlsson, G., Danielsson, H., Helbig, T. 2019. Implementering av EMEP EEA Guidebook 2016. SMED PM 2019.

Transportstyrelsen 2014, Möjligheten att minska utsläppen av sot från arbetsmaskiner – Uppdrag att analysera ett nationellt krav på partikelfilter i stora arbetsmaskiner. TSG 2013-1541

USEPA 2005. Exhaust emission factors for nonroad engine modeling: spark-ignition. EPA420-R-05-019, NR-010e

USEPA 2010. Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling - Compression Ignition, EPA-420-R-10-018

Wetterberg C, Magnusson R, Lindgren M, Åström S., 2007. Utsläpp från större dieseldrivna arbetsmaskiner – Inventering, kunskapsuppbyktnad och studier om åtgärder och styrmedel. Rapport – miljö, teknik och lantbruk 2007:03. Institutionen för biometri och teknik SLU

Winther, M., Nielsen, O.-K., 2006. Fuel use and emissions from non-road machinery in Denmark from 1985-2004 - and projections from 2005-2030. Danish Ministry of the Environment project 1092, 2006.

3 Annex 3: Other detailed methodological descriptions for individual sources or sink categories

Annex 3:1
Brief description of the Excel-model for calculation of emissions of fluorinated gases

Annex 3:2
Land Use, Land-Use Change and Forestry (CRT sector 4)

Annex 3:3
Methodological issues for solvent and other product use (CRT 2.D.3)

Annex 3:4
Rationale for data sources used for key categories in industrial processes sector (CRT 2)

Annex 3:5
Documents from Swedish Refrigeration & Heat Pump Association and Swedish Car Recyclers Association

3.1 Annex 3:1: Brief description of the Excel-model for calculation of emissions of fluorinated gases

3.1.1 Background

In 2000, the first inventory of actual emissions of fluorinated greenhouse gases in Sweden was performed, covering the time period 1990-99 (Kindbom et. al 2001). At this time, a first version of an excel model was developed. In early 2004, the model was refined concerning the calculations from the accumulated bank. After the improvement, the leakage factor for equipment produced one specific year is used throughout its lifetime. For several sub-sources the produced newer equipment has been assigned lower annual leakage, while the older equipment still is assigned the original higher leakage rate in the calculations.

In 2005 a thorough update of the calculations and the model was made since additional information had become available, indicating that an update of the way of utilizing background data, and of the calculation methodology was necessary (Kindbom, K. 2005).

Activity data used for calculating emissions from the categories stationary refrigeration (HFCs and PFCs) and electrical insulation (SF_6) were revised in cooperation with Product Register staff at the Swedish Chemicals Agency. Use of NF_3 is not occurring in Sweden. Furthermore, national calculation methodologies for emissions from semi-conductor manufacture and from foam blowing were studied in relation to the descriptions in IPCC Good Practice Guidance (2000). The result from these comparisons was that the methodology for calculating emissions from semi-conductor manufacture was revised according to the Tier 1 methodology given in IPCC Good Practice Guidance, while the national method for calculating emissions from foam blowing was retained.

Due to improved information during the course of the work, revisions of emission calculations were also made for mobile air conditioning and for metered dose inhalers. Additionally, from the improved information on fluorinated substances followed that the reporting of potential emissions, where previously only data from 1995 and on were covered, could be made complete for the whole time series.

3.1.2 Structure of the Excel model

The model consists of an Excel file with sheets for each sub-source considered where all input data from 1990 until present is registered and where calculations of accumulated amounts and actual emissions occur.

The individual sub-source sheets may look slightly different as far as the input data cells are concerned. These have been adapted to suit the actual input data available and needed for the calculations. For all sub-sources, calculations are however made concerning annual accumulated bank and actual emissions by substance. Where appropriate, also imported and exported amounts in products are calculated.

3.1.3 Input data and calculated data

Every sub-source sheet has input cells for each year where the production, import and export of F-gases for that particular source are entered. For each year, an expected lifetime, leakage factors and a minimum content factor is given. Each sub-source then has its specific composition of use of species of HFC, PFC and SF_6, which are calculated separately. For each component the leakage in each year is calculated, taking into account the leakage from production, the leakage from the accumulated bank and from decommissioning. In these calculations, each year uses the leakage factor for that year's production until minimum content or the expected lifetime is reached.

Changes in accumulated amounts each year, resulting from additional amounts of HFC, PFC and SF_6 imported and used within the country, as well as the decline in accumulated stock caused by exports or emissions from operating systems, have been taken into consideration. Most calculations are made with standard worksheet functions in excel. But to simplify the worksheets, some VBA functions have been written. These are:

```
Function accumulated_minus_leakage (year_range, cond_range, _
            year, sum_range, leakage_range, min_content)
```

Calculates the sum of each year's additions of HFC, PFC and SF_6 minus the leakage taking into account the different leakage factors for each year and the minimum content in each equipment.

```
Function leakage_per_year (year_range, cond_range, _
            year, sum_range, leakage_range, min_content)
```

Calculates the sum of the leakage of the accumulated bank.

3.1.4 Development of new functionalities in the model in 2005

Most of the information necessary for a complete reporting of fluorinated greenhouse gases according to the guidelines was already present as background data in the model. The model until 2005 however efficiently supported only the compilation of annual actual emissions. The development in 2005 in particular applied to the information required in the background tables in the CRT reporting system.

New definitions relating to the reporting requirements were developed and included in all source specific data sheets. These cover all required data in the CRT background tables, such as the amounts of chemical filled in new manufactured products, accumulated stock and remaining amounts at decommissioning, as well as the emission factors for production, during use and at decommissioning.

Some adjustment and development relating to specific sources and calculation sheets were also made:

- an aggregation of sources in the group of stationary refrigeration and air conditioning, with previously seven separate sources/sheets were aggregated into three calculation sheets.
- the calculations for metered dose inhalers and technical (other) aerosols were split on two separate sheets.
- the calculations of emissions of SF_6 from electrical equipment was split on two separate sheets, one for emissions from manufacture of gas insulated switchgear and one for electrical insulation.
- a harmonisation of the presentation of columns and calculations in the different sheets/sources in the model was also made, since source-specific improvements and changes over time had made the calculation sheets develop along different lines.
- sheets for registering and adjustment of import and export data from the Product Register were added to the model. This enables the automatic calculation of volumes of chemicals not already accounted for in the model. As a result, surplus HFCs not already accounted for are automatically allocated to stationary refrigeration and accordingly for SF_6, which is automatically allocated to electrical insulation.

3.1.5 Review of the model input and output in 2011

In 2011, SMED performed a review study (Gustafsson, T., 2011) on the national model for estimating emissions of fluorinated greenhouse gases in Sweden. The aim of the study was to improve the quality of the collection and emission estimation system in Sweden for F-gases reported to the UNFCCC and the EU Monitoring Mechanism, and especially in order to enable better annual follow-up of changes in chemicals flows and emissions of F-gases, e.g. due to increased amounts of HFC recovered and the enforced national and international legislations.

The national statistics available and the most important additional information sources and emission factors were reviewed. The results of the study showed that the national statistics from the Swedish Chemicals Agency and the additional information sources continues to be a good foundation for the Swedish emission inventory reporting.

In the study, no major adjustments were recommended for the collection and emission estimation system, but there were some suggestions on modifications of emission factors and model macros. In addition, the study included several recommendations for future improvements on emission inventory quality control checks as well as on national data management procedures.

3.1.6 References Annex 3:1

Kindbom, K., Haeger Eugensson, M., Persson, K. (2001). Kartläggning och beräkning av potentiella och faktiska utsläpp av HFC, FC och SF_6 i Sverige. IVL report B 1428. (In Swedish)

Kindbom, K. (2005) Revision of Methodology and Estimated Emissions of Fluorinated Greenhouse Gases in Sweden. SMED Report 16 2005.

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 98 2011.

3.2 Annex 3:2: Land Use, Land-Use Change and Forestry (CRT sector 4)

In the following chapter, we provide additional information on methodological issues used in the inventory for the LULUCF-sector. The structure follows chapter "6.4.2 Methodological issues" in the NIR and we refer to the corresponding NIR-chapter where appropriate.

3.2.1 Methodological issues, CRT-tables 4A, 4B, 4C, 4D, 4E and 4F

3.2.1.1 SAMPLE BASED ESTIMATIONS

The sample frame of the Swedish National Forest Inventory (NFI) 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 and a specific number of sample units are sampled per stratum. Each cluster (tract) of sample plots is assumed to be the sample unit (Figure 6.3 and 6.4 in NIR). The inventoried area of tract number *j* will represent a large area in the estimations of area weight and the sum of all represented areas will be equal to the total county area (A_i).

$$Area\,weight_{ij} = \frac{A_i}{n_i \cdot a_{ij}}$$

where $Area\ weight_{ij}$ = the area that tract *j* within county *i* will represent, n_i = number of sampled tracts within county *i*, and a_{ij} = the inventoried area of tract *j* within county *i*. In a consistent manner, the $Area\ weight_{ij}$ will be the same for each year from 1990 onward. Whole plots or parts of a plot may change land-use category by time but the total tract area will always represent the same area. At the county level, the reported value (e.g. the change in carbon stocks for land-use category Forest land remaining Forest land) will be estimated by a ratio estimator[104].

$$\hat{Y}_i = A_i \frac{\hat{X}_i}{\hat{A}_i}$$

where $\hat{Y}_i$ = the ratio estimated value, A_i = the measured area (determined 1984 by the national land survey; Lantmäteriet[105]). $\hat{X}_i$ = the estimated value of the variable of interest according to Horvitz-Thompson and $\hat{A}_i$ = the estimated area according to Horvitz-Thompson. Index *i* refers to county. If $\hat{X}_i$ refers to area, the total area will always be the same as the measured area of Sweden.

104 Thompson, 1992

105 Lantmäteriet, http://www.lantmateriet.se/

The two values estimated by the Horvitz-Thompson estimator are calculated similarly, e.g. as:

$$\hat{X}_i = Area\,weight_{ij} \sum_{j=1}^{n_i} x_{ij}$$

x_{ij} = is the inventoried value of tract *j* (within county *i*).

Finally the reported value on national level, $\hat{Y}$, is estimated as:

$$\hat{Y} = \sum_{i=1}^{N} \hat{Y}_i$$

N = the total number of counties in Sweden.

Sweden only reports “human induced” carbon stock changes, where “human induced” has the interpretation of “managed”, i.e. the carbon stock change on unmanaged land are set to zero. However, the observed carbon stock on unmanaged land is considered when calculating stock changes after conversions between unmanaged and managed land and vice versa. All areas, managed or unmanaged, are reported. On request from reviewers (ARR 2019), carbon stock changes are reported for land converted to Other land even if Other land is considered unmanaged.

Land areas have moved between counties since 1984 but the total area at national level is the same. This influence on the weights in the estimators used to calculate the areas but the effect on the estimates is negligible.

3.2.1.2 THE LULUCF REPORTING DATABASE

The reporting database is based on permanent sample plots inventoried by the NFI. In total, around 40 000 permanent sample plots were laid out during the period 1983-1987 representing the whole area of the country. Thus, the land use for all land and fresh-water areas are monitored. The permanent sample plots have been re-inventoried at intervals of 5-10 years, however, for economic reasons, the number of inventoried permanent sample plots have been reduced to around 30 000. The land use of each plot (or sub-plot for plots divided in two or more land-use classes) is described from the year of the first inventory (1983-1987) and every year thereafter. The land use of years between inventories has been interpolated.

Each single sample plot has been inventoried in one of ten inventory intervals (Table A3:2.1). When all plots of a specific reporting year have been re-inventoried at least once, after the specific reporting year, the figures will be re-calculated based on all sample plots. For submission 2024, all sample plots have been re-inventoried for 1990-2018 and, thus, these years are based on measurements of all 30 000 re-measured plots. The years 2019-2022 will be based on gradually smaller number of measured plots. Theoretically, both the years represented by a limited number of measured plots and the reported years including all records of measured data will be unbiased. However, the accuracy will be better in the latter case.

To further improve the calculations for the years not inventoried or interpolated, each interval of data is extrapolated for years up to the latest reported year (for example, cycles 7 and 8 in Tabel A3:2.1 have been extrapolated one year up to 2022). This means that the average for each reported year, for which there is not a full record of plots inventoried or interpolated, is weighted, thus reducing the significance of the inventory measured the last reported year. Using only data from one year of an inventory may cause unrealistic annual variations caused by random variation of the sample.

Table A3:2.1. A single sample plot is inventoried in one of ten inventory intervals. Blue coloured background refers to measurements and no colour refers to interpolated data. Brown coloured background means that data has been extrapolated.

1	2	3	4	5	6	7	8	9	10
1983	1983	-	-	-	-	-	-	-	-
1984	1984	1984	1984	-	-	-	-	-	-
1985	1985	1985	1985	1985	1985	-	-	-	-
1986	1986	1986	1986	1986	1986	1986	1986	-	-
1987	1987	1987	1987	1987	1987	1987	1987	1987	1987
1988	1988	1988	1988	1988	1988	1988	1988	1988	1988
1989	1989	1989	1989	1989	1989	1989	1989	1989	1989
1990	1990	1990	1990	1990	1990	1990	1990	1990	1990
1991	1991	1991	1991	1991	1991	1991	1991	1991	1991
1992	1992	1992	1992	1992	1992	1992	1992	1992	1992
1993	1993	1993	1993	1993	1993	1993	1993	1993	1993
1994	1994	1994	1994	1994	1994	1994	1994	1994	1994
1995	1995	1995	1995	1995	1995	1995	1995	1995	1995
1996	1996	1996	1996	1996	1996	1996	1996	1996	1996
1997	1997	1997	1997	1997	1997	1997	1997	1997	1997
1998	1998	1998	1998	1998	1998	1998	1998	1998	1998
1999	1999	1999	1999	1999	1999	1999	1999	1999	1999
2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
2001	2001	2001	2001	2001	2001	2001	2001	2001	2001
2002	2002	2002	2002	2002	2002	2002	2002	2002	2002
2003	2003	2003	2003	2003	2003	2003	2003	2003	2003
2004	2004	2004	2004	2004	2004	2004	2004	2004	2004
2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
2007	2007	2007	2007	2007	2007	2007	2007	2007	2007
2008	2008	2008	2008	2008	2008	2008	2008	2008	2008
2009	2009	2009	2009	2009	2009	2009	2009	2009	2009
2010	2010	2010	2010	2010	2010	2010	2010	2010	2010
2011	2011	2011	2011	2011	2011	2011	2011	2011	2011
2012	2012	2012	2012	2012	2012	2012	2012	2012	2012
2013	2013	2013	2013	2013	2013	2013	2013	2013	2013
2014	2014	2014	2014	2014	2014	2014	2014	2014	2014
2015	2015	2015	2015	2015	2015	2015	2015	2015	2015
2016	2016	2016	2016	2016	2016	2016	2016	2016	2016
2017	2017	2017	2017	2017	2017	2017	2017	2017	2017
2018	2018	2018	2018	2018	2018	2018	2018	2018	2018
2019	2019	2019	2019	2019	2019	2019	2019	2019	2019
2020	2020	2020	2020	2020	2020	2020	2020	2020	2020
2021	2021	2021	2021	2021	2021	2021	2021	2021	2021
2022	2022	2022	2022	2022	2022	2022	2022	2022	2022

An example of the inventory cycle for a sample plot can be found in Figure A3:2.1.

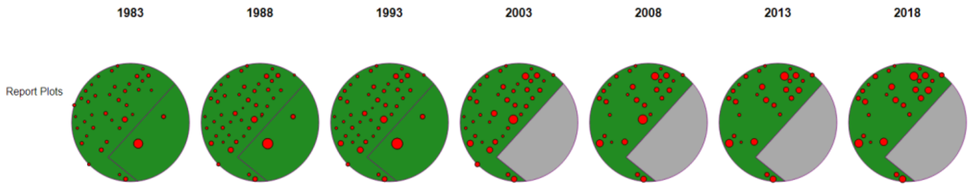

Figure. A3:2.1. An example of the inventory cycle for a sample plot. A part of the plot was deforested between 1993-2003 and illustrate the possibility to report emissions/removals separately per plot part. The filled circles mark trees and the size of the circles is proportional to the size of the trees.

Methodology living biomass CRT 4A, 4B, 4C, 4D, 4E and 4F

A national methodology (Tier 3) is used. The aboveground biomass per tree fractions is estimated by applying Marklund's[106] biomass functions to sample trees on permanent sample plots of the NFI[107]. The below-ground biomass pool is estimated by Petersson's and Ståhl's[108] biomass functions applied to the same trees. The conversion factor 0.50 is used to convert dry weight biomass to carbon[109]. Estimates are based on repeated measurements and the stock change of for a specific year (X) is calculated as the difference in stock between year X and year X-1.

Marklund's single tree allometric regression functions (Table A3:2.2) were developed for predicting biomass of the following tree fractions; needles (not leaves), branches, bark and stem for Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*) and birch (*Betula pendula* and *Betula pubescens*). The total fresh weight of each tree (in total, about 1300 trees) and the fresh weight of samples from different fractions were measured in field. The dry weight of each sample, defined as the constant weight at 105°C, was determined in the laboratory. The calculations of dry weight per fraction were based on these measurements. The trees were selected from 123 stands from different parts of Sweden, covering a wide variety of stand and site conditions.

Petersson and Ståhl developed allometric single tree below ground biomass functions for Scots pine, Norway spruce and birch in Sweden (Table A3:2.2). The idea was to calibrate an existing comprehensive data set of about 600 trees inventoried by Marklund that only covered the stump and coarse roots, by a new data set that covered roots down to 2 mm diameter. The new data set consisted of

[106] Marklund, 1987 and 1988

[107] Ranneby et al., 1987

[108] Petersson and Ståhl, 2006

[109] National Board of Forestry, 2000

about 80 trees sampled using the same sampling design as Marklund, but supplemented with a detailed inventory of the fine root fractions remaining in the ground. The old data set was calibrated before the two data sets were merged. The merged data set was used for deriving the functions.

At application, trees with a diameter at breast height (DBH) larger than 99 mm are positioned on the sample plots and perfectly matched to land use over time, while all small trees, 0-99 mm at DBH, are reported under Forest land remaining Forest land/ FM. The net carbon stock change of small trees is calculated as the average net carbon stock change over time (1990-2010) and was estimated to -3.986 M ton CO_2 per year. This removal is assumed constant for every reported year. Change in living biomass for small trees is calculated with regression. This is due to large sampling variation for small tree estimation. Small and large trees are inventoried with different inventory designs. There is no risk of overlapping estimates.

Table A3:2.2. The simplest biomass functions applied to trees only measured for stem diameter at breast height (1.3 m) and species. TVSTAM=dry weight, stem including bark [kg], TVLGREN=dry weight, branches and needles (not leaves) [kg], TVBARR=dry weight, needles (not leaves) [kg], TVROTSTU=dry weight, stump and roots down to 2 mm [0.1 kg], D=stem diameter at breast height (1.3 m) [cm] and dbh=stem diameter at breast height (1.3 m) [mm].

Biomass function	Unit	Reference
Scots pine (Pinus sylvestris)		
TVSTAM=exp(11.3264*D/(D+13.)-2.338)	[kg]	Marklund, T-1
TVLGREN=exp(9.1015*D/(D+10.)-2.8604)	[kg]	Marklund, T-13
TVBARR=exp(7.7681*D/(D+7.)-3.7983)	[kg]	Marklund, T-17
TVROTSTU=exp(3.44275+((dbh/(dbh+113))*11.06537)+((0.35449**2)/2.))/100.	[0.1 kg]	Petersson & Ståhl
Norway spruce (Picea abies)		
TVSTAM=exp(11.3341*D/(D+14.)-2.0571)	[kg]	Marklund, G-1
TVLGREN=exp(8.5242*D/(D+13.)-1.2804)	[kg]	Marklund, G-11
TVBARR=exp(7.8171*D/(D+12.)-1.9602)	[kg]	Marklund, G-15
TVROTSTU=exp(4.58761+((dbh/(dbh+138))* 10.44035)+((0.32308**2)/2.))/100.	[0.1 kg]	Petersson & Ståhl
Birch (Betula pendula and B. pubescens)		
TVSTAM=exp(11.0735*D/(D+8.)-3.0932)	[kg]	Marklund, B-1
TVLGREN=exp(10.2806*D/(D+10.)-3.3633)	[kg]	Marklund, B-11
TVROTSTU=exp(6.17080+((dbh/(dbh+225))* 10.01111)+((0.36266**2)/2.))/100.	[0.1 kg]	Petersson & Ståhl

3.2.1.3 VALIDATING CHANGES IN LIVING BIOMASS

Reported changes in living biomass were validated using the same method as reported but stem volume was converted to CO_2 with the constant 1.375 t CO_2 $m^3_{sk}{}^{-1}$ (assuming that 1 m^3 stem wood corresponds to 0.75 tonne whole tree dry wood with a carbon content of 50%). Small trees, dbh<100 mm, are added in the same way (as a contant of -4.0 Mt $year^{-1}$). The constant, 1.375, refers to total stock and not change in stock.The individual biomass functions used in the reporting och carbon stock changes consider that this relationship is not constant by e.g. tree age (Figure A.3.2.2).

Reported change in living biomass was validated using the default method (growth minus drain) and five-year running averages from the NFI[110]. The growth and drain were converted to CO_2 with the constant 1.375 and -4.0 Mt year $^{-1}$ was added for small trees. Again, the contant used cannot handle the allocation of growth among smaller and bigger trees. The NFI data consists of both temporary and permananet sample units (Figure A.3.2.3).

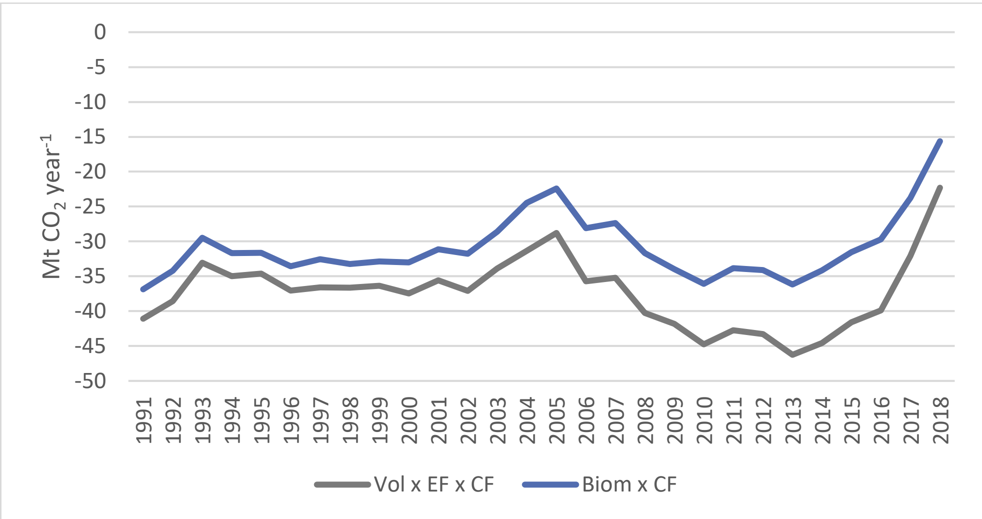

Figure. A3:2.2. Validating reported change in living biomass (Biom x CF) with change in volume (Vol x EF x CF) and same underlying inventory designs (stock difference)

[110] Skogsdata 2023, p.68, 2023

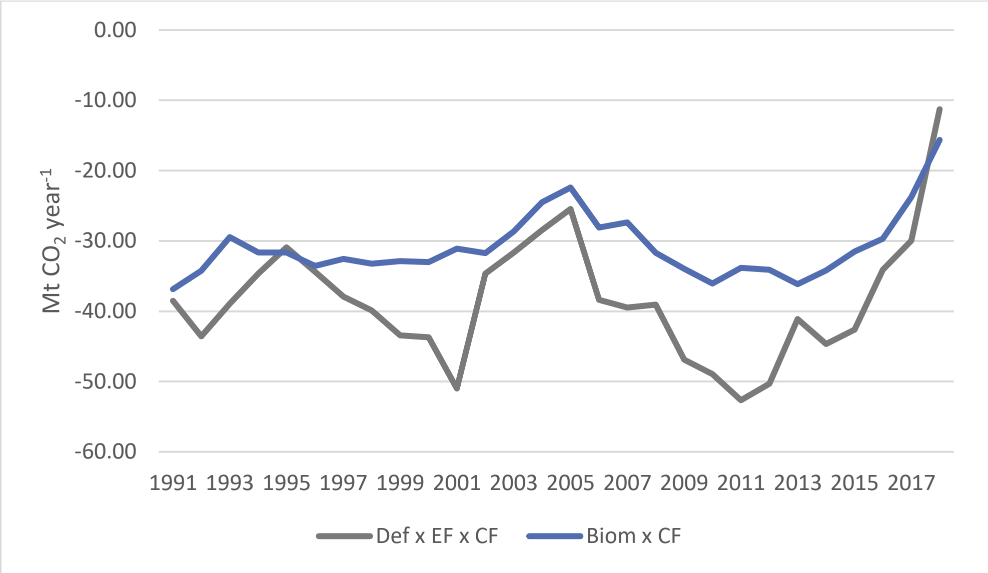

Figure. A3:2.3. Validating reported change in living biomass (Biom x CF) with change in volume (Def x EF x CF) and the default method

3.2.1.4 METHODOLOGY DEAD ORGANIC MATTER CRT-TABLES 4A, 4B, 4C, 4D, 4E AND 4F

A national methodology is used to estimate the dead organic matter pool. The pool includes different sub-pools (dead wood, coarse litter and the organic soil horizon) that are estimated using different methods.

3.2.1.4.1 Methodology dead wood CRT-tables 4A, 4B, 4C, 4D, 4E and 4F

The inventory of fallen and standing dead wood within the NFI began in 1994 for northern Sweden and from 1995 for the whole country. However, for consistency reasons only inventory data from 1997 and onwards is used. Thus the same value is reported 1990-1997 (extrapolation). The inventory cycles used are quite complicated (Table A3:2.3). This is a compromise to, in an acceptable way, match existing data to specific reporting years. From reporting year 2008, the methodology is fixed and consistent in the way that data for each reported year is based on the stock change of two consecutive inventories for all five inventory cycles used. Due to a five-year inventory cycle, the five most recent reporting years are updated each year and are thereafter fixed. Thus reported years 1990-2018 are now fixed.

The carbon content in dead wood is assessed by first measuring the volume of dead wood and assessing the degree of decomposition on the NFI plot. The volume is converted volume to carbon content by multiplying the volume by constants. The constants are differentiated according to decay class and species[111].

[111] Sandström et al., 2007

Sandström *et al.* developed conversion factors from dead wood volume per decay class to biomass for the species Norway spruce, Scots pine and birch in Sweden. About 2500 discs were collected from logs in managed forests located on 290 NFI[112] sample plots and in 11 strips located in preserved forests. The data represented different site-, stand-, species- and dead wood properties in Sweden. The volume per sample disc was measured (divided into species and decay classes). The dry weight of each sample, defined as the constant weight at 85°C, was measured at the laboratory. The carbon content per dry weight biomass for Norway spruce and Scots pine was estimated to 50.0 and 51.2% of the dry weight biomass pool respectively, based on a sub-sample. The conversion factors decreased significantly with decay class and the average dry densities were 0.226, 0.239 and 0.275 [g cm^{-3}], for Norway spruce, Scots pine and birch, respectively (Table A3:2.4A).

Below-ground dead wood originating from stump and root systems is partly estimated and partly modelled. The input (gain of carbon) to this pool is estimated as the difference between growth (in CO_2) minus net change in living biomass (representing the harvest). The long time series is necessary to consider the loss of carbon from decomposition of “historical stumps”. The stump pool will end up in a removal if harvest is gradually increasing, i.e. if input is higher than output.

A constant is used to convert whole tree harvest to retained stump and root system biomass, i.e. 1 m^3 stem wood is assumed to correspond to 750 kg whole tree biomass and to 184 kg stump and root system biomass (dry wood). The output (loss of carbon) is modelled by a decomposition function[113]. Input and output is considered from 1853-2021 (Table A3:2.4B).

The constant used to convert whole tree harvest to retained stump and root system biomass is derived by applying biomass functions[114] and stem volume functions[115] to sample trees inventoried by the National Forest Inventory and representing the standing stock of Sweden. The methodology chosen harmonizes fluctuations in living biomass with net removals from stumps. Thus, if harvest increase in relation to the growth, the net removals in living biomass will decrease while the net removal of stumps will most likely increase.

Note that validation data presented in table A3:2.4B is used only for validation and is derived similarly as for reported data but using different data sources. The harvest (inflow of stumps to the pool) for the reported data is based on growth minus net removal in living biomass as described above while harvest for the validation data is based on production statistics from the Swedish Forest Agency.

[112] Ranneby et al., 1987

[113] Melin et. al. 2009

[114] Marklund, 1988, Petersson and Ståhl, 2006

[115] Näslund 1947

Table A3:2.3. Description on data-sets used to estimate changes in the dead wood pool.

Reporting year	Trend between years		No. of plots
1990…1997	1997	2004	6000
1998	1997/1998	2004/2005	12000
1999	1997/1998/1999	2004/2005/2006	18000
2000…2004	1997/1998/1999/2000	2004/2005/2006/2007	24000
2005	1998/1999/2000	2005/2006/2007	18000
2006	1999/2000	2006/2007	12000
2007	2000	2007	6000
2008	2003/2004/2005/2006/2007	2008/2009/2010/2011/2012	30000
2009	2004/2005/2006/2007/2008	2009/2010/2011/2012/2013	30000
2010	2005/2006/2007/2008/2009	2010/2011/2012/2013/2014	30000
2011	2006/2007/2008/2009/2010	2011/2012/2013/2014/2015	30000
2012	2007/2008/2009/2010/2011	2012/2013/2014/2015/2016	30000
2013	2008/2009/2010/2011/2012	2013/2014/2015/2016/2017	30000
2014	2009/2010/2011/2012/2013	2014/2015/2016/2017/2018	30000
2015	2010/2011/2012/2013/2014	2015/2016/2017/2018/2019	30000
2016	2011/2012/2013/2014/2015	2016/2017/2018/2019/2020	30000
2017	2012/2013/2014/2015/2016	2017/2018/2019/2020/2021	30000
2018	2013/2014/2015/2016/2017	2018/2019/2020/2021/2022	30000
2019	2014/2015/2016/2017	2019/2020/2021/2022	24000
2020	2015/2016/2017	2020/2021/2022	18000
2021	2016/2017	2021/2022	12000
2022	2017	2022	6000

Table A3:2.4.A Net removal (-) in lying or standing dead wood [Mt CO_2]

Reporting year	Forest land	Cropland	Grassland	Settlements
1990…1997	-1.79	-0.02	-0.03	-0.03
1998	-2.65	-0.01	-0.03	-0.01
1999	-2.00	-0.01	-0.03	0.01
2000…2004	-2.04	-0.01	-0.03	-0.02
2005	-2.12	0.00	-0.03	0.01
2006	-1.44	0.00	-0.03	0.02
2007	-2.16	0.00	-0.02	0.00
2008	-1.31	0.00	0.00	0.00
2009	-0.93	0.00	0.03	0.00
2010	-1.06	0.00	0.02	0.00
2011	-1.60	-0.01	0.02	0.00
2012	-1.70	0.00	0.02	0.00
2013	-1.95	0.00	0.01	0.00
2014	-2.49	0.00	-0.01	0.00
2015	-2.48	-0.01	-0.01	0.00
2016	-3.12	-0.01	-0.01	0.00
2017	-3.50	-0.01	-0.01	0.00
2018	-3.89	-0.01	-0.01	0.00
2019	-4.06	-0.01	-0.01	0.00
2020	-4.56	-0.01	-0.01	0.00
2021	-4.41	-0.01	-0.01	0.00
2022	-4.73	-0.01	-0.02	0.00

Table A3:2.4.B Net removal (-) in stump and root systems [Mt CO_2] based on Growth minus net Cange in living biomass (Reported) and from Harvest statistics (Validation).

Reporting year	Reported	Validation
1990	-2.94	-1.55
1991	-2.19	-0.94
1992	-5.00	-1.67
1993	-4.30	-1.90
1994	-4.01	-2.55
1995	-3.09	-5.17
1996	-3.10	-2.26
1997	-4.08	-3.74
1998	-3.90	-3.64
1999	-5.16	-2.76
2000	-5.73	-4.32
2001	-9.61	-3.99
2002	-8.29	-5.36
2003	-8.71	-5.45
2004	-9.22	-6.34
2005	-9.69	-17.79
2006	-7.99	-3.08
2007	-8.18	-8.23
2008	-7.62	-4.78
2009	-7.30	-1.83
2010	-7.51	-5.05
2011	-8.45	-5.12
2012	-7.82	-3.50
2013	-6.80	-3.55
2014	-6.14	-5.41
2015	-5.27	-4.65
2016	-4.93	-4.30
2017	-5.91	-4.85
2018	-7.39	-4.15
2019	-7.00	-4.53
2020	-6.63	-4.39
2021	-6.37	-5.51
2022	-6.12	-5.19

3.2.1.5 METHODOLOGY LITTER CRT-TABLES 4A, 4B, 4C, 4D, 4E AND 4F

The carbon in the litter pool is estimated based on three different sources (i) coarse litter (ii) annual litter fall and (iii) litter < 2 mm. Coarse litter is defined as dead organic material with a "stem diameter" between 10-100 mm and originating from dead trees. Coarse litter is not inventoried but calculated as 15% of the aboveground fallen or standing dead wood. Litter originating from stem harvest and thinnings and remaining on site are included through these calculations. Annual litter fall for coniferous species is calculated using empirical functions (Table A3:2.5) and annual litter fall for deciduous species by biomass functions based on leaf biomass. The annual litter pool is included since it will not be part of any of the other fractions. It may contain both coarse and fine litter but is not related to dead wood like the coarse litter fraction defined above, and it is not part of the fine litter fraction sampled since all parts of the litter layer that are considered to have fallen during the inventory year are removed before sampling. 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 from the O or H horizon sample which is taken on an area basis, weighed and analysed for carbon content.

The annual stock change in the O horizon carbon stock is based on samples from re-inventoried plots between 1993 and 2020 (values for 1990-1992 and 2021 - 2022 are extrapolated). The stocks of dead wood and the three different litter fractions are presented in Table A3:2.6.

Table A3:2.5. Functions used to estimate the litter part of the dead organic matter pool.

Coarse litter (CL)		**Unit**
CL=0.15•DW		[kg ha^{-1}]
CCL=0.5•CL/1000	(CCL=Carbon in coarse litter)	[Mg ha^{-1}]
Annual litterfall (AL)		
ALNS=16509-245.8•Lat+5.22•BANS		[kg ha^{-1}][116]
ALPS=6906-102.3•Lat+46.4*BAPS-4.5•Age		[kg ha^{-1}][117]
ALD= ND•0.00371•ABDH$^{1.11993}$		[kg ha^{-1}][118]
CAL=0.5• (ALNS+ALPS+ALD)/1000	(CAL=Carbon in annual litterfall)	[Mg ha^{-1}]
Fine litter (CFL) <2 mm		
CFL=SDW•Cconc•0.01/SA		[Mg ha^{-1}]
Total litter carbon (CTL)		
CTL=CCL+CAL+CFL		[Mg ha^{-1}]

The following abbreviations are used in Table A3:2.5;

CL=coarse litter,
DW=dead wood,
AL=Annual litterfall,
NS=Norway Spruce,
PS=Scots pine,
D=deciduous,
Lat=Latitude,
BA=basal area,
Age=tree age,
ND=number of deciduous stems ha^{-1},
ABDH=average diameter at breast height (1.3 m),
C=carbon,
Cconc=Carbon concentration in%,
SDW=sample dry weight in Mg,
SA=sampled area in ha,
TL=total litter

[116] Berg et al., 1999a

[117] Berg et al., 1999b

[118] Johansson, 1999

Table A3:2.6. Carbon stock in dead wood (excluding stumps) and the three litter fractions coarse litter, fine litter and annual litterfall. For definitions of the dead wood and litter fractions see NIR section 6.4.1.2.

Year	Forest land				Grassland			
	Dead wood	Coarse litter	Fine litter	Annual litterfall	Dead wood	Coarse litter	Fine litter	Annual litterfall
	t C ha^{-1}				t C ha^{-1}			
1990	1.0	0.15	24.5	0.77	0.19	0.028	0.79	0.21
2000	1.0	0.15	23.8	0.79	0.19	0.028	0.59	0.22
2005	1.1	0.15	23.5	0.82	0.19	0.028	0.40	0.23
2006	0.9	0.15	23.5	0.82	0.19	0.029	0.37	0.22
2007	0.9	0.15	23.5	0.83	0.19	0.029	0.38	0.22
2008	1.1	0.15	23.6	0.83	0.19	0.029	0.39	0.22
2009	0.9	0.15	23.6	0.84	0.20	0.030	0.56	0.22
2010	1.0	0.15	23.8	0.84	0.20	0.030	2.16	0.22
2011	1.0	0.15	23.9	0.84	0.20	0.030	3.82	0.21
2012	1.0	0.15	24.1	0.84	0.20	0.030	3.96	0.21
2013	1.1	0.15	24.1	0.84	0.20	0.030	3.89	0.21
2014	1.1	0.15	24.4	0.84	0.20	0.031	4.05	0.21
2015	1.1	0.15	24.7	0.84	0.20	0.031	4.32	0.21
2016	1.1	0.15	25.0	0.84	0.21	0.031	4.68	0.20
2017	1.2	0.13	25.2	0.85	0.13	0.019	4.94	0.19
2018	1.3	0.16	25.5	0.85	0.13	0.019	5.20	0.19
2019	1.2	0.13	25.6	0.84	0.08	0.013	9.19	0.19
2020	1.4	0.14	25.8	0.84	0.22	0.032	12.5	0.19
2021	1.3	0.17	25.8	0.84	0.48	0.072	12.5	0.19
2022	1.4	0.14	25.8	0.84	0.04	0.007	12.5	0.19

3.2.1.6 METHODOLOGY SOIL ORGANIC CARBON FOREST LAND AND GRASSLAND ON MINERAL SOILS CRT 4A AND 4C

The method is a Tier 3 method. The estimates are based on repeated measurements 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:

$$SOCi = C_i \cdot Wfe_i,$$

where SOC_i is the amount of carbon found in soil layer $_i$ [Mg ha^{-1}] and C_i is the carbon concentration [%] in the fine earth fraction (<2 mm) and *Wfe*, is the amount of fine earth in the soil layer [Mg ha^{-1}]. The amount of fine earth is dependent on the bulk density and the amount of gravel, stones and boulders in the soil, hereafter referred to as stoniness. There are no direct measurements of stoniness in the soil inventory during the period 1993 to 2002. However, measurements of the stoniness started in 2003 and was completed for all plots in 2012 using a modified Viro-method [119]. Since data on stoniness is not expected to change, the reported data can be recalculated for the whole reporting period at the end of the commitment period. For this reporting period the relationships between stoniness data collected in the inventory and a measured boulder frequency available for all plots were used. Separate relationships were determined for the categories till, poorly sorted waterlaid sediments and well-sorted waterlaid sediments. It is important to note

[119] Viro, 1952.

that any error in the estimate of stoniness have no influence on the direction of change in the soil organic carbon pool but that it might affect the magnitude of the change slightly (Table A3:2.7).

Table A3:2.7. Stoniness correction coefficients.

Boulders (number/plot)	Parent material class	Stoniness (vol-%)
0	Well sorted sediment.	3.64
1-10	Well sorted sediment	4.72
11-50	Well sorted sediment	8.10
51-100	Well sorted sediment	ND
>100	Well sorted sediment	ND
0	Poorly sorted sediments and glacial till	23.6
1-10	Poorly sorted sediments and glacial till	31.2
11-50	Poorly sorted sediments and glacial till	37.5
51-100	Poorly sorted sediments and glacial till	46.9
>100	Poorly sorted sediments and glacial till	54.2

Bulk density (BD) is not measured for the mineral soil samples. Bulk density is instead predicted using a pedotransfer function,

$$BD = 1.5463 \cdot e^{-0.3130\sqrt{C_i}} + 0.00207\,AD$$

where C_i is the carbon concentration [%] in the fine earth fraction (<2 mm) and AD the average depth of the soil layer in cm.

After the estimates for stoniness and bulk density have been made the carbon amount in each sampled soil horizon at each plot is determined. Thereafter the soil carbon in soil horizons not sampled is determined by interpolation between layers and finally the soil carbon content down to 50 cm can be calculated on a plot basis.

Until 2012 the only soil sample taken on grazing land (Grassland) in the soil inventory was the 0-10 cm sample. From 2013 and onwards the soil profiles on grazing land are sampled exactly as the ones on forest land. Due to lack of data from deeper soil layers the calculation of soil carbon stock on Grassland soils utilizes a simplified interpolation where the soil carbon amount down to 50 cm is interpolated from 10 cm down to 50 cm where the C amount is assumed to be 0 (Figure A3:2.4).

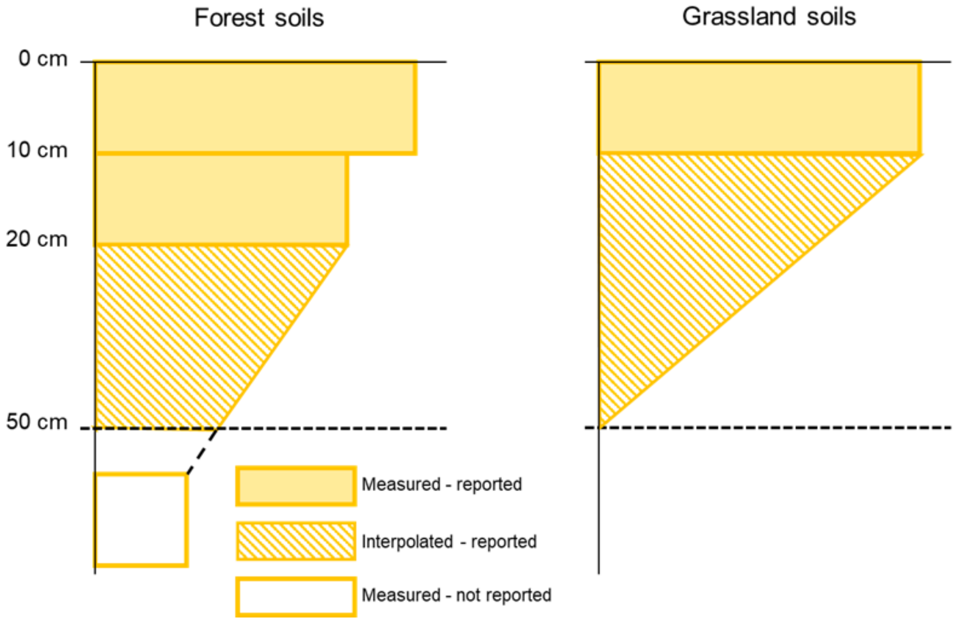

Figure A3:2.4. Measured and interpolated soil profile sections in Forest and Grassland soils.

The annual carbon stock change for each plot is estimated using interpolation between the inventory years and extrapolation for years before and after the inventory of a single plot. The method of how the values are calculated and interpolated described below was changed in submission 2023. As a background on the reasons for change and a comparison between the previous and current methods we refer to the following report[120]. For example, the carbon stock change for a plot measured in 2002 and 2012 will be calculated by subtraction of the measured carbon stock value in 2002 from the one measured 2012. The carbon stock change will thereafter be divided by the number of years between inventories and the resulting annual change distributed to the years between the measurement years so that the sum of changes for all years between the measurement years will equal the measured change. The annual change is interpolated between 2002 and 2012 but also extrapolated for 1990-2001 and for 2013-2021 assuming the the change is constant over time. Plots that are inventoried three times have two different levels of change, one between the first and second stock measurement and one between the second and third stck measurement. For these plots, the change used is the weighted average of the two change levels. The stock change for the entire category that is reported is then the average of the changes for all inventoried plots. The estimate of annual carbon stock change for each plot is area weighted with an area factor using the same method as described in section 3.1.1. Plots that have not

[120] Karltun, 2022

been re-inventoried for some reason are assumed to have no change in carbon stock. The principle is illustrated in Figure A3:2.5. The upper panel shows the measured amount of soil carbon for three plots of which plot one and two have been measured three times and plot three only two times. The change is equally distributed among the years between measurements and also extrapolated backwards and forwards in time so that each re-measured plot influences the whole time series. The lower panel show the resulting rates of change in soil carbon for the three plots. If we had a value for each plot every year the resulting averaged change would be a straight line. However, due to land-use change and changes in classification of mineral and organic soils plots may leave or join the time series. Hence, there will be some variations between years in the time series. The phasing in of new inventory data each year will lead to a recalculation of the whole time series between submissions and will result in a shift upwards or downwards depending on the level of the most recently added data in relation to data already included in the estimate.

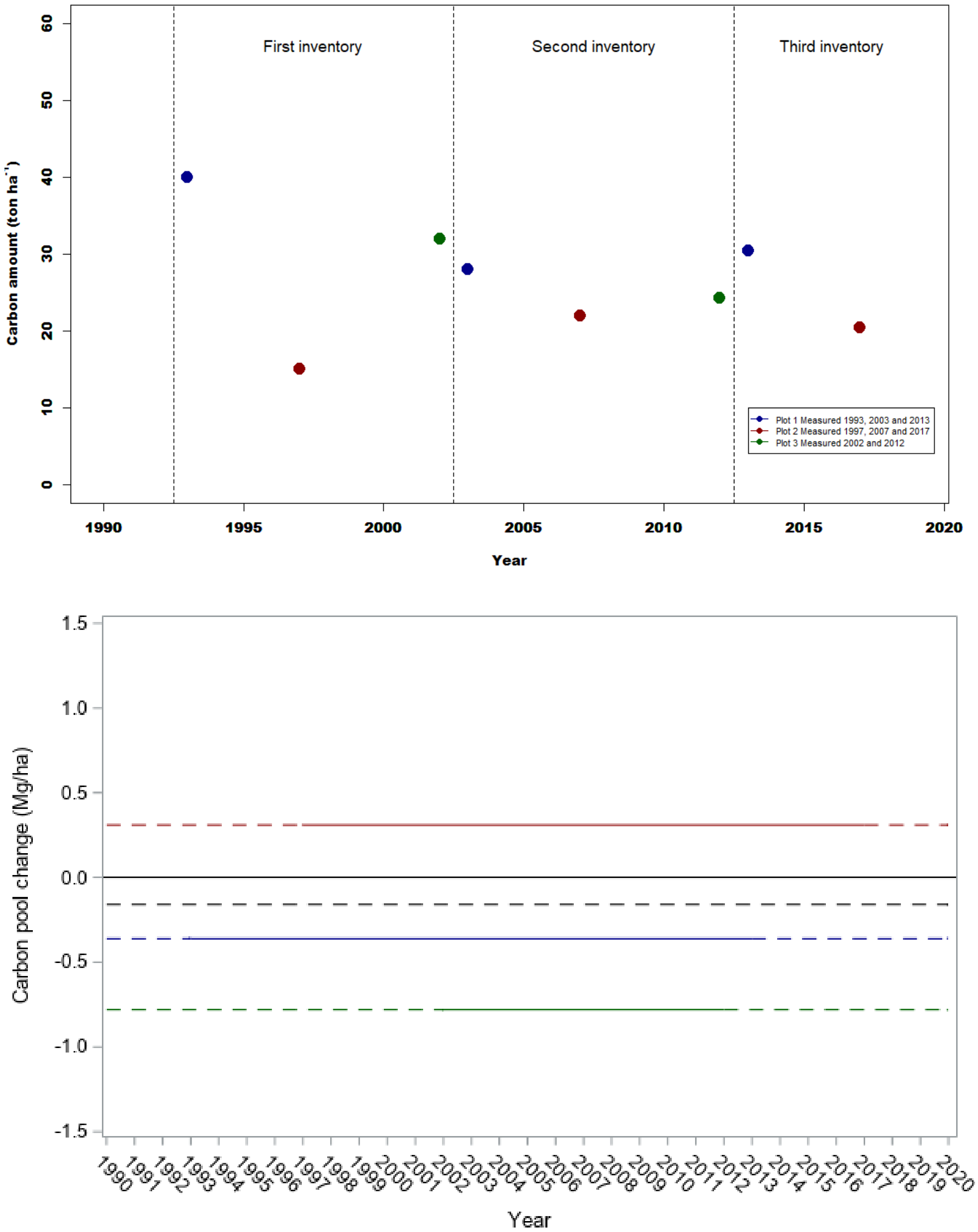

Figure A3:2.5. Principle for sampling and interpolation of data for DOM and soil carbon. The upper panel shows sampled amounts for three plots during the three inventories. Dots mark amounts and year of sampling. Note that one plot (green) is not yet sampled in the third inventory. The lower panel shows the resulting differences and how they are extrapolated and interpolated. For plots inventoried more than two times the change is the average change over the whole time series. The black dashed line in lower panel mark the average carbon change corresponding to the reported change.

3.2.1.7 METHODOLOGY SOIL ORGANIC CARBON FOREST LAND AND GRASSLAND ON ORGANIC SOILS CRT 4A AND 4C

Organic soils are soils that are classified as Histosols. The soil is considered drained if there is a ditch observed within 25 m from the inventory plot centre.

The CO_2 emissions/removals of drained organic forest and grassland soils is calculated as the sum of on-site CO_2 emissions/removals and dissolved organic carbon (DOC) exported from drained organic soils.

$$CO_{2\ organic/drained} = CO_{2\ on\text{-}site} + CO_{2\ DOC}$$

On-site emissions from drained organic soils are calculated using a set of emission factors differentiated through two different classes of nutrient status (nutrient rich and nutrient poor) and two different climate zones (temperate and boreal)[121]. The method is a Tier 1 method where the emission factors are taken from the 2013 IPCC Wetland Supplement to the 2006 GL[16]. The method is identical for Forest land remaining Forest land and for Grassland remaining Grassland and can be expressed in the following way:

$$CO_{2,LU} = \sum_{i,j} \mathrm{A}_{i,j} \cdot EF_{i,j} \cdot 44/12$$

Where $CO_{2,LU}$ is the emissions for the actual land-use category, $A_{i,j}$ and $EF_{i,j}$ the area and emission factor for each subcategory where *i* denotes the nutrient class and *j* the climate zone. Emission factors represent the annual net change of soil organic carbon (SOC) plus below-ground portion of litter carbon (see IPCC WL supplement page 2.49). Emission factors are applied without any consideration to additional carbon inputs from litter as the emission factors presented by the IPCC were already adjusted . Note that litter reported in the CRT-tables only comprise litter on mineral soils. Estimates are interpolated and area weighted as described above for mineral soils.

The limit between nutrient poor and nutrient rich drained organic soils should be drawn between ombrotrophic and minerotrophic conditions according to the Wetland Supplement[16]. This categorization is not directly available in the NFI. However, the categories can be determined using the field- and ground layer vegetation communities as a proxy. Some vegetation types are found on both nutrient rich and nutrient poor conditions, or to be more concrete – they are found when the conditions are intermediate between nutrient rich and nutrient poor. The categorization of the different vegetation types used are given in Table A3:2.8 below.

[121] Lindgren and Lundblad (2014)

If information on the field layer vegetation community from the NFI is used to set the limit between nutrient poor and nutrient rich, the intermediate class vegetation (group 12 and 13) should most likely be located in the nutrient rich category. This assumption avoid the underestimation of GHG emissions as nutrient rich conditions are associated with higher emissions.

Table A3:2.8. Categorization of vegetation types.

Nutrient rich	Nutrient poor
01 – Tall herbs without shrubs	10 – Tall *Carex*
02 – Tall herbs with shrubs/blueberry	11 – Low *Carex*
03 – Tall herbs with shrubs/lingonberry	14 – Lingonberry
04 – Low herbs without shrubs	15 – Crowberry/*Calluna*
05 – Low herbs with shrubs/blueberry	16 – Poor shrubs
06 – Low herbs with shrubs/lingonberry	
07 – Without field layer (no plants, just mosses)	
08 – Broad grasses	
09 – Narrow grasses	
12 – Horsetail	
13 – Blueberry	

Sweden is divided into two climatic zones so that each county south of Värmland, Gävleborg, and Dalarna belongs to the temperate zone and the remaining counties belong to the boreal zone (see Figure A.3:2.6) This corresponds to the climatic zone differentiation made by IPCC for the southern region of Sweden in calculations of temperate averages within the Wetlands Supplement[122].

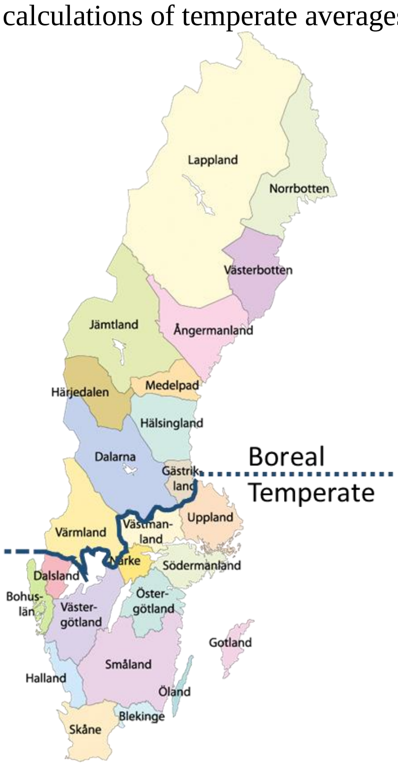

Figure A3:2.6. Map showing the border between the boreal and the temperate zone in Sweden.

[122] 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands

Emission factors for Forest land are taken from the IPCC 2013 supplement for Wetlands (see Table A3:2.9). The emission factors in the supplement were evaluated in a project to determine which factors that were most suitable for Sweden.

Data on emissions from grasslands are scarce and most often taken from studies looking at intensively used grasslands where nutrients are commonly applied. For this reason, the emission factors for Grasslands proposed in the IPCC Wetland supplement were put aside in favour of those applied on Forest Land as Swedish Grasslands in the reporting only includes those that are natural pastures. As a response to the UNFCCC ARR 2019 (L.5) an assessment of the emission factors was performed in which information from the SFSI of Swedish drained organic semi-natural pastures and forestlands were compared and analysed[123]. The data analysis of drained organic Swedish soils could not distinguish between the two land-use categories semi-natural pasture and forest land with respect to carbon nitrogen ratio, an indicator of peat degradation which varies with land use. The literature study indicates that the IPCC's default emission factors for grassland overestimate the total emission of semi-natural pastures, whereas it does not support the notion by the ERT that the IPCC's emission factors for forest land underestimate the emissions from semi-natural pastures in Sweden. It was concluded, that the results of the investigation support a continued use of the IPCC's default emission factors for forest land for drained organic semi-natural pasture.

Table A3:2.9 On-site and off-site (DOC) emission factors for drained organic forest soils.

Land category	Climate	Nutrient status	Emissions from soil	DOC
			t CO_2-C ha^{-1}	t CO_2-C ha^{-1}
Forest	Boreal	Rich	0.93	0.07
		Poor	0.25	
	Temperate	Rich	2.6	0.10
		Poor	2.6	
Grassland	Boreal	Rich	0.93	0.04
		Poor	0.25	
	Temperate	Rich	2.6	0.10
		Poor	2.6	

The area data for Forest land remaining forest land and Grassland remaining grassland are presented in Table A3:2.10. Since the figures are more or less constant for the whole period only the first and last year in the time series are shown.

[123] Lindahl and Lundblad, 2021

Table A3:2.10. The area of different drained organic forest soils classes.

	Forest remaining forest land [kha]					Grassland remaning grassland [kha]				
	Boreal		Temperate			Boreal		Temperate		
	poor	rich	poor	rich	total	poor	rich	poor	rich	Total
1990	253	369	72	296	989	0	4	0	20	24
2022	248	334	70	307	960	0	4	0	13	17

Emissions from organic soils are also included for land-use change categories. However, since there is no information on whether the organic soils for these categories are drained or not it is assumed that these soils are drained to the same extent as the corresponding remaining land category. This is handled in the calculations by using the implied emission factor for all organic soils, i.e. the average emission per hectar for all Forest land remaining forest land and all Grassland remaining grassland on organic soils (see IEF in CRT table 4.A and 4.C and table A3:2.14). The total area of land on organic soils converted to Forest land was 17 kha in 2022 and the total area of land on organic soils converted to Grassland was 12 kha in 2022.

Off-site emissions of DOC are included using the same areas as described for the on-site emissions as described above. A newly developed model[124] is used to calculate the emissions of DOC. The model is based on data from small watercourses (catchment area <5 km^2), selected to include only watercourses with a large proportion (>20%) of organic soils in the catchment area representing large parts of Sweden's area of forests and wetlands. The model is used together with run-off data for estimating DOC exports from drained organic soils identified in the SFSI and to estimate regional emission factors for drained organic forest and grassland soils to be used for LUC-categories (see table A3:2.9).

3.2.1.8 METHODOLOGY SOIL ORGANIC CARBON FOR CROPLAND ON MINERAL SOILS CRT 4B

Swedish arable land covers approximately 2.8 Mha and the total soil organic C pool varies regionally between about 70 to 90 Mg C ha^{-1} in topsoil mineral soils. The five-parameter soil carbon model ICBM region concept (ICBMr) is used to calculate an annual C balance of the soil based on national agricultural crop yield and manure statistics, and uses allometric functions to estimate the annual C inputs to soil from crop residues[125]. The method is a Tier III method, running the model for eight production regions (see Figure A3:2.7.).
The ICBM model has two different pools, a young pool with a high turnover and an old pool representing more stable soil carbon.The annual carbon inputs to soil from crop residues and manures is one of the driving variables. They are going through the young and transitory carbon pool before transferred into the old pool. The ICBMr concept calculates soil carbon changes with annual discrete time steps.

[124] Wallin et al., 2021

[125] Andrén et al., 2004; . Andrén, O. et. al. 2008

Yield statistics for the previous year (at time t-1) are used for calculating annual C inputs to soil from crop residues which enter the young pool immediately after each discrete annual time step (t). This implies that there are large instantaneous inputs every year and consequently, the young pool becomes highly variable between successive years.

The ICBM model, as most soil organic carbon models, is evolving over time, where a continuous model development leads to updated versions. Recently, there was a global review concerning the validation of existing soil organic carbon models and models version today[126]. According to their criteria for validating models, it was reported that the ICBM model had been validated for cropland, grassland, and cropland to grassland on long-term field experiments in Sweden[127] and Canada[128]. This refers to the original ICBM model version calibrated on the long-term frame trial in Uppsala (Sweden)[129], which is the version that was adapted (i.e., ICBMr) for use in the Swedish greenhouse gas inventory[130]. There are also other applied studies with this ICBM version following similar validation criterions with data from long-term field experiments for cropland and grasslands in Sweden[131], Sweden and Europe[132], and for other regions with soil and climatic conditions representative for Sweden[133].

Since the 2023-year's submission, Sweden is using an updated version of ICBM in the Swedish greenhouse gas inventory, based on recent model development[134]. Briefly, the updated ICBM model was calibrated on 28-years of additional data from the long-term frame trial in Uppsala, Sweden. Data from a new large-plot long-term sister experiment was used for validation, whereas the decomposition of the old pool and the annual soil climate parameter were validated on a European network of long-term bare fallow experiments.[135][136][137] Compared to the original ICBM version, the model now considers above- and belowground and manure C inputs separately (ICBM/3), where the [138]humification coefficient for belowground crop residues is 2.6 times higher than that for aboveground crop

126 Garsia et al 2023

127 Kätterer et al 2008

128 Campbell et al 2007

129 Andrén and Kätterer 1997, Kätterer and Andrén 2021

130 Andrén et al 2004, Andrén et al 2008

131 Kätterer et al 2004, Bolinder et al 2012

132 Kätter and Andrén 1999

133 Bolinder et al 2006, Bolinder et al 2008

134 Menichetti et al 2023

135 Andrén and Kätterer, 1997

136 Kröbel et al., 2016

137 Menichetti et al., (manuscript).

138 Kätterer et al., 2011, 2014.

residues, in agreement with results from Swedish long-term field experiments. Otherwise, the underlying mathematical approach is identical, having one young and one old pool, and an annual soil climate parameter, and its use within the ICBMr concept is the same. The results showed that such a simple model structure and underlying assumptions remain robust enough to describe soil organic carbon dynamics over six decades. Since the release of ICBM in 1997, there are more than one hundred applications using the model and its subcomponents in the scientific literature, they are described in the supplementary material[139]. Two adjustments relating to activity data were also included since submission 2023. As the method of collecting yield statistics for ley[140] has changed over time, we adopted a new allometric function, which is comparable to the one used in the Finnish reporting system[141], and the time series with carbon inputs from manures were also improved[142].

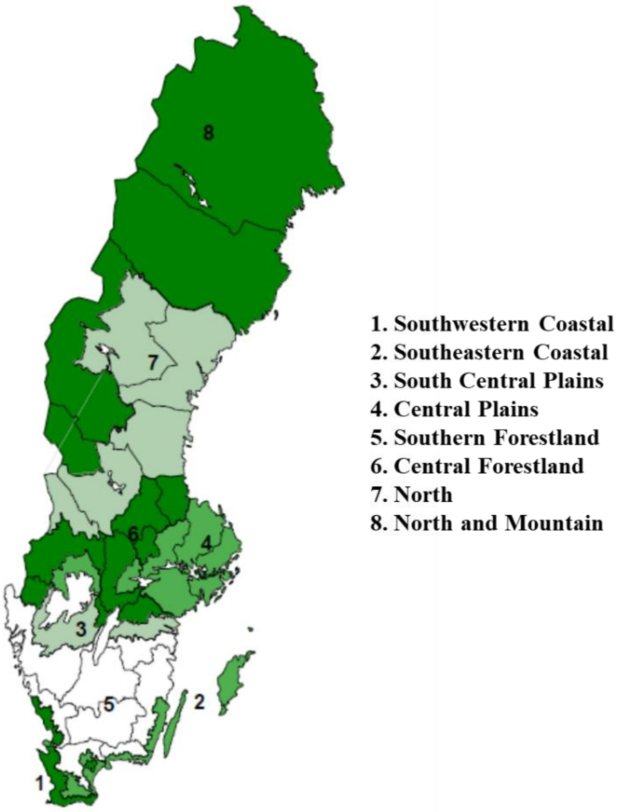

Figure. A3:2.7. The eight Swedish agricultural production regions (PO8, bold character). The production regions are designed according to pedo-climatic conditions such as similarities in soil type, topography and climate (Adapted from SCB, Statistics Sweden and Andrén et al. 2008).

Gridded climatic data together with crop type and soil type are used to calculate the annual soil climate parameter which is affecting the soil organic carbon

[139] Menichetti et al 2023

[140] Taghizadeh-Toosi et al., 2020

[141] Palosuo et al., 2015

[142] Bolinder et al., 2022

decomposition rates in each region and year. SMHI (www.smhi.se) is providing the gridded climatic data. Since SMHI is collecting the gridded data from different sources for different periods, the horizontal resolution of the grids can vary in time and per parameter in the range of ca 3-22 km. The used data sources are the PTHBV database, the MESAN analysis system, the HIRLAM forecasting model and results from the EURO4M reanalysis project.

The annual soil climate parameter is calculated for all crop- and soil type permutations in each region. The model set up for the reporting to UNFCCC uses 14 soil types and 9 crop types, which gives 126 parameter sets for each year and region, each representing a fraction of the region's area. For each year, region, crop and soil type, ICBM-region calculates the change in soil organic carbon per hectare. Thereafter, an area weighted annual change per hectare is derived that sums up the changes to, e.g., national level changes (see Figure A3:2.8.) by using the area estimates from the NFI (as described in previous sections).
The annual total carbon stock changes in the time-series calculated with ICBM for the eight production regions varies between about 20 to 140 kg C ha^{-1} yr^{-1}, and are representing typical values of stock change rates for different management practices observed in mineral cropland soils[143]. The most dynamic contributing factors to inter-annual differences are mainly from changes in crop types and yields, as well as weather conditions the specific years.

From submission 2020 and onwards, the reporting is only including changes in the old carbon pool representing the more stable carbon. This pool reflects the long-term changes in soil carbon, and we are now expressing the CSC as a three-year moving average. This change in the reporting of results does not affect the previously reported long-term national average trends (i.e., using the young plus old pool) since the young pool has a high turnover, and the long-term change in this pool (i.e., less than ±0.5 kg C ha^{-1}) is negligible compared to the old pool. Similarly, using a three-year moving average is only smoothing out the time series of data for annual national CSC without affecting the total reported change over a long period (i.e., deviation less than ±0.5%).

[143] Bolinder et al., 2020; Kätterer and Bolinder, 2022

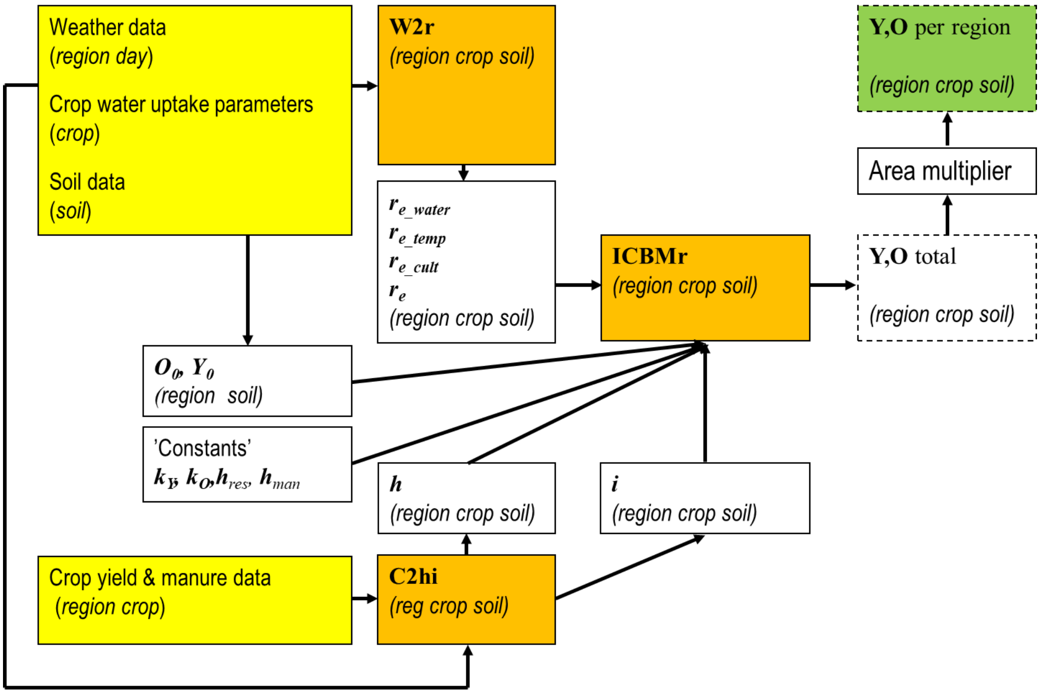

Figure A3:2.8. The ICBMregion concept. Crop, weather, and soil data for each region are used in the weather-to-re module W2r, calculating soil climate, r_e, for each region, crop and soil (top left). The initial carbon mass values O_0, Y_0 are taken from soil inventory data. Parameters k_Y, k_O, h_{res}, h_{man} are regarded as constants, and the indices *res* and *man* indicate crop residues and manure, respectively. Crop yield and manure input data are used to calculate carbon input to soil *i*, as well as a weighted *h*, estimated by the allometric functions in the C2hi module. The two initial values O_0, Y_0 and the five parameters r_e, k_Y, k_O, h and i are then used for calculating total young (Y) and old (O) carbon [kg ha^{-1}] These values are then multiplied by the actual area to obtain totals for, e.g. a region.

3.2.1.9 METHODOLOGY SOIL ORGANIC CARBON FOR CROPLAND ON ORGANIC SOILS CRT 4B

The area of organic soils on cropland was assessed in a recent study[144]. In this study, geographical information about soil types and agricultural databases (IACS) were used to estimate the distribution and land use of agricultural organic soils in Sweden. To avoid double counting of areas, only agricultural land either used for crop cultivation or kept in such a condition that it can be used for crop cultivation was considered. Other areas assessed within the agricultural databases, such as grazing land and wetlands, were withdrawn from the estimated area of organic soil since these areas are included in the reporting under Grassland and Wetland respectively.

The total area of agricultural land within the agricultural database in 2008 was estimated to be 2 953 kha of which 131 kha was classified as organic soils. In 2015, the total area of agricultural land and agricultural organic soils had decreased to 2 675 kha and 110 kha respectively. Since then, a continously yearly decline in

[144] Lindahl and Lundblad. 2022

both agricultural land and agricultural organic soils was observed until 2021 for which the total area of agricultural land was estimated to be 2 654 050 ha of which 107 663 ha was classified as organic soils.

Since the reporting of LULUCF is based on the NFI-sample of all land-use categories we calculate the annual area of organic soils on cropland based on the relationship between the estimates of organic soils and the total Cropland area for 2008, 2015 and 2021 respectively based on the study mentioned above. The relationship between organic soil and total Cropland area for intermediate years is interpolated using the 2008-2015 and the 2015-2021 trends in the relationship organic soils vs. total agricultural area. The years from 1990 to 2007 and 2022 are based on extrapolation of these trends. .

Since Submission 2015 a national emission factor for cropland on organic soils is used to calculate the mean annual carbon loss per area. A literature review containing many of the references within the IPCC Wetland supplement[145] was made and the result was a lower emission factor (6.1 ton CO_2-C ha^{-1} yr^{-1}) than the one presented in the WL supplement. The updated emission factor was developed using Swedish, Norwegian and Finnish studies and did not take into account differences in the methods used in the studies. Such corrections were made in the WL GL but since these adjustments are not covered in detail within the WL GL it was impossible to use exactly the same method. Despite differences in method, it was recommended to use the national emission factor to avoid studies from countries with temperature conditions that are not fully representable for Sweden as temperature exerts a strong control on emissions[146] .

Emissions from DOC are included using the same area of organic cropland soils as described above and an emission factor of 0.12 t CO_2-C ha^{-1} yr^{-1}[147], i.e., the IPCC default emission factor for boreal conditions. Results from rewetted peat extraction areas, drained organic Forest lands and forested former peat extraction areas in Sweden confirm that the value is within the range for Swedish conditions[148] The study by Wallin et. al., 2021 indicated that there is a gradient towards higher concentrations of TOC in southeastern Sweden. However, the average emission in that study was lower than the standard IPCC-factor for boreal conditions. It was also uncertain how large share of the areas studied in Wallin et al is represented by cropland. Therefore, it was decided to use the IPCC factor (boreal zone) for cropland for the entire country. It should thus be noted that most of the sites used for the data in the study by Wallin et.al. (2021) originates from the western and south-western part of the country and in average the emissions are 0.1 for the

[145] The 2013 IPCC Supplement to the 2006 GLfor National GHG Inventories: Wetlands

[146] Lindgren and Lundblad, 2014

[147] Lindgren and Lundblad, 2014

[148] Lindgren and Lundblad, 2014

temperate zone calculated for forest soils (see table A3:2.9). It should also be noted that the few studies represented in the IPCC default factor originates from natural peatlands in Canada, USA, UK, Ireland and Australia and it can be questioned how representative they are for Swedish conditions. In a recent study[149] in Sweden the effect of drainage on DOC was estimated to around 20% whereas IPCC indicates an effect of 60% where it can be observed that the study included in the IPCC estimate from Finland[150] indicates an increase by only 15%. Using the average discharge from the boreal and temperate zones in Sweden, the emission factors using the studies in the IPCC default estimates (see table 2A.2 and 2.A.3 in IPCC WL supplement) would be 0.18 and 0.19 t CO_2-C ha^{-1} yr^{-1} using a drainage effect of 60% and 0.13 and 0.14 t CO_2-C ha^{-1} yr^{-1} using a drainage effect of 20%. We therefore argue that using the IPCC default factor for the whole of Sweden do not severely underestimate the DOC emissions.
The annual emission from organic soils for Cropland remaining cropland is calculated as:

$$CO_{2,Organiccropland} = A \cdot (EF_{soil} + EF_{DOC}) \cdot 44/12$$

Where A is the annual area of organic soils estimated as described above, EF_{soil} is the emission factor for the loss to the atmosphere and EF_{DOC} is the loss of dissolved carbon.

3.2.1.10 METHODOLOGY CO_2 EMISSIONS AND NON-CO_2 EMISSIONS FROM MINERALIZATION WHEN EXTRACTING PEAT CRT 4D AND 4 (II)

The CO_2 and non-CO_2 GHG emissions due to peat extraction comprise the on-site GHG emissions and off-site release of carbon (DOC) as well as off-site release of CO_2 from extracted peat for horticultural use.

The emitted greenhouse gases from areas used for extracting peat is calculated as the product of the extracted area and an emission factor for each of the gases CO_2, N_2O and CH_4:

Emissions (gas)=P•EF

where *P*=production area [ha] and *EF*=emission factor [ton ha^{-1} yr^{-1}]. The production area is the area suitable for peat extraction which is a limited part of the concession area for peat extraction. It should be noted that peat extraction is only carried out on parts of the production area. The peat extraction is usually proceeding on the same production area during several years. After extraction, the area is 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. During the period 1990-2009, production areas are obtained

[149] Tong 2022

[150] Heikkinen, 1990

from Svenska Torvproducentföreningen[151]. From 2010-2021 the production area has been provided by the Swedish geological survey. Since this submission the production area is reported by the peat producer companies directly in the Swedish Environmental Reporting Portal.

The study by Lindgren and Lundblad[152] proposes that the emission factors including also the emissions due to DOC and ditches presented in the wetland Supplement should be used to calculate the emissions from peat production areas. The emission factors can be found in Table A3:2.11 and the extracted area as well as the amount of produced peat for horticultural use are found in Table A3:2.12.

Table A3:2.11. The emission factors for peat extraction areas.

	Emission Factors (unit mass per hectare)				
	t CO_2-C	kg N_2O-N	kg CH_4	ditch kg CH_4	DOC t CO_2-C
Peat Extraction	2.8	0.3	6.1	26.2	0.12

Table A3:2.12. The peat production area and the production of horticultural peat.

Year	Production area [ha]	Production of horticultural peat [1000 $m^3 \cdot yr^{-1}$]
1990	6600	794
1991	6100	785
1992	6600	900
1993	6400	915
1994	7000	1066
1995	7700	1055
1996	6800	1084
1997	8100	1203
1998	6700	671
1999	9700	1460
2000	10400	1000
2001	10500	1400
2002	10200	1800
2003	9400	1500
2004	8000	1108
2005	10300	1545
2006	6200	1716
2007	10300	1302
2008	9159	1434
2009	8515	1198
2010	7597	1250
2011	8366	1611
2012	8693	977
2013	8156	1 815
2014	9585	1512
2015	10127	1266
2016	10376	1676

151 Svenska Torvproducentföreningen, 2006

152 Lindgren and Lundblad, 2014

Year	Production area [ha]	Production of horticultural peat [1000 m^3▪yr^{-1}]
2017	8987	1662
2018	11906	1604
2019	7657	1598
2020	6300	1913
2021	4459	2233
2022	9939	2640

The off-site emissions from horticultural peat are based on the annual production volume (Table A3:2.12) and a national estimate of the carbon content of peat based on information from the peat producers in Sweden. The estimate is based on the following assumptions for the harvested peat: A dry density of 100 kg m^{-3}, carbon content of 55%, and an organic content of 96%. The resulting carbon content was estimated to 0.053 ton C m^{-3} of air-dry peat.

The annual emission from remaing peat in use was based on measurements of carbon stocks in a long-term trial (1956-2009) in Sweden where peat was used as amendment to the soil[153]. Based on the initial and final carbon content and the annual addition of carbon an annual decomposition rate of 3 % was estimated and used for the calculations of emissions from horticultural peat:

$$CO_{2,HP} = C_X \cdot D \cdot 44/12$$

Where $CO_{2,HP}$ is the annual emission C_X the actual carbon stock (t C) and D the decomposition rate (0.03). Note that the decomposition rate has been revised in this submission due to a reevaulation of the information provided in Kätterer et.al. (2011).
The annual carbon stock a given year (X) is calculated as:

$$C_X = (C_{X-1} + \Delta C_i)$$

Where $C_{X-1}$is the remaining carbon from previous year and ΔC_i is the annual addition of carbon from harvested horticultural peat.

On-site emissions of CO_2 (including off-site DOC) and off-site emissions from peat used for horticulture are reported aggregated in CRT-table 4.D (4.D.1.1, peat extraction remaining peat extraction) whereas emissions of N_2O and CH_4 are reported in CRT-table 4(II). All reported emissions are shown in table A3:2.13 below.

153 Kätterer et al., 2011

Table A3:2.13. On site and off-site emissions of CO_2 and non-CO2 gases from production of peat.

Year	kt CO_2			kt N_2O	kt CH_4
	On-site	Off-site hort use	Off-site DOC		
1990	68	5	2.9	0.003	0.21
1991	63	9	2.7	0.003	0.20
1992	68	14	2.9	0.003	0.21
1993	66	19	2.8	0.003	0.21
1994	72	25	3.1	0.003	0.23
1995	79	30	3.4	0.004	0.25
1996	70	35	3.0	0.003	0.22
1997	83	41	3.6	0.004	0.26
1998	69	44	2.9	0.003	0.22
1999	100	51	4.3	0.005	0.31
2000	107	56	4.6	0.005	0.34
2001	108	62	4.6	0.005	0.34
2002	105	71	4.5	0.005	0.33
2003	97	77	4.1	0.004	0.30
2004	82	81	3.5	0.004	0.26
2005	106	88	4.5	0.005	0.33
2006	64	95	2.7	0.003	0.20
2007	106	100	4.5	0.005	0.33
2008	94	105	4.0	0.004	0.30
2009	87	109	3.7	0.004	0.28
2010	78	113	3.3	0.004	0.25
2011	86	119	3.7	0.004	0.27
2012	89	121	3.8	0.004	0.28
2013	84	128	3.6	0.004	0.26
2014	98	133	4.2	0.005	0.31
2015	104	137	4.5	0.005	0.33
2016	107	142	4.6	0.005	0.34
2017	92	148	4.0	0.004	0.29
2018	122	153	5.2	0.006	0.38
2019	79	157	3.4	0.004	0.25
2020	65	164	2.8	0.003	0.20
2021	46	172	2.0	0.002	0.14
2022	102	182	4.4	0.005	0.32

3.2.1.11 METHODOLOGY FOR DEAD ORGANIC MATTER AND SOIL ORGANIC CARBON FOR CONVERSION BETWEEN LAND-USE CATEGORIES CRT-TABLES 4A.2.1-5, 4B.2.1-5, 4C.2.1-5 AND, 4E.2.1-5

In general (except for dead wood and coarse litter), the carbon stock changes associated with conversion of land are estimated using an emission/removal factor in combination with the land use change area according to the NFI (see 3.2.1.1 and 3.2.1.2 above). The emission/removal factor is applied to the accumulated area, i.e., the area converted during the last 20-year period.

As wetland is normally considered unmanaged, no carbon stock changes are reported except for land used for peat extraction. As IPPC in its 2019 refinement presented methods for land converted to flooded land an investigation was done to asses whether any land conversion to flooded land according to the definition could be observed in Sweden. However, according to the investigation in 2021[154] no new reservoirs <20 years could be found. The investigation pointed out that a detailed inventory of reservoirs, along with their ages and surface areas is needed. It was also stated that more studies related to emission measurements are needed from ponds in the boreal zone.

3.2.1.11.1 Dead wood and coarse litter

The dead wood part (and the coarse litter part) of the dead organic matter pool is calculated using the total dead wood carbon stock change for each main land-use category, i.e., Forest land, Cropland, Grassland, Wetland, Settlement and Other land as estimated by the NFI as described in section 3.2.4.1. Due to a recommendation in the ARR2022, the allocation of carbon stock change in the dead wood pool (and coarse litter) to different land use and land use change categories has been overseen in this submission.

For forest land all measured carbon stock changes in dead wood is now allocated to forest land remaining forest land. The reason is that (i) it is not likely that the same dead wood carbon stock change per area can be assumed for afforested areas (the amount of dead wood for the first 20 year of conversion is likely to be very small) and (ii) for changes from wetland and other land to forest land the assumption is that the carbon pool is in balance as these land use changes are merely related to reassesement of land use in field or a gradual shift from one definition to anther rather than real land use changes.

For the cropland category, dead wood carbon stock changes most likely relates to dead wood on forest islets within a field and in that case there is no reason to believe that there is a real difference whether the land is undergoing land use change or are under permanent use. Therefore dead wood in the cropland cateory is allcocated according to the relative area of each subcategory.
For the grassland category the assumption is eqvivalent to the assumption for cropland, i.e. that dead wood for the category is distributed according to the relative areas.

A small amount of dead wood is observed on Settlement and similar to assumptions above for cropland and grassland, the carbon stock change in dead wood is evenly distributed on settlement remaining settlement and conversion to settlement from forest land, cropland and grassland. For Wetland and Other land, no dead wood has been observed and the assumption therefore is that the carbon pool is in balance.

[154] Peacock 2022

3.2.1.11.2 Litter and soil organic carbon

The lost or sequestered carbon for the litter and soil organic carbon pools is calculated as the product of the total area in the conversion category and an emission factor (Table A3:2.14).

The emission factors for litter and soil organic carbon are based on different assumptions related to the carbon stock of the land use before conversion and the effect of the conversion on the carbon stock.

An important difference between specific categories is that if the carbon stock change is reported for the final land use (estimated using measurements or by modelling), the carbon stock change factor for the land use change category are set to represent the 20 first years of the transition to a new status rather than the total change between a soil in equilibrium associated to a specific land use category to a soil in equilibrium representing another land use category. This is due to the fact that measured plots, included in the estimate for the remaining category, comprise all plots that belongs to the category, i.e., also plots that was converted more than 20 years ago. If changes on the soil organic carbon pool is not reported for the remaining category, i.e., it is assumed to be in a steady state, the carbon stock change factor for the 20 year transition period is estimated to include the total loss or gain of carbon due to the land use change.

Average soil carbon content in the mineral soil carbon pool was 75 t C ha^{-1} for grassland, 83 t C ha^{-1} for Cropland and 55 t C ha^{-1} for Forest land. The litter pool (forest land) was 25 t C ha^{-1} For conversions on organic soils the emission factor used is the same as for the initial or the final land use as described below. All emissions from converted land on organic soils also include off-site loss of DOC according to the same assumptions as for drained organic soils.

Conversion to forest land (4.A.2.1-5)

For conversion to forest a period of 100 years was assumed until the soil and litter layer reach a new balance according to the assumption above, i.e., that the converted plots will be included in the sample for forest remaining forest land after 20 years. The resulting CSC factor indicate a loss of carbon of 0.26 and 0.2 t C ha^{-1} for conversion from cropland and grassland respectively which is in the same magnitude as the reference carbon stocks for cropland and grassland is used with the factor for land use representing set aside in table 5.5 of IPCC 2006 GL over a 20 year period. Set aside of cropland for the first decades can be assumed to be equivalent to conversion to forest as it also means that the input of carbon to the soil will be smaller over a period of several decades. For the mineral soil layer, conversion from settlement and other land was assumed to not result in any changes in the soil carbon pool as conversion from settlement mainly relates to reclassification of land use, rather than real land use change and conversion from other land often is land with bare rock (see Karltun 2015)[155]. For organic soils, the same implied emission factor as for cropland remaining cropland was used for conversion from cropland to forest land as it is unlikely that the soil changes in character during the 20-year period. For the other conversion categories, the implied emission factor for forest land remaining forest land was used for organic soils.

Conversion to cropland (4.B.2.1-5)

For conversion from forest to cropland the change between the original carbon stock and the final carbon stocks (mineral soil and litter) was distributed over the 20-year transition period. For conversion of grassland to cropland, observations from Karltun et al (2015) was used to estimate how large share of the converted area that was affected of the land use change (ca 50% of the area) and associated change in carbon stocks. For conversions from settlement and other land the carbon stock was assumed to remain and corresponding to cropland remaining cropland based on (Karltun et al 2015). For organic soils, the same implied emission factor as for cropland remaining cropland was used

Conversion to Grassland (4.C.2.1-5)

For conversion of forest land to grassland the carbon stock change was set to the average for forest land remaining forest land (1990-2022) as there was no observed effect on the converted areas in the assessment in Karltun et al (2015). For conversion of cropland to grassland the carbon stock change was set to the average for grassland remaining grassland (1990-2022) as there was no observed effect on the converted areas in the assessment in Karltun et al (2015) and these areas is more associated to grassland soils than cropland. According to Karltun et al (2015) about 10% of the litter layer was lost de to conversion of forest land to grassland. For organic soils the emission factor for drained organic grassland soils was used except for conversion for cropland converted to grassand where the emission factor for cropland remaining cropland was used.

Conversion to Settlement (4.E.2.1-5)

The effect on the carbon stocks in mineral soils and litter from Karltun et al (2015) has been used for mineral soils and for litter (forest land converted to settlement). As no carbon stock changes in mineral soils or litter is reported for settlement remaining settlement, all carbon is assumed to be lost during the 20-year conversion period for those of the assessed plots that is affected. On average 33% of the plots converted from forest land to settlement is affected the corresponding share for conversion from cropland, grassland and other land was 26%, 7% and 50% respectively. For other land, the carbon stock of forest land was used as reference. For conversion to settlement on organic soils, a reference carbon stock of 1000 t C ha^{-1} was used in combination with the assumption that 3% of the carbon was lost annually (as for horticultural peat) which result in a loss of 22 t C

155 Karltun et al 2015

ha^{-1} over a 20-year period. The same share of plots affected as described above according to Karltun et al (2015) was used (33% for forest land, 26% for cropland, 7% for grassland and 40% for other land).

Conversion to Other land (4.F.2.1-5)

For forest land converted to other land, the entire carbon stock is assumed to be lost over the 20-year period on 7% of the affected plots according to Karltun et al (2015). For Grassland converted to Other land, no change is assumed and the carbon stock change is set to grassland remaining grassland. Changes between wetland and settlement to other land is rare and as there are no carbon stock changes associated to these remaining categories the change factor is set to zero.

Table A3:2.14. The removal/emission factors used to calculate changes in carbon pools on converted land.

Removals/emissions (-) [t C ha^{-1} yr^{-1}]	Soil organic carbon		Litter
	Mineral soils	Organic soils	
A 2.1 Cropland converted to Forest Land	-0.28	-6.1	0.25
A 2.2 Grassland converted to Forest Land	-0.2	-1.6	0.25
A 2.3 Wetland converted to Forest Land	-	-1.6	0.25
A 2.4 Settlements converted to Forest Land	0	-1.6	0.25
A 2.5 Other land converted to Forest Land	0	-1.6	0.25
B 2.1 Forest land converted to Cropland	1.4	-6.1	-1.25
B 2.2 Grassland converted to Cropland	0.2	-6.1	-0.04
B 2.3 Wetland converted to Cropland	-	-6.1	-
B 2.4 Settlements converted to Cropland	0.05	-6.1	-
B 2.5 Other land converted to Cropland	0.05	-6.1	-
C 2.1 Forest land converted to Grassland	0.22	-3.1	-0.13
C 2.2 Cropland converted to Grassland	0.26	-6.1	-
C 2.3 Wetland converted to Grassland	-	-3.1	-
C 2.4 Settlements converted to Grassland	0.26	-3.1	-
C 2.5 Other land converted to Grassland	0.26	-3.1	-
E 2.1 Forest land converted to Settlements	-0.91	-7.5	-0.495[1]
E 2.2 Cropland converted to Settlements	-1.12	-6.2	0
E 2.3 Grassland converted to Settlements	-0.26	-1.6	0
E 2.4 Wetlands converted to Settlements	-	-	0
E 2.5 Other land converted to Settlements	-1.38	-	0
F 2.1 Forest land converted to Other land	-0.2	-1.6	-0.1
F 2.2 Cropland converted to Other land	-	-6.1	0
F 2.3 Grassland converted to Other land	0.26	-3.1	0
F 2.4 Wetlands converted to Other land	0	-	0
F 2.5 Settlements converted to Other land	0	-	0

3.2.2 CRT 4(I), 4(II), 4(III), 4(IV) and 4(V)

This section relates to NIR section 6.4.2.

3.2.2.1 DIRECT N_2O EMISSIONS FROM N-FERTILIZATION, CRT 4(I)

The reported annual $N_2O_{direct\ fertilizer}$ [kt yr^{-1}] is calculated as:

$$N_2O_{direct\ fertilizer} = F_{synt} \bullet EF \bullet 44/28$$

where F_{synt}= is the amount of synthetic fertilizer nitrogen applied [kt yr^{-1}] and *EF* is the emission factor for N_2O emissions from N-inputs (IPCC-default emission factor EF_1 of 1%[156]). Finally, N_2O-N is converted by multiplying N by 44/28 (Table A3:2.15). Note that the emissions factor was updated in Submission 2015 to comply with the IPCC 2006 GL.

Table A3:2.15. The annual amount of synthetic fertilizer sold for application in forestry and the annual direct N_2O emission from nitrogen fertilization.

Year	Fertilized area, kha	Synthetic fertilizer, N, kt yr^{-1}	Emission, N_2O, kt yr^{-1}
1990	69.2	10479	0.165
1991	42.7	6104	0.096
1992	28.6	4293	0.067
1993	26.8	3809	0.060
1994	24.0	3354	0.053
1995	27.3	3885	0.061
1996	24.1	3518	0.055
1997	18.8	2771	0.044
1998	19.3	2808	0.044
1999	24.9	3662	0.058
2000	24.3	3597	0.057
2001	20.6	3044	0.048
2002	13.8	2100	0.033
2003	16.9	2491	0.039
2004	22.4	3116	0.049
2005	34.2	4624	0.073
2006	33.4	4964	0.078
2007	46.5	6971	0.110
2008	59.6	8941	0.141
2009	55.5	8325	0.131
2010	80.4	12000	0.189
2011	52.9	7930	0.125
2012	45.6	6835	0.107
2013	23.9	3580	0.056
2014	22.5	3390	0.053
2015	33.2	5000	0.079
2016	29.3	4410	0.069
2017	25.1	3786	0.059
2018	30.5	4585	0.073
2019	35.9	5385	0.085
2020	42.2	6331	0.099
2021	42.7	6405	0.101
2022	9.9	1485	0.023

[156] Table 11.1 in Intergovernmental Panel on Climate Change, 2006.

3.2.2.2 NON-CO_2 EMISSIONS FROM DRAINED ORGANIC SOILS, CRT 4(II)

A Tier 1 methodology is used, and the reported figures refer to N_2O-N and CH_4 for each land use category with different emission factors depending on nutrient status and climate and multiplied with corresponding areas (forest land and grassland).

Emission of CH_4 organic includes emissions from the soil itself and from the ditches. The fraction of ditches of the total drained organic areas is based on the IPCC 2013 Wetland supplement and was set to 2.5% for Forest land, 5% for Cropland and 5% for Grassland[157].

The emission factors can be found in Table A3:2.16. Emission factors are either based on the WL SL or country specific as noted in the table.

The same source of data for AD as for CO_2-emissions is used to calculate the emissions for drained organic soils for Forest land, Cropland and Grassland. Emissions from Wetlands are covered under section 1.1.9.

Table A3:2.16. Emission factors for non-CO_2 emissions from drained organic soils.

Land category	Climate	Nutrient status	Emission Factors (unit mass per hectare)		
			kg N_2O-N	kg CH_4	ditch kg CH_4
Forest	Boreal	Rich	3.2	2	5.4
		poor	0.22	7	5.4
	Temperate	Rich	2.8	2.5	5.4
		poor	2.8	2.5	5.4
Cropland	Boreal/ Temperate		IE	0	58.3
Grassland	Boreal	Rich	3.2	1.4	10.85
		poor	0.22	1.4	10.85
	Temperate	Rich	2.8	2.5	10.85
		poor	2.8	2.5	10.85

3.2.2.3 N_2O EMISSIONS FROM DISTURBANCE ASSOCIATED WITH LAND USE OR MANAGEMENT CHANGE, CRT 4(III)

A Tier 1 methodology is used. The reported annual N_2O emission from disturbance associated with land use conversion to Cropland (N_2O_{conv} [kt yr^{-1}]) is calculated according to the equation below, based on equation 11.8 in IPCC 2006 GL (IPCC[158]):

[157] Lindgren and Lundblad, 2014

[158] Intergovernmental Panel on Climate Change, 2006

$$N_2O_{conv} = \Delta C_{min} \cdot \frac{1}{C:N_{ratio}} \cdot EF \cdot 44/28$$

where ΔC_{min} is the annual emission of carbon due to soil mineralization (IPCC[159]), EF is the emitted proportion N_2O from N mineralized including volatilization (a constant of 1%; IPCC) and 44/28 is used to convert N to N_2O. The amount of carbon lost is taken from the corresponding carbon stock changes for the relevant categories. $C{:}N_{ratio}$ is the average ratio between carbon and nitrogen in the soil. Previously the default ratio of 15 was used for forest land, grassland and settlements whereas a ratio of 10 was used for cropland. As recommended by reviewers, the C:N ratio has now been updated for most of the reported categories to comply with the initial conditions before LUC or according to the management system. For Cropland remaining Cropland the C:N ratio has been estimated for each of the eight production regions (as described in section 3.1.9) based on the Soil and crop inventory[160]. The C:N ratio varied from 10 to 14 with the highest values in the northern part of the country. For the calculations of mineralisation, regional data on carbon stock changes from the calculations described in section 3.1.9 was used.

For the LUC-categories, C:N ratios were obtained from the SFSI and for land use change from Forest land a C:N ratio of 23 was used, for Land use change from Grassland a C:N ratio of 17 was used and for Land use change from Cropland (and for Settlement converted to Cropland) a C:N ratio of 11 was used. For LUC from other land a C:N ratio of 15 was used.

3.2.2.4 INDIRECT EMISSIONS OF N_2O

In addition to the direct emissions of N_2O from managed soils that occur through a direct pathway (i.e., directly from the soils to which N is applied), emissions of N_2O also take place through two indirect pathways, namely the volatilisation of N following the application of synthetic and organic N fertilizers and the leaching and runoff from land of N from synthetic and organic fertiliser additions.

The method to calculate the emissions is Tier 1 for volatilisation and Tier 2 for leaching and run-off. Both methods are based on the amount of synthetic fertilizer applied on forest soils, adding the annual amount of N mineralised in mineral soils associated with loss of soil C from soil organic matter, as a result of changes to land use or management in regions where leaching/runoff occurs to the leaching part.

The parameters used for volatilisation was the IPCC default values $Frac_{GASF}$ = 0.1 and EF_4 = 0.01 [kg N–N_2O (kg NH_3–N + NO_x–N volatilised)$^{-1}$]. $Frac_{GASF}$ is the fraction of synthetic fertiliser N that volatilises as NH3 and NOx, kg N volatilised

[159] Intergovernmental Panel on Climate Change, 2003.

[160] https://www.slu.se/en/departments/soil-environment/environment/akermarksinventeringen/undersokningar/soil-and-crop-inventory/

(kg of N applied)$^{-1}$. For run-off the $Frac_{LEACH}$ was based on the average leakage from forest soils in Ring (2007). $Frac_{LEACH}$ was therefore set to 0.075 and the emission factor used was the IPCC-default (EF_5=0.0075). Emission was calculated according to:

$$N_2O_{indirect} = N_2O - N_{direct} \cdot (Frac_{GASF} \cdot EF_4 + Frac_{LEACH} \cdot EF_5) \cdot 44/28$$

3.2.2.5 EMISSIONS FROM BIOMASS BURNING, CRT 4(V)

Calculations of emissions from biomass burning are based on the area burned, the average standing stock on these areas, and on assumptions on the amount of biomass burned. Based on the average above ground standing stock of living and dead biomass on Forest land remaining forest land and by assuming that 25% of the biomass is burned, the amount of carbon burned is assumed to be 5.78, 1.02 and 0.72 C [Mg ha^{-1}] for the categories "Forest", "Sparsely covered by trees" and "No tree cover", respectively. The biomass of dead wood constitutes about 0.3-0.6% of this biomass. When controlled burning is performed for regeneration or nature conservation purposes, respectively, 1.15 and 5.78 C [Mg ha^{-1}] are assumed to be released. The annual emission of carbon dioxide (CO_2-burning [kt yr^{-1}]) due to burning of wildfires or controlled burning is calculated as:

$$CO_{2burning} = A \bullet B \bullet 44/12$$

where A=the annual burned area [ha yr^{-1}], B=amount of carbon burned [kt ha^{-1}].

The annual emission of nitrous dioxide ($N_2O_{burning}$ [kt yr^{-1}]) due to burning of wildfires or controlled burning is calculated as:

$$N_2O_{burning} = A \bullet B \bullet 0.01 \bullet 0.007 \bullet 44/28$$

The annual emission of methane ($CH_{4-burning}$ [kt yr^{-1}]) due to burning of wildfires or controlled burning is calculated as:

$$CH_{4burning} = A \bullet B \bullet 0.012 \bullet 16/12$$

Emissions are presented in table A3:2.17. To avoid double counting in the submission, CO_2 emissions from biomass burning is assumed to be included (IE) in estimates of living biomass. For information purposes, the CO_2 emissions from biomass burning are found inside brackets in Table A3:2.17. The method is Tier 1 and the emission factors are IPCC-default.

Table A3:2.17. Annual emissions from biomass burning.

Year	Fire category [ha yr-1]					Annual emissions		
		Wildfire		Controlled burning		CO_2	N_2O	CH_4
	Forest	Sparsely covered by trees	No tree cover	Regene-ration	Bio-diversity	[kt yr^{-1}]	[kt yr^{-1}]	[kt yr^{-1}]
1990	567	647	924	459	0	IE (19)	0.00056	0.082
1991	567	647	924	155	0	IE (18)	0.00053	0.076
1992	567	647	924	201	0	IE (18)	0.00053	0.077
1993	567	647	924	334	0	IE (18)	0.00055	0.080
1994	567	647	924	152	0	IE (18)	0.00053	0.076
1995	567	647	924	177	0	IE (18)	0.00053	0.077
1996	567	647	924	455	0	IE (19)	0.00056	0.082
1997	3810	1092	1484	1720	0	IE (96)	0.00288	0.419
1998	77	123	219	570	0	IE (5)	0.00015	0.022
1999	793	292	229	2493	200	IE (32)	0.00097	0.141
2000	583	329	439	1538	400	IE (28)	0.00084	0.122
2001	412	286	555	2744	600	IE (33)	0.00099	0.144
2002	875	413	305	3802	800	IE (50)	0.00151	0.220
2003	1316	1016	1665	3073	1 000	IE (66)	0.00198	0.288
2004	895	350	437	3894	1 200	IE (58)	0.00174	0.254
2005	664	474	423	3288	1 400	IE (54)	0.00163	0.238
2006	4645	534	524	4103	1 410	IE (143)	0.00429	0.623
2007	522	311	255	1650	377	IE (26)	0.00079	0.114
2008	4280	713	433	3284	2012	IE (142)	0.00427	0.621
2009	730	282	392	1613	256	IE (29)	0.00086	0.125
2010	143	136	241	434	99	IE (8)	0.00023	0.033
2011	348	309	285	1572	433	IE (23)	0.00070	0.101
2012	108	85	288	940	182	IE (10)	0.00031	0.045
2013	476	315	715	1120	539	IE (27)	0.00081	0.118
2014	10498	2123	2043	2796	1804	IE (278)	0.00834	1.213
2015	256	95	243	770	326	IE (15)	0.00046	0.066
2016	712	262	325	874	441	IE (28)	0.00084	0.122
2017	441	168	812	667	327	IE (20)	0.00061	0.089
2018	21 580	874	1 885	560	361	IE (474)	0.01421	2.067
2019	790	215	251	452	395	IE (27)	0.00080	0.117
2020	396	188	229	572	158	IE (15)	0.00044	0.064
2021	486	114	265	583	380	IE (20)	0.00061	0.089
2022	419	236	256	583	380	IE (19)	0.00058	0.084

3.2.3 Uncertainties and time series consistency

This section relates to NIR section 6.4.3.

3.2.3.1 LIVING BIOMASS, CRT 4A, 4B, 4C, 4D, 4E AND 4F

The estimated accuracy of the living biomass pool depends mainly on the sample design of the NFI. Results from the control inventory of the NFI indicate that measurement errors, registration errors and errors caused by the instruments (callipers) could be assumed to be close to zero. Potential bias induced by incorrectly specified models and an unrepresentative derivation data could probably be ignored.

The reported estimated standard errors of the estimates are calculated by formulas for a ratio estimator[161]. The tracts (clusters) are assumed to be sample units and these units are assumed to be randomly distributed within strata. Small trees, shrubs and other vegetation, such as herbs, are not included in the figures. It is assumed that the net change in the stock of this vegetation is small.
A ratio estimator is calculated on county level:

$$\hat{Y}_i = A_i \frac{\hat{X}_i}{\hat{A}_i} = A_i \frac{\sum x_{ij}}{\sum a_{ij}} = A_i \cdot R_i$$

where $\hat{Y}_i$ = the ratio estimated value for county *i* (for example the change in biomass stock), A_i = the measured area of county *i*, $\hat{X}_i$ = the estimated value of the variable of interest according to Horvitz-Thompson for county *i* and $\hat{A}_i$ = the estimated area according to Horvitz-Thompson for county *i*. $\sum x_{ij}$ is the sum of the variable of interest over sampling units (tract) *j* within county *i*. $\sum a_{ij}$ is the total inventoried area over sampling units (tract) *j* within county *i*. The estimated variance on county level is calculated as:

$$\hat{Var}(\hat{Y}_i) \approx \frac{A_i^2}{(\sum a_{ij})^2} \cdot n_i \cdot S^2_{y_{ij} - R_i \cdot a_{ij}}$$

where n_i=the number of sampling units (tracts) within county *i* and $S^2_{y_{ij} - R_i \cdot a_{ij}}$ is the standard deviation based on y_{ij}-R_i·a_{ij}. Each county constitutes a stratum and the estimated variance over all strata (whole Sweden) is calculated as:

$$\hat{Var}\left(\hat{Y}_{Swe}\right) = \sum_{i=1}^{N} \hat{Var}\left(\hat{Y}_i\right)$$

[161] Thompson, 1992

where N=number of strata (counties in Sweden), $\hat{Var}\left(\hat{Y}_{Swe}\right)$ = the estimated variance for the reported estimate on national level and the corresponding standard error of this estimate is:

$$SE = \sqrt{\hat{Var}(\hat{Y}_{Swe})}$$

Finally, the reported Uncertainty is calculated as:

$$Uncertainty = 2 \cdot SE$$

3.2.3.2 EVALUATING CONSEQUENCES FROM EXTRAPOLATION.

To reduce the effect of random variation and to make estimates more consistent for estimates of the most recent years, Sweden has introduced extrapolation for inventory cycles without a full record. Each inventory cycle is extrapolated 0, 1, 2, 3, and 4 years, respectively, but after a re-inventory, extrapolated values are substituted by values based on measurements. The advantages with extrapolation are mainly a reduced effect of random sampling variation and a more consistent (harmonised) reporting. A disadvantage is that, e.g., a large true change in removal from e.g., increased harvest intensity in 2021 would only influence on 20% of the sample plots the first year and it takes five years until the full effect of such change is reflected by all sample plots. In other words, extrapolation reports a trend based on historical data and average out estimates over time. Observe that the extrapolation is made per land use category/ land use change category, activity but not per plot.

There are different options to extrapolate data for cycles with an incomplete data record. Sweden uses trend extrapolation. Trend extrapolation is based on the five years former the missing data and is used for all estimates of changes in living biomass and areas.

In submission 2014, consequences of different extrapolation techniques were evaluated. It was concluded that i) extrapolation improved the accuracy of estimates compared with un-weighted (no extrapolation) estimates, and ii) that extrapolation based on the 5 former years was a reasonable trade of between averaging out data and being up to date. From submission 2015, average extrapolation is substituted by trend extrapolation. Using trend extrapolation, the estimated total land and freshwater area is the same for both measured (with a full record of around 30000 sample plots) and extrapolated areas (the four most recent years).

3.2.4 References annex 3:2

Andrén, O., & Kätterer, T. 1997. ICBM – the Introductory Carbon Balance Model for exploration of soil carbon balances. Ecological Applications, 7, 1226-1236.

Andrén, O., Kätterer, T., & Karlssson, T. 2004. ICBM regional model for estimations of dynamics of agricultural soil carbon pools. Nutrient Cycling in Agroecosystems, 70, 231-239.

Andrén, O., Kätterer, T., Karlsson, T., & Eriksson, J. 2008. Soil C balances in Swedish agricultural soils 1990-2004, with preliminary projections. Nutrient Cycling in Agroecosystems, 81, 129-144.

Berg, B., Albrektsson, A., Berg, M.P., Cortina, J., Johansson, M-B., Gallardo, A., madeira,M., Pausaa,J., Kratz,W., Vallejo, R., and McClaugherty, C. 1999b. Amounts of litterfall in some pine forests in a European transect, in particular Scots pine. Ann. For. Sci. 56:625-639.

Berg, B., Johansson, M-B., Tjarve, I., Gaitneks, T., Rokjanis, B., Beier, C., Rothe, A., Bolger, T., Göttlein, A. and Gertsberger, P. 1999a. Needle litterfall in a northern European spruce forest transect. Reports in Ecology and Forest Soils, Report 80, Department of forest Soils, Swedish university of agricultural Sciences, Uppsala, Sweden. 36 pp.

Bolinder, M.A., Andrén, O., Kätterer, T., and Parent, L.E. 2008. Soil organic carbon sequestration potential for Canadian agricultural ecoregions calculated using the Introductory Carbon Balance Model. Canadian Journal of Soil Science, 88: 451-460.

Bolinder, M.A., VandenBygaart, A.J., Gregorich, E.G., Angers, D.A., and Janzen, H.H. 2006. Modelling soil organic carbon stock change for estimating whole-farm greenhouse gas emissions. Canadian Journal of Soil Science, 86: 419-429.

Bolinder, M.A., Fortin, J.G.,Anctil, F., Andrén, O., Kätterer, T., de Jong, R., & Parent, L.E. 2012. Spatial and temporal variability of soil biological activity in the Province of Québec, Canada (45-58 oN, 1960-2009) – calculations based on climate records. Climatic Change, Volume: 117 Issue: 4 Pages: 739-755

Bolinder, M.A., Kätterer, T., Andrén, O., and Parent, L.E. 2012. Estimating carbon inputs to soil in forage-based crop rotations and modeling the effects on soil carbon dynamics in a Swedish long-term field experiment. Canadian Journal of Soil Science, 92:821-833.

Bolinder, M.A., Crotty, F., Elsen, A., Frac, M., Kismányoky, T., Lipiec, J., Tits, M., Zoltán, T., & Kätterer, T. 2020. The effect of crop residues, cover crops, manures and nitrogen fertilization on soil organic carbon changes in agroecosystems: a synthesis of reviews. Mitigation and Adaptation Strategies for Global Change 25 (2020) 929-952.

Bolinder MA, Hytteborn J, Lang R, Lundblad M, Kätterer T. 2022. Coordination of common input data for manure in the agricultural sector and for ICBM in the LULUCF sector. SMED Rapport Nr X 2022.

Campbell, C.A., VandenBygaart, A.J., Grant, B., Zentner, R.P., McConkey, B.G., Lemke, R., Gregorich, E.G., and Fernandez. M.R. 2007. Quantifying carbon sequestration in a conventionally tilled crop rotation study in southwestern Saskatchewan. Canadian Journal of Soil Science, 87: 23-38.

Garsia, A., Moinet, A., Vazquez, C., Creamer, R.E., and Moinet, G.Y.K. 2023. The challenge of selecting an appropriate soil organic carbon simulation model: A comprehensive global review and validation assessment. Global Change Biology, 00: 1-15. DOI: 10.1111/gcb.16896

Heikkinen, K. 1990. Transport of organic and inorganic matter in river, brook and peat mining water in the drainage basin of the River Kiiminkijoki. Aqua Fennica 20: 143–155.

Intergovernmental Panel on Climate Change. 2003. Good Practice Guidance for Land Use, Land-Use Change and Forestry. Penman, J., Gytarsky, M., Hiraishi, T., Krug T., Kruger, D., Pipatti, R., Buendia, L., Miwa, K., Ngara, T., Tanabe, K., and Wagner, F. (Eds.). IPCC/OECD/IEA/IGES, Hayama, Japan. ISBN 4-88788-003-0.

Intergovernmental Panel on Climate Change. 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Ektleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

Intergovernmental Panel on Climate Change. 2014. 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands, Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M. and Troxler, T.G. (eds). Published: IPCC, Switzerland.

Johansson,T. 1999. Biomass equations for determining fractions of pendula and pubescent birches growing on abandoned farmland and some practical implications. Biomass and Bioenergy, 16:223-238.

Karltun E, Nilsson T, Lundblad M. 2015. Litter and soil carbon stock changes in connection to land-use changes - A method assessment for the Swedish LULUCF carbon inventory. SMED Report No 204 2015

Karltun, E. 2022. Changed calculations of time series for litter and soil carbon for Forest remaining forest and Grassland remaining grassland. SMED Rapport Nr XX 2022.

Karltun et. al (manuscript) Soil carbon dynamics under a chronosequence of forests planted on agricultural land, as shown by 14C-bomb analysis. Swedish University of Agricultural Sciences.

Kröbel R, Bolinder MA, Janzen HH, Little SM, Vandenbygaart AJ, Kätterer T. 2016. Canadian farm-level soil carbon change assessment by merging the greenhouse gas model Holos with the Introductory Carbon Balance Model (ICBM). Agricultural Systems. 143: 76-85.

Kätterer, T., and Andrén, O. 1999. Long-term agricultural field experiments in Northern Europé: analysis of the influence of management on soil carbon stocks using the ICBM model. Agriculture, Ecosystems and Environment, 72: 165-179.

Kätterer, T., Andrén, O., and Persson, J. 2004. The impact of altered management on long-term agricultural soil carbon stocks - a Swedish case study. Nutrient Cycling in Agroecosystems, 70: 179-187.

Kätterer, T., Andersson, L., Andrén, O., and Persson, J. 2008. Long-term impact of chronosequential land use change on soil carbon stocks on a Swedish farm. Nutrient Cycling and Agroecosystems, 81: 145-155.

Kätterer, T, Bolinder, M, Andrén, O, Kirchmann, H, Menichetti, L. 2011. Roots contribute more to refractory soil organic matter than above-ground crop residues, as revealed by a long-term field experiment. Agriculture, Ecosystems and Environment 141 (2011) 184–192.

Kätterer T, Börjesson G, Kirchmann H. 2014. Changes in organic carbon in topsoil and subsoil and microbial community composition caused by repeated additions of organic amendments and nitrogen fertilization in a long-term field experiment in Sweden. Agriculture, Ecosystems and Environment. 189: 110-118.

Kätterer, T., and Andrén, O. 2021. The ICBM family of analytically solved models of soil carbon, nitrogen and microbial biomass dynamics - descriptions and application examples. Ecological Modelling, 136: 191-207.

Lindahl, A., & Lundblad, M. 2021.Växthusgasemissioner från dränerad organogen naturbetesmark – Uppdatering av nationella emissionsfaktorer (CO_2, N_2O, CH_4) för Sveriges rapportering av LULUCF-sektorn till FN och EU. SMED Rapport Nr 14 2021.

Lindahl, A., Lundblad, M. 2022.Genomgång av hantering av organogena marker inom klimatrapporteringen. SMED Rapport Nr 6 2022.

Lindgren, A. and Lundblad, M. 2014. Towards new reporting of draind organic soils under the UNFCCC – assessment of emission factors and areas in Sweden. SLU. Department of Soil and Environment, Rapport 14. Uppsala 2014.

Länk https://www.slu.se/en/departments/soil-environment/environment/akermarksinventeringen/undersokningar/soil-and-crop-inventory/

Marklund, L.G. 1987. Biomass functions for Norway spruce in Sweden. Swedish University of Agricultural Sciences, Department of Forest Survey, report 43. 127p. ISSN 0348-0496.

Marklund, L.G. 1988. Biomassafunktioner för tall, gran och björk i Sverige. Sveriges Lantbruksuniversitet, Institutionen för skogstaxering, rapport 45. 73 sidor ISSN 0348-0496.

Melin Y., Petersson H., Nordfjell T . 2009. Decomposition of stump and root systems of Norway spruce in Sweden - a modelling approach. Forest Ecology and Management . 257: 5, 1445-1451

Menichetti, L., Kätterer, T., and Bolinder, M.A. 2023. Bayesian calibration of the ICBM/3 soil organic carbon model constraint by data from long-term experiments and uncertainties of C inputs. Carbon Management, in revision.

National Board of Forestry. 2000. Skogliga konsekvensanalyser 1999. Skogsstyrelsen, Jönköping 2000. 331 sidor. ISSN 1100-0295.

Näslund M. 1947. Funktioner och tabeller för kubering av stående träd . Tall, gran och björk i södra Sverige samt i hela landet. Meddelande från Statens skogsforskningsinstitut. Band 36:3. Stockholm.

Palosuo T, Heikkinen J, Regina K. 2015. Method for estimating soil carbon stock changes in Finnish mineral cropland and grassland soils. Carbon Management. 6: 207-220.

Peacock M. 2022. UT-05 Utredningsbehov inom inventeringen kopplat till 2019 Refinement, Katowice-beslutet, LULUCF-förordningen och EMEP/EEA Guidebook 2019-mall. Växthusgasutsläpp från ”Flooded Land” A National Assessment of Methane Emissions from Flooded Land. PM.

Petersson, H., and Ståhl, G. 2006. Functions for Below Ground Biomass of Pinus sylvestris, Picea abies, Betula pendula and B. pubescens in Sweden. Scandinavian Journal of Forest Research, 21(Suppl 7): 84-93.

Ranneby, B., Cruse, T., Häktlund, B., Jonasson, H., and Swärd, J. 1987. Designing a new national forest survey for Sweden. Studia Forestalia Suecica 177, 29 p.

Sandström, F., Petersson, H., Kruys, N. & Ståhl, G. 2007. Biomass conversion factors (density and carbon concentration) by decay classes for dead wood of Pinus sylvestris, Picea abies and Betula spp. in boreal forests of Sweden. Forest Ecology & Management, 243: 19-27.

Svenska Torvproducentföreningen. 2006. Torvåret 2005 – Statistik över Sveriges Torvproduktion 2005. Sammanställd av Svenska Torvproducentföreningen, In Swedish

Taghizadeh-Toosi A, Cong W-F, Eriksen J, Mayer J, Olesen JE, Keel SG, Glendining M, Kätterer T, Christensen BT. 2020. Visiting dark sides of model simulation of carbon stocks in European temperate agricultural soils: allometric function and model initialization. Plant and Soil. 450: 255-272.

Thompson, S.K. 1992. Sampling. Wiley Series in Probabilty and Mathematical Statistics, USA, 343 p. ISBN 0-471-54045-5.

Thuille, A. and Schulzem E-D. 2006. Carbon dynamics in successional and afforested spruce stands in Thuringia and the Alps. Global Change Biology (2006) 12, 325-342.

Tong C.H.M. 2022. The greenhouse gas balance of drained forest landscapes in boreal Sweden. Doctoral Thesis No. 2022:43 Faculty of Forest Sciences. Acta Universitatis Agriculturae Sueciae 2022:43

Vesterdal et. al. 2007. Carbon Sequestration in Soil and Biomass Following Afforestation: Experiences from Oak and Norway Spruce Chronosequences in Denmark, Sweden and the Netherlands. In: Environmental effects of afforestation in north-western Europe. 19-52. Springer Plant and vegetation 2007.

Viro, 1952. On the determination of stoniness. Comm. Inst. For. Fenn. 40:1-19.

Wallin, M., Bishop, K., Fölster, J., Löfgren, S., Lundblad, M. 2021 Koncentration och export av TOC från dikad organogen mark. En rumsligt upplöst modell för nationell skattning. SMED Rapport Nr 17 2021.

3.3 Annex 3:3: Methodological issues for solvent use (in CRT sector 2.D.3 Non-energy products from fuels and solvent use)

In 2016, Swedish Environmental Emissions Data (SMED) in cooperation with the Swedish Chemicals Agency (Skårman et al., 2016[162]), has further developed the calculation model for estimating the national emissions of NMVOC and CO_2 from use of solvents in Sweden. The model has been revised in order to meet international reporting requirements according to CLRTAP and UNFCCC as well as to support national needs. The model makes it possible to test different sets of emission factors within the solvent use sector. This function can be used to assess different actions and emission reduction potentials. Furthermore, the model can generate emissions per user category and product group. This information can be used when following-up the Swedish environmental quality objectives.

The calculation model is consumption-based with a product-related approach. Amounts of NMVOC and C in solvents and solvent-based products, produced in, imported to, used in, and exported from Sweden, was derived from the Swedish Product Register hosted by the Swedish Chemicals Agency. Emission factors from the literature have been used as far as possible, but in the case when emission factors are unavailable, country-specific emission factors have been developed.

3.3.1 Definition of NMVOC

According to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006), NMVOCs are defined as:

"any non-methane organic compound having at 293.15 K a vapour pressure of 0.01 kP or more, or having a corresponding volatility under the particular conditions of use."

3.3.2 Substance list

A manual selection has been made in order to select each substance with vapour pressure of 0.01 kPa or more at 293.15° K according to the chosen definition of NMVOC. The final substance list contains 427 substances defined as NMVOC. The list includes CAS-number, name, molecular formula and carbon share for each substance. The carbon share for each substance has been calculated based on the molecular formula. In some cases, a mixture of substances are included in the substance list, and for the mixtures the carbon content has been estimated by the Swedish Chemicals Agency as 85% of NMVOC, based on information in the Products Register. In cases where the carbon content cannot be derived from the

[162] Skårman et al., 2016. Swedish method for estimating emissions from Solvent Use. Further development of the calculation model. SMED report 192.

Products Register, the default value of 60%, given in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, has been used.

Emissions of CO_2 has been calculated with the following equation:

$$\text{Emission } (CO_2) = C_{quantity} \times \text{Emission Factor} \times \frac{44}{12}$$

$C_{quantity}$ is the carbon quantity of the solvents. 44 and 12 are the molecular weights of CO_2 and C, respectively.

3.3.3 Activity data

The substance list has been used to extract quantities of NMVOC and C in substances found in the Products Register. Data extractions have been made for each year from 1992. The extractions show for each year:

- The intended use of the product, the product type (functional code)
- Industry to which the product is sold (industry category)
- Quantity NMVOC
- Quantity C
- Number of products

When analysing the extractions from the Products Register, data for 1992-1994 showed not to be reliable to use for quantitative estimates of NMVOC and C emissions. The reason is that during this period the emissions of many substances still were reported as intervals, even if work has been done by the Swedish Chemicals Agency in order to further specify the amounts. There were also changes in the code system during this period. Therefore, data from the Products Register are only used for 1995 and onwards.

Due to the two-year delay in official statistics from the Products Register, activity data for the last year in the reported time series is not published in time to be used in the latest submission and hence Sweden has chosen to equal data for the last year with data for the year before that. Estimated values for last year of one submission will always be updated with official data in the next submission.

3.3.4 Allocation

The extractions from the Products Register for 1995 and onwards have been used in order to compile a connection diagram with all combinations of "product codes" and "industry categories". For all combinations, decisions whether to include or exclude from reporting are based on expert judgements in order to avoid double-counting. If the combination should be included, it has been given a specific:

- SNAP-code (according to EMEP/EEA guidebook)
- Industry group (grouping industry categories)

- Product group (grouping of product codes)
- Use category (industry, consumer and other)

Furthermore, it has to be determined if the product is used as raw material or not. Quantities of NMVOC used as raw material have been identified and handled separately from other quantities, since most of the solvents used as raw material will not be emitted but bound in products.

In order to avoid double-counting of reported emissions within other sectors, an expert judgement has been made on both industry category and product function. All industrial activities reported in other CRT-codes are excluded from the extractions from the Products Register.

The sold amount of solvent is not always identical to the amount of solvent used, i.e. stock of solvents. Up until submission 2019, activity data has therefore been recalculated using a running average over three years. This led to the need for updating of reported emissions for the latest three years in the time series in every new submission. In submission 2020, the recalculation of activity data has been updated[163] based on the assumption that sold amounts of solvents in a specific year are not used entirely within the same year. For a sold amount of a specific solvent, the amounts of this specific solvent used, and the corresponding emissions are distributed over three consecutive years, the first year being the year where the respective solvents are sold. This is done by defining consumption rates of solvents per CRT subcategory sector (see Table A3:3.1).

Table A3:3.1. Consumption rates for product groups sold in year X, estimated per CRT subcategory.

CRT subcategory	X	X+1	X+2
Domestic solvent use including fungicides	70%	20%	10%
Coating applications	80%	15%	5%
Degreasing	85%	10%	5%
Dry cleaning	85%	10%	5%
Chemical products	85%	10%	5%
Printing	85%	10%	5%
Other solvent use	75%	15%	10%

When calculating amounts used and emissions from products containing solvents sold in 2016 allocated to domestic solvent use including fungicides, 70% of these solvents are assumed be used in 2016, 20% in 2017 and 10% in 2018. Calculated emissions from usage of these solvents are distributed likewise. Therefore, reported emissions for a certain year after 1996 always include emissions from solvent use from solvents sold within the two previous years. Emissions and activity data for

[163] Helbig, T., Danielsson, H. (2019)

1995 and 1996 have been interpolated due to the calculation approach suggesting allocating a share of emissions from solvent use in 1993 and 1994 to 1995 and 1996 respectively. However, based on expert judgement it was decided that emissions and activity data for the years 1990-1994 are not changed.

3.3.5 Emission factors

Emission factors given in the literature, for example the EMEP/EEA guidebook (EEA, 2016), EU legislations, and other countries Informative Inventory Reports have been compiled and included in the model. Two emission factors have been developed for each activity; one for solvents used as raw material and one for the remaining quantities. The emission factors for raw material have been set to 0.001 for all SNAP codes, since most of the solvents will end up in the product and will not be emitted during production. A new emission factor for products used diluted in water or removed with water has been introduced in the new model. The new emission factor is set to 0.275 and it has been calculated as average of 0.05 and 0.5 according to the information in the EMEP/EEA Guidebook 2016 for domestic solvent use including fungicides, section 3.2.4. (EEA, 2016). In the previous estimates, these products were not treated separately and consequently the emission factor of 0.95 was used also for water diluted products. The country-specific emission factors have been developed in order to adjust to the old time series 1990-2001, developed by SMED in 2002 (Kindbom et. al., 2004). However, for some activities, errors have been identified in previously reported data for 1990, and consequently those emissions have been corrected. Furthermore, application techniques, available information in the environmental reports for specific industries, as well as other pathways of release (e.g. water), have been considered when developing the country-specific emission factors.

Country-specific emission factors for solvent use are presented in Tables A3:3.2-A3:3.6.

Table A3:3.2. Country specific emission factors for SNAP codes in "Domestic solvent use including fungicides". Emission factor references given at the end of Annex 3:3. EFs in italic are interpolated.

Year	060408ei	060408eii	060408fi	060408fii	060408gi	060408gii	060408hi	060408hii	060408i	060411
1995	0.95[1]	0.275[2]	0.95[1]	0.275[2]	0.95[1]	0.275[2]	0.95[1]	0.275[2]	0.95[1]	0.95[1]
2000	0.95[1]	0.275[2]	0.95[1]	0.275[2]	0.95[1]	0.275[2]	0.95[1]	0.275[2]	0.95[1]	0.95[1]
2010	0.95[1]	0.275[2]	0.95[1]	0.275[2]	0.95[1]	0.275[2]	0.95[1]	0.275[2]	0.95[1]	0.95[1]
From 2015 onwards	0.95[1]	0.275[2]	0.95[1]	0.275[2]	0.95[1]	0.275[2]	0.95[1]	0.275[2]	0.95[1]	0.95[1]

Table A3:3.3. Country specific emission factors for SNAP codes in "Coating applications". Emission factor references given at the end of Appendix II. EFs in italic are interpolated.

Year	060101	060102	060103	060104	060105	060106	060107	060108	060109
1995	0.95[1]	0.95[1]	0.95[1]	0.95[1]	0.25[4]	0.84[3]	0.29[1]	0.95[1]	0.95[1]
2000	*0.79*	*0.79*	0.95[1]	0.95[1]	0.25[4]	0.84[3]	0.17[3]	*0.83*	0.95[1]
2010	*0.54*	*0.54*	0.95[1]	0.95[1]	0.25[4]	0.84[3]	0.17[3]	*0.59*	0.95[1]
From 2015 onwards	0.45[3]	0.45[3]	0.95[1]	0.95[1]	0.25[4]	0.84[3]	0.17[3]	0.50[3]	0.95[1]

Table A3:3.4. Country specific emission factors for SNAP codes in "Degreasing", "Dry cleaning" and "Printing". Emission factor references given at the end of Appendix II. EFs in italic are interpolated.

Year	060201	060203	060204	060202	060403
1995	0.61[5]	0.61[5]	0.61[5]	0.30[6]	0.65[1]
2000	0.47[5]	0.47[5]	0.47[5]	0.30[6]	*0.59*
2010	0.19[5]	0.19[5]	0.19[5]	0.30[6]	*0.39*
From 2015 onwards	0.19[5]	0.19[5]	0.19[5]	0.30[6]	0.30[3]

Table A3:3.5. Country specific emission factors for SNAP codes in "Chemical products". Emission factor references given at the end of Appendix II. EFs in italic are interpolated.

Year	060305	060307	060308	060309	060311	060312	060313	060314
1995	0.30[1]	0.004[1]	0.004[1]	0.004[1]	0.004[1]	0.03[3]	0.010[1]	0.50[1]
2000	0.27[1]	0.003[3]	0.003[3]	0.003[3]	0.003[3]	0.03[3]	0.008[1]	0.29[1]
2010	0.25[1]	0.003[3]	0.003[3]	0.003[3]	0.003[3]	0.03[3]	0.003[3]	0.20[1]
From 2015 onwards	0.25[1]	0.003[3]	0.003[3]	0.003[3]	0.003[3]	0.03[3]	0.002[3]	0.20[1]

Table A3:3.6. Country specific emission factors for SNAP codes in "Other solvent and product use". Emission factor references given at the end of Appendix II. EFs in italic are interpolated.

Year	060405	060406	060407	060409	060412i	060412ii
1995	0.56[7]	0.64[1]	0.95[1]	0.95[1]	0.95[1]	0.275[2]
2000	0.56[7]	*0.59*	0.95[1]	0.95[1]	0.95[1]	0.275[2]
2010	0.56[7]	*0.33*	0.95[1]	0.95[1]	0.95[1]	0.275[2]
From 2015 onwards	0.56[7]	0.22[3]	0.95[1]	0.95[1]	0.95[1]	0.275[2]

[1] Skårman, T., Danielsson, H., Henningsson, E., Östman, M. 2006. Revised Method for Estimating Emissions of NMVOC from Solvent and Other Product Use in Sweden. SMED Report no 75

[2] EMEP/EEA air pollutant emission inventory guidebook - 2016. 2.D.3.a Domestic solvent use including fungicides.

[3] Environmental reports

[4] EMEP/EEA air pollutant emission inventory guidebook - 2016. 2.D.3.d Coating applications. Table 3-20.

[5] EMEP/EEA air pollutant emission inventory guidebook - 2016. 2.D.3.e Degreasing. Table 3-4. Abatement efficiency from the GAINS model.

[6] EMEP/EEA air pollutant emission inventory guidebook - 2016. 2.D.3.f Dry cleaning. Table 3-3.

[7] EMEP/EEA air pollutant emission inventory guidebook - 2016. 2.D.3.i, 2.G Other solvent and product use. Table 3-11.

3.3.6 References Annex 3:3

EEA (2016). EMEP/EEA air pollutant emission inventory guidebook 2016. https://www.eea.europa.eu/publications/emep-eea-guidebook-2016

Helbig, T., Danielsson, H. (2019). Uppdatering av utsläppsberäkningen i lösningsmedelmodellen. SMED PM 2019-08-12.

IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 1 General Guidance and Reporting.

Kindbom, K., Boström, C.-Å., Skårman, T., Gustafsson, T., Talonpoika, M. (2004). ”Estimated emissions of NMVOC in Sweden 1988-2001”. On behalf of the Swedish Environmental Protection Agency. SMED and SMED&SLU Report. Series No 6 2004.

Skårman, T., Danielsson, H., Henningsson, E., Östman, M. 2006. Revised Method for Estimating Emissions of NMVOC from Solvent and Other Product Use in Sweden. SMED Report no 75

Skårman, T., Danielson, H., Jerksjö, M., Ifverberg, M. 2016. Swedish method for estimating emissions from Solvent Use. Further development of the calculation model. SMED Report No 192 2016

3.4 Annex 3:4: Rationale for data sources used for key categories in industrial processes sector (CRT 2)

For facility and emission estimates, the data has been compared and evaluated with other available data sources in terms of timing of reporting, accuracy, transparency, time-series consistency and completeness. In many cases, where available, EU ETS data is judged to give the best estimates. See Table A3:4.1 for the rationale for data sources used for key categories in the industrial process sector.

For the key category 2.F.1 (Refrigeration and Air Conditioning Equipment), the rationale for choosing methodologies and data sources used are described under NIR 4.7.

Table A3:4.1. Rationale for data sources used for key categories in the industrial processes sector.

Key category	Available data source	Used data source	Rationale for data source used
2.A.1 CO_2	From 1990: - National production statistics - Production statistics from the company - IPCC default EF - Emissions data from personal communication with the companies From 2004: - Environmental reports from the companies From 2005: - Production statistics and emissions from EU ETS	1990 – 2004: - Production statistics from the company - IPCC default EF - Emissions data from personal communication with the companies From 2005: - Production statistics and emissions from EU ETS	1990-2004: Production statistics from the company gives best estimates (highest tier) compared to national statistics. Additional emission data from the company needed to estimate CO_2 from CKD, by-pass dust and organic compounds in raw meal. From 2005: We judge that EU ETS data gives the best estimates (highest tier).
2.A.2 CO_2	From 1990: - National production statistics from the Swedish Lime Association - IPCC default EF From 2005: - Emissions from EU ETS. Production statistics calculated from reported emissions.	1990 - 2004 - National production statistics from the Swedish Lime Association - IPCC default EF From 2005: - Emissions from EU ETS. Production statistics calculated from reported emissions.	1990-2004: Production statistics from the Swedish Lime Association company gives best estimates. From 2005: We judge that EU ETS data gives the best estimates (highest tier).

Key category	Available data source	Used data source	Rationale for data source used
2.B.2 N_2O	1991-1993: - National production statistics - IPCC default EF - Country specific EF 1990 and 1994-2012: - National production statistics - Production statistics and emission data from personal communication with the companies - IPCC default EF - Country specific EF From 2002: - Environmental reports from the companies	1990, 1994-2001: - Production statistics and emission data from personal communication with the companies 1991 – 1993: - National production statistics and country specific EF From 2002: - Environmental reports from the companies	Data from environmental reports give correct estimates. Using data from the facilities gives more accurate emissions compared to estimates based on production statistics and EF. 1991 – 1993: reported emissions are based on national production statistics and national EF due to lack of company data.
2.C.1 (2.C.1.a) CO_2	From 1990: - National production statistics - Energy statistics surveys - Production statistics, carbon contents and emission data from personal communication with the companies - National EF - IPCC default EF From 2004: - Environmental reports from the companies From 2005: - Emissions from EU ETS	1990 – 2004: - Carbon contents and emission data from personal communication with the companies - Energy statistics surveys - National EF From 2012: - Emissions from EU ETS - Emission data from personal communication with the companies - Environmental reports from the companies - National EF	Different data sources are used depending on facility and year. Facility related information from the companies gives best estimates (highest tier) compared to national statistics and IPCC default EF. We judge that EU ETS data gives the best estimates (highest tier). From 2005, emissions are collected from EU ETS for all facilities except one where data in EU ETS is lacking.
2.C.1 (2.C.1.c – iron sponge and iron powder) CO_2	From 1990: - National production statistics - Emission data from personal communication with the company - Energy statistics surveys - National EF - IPCC default EF From 2004: - Environmental reports from the company From 2005: - Emissions from EU ETS	1990 – 2004: - Emission data from personal communication with the company From 2005: - Emissions from EU ETS for the company	1990-2004: Facility related information from the company gives better estimates (highest tier) compared to national statistics and IPCC default EF. From 2005: We judge that EU ETS data gives the best estimates (highest tier).

Key category	Available data source	Used data source	Rationale for data source used
2.C.1 (2.C.1.b – primary pig iron and steel) CO_2	From 1990: - National production statistics - Production statistics from the companies - IPCC default EF From 2003: - Environmental reports from the companies	1990 – 2002: - Production statistics from the companies and average CO_2 IEF 2003-2007. From 2003: - Environmental reports from the companies	1990-2002: Splicing technique based on IPCC good practice guidance. From 2003: Most accurate for UNFCCC reporting. Same CO_2 emissions as in EU ETS since 2008. 2005-2007, EU ETS data did not contain all CO_2 sources.
2.C.1 (2.C.1.d) CO_2	From 1990: - National production statistics - IPCC default EF - Activity data from personal communication with the companies	1990 – 1995: - National production statistics and IPCC default EF.	No national EF available.
2.C.1 (2.C.1.e) CO_2	From 1990: - National production statistics - IPCC default EF - Activity data from personal communication with the companies From 2005: - Emissions from EU ETS	1990-2008: - Activity data from the company and IEF for 2009 (bentonite) and 2005 (organic binders) From 2005: - EU ETS	Different data sources are used depending on facility and year. We judge that EU ETS data gives the best estimates (highest tier). EU ETS data has not been complete until 2009 for all facilities.
2.C.3 PFCs	From 1990: - National production statistics - Production statistics and emission data from personal communication with the companies - IPCC default EF From 1992: - Anode effects in min/oven day from the company From 2004: - Environmental reports from the companies	1990 - 1991 - Production statistics and anode effects in min/oven day for 1992 from the company, and IPCC default EF From 1992: - Production statistics and anode effects in min/oven day from the company, and IPCC default EF	Production statistics and anode effects in min/oven day from the company and IPCC default EF gives the best estimate (Tier 2) by PFCs. In environmental reports, only data on total PFCs are reported.

3.5 Annex 3:5: Documents from Swedish Refrigeration & Heat Pump Association and Swedish Car Recyclers Association

Swe Environmental Protection Agency
IVL Swedish Environmental Research Institute

Stockholm den 12 oktober 2016

Recovery of fluorinated greenhouse gases at decommissioning of stationary and mobile systems in Sweden.

The use of ozone depleting substances and fluorinated greenhouse gases for refrigerants is regulated according to the Swedish Refrigeration Code of Best Practice. This standard, which was developed in the 1980's and published in 1988, has since seen continuous development. The standard was supplemented by regulations issued by SWEDAC (Sweden's national accreditation body). There are also supplementing fact sheets associated to this Swedish Refrigeration Code of Best Practice.

The Swedish Refrigeration Code of Best Practice is applicable to all types of stationary and mobile refrigeration, air conditioning and heat pump equipment that contain CFCs, HCFCs and HFCs as refrigerants. The standard stipulates responsibilities associated with installation and service as well as responsibilities that lie with the supplier of refrigerants. It also includes general directives on the choice of refrigerants and requirements on design, service, maintenance, operation and decommissioning of equipment.

In addition to the Swedish Refrigeration Code of Best Practice, there is also a Swedish regulation on fluorinated greenhouse gases and ozone depleting substances, "Förordning om fluorerade växthusgaser och ozonnedbrytande ämnen" (2007:846) that was taken into force 2008-01-01, and the EU regulation on fluorinated greenhouse gases (now 517/2014).

Sweden has since long had stringent requirements that the installation, service, maintenance and decommissioning only should be performed by certified personnel and businesses.

In Sweden, producers and importers of products, such as stationary and mobile refrigeration, air conditioning and heat pump equipment are obliged to reclaim end-of-life equipment. In addition, importer and distributers of refrigerants are required by law to free of charge reclaim recovered amounts of all refrigerant fluids, and provide container for this purpose. Recovered

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amounts of refrigerants that are not recycled must, by law, be destroyed. No emissions of HFCs are allowed from the destruction/incineration processes.

Stationary refrigeration

We, the Swedish Refrigeration & Heat Pump Association, "Svenska Kyl- och Värmepumpföreningen", business association for stationary and mobile refrigeration, air conditioning and heat pump equipment, make the judgement that in Sweden at least 95 % of fluorinated greenhouse gases are recovered at decommissioning of stationary refrigeration, air conditioning and heat pump equipment.
For transport refrigeration, we make the judgement that the corresponding recovery efficiency is 85%.

Taking into consideration that the Swedish Refrigeration Code of Best Practice have been in use since the 80's we strongly claim that these recovery factors have been valid for the entire time series from 1990 onward.

We would also point out that the rate of leakage at decommissioning in Sweden should be corresponding to that of other countries with equally stringent regulations and requirements. One example is the Netherlands, which in its RIVM Report 2016-0055 reports a recovery rate of 95 %.

Thus, we strongly support the continuous use of the existing national factors for stationary refrigeration, air conditioning and heat pump equipment and transport refrigeration in the Swedish Greenhouse gas emission inventory as presented in the table below.

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Swedish emission factors for decommissioning of stationary refrigeration, air conditioning, heat pump equipment and transport refrigeration

	Domestic refrigeration	Heat pumps	Transport refrigeration	All other stationary refrigeration
1990	5%	5%	15%	5%
1991	5%	5%	15%	5%
1992	5%	5%	15%	5%
1993	5%	5%	15%	5%
1994	5%	5%	15%	5%
1995	5%	5%	15%	5%
1996	5%	5%	15%	5%
1997	5%	5%	15%	5%
1998	5%	5%	15%	5%
1999	5%	5%	15%	5%
2000	5%	5%	15%	5%
2001	5%	5%	15%	5%
2002	5%	5%	15%	5%
2003	5%	5%	15%	5%
2004	5%	5%	15%	5%
2005	5%	5%	15%	5%
2006	5%	5%	15%	5%
2007	5%	5%	15%	5%
2008	5%	5%	15%	5%
2009	5%	5%	15%	5%
2010	5%	5%	15%	5%
2011	5%	5%	15%	5%
2012	5%	5%	15%	5%
2013	5%	5%	15%	5%
2014	5%	5%	15%	5%
2015	5%	5%	15%	5%

Best regards,

Per Jonasson
Managing Director
Swedish Refrigeration & Heat Pump Association

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Sveriges Bilåtervinnares Riksförbund
Branschförbund sedan 1961

Recovery of fluorinated greenhouse gases at decommissioning of mobile air-conditioning (MAC) systems in Sweden

The use of ozone depleting substances and fluorinated greenhouse gases for cooling agents is regulated according to Swedish Refrigerants Code of Best Practice. This standard, which was developed in the 1980's and published in 1988, has since seen continuous development. The standard was supplemented by regulations issued by SWEDAC (Sweden's national accreditation body). There are also supplementing fact sheets associated to the Swedish Refrigerants Order.
Swedish Refrigerants Code of Best Practiceis applicable to all types of stationary and mobile refrigeration, air conditioning and heat pump equipment that contain chlorofluorocarbons, HCFCs and HFCs as refrigerants. The standard stipulates responsibilities associated with installation and service as well as responsibilities that lie with the supplier of cooling agents. It also includes general directives on the choice of refrigerants and requirements on design, service, maintenance, operation and decommissioning of equipment.

In addition to Swedish Refrigerants Order, there is also a Swedish regulation on fluorinated greenhouse gases and ozone depleting substances "Förordning om fluorerade växthusgaser och ozonnedbrytande ämnen" (2007:846) that was taken into force 2008-01-01, and the EU regulation on fluorinated greenhouse gases (now 517/2014).

In Sweden, producers and importers of products, such as stationary and mobile refrigeration, air conditioning and heat pump equipment are obliged to reclaim end-of-life equipment. In addition, importer and distributers of refrigerants are required by law to free of charge reclaim recovered amounts of all refrigerant fluids, and provide container for this purpose. Recovered amounts of refrigerants that are not recycled must, by law, be destroyed. No emissions of HFCs are allowed from the destruction/incineration processes.

Sweden has since long had stringent requirements that the installation, service, maintenance and decommissioning only should be performed by certified personnel and businesses. Since 1965 road vehicles in Sweden are annually undergoing maintenance checks. This ensure high technical standard of equipment and vehicle performance. During maintenance checks, if needed, MACs are emptied, the refrigerant fluids reclaimed and filtered, and then refilled into the MACs.

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In Sweden, it is illegal to dump end-of-life vehicles. Instead end-of-life vehicles are recovered and dismantled by SWEDAC accredited companies. Vehicle dismantling companies are obliged by law to drain off and recover all remaining AC fluids. The recovered amounts of HFCs are sent for recycling or destruction to the refrigerant distributing companies. Only SWEDAC accredited companies are allowed to drain off and recover remaining MAC fluids. Hence, only minor amounts of refrigerants are emitted during the recovery processes at the dismantling and disposal sites.
Each year, thousands of car accidents causing complete or partial release of AC refrigerants occurs in Sweden. Many of these vehicles are judged to be too damaged for further use and are sent for decommissioning. There is no national annual statistics available on the number of car accidents leading to decommissioning.

Vehicle dismantling is one of the oldest methods of recycling in Sweden. There are companies that have been dismantling cars since 1920 and are still in the trade. We, the Swedish Car Recyclers Association, "Sveriges Bilåtervinnares Riksförbund", started in 1961 and are a federation of companies in the car dismantling trade. The association´s purpose is to promote beneficial development in the car dismantling trade in Sweden and achieve optimal recycling of raw material and spare parts from cars.

The Swedish Car Recyclers Association makes the judgement that 90 % of fluorinated greenhouse gases are remaining at decommissioning of ACs in cars, trucks and busses in Sweden and that the recovery efficiency on average is at least 85%. This figure includes the AC erupted due to car accidents (contributing to less than ten per cent reduction of the recovery efficiency). Taking into consideration that the Swedish Refrigeration Code of Best Practice have been in use since the 80's we strongly claim that these recovery factors have been valid for the entire time series from 1990 onward.
Thus, we strongly support the continuous use of the existing national factors for ACs in cars, trucks and busses (90% refrigerants remaining at decommissioning and 85% recovery efficiency) in the Swedish Greenhouse gas emission inventory for the entire time series 1990-2014.

Best regards

Michael Abraham
Förbundsdirektör

Stockholm 2016-10-12

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4 Annex 4: CO_2 reference approach and comparison with sectoral approach, and relevant information on the national energy balance

This Annex describes how fuel consumption and CO_2 emissions are estimated in relation to;

- the reference approach, CRT 1Ab (4.1),
- methods and data sources for feedstocks and non-energy use of fuel, CRT 1Ad (4.2),
- the comparison of fuel consumption and CO_2 emission estimations based on the reference approach and the sectoral approach, CRT 1Ac (4.3),
- a detailed analysis of the comparison by fuel group (4.4),
- the structure of the national energy balances (4.5),
- comparison with internationall reportings (4.6) and
- planned improvements related to these areas (4.7).

4.1 Reference approach, CRT 1Ab

The reference approach includes all domestic fuel consumption in Sweden regardless of sector. The reference approach is based on the supply of fuels in line with 2006 IPCC Guidelines, Tier 1. Input data for the reference approach are provided by the Swedish Energy Agency and is consistent with the data delivered for publication in the Eurostat database[164] for years 1990 to 2004. From 2005 and onwards the Swedish Energy Balances are used. The main source is the monthly fuel statistics including supply and delivery of petroleum products, but foreign trade statistics is also used. The reason for not using energy balance data for 1990-2004 is that data for these years are not available. The only exception of the source data is for non-energy use regarding solid fuels, where instead the same data as for CRT 2 in the sectoral approach is used. The reason for this is that the non-energy use variable in the Energy Balances for solid fuels differs too much from the one used in the GHG inventory, leading to a comparison that is not reasonable. Moreover, the non-energy use variable in the Swedish energy balances primarily aims at describing the energy quantities of the portion of product manufacturing raw materials that are not generating emissions.

[164] Eurostat, 2015 http://ec.europa.eu/eurostat/data/database

The differences between reference and sectoral approach have often been large and difficult to explain. Several studies have been made in order to solve the problems[165]. Since submission 2016 a developing project has been ongoing in order to reconcile the differences between the reference and sectoral approach. The focus on these projects have been on fuel type level and in depth investigations on discrepancies between the two data sources. The main findings have been found within the fuel groups Liquid and Solid Fuels[166]. The discrepancies within liquid and solid fuels have been reduced as a result of investigating using non-energy use data from the Swedish energy balance as well as from the IPPU (CRT 2) sector.

In CRT Table 1Ab, fuel quantities are presented in TJ. In the input data the fuels are in several cases (e.g. gas/diesel oil and other oil) on a lower aggregate level than in the CRT tables. In these cases, the conversion factors are implied NVCs resulting from dividing the TJ with the quantity of fuel type, i.e. a weighted average. For those fuels only available in TJ and 1000 toe (e.g. natural gas and biomass), the reporting units in the CRT tables are also in TJ and toe. Hence, the conversion factor is set to 1 and 41.68 respectively for these fuels. The conversion factors used in submission 2024 are found in table A.4.1.

The NCV values used in submission 2024 are described in Annex 2 for both stationary and transport combustion. Diesel NCV in Table 1D and in 1Ab is 35.28 TJ/m^3. The NCV values for Residual Fuel Oil are the same in Table 1D and 1Ab, 39.53 TJ/m^3. However, the NCV used in stationary combustion in SA (Tables 1AA1, 1AA2 and 1AA4) is a bit lower; 38.34 TJ/m^3.

[165] Gustafsson, 2007a, Hedlund and Lidén, 2010, Andersson, Eklund, Gerner & Gustafsson, 2012, Gerner, Andersson & Gustafsson, 2013

[166] Viklund, L., Gerner, A., Ortiz, C., Gustafsson, T. 2016. Skillnader mellan reference approach och sectoral approach i den nationella växthusgasinventeringen. SMED report No 2016: 202

Table A4.1. Conversion factors used in submission 2024 for emission year 2022

Fuel Type	Converstion Factor (TJ/Unit)
Bitumen	41.87
Coke Oven/Gas Coke	28.05
Coking Coal	27.21
Crude Oil	36.26
Ethane	50.40
Gas Biomass	41.87
Gas/Diesel Oil	35.87
Gasoline	32.78
Jet Kerosene	35.28
LPG	46.05
Lignite	8.50
Liquid Biomass	41.87
Lubricants	44.13
Natural Gas	39.60
Naphtha	32.78
Natural Gas	39.60
Other Oil	29.13
Other non-fossil fuels (biogenic waste)	41.87
Peat	41.87
Petroleum Coke	34.80
Refinery Feedstocks	36.26
Residual Fuel Oil	39.53
Solid Biomass	41.87
Waste (non-biomass fraction)	41.87

Emission factors used in the reference approach are the same as those used in the sectoral approach, multiplied by 12/44 to convert the emission factor for CO_2 to an emission factor for carbon (C). In those cases where the fuels are shown on a less aggregated level in the input data, the emission factors are as the NCVs implied emission factors per fuel type (weighted averages).

The emission factors used in the sectoral approach already take into account that some part of the carbon remains unoxidized. This is the reason why the parameter “fraction of carbon oxidized” is set to 1.00. For crude oil, bitumen, lubricants and refinery feedstocks, which are not reported in the sectoral approach, the emission factors used are default values from 2006 IPCC Guidelines.

The parameter "Carbon excluded" for each fuel is calculated as

$$C_{excl} = FC_{ne-use} * NCV * EF_c$$

where C_{excl}= excluded carbon in tonne, $FC_{ne\text{-}use}$ = fuel consumption for non-energy purposes in physical unit, NCV=net calorific value and EF_C= emission factor as tonne C per TJ fuel. The values reported are the same as reported in CRT 1Ad (feedstocks and non-energy use).

4.2 Feedstocks and non-energy use of fuels, CRT 1Ab, 1Ac and 1Ad

Activity data for 1990-2022 on feedstocks and non-energy use of fuels in CRT 1Ad is consistent with the data reported in the Energy balances for fuel types LPG and Natural Gas, whereas all other non-energy fuels are consistent with data reported under the IPPU sector in the GHG inventory.

Carbon emission factors and carbon excluded are the same as reported in CRT 1Ab when it does not occur in IPPU. If occurring in IPPU then carbon excluded is consistent with the carbon excluded in IPPU (Table 1Ad). CO_2 from non-energy use reported in the sectoral approach in other categories than CRT 1A includes emissions from fuels used in industrial processes (CRT 2), petroleum coke burned in catalytic crackers (all CRT 1B).

Table A4.2. Comparison of NEU in table 1Ab and 1Ad for 2022

Fuel Type	Carbon stored 1Ab (kt CO_2)	Carbon excluded 1Ad (kt CO_2)	TJ Carbon stored 1Ab	TJ Carbon excluded 1Ad	% Difference C stored/Excluded	% Difference TJ
Bitumen	428	428	19448	20185	0%	-4%
Coke Oven/Gas Coke	808	808	27713	46848	0%	-41%
Ethane	505	505	31719	31718	0%	0%
LPG	265	0	14981	14981	100%	0%
Lubricants	287	287	17551	14360	0%	22%
Naphtha	237	237	12105	11890	0%	2%
Natural Gas	68	68	6996	4464	0%	57%
Other Bituminous Coal	99	99	3304	3269	0%	1%
Other Oil	0.3	0.3	13	15	0%	-13%
Petroleum Coke	6	6	0	0	100%	0%

The NEU in TJ is significantly different between CRT 1Ad and 1Ab for the fuel types Coke Oven/Gas Coke, Lubricants and Naphtha. The reason for this is that different data sources are used in 1Ad and 1Ab for these fuels.

4.2.1 Revisions of Non-energy use

In submission 2024 the NEU reported in IPPU was revised. The following changes were made:

- Change in calorific values from constant to annually updated for 13 facilities.
- Activity data for one facility, previously reported as coke, now divided between petroleum coke and coke.
- Activity data from the Swedish Chemicals Agency is only available with a one-year-delay. Affects data for lubricants and paraffin waxes.

4.3 Comparison of the reference approach and the sectoral approach, CRT 1Ac

In order to follow the 2006 IPCC Guidelines and ensure that no emissions or double counting occurs, it is necessary to compare the results in the sectoral approach (calculated bottom-up) with the results in the reference approach (calculated top-down). Large differences indicate possible errors, and according to the UNFCCC reporting guidelines, differences should be investigated if they are larger than ± 2%.

Figure A4.1 shows the differences in fuel consumption and CO_2 emissions between the reference approach and the sectoral approach between 1990-2022 (as reported in CRT 1Ac). Fuel consumption and CO_2 emissions from the reference approach differ with more than 2% from the sectoral approach for most years. However, the energy consumption and emissions in reference approach is mostly lower than the sectoral approach. The total difference between RA and SA for submission year 2022 is -7 % for fuel consumption and -7 % for CO_2 emissions.

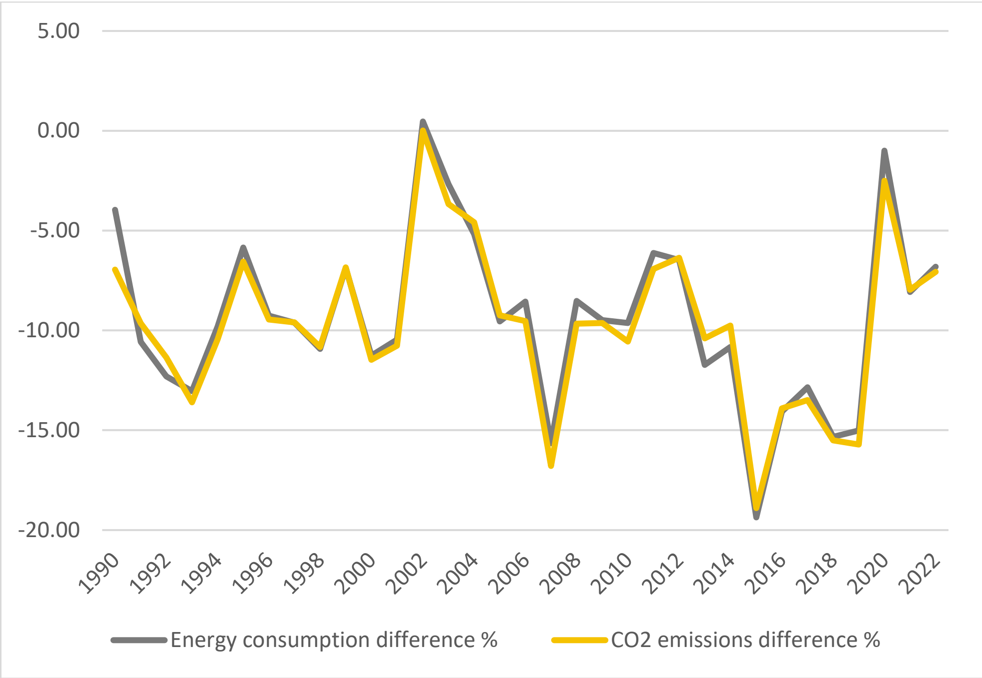

Figure A4.1. Difference (RA-SA) as the share (%) of SA, all fossil fuels (CRT 1Ac).

Table A4.3. Fuel consumption all fuel types (including biomass) comparison between the consumption side of the Energy balance with SA for 2022 for industry, transport and other sector (excluding electricity and heat production, 1A1a)

	EB Final consumption (PJ)	CRT SA (PJ)	Difference (%)	Comment
Industry	*320*	*332*	*-4*	*1a2 Excluding construction in EB*
Construction	*9*	*-*	*-*	*1a2. Construction is included in 1a2 in CRT-tables*
Ind+ Constr	330	332	-1	1a2. Working machinery is allocated to transports in EB but in industry in CRT
Transport	258	264	-2	1a3
Other	79	79	0.0	1a4
Total	679	683	-1.2	

The energy consumption of the industry (CRT 1A2), transport (CRT 1A3) and other sector (CRT 1A4) is thus comparable with the final consumption from the Energy balance. Hence, no large systematic differences in SA on an overall scale are apparent for the sub-sectors included in the table. Below, analyses of the differences due to differences between supply and consumption statistics in the energy balances and the use of different data source between RA and SA are presented.

4.4 Analyses of differences

In the following analysis, the reference approach is compared with the "real" sums for each fuel group from the sectoral approach in order to improve the transparency and show the "real" differences.

4.4.1 Liquid fuels

Due to a methodological change in 2018, residual fuel oil and gas/diesel oil consumption was updated. In contrast to the GHG inventory, the data supplier of the Swedish Energy Balance did not revise the whole time-series of gas/diesel oil consumption backwards due to less strict requirements regarding time-series consistency for Energy Balances. This results in larger differences in the RA and SA for the years 1990-2018.

For liquid fuels, the 1990-2022 time series difference fluctuates considerably. For the years 1990-2001, the fuel consumption for RA is lower than SA, but for the latter part of the time series, fuel consumption for RA tends to exceed SA for some years. After 2015, the RA is again lower than SA. The inter-annual fluctuations are however still relatively large (Figure A4.2).

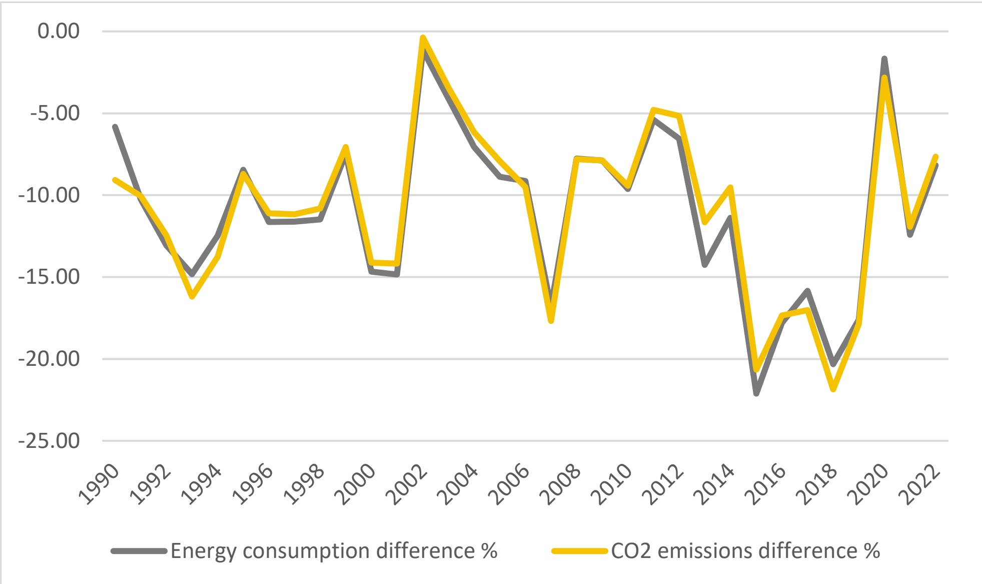

Figure A4.2 Difference (RA-SA) as percent of (SA). Liquid fuels.

4.4.1.1 ANALYSIS OF IMPLIED EMISSION FACTORS

As described in sections 2.3.2.2, emission factors for refinery gas and by-products in the petrochemical industry have gradually decreased in recent years based on information from facilities. This indicates that more carbon is stored in the produced fuels and other products, and less carbon remains in the by-products that are combusted on site and reported in CRT 1A(a) (e.g. refinery gas). In the reference approach, IPCC default emission factors are used for crude oil and refinery feedstocks.

Refinery gas combusted at refineries, which is reported in CRT 1A1b in the sectoral approach, is shown as consumption for non-energy purposes in the energy balance. After correction for this, the relative difference is lower for most years Figure A4.3).

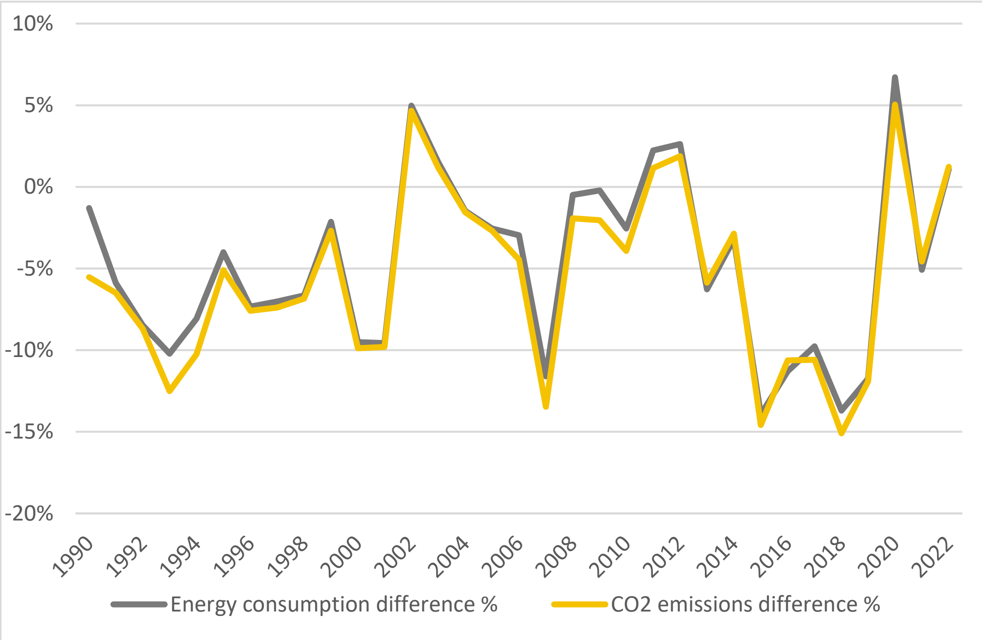

Figure A4.3. Difference between RA and SA for liquid fuel consumption and CO_2 emissions after correcting for refinery gas combusted in SA 1Ab.

It should be noted that the CO2 emissions from combustion of refinery gas reported in CRT 1A1b are the emissions reported to ETS. These emissions are calculated by the facilities based on measurement of carbon content in the gas. Hence, the emissions reported in the inventory are accurate, but the energy content may be less certain.

In Table A4.4, the CO_2 implied emission factors (IEF) for the most common liquid fuels 1990, 1995, 2000, 2005-2022 are presented. The difference expressed as CO_2 emissions is for the most part larger than the difference expressed as fuel consumption (FC), which indicates a divergence in the emission factors in those years. The SA IEF show a slight variation over the years compared with the RA IEF due to a lower share of consumption of fuels with high emission factors. The emission factors for refinery gas are implicit in later years when data is taken from the EU ETS database. The CO_2 emissions are considered to be accurate, but the calorific values are considered to be quite uncertain.

Table A4.4. Implied CO_2 emission factors for reference and sectoral approach in submission 2024.

Year	Residual Fuel Oil (SA)	Domestic Heating Oil (SA)	Diesel Oil (SA)	Gasoline (SA)	Jet Kerosene (SA)	LPG (SA)	Refinery gas (SA)	Methane etc (SA)	Fossil Part of Biofuels	CO_2 IEF SA	CO_2 IEF RA
1990	76.51	74.22	74.26	72	71.5	65.1	59.3	55		72.73	73.26
1995	76.59	74.21	72.68	72	71.5	65.1	59.3	55		72.57	73.12
2000	76.83	74.2	72.2	72	71.5	65.1	59.3	53.37	75.6	72.25	73.28
2005	76.97	74.17	72.2	72	71.5	65.04	59.3	52.7	75.6	72.30	73.16
2010	77.11	74.13	72.2	72	71.5	65.1	56.19	49.74	75.6	71.98	73.20
2015	76.84	73.91	72.2	72	71.5	65.14	52.47	57.28	75.59	71.11	73.11
2016	77.32	73.93	72.2	72	71.5	65.12	74.13	62.08	75.58	72.92	73.14
2017	77.44	73.9	72.2	72	71.5	65.12	77.29	61.74	75.22	73.15	73.17
2018	77.15	73.94	72.2	72	71.5	65.11	75.02	61.81	75.29	72.94	73.20
2019	77.49	73.91	72.2	72	71.5	65.14	73.46	58.55	75.53	72.95	72.90
2020	77.43	73.87	72.2	72	71.5	65.11	68.04	49.42	75.29	72.75	73.30
2021	77.41	73.92	72.2	72	71.5	65.15	72.5	46.73	75.26	72.90	73.04
2022	77.38	73.87	72.2	72	71.5	65.12	69.41	47.21	77.38	72.54	72.845

4.4.1.2 DIFFERENCES BETWEEN RA-SA AND THE STATISTICAL DIFFERNCE IN THE ENERGY BALANCE

The differences between RA and SA since 2005 are often smaller than the statistical difference for liquid fuels in energy amounts of PJ (Figure A4.4). The statistical difference is not included in the apparent consumption since it is a figure that shall balance the whole energy balance in cases of over- or underestimates of the delivery or the consumption side. It is however not possible to know if the over or under estimation is on the delivery or the consumption side. These statistical differences of liquid fuels in the energy balance, affect the comparison, especially since they are larger than the estimated difference between RA and SA.

When the statistical difference is positive, the delivery side is larger than the consumption side, and when it is negative the delivery side is lower than the consumption side in the energy balance. The statistical difference varies over time with both positive and negative statistical differences. Due to this, the comparison of liquid fuels is difficult to explain because the delivery side for liquid fuels in the energy balance has its own statistical difference that is larger than the estimated differences between RA and SA. So, for this case the comparison is not possible, and should rather be compared to the final consumption, which was made for all fuels in former section.

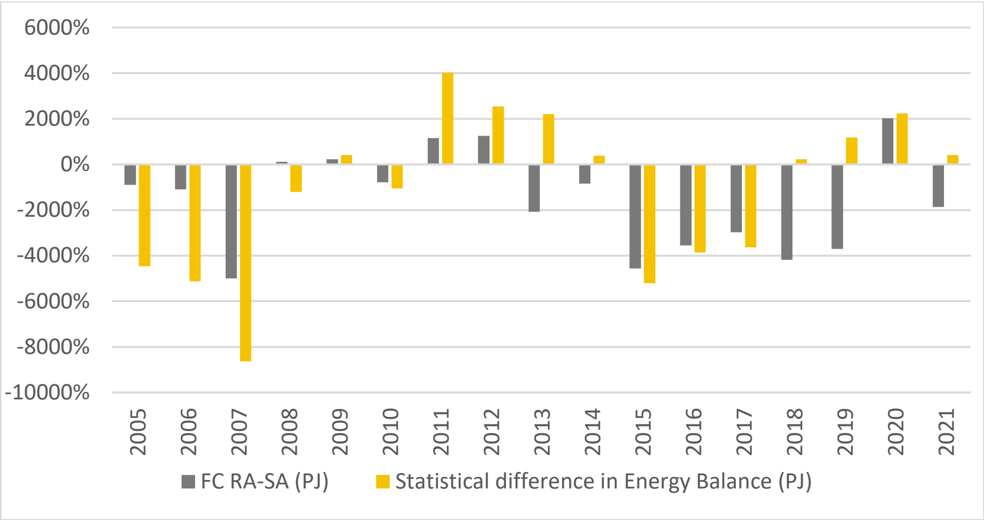

Figure A4.4. Comparison of the differences between RA and SA with the statistical differences in the EB for Liquid fuels between 2005 and 2022.

4.4.2 Solid fuels

Differences in fuel consumption (FC) and CO_2 emissions between reference and sectoral approach (as reported in CRT 1Ac) for solid fuels 1990-2022 are presented in Figure A4.5. The differences in fuel consumption and CO_2 emissions from solid fuels vary between the years. The fuel consumption varies more than the emission for some years. The significant gaps are mainly due to the use of different data sources and thus different scopes and methodologies in the RA compared to the SA.

In submission 2024, the NEU for solid fuels in IPPU was used for estimate of carbon excluded and apparent consumption in RA. The solid fuel activity data used for NEU was retrieved from the facilities' own environmental reports. In submission 2024, the IEFs vary between 77 and 103 kg CO_2/TJ.

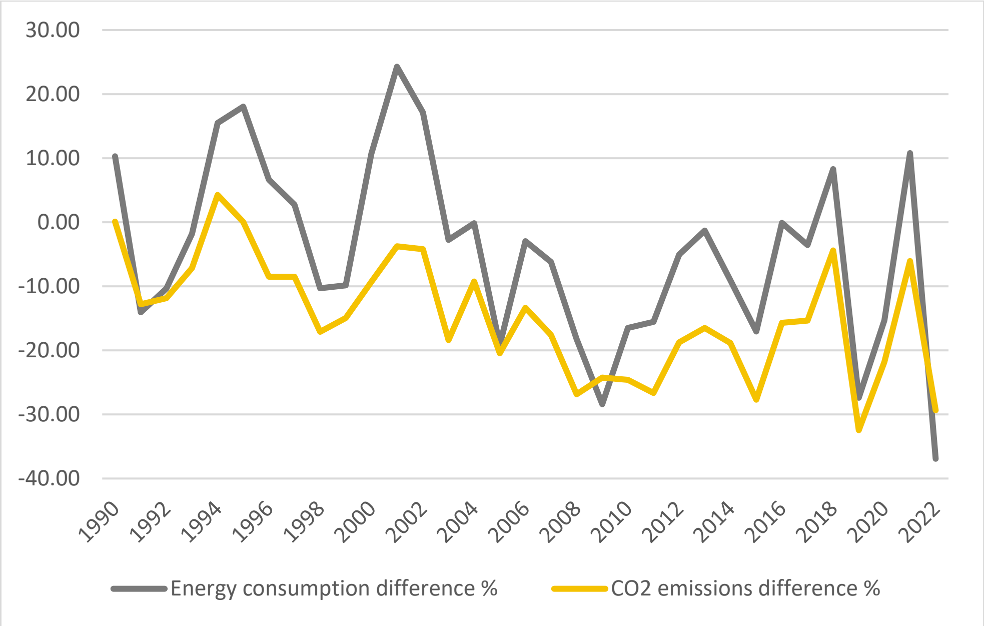

Figure A4.5 Fuel consumption (FC) and CO_2 emissions for Solid fuels: Difference RA-SA expressed as percent of SA.

In emission year 2022, the relative difference between RA and SA is -29% for CO_2 emissions while the difference in fuel consumption is -36%. The reason for this deviance is due to large stock changes and export reported in the Energy balances, used for RA.

The energy balance's rows of delivery are problematic to use as comparison with SA due to differences between delivery and consumption, shown in the large and highly variable statistical differences. In Table A4.5, a compensation for the statistical differences of solid fuels in the Energy balance was taken into account, which resulted in lower differences in the energy consumption estimated in RA compared to the one in SA.

Table A4.5. Relative difference for Solid fuels between RA and SA after correction of statistical differences in Energy balance between 2005 and 2022.

Year	App Cons RA (PJ)	App Cons SA (PJ)	Relative difference %	Statistical difference in EB (PJ)	App Cons RA after statistical difference in EB (PJ)	Relative difference after statistical differnce in EB (%)
2005	37.0	45.8	-19.19	-8.6	45.6	0%
2006	45.7	47.0	-2.95	-6.8	52.5	12%
2007	38.5	41.1	-6.21	-9.1	47.6	16%
2008	31.3	38.3	-18.23	-13.9	45.2	18%
2009	21.4	29.9	-28.40	-2.6	24.1	-20%
2010	32.9	39.5	-16.50	-6.8	39.7	1%
2011	32.3	38.2	-15.55	-1.9	34.2	-10%
2012	34.4	36.3	-5.05	1.2	33.2	-8%
2013	37.2	37.7	-1.31	-0.2	37.4	-1%
2014	30.8	33.9	-9.05	0.3	30.5	-10%
2015	28.3	34.2	-17.04	-0.9	29.2	-14%
2016	30.9	30.9	-0.12	5.0	25.9	-16%
2017	32.3	33.5	-3.54	1.1	31.2	-7%
2018	35.2	32.5	8.28	8.4	26.8	-18%
2019	19.8	27.2	-27.42	-2.0	21.8	-20%
2020	20.6	24.3	-15.32	2.0	18.6	-23%
2021	25.2	22.8	10.81	2.3	22.9	1%
2022	14.3	22.7	-36.92	-4.0	18.3	-19%

For reference approach, trade statistics from the energy balance is the main data source for import, export and stock change. For the sectoral approach, various data sources are used. These sources are energy surveys as described in Annex 2, but also other sources such as environmental reports, data from EU-ETS and other information gathered directly from the facilities. These other sources are mainly used for CRT 2 and 1B, but also for CRT 1A1c and 1A2a for the largest primary iron and steel works as described in NIR Section 3 and 4. The use of other data sources than energy balance data derives from the need to estimate as accurate GHG emissions as possible. This need causes divergences between RA and SA as carbon flows in RA data are allocated differently than in the SA data, especially regarding stock changes.

In the sectoral approach, detailed data on solid fuels from different sources are collected and compiled. As Sweden uses large quantities of solid fuels in integrated iron and steel production industries, it is important to keep track of carbon flows. As described in NIR section 4.4.1.2 and Annex 3:4 detailed data on plant station level is available from the companies and used in the SA to allocate energy and CO_2 emissions in different CRT categories. The allocation model differs from the results of the survey statistics used in the RA and CRT 1Ad. Data on allocation of energy and CO_2 from solid fuels in the integrated iron and steel works, sectoral approach, is presented in Table A4.3.

In Sweden, large quantities of primary fuels (mainly coking coal and other bituminous coal) are transformed into secondary (e.g. coke) and tertiary fuels (e.g.

coke oven gas and blast furnace gas) or used as reduction agents in the transformation process. During the iron and steel making process large amounts of energy is transformed from the solid fuels into heat. Some of this heat is used for energy recovery, but the heat losses are significant. In line with the 2006 IPCC Guidelines, to avoid double counting of energy and CO_2 emissions, quantities of produced secondary and tertiary fuels are not reported in the RA. Quantities of fuels used for non-energy purposes and feedstocks are reported as ‘carbon excluded’ in CRT 1Ab and deducted from ‘apparent consumption’ in CRT 1Ac. This is in accordance with the 2006 IPCC guidelines and enables comparison with SA data derived from CRT 1AA and reported in CRT 1Ac.

Sweden is continuously making efforts to improve solid fuels discrepancies through cooperation with the Swedish Energy Agency and the steelworks operators in particular. In order to resolve the remaining differences, the collaboration project between the Swedish EPA, Swedish Energy Agency, Statistics Sweden and SMED was initiated. Sweden has during the past years tried to harmonise and understand the differences between the two AD sets to find ways to decrease the differences and report a more transparent comparison. However, despite the efforts and a decrease in percentual difference, the comparison remains with large differences between RA and SA due to that there has not been any ways in harmonising the two AD sets and still fit their origin purpose. That is why we now will focus in explaining why the comparison between RA and SA for the integrated iron and steel sector has these problems and instead expand the method of comparison by using the whole energy balance (not only the delivery side) to show that the SA estimates are in line with the RA.

4.4.3 Gaseous fuels

The differences for gaseous fuels are mostly around 2% but larger some years, especially for the years 2005, 2015, 2017 and 2022 (Table A4.6). For the RA, gaseous fuels for non-energy use and feedstocks were not reported separately from apparent consumption. Natural gas has been used for non-energy use and feedstocks since 2004 in the GHG inventory, which is reflected in the sectoral approach[167]. The differences occurring 2022 has several potential reasons. We can confirm that the final consumption value in the Energy Balances matches with the fuel consumption in the sectoral approach. Unfortunately, these values are confidential therefore not possible to publish here. In the Non-energy use we have seen differences between the IPPU sector and the Non-energy use for the energy balances. This is partly caused by different emission factors used partly because different data reported in the Energy Balances, EU ETS and in the Environmental reports. We are already in contact with some of the facilities and planning to investigate the differences.

[167] Ortiz, C., Jonsson, M., Yaramenka, K., Helbig, T. 2017.

Table A4.6. Energy from gaseous fuels in RA and SA.

Year	PJ, RA	PJ, SA	difference PJ(RA)-PJ(SA)	difference,%
1990	24.4	24.2	-0.3	-1.20
1995	32.5	31.6	-0.9	-2.79
2000	32.0	32.5	0.5	1.47
2005	28.2	32.6	4.4	15.80
2010	55.7	57.1	1.4	2.46
2015	30.0	32.3	2.3	7.70
2016	34.4	35.2	0.8	2.20
2017	26.7	24.1	-2.6	-9.65
2018	27.9	26.9	-1.1	-3.81
2019	26.1	27.3	1.2	4.53
2020	22.8	23.4	0.6	2.44
2021	28.5	30.7	2.3	7.93
2022	28	20.88	7.1	34.11

4.4.4 Other fossil fuels

This category includes the fossil fraction of municipal waste, industrial waste and any non-specified fuels that cannot be classified as purely solid, liquid, gaseous or biomass. The emission factors used in sectoral approach vary the very last years due to the fact that Sweden collects plant specific emission factors some of the waste incineration plants (Table A4.7). The other plants in SA then apply the same emission factor as the average of these plants the year before. This is because Sweden started to use plant specific emission factors for plants that measure the biogenic carbon content in the flue gases and reports emissions annually to EU-ETS in 2015. The emission factor for RA is still 94.3 for all years, pending investigation.

Table A4.7. Emission factors for other fossil fuels (municipal waste and non-specified fossil fuels) in RA and SA.

Year	Municipal waste RA	Municipal waste SA (8 largest plants)	Municipal waste SA (Other plants)	Non specified fossil fuels SA and RA
1990	94.3	94.3	94.3	30
2015	94.3	94.9	94.3	30
2016	94.3	94.15	94.9	30
2017	94.3	95.93	94.15	30
2018	94.3	96.11	95.93	30
2019	94.3	97.42	96.11	30
2020	94.3	97.37	97.42	30
2021	94.3	97.37	97.37	30
2022	94.3	93.80	93.54	30

In the sectoral approach, fossil municipal waste accounts for 42-77% of the fuels reported as “other fossil fuels”. In the RA, this share is close to 100% in the years 1990-98 and 86-97% in more recent years. This explains the fact that the aggregate IEF for “other fossil fuels” is systematically higher in RA than in SA although the same emission factors are applied for the individual fuels.

In the Swedish energy surveys, “municipal waste” is one single fuel including both the fossil and the biogenic fraction. In the sectoral approach, 36% is allocated to other fossil fuels and 64% to biomass (see Annex 2). An analysis of the RA data indicates that in 1990-2004, the proportions were 40% biogenic and 60% fossil. From 2004 and onwards, the relation is reversed and 60% is biogenic and 40% fossil. This explains the shift in the time series when RA and SA are compared.

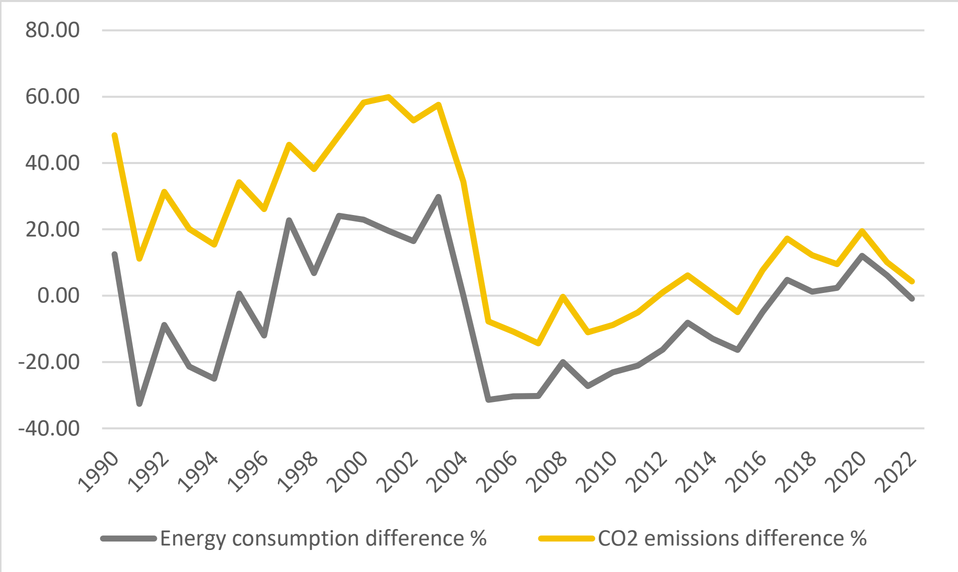

Figure A4.6 Difference in Other fossil fuels, RA-SA as percent of SA. Fuel consumption (FC) and CO_2 emissions.

When the sums of biogenic and fossil municipal waste according to RA and SA are compared, the differences are fluctuating and not systematic. The amounts of other fossil fuels, however, are systematically much higher in the sectoral approach. This indicates allocation differences, possibly both regarding waste/other fossil fuels and other fossil fuels/solid fuels. The amounts of waste (biogenic and fossil) and other fossil fuels are shown in Figure A4.7.

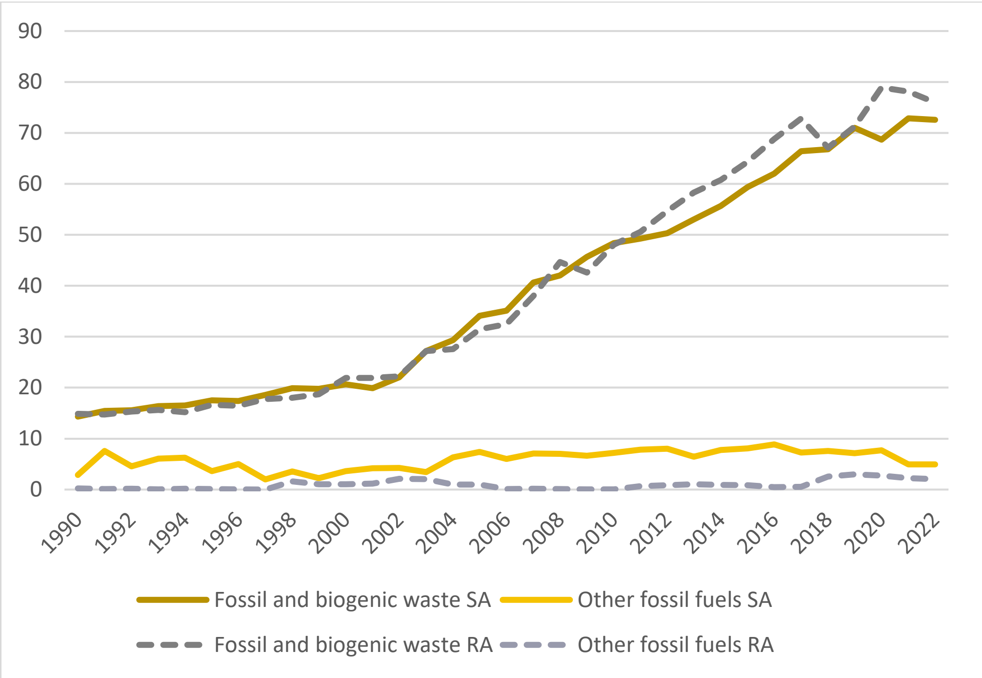

Figure A4.7 Consumption of waste and other fossil fuels, RA and SA.

When fossil waste and other non-specified fossil fuels are aggregated, the fuel consumption is slightly higher in the sectoral approach (Table A4.8), except for the latest two years where it is slightly lower.

Table A4.8. Aggregate consumption of fossil waste and other fossil fuels, RA and SA.

Year	PJ, RA	PJ, SA	difference PJ(RA)-PJ(SA)	difference,%
1990	9.0	8.0	1.0	12%
1995	10.0	9.9	0.1	1%
2000	13.6	11.0	2.5	23%
2005	13.5	19.7	-6.2	-31%
2010	19.3	25.0	-5.8	-23%
2015	26.2	31.4	-5.1	-16%
2016	33.3	35.1	-1.7	-5%
2017	35.3	33.7	1.6	5%
2018	34.4	34.0	0.4	1%
2019	36.9	36	0.9	2%
2020	40.3	36	4.3	12%
2021	39.4	37.1	2.2	6%
2022	38.3	38.7	0.4	1

4.4.5 Peat

Peat is sparsely used in Sweden and accounts for around 2% of the fossil fuel consumption. The RA/SA-differences are fluctuating and small in absolute numbers (3.3 PJ at the most but typically around 1 PJ or less). The differences are mainly due to the use of different NCVs in RA compared to SA. The calorific values for peat are quite variable due to variations in moisture content and the fact that briquettes and raw peat are reported together. In the quarterly fuel survey, peat is mostly reported in the unit tonne and the calorific values are also reported. These NCVs used in the sectoral approach are considered to be accurate. In the years 2007-2020, the annual average NCV for peat reported in tonnes varies between around 10.5 GJ/tonne to around 11.1 GJ/tonne in 2008, a relative difference of 9%. In the reference approach data, the activity data was delivered in toe which means that the NCV for peat is not available.

4.5 National energy balance

As stated above, the input activity data for reference approach is based on the reported energy balances to Eurostat between years 1990 and 2004 and from 2005 from the Energy Balances. Minor differences occur due to the early time plan for the GHG inventory which means that the energy balance has not yet been compiled when activity data is delivered to the GHG inventory staff. The information in this section is taken from Statistics Sweden. Tables referred to can be found at the Statistics Sweden website[168].

The purpose of energy balances is to give a brief description of supply, transformation and final consumption of energy for follow-up and analysis of Sweden's maintenance of energy.

Before the oil crisis in 1973, the main purpose of the energy statistics was to account for the supply of specific types of energy. Due to the oil crisis the need to relate the oil problems to energy issues in general increased, as well as the interest in more extensive information about energy consumption. For that reason, energy balance models were developed both nationally and internationally with the purpose to describe the entire flow of energy for different energy carriers, from extraction and import through transformation to export or domestic consumption. Principles for the presentation of Swedish energy balances were compiled by Statistics Sweden in cooperation with the Swedish Energy authority and the Council of Transport (that was later closed down). In the official statistics, quarterly energy balances with relatively brief accounts for the energy consumption side have been published since 1975. Yearly energy balances with a more detailed and thoroughly account for the energy consumption side have been compiled since 1987, with time series back to 1983.

4.5.1 Balance sheets of energy sources

The balance sheets of energy sources are showing the total supply and consumption of energy sources expressed in original units, i.e., units recorded in the primary statistics – mainly commercial units. The production of derived energy commodities is recorded on the supply – side of the balance sheets of energy sources, which is not the case in the energy balance sheets. The balance sheets of energy sources also include specifications of input–output and energy consumption in energy conversion industries. Since 2005 the balance sheets of energy sources are published at the website of Swedish Energy Agency in the Statistical database.

4.5.2 Energy balance sheets

The energy balance sheets are based on data primary recorded in the balance sheets of energy sources, here expressed in a common energy unit, TJ (terajoule). The production of derived energy is here recorded in a second flow-step comprising

[168] EN 20 SM series http://www.scb.se/EN0202

energy turnover in energy conversion and is also specified in complementary input-output tables for energy conversion industries. Since 2005 the Energy balance sheets are published at the website of Swedish Energy Agency in the Statistical database.

The following items are shown in the energy balance sheets:

Delivery side:
1 Gross consumption of primary energy and equivalents
1.1 Inland supply of primary energy
1.2 Gross production by energy conversion industries
1.3 Import
1.4 Export
1.5 Bunkering for foreign shipping
1.6 Changes in stocks
2 Statistical differences (supply-level)

Consumption side:
3 Total consumption
3.1 Transformation inputs
3.2 Input for conversion into derivative energy forms (sources)
3.3 Consumption by energy producing industries
3.4 Losses in transport and distribution
3.5 Consumption for non-energy purposes
3.6 Final inland consumption
3.6.1 Industry statistics' level
3.6.2 Construction
3.6.3 Transport
3.6.4 Other (non-specified)

Gross consumption of primary energy and equivalents (1) is calculated from the following items: Inland supply (1.1), Import (1.3), Export (1.4) Changes in stocks (1.6) and Statistical differences (2). The gross consumption is calculated as (1) = (1.1) + (1.3) – (1.4) – (1.5) – 1.6).
Concerning biofuels, peat and waste etc., the total consumption for energy purpose is recorded as inland supply of primary energy.

Bunker fuel for international navigation is fuel used by both Swedish and foreign ships with final destination outside the Swedish territory. Bunker fuels for aviation are not reported in the Swedish energy balances, i.e. all aviation fuels are aggregated with some other fuels and reported as domestic consumption.

Statistical differences (2) between total consumption measured from supply-side and actual consumption statistics.

Input for conversion into derivative energy (3.2) covers the input of crude oil and other feed stocks in refineries, coal for conversion to coke and coke-oven gas in coke-oven plants, the estimated net quantity of coke that is converted into blast furnace gas (100 per cent efficiency in the conversion is assumed), electricity for pumping in pumping stations, the fuel consumption in conventional thermal power plants, heating (or heat-electric) plants and gasworks, consumption of fuels for production of electric energy in industrial back pressure power stations and consumed nuclear fuel and utilised primary hydro power in nuclear power plants respectively hydro-electric power plants.

Transformation inputs (3.1) are flows which occurs when petroleum products are reclassified. A product might after several treatments get other properties and is thus classified as another product. Examples are when products mix or a product like Naphtha is converted into other oils, re-flows of products in refineries.

Production of derivative energy (3.2). The production is calculated gross, i.e., including own consumption and losses in transmission and distribution.

Consumption by energy producing industries (3.3) covers the consumption of electric energy, fuel oils, gases etc. for the operation of power stations, thermal power plants, refineries, coke-oven plants and gasworks (1990-2010).

Losses in transport and distribution (3.4) covers losses in deliveries of electric energy, gas work gas, coke-oven gas, blast-furnace gas and district heating.

Consumption for non-energy purposes (3.5) covers products that are used as input in chemical industries as raw material as well as other non-energy purposes.

Final inland consumption (3.6) covers all consumption not covered by titles 1–8.

The efficiency of the final consumption in not considered in the balance sheets. The quantities (recalculated to terajoules= 10^{12} joules) as recorded under final consumption refer to the total energy actually consumed by the consumers including conversion losses.

4.5.3 Main results from developing projects to decrease differences between RA and SA

During submission 2024, the development projects with the aim to reduce the differences between RA and SA were not prioritized. However, continued efforts are planned to investigate the reasons behind the large differences in gaseous fuels and solid fuels and hopefully increase the comparability, and with the priority to improve the description of the differences in the future.

4.6 Comparison with international data

4.6.1.1 RA COMPARISON IN IMPLEMENTING REGULATION ARTICLE 12: REPORTING ON CONSISTENCY WITH ENERGY DATA

Each year, Sweden fills in a comparison of the energy consumption reported in the RA of the GHG-inventory with Sweden's reported energy consumption to Eurostat to EU in the annex Implementing Regulation Article 12: Reporting on consistency with energy data. The data forming the reporting to Eurostat is the same as the one to the International Energy Agency (IEA). The Swedish Energy Agency is responsible for reporting to Eurostat and to the IEA. Since the RA energy consumption AD is from the Energy Balances, which also forms large parts of the other international reportings, small differences between the reportings are expected. However, the reportings have different methods for quantifying consumption of some fuels and in some cases the Swedish Energy Agency uses other national statistics in the international reportings.

Some of the largest difference between the RA och the GHG reporting and the reporting to Eurostat are in submission 2024:

- Jet Kerosene: International bunkers are deducted from apparent consumption in GHG inventory according to IPCC guidelines, but not in Eurostat according to their definition of apparent consumption. Differences in the fraction of international flights and in stock changes between the data sources. In addition, in GHG inventory other Kerosene is included here due to aggregations in data source.
- Gas/diesel oil: There are differences between import/export and country divided import/export.
- Bitumen: Import and export are from different sources. In the GHG inventory, the data is from foreign statistics and for Eurostat the monthly survey.
- Ethane, Naphtha, Lubricants, Refinery Feedstocks and Other Oil: Differences in NCV.
- Petroleum Coke: Import and export are from different sources. In the GHG inventory the data is from foreign statistics and for Eurostat the monthly survey. Petroleum Coke import and export is not reported in the monthly survey.
- Coking Coal: Other bituminous coal is included in Coking coal in GHG inventory. Difference including bituminous coal in Eurostat delivery result in 6% which in turn are due to different NCVs.
- Coke oven/Gas coke: Differences in stock changes from the data sources. The Energy Balances (GHG inventory) uses beside the monthly statistics, Quaternary statistics and for the Eurostat only the monthly statistics is used for the iron and steel works.
- Natural gas: Differences in NCV. GHG inventory AC is made with NCV while in the reporting to Eurostat is in GCV.

- Waste (non-biomass fraction): Diverse sources in GHG and Eurostat reporting. In GHG inventory data comes from a more detailed statistical product (Annual statistics on energy use in manufacturing industry-ISEN) than for the Eurostat reporting (Quaternary Energy Statistics). More fractions of waste are included in ISEN.
- Peat: In the GHG inventory the value of peat is the total in flow including the net import. The import is not reported in the Energy Balances while it is reported to Eurostat.

4.6.1.2 DISCREPANCIES BETWEEN SA, RA AND INTERNATIONAL REPORTING FOUND IN LAST SUBMISSIONS (2020 - 2022)

During submission 2022, there were no new questions or issues addressed by international reviewers regarding discrepancies between SA, RA and international reporting. However, the issues from submission 2020 are still valid and therefore explanations from then are still included in this submission.

4.6.1.2.1 Natural Gas

During the EU review of Sweden’s submission 2020 and 2021, it was noted that there may be an over/underestimate of emissions when comparing Natural gas (NG) energy consumptions reported in the GHG inventory SA and Eurostat NG energy consumptions of Gaseous fuels at 1A level for 2005, 2016, 2017, and 2019.

The explanation is the use of Liquified Natural Gas (LNG) in Swedish refineries and some petrochemical facilities that produces hydrogen production (reported in 1B2A1, CRT: 1B2a). The production increases since 2016 due to that one refinery increased its production of hydrogen gas. In 2017, there is a significant increase of this production due to that a second refinery started to produce the gas. We found that one refinery that uses LNG for hydrogen production was not included in the NEU (this is however revised and included in submission 2021, see section in Appendix 4.2.1 Revisions of Non-energy use). The energy consumption of LNG for hydrogen production was for this facility 114 200 ton (ca 5400 TJ). With this amount, the discrepancies are lower. For 2017 the amounts of LNG for hydrogen production were estimated to 115 600 ton (5 700 TJ). These emissions are reported in CRT 1B2A1, where AD is not only from the use of LNG but also other feedstock including internal gases and butane for this facility.

A comparison of the natural gas consumption and NEU at 1A level shows that the GHG-inventory and the EB are more harmonized than with Eurostat data (Table A.4.9). For the NEU in 2005, there is no reported NEU to Eurostat at all, which causes the differences between SA and Eurostat. In 2016 and 2017 the differences are larger, the statistical difference in the Energy Balance is also larger in these years. The 2020 years values from Eurostat are not ready at the time of compiling these results.

Table A4.9. Comparison of Natural gas consumption and NEU of GHG-inventory and reported amounts to Eurostat

Year	Naturgas	GHG-inventory	Eurostat [169]	EB[170]	Diff Eurostat	Diff EB	Relative difference Eurostat	Relative difference EB
2005	Consumption	28154	31042	31403	-2888	-3249	-10%	-9%
2005	NEU	2398	0	2414	2398	-16	100%	27%
2016	Consumption	34325	30414	34921	3911	-596	11%	-3%
2016	NEU	4409	3999	4444	410	-35	9%	24%
2017	Consumption	26560	18888	27182	7672	-622	29%	9%
2017	NEU	13742	10308	14500	3434	-758	25%	-28%
2018	Consumption	27843	27458	28020	385	-177	1%	4%
2018	NEU	14449	14453	14376	-4	73	0%	-12%
2019	Consumption	26042	25909	27068	133	-1026	1%	-17%
2019	NEU	14407	14181	14371	226	36	2%	0%
2020	Consumption	22556	-	24036	22556	-1480	-	4%
2020	NEU	16796	-	16762	16796	34	-	0%

There are also the differences in used NCV by Eurostat and the GHG-inventory. The use of LNG is estimated with the same EF as for natural gas in Eurostat. The NCV used for LNG is 49.30 GJ/1000m^3 and for natural gas 37.37 GJ/1000m^3. The gaseous fuels are in the beginning in tons. In order to convert to volume, in m^3. The conversion factor of 0.00129 for normal m^3 and 0.001363 for standard m^3 is used. The values of gaseous fuels are reported as standard m^3, while they are in the Energy balance in normal m^3. Nm^3 stands for normal m$_3$ at 0 °C and atmosphere pressure (101,325 kPa) and Sm^3 stands for standard m^3 at 15 °C atmosphere pressure (101,325 kPa). Between standard and normal m^3 there is a factor of 1.054913. Thus, the values in the EB should be multiplied with the factor in order to be comparable with the values reported to Eurostat. In addition, there are differences in the NCVs used. For 2019 the NCV reported to Eurostat was 38.47 (GJ/1000 m^3) for both natural gas and LNG. The NCV used in RA for natural gas was 39.6 (GJ/1000 m3), which is the same used in SA. However, this NCV is not the same as in the Energy balance. The NCV in RA is taken from the Danish Energy Agency.

The Energy agency has two different ways of adding LNG and natural gas. In the Energy balance, the LNG in volume are estimated to natural gas in volumes. In the

[169] Eurostat, 2021. https://ec.europa.eu/eurostat/web/energy/data/energy-balances

[170] Swedsih Energy Agency, 2021. Statistical database. https://www.energimyndigheten.se/statistik/den-officiella-statistiken/statistikprodukter/arlig-energibalans/?currentTab=0#mainheading

Eurostat reporting LNG is summed with natural gas in energy amounts. This creates differences due to different NCV for LNG and natural gas.

When compensating for the standard vs normal m^3 the difference is around 0.5% for 2019 years consumption. (41364 TJ*1,054913=43635). Please find our calculations enclosed for further explanations. When calculating the energy consumption according to the NCV from the Energy balance the difference is around 3%. The TJ value of Eurostat of 39464 TJ NCV is the 43851 TJ GCV multiplied with a factor of 0.9 made by Eurostat, which is the conversion between GCV and NCV. The value of 43851 TJ is in NCV for RA in CRT and the value of 39464 TJ NCV in Eurostat has to be answered by Eurostat. The values in NCV that is reported in RA in the GHG inventory has been delivered by the Swedish Energy Agency in NCV.

During the review of submission 2021, we also found that the NCV used for estimating the TJ of LNG from some facilities are lower than the one used in the EB, especially for 2018. A compensation of the NCV for 2018 lead to a difference of 67 TJ between the GHG inventory and the EB for natural gas for both consumption and NEU. After compensation for the NCV, the fraction of the difference was found to be 19 kton CO_2-eq., which is below 0.05% of the total emissions (i.e. about 25.9 kton CO_2-eq.).

There are some smaller differences regarding the import and exports of natural gas in the two reportings. The main source is the same in both reportings. However, to the Eurostat reporting a summary of the preliminary monthly values are summed to yearly. In the Energy balance the final values are used (The foreign statistics revise their monthly values backwards).

The emissions estimated for NEU are directly taken from the facilities own environmental reports and have thus a high quality and accuracy. The non-energy use in TJ is however less certain due to that the energy for non-energy use is estimated from the emissions except for when the TJ is directly reported. The use of natural gas for NEU in the petrochemical industry is difficult to estimate due to that the facilities do not always distinguish between NEU and energy use in their reporting. Therefore, Sweden, has the strategy to each year work with an quality control process between the two sectors. We have developed a tool that assures that all the facilities that have emissions in both sectors are carefully investigated and sum up to either the EU-ETS database emissions or/and the facilities own reported emissions in their environmental reports. CO_2 emissions from this process are reported by the facility and this data is considered to be of high quality. Total emissions from the facility that uses Natural Gas/LNG add up to total emissions reported in the GHG inventory, controlled by using the above mentioned cross-checking tool. The amount of natural gas for NEU is however not reported separately from natural gas used for energy use, and so the NEU natural gas is estimated from CO_2 emissions, using a conversion factor which is fairly uncertain as carbon is stored in the product. This results in uncertain NEU data, which could explain the difference to the EB, however the corresponding process emissions reported in the GHG inventory are of good quality.

4.6.1.2.2 Liquid Fuels

In submission 2021, there were no review issues regarding liquid fuels comparison between RA, SA and Eurostat.

In submission 2020, there was also a notable difference between SA and reported amounts to Eurostat regarding Liquid Fuels. The difference was +8.9% for 1A liquid fuels (CRT: 348193 TJ; Eurostat: 319656 TJ). A comparison of the reported table "Annual oil" and the source of the fuel combustion in the GHG-inventory (Quaternary Fuel Statistics) by fuel type and industrial sector, revealed that the differences in fuel consumption between IEA/Eurostat and the GHG-inventory are found in the fuel types Fuel oil – low Sulphur, Diesel oil and Methane.

In total, we could explain around 16000 TJ that are not reported to the IEA/Eurostat but are included in the GHG-inventory.

- Fuel oil – low Sulphur: The main reason for the differences are different sources of activity data. In the IEA/Eurostat reporting, Energy consumption in manufacturing industry is used while in the GHG-inventory, the Quaternary Energy Statistics is used. The differences found was around 3000 TJ. In addition to this, Sweden reports the fuel amounts in m^3, which is converted to ton for the IEA-reporting. Regarding the amounts in m^3 there is a total coherence between the different reportings. We also report the NCV to IEA, but there are no possibilities to report different NCV values at sector level. When using different heavy oils with different NCV it is not possible to use the NCV value in IEA for the whole industry sector. However, the largest difference here is still in the different sources between the Quaternary energy statistics and the Energy consumption in Annual statistics on energy use in manufacturing industry. The Energy consumption in Annual statistics on energy use in manufacturing industry is actually a better source since it covers all the manufacturing industries. However, the timing of when that source is ready too late for preparation to use in the GHG-inventory. The Quaternary energy statistics is described rather thoroughly in section 2.1.1 in the Annex. The sample of the quarterly fuel statistics is based on the sample for the annual statistics of energy use in manufacturing industry, except for electricity and heat production for which the quarterly fuel statistics is a total survey.

- Diesel oil: The reason for the difference is different sources for the mobile combustion of working machinery in the industry sector reporting to IEA/Eurostat and the GHG-inventory. The differences are about 10 000 TJ regarding the consumption of working machinery in the industry sector.

The methods used in the inventory are described in NIR in the energy sector chapters of Mobile combustion 3.2.15 Other Industries (CRT 1.A.2.g). In IEA/Eurostat the combustion are from the Energy consumption in manufacturing industry, which report a lower energy consumption than the method used in the GHG-inventory. The Swedish Energy Agency has during the past years, together with the GHG compilers, worked to harmonize the amounts of fuel used in the transport sector. However, for working machinery used in the industry sector, the harmonization has not yet been done. The model used to estimate the fuel consumption by working machinery in CRT 1.A.2.g in the Swedish GHG inventory, results in a higher fuel consumption compared to the result in the statistical surveys regarding the energy consumption by working machinery. It is unclear whether the model overestimates the consumption of petroleum-based fuels for working machinery or if the statistical products (Quaternary energy statistics, Monthly energy statistics, Energy consumption in manufacturing industry) underestimates their consumption. This issue needs to be further investigated in order to be able to harmonize this consumption. In the next coming years, the Energy agency and the GHG-compilers will continue to work with this harmonization. However, this is mainly an issue regarding allocation of fuel to different sectors. The GHG inventory allocates a higher fuel consumption to working machinery while the Energy Agency allocates more fuel to road traffic. On a national level, the fuel consumption in the GHG inventory and in the energy balances are on the same level. We have further analyzed the energy consumption by comparing the gas/diesel oil of 2018 reported to Eurostat (166972 TJ), the EB (170964 TJ) and the GHG inventory (171402 TJ) and found that the consumption of gas/diesel oil is comparable and harmonized between the GHG-inventory and the EB. However, the amounts found in Eurostat table are not (166972 TJ: 3985 (ktoe)*41.8 (TJ/ktoe). A further investigation on this fuel type, reveals that the NCV used by Eurostat are low for this fuel type. The amounts reported in m^3 are the same used in the EB and reported to Eurostat. As explained before, Sweden reports the NCV at fuel type. In this Eurostat category of fuels the NCV values used are for EO1 (which is lower than for Diesel oil) which gives a lower total than the one in the EB and in the GHG-inventory. The introduced difference by using one NCV in this fuel group gives differences of 4000TJ.

- Methane: Methane is mostly combusted in the petrochemical industries in Sweden. These amounts are not reported to IEA/Eurostat. The amounts of methane are however reported in the Swedish Energy Balances. In the GHG-inventory, the methane reported under 1.A.2 is related to methane for stationary combustion. Due to allocation complexity of the fuel consumption in these industries, Sweden allocates a large part of the methane consumption in petrochemical industry under IPPU sector. The amounts of methane used in the industry sector is around 3000 TJ.

Of the initial discrepancy of 16000 TJ found by the reviewers, we have explained 12 400 TJ. This insight shows clearly that the Eurostat table is not complete, and that the consumption is not coherent with the actual consumption in ktoe and TJ due to that Eurostat uses a single NCV within its fuel categories that constitutes of more than one fuel type or the same NCV within a sector that uses the same fuel type with different NCVs. The energy consumption in Swedish EB and GHG-inventory is estimated at facility level with NCV for each facility and within each sector and is then a more precise estimate than the Eurostat tables that transform data at a coarser level. In the Eurostat ENERGY STATISTICS WORKING GROUP report of 7-9 November 2019 the used NCV is lower than for any other country.

In the GHG-inventory the Quaternary energy statistics is used and the Energy statistics of the manufacturing industries (yearly statistics), is mainly used in the EB and to Eurostat. There are however some differences also between the EB and to Eurostat (see MMR Annex 12). The comparison of the international data would improve if the GHG-inventory used the Energy statistics of the manufacturing industries instead of the Quaternary energy statistics, but as said before this data source is not ready in time for the GHG-compilers to prepare the submission.

The GHG-inventory compilers will also during 2020-2021 investigate if there are any overlapping between stationary and mobile combustion for petroleum-based fuel. The overlapping between stationary combustion and transport sector will be the focus, but the total fuel amounts used will aim at the same values as published in the EB and reported to Eurostat, since the transport sector uses these values as reference.

Finally, the EB is a compilation of around 20 statistical products and in addition there are some complementary estimates made, especially for those statistical products that are intermittent. There is a quality description (Kvalitetsdeklaration)[171] and a method documentation (Årlig energibalans)[172] of the EB.

[171] Documentation Energy Balance: https://www.energimyndigheten.se/globalassets/statistik/energibalans/arlig-energibalans/ovrigt/dokumentation-och-beskrivning-version-2018_1.pdf

[172] Quality description Energy Balance: http://www.energimyndigheten.se/globalassets/statistik/officiell-statistik/statistikprodukter/arlig-energibalans/bas/en0202_kvalitetsdeklaration_2018.pdf

4.7 Planned improvements

In order to investigate and explain and possibly solve the discrepancies, the cooperation between Swedish EPA, the Swedish Energy Agency, SMED and Statistics Sweden will continue during submission 2025 with the following priorities:

- Improving the description of the discrepancies remaining in NIR. The improvements are still ongoing and during submission 2024 the work will focus on summarizing all the efforts Sweden has made during the last 6 years in a comprehensive and transparent report with parts included in chapter in Annex 4. The report will describe the problems as well as the improvements made during the last years regarding the comparison between RA and SA in a transparent and clear way, but also include why Sweden has difficulties in comparing RA with SA.
- Investigation of a more transparent way of converting natural gas amounts in fuel between the Energy balances and the international reporting to Eurostat/IEA. This will be, if prioritized, made by the Swedish Energy Agency, and will improve the comparability of Gaseous fuels in the EU-MMR-annex, the comparison between RA in the GHG inventory and Ra in the international reporting.
- A Nordic cooperation with Sweden, Finland, Norway, Denmark and Island regarding issues regarding RA has been initiated during submission 2023. The cooperations' aim is to compare and share difficulties and solutions in our problems and will continue during next submission (2025).
- A harmonization of the three energy statistics products Energy use in the manufacturing industry (ISEN), Quarterly fuel statistics (KvBr) and Electricity supply, district heating and supply of natural and gasworks gas (AREL) is ongoing and the first report on the screening of the three products and how three different scenarios might be harmonised in order to minimize the reporting and avoid double reporting. This work is a cooperation between Statistics Sweden and the Swedish Energy Agency. The effects of this harmonization will hopefully result in better harmonized energy consumption for Sweden and also in the GHG-reporting compared with national statistics such as the Energy Balance and international reporting to Eurostat. This is a long-term activity and goal, and results from this will not be seen in the near future.

4.8 References Annex 4

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

Documentation Energy Balance: https://www.energimyndigheten.se/globalassets/statistik/energibalans/arlig-energibalans/ovrigt/dokumentation-och-beskrivning-version-2018_1.pdf

EN20SM Series. Årliga energibalanser (Annual Energy Balance Sheets). Energy statistics. Available att http://www.scb.se/EN0202

Eurostat, 2021. https://ec.europa.eu/eurostat/web/energy/data/energy-balances

Gerner, A., Andersson, M., Gustafsston, T., 2013. Differences between Eurostat and CRT data in Swedish reporting. SMED Report No 125 2013

Gustafsson, T. 2007a. Översyn av rapportering till Reference Approach, bränsleanvändning för icke-energiändamål samt jämförelsen mellan Reference och Sectoral Approach. (eng. Overhaul of reporting of the reference approach, the non-energy use of fuels and the comparison of reference and sectoral approach). SMED report 80:2007

Gustafsson, T., Gerner, A., Lidén, M. 2011. Emissions from integrated iron and steel industry in Sweden. SMED Report no 97, 2011.

Hedlund, H and Lidén, M. 2010. Jämförelse av energirapportering till IEA och UNFCCC. (eng. Comparison of energy reported to the IEA and the UNFCCC) SMED report 91:2010

Josefsson Ortiz, C., Yaramenka, K., Kindbom, K. & Eklund V.2021. Minska skillnader mellan Reference och Sectoral approach - NEU, eldningsoljor 1 & övriga bränslen. SMED Memorandum, 2021.

Ortiz, C., Jonsson, M., Yaramenka, K., Helbig, T. 2017. Skillnader mellan reference approach och sectoral approach i den nationella växthusgasinventeringen - En analys av Energi för icke energiändamål. SMED report no 2017:12

Quality description Energy Balance: http://www.energimyndigheten.se/globalassets/statistik/officiell-statistik/statistikprodukter/arlig-energibalans/bas/en0202_kvalitetsdeklaration_2018.pdf

Schöllin, M. 2002. CO_2 emissions inventories harmonisation- the Swedish case. Report made by Statistics Sweden, Energy Statistics. Eurostat file no. 200045500002.

Swedish Energy Agency, 2014. Annual energy balances. http://www.energimyndigheten.se/en/Facts-and-figures1/Statistics/

Swedish Energy Agency, 2015 http://www.energimyndigheten.se/Statistik/Energibalans/Energivarubalans/

Swedsih Energy Agency, 2021. Statistical database. https://www.energimyndigheten.se/statistik/den-officiella-statistiken/statistikprodukter/arlig-energibalans/?currentTab=0#mainheading

Statistics Sweden 2015. Data from Sweden's Statistical Databases (SSD) downloaded 2015-01-16 http://www.statistikdatabasen.scb.se/pxweb/sv/ssd/START__EN__EN0202/EbArDetalj/?rxid=ca2cb6a7-0321-4fb4-99a4-2c790cbe06bb

Viklund, L., Gerner, A., Ortiz, C., Gustafsson T. 2016. Skillnader mellan reference approach och sectoral approach i den nationella växthusgasinventeringen. SMED Rapport Nr 2016: 202.

5 Annex 5: Assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded for the annual inventory submission

5.1 GHG inventory

5.1.1 General assessment of completeness

The Swedish inventory covers both emissions and removals in Sweden, all greenhouse gases required and all relevant sources and sinks with a few exceptions. A general assessment of the completeness in the Swedish Greenhouse Gas Inventory is given in Chapter 1.8 in the main National Inventory Report.

Below, Table A5.1 lists all instances of the use of the notation key NE, not estimated, in the Swedish inventory, including short explanations to why these are not estimated. For sources considered insignificant an estimated level of emissions (kton CO_2 eq.) are given. National total (not including LULUCF) for emissions of greenhouse gases in 2022 is 51 093.7 kton CO_2 eq. 0.05% of the national total is 25.55 kton CO_2 eq. – for each of the sources listed in Table A5.1 the estimated level of emissions is below this threshold. The total for sources with estimated level of emission is 4.12 kton CO_2-eq, which is 0.008% (<0.1%) of the national total for 2022.

Further explanations and justifications are given in the following paragraphs.

Table A5.1. Summary of sources not estimated.

Sources and sinks not estimated (NE)				
GHG	**Sector**	**Source/sink category**	**Explanation**	**Estimated level of emission (kton CO_2eq)**
CH_4	1. Energy	1.B.2.B.1 Charcoal production	No default method/EF provided by IPCC	-
CO_2	1. Energy	1.B.2.A.3 Transport	No default method/EF provided by IPCC	-
N_2O	1. Energy	1.A.3.d Transport/1D international navigation	No default EF provided by IPCC	-
CH_4	2. IPPU	2.B.10. Other non-specified	Considered insignificant	0.1
N_2O	2. IPPU	2.B.10. Other non-specified	No default method/EF provided by IPCC	-
CO_2	2. IPPU	2.B.10. Other non-specified	No default method/EF provided by IPCC	-
CH_4	2. IPPU	2.B.10. Pharmaceutical industry	No default method/EF provided by IPCC	-
CO_2	2. IPPU	2.B.10. Sulphuric acid production	No default method/EF provided by IPCC	-
CH_4	2. IPPU	2.C.1.e Pellet	No default method/EF provided by IPCC	-
CH_4	2. IPPU	2.C.7.c Other metal production	No default method/EF provided by IPCC	-
SF_6	2. IPPU	2.G.2 (accelerators)	Considered insignificant	0.02
SF_6/ PFC	2. IPPU	2.G.2 (awacs)	No information available on military applications/systems using SF_6 or heat transfer fluids in high-powered electronic applications using PFCs.	-
CO_2	2. IPPU	2.G.4 Tobacco smoking	No default method/EF provided by IPCC	-
CO_2	4. LULUCF	4.E.1 Mineral soils	No default method provided by IPCC	-
CO_2	4. LULUCF	4.E.1 Organic soils	No default method provided by IPCC	-
CO_2	4. LULUCF	4.E.1 Net carbon stock change in dead organic matter	No default method provided by IPCC	-
CO_2	4. LULUCF	4.G Annual Change in stock	Since these emissions are voluntary to report, Sweden do not report HWP in SWDS	-
CO_2	4. LULUCF	4.G Gains	Since these emissions are voluntary to report, Sweden do not report HWP in SWDS	-
CO_2	4. LULUCF	4.G Losses	Since these emissions are voluntary to report, Sweden do not report HWP in SWDS	-
CO_2	4. LULUCF)	4.G Net CO_2 emissions/ removals from HWP in SWDS	Since these emissions are voluntary to report, Sweden do not report HWP in SWDS	-
CO_2 CH_4 N_2O	5. Waste	5.C.2.2.a Landfill Fires	Considered insignificant/No default method/EF provided by IPCC	4
CO_2	Memo item	Indirect CO_2	Indirect emissions are voluntary to report. Sweden do not estimate indirect CO_2 emissions	-
Total for sources where estimated level of emission is available				4.12

5.1.1.1 ENERGY

The emissions of N_2O from ships running on LNG are not estimated for 2019, due to lack of emission factor in IPCC Guidelines 2006 or elsewhere.

Fugitive emissions of CH_4 from charcoal production are not estimated since no methodology for estimating these emissions is available in the 2006 IPCC Guidelines.

5.1.1.2 INDUSTRIAL PROCESSES AND SOLVENT USE

Emissions from the sources specified below have not been estimated due to lack of information, but the emissions are expected to be insignificant.

For CH_4 emissions from ethylene production, a default methodology is provided by the 2006 IPCC Guidelines. The company's own expert judgment is an emission level of 4 t CH_4 (0.1 kt CO_2 eq). Using default EFs, the estimated emission would be between 20-90 t CH_4, or 0.5-2.25 kt CO_2 eq. Thus, the company's own expert judgment is below the result of the default method and well below the threshold for individual emission sources (see table A5.1 above) . Sweden has therefore chosen to report NE for this source, as it is judged to be insignificant in relation to the amount of effort it would require to obtain a complete and consistent time series.

CH_4 emissions from pellet production have not been estimated since no methodology is available in the 2006 IPCC Guidelines for estimating these emissions.

CO_2 emissions from tobacco smoking have not been estimated due to lack of information, but the emissions are expected to be insignificant. There is no methodology available in the 2006 IPCC Guidelines for estimating these emissions

5.1.1.3 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. There are, however, some marginal animal groups, which are not included, such as fur-bearing animals (foxes and chinchillas). These groups are very small and there are no default methodologies 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.

5.1.1.4 LAND USE, LAND USE CHANGE AND FORESTRY

The inventory covers all categories. However according to the guidelines only emissions/removals for managed land are reported. Only a few categories where methods are not available (4.E.1) or where reporting are voluntary (4.G) are reported as NE.

5.1.1.5 WASTE

Accidental landfill fires occur in Sweden; however, emissions of CO_2, CH_4 and N_2O are reported NE since there is no default method provided by the 2006 IPCC Guidelines that can be applied in this case. The accidental landfill fires do not refer to regular burning of waste, but to accidental fires. A rough estimation from 2003 suggested that collected emissions of CO_2, CH_4 and N_2O amounted to about 4 kt CO_2-eq. in 2002, based on assumptions of the fossil carbon content of the waste, default emission factors and statistics on landfill fires in 2002. Corresponding statistics is not available for other years. Thus, emissions are estimated to be below the threshold of 0.05% of national total emissions (about 30 kton CO_2 eq.). Emissions are estimated to be insignificant in relation to the amount of effort it would require obtaining activity and emission data. All other data are complete.

6 Annex 7: Uncertainties

6.1 Methodology for Uncertainty analysis

Uncertainty estimates are performed for 1990 and the latest reported year for direct greenhouse gases, e.g., CO_2, CH_4, N_2O and F-gases. For sources based on fuel consumption that share the same activity data, and consequently are correlated, we have adjusted the activity data uncertainties to account for that. For the emission factor uncertainties, we have not done any adjustment due to potential correlations, the reason being that it is difficult to identify possible correlations and the relative effect of these. As of submission 2011, emission data is imported to the SAS® software[173] from the Technical Production System, ensuring consistence in data reported in the CRT Reporter. In SAS, emissions and uncertainty estimates are merged and aggregated to the proper IPCC category consistent with the category split used for the key category analysis.

6.2 Estimating uncertainties for each source

When estimating uncertainties for each source, a wide range of information has been used. IPCC recommendations have been studies as well as fluctuations in time series, comparison with other sources, studies of statistical differences and studies of reports that are the basis for instance for many emission factors. Below some comments are given on how the work was conducted for each sector.

6.2.1 CRT 1. Stationary combustion

Uncertainties for activity data are estimated for each year, fuel type and CRT sector. Uncertainties for emission factors are estimated for each greenhouse gas, year, fuel type and CRT sector.

Several expert elicitations have been performed, with SMED reports and information from the IPCC as the main basis for the expert judgements. In some cases, no referenced information was available, and in those cases very rough expert judgements had to be made.

6.2.2 CRT 1. Mobile combustion

Activity data on fuel consumption are based on national statistics on fuel deliveries. Uncertainty estimates are mostly based on SMED reports and expert judgements, but in a few cases IPCC and CORINAIR default recommendations have been applied. Uncertainty estimates for activity data, emission factors and actual emissions for mobile combustion sources are set to be the same 1990 as the latest reported year.

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http://www.scb.se/Statistik/EN/EN0202/2009I10/EN0202_2009I10_SM_E

6.2.3 CRT 1. Fugitive emissions, CO_2

The emission factors used in the calculations are based on IPCC defaults or on information on emission factors and/or emissions directly from the companies. Generally, 5% have been assigned as uncertainty to the emission factors when no other indications or relevant information affecting the uncertainty have been available.

6.2.4 CRT 1. Fugitive emissions, CH_4 and N_2O

The emission factors used in the calculations are based on IPCC defaults or on information on emission factors and/or emissions directly from the companies. Generally, 5% have been assigned as uncertainty to the emission factors when no other indications or relevant information affecting the uncertainty have been available.

6.2.5 CRT 2. Industrial processes, CO_2

The emission factors used in the calculations are based on IPCC defaults or on information on emission factors and/or emissions directly from the companies. Generally, 5% have been assigned as uncertainty to the emission factors when no other indications or relevant information affecting the uncertainty have been available.

6.2.6 CRT 2. Industrial processes, F-gases

Activity data for most sources in CRT 2.F.1, refrigeration and air conditioning equipment, is based on national statistics. Uncertainty was assigned in cooperation with the Swedish Chemicals Agency. Other activity data is obtained directly from producers or consumers, and uncertainty was discussed with relevant experts, if possible. Emission factors are IPCC default, country specific, obtained from producers/consumers or derived in discussion with national experts. Uncertainty estimates are to a large extent based on expert judgements.

6.2.7 CRT 2. Industrial processes, CH_4 and N_2O

For nitric acid production, uncertainty estimates were obtained from producers. For other sources, expert judgements or suktested uncertainties from IPCC Guidelines and Good Practice Guidance were used, if available. In estimating uncertainties by expert judgements for some sources, Environmental reports from comparable facilities were used as a basis for estimating reasonable uncertainty levels.

6.2.8 CRT 2. Solvent use

Activity data are obtained from national statistics at the Swedish Chemicals Agency. Uncertainty estimates were discussed and assigned in cooperation with experts at the Products register at the Swedish Chemicals Agency. Uncertainty estimates for the country specific emission factors used were estimated by expert judgements.

6.2.9 CRT 3. Agriculture

Uncertainty estimates are generally collected from the same source as emission estimates, for instance IPCC or nationally referenced data. If no uncertainty estimates are available, estimates from similar statistics are used instead. When neither uncertainty estimates nor any similar statistics are available, expert judgements has to be made. Uncertainty estimates are assigned on an aggregated level similar to the ones presented in the NIR.

6.2.10 CRT 4. LULUCF

Uncertainty estimates are generally based on area sampling, but to some extent expert judgements and IPCC default values are also applied. Equation 6.3 and 6.4 in Good Practice Guidance have been used to fit the uncertainty estimates to the level of aggregation presented in the result tables below.

6.2.11 CRT 5. Waste

Uncertainty estimates are collected from IPCC (for emission factors) and IPCC combined with expert judgements (for activity data). Uncertainty estimates are assigned on the same aggregated level as presented in the NIR, which is per CRT sector (e.g. 5A Solid waste disposal).

6.3 Combining and aggregating uncertainties for all sectors

The uncertainty analysis is performed according to the approach 1 as described in IPCC 2006 guidelines. See especially equation 3.1 and 3.2, and table 3.3.

6.4 Results

Table A7.1. Approach 1 uncertainty assessment for national total emissions in 2022 and base year (1990), including LULUCF.

Table A7.1. Approach 1, uncertainty, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 1 a Public Electricity and Heat Production: Biomass	CH4	4.2	1.5	29.95	29.99	41.1	1.53	30.67	30.71	0	879.64	0
1 A 1 a Public Electricity and Heat Production: Biomass	N2O	10.83	1.5	29.95	29.99	94.8	1.52	30.4	30.44	0.0001	775.51	0
1 A 1 a Public Electricity and Heat Production: Gaseous Fuels	CH4	0.24	1.79	17.87	17.96	C	1.78	17.84	17.93	C	C	C
1 A 1 a Public Electricity and Heat Production: Gaseous Fuels	CO2	485.58	1.79	4.47	4.81	C	1.78	4.46	4.8	C	C	C
1 A 1 a Public Electricity and Heat Production: Gaseous Fuels	N2O	0.23	1.79	17.87	17.96	C	1.78	17.84	17.93	C	C	C
1 A 1 a Public Electricity and Heat Production: Liquid Fuels	CH4	0.4	1.67	33.41	33.45	C	1.2	24.09	24.12	C	C	C
1 A 1 a Public Electricity and Heat Production: Liquid Fuels	CO2	1277	1.68	1.68	2.38	C	1.2	1.2	1.7	C	C	C
1 A 1 a Public Electricity and Heat Production: Liquid Fuels	N2O	2.47	1.7	170.04	170.05	C	1.2	110.9	110.91	C	C	C
1 A 1 a Public Electricity and Heat Production: Peat	CH4	3.37	5.46	39.01	39.39	0.31	1.95	38.91	38.96	0	-90.67	0
1 A 1 a Public Electricity and Heat Production: Peat	CO2	1150.05	5.46	15.6	16.53	107.26	1.95	19.46	19.55	0	-90.67	0
1 A 1 a Public Electricity and Heat Production: Peat	N2O	28.97	5.46	31.21	31.68	1.35	1.95	38.91	38.96	0	-95.34	0
1 A 1 a Public Electricity and Heat Production: Solid Fuels	CH4	1.01	1.55	54.29	54.32	0.18	1.91	28.62	28.68	0	-81.99	0
1 A 1 a Public Electricity and Heat Production: Solid Fuels	CO2	4230.9	1.34	6.71	6.84	1609.68	1.94	9.72	9.91	0.0016	-61.95	0.002
1 A 1 a Public Electricity and Heat Production: Solid Fuels	N2O	36.39	1.9	18.98	19.08	0.24	1.48	14.83	14.91	0	-99.33	0
1 A 1 a Public Electricity and Heat Production:Other Fuels	CH4	2.36	1.68	20.26	20.32	10.16	1.11	24.61	24.64	0	330.69	0

Table A7.1. Approach 1, uncertainty, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 1 a Public Electricity and Heat Production:Other Fuels	CO2	524.33	1.53	19.96	20.02	3101.18	1.56	15.58	15.65	0.0145	491.45	0.056
1 A 1 a Public Electricity and Heat Production:Other Fuels	N2O	19.08	1.06	21.15	21.17	76.9	1.11	22.18	22.21	0	303.03	0
1 A 1 b Petroleum refining: Gaseous Fuels	CH4	0				C	2	20	20.1	C	C	C
1 A 1 b Petroleum refining: Gaseous Fuels	CO2	0				C	2	5	5.39	C	C	C
1 A 1 b Petroleum refining: Gaseous Fuels	N2O	0				C	2	20	20.1	C	C	C
1 A 1 b Petroleum refining: Liquid Fuels	CH4	0.8	10	100	100.5	C	10	100	100.5	C	C	C
1 A 1 b Petroleum refining: Liquid Fuels	CO2	1777.89	10	5	11.18	C	10	5	11.18	C	C	C
1 A 1 b Petroleum refining: Liquid Fuels	N2O	1.21	10	80	80.62	C	10	80	80.62	C	C	C
1 A 1 c Manufacture of Solid fuels and Other Energy Industries: Solid Fuels	CH4	0.12	5	20	20.62	0.12	5	20	20.62	0	-2.54	0
1 A 1 c Manufacture of Solid fuels and Other Energy Industries: Solid Fuels	CO2	300.32	5	5	7.07	372.36	5	5	7.07	0	23.99	0
1 A 1 c Manufacture of Solid fuels and Other Energy Industries: Solid Fuels	N2O	0.12	5	20	20.62	0.11	5	20	20.62	0	-2.54	0
1 A 2 a Iron and Steel: Biomass	CH4	0	10	100	100.5	0.01	5	40	40.31	0	505.58	0
1 A 2 a Iron and Steel: Biomass	N2O	0	10	100	100.5	0.01	5	40	40.31	0	505.58	0
1 A 2 a Iron and Steel: Gaseous Fuels	CH4	0.01	5	20	20.62	0.07	5	20	20.62	0	494.16	0
1 A 2 a Iron and Steel: Gaseous Fuels	CO2	25.21	5	5	7.07	150.22	5	5	7.07	0	495.93	0

Table A7.1. Approach 1, uncertainty, incl LULUCF

IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 2 a Iron and Steel: Gaseous Fuels	N2O	0.01	5	20	20.62	0.07	5	20	20.62	0	494.16	0
1 A 2 a Iron and Steel: Liquid Fuels	CH4	0.3	5	30	30.41	0.22	5	20	20.62	0	-25.33	0
1 A 2 a Iron and Steel: Liquid Fuels	CO2	830.77	5	5	7.07	555.19	5	5	7.07	0.0001	-33.17	0
1 A 2 a Iron and Steel: Liquid Fuels	N2O	1.12	5	50	50.25	0.4	5	50	50.25	0	-64.08	0
1 A 2 a Iron and Steel: Other Fuels	CH4	0				0.01	10	100	100.5	0		0
1 A 2 a Iron and Steel: Other Fuels	CO2	0				1.18	10	100	100.5	0		0
1 A 2 a Iron and Steel: Other Fuels	N2O	0				0.01	10	100	100.5	0		0
1 A 2 a Iron and Steel: Solid Fuels	CH4	0.11	2.88	19.21	19.42	0.09	2	20	20.1	0	-24.77	0
1 A 2 a Iron and Steel: Solid Fuels	CO2	849.67	2.95	4.92	5.74	616.69	2	5	5.39	0.0001	-27.42	0
1 A 2 a Iron and Steel: Solid Fuels	N2O	0.15	2.26	15.07	15.24	0.08	2	20	20.1	0	-46.37	0
1 A 2 b Non-ferrous metals: Gaseous Fuels	CH4	0.01	5	20	20.62	0.01	5	20	20.62	0	52.82	0
1 A 2 b Non-ferrous metals: Gaseous Fuels	CO2	10.44	5	5	7.07	15.9	5	5	7.07	0	52.22	0
1 A 2 b Non-ferrous metals: Gaseous Fuels	N2O	0	5	20	20.62	0.01	5	20	20.62	0	52.82	0
1 A 2 b Non-ferrous metals: Liquid Fuels	CH4	0.04	5	30	30.41	0.03	5	20	20.62	0	-17.32	0
1 A 2 b Non-ferrous metals: Liquid Fuels	CO2	109.86	5	5	7.07	83.26	5	5	7.07	0	-24.21	0
1 A 2 b Non-ferrous metals: Liquid Fuels	N2O	0.16	5	50	50.25	0.09	5	50	50.25	0	-43.27	0
1 A 2 b Non-ferrous metals: Solid Fuels	CH4	0.01	10	100	100.5	0					-100	
1 A 2 b Non-ferrous metals: Solid Fuels	CO2	8.48	10	100	100.5	0					-100	

Table A7.1. Approach 1, uncertainty, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 2 b Non-ferrous metals: Solid Fuels	N2O	0.01	10	100	100.5	0					-100	
1 A 2 c Chemicals: Biomass	CH4	0.18	5	40	40.31	C	5	40	40.31	C	C	C
1 A 2 c Chemicals: Biomass	N2O	0.76	5	40	40.31	1.33	5	40	40.31	0	73.87	0
1 A 2 c Chemicals: Gaseous Fuels	CH4	0.08	5	20	20.62	C	5	20	20.62	C	C	C
1 A 2 c Chemicals: Gaseous Fuels	CO2	154.61	5	5	7.07	C	5	5	7.07	C	C	C
1 A 2 c Chemicals: Gaseous Fuels	N2O	0.07	5	20	20.62	0.04	5	20	20.62	0	-50.39	0
1 A 2 c Chemicals: Liquid Fuels	CH4	0.18	5	30	30.41	C	5	20	20.62	C	C	C
1 A 2 c Chemicals: Liquid Fuels	CO2	424.22	5	20	20.62	C	5	5	7.07	C	C	C
1 A 2 c Chemicals: Liquid Fuels	N2O	0.66	5	50	50.25	0.28	5	50	50.25	0	-57.96	0
1 A 2 c Chemicals: Other Fuels	CH4	0.02	10	100	100.5	C	10	100	100.5	C	C	C
1 A 2 c Chemicals: Other Fuels	CO2	2.83	10	100	100.5	C	10	100	100.5	C	C	C
1 A 2 c Chemicals: Other Fuels	N2O	0.03	10	100	100.5	C	10	100	100.5	C	C	C
1 A 2 c Chemicals: Solid Fuels	CH4	0.03	4	20	20.4	C	2	40	40.05	C	C	C
1 A 2 c Chemicals: Solid Fuels	CO2	100.86	4	5	6.4	C	2	5	5.39	C	C	C
1 A 2 c Chemicals: Solid Fuels	N2O	0.43	4	40	40.2	C	2	40	40.05	C	C	C
1 A 2 d Pulp, Paper and Print: Biomass	CH4	11.7	2	40	40.05	12.79	8	40	40.79	0	9.3	0
1 A 2 d Pulp, Paper and Print: Biomass	N2O	50.58	2	40	40.05	53.63	8	40	40.79	0	6.03	0
1 A 2 d Pulp, Paper and Print: Gaseous Fuels	CH4	0.03	2	20	20.1	0.02	5	20	20.62	0	-48.88	0

Table A7.1. Approach 1, uncertainty, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 2 d Pulp, Paper and Print: Gaseous Fuels	CO2	65.91	2	5	5.39	33.61	5	5	7.07	0	-49.01	0
1 A 2 d Pulp, Paper and Print: Gaseous Fuels	N2O	0.03	2	20	20.1	0.02	5	20	20.62	0	-48.88	0
1 A 2 d Pulp, Paper and Print: Liquid Fuels	CH4	0.55	2	40	40.05	0.18	5	30	30.41	0	-66.39	0
1 A 2 d Pulp, Paper and Print: Liquid Fuels	CO2	1785.65	2	5	5.39	545.33	5	5	7.07	0.0001	-69.46	0
1 A 2 d Pulp, Paper and Print: Liquid Fuels	N2O	3.58	2	50	50.04	0.91	5	50	50.25	0	-74.68	0
1 A 2 d Pulp, Paper and Print: Other Fuels	CH4	0.29	10	40	41.23	0.2	10	100	100.5	0	-30.01	0
1 A 2 d Pulp, Paper and Print: Other Fuels	CO2	39.64	10	100	100.5	57.75	10	100	100.5	0.0002	45.7	0.001
1 A 2 d Pulp, Paper and Print: Other Fuels	N2O	0.37	10	100	100.5	0.31	10	100	100.5	0	-15.66	0
1 A 2 d Pulp, Paper and Print: Solid Fuels	CH4	0.14	5	20	20.62	0	7	40	40.61	0	-99.11	0
1 A 2 d Pulp, Paper and Print: Solid Fuels	CO2	264.58	5	5	7.07	4.29	7	5	8.6	0	-98.38	0
1 A 2 d Pulp, Paper and Print: Solid Fuels	N2O	1.66	5	40	40.31	0.02	7	40	40.61	0	-98.89	0
1 A 2 e Food Processing, Beverages and Tobacco: Biomass	CH4	0.08	5	100	100.12	0.53	5	40	40.31	0	589.66	0
1 A 2 e Food Processing, Beverages and Tobacco: Biomass	N2O	0.24	5	40	40.31	1.71	5	40	40.31	0	603.94	0
1 A 2 e Food Processing, Beverages and Tobacco: Gaseous Fuels	CH4	0.13	5	20	20.62	0.06	5	20	20.62	0	-48.52	0
1 A 2 e Food Processing, Beverages and Tobacco: Gaseous Fuels	CO2	253.8	5	5	7.07	130.15	5	5	7.07	0	-48.72	0
1 A 2 e Food Processing, Beverages and Tobacco: Gaseous Fuels	N2O	0.12	5	20	20.62	0.06	5	20	20.62	0	-48.52	0
1 A 2 e Food Processing, Beverages and Tobacco: Liquid Fuels	CH4	0.19	5	40	40.31	0.04	5	30	30.41	0	-79.42	0
1 A 2 e Food Processing, Beverages and Tobacco: Liquid Fuels	CO2	596.36	5	5	7.07	102.32	5	5	7.07	0	-82.84	0

Table A7.1. Approach 1, uncertainty, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 2 e Food Processing, Beverages and Tobacco: Liquid Fuels	N2O	1.15	5	50	50.25	0.12	5	50	50.25	0	-89.33	0
1 A 2 e Food Processing, Beverages and Tobacco: Other Fuels	CH4	0.03	10	40	41.23	0	10	100	100.5	0	-87.07	0
1 A 2 e Food Processing, Beverages and Tobacco: Other Fuels	CO2	4.61	10	100	100.5	0.48	10	100	100.5	0	-89.6	0
1 A 2 e Food Processing, Beverages and Tobacco: Other Fuels	N2O	0.04	10	100	100.5	0	10	100	100.5	0	-90.23	0
1 A 2 e Food Processing, Beverages and Tobacco: Solid Fuels	CH4	0.03	5	20	20.62	0	5	20	20.62	0	-88.1	0
1 A 2 e Food Processing, Beverages and Tobacco: Solid Fuels	CO2	90.65	5	5	7.07	12.29	5	5	7.07	0	-86.44	0
1 A 2 e Food Processing, Beverages and Tobacco: Solid Fuels	N2O	0.38	5	40	40.31	0.05	5	40	40.31	0	-88.1	0
1 A 2 f Non-metallic minerals: Biomass	CH4	0.03	4.92	49.21	49.46	C	4.72	47.16	47.4	C	C	C
1 A 2 f Non-metallic minerals: Biomass	N2O	0.11	4.98	59.79	59.99	C	4.32	51.81	51.99	C	C	C
1 A 2 f Non-metallic minerals: Gaseous Fuels	CH4	0.03	5.36	7.09	8.89	C	4.06	7.37	8.41	C	C	C
1 A 2 f Non-metallic minerals: Gaseous Fuels	CO2	65.28	5.36	2.13	5.77	C	4.06	2.21	4.62	C	C	C
1 A 2 f Non-metallic minerals: Gaseous Fuels	N2O	0.03	5.36	7.09	8.89	0.05	4.06	7.37	8.41	0	68.2	0
1 A 2 f Non-metallic minerals: Liquid Fuels	CH4	0.22	4.66	12.03	12.91	C	8.24	16.76	18.68	C	C	C
1 A 2 f Non-metallic minerals: Liquid Fuels	CO2	625.45	4.56	1.2	4.71	C	8.55	0.86	8.59	C	C	C
1 A 2 f Non-metallic minerals: Liquid Fuels	N2O	1.07	4.82	12.16	13.08	0.68	9.47	18.96	21.2	0	-36.87	0
1 A 2 f Non-metallic minerals: Other Fuels	CH4	0				C	10	50	50.99	C	C	C
1 A 2 f Non-metallic minerals: Other Fuels	CO2	0				C	10	60	60.83	C	C	C
1 A 2 f Non-metallic minerals: Other Fuels	N2O	0				C	10	60	60.83	C	C	C

Table A7.1. Approach 1, uncertainty, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 2 f Non-metallic minerals: Solid Fuels	CH4	0.35	8.45	8.54	12.01	0.13	8.48	8.58	12.06	0	-61.75	0
1 A 2 f Non-metallic minerals: Solid Fuels	CO2	1141.51	8.34	1.69	8.51	C	8.26	1.68	8.43	C	C	C
1 A 2 f Non-metallic minerals: Solid Fuels	N2O	4.89	8.52	17.2	19.2	C	8.39	17.02	18.98	C	C	C
1 A 2 g vii Off-road vehicles and other machinery: Liquid Fuels	CH4	2.13	2.91	35.36	35.48	0.9	2.76	35.65	35.76	0	-57.7	0
1 A 2 g vii Off-road vehicles and other machinery: Liquid Fuels	CO2	987.32	4.88	3.9	6.25	1114.02	4.91	3.93	6.28	0.0003	12.83	0.002
1 A 2 g vii Off-road vehicles and other machinery: Liquid Fuels	N2O	11.19	4.96	49.57	49.81	19.27	4.97	49.75	50	0	72.22	0
1 A 2 g vii Off-road vehicles and other machinery: Other Fossil Fuels	CO2	0				4.66	5	10	11.18	0		0
1 A 2 g viii Other: Biomass	CH4	7.37	4.9	39.22	39.53	C	4.48	35.86	36.14	C	C	C
1 A 2 g viii Other: Biomass	N2O	31.67	4.91	39.26	39.57	C	4.62	36.97	37.26	C	C	C
1 A 2 g viii Other: Gaseous Fuels	CH4	0.06	2.92	5.85	6.54	0.02	2.97	5.94	6.64	0	-69.73	0
1 A 2 g viii Other: Gaseous Fuels	CO2	113.11	2.92	1.17	3.15	C	2.97	1.19	3.2	C	C	C
1 A 2 g viii Other: Gaseous Fuels	N2O	0.05	2.92	5.85	6.54	0.02	2.97	5.94	6.64	0	-69.73	0
1 A 2 g viii Other: Liquid Fuels	CH4	0.87	2.28	4.56	5.1	0.22	2.85	5.71	6.38	0	-74.98	0
1 A 2 g viii Other: Liquid Fuels	CO2	2061.61	1.97	0.75	2.11	595.19	3.07	0.61	3.13	0	-71.13	0
1 A 2 g viii Other: Liquid Fuels	N2O	3.96	2	3.99	4.46	1.09	3.46	6.92	7.74	0	-72.39	0
1 A 2 g viii Other: Other Fuels	CH4	0				C	5	40	40.31	C	C	C
1 A 2 g viii Other: Other Fuels	CO2	0				3.32	5	40	40.31	0		0

Table A7.1. Approach 1, uncertainty, incl LULUCF **IPCC Source Category**	**Substance**	**Base year emissions or removals (kt CO_2-eq)**	**Activity data uncertainty in Baseyear (%)**	**Emission factor uncertainty in Baseyear (%)**	**Combined uncertainty in Baseyear (%)**	**Year 2022 emissions or removals (kt CO_2-eq)**	**Activity data uncertainty in 2022 (%)**	**Emission factor uncertainty in 2022 (%)**	**Combined uncertainty in 2022 (%)**	**Contribution to variance in 2022 (%)**	**Inventory trend for 2022 with respect to base year (%)**	**Uncertainty introduced into the trend (%)**
1 A 2 g viii Other: Other Fuels	N2O	0				0.03	5	40	40.31	0		0
1 A 2 g viii Other: Solid Fuels	CH4	0.04	2.73	5.46	6.11	C	4.82	9.63	10.77	C	C	C
1 A 2 g viii Other: Solid Fuels	CO2	98.42	3.33	3.33	4.71	C	4.61	0.92	4.7	C	C	C
1 A 2 g viii Other: Solid Fuels	N2O	0.34	3.51	7.02	7.85	C	4.65	18.61	19.18	C	C	C
1 A 3 a Domestic Aviation: Aviation Gasoline	CH4	0.01	10	10	14.14	0	10	10	14.14	0	-93.03	0
1 A 3 a Domestic Aviation: Aviation Gasoline	CO2	14.91	7.91	3.95	8.84	2.39	8.21	4.1	9.17	0	-83.97	0
1 A 3 a Domestic Aviation: Aviation Gasoline	N2O	0.28	7.35	147.09	147.28	0.03	7.07	141.47	141.65	0	-87.55	0
1 A 3 a Domestic Aviation: Biomass	CH4	0				0	10	10	14.14	0		0
1 A 3 a Domestic Aviation: Biomass	N2O	0				0.01	7.07	141.47	141.65	0		0
1 A 3 a Domestic Aviation: Jet Kerosene	CH4	0.61	10	10	14.14	0.12	10	10	14.14	0	-80.28	0
1 A 3 a Domestic Aviation: Jet Kerosene	CO2	658.13	7.91	3.95	8.84	298.64	8.21	4.1	9.17	0	-54.62	0
1 A 3 a Domestic Aviation: Jet Kerosene	N2O	11.91	7.35	147.09	147.28	4.2	7.07	141.47	141.65	0	-64.78	0
1 A 3 b i Road Transportation, Cars: Biomass	CH4	0				1.08	3.54	141.46	141.51	0		0
1 A 3 b i Road Transportation, Cars: Biomass	CO2	0				4.12	5	10	11.18	0		0
1 A 3 b i Road Transportation, Cars: Biomass	N2O	0				0.33	4.01	160.35	160.4	0		0
1 A 3 b i Road Transportation, Cars: Diesel oil	CH4	0.44	4.99	44.93	45.21	5.99	4.99	44.95	45.22	0	1263.98	0
1 A 3 b i Road Transportation, Cars: Diesel oil	CO2	524.25	4.99	4.99	7.06	3148.1	4.99	1.01	5.09	0.0016	500.5	0.013
1 A 3 b i Road Transportation, Cars: Diesel oil	N2O	0.13	8.24	65.98	66.49	61.14	4.99	64.83	65.02	0.0001	48554.44	0

Table A7.1. Approach 1, uncertainty, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 3 b i Road Transportation, Cars: Fossil part of biodiesel and biogasoline	CO2	0				16.46	4.99	9.97	11.15	0		0
1 A 3 b i Road Transportation, Cars: Gasoline	CH4	160.96	3	40	40.11	8.79	3	39.79	39.9	0	-94.54	0
1 A 3 b i Road Transportation, Cars: Gasoline	CO2	11993.59	3	4	5	5047.98	3	3.99	4.99	0.0039	-57.91	0.014
1 A 3 b i Road Transportation, Cars: Gasoline	N2O	118.23	3	59.96	60.04	6.18	4.16	58.48	58.62	0	-94.77	0
1 A 3 b i Road Transportation, Cars: LPG	CH4	0.01	5	65	65.19	0					-100	
1 A 3 b i Road Transportation, Cars: LPG	CO2	0.31	5	5	7.07	0					-100	
1 A 3 b i Road Transportation, Cars: LPG	N2O	0	5	65	65.19	0					-100	
1 A 3 b ii Road Transportation, Light duty trucks: Biomass	CH4	0				0.01	5	200	200.06	0		0
1 A 3 b ii Road Transportation, Light duty trucks: Biomass	N2O	0				0	5	200	200.06	0		0
1 A 3 b ii Road Transportation, Light duty trucks: Diesel oil	CH4	0.06	5	45	45.28	1.88	5	45	45.28	0	2964.43	0
1 A 3 b ii Road Transportation, Light duty trucks: Diesel oil	CO2	173.72	5	5	7.07	1208.8	5	1	5.1	0.0002	595.83	0.002
1 A 3 b ii Road Transportation, Light duty trucks: Diesel oil	N2O	0.02	5	65	65.19	20.19	5	65	65.19	0	88184.32	0
1 A 3 b ii Road Transportation, Light duty trucks: Fossil part of biodiesel and biogasoline	CO2	0				5.19	5	10	11.18	0		0
1 A 3 b ii Road Transportation, Light duty trucks: Gaseous Fuels	CH4	0				0.03	5	200	200.06	0		0
1 A 3 b ii Road Transportation, Light duty trucks: Gaseous Fuels	CO2	0				0.82	5	10	11.18	0		0
1 A 3 b ii Road Transportation, Light duty trucks: Gaseous Fuels	N2O	0				0.01	5	200	200.06	0		0

Table A7.1. Approach 1, uncertainty, incl LULUCF

IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 3 b ii Road Transportation, Light duty trucks: Gasoline	CH4	10.14	3	40	40.11	0.22	3	40	40.11	0	-97.81	0
1 A 3 b ii Road Transportation, Light duty trucks: Gasoline	CO2	833.91	3	4	5	85.04	3	4	5	0	-89.8	0
1 A 3 b ii Road Transportation, Light duty trucks: Gasoline	N2O	6.69	3	60	60.07	0.3	3	60	60.07	0	-95.46	0
1 A 3 b iii Road Transportation, Heavy duty trucks: Biomass	CH4	0.01	5	200	200.06	0.11	4.85	68.19	68.36	0	1046.61	0
1 A 3 b iii Road Transportation, Heavy duty trucks: Biomass	CO2	0				0.9	5	10	11.18	0		0
1 A 3 b iii Road Transportation, Heavy duty trucks: Biomass	N2O	0.13	5	200	200.06	3.34	4.21	168.49	168.54	0	2550.82	0
1 A 3 b iii Road Transportation, Heavy duty trucks: Diesel oil	CH4	3.59	3.84	65.68	65.79	0.14	4.38	47.32	47.52	0	-96.04	0
1 A 3 b iii Road Transportation, Heavy duty trucks: Diesel oil	CO2	3820.09	4.14	4.47	6.1	2789.51	4.76	0.95	4.86	0.0011	-26.98	0.009
1 A 3 b iii Road Transportation, Heavy duty trucks: Diesel oil	N2O	12.35	4.08	66.41	66.53	68.17	4.51	61.84	62	0.0001	452.05	0
1 A 3 b iii Road Transportation, Heavy duty trucks: Fossil part of biodiesel and biogasoline	CO2	0				20.07	3.56	7.12	7.97	0		0
1 A 3 b iii Road Transportation, Heavy duty trucks: Gaseous Fuels	CH4	0.19	2.58	55.63	55.69	1.65	4.93	49.34	49.59	0	764	0
1 A 3 b iii Road Transportation, Heavy duty trucks: Gaseous Fuels	CO2	21.9	2.69	3.71	4.58	9.2	3.7	7.28	8.17	0	-57.99	0
1 A 3 b iii Road Transportation, Heavy duty trucks: Gaseous Fuels	N2O	0.1	2.66	84.53	84.57	0.1	4.53	180.2	180.26	0	-2.27	0
1 A 3 b iii Road Transportation, Heavy duty trucks: LNG	CH4	0				0.24	5	15	15.81	0		0
1 A 3 b iii Road Transportation, Heavy duty trucks: LNG	CO2	0				2.71	5	10	11.18	0		0
1 A 3 b iv Road Transportation, Motorcycles: Fossil part of biodiesel and biogasoline	CO2	0				0.05	5	10	11.18	0		0

Table A7.1. Approach 1, uncertainty, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 3 b iv Road Transportation, Motorcycles: Gasoline	CH4	2.38	3	40	40.11	2.67	3	40	40.11	0	12.33	0
1 A 3 b iv Road Transportation, Motorcycles: Gasoline	CO2	39.15	3	4	5	81.74	3	4	5	0	108.78	0
1 A 3 b iv Road Transportation, Motorcycles: Gasoline	N2O	0.17	3	60	60.07	0.38	3	60	60.07	0	117.13	0
1 A 3 c Railways: Liquid Fuels	CH4	0.16	5	150	150.08	0.07	5	150	150.08	0	-58.12	0
1 A 3 c Railways: Liquid Fuels	CO2	102.94	5	5	7.07	41.29	5	5	7.07	0	-59.89	0
1 A 3 c Railways: Liquid Fuels	N2O	0.21	5	200	200.06	0.09	5	200	200.06	0	-58.12	0
1 A 3 d Domestic Navigation: Biomass	CH4	0				0	5	50	50.25	0		0
1 A 3 d Domestic Navigation: Biomass	N2O	0				0.37	5	50	50.25	0		0
1 A 3 d Domestic Navigation: Gas/Diesel Oil	CH4	3.13	4.97	198.62	198.68	3.52	4.93	197.28	197.34	0	12.39	0
1 A 3 d Domestic Navigation: Gas/Diesel Oil	CO2	257.3	2.63	2.45	3.59	438.8	2.75	2.61	3.79	0	70.54	0
1 A 3 d Domestic Navigation: Gas/Diesel Oil	N2O	3.33	2.91	44.97	45.07	5.33	3.04	49.62	49.71	0	59.86	0
1 A 3 d Domestic Navigation: Gasoline	CH4	0				0.01	5	50	50.25	0		0
1 A 3 d Domestic Navigation: Gasoline	CO2	0				0.38	5	5	7.07	0		0
1 A 3 d Domestic Navigation: Gasoline	N2O	0				0	5	50	50.25	0		0
1 A 3 d Domestic Navigation: LNG	CH4	0				18.21	10	60	60.83	0		0
1 A 3 d Domestic Navigation: LNG	CO2	0				52.33	10	10	14.14	0		0
1 A 3 d Domestic Navigation: Residual Oil	CH4	0.04	15	40	42.72	0.03	15	40	42.72	0	-22.68	0
1 A 3 d Domestic Navigation: Residual Oil	CO2	195	15	5	15.81	168.04	15	5	15.81	0	-13.82	0

Table A7.1. Approach 1, uncertainty, incl LULUCF **IPCC Source Category**	**Substance**	**Base year emissions or removals (kt CO_2-eq)**	**Activity data uncertainty in Baseyear (%)**	**Emission factor uncertainty in Baseyear (%)**	**Combined uncertainty in Baseyear (%)**	**Year 2022 emissions or removals (kt CO_2-eq)**	**Activity data uncertainty in 2022 (%)**	**Emission factor uncertainty in 2022 (%)**	**Combined uncertainty in 2022 (%)**	**Contribution to variance in 2022 (%)**	**Inventory trend for 2022 with respect to base year (%)**	**Uncertainty introduced into the trend (%)**
1 A 3 d Domestic Navigation: Residual Oil	N2O	2.57	15	40	42.72	2.07	15	40	42.72	0	-19.51	0
1 A 3 e Other Transportation: Biomass	CH4	0				0	5	50	50.25	0		0
1 A 3 e Other Transportation: Biomass	N2O	0				0	5	50	50.25	0		0
1 A 3 e Other Transportation: Gaseous fuels	CH4	0	5	150	150.08	0	5	150	150.08	0	41.02	0
1 A 3 e Other Transportation: Gaseous fuels	CO2	1.68	5	5	7.07	2.33	5	5	7.07	0	38.33	0
1 A 3 e Other Transportation: Gaseous fuels	N2O	0	5	1000	1000.01	0	5	1000	1000.01	0	41.02	0
1 A 3 e Other Transportation: Other Fossil Fuels	CO2	0				0.63	5	10	11.18	0		0
1 A 3 e Other Transportation: Total	CH4	1.49	5	125	125.1	0.17	5	125	125.1	0	-88.3	0
1 A 3 e Other Transportation: Total	CO2	1051.53	5	5	7.07	353.76	5	5	7.07	0	-66.36	0
1 A 3 e Other Transportation: Total	N2O	15.6	5	125	125.1	5.67	5	125	125.1	0	-63.63	0
1 A 4 a Commercial/Institutional: Biomass	CH4	1.46	10	100	100.5	0.27	10	100	100.5	0	-81.38	0
1 A 4 a Commercial/Institutional: Biomass	N2O	0.75	10	100	100.5	1.72	10	100	100.5	0	127.32	0
1 A 4 a Commercial/Institutional: Gaseous Fuels	CH4	0.04	10	20	22.36	0.11	10	20	22.36	0	162.18	0
1 A 4 a Commercial/Institutional: Gaseous Fuels	CO2	86.09	10	5	11.18	224.85	10	5	11.18	0	161.19	0
1 A 4 a Commercial/Institutional: Gaseous Fuels	N2O	0.04	10	20	22.36	0.11	10	20	22.36	0	162.18	0
1 A 4 a Commercial/Institutional: Gasoline	CH4	3.33	5	50	50.25	1.35	5	50	50.25	0	-59.41	0
1 A 4 a Commercial/Institutional: Gasoline	CO2	78.36	5	5	7.07	75.04	5	5	7.07	0	-4.24	0

Table A7.1. Approach 1, uncertainty, incl LULUCF

IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 4 a Commercial/Institutional: Gasoline	N2O	0.33	5	50	50.25	0.36	5	50	50.25	0	7.31	0
1 A 4 a Commercial/Institutional: Liquid Fuels	CH4	2.27	18.2	36.67	40.94	0.18	8.68	33.8	34.9	0	-92.15	0
1 A 4 a Commercial/Institutional: Liquid Fuels	CO2	2612.33	18.74	0.99	18.76	291.1	8.21	3.12	8.79	0	-88.86	0
1 A 4 a Commercial/Institutional: Liquid Fuels	N2O	7.04	14.5	32.05	35.17	3.3	4.85	47.32	47.57	0	-53.17	0
1 A 4 a Commercial/Institutional: Other Fossil Fuels	CO2	0				0.81	5	10	11.18	0		0
1 A 4 b Residential: Biomass	CH4	107.42	10	100	100.5	54.54	10	100	100.5	0.0002	-49.23	0
1 A 4 b Residential: Biomass	N2O	41.57	10	100	100.5	39.59	10	100	100.5	0.0001	-4.76	0
1 A 4 b Residential: Gaseous Fuels	CH4	0.04	10	20	22.36	0.04	10	20	22.36	0	-12.73	0
1 A 4 b Residential: Gaseous Fuels	CO2	86.09	10	5	11.18	74.86	10	5	11.18	0	-13.04	0
1 A 4 b Residential: Gaseous Fuels	N2O	0.04	10	20	22.36	0.04	10	20	22.36	0	-12.73	0
1 A 4 b Residential: Liquid Fuels	CH4	7.89	11.75	27.93	30.3	2.99	3.01	29.08	29.23	0	-62.07	0
1 A 4 b Residential: Liquid Fuels	CO2	6211.59	19.16	0.97	19.19	366.27	9.19	1.58	9.32	0.0001	-94.1	0.001
1 A 4 b Residential: Liquid Fuels	N2O	14.32	17.67	35.57	39.72	1.71	4.42	21.64	22.08	0	-88.08	0
1 A 4 b Residential: Other Fossil Fuels	CO2	0				0.2	5	10	11.18	0		0
1 A 4 c Agriculture/Forestry/Fisheries: Biomass	CH4	5.25	10	100	100.5	2.15	10	100	100.5	0	-59.06	0
1 A 4 c Agriculture/Forestry/Fisheries: Biomass	N2O	2.99	10	100	100.5	3.55	10	100	100.5	0	18.76	0
1 A 4 c Agriculture/Forestry/Fisheries: Domestic Heating Oil	CH4	0.03	15	50	52.2	0.01	30	50	58.31	0	-58.68	0
1 A 4 c Agriculture/Forestry/Fisheries: Domestic Heating Oil	CO2	200.22	15	5	15.81	82.73	30	5	30.41	0	-58.68	0

Table A7.1. Approach 1, uncertainty, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 4 c Agriculture/Forestry/Fisheries: Domestic Heating Oil	N2O	2.55	15	50	52.2	1.05	30	50	58.31	0	-58.68	0
1 A 4 c Agriculture/Forestry/Fisheries: Fossil part of biodiesel and biogasoline	CO2	0				3.02	3.54	7.09	7.92	0		0
1 A 4 c Agriculture/Forestry/Fisheries: Gaseous Fuels	CH4	0.02	10	20	22.36	0	10	20	22.36	0	-76.47	0
1 A 4 c Agriculture/Forestry/Fisheries: Gaseous Fuels	CO2	33.11	10	5	11.18	7.76	10	5	11.18	0	-76.56	0
1 A 4 c Agriculture/Forestry/Fisheries: Gaseous Fuels	N2O	0.02	10	20	22.36	0	10	20	22.36	0	-76.47	0
1 A 4 c Agriculture/Forestry/Fisheries: Gasoline	CH4	0.32	4.76	47.57	47.8	0.52	3.58	35.79	35.97	0	63.15	0
1 A 4 c Agriculture/Forestry/Fisheries: Gasoline	CO2	12.6	4.6	4.6	6.5	32.72	3.59	3.59	5.08	0	159.72	0
1 A 4 c Agriculture/Forestry/Fisheries: Gasoline	N2O	0.02	3.69	36.88	37.06	0.22	3.54	35.36	35.53	0	878.06	0
1 A 4 c Agriculture/Forestry/Fisheries: Liquid Fuels	CH4	4.12	2.5	32.5	32.59	3.31	2.8	45.84	45.93	0	-19.55	0
1 A 4 c Agriculture/Forestry/Fisheries: Liquid Fuels	CO2	1400.47	4.99	2.77	5.71	836.41	3.79	0.63	3.84	0.0001	-40.28	0.001
1 A 4 c Agriculture/Forestry/Fisheries: Liquid Fuels	N2O	12.77	3.5	33.73	33.91	12.26	3.5	34.82	34.99	0	-3.99	0
1 A 4 c Agriculture/Forestry/Fisheries: Solid Fuels	CH4	0.19	10	20	22.36	0					-100	
1 A 4 c Agriculture/Forestry/Fisheries: Solid Fuels	CO2	157.08	10	3	10.44	0					-100	
1 A 4 c Agriculture/Forestry/Fisheries: Solid Fuels	N2O	0.68	10	40	41.23	0					-100	
1 B 1 c Fugitive emissions from Solid Fuels	CH4	0	70	20	72.8	0.01	50	20	53.85	0	74.96	0
1 B 1 c Fugitive emissions from Solid Fuels	CO2	5.32	70	5	70.18	11.76	50	5	50.25	0	121.18	0
1 B 1 c Fugitive emissions from Solid Fuels	N2O	0	70	20	72.8	0.01	50	20	53.85	0	74.96	0

Table A7.1. Approach 1, uncertainty, incl LULUCF

IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 B 2 a Oil	CH4	13.58	0.1	364.13	364.13	1.23	0	50	50	0	-90.96	0
1 B 2 a Oil	CO2	254.82	17.06	8.53	19.08	0					-100	
1 B 2 a Oil	N2O	1.01	18.83	23.57	30.17	0					-100	
1 B 2 b Natural gas	CH4	75.38	0	49.14	49.14	36.52	0	47.08	47.08	0	-51.55	0
1 B 2 b Natural gas	CO2	2.6	0	49.98	49.98	0.03	0	47.09	47.09	0	-98.85	0
1 B 2 c Venting and flaring	CH4	0.17	42.29	76.5	87.41	0.02	0.01	49.99	49.99	0	-86.86	0
1 B 2 c Venting and flaring	CO2	73.48	50	30	58.31	0.01	49.89	9.98	50.87	0	-99.99	0
1 B 2 c Venting and flaring	N2O	0.12	50	80	94.34	0	50	30	58.31	0	-100	0
2 A 1 Cement Production	CO2	1271.95	2	5	5.39	C	2	5	5.39	C	C	C
2 A 2 Lime Production	CO2	331.6	15.04	4.23	15.63	C	5.05	1.87	5.39	C	C	C
2 A 3 Glass Production	CO2	53.5	0	7	7	15.89	0	7	7	0	-70.3	0
2 A 4 Other	CO2	15.44	5.51	4.01	6.82	5.47	3.37	4.24	5.42	0	-64.57	0
2 B 10 Other	CH4	0.79	0	89.81	89.81	C	0	90.12	90.12	C	C	C
2 B 10 Other	CO2	514.02	0	4.47	4.47	C	0	4.12	4.12	C	C	C
2 B 10 Other	N2O	18.43	0	93.39	93.39	0.74	0	119.24	119.24	0	-95.98	0
2 B 2 Nitric Acid Production	N2O	695.63	2	5	5.39	5.53	2	5	5.39	0	-99.21	0
2 B 5 Carbide production	CO2	67.98	10	5	11.18	C	10	5	11.18	C	C	C
2 C 1 Iron and Steel Production	CH4	21.04	4.93	24.64	25.13	0.31	4.27	5.15	6.68	0	-98.54	0

Table A7.1. Approach 1, uncertainty, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
2 C 1 Iron and Steel Production	CO2	2636.63	4.01	4.51	6.04	2520.96	4.24	4.24	6	0.0014	-4.39	0.008
2 C 2 Ferroalloys production	CH4	0.75	5	100	100.12	0					-100	
2 C 2 Ferroalloys production	CO2	227.58	5	5	7.07	196.72	5	5	7.07	0	-13.56	0
2 C 3 Aluminium production	CO2	132.86	2	5	5.39	174.66	2	5	5.39	0	31.46	0
2 C 3 Aluminium production	PFCs	510.94	2	30	30.07	34.43	2	5	5.39	0	-93.26	0
2 C 7 Other	CO2	275.78	6	6	8.49	257.02	4	5	6.4	0	-6.8	0
2 D 1 Lubricant use	CO2	157.87	5	50	50.25	C	5	50	50.25	C	C	C
2 D 2 Paraffin wax use	CO2	17.73	10	50	50.99	C	10	50	50.99	C	C	C
2 D 3 Other	CO2	217.39	7.54	12.49	14.59	C	12.67	6.83	14.4	C	C	C
2 F 1 Refrigeration and air conditioning	HFCs	4.65	32.14	64.32	71.9	785.82	17.06	34.44	38.44	0.0056	16803.63	0.028
2 F 2 Foam blowing agents	HFCs	0				10.26	2	20	20.1	0		0
2 F 3 Fire protection	HFCs	0				0.23	4.67	18.66	19.23	0		0
2 F 4 Aerosols	HFCs	1.3	50	20	53.85	14.69	5	19.63	20.25	0	1030.31	0
2 G 1 Electrical equipment	SF6	78.93	9	17.99	20.11	34.17	8.65	17.31	19.35	0	-56.7	0
2 G 2 SF6 and PFCs from other product use	SF6	2.42	4.88	48.81	49.05	4.36	4.15	49.42	49.6	0	79.97	0
2 G 3 N2O from product uses	N2O	77.13	10	10	14.14	65.46	10	10	14.14	0	-15.13	0
2 H 1 Pulp and paper	CH4	6.81	6.51	19.53	20.59	C	6.7	20.09	21.18	C	C	C
2 H 1 Pulp and paper	CO2	0.59	5.62	4.01	6.9	C	7	5	8.6	C	C	C

Table A7.1. Approach 1, uncertainty, incl LULUCF

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2 H 1 Pulp and paper	N2O	56.62	6.44	20.25	21.25	80.34	6.65	19.96	21.04	0	41.9	0
2 H 3 Other (NFR 2A6)	CO2	18.43	0	6	6	C	0	6	6	C	C	C
2.C.4 Magnesium foundry	HFCs	0				0.52	0	20	20	0		0
2.C.4 Magnesium foundry	SF6	23.5	0	71.8	71.8	0					-100	
3 A 1 Dairy cattle	CH4	1810.7	5	20	20.62	1240.85	5	20	20.62	0.004	-31.47	0.01
3 A 1 Non-dairy cattle	CH4	1418.93	5	25	25.5	1619.62	5	25	25.5	0.0105	14.14	0.031
3 A 2 Sheep	CH4	102.31	5	40	40.31	128.5	5	40	40.31	0.0002	25.6	0
3 A 4 Goats	CH4	1.39	5	40	40.31	4.01	5	40	40.31	0	188.84	0
3 A 4 Horses	CH4	159.06	5	40	40.31	179.17	5	40	40.31	0.0003	12.64	0.001
3 A 4 Raindeer	CH4	88.62	5	40	40.31	84.11	5	40	40.31	0.0001	-5.09	0
3 A 4 Swine	CH4	99.07	5	40	40.31	60.74	5	40	40.31	0	-38.69	0
3 B 1 Dairy cattle	CH4	105.86	20	50	53.85	79.58	20	50	53.85	0.0001	-24.83	0
3 B 1 Dairy cattle	N2O	93	14.9	37.26	40.13	60.67	18.23	45.57	49.08	0.0001	-34.76	0
3 B 1 Non-dairy cattle	CH4	68.55	20	50	53.85	125.56	20	50	53.85	0.0003	83.17	0.001
3 B 1 Non-dairy cattle	N2O	63.35	12.18	30.45	32.8	78.52	13.45	33.63	36.22	0	23.95	0
3 B 3 Swine	CH4	67.13	20	50	53.85	62.72	20	50	53.85	0.0001	-6.57	0
3 B 3 Swine	N2O	37.99	13.04	32.59	35.1	24.05	15.71	39.28	42.31	0	-36.68	0
3 B 4 Fur-bearing animals	CH4	5.65	20	50	53.85	2.57	20	50	53.85	0	-54.53	0

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3 B 4 Fur-bearing animals	N2O	2.84	20	50	53.85	1.29	20	50	53.85	0	-54.53	0
3 B 4 Goats	CH4	0.02	20	50	53.85	0.06	20	50	53.85	0	188.84	0
3 B 4 Goats	N2O	0.04	20	50	53.85	0.11	20	50	53.85	0	188.84	0
3 B 4 Horses	CH4	13.79	20	50	53.85	15.53	20	50	53.85	0	12.64	0
3 B 4 Horses	N2O	21.13	13.37	33.42	35.99	23.8	13.37	33.42	35.99	0	12.64	0
3 B 4 Poultry	CH4	9.42	15.02	37.54	40.44	15.22	13.84	34.6	37.27	0	61.6	0
3 B 4 Poultry	N2O	16.56	13.07	32.68	35.2	26.92	14.1	35.26	37.98	0	62.6	0
3 B 4 Reindeer	CH4	2.55	20	50	53.85	2.42	20	50	53.85	0	-5.09	0
3 B 4 Sheep	CH4	2.16	20	50	53.85	2.71	20	50	53.85	0	25.6	0
3 B 4 Sheep	N2O	2.36	20	50	53.85	3.85	20	50	53.85	0	63.24	0
3 B Indirect N2O emissions	N2O	91.63	20	400	400.5	72.5	20	400	400.5	0.0052	-20.88	0.012
3 D a 1 Inorganic N fertilizers	N2O	934.88	5	80	80.16	769.78	5	80	80.16	0.0234	-17.66	0.055
3 D a 2 a Animal manure applied to soils	N2O	319.67	5	80	80.16	285.19	5	80	80.16	0.0032	-10.78	0.008
3 D a 2 b Sewage sludge applied to soils	N2O	4.91	5	80	80.16	22.01	5	80	80.16	0	347.84	0
3 D a 2 c Other organic fertilizers applied to soils	N2O	7.08	5	80	80.16	44.04	5	80	80.16	0.0001	522.03	0
3 D a 3 Urine and dung deposited by grazing animals	N2O	67.26	11.92	148.39	148.86	67.52	12.18	151.53	152.02	0.0006	0.39	0.002
3 D a 4 Crop residues applied to soils	N2O	402.38	20	80	82.46	360.22	20	80	82.46	0.0054	-10.48	0.015

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3 D a 5 Mineralization/immobilization associated with loss/gain of soil organic matter	N2O	0				72.51	20	80	82.46	0.0002		0.001
3 D a 6 Cultivation of organic soils (i.e. histosols)	N2O	880.73	5	85	85.15	604.36	5	85	85.15	0.0163	-31.38	0.034
3 D b 1 Atmospheric deposition	N2O	91.46	20	400	400.5	83.52	20	400	400.5	0.0069	-8.69	0.017
3 D b 2 Nitrogen leaching and run-off	N2O	236.08	20	150	151.33	166.3	20	150	151.33	0.0039	-29.56	0.009
3 G Liming	CO2	173.4	3.69	7.38	8.25	122.44	4.01	8.01	8.96	0	-29.39	0
3 H Urea application	CO2	4.35	5	10	11.18	0.09	5	10	11.18	0	-97.91	0
4 A 1 Forest land remaining forest land	CH4	2	0	88.95	88.95	1.88	0	73.17	73.17	0	-5.77	0
		-				-						
4 A 1 Forest land remaining forest land	CO2	53249.07	0	15.15	15.15	39490.06	0	17.74	17.74	3.018	-25.84	6.921
4 A 1 Forest land remaining forest land	N2O	43.77	0	49.85	49.85	6.31	0	49.05	49.05	0	-85.59	0
4 A 2 1 Cropland converted to forest land	CO2	149.08	0	27.18	27.18	46.67	0	18.82	18.82	0	-68.7	0
4 A 2 1 Cropland converted to forest land	N2O	2.32	0	100	100	8.28	0	100	100	0	257.48	0
4 A 2 2 Grassland converted to forest land	CO2	-21.28	0	21.13	21.13	-41.67	0	25.35	25.35	0	95.78	0
4 A 2 2 Grassland converted to forest land	N2O	0.83	0	100	100	3.71	0	100	100	0	347.27	0
4 A 2 3 Wetlands converted to forest land	CO2	-3.08	0	24.61	24.61	-147.39	0	39.94	39.94	0.0002	4679.06	0.001
4 A 2 4 Settlements converted to forest land	CO2	-30.39	0	26.74	26.74	-364.8	0	25.78	25.78	0.0005	1100.26	0.002
4 A 2 5 Other land converted to forest land	CO2	0				-56.45	0	35.43	35.43	0		0

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4 A Drained organic soils	CH4	255.41	0	100	100	250.74	0	100	100	0.0039	-1.83	0.01
4 A Drained organic soils	N2O	1014.93	0	100	100	1022.78	0	100	100	0.0644	0.77	0.169
4 B 1 Cropland remaining cropland	CO2	2681.33	0	28.36	28.36	2823.22	0	28.63	28.63	0.0402	5.29	0.107
4 B 2 1 Forest land converted to cropland	CO2	0				-9.26	0	36.03	36.03	0		0
4 B 2 2 Grassland converted to cropland	CO2	-6.86	0	37.52	37.52	-25.55	0	38.48	38.48	0	272.28	0
4 B 2 4 Settlements converted to cropland	CO2	-0.61	0	48.3	48.3	-1.95	0	39.55	39.55	0	219.96	0
4 B Drained organic soils	CH4	265.35	0	100	100	182.08	0	100	100	0.002	-31.38	0.004
4 C 1 Grassland remaining grassland	CH4	0.3	0	100	100	0.08	0	100	100	0	-72.28	0
4 C 1 Grassland remaining grassland	CO2	-559.47	0	27.77	27.77	-532.23	0	20.12	20.12	0.0007	-4.87	0.002
4 C 1 Grassland remaining grassland	N2O	0.02	0	100	100	0.01	0	100	100	0	-72.6	0
4 C 2 1 Forest land converted to grassland	CO2	418.84	0	66.5	66.5	731.11	0	60.05	60.05	0.0119	74.56	0.038
4 C 2 2 Cropland converted to grassland	CO2	4.74	0	30.82	30.82	104.2	0	35.01	35.01	0.0001	2098.87	0
4 C 2 3 Wetlands converted to grassland	CO2	0				-2.12	0	19.54	19.54	0		0
4 C 2 4 Settlements converted to grassland	CO2	-20.61	0	18.46	18.46	-11.56	0	19.41	19.41	0	-43.91	0
4 C 2 5 Other land converted to grassland	CO2	0				-6.79	0	17.37	17.37	0		0
4 C Drained organic soils	CH4	10	0	100	100	20.95	0	100	100	0	109.65	0
4 D 1 1 Peat extraction remaining peat extraction	CO2	75.29	0	50	50	288.6	0	50	50	0.0013	283.3	0.005
4 D 1 Wetlands remaining wetlands	CH4	5.97	0	100	100	8.99	0	100	100	0	50.59	0

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IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
4 D 1 Wetlands remaining wetlands	N2O	0.82	0	100	100	1.24	0	100	100	0	50.63	0
4 E 1 Settlements remaining settlements	CO2	-29.9	0	21.88	21.88	-249.8	0	17.25	17.25	0.0001	735.42	0
4 E 2 1 Forest land converted to settlements	CO2	2241.11	0	57.3	57.3	2209.51	0	29.67	29.67	0.0264	-1.41	0.068
4 E 2 1 Forest land converted to settlements	N2O	10.59	0	100	100	25.86	0	100	100	0	144.19	0
4 E 2 2 Cropland converted to settlements	CO2	100.05	0	49.78	49.78	325.27	0	49.82	49.82	0.0016	225.12	0.006
4 E 2 2 Cropland converted to settlements	N2O	10.38	0	100	100	33.7	0	100	100	0.0001	224.81	0
4 E 2 3 Grassland converted to settlements	CO2	2.6	0	49.09	49.09	-0.85	0	26.06	26.06	0	-132.6	0
4 E 2 3 Grassland converted to settlements	N2O	0.18	0	100	100	0.6	0	100	100	0	238.29	0
4 E 2 5 Other Land converted to settlements	CO2	10.01	0	50	50	21.14	0	50	50	0	111.16	0
4 E 2 5 Other Land converted to settlements	N2O	0.76	0	100	100	1.6	0	100	100	0	111.16	0
4 F 2 Land Converted to Other Land	CO2	224.65	0	66.61	66.61	-5.78	0	28.24	28.24	0	-102.57	0
4 F Other Land	N2O	0.07	0	100	100	0.76	0	100	100	0	1026.56	0
4 G Total HWP from domestic harvest	CO2	-5006.61	0	25.74	25.74	-8391.68	0	30.43	30.43	0.4013	67.61	1.282
4 Nitrogen Leaching and Run-off	N2O	6.83	0	73.38	73.38	1.01	0	72.51	72.51	0	-85.24	0
5 A 1 Managed waste disposal sites	CH4	3846.51	40	50	64.03	509.09	25	50	55.9	0.005	-86.76	0.013
5 B 1 Composting	CH4	7.95	0	30.4	30.4	37.05	0	30.4	30.4	0	366.3	0
5 B 1 Composting	N2O	4.51	0	50.2	50.2	21.04	0	50.2	50.2	0	366.3	0
5 B 2 Anaerobic Digestion at Biogas Facilities	CH4	0.3	5	25	25.5	40.09	5	25	25.5	0	13172.18	0

Table A7.1. Approach 1, uncertainty, incl LULUCF

IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
5 C 1 Waste Incineration	CH4	0.01	10	10	14.14	0.01	10	10	14.14	0	6.02	0
5 C 1 Waste Incineration	CO2	43.85	10	10	14.14	111.22	10	10	14.14	0	153.61	0
5 C 1 Waste Incineration	N2O	0.88	10	100	100.5	4.79	10	100	100.5	0	445.84	0
5 D 1 Domestic wastewater	CH4	41.81	0	44.91	44.91	36.11	0	41.53	41.53	0	-13.62	0
5 D 1 Domestic wastewater	N2O	200.65	0	47.13	47.13	184.93	0	49	49	0.0005	-7.83	0.001
1 A 1 a Public Electricity and Heat Production: Biomass	CH4	4.2	1.5	29.95	29.99	41.1	1.53	30.67	30.71	0	879.64	0
1 A 1 a Public Electricity and Heat Production: Biomass	N2O	10.83	1.5	29.95	29.99	94.8	1.52	30.4	30.44	0.0001	775.51	0
1 A 1 a Public Electricity and Heat Production: Gaseous Fuels	CH4	0.24	1.79	17.87	17.96	C	1.78	17.84	17.93	C	C	C
1 A 1 a Public Electricity and Heat Production: Gaseous Fuels	CO2	485.58	1.79	4.47	4.81	C	1.78	4.46	4.8	C	C	C
1 A 1 a Public Electricity and Heat Production: Gaseous Fuels	N2O	0.23	1.79	17.87	17.96	C	1.78	17.84	17.93	C	C	C
Total		**19873.51**				**4031.66**			**192.32**	**100.00**	**-79.71**	**30.023**

Table A7.2. Approach 1 uncertainty assessment for national total emissions in 2022 and in base year (1990), excluding LULUCF.

Table A7.2. Approach 1, uncertainty, incl LULUCF **IPCC Source Category**	**Substance**	**Base year emissions or removals (kt CO_2-eq)**	**Activity data uncertainty in Baseyear (%)**	**Emission factor uncertainty in Baseyear (%)**	**Combined uncertainty in Baseyear (%)**	**Year 2022 emissions or removals (kt CO_2-eq)**	**Activity data uncertainty in 2022 (%)**	**Emission factor uncertainty in 2022 (%)**	**Combined uncertainty in 2022 (%)**	**Contribution to variance in 2022 (%)**	**Inventory trend for 2022 with respect to base year (%)**	**Uncertainty introduced into the trend (%)**
1 A 1 a Public Electricity and Heat Production: Biomass	CH4	4.20	1.50	29.95	29.99	41.10	1.53	30.67	30.71	0.01	879.64	0.000
1 A 1 a Public Electricity and Heat Production: Biomass	N2O	10.83	1.50	29.95	29.99	94.80	1.52	30.40	30.44	0.04	775.51	0.000
1 A 1 a Public Electricity and Heat Production: Gaseous Fuels	CH4	0.24	1.79	17.87	17.96	C	1.78	17.84	17.93	0.00	C	C
1 A 1 a Public Electricity and Heat Production: Gaseous Fuels	CO2	485.58	1.79	4.47	4.81	C	1.78	4.46	4.80	0.00	C	C
1 A 1 a Public Electricity and Heat Production: Gaseous Fuels	N2O	0.23	1.79	17.87	17.96	C	1.78	17.84	17.93	0.00	C	C
1 A 1 a Public Electricity and Heat Production: Liquid Fuels	CH4	0.40	1.67	33.41	33.45	C	1.20	24.09	24.12	0.00	C	C
1 A 1 a Public Electricity and Heat Production: Liquid Fuels	CO2	1277.00	1.68	1.68	2.38	C	1.20	1.20	1.70	0.00	C	C
1 A 1 a Public Electricity and Heat Production: Liquid Fuels	N2O	2.47	1.70	170.04	170.05	C	1.20	110.90	110.91	0.00	C	C
1 A 1 a Public Electricity and Heat Production: Peat	CH4	3.37	5.46	39.01	39.39	0.31	1.95	38.91	38.96	0.00	-90.67	0.000
1 A 1 a Public Electricity and Heat Production: Peat	CO2	1150.05	5.46	15.60	16.53	107.26	1.95	19.46	19.55	0.02	-90.67	0.000
1 A 1 a Public Electricity and Heat Production: Peat	N2O	28.97	5.46	31.21	31.68	1.35	1.95	38.91	38.96	0.00	-95.34	0.000
1 A 1 a Public Electricity and Heat Production: Solid Fuels	CH4	1.01	1.55	54.29	54.32	0.18	1.91	28.62	28.68	0.00	-81.99	0.000
1 A 1 a Public Electricity and Heat Production: Solid Fuels	CO2	4230.90	1.34	6.71	6.84	1609.68	1.94	9.72	9.91	1.25	-61.95	0.000
1 A 1 a Public Electricity and Heat Production: Solid Fuels	N2O	36.39	1.90	18.98	19.08	0.24	1.48	14.83	14.91	0.00	-99.33	0.000
1 A 1 a Public Electricity and Heat Production:Other Fuels	CH4	2.36	1.68	20.26	20.32	10.16	1.11	24.61	24.64	0.00	330.69	0.000
1 A 1 a Public Electricity and Heat Production:Other Fuels	CO2	524.33	1.53	19.96	20.02	3101.18	1.56	15.58	15.65	11.54	491.45	0.004
1 A 1 a Public Electricity and Heat Production:Other Fuels	N2O	19.08	1.06	21.15	21.17	76.90	1.11	22.18	22.21	0.01	303.03	0.000
1 A 1 b Petroleum refining: Gaseous Fuels	CH4	0.00				C	2.00	20.00	20.10	0.00	C	C

Table A7.2. Approach 1, uncertainty, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 1 b Petroleum refining: Gaseous Fuels	CO2	0.00				C	2.00	5.00	5.39	0.00	C	C
1 A 1 b Petroleum refining: Gaseous Fuels	N2O	0.00				C	2.00	20.00	20.10	0.00	C	C
1 A 1 b Petroleum refining: Liquid Fuels	CH4	0.80	10.00	100.00	100.50	C	10.00	100.00	100.50	0.01	C	C
1 A 1 b Petroleum refining: Liquid Fuels	CO2	1777.89	10.00	5.00	11.18	C	10.00	5.00	11.18	3.83	C	C
1 A 1 b Petroleum refining: Liquid Fuels	N2O	1.21	10.00	80.00	80.62	C	10.00	80.00	80.62	0.00	C	C
1 A 1 c Manufacture of Solid fuels and Other Energy Industries: Solid Fuels	CH4	0.12	5.00	20.00	20.62	0.12	5.00	20.00	20.62	0.00	-2.54	0.000
1 A 1 c Manufacture of Solid fuels and Other Energy Industries: Solid Fuels	CO2	300.32	5.00	5.00	7.07	372.36	5.00	5.00	7.07	0.03	23.99	0.000
1 A 1 c Manufacture of Solid fuels and Other Energy Industries: Solid Fuels	N2O	0.12	5.00	20.00	20.62	0.11	5.00	20.00	20.62	0.00	-2.54	0.000
1 A 2 a Iron and Steel: Biomass	CH4	0.00	10.00	100.00	100.50	0.01	5.00	40.00	40.31	0.00	505.58	0.000
1 A 2 a Iron and Steel: Biomass	N2O	0.00	10.00	100.00	100.50	0.01	5.00	40.00	40.31	0.00	505.58	0.000
1 A 2 a Iron and Steel: Gaseous Fuels	CH4	0.01	5.00	20.00	20.62	0.07	5.00	20.00	20.62	0.00	494.16	0.000
1 A 2 a Iron and Steel: Gaseous Fuels	CO2	25.21	5.00	5.00	7.07	150.22	5.00	5.00	7.07	0.01	495.93	0.000
1 A 2 a Iron and Steel: Gaseous Fuels	N2O	0.01	5.00	20.00	20.62	0.07	5.00	20.00	20.62	0.00	494.16	0.000
1 A 2 a Iron and Steel: Liquid Fuels	CH4	0.30	5.00	30.00	30.41	0.22	5.00	20.00	20.62	0.00	-25.33	0.000
1 A 2 a Iron and Steel: Liquid Fuels	CO2	830.77	5.00	5.00	7.07	555.19	5.00	5.00	7.07	0.08	-33.17	0.000
1 A 2 a Iron and Steel: Liquid Fuels	N2O	1.12	5.00	50.00	50.25	0.40	5.00	50.00	50.25	0.00	-64.08	0.000

Table A7.2. Approach 1, uncertainty, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 2 a Iron and Steel: Other Fuels	CH4	0.00				0.01	10.00	100.00	100.50	0.00		0.000
1 A 2 a Iron and Steel: Other Fuels	CO2	0.00				1.18	10.00	100.00	100.50	0.00		0.000
1 A 2 a Iron and Steel: Other Fuels	N2O	0.00				0.01	10.00	100.00	100.50	0.00		0.000
1 A 2 a Iron and Steel: Solid Fuels	CH4	0.11	2.88	19.21	19.42	0.09	2.00	20.00	20.10	0.00	-24.77	0.000
1 A 2 a Iron and Steel: Solid Fuels	CO2	849.67	2.95	4.92	5.74	616.69	2.00	5.00	5.39	0.05	-27.42	0.000
1 A 2 a Iron and Steel: Solid Fuels	N2O	0.15	2.26	15.07	15.24	0.08	2.00	20.00	20.10	0.00	-46.37	0.000
1 A 2 b Non-ferrous metals: Gaseous Fuels	CH4	0.01	5.00	20.00	20.62	0.01	5.00	20.00	20.62	0.00	52.82	0.000
1 A 2 b Non-ferrous metals: Gaseous Fuels	CO2	10.44	5.00	5.00	7.07	15.90	5.00	5.00	7.07	0.00	52.22	0.000
1 A 2 b Non-ferrous metals: Gaseous Fuels	N2O	0.00	5.00	20.00	20.62	0.01	5.00	20.00	20.62	0.00	52.82	0.000
1 A 2 b Non-ferrous metals: Liquid Fuels	CH4	0.04	5.00	30.00	30.41	0.03	5.00	20.00	20.62	0.00	-17.32	0.000
1 A 2 b Non-ferrous metals: Liquid Fuels	CO2	109.86	5.00	5.00	7.07	83.26	5.00	5.00	7.07	0.00	-24.21	0.000
1 A 2 b Non-ferrous metals: Liquid Fuels	N2O	0.16	5.00	50.00	50.25	0.09	5.00	50.00	50.25	0.00	-43.27	0.000
1 A 2 b Non-ferrous metals: Solid Fuels	CH4	0.01	10.00	100.00	100.50	0.00					-100.00	
1 A 2 b Non-ferrous metals: Solid Fuels	CO2	8.48	10.00	100.00	100.50	0.00					-100.00	
1 A 2 b Non-ferrous metals: Solid Fuels	N2O	0.01	10.00	100.00	100.50	0.00					-100.00	
1 A 2 c Chemicals: Biomass	CH4	0.18	5.00	40.00	40.31	C	5.00	40.00	40.31	0.00	C	C
1 A 2 c Chemicals: Biomass	N2O	0.76	5.00	40.00	40.31	1.33	5.00	40.00	40.31	0.00	73.87	0.000
1 A 2 c Chemicals: Gaseous Fuels	CH4	0.08	5.00	20.00	20.62	C	5.00	20.00	20.62	0.00	C	C
1 A 2 c Chemicals: Gaseous Fuels	CO2	154.61	5.00	5.00	7.07	C	5.00	5.00	7.07	0.00	C	C

Table A7.2. Approach 1, uncertainty, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 2 c Chemicals: Gaseous Fuels	N2O	0.07	5.00	20.00	20.62	0.04	5.00	20.00	20.62	0.00	-50.39	0.000
1 A 2 c Chemicals: Liquid Fuels	CH4	0.18	5.00	30.00	30.41	C	5.00	20.00	20.62	0.00	C	C
1 A 2 c Chemicals: Liquid Fuels	CO2	424.22	5.00	20.00	20.62	C	5.00	5.00	7.07	0.02	C	C
1 A 2 c Chemicals: Liquid Fuels	N2O	0.66	5.00	50.00	50.25	0.28	5.00	50.00	50.25	0.00	-57.96	0.000
1 A 2 c Chemicals: Other Fuels	CH4	0.02	10.00	100.00	100.50	C	10.00	100.00	100.50	0.00	C	C
1 A 2 c Chemicals: Other Fuels	CO2	2.83	10.00	100.00	100.50	C	10.00	100.00	100.50	0.03	C	C
1 A 2 c Chemicals: Other Fuels	N2O	0.03	10.00	100.00	100.50	C	10.00	100.00	100.50	0.00	C	C
1 A 2 c Chemicals: Solid Fuels	CH4	0.03	4.00	20.00	20.40	C	2.00	40.00	40.05	0.00	C	C
1 A 2 c Chemicals: Solid Fuels	CO2	100.86	4.00	5.00	6.40	C	2.00	5.00	5.39	0.00	C	C
1 A 2 c Chemicals: Solid Fuels	N2O	0.43	4.00	40.00	40.20	C	2.00	40.00	40.05	0.00	C	C
1 A 2 d Pulp, Paper and Print: Biomass	CH4	11.70	2.00	40.00	40.05	12.79	8.00	40.00	40.79	0.00	9.30	0.000
1 A 2 d Pulp, Paper and Print: Biomass	N2O	50.58	2.00	40.00	40.05	53.63	8.00	40.00	40.79	0.02	6.03	0.000
1 A 2 d Pulp, Paper and Print: Gaseous Fuels	CH4	0.03	2.00	20.00	20.10	0.02	5.00	20.00	20.62	0.00	-48.88	0.000
1 A 2 d Pulp, Paper and Print: Gaseous Fuels	CO2	65.91	2.00	5.00	5.39	33.61	5.00	5.00	7.07	0.00	-49.01	0.000
1 A 2 d Pulp, Paper and Print: Gaseous Fuels	N2O	0.03	2.00	20.00	20.10	0.02	5.00	20.00	20.62	0.00	-48.88	0.000
1 A 2 d Pulp, Paper and Print: Liquid Fuels	CH4	0.55	2.00	40.00	40.05	0.18	5.00	30.00	30.41	0.00	-66.39	0.000
1 A 2 d Pulp, Paper and Print: Liquid Fuels	CO2	1785.65	2.00	5.00	5.39	545.33	5.00	5.00	7.07	0.07	-69.46	0.000
1 A 2 d Pulp, Paper and Print: Liquid Fuels	N2O	3.58	2.00	50.00	50.04	0.91	5.00	50.00	50.25	0.00	-74.68	0.000
1 A 2 d Pulp, Paper and Print: Other Fuels	CH4	0.29	10.00	40.00	41.23	0.20	10.00	100.00	100.50	0.00	-30.01	0.000

Table A7.2. Approach 1, uncertainty, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 2 d Pulp, Paper and Print: Other Fuels	CO2	39.64	10.00	100.00	100.50	57.75	10.00	100.00	100.50	0.16	45.70	0.000
1 A 2 d Pulp, Paper and Print: Other Fuels	N2O	0.37	10.00	100.00	100.50	0.31	10.00	100.00	100.50	0.00	-15.66	0.000
1 A 2 d Pulp, Paper and Print: Solid Fuels	CH4	0.14	5.00	20.00	20.62	0.00	7.00	40.00	40.61	0.00	-99.11	0.000
1 A 2 d Pulp, Paper and Print: Solid Fuels	CO2	264.58	5.00	5.00	7.07	4.29	7.00	5.00	8.60	0.00	-98.38	0.000
1 A 2 d Pulp, Paper and Print: Solid Fuels	N2O	1.66	5.00	40.00	40.31	0.02	7.00	40.00	40.61	0.00	-98.89	0.000
1 A 2 e Food Processing, Beverages and Tobacco: Biomass	CH4	0.08	5.00	100.00	100.12	0.53	5.00	40.00	40.31	0.00	589.66	0.000
1 A 2 e Food Processing, Beverages and Tobacco: Biomass	N2O	0.24	5.00	40.00	40.31	1.71	5.00	40.00	40.31	0.00	603.94	0.000
1 A 2 e Food Processing, Beverages and Tobacco: Gaseous Fuels	CH4	0.13	5.00	20.00	20.62	0.06	5.00	20.00	20.62	0.00	-48.52	0.000
1 A 2 e Food Processing, Beverages and Tobacco: Gaseous Fuels	CO2	253.80	5.00	5.00	7.07	130.15	5.00	5.00	7.07	0.00	-48.72	0.000
1 A 2 e Food Processing, Beverages and Tobacco: Gaseous Fuels	N2O	0.12	5.00	20.00	20.62	0.06	5.00	20.00	20.62	0.00	-48.52	0.000
1 A 2 e Food Processing, Beverages and Tobacco: Liquid Fuels	CH4	0.19	5.00	40.00	40.31	0.04	5.00	30.00	30.41	0.00	-79.42	0.000
1 A 2 e Food Processing, Beverages and Tobacco: Liquid Fuels	CO2	596.36	5.00	5.00	7.07	102.32	5.00	5.00	7.07	0.00	-82.84	0.000
1 A 2 e Food Processing, Beverages and Tobacco: Liquid Fuels	N2O	1.15	5.00	50.00	50.25	0.12	5.00	50.00	50.25	0.00	-89.33	0.000
1 A 2 e Food Processing, Beverages and Tobacco: Other Fuels	CH4	0.03	10.00	40.00	41.23	0.00	10.00	100.00	100.50	0.00	-87.07	0.000
1 A 2 e Food Processing, Beverages and Tobacco: Other Fuels	CO2	4.61	10.00	100.00	100.50	0.48	10.00	100.00	100.50	0.00	-89.60	0.000
1 A 2 e Food Processing, Beverages and Tobacco: Other Fuels	N2O	0.04	10.00	100.00	100.50	0.00	10.00	100.00	100.50	0.00	-90.23	0.000
1 A 2 e Food Processing, Beverages and Tobacco: Solid Fuels	CH4	0.03	5.00	20.00	20.62	0.00	5.00	20.00	20.62	0.00	-88.10	0.000
1 A 2 e Food Processing, Beverages and Tobacco: Solid Fuels	CO2	90.65	5.00	5.00	7.07	12.29	5.00	5.00	7.07	0.00	-86.44	0.000
1 A 2 e Food Processing, Beverages and Tobacco: Solid Fuels	N2O	0.38	5.00	40.00	40.31	0.05	5.00	40.00	40.31	0.00	-88.10	0.000

Table A7.2. Approach 1, uncertainty, incl LULUCF

IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 2 f Non-metallic minerals: Biomass	CH4	0.03	4.92	49.21	49.46	C	4.72	47.16	47.40	0.00	C	C
1 A 2 f Non-metallic minerals: Biomass	N2O	0.11	4.98	59.79	59.99	C	4.32	51.81	51.99	0.00	C	C
1 A 2 f Non-metallic minerals: Gaseous Fuels	CH4	0.03	5.36	7.09	8.89	C	4.06	7.37	8.41	0.00	C	C
1 A 2 f Non-metallic minerals: Gaseous Fuels	CO2	65.28	5.36	2.13	5.77	C	4.06	2.21	4.62	0.00	C	C
1 A 2 f Non-metallic minerals: Gaseous Fuels	N2O	0.03	5.36	7.09	8.89	0.05	4.06	7.37	8.41	0.00	68.20	0.000
1 A 2 f Non-metallic minerals: Liquid Fuels	CH4	0.22	4.66	12.03	12.91	C	8.24	16.76	18.68	0.00	C	C
1 A 2 f Non-metallic minerals: Liquid Fuels	CO2	625.45	4.56	1.20	4.71	C	8.55	0.86	8.59	0.02	C	C
1 A 2 f Non-metallic minerals: Liquid Fuels	N2O	1.07	4.82	12.16	13.08	0.68	9.47	18.96	21.20	0.00	-36.87	0.000
1 A 2 f Non-metallic minerals: Other Fuels	CH4	0.00				C	10.00	50.00	50.99	0.00	C	C
1 A 2 f Non-metallic minerals: Other Fuels	CO2	0.00				C	10.00	60.00	60.83	0.92	C	C
1 A 2 f Non-metallic minerals: Other Fuels	N2O	0.00				C	10.00	60.00	60.83	0.00	C	C
1 A 2 f Non-metallic minerals: Solid Fuels	CH4	0.35	8.45	8.54	12.01	0.13	8.48	8.58	12.06	0.00	-61.75	0.000
1 A 2 f Non-metallic minerals: Solid Fuels	CO2	1141.51	8.34	1.69	8.51	C	8.26	1.68	8.43	0.07	C	C
1 A 2 f Non-metallic minerals: Solid Fuels	N2O	4.89	8.52	17.20	19.20	C	8.39	17.02	18.98	0.00	C	C
1 A 2 g vii Off-road vehicles and other machinery: Liquid Fuels	CH4	2.13	2.91	35.36	35.48	0.90	2.76	35.65	35.76	0.00	-57.70	0.000
1 A 2 g vii Off-road vehicles and other machinery: Liquid Fuels	CO2	987.32	4.88	3.90	6.25	1114.02	4.91	3.93	6.28	0.24	12.83	0.000
1 A 2 g vii Off-road vehicles and other machinery: Liquid Fuels	N2O	11.19	4.96	49.57	49.81	19.27	4.97	49.75	50.00	0.00	72.22	0.000
1 A 2 g vii Off-road vehicles and other machinery: Other Fossil Fuels	CO2	0.00				4.66	5.00	10.00	11.18	0.00		0.000

Table A7.2. Approach 1, uncertainty, incl LULUCF **IPCC Source Category**	**Substance**	**Base year emissions or removals (kt CO_2-eq)**	**Activity data uncertainty in Baseyear (%)**	**Emission factor uncertainty in Baseyear (%)**	**Combined uncertainty in Baseyear (%)**	**Year 2022 emissions or removals (kt CO_2-eq)**	**Activity data uncertainty in 2022 (%)**	**Emission factor uncertainty in 2022 (%)**	**Combined uncertainty in 2022 (%)**	**Contribution to variance in 2022 (%)**	**Inventory trend for 2022 with respect to base year (%)**	**Uncertainty introduced into the trend (%)**
1 A 2 g viii Other: Biomass	CH4	7.37	4.90	39.22	39.53	C	4.48	35.86	36.14	0.00	C	C
1 A 2 g viii Other: Biomass	N2O	31.67	4.91	39.26	39.57	C	4.62	36.97	37.26	0.00	C	C
1 A 2 g viii Other: Gaseous Fuels	CH4	0.06	2.92	5.85	6.54	0.02	2.97	5.94	6.64	0.00	-69.73	0.000
1 A 2 g viii Other: Gaseous Fuels	CO2	113.11	2.92	1.17	3.15	C	2.97	1.19	3.20	0.00	C	C
1 A 2 g viii Other: Gaseous Fuels	N2O	0.05	2.92	5.85	6.54	0.02	2.97	5.94	6.64	0.00	-69.73	0.000
1 A 2 g viii Other: Liquid Fuels	CH4	0.87	2.28	4.56	5.10	0.22	2.85	5.71	6.38	0.00	-74.98	0.000
1 A 2 g viii Other: Liquid Fuels	CO2	2061.61	1.97	0.75	2.11	595.19	3.07	0.61	3.13	0.02	-71.13	0.000
1 A 2 g viii Other: Liquid Fuels	N2O	3.96	2.00	3.99	4.46	1.09	3.46	6.92	7.74	0.00	-72.39	0.000
1 A 2 g viii Other: Other Fuels	CH4	0.00				C	5.00	40.00	40.31	0.00	C	C
1 A 2 g viii Other: Other Fuels	CO2	0.00				3.32	5.00	40.00	40.31	0.00		0.000
1 A 2 g viii Other: Other Fuels	N2O	0.00				0.03	5.00	40.00	40.31	0.00		0.000
1 A 2 g viii Other: Solid Fuels	CH4	0.04	2.73	5.46	6.11	C	4.82	9.63	10.77	0.00	C	C
1 A 2 g viii Other: Solid Fuels	CO2	98.42	3.33	3.33	4.71	C	4.61	0.92	4.70	0.01	C	C
1 A 2 g viii Other: Solid Fuels	N2O	0.34	3.51	7.02	7.85	C	4.65	18.61	19.18	0.00	C	C
1 A 3 a Domestic Aviation: Aviation Gasoline	CH4	0.01	10.00	10.00	14.14	0.00	10.00	10.00	14.14	0.00	-93.03	0.000
1 A 3 a Domestic Aviation: Aviation Gasoline	CO2	14.91	7.91	3.95	8.84	2.39	8.21	4.10	9.17	0.00	-83.97	0.000
1 A 3 a Domestic Aviation: Aviation Gasoline	N2O	0.28	7.35	147.09	147.28	0.03	7.07	141.47	141.65	0.00	-87.55	0.000
1 A 3 a Domestic Aviation: Biomass	CH4	0.00				0.00	10.00	10.00	14.14	0.00		0.000
1 A 3 a Domestic Aviation: Biomass	N2O	0.00				0.01	7.07	141.47	141.65	0.00		0.000

Table A7.2. Approach 1, uncertainty, incl LULUCF

IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 3 a Domestic Aviation: Jet Kerosene	CH4	0.61	10.00	10.00	14.14	0.12	10.00	10.00	14.14	0.00	-80.28	0.000
1 A 3 a Domestic Aviation: Jet Kerosene	CO2	658.13	7.91	3.95	8.84	298.64	8.21	4.10	9.17	0.04	-54.62	0.000
1 A 3 a Domestic Aviation: Jet Kerosene	N2O	11.91	7.35	147.09	147.28	4.20	7.07	141.47	141.65	0.00	-64.78	0.000
1 A 3 b i Road Transportation, Cars: Biomass	CH4	0.00				1.08	3.54	141.46	141.51	0.00		0.000
1 A 3 b i Road Transportation, Cars: Biomass	CO2	0.00				4.12	5.00	10.00	11.18	0.00		0.000
1 A 3 b i Road Transportation, Cars: Biomass	N2O	0.00				0.33	4.01	160.35	160.40	0.00		0.000
1 A 3 b i Road Transportation, Cars: Diesel oil	CH4	0.44	4.99	44.93	45.21	5.99	4.99	44.95	45.22	0.00	1263.98	0.000
1 A 3 b i Road Transportation, Cars: Diesel oil	CO2	524.25	4.99	4.99	7.06	3148.10	4.99	1.01	5.09	1.26	500.50	0.001
1 A 3 b i Road Transportation, Cars: Diesel oil	N2O	0.13	8.24	65.98	66.49	61.14	4.99	64.83	65.02	0.08	48554.44	0.000
1 A 3 b i Road Transportation, Cars: Fossil part of biodiesel and biogasoline	CO2	0.00				16.46	4.99	9.97	11.15	0.00		0.000
1 A 3 b i Road Transportation, Cars: Gasoline	CH4	160.96	3.00	40.00	40.11	8.79	3.00	39.79	39.90	0.00	-94.54	0.000
1 A 3 b i Road Transportation, Cars: Gasoline	CO2	11993.59	3.00	4.00	5.00	5047.98	3.00	3.99	4.99	3.10	-57.91	0.001
1 A 3 b i Road Transportation, Cars: Gasoline	N2O	118.23	3.00	59.96	60.04	6.18	4.16	58.48	58.62	0.00	-94.77	0.000
1 A 3 b i Road Transportation, Cars: LPG	CH4	0.01	5.00	65.00	65.19	0.00					-100.00	
1 A 3 b i Road Transportation, Cars: LPG	CO2	0.31	5.00	5.00	7.07	0.00					-100.00	
1 A 3 b i Road Transportation, Cars: LPG	N2O	0.00	5.00	65.00	65.19	0.00					-100.00	
1 A 3 b ii Road Transportation, Light duty trucks: Biomass	CH4	0.00				0.01	5.00	200.00	200.06	0.00		0.000
1 A 3 b ii Road Transportation, Light duty trucks: Biomass	N2O	0.00				0.00	5.00	200.00	200.06	0.00		0.000

Table A7.2. Approach 1, uncertainty, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 3 b ii Road Transportation, Light duty trucks: Diesel oil	CH4	0.06	5.00	45.00	45.28	1.88	5.00	45.00	45.28	0.00	2964.43	0.000
1 A 3 b ii Road Transportation, Light duty trucks: Diesel oil	CO2	173.72	5.00	5.00	7.07	1208.80	5.00	1.00	5.10	0.19	595.83	0.000
1 A 3 b ii Road Transportation, Light duty trucks: Diesel oil	N2O	0.02	5.00	65.00	65.19	20.19	5.00	65.00	65.19	0.01	88184.32	0.000
1 A 3 b ii Road Transportation, Light duty trucks: Fossil part of biodiesel and biogasoline	CO2	0.00				5.19	5.00	10.00	11.18	0.00		0.000
1 A 3 b ii Road Transportation, Light duty trucks: Gaseous Fuels	CH4	0.00				0.03	5.00	200.00	200.06	0.00		0.000
1 A 3 b ii Road Transportation, Light duty trucks: Gaseous Fuels	CO2	0.00				0.82	5.00	10.00	11.18	0.00		0.000
1 A 3 b ii Road Transportation, Light duty trucks: Gaseous Fuels	N2O	0.00				0.01	5.00	200.00	200.06	0.00		0.000
1 A 3 b ii Road Transportation, Light duty trucks: Gasoline	CH4	10.14	3.00	40.00	40.11	0.22	3.00	40.00	40.11	0.00	-97.81	0.000
1 A 3 b ii Road Transportation, Light duty trucks: Gasoline	CO2	833.91	3.00	4.00	5.00	85.04	3.00	4.00	5.00	0.00	-89.80	0.000
1 A 3 b ii Road Transportation, Light duty trucks: Gasoline	N2O	6.69	3.00	60.00	60.07	0.30	3.00	60.00	60.07	0.00	-95.46	0.000
1 A 3 b iii Road Transportation, Heavy duty trucks: Biomass	CH4	0.01	5.00	200.00	200.06	0.11	4.85	68.19	68.36	0.00	1046.61	0.000
1 A 3 b iii Road Transportation, Heavy duty trucks: Biomass	CO2	0.00				0.90	5.00	10.00	11.18	0.00		0.000
1 A 3 b iii Road Transportation, Heavy duty trucks: Biomass	N2O	0.13	5.00	200.00	200.06	3.34	4.21	168.49	168.54	0.00	2550.82	0.000
1 A 3 b iii Road Transportation, Heavy duty trucks: Diesel oil	CH4	3.59	3.84	65.68	65.79	0.14	4.38	47.32	47.52	0.00	-96.04	0.000
1 A 3 b iii Road Transportation, Heavy duty trucks: Diesel oil	CO2	3820.09	4.14	4.47	6.10	2789.51	4.76	0.95	4.86	0.90	-26.98	0.001
1 A 3 b iii Road Transportation, Heavy duty trucks: Diesel oil	N2O	12.35	4.08	66.41	66.53	68.17	4.51	61.84	62.00	0.09	452.05	0.000
1 A 3 b iii Road Transportation, Heavy duty trucks: Fossil part of biodiesel and biogasoline	CO2	0.00				20.07	3.56	7.12	7.97	0.00		0.000

Table A7.2. Approach 1, uncertainty, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 3 b iii Road Transportation, Heavy duty trucks: Gaseous Fuels	CH4	0.19	2.58	55.63	55.69	1.65	4.93	49.34	49.59	0.00	764.00	0.000
1 A 3 b iii Road Transportation, Heavy duty trucks: Gaseous Fuels	CO2	21.90	2.69	3.71	4.58	9.20	3.70	7.28	8.17	0.00	-57.99	0.000
1 A 3 b iii Road Transportation, Heavy duty trucks: Gaseous Fuels	N2O	0.10	2.66	84.53	84.57	0.10	4.53	180.20	180.26	0.00	-2.27	0.000
1 A 3 b iii Road Transportation, Heavy duty trucks: LNG	CH4	0.00				0.24	5.00	15.00	15.81	0.00		0.000
1 A 3 b iii Road Transportation, Heavy duty trucks: LNG	CO2	0.00				2.71	5.00	10.00	11.18	0.00		0.000
1 A 3 b iv Road Transportation, Motorcycles: Fossil part of biodiesel and biogasoline	CO2	0.00				0.05	5.00	10.00	11.18	0.00		0.000
1 A 3 b iv Road Transportation, Motorcycles: Gasoline	CH4	2.38	3.00	40.00	40.11	2.67	3.00	40.00	40.11	0.00	12.33	0.000
1 A 3 b iv Road Transportation, Motorcycles: Gasoline	CO2	39.15	3.00	4.00	5.00	81.74	3.00	4.00	5.00	0.00	108.78	0.000
1 A 3 b iv Road Transportation, Motorcycles: Gasoline	N2O	0.17	3.00	60.00	60.07	0.38	3.00	60.00	60.07	0.00	117.13	0.000
1 A 3 c Railways: Liquid Fuels	CH4	0.16	5.00	150.00	150.08	0.07	5.00	150.00	150.08	0.00	-58.12	0.000
1 A 3 c Railways: Liquid Fuels	CO2	102.94	5.00	5.00	7.07	41.29	5.00	5.00	7.07	0.00	-59.89	0.000
1 A 3 c Railways: Liquid Fuels	N2O	0.21	5.00	200.00	200.06	0.09	5.00	200.00	200.06	0.00	-58.12	0.000
1 A 3 d Domestic Navigation: Biomass	CH4	0.00				0.00	5.00	50.00	50.25	0.00		0.000
1 A 3 d Domestic Navigation: Biomass	N2O	0.00				0.37	5.00	50.00	50.25	0.00		0.000
1 A 3 d Domestic Navigation: Gas/Diesel Oil	CH4	3.13	4.97	198.62	198.68	3.52	4.93	197.28	197.34	0.00	12.39	0.000
1 A 3 d Domestic Navigation: Gas/Diesel Oil	CO2	257.30	2.63	2.45	3.59	438.80	2.75	2.61	3.79	0.01	70.54	0.000
1 A 3 d Domestic Navigation: Gas/Diesel Oil	N2O	3.33	2.91	44.97	45.07	5.33	3.04	49.62	49.71	0.00	59.86	0.000
1 A 3 d Domestic Navigation: Gasoline	CH4	0.00				0.01	5.00	50.00	50.25	0.00		0.000

Table A7.2. Approach 1, uncertainty, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 3 d Domestic Navigation: Gasoline	CO2	0.00				0.38	5.00	5.00	7.07	0.00		0.000
1 A 3 d Domestic Navigation: Gasoline	N2O	0.00				0.00	5.00	50.00	50.25	0.00		0.000
1 A 3 d Domestic Navigation: LNG	CH4	0.00				18.21	10.00	60.00	60.83	0.01		0.000
1 A 3 d Domestic Navigation: LNG	CO2	0.00				52.33	10.00	10.00	14.14	0.00		0.000
1 A 3 d Domestic Navigation: Residual Oil	CH4	0.04	15.00	40.00	42.72	0.03	15.00	40.00	42.72	0.00	-22.68	0.000
1 A 3 d Domestic Navigation: Residual Oil	CO2	195.00	15.00	5.00	15.81	168.04	15.00	5.00	15.81	0.03	-13.82	0.000
1 A 3 d Domestic Navigation: Residual Oil	N2O	2.57	15.00	40.00	42.72	2.07	15.00	40.00	42.72	0.00	-19.51	0.000
1 A 3 e Other Transportation: Biomass	CH4	0.00				0.00	5.00	50.00	50.25	0.00		0.000
1 A 3 e Other Transportation: Biomass	N2O	0.00				0.00	5.00	50.00	50.25	0.00		0.000
1 A 3 e Other Transportation: Gaseous fuels	CH4	0.00	5.00	150.00	150.08	0.00	5.00	150.00	150.08	0.00	41.02	0.000
1 A 3 e Other Transportation: Gaseous fuels	CO2	1.68	5.00	5.00	7.07	2.33	5.00	5.00	7.07	0.00	38.33	0.000
1 A 3 e Other Transportation: Gaseous fuels	N2O	0.00	5.00	1000.00	1000.01	0.00	5.00	1000.00	1000.01	0.00	41.02	0.000
1 A 3 e Other Transportation: Other Fossil Fuels	CO2	0.00				0.63	5.00	10.00	11.18	0.00		0.000
1 A 3 e Other Transportation: Total	CH4	1.49	5.00	125.00	125.10	0.17	5.00	125.00	125.10	0.00	-88.30	0.000
1 A 3 e Other Transportation: Total	CO2	1051.53	5.00	5.00	7.07	353.76	5.00	5.00	7.07	0.03	-66.36	0.000
1 A 3 e Other Transportation: Total	N2O	15.60	5.00	125.00	125.10	5.67	5.00	125.00	125.10	0.00	-63.63	0.000
1 A 4 a Commercial/Institutional: Biomass	CH4	1.46	10.00	100.00	100.50	0.27	10.00	100.00	100.50	0.00	-81.38	0.000
1 A 4 a Commercial/Institutional: Biomass	N2O	0.75	10.00	100.00	100.50	1.72	10.00	100.00	100.50	0.00	127.32	0.000

Table A7.2. Approach 1, uncertainty, incl LULUCF

IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 4 a Commercial/Institutional: Gaseous Fuels	CH4	0.04	10.00	20.00	22.36	0.11	10.00	20.00	22.36	0.00	162.18	0.000
1 A 4 a Commercial/Institutional: Gaseous Fuels	CO2	86.09	10.00	5.00	11.18	224.85	10.00	5.00	11.18	0.03	161.19	0.000
1 A 4 a Commercial/Institutional: Gaseous Fuels	N2O	0.04	10.00	20.00	22.36	0.11	10.00	20.00	22.36	0.00	162.18	0.000
1 A 4 a Commercial/Institutional: Gasoline	CH4	3.33	5.00	50.00	50.25	1.35	5.00	50.00	50.25	0.00	-59.41	0.000
1 A 4 a Commercial/Institutional: Gasoline	CO2	78.36	5.00	5.00	7.07	75.04	5.00	5.00	7.07	0.00	-4.24	0.000
1 A 4 a Commercial/Institutional: Gasoline	N2O	0.33	5.00	50.00	50.25	0.36	5.00	50.00	50.25	0.00	7.31	0.000
1 A 4 a Commercial/Institutional: Liquid Fuels	CH4	2.27	18.20	36.67	40.94	0.18	8.68	33.80	34.90	0.00	-92.15	0.000
1 A 4 a Commercial/Institutional: Liquid Fuels	CO2	2612.33	18.74	0.99	18.76	291.10	8.21	3.12	8.79	0.03	-88.86	0.000
1 A 4 a Commercial/Institutional: Liquid Fuels	N2O	7.04	14.50	32.05	35.17	3.30	4.85	47.32	47.57	0.00	-53.17	0.000
1 A 4 a Commercial/Institutional: Other Fossil Fuels	CO2	0.00				0.81	5.00	10.00	11.18	0.00		0.000
1 A 4 b Residential: Biomass	CH4	107.42	10.00	100.00	100.50	54.54	10.00	100.00	100.50	0.15	-49.23	0.000
1 A 4 b Residential: Biomass	N2O	41.57	10.00	100.00	100.50	39.59	10.00	100.00	100.50	0.08	-4.76	0.000
1 A 4 b Residential: Gaseous Fuels	CH4	0.04	10.00	20.00	22.36	0.04	10.00	20.00	22.36	0.00	-12.73	0.000
1 A 4 b Residential: Gaseous Fuels	CO2	86.09	10.00	5.00	11.18	74.86	10.00	5.00	11.18	0.00	-13.04	0.000
1 A 4 b Residential: Gaseous Fuels	N2O	0.04	10.00	20.00	22.36	0.04	10.00	20.00	22.36	0.00	-12.73	0.000
1 A 4 b Residential: Liquid Fuels	CH4	7.89	11.75	27.93	30.30	2.99	3.01	29.08	29.23	0.00	-62.07	0.000
1 A 4 b Residential: Liquid Fuels	CO2	6211.59	19.16	0.97	19.19	366.27	9.19	1.58	9.32	0.06	-94.10	0.000
1 A 4 b Residential: Liquid Fuels	N2O	14.32	17.67	35.57	39.72	1.71	4.42	21.64	22.08	0.00	-88.08	0.000
1 A 4 b Residential: Other Fossil Fuels	CO2	0.00				0.20	5.00	10.00	11.18	0.00		0.000

Table A7.2. Approach 1, uncertainty, incl LULUCF

IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 A 4 c Agriculture/Forestry/Fisheries: Biomass	CH4	5.25	10.00	100.00	100.50	2.15	10.00	100.00	100.50	0.00	-59.06	0.000
1 A 4 c Agriculture/Forestry/Fisheries: Biomass	N2O	2.99	10.00	100.00	100.50	3.55	10.00	100.00	100.50	0.00	18.76	0.000
1 A 4 c Agriculture/Forestry/Fisheries: Domestic Heating Oil	CH4	0.03	15.00	50.00	52.20	0.01	30.00	50.00	58.31	0.00	-58.68	0.000
1 A 4 c Agriculture/Forestry/Fisheries: Domestic Heating Oil	CO2	200.22	15.00	5.00	15.81	82.73	30.00	5.00	30.41	0.03	-58.68	0.000
1 A 4 c Agriculture/Forestry/Fisheries: Domestic Heating Oil	N2O	2.55	15.00	50.00	52.20	1.05	30.00	50.00	58.31	0.00	-58.68	0.000
1 A 4 c Agriculture/Forestry/Fisheries: Fossil part of biodiesel and biogasoline	CO2	0.00				3.02	3.54	7.09	7.92	0.00		0.000
1 A 4 c Agriculture/Forestry/Fisheries: Gaseous Fuels	CH4	0.02	10.00	20.00	22.36	0.00	10.00	20.00	22.36	0.00	-76.47	0.000
1 A 4 c Agriculture/Forestry/Fisheries: Gaseous Fuels	CO2	33.11	10.00	5.00	11.18	7.76	10.00	5.00	11.18	0.00	-76.56	0.000
1 A 4 c Agriculture/Forestry/Fisheries: Gaseous Fuels	N2O	0.02	10.00	20.00	22.36	0.00	10.00	20.00	22.36	0.00	-76.47	0.000
1 A 4 c Agriculture/Forestry/Fisheries: Gasoline	CH4	0.32	4.76	47.57	47.80	0.52	3.58	35.79	35.97	0.00	63.15	0.000
1 A 4 c Agriculture/Forestry/Fisheries: Gasoline	CO2	12.60	4.60	4.60	6.50	32.72	3.59	3.59	5.08	0.00	159.72	0.000
1 A 4 c Agriculture/Forestry/Fisheries: Gasoline	N2O	0.02	3.69	36.88	37.06	0.22	3.54	35.36	35.53	0.00	878.06	0.000
1 A 4 c Agriculture/Forestry/Fisheries: Liquid Fuels	CH4	4.12	2.50	32.50	32.59	3.31	2.80	45.84	45.93	0.00	-19.55	0.000
1 A 4 c Agriculture/Forestry/Fisheries: Liquid Fuels	CO2	1400.47	4.99	2.77	5.71	836.41	3.79	0.63	3.84	0.05	-40.28	0.000
1 A 4 c Agriculture/Forestry/Fisheries: Liquid Fuels	N2O	12.77	3.50	33.73	33.91	12.26	3.50	34.82	34.99	0.00	-3.99	0.000
1 A 4 c Agriculture/Forestry/Fisheries: Solid Fuels	CH4	0.19	10.00	20.00	22.36	0.00					-100.00	
1 A 4 c Agriculture/Forestry/Fisheries: Solid Fuels	CO2	157.08	10.00	3.00	10.44	0.00					-100.00	
1 A 4 c Agriculture/Forestry/Fisheries: Solid Fuels	N2O	0.68	10.00	40.00	41.23	0.00					-100.00	

Table A7.2. Approach 1, uncertainty, incl LULUCF

IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
1 B 1 c Fugitive emissions from Solid Fuels	CH4	0.00	70.00	20.00	72.80	0.01	50.00	20.00	53.85	0.00	74.96	0.000
1 B 1 c Fugitive emissions from Solid Fuels	CO2	5.32	70.00	5.00	70.18	11.76	50.00	5.00	50.25	0.00	121.18	0.000
1 B 1 c Fugitive emissions from Solid Fuels	N2O	0.00	70.00	20.00	72.80	0.01	50.00	20.00	53.85	0.00	74.96	0.000
1 B 2 a Oil	CH4	13.58	0.10	364.13	364.13	1.23	0.00	50.00	50.00	0.00	-90.96	0.000
1 B 2 a Oil	CO2	254.82	17.06	8.53	19.08	0.00					-100.00	
1 B 2 a Oil	N2O	1.01	18.83	23.57	30.17	0.00					-100.00	
1 B 2 b Natural gas	CH4	75.38	0.00	49.14	49.14	36.52	0.00	47.08	47.08	0.01	-51.55	0.000
1 B 2 b Natural gas	CO2	2.60	0.00	49.98	49.98	0.03	0.00	47.09	47.09	0.00	-98.85	0.000
1 B 2 c Venting and flaring	CH4	0.17	42.29	76.50	87.41	0.02	0.01	49.99	49.99	0.00	-86.86	0.000
1 B 2 c Venting and flaring	CO2	73.48	50.00	30.00	58.31	0.01	49.89	9.98	50.87	0.00	-99.99	0.000
1 B 2 c Venting and flaring	N2O	0.12	50.00	80.00	94.34	0.00	50.00	30.00	58.31	0.00	-100.00	0.000
2 A 1 Cement Production	CO2	1271.95	2.00	5.00	5.39	C	2.00	5.00	5.39	0.20	C	C
2 A 2 Lime Production	CO2	331.60	15.04	4.23	15.63	C	5.05	1.87	5.39	0.03	C	C
2 A 3 Glass Production	CO2	53.50	0.00	7.00	7.00	15.89	0.00	7.00	7.00	0.00	-70.30	0.000
2 A 4 Other	CO2	15.44	5.51	4.01	6.82	5.47	3.37	4.24	5.42	0.00	-64.57	0.000
2 B 10 Other	CH4	0.79	0.00	89.81	89.81	C	0.00	90.12	90.12	0.00	C	C
2 B 10 Other	CO2	514.02	0.00	4.47	4.47	C	0.00	4.12	4.12	0.04	C	C
2 B 10 Other	N2O	18.43	0.00	93.39	93.39	0.74	0.00	119.24	119.24	0.00	-95.98	0.000
2 B 2 Nitric Acid Production	N2O	695.63	2.00	5.00	5.39	5.53	2.00	5.00	5.39	0.00	-99.21	0.000

Table A7.2. Approach 1, uncertainty, incl LULUCF

IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
2 B 5 Carbide production	CO2	67.98	10.00	5.00	11.18	C	10.00	5.00	11.18	0.00	C	C
2 C 1 Iron and Steel Production	CH4	21.04	4.93	24.64	25.13	0.31	4.27	5.15	6.68	0.00	-98.54	0.000
2 C 1 Iron and Steel Production	CO2	2636.63	4.01	4.51	6.04	2520.96	4.24	4.24	6.00	1.12	-4.39	0.000
2 C 2 Ferroalloys production	CH4	0.75	5.00	100.00	100.12	0.00					-100.00	
2 C 2 Ferroalloys production	CO2	227.58	5.00	5.00	7.07	196.72	5.00	5.00	7.07	0.01	-13.56	0.000
2 C 3 Aluminium production	CO2	132.86	2.00	5.00	5.39	174.66	2.00	5.00	5.39	0.00	31.46	0.000
2 C 3 Aluminium production	PFCs	510.94	2.00	30.00	30.07	34.43	2.00	5.00	5.39	0.00	-93.26	0.000
2 C 7 Other	CO2	275.78	6.00	6.00	8.49	257.02	4.00	5.00	6.40	0.01	-6.80	0.000
2 D 1 Lubricant use	CO2	157.87	5.00	50.00	50.25	C	5.00	50.00	50.25	0.53	C	C
2 D 2 Paraffin wax use	CO2	17.73	10.00	50.00	50.99	C	10.00	50.00	50.99	0.01	C	C
2 D 3 Other	CO2	217.39	7.54	12.49	14.59	C	12.67	6.83	14.40	0.02	C	C
2 F 1 Refrigeration and air conditioning	HFCs	4.65	32.14	64.32	71.90	785.82	17.06	34.44	38.44	4.46	16803.63	0.002
2 F 2 Foam blowing agents	HFCs	0.00				10.26	2.00	20.00	20.10	0.00		0.000
2 F 3 Fire protection	HFCs	0.00				0.23	4.67	18.66	19.23	0.00		0.000
2 F 4 Aerosols	HFCs	1.30	50.00	20.00	53.85	14.69	5.00	19.63	20.25	0.00	1030.31	0.000
2 G 1 Electrical equipment	SF6	78.93	9.00	17.99	20.11	34.17	8.65	17.31	19.35	0.00	-56.70	0.000
2 G 2 SF6 and PFCs from other product use	SF6	2.42	4.88	48.81	49.05	4.36	4.15	49.42	49.60	0.00	79.97	0.000
2 G 3 N2O from product uses	N2O	77.13	10.00	10.00	14.14	65.46	10.00	10.00	14.14	0.00	-15.13	0.000
2 H 1 Pulp and paper	CH4	6.81	6.51	19.53	20.59	C	6.70	20.09	21.18	0.00	C	C

Table A7.2. Approach 1, uncertainty, incl LULUCF

IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
2 H 1 Pulp and paper	CO2	0.59	5.62	4.01	6.90	C	7.00	5.00	8.60	0.00	C	C
2 H 1 Pulp and paper	N2O	56.62	6.44	20.25	21.25	80.34	6.65	19.96	21.04	0.01	41.90	0.000
2 H 3 Other (NFR 2A6)	CO2	18.43	0.00	6.00	6.00	C	0.00	6.00	6.00	0.00	C	C
2.C.4 Magnesium foundry	HFCs	0.00				0.52	0.00	20.00	20.00	0.00		0.000
2.C.4 Magnesium foundry	SF6	23.50	0.00	71.80	71.80	0.00					-100.00	
3 A 1 Dairy cattle	CH4	1810.70	5.00	20.00	20.62	1240.85	5.00	20.00	20.62	3.20	-31.47	0.000
3 A 1 Non-dairy cattle	CH4	1418.93	5.00	25.00	25.50	1619.62	5.00	25.00	25.50	8.34	14.14	0.001
3 A 2 Sheep	CH4	102.31	5.00	40.00	40.31	128.50	5.00	40.00	40.31	0.13	25.60	0.000
3 A 4 Goats	CH4	1.39	5.00	40.00	40.31	4.01	5.00	40.00	40.31	0.00	188.84	0.000
3 A 4 Horses	CH4	159.06	5.00	40.00	40.31	179.17	5.00	40.00	40.31	0.26	12.64	0.000
3 A 4 Raindeer	CH4	88.62	5.00	40.00	40.31	84.11	5.00	40.00	40.31	0.06	-5.09	0.000
3 A 4 Swine	CH4	99.07	5.00	40.00	40.31	60.74	5.00	40.00	40.31	0.03	-38.69	0.000
3 B 1 Dairy cattle	CH4	105.86	20.00	50.00	53.85	79.58	20.00	50.00	53.85	0.09	-24.83	0.000
3 B 1 Dairy cattle	N2O	93.00	14.90	37.26	40.13	60.67	18.23	45.57	49.08	0.04	-34.76	0.000
3 B 1 Non-dairy cattle	CH4	68.55	20.00	50.00	53.85	125.56	20.00	50.00	53.85	0.22	83.17	0.000
3 B 1 Non-dairy cattle	N2O	63.35	12.18	30.45	32.80	78.52	13.45	33.63	36.22	0.04	23.95	0.000
3 B 3 Swine	CH4	67.13	20.00	50.00	53.85	62.72	20.00	50.00	53.85	0.06	-6.57	0.000
3 B 3 Swine	N2O	37.99	13.04	32.59	35.10	24.05	15.71	39.28	42.31	0.01	-36.68	0.000
3 B 4 Fur-bearing animals	CH4	5.65	20.00	50.00	53.85	2.57	20.00	50.00	53.85	0.00	-54.53	0.000

Table A7.2. Approach 1, uncertainty, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
3 B 4 Fur-bearing animals	N2O	2.84	20.00	50.00	53.85	1.29	20.00	50.00	53.85	0.00	-54.53	0.000
3 B 4 Goats	CH4	0.02	20.00	50.00	53.85	0.06	20.00	50.00	53.85	0.00	188.84	0.000
3 B 4 Goats	N2O	0.04	20.00	50.00	53.85	0.11	20.00	50.00	53.85	0.00	188.84	0.000
3 B 4 Horses	CH4	13.79	20.00	50.00	53.85	15.53	20.00	50.00	53.85	0.00	12.64	0.000
3 B 4 Horses	N2O	21.13	13.37	33.42	35.99	23.80	13.37	33.42	35.99	0.00	12.64	0.000
3 B 4 Poultry	CH4	9.42	15.02	37.54	40.44	15.22	13.84	34.60	37.27	0.00	61.60	0.000
3 B 4 Poultry	N2O	16.56	13.07	32.68	35.20	26.92	14.10	35.26	37.98	0.01	62.60	0.000
3 B 4 Reindeer	CH4	2.55	20.00	50.00	53.85	2.42	20.00	50.00	53.85	0.00	-5.09	0.000
3 B 4 Sheep	CH4	2.16	20.00	50.00	53.85	2.71	20.00	50.00	53.85	0.00	25.60	0.000
3 B 4 Sheep	N2O	2.36	20.00	50.00	53.85	3.85	20.00	50.00	53.85	0.00	63.24	0.000
3 B Indirect N2O emissions	N2O	91.63	20.00	400.00	400.50	72.50	20.00	400.00	400.50	4.13	-20.88	0.000
3 D a 1 Inorganic N fertilizers	N2O	934.88	5.00	80.00	80.16	769.78	5.00	80.00	80.16	18.63	-17.66	0.000
3 D a 2 a Animal manure applied to soils	N2O	319.67	5.00	80.00	80.16	285.19	5.00	80.00	80.16	2.56	-10.78	0.000
3 D a 2 b Sewage sludge applied to soils	N2O	4.91	5.00	80.00	80.16	22.01	5.00	80.00	80.16	0.02	347.84	0.000
3 D a 2 c Other organic fertilizers applied to soils	N2O	7.08	5.00	80.00	80.16	44.04	5.00	80.00	80.16	0.06	522.03	0.000
3 D a 3 Urine and dung deposited by grazing animals	N2O	67.26	11.92	148.39	148.86	67.52	12.18	151.53	152.02	0.52	0.39	0.000
3 D a 4 Crop residues applied to soils	N2O	402.38	20.00	80.00	82.46	360.22	20.00	80.00	82.46	4.32	-10.48	0.000
3 D a 5 Mineralization/immobilization associated with loss/gain of soil organic matter	N2O	0.00				72.51	20.00	80.00	82.46	0.17		0.000

Table A7.2. Approach 1, uncertainty, incl LULUCF IPCC Source Category	Substance	Base year emissions or removals (kt CO_2-eq)	Activity data uncertainty in Baseyear (%)	Emission factor uncertainty in Baseyear (%)	Combined uncertainty in Baseyear (%)	Year 2022 emissions or removals (kt CO_2-eq)	Activity data uncertainty in 2022 (%)	Emission factor uncertainty in 2022 (%)	Combined uncertainty in 2022 (%)	Contribution to variance in 2022 (%)	Inventory trend for 2022 with respect to base year (%)	Uncertainty introduced into the trend (%)
3 D a 6 Cultivation of organic soils (i.e. histosols)	N2O	880.73	5.00	85.00	85.15	604.36	5.00	85.00	85.15	12.96	-31.38	0.000
3 D b 1 Atmospheric deposition	N2O	91.46	20.00	400.00	400.50	83.52	20.00	400.00	400.50	5.48	-8.69	0.000
3 D b 2 Nitrogen leaching and run-off	N2O	236.08	20.00	150.00	151.33	166.30	20.00	150.00	151.33	3.10	-29.56	0.000
3 G Liming	CO2	173.40	3.69	7.38	8.25	122.44	4.01	8.01	8.96	0.01	-29.39	0.000
3 H Urea application	CO2	4.35	5.00	10.00	11.18	0.09	5.00	10.00	11.18	0.00	-97.91	0.000
5 A 1 Managed waste disposal sites	CH4	3846.51	40.00	50.00	64.03	509.09	25.00	50.00	55.90	3.96	-86.76	0.019
5 B 1 Composting	CH4	7.95	0.00	30.40	30.40	37.05	0.00	30.40	30.40	0.01	366.30	0.000
5 B 1 Composting	N2O	4.51	0.00	50.20	50.20	21.04	0.00	50.20	50.20	0.01	366.30	0.000
5 B 2 Anaerobic Digestion at Biogas Facilities	CH4	0.30	5.00	25.00	25.50	40.09	5.00	25.00	25.50	0.01	13172.18	0.000
5 C 1 Waste Incineration	CH4	0.01	10.00	10.00	14.14	0.01	10.00	10.00	14.14	0.00	6.02	0.000
5 C 1 Waste Incineration	CO2	43.85	10.00	10.00	14.14	111.22	10.00	10.00	14.14	0.01	153.61	0.000
5 C 1 Waste Incineration	N2O	0.88	10.00	100.00	100.50	4.79	10.00	100.00	100.50	0.00	445.84	0.000
5 D 1 Domestic wastewater	CH4	41.81	0.00	44.91	44.91	36.11	0.00	41.53	41.53	0.01	-13.62	0.000
5 D 1 Domestic wastewater	N2O	200.65	0.00	47.13	47.13	184.93	0.00	49.00	49.00	0.40	-7.83	0.000
1 A 1 a Public Electricity and Heat Production: Biomass	CH4	4.20	1.50	29.95	29.99	41.10	1.53	30.67	30.71	0.01	879.64	0.000
1 A 1 a Public Electricity and Heat Production: Biomass	N2O	10.83	1.50	29.95	29.99	94.80	1.52	30.40	30.44	0.04	775.51	0.000
1 A 1 a Public Electricity and Heat Production: Gaseous Fuels	CH4	0.24	1.79	17.87	17.96	C	1.78	17.84	17.93	0.00	C	C
1 A 1 a Public Electricity and Heat Production: Gaseous Fuels	CO2	485.58	1.79	4.47	4.81	C	1.78	4.46	4.80	0.00	C	C
Total		**71263.21**				**45249.27**			**3.16**	**100.00**	**-36.50**	**1.844**

7 Annex 8: Other Annexes

Annex 8:1 Description of the Emission Trading Scheme and comparison to the national inventory system

Annex 8:2 Normal-year corrected emissions

Annex 8:3 Environmental reports

7.1 Annex 8:1: EU Emissions Trading System in Sweden and comparison to the national inventory

The EU Emissions Trading System (EU ETS) was launched in January 2005. The system is based on the EU ETS Directive[174], which is implemented in Sweden through the Act (2004:1199) and the Ordinance (2004:1205) on Emissions Trading.

From the beginning, EU ETS covered emissions of carbon dioxide from combustion installations and energy intensive industry (mineral oil refineries, coke ovens, iron and steel industry, pulp and paper industry and mineral industry). The scope was extended in 2013 with new greenhouse gases (nitrous oxide and perfluorocarbons) and with some new industrial activities.

Installations subject to EU ETS need a permit to emit greenhouse gases and all emissions have to be monitored and reported according to EU Regulation 601/2012. About half of the allowances are allocated for free based on fully harmonized principles. The rest of the allowances are auctioned. No free allocation is given to electricity production. EU ETS covers in Sweden approximately 750 installations (**Error! Reference source not found.**). The Swedish Environmental Protection Agency is competent authority for permitting, allocation and compliance and enforcement and the Swedish Energy Agency is competent authority for issues concerning the Union Registry.

Table A8:1.1. Swedish installations subject to EU ETS 2022.

Category	Number
Combustion installations – production of electricity and heat	605
Iron and steel industry	21
Chemical industry	15
Food and drink industry	5
Metal industry (excluding iron and steel)	4
Mineral industry (excluding metals)	18
Pulp and paper industry including printing	47
Mineral oil refineries including distribution of oil and gas	5
Other industry	18
Total	**738**

[174] DIRECTIVE 2003/87/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC

7.1.1 Main Activities in the EU ETS

7.1.1.1 COMBUSTION INSTALLATIONS

The majority (about 80%) of the Swedish ETS-installations are combustion installations. The EU ETS directive states that combustion installations with a rated thermal input exceeding 20 MW should be covered by the system. Sweden has also included, by opt-in, all combustion installations that deliver heat to district heating networks with an aggregated installed capacity exceeding 20 MW. This is the main reason for the comparatively large number of installations in the Swedish part of the system.

Co-incineration of municipal waste was included in the system in 2013. Incineration of other kinds of waste, such as industrial waste, has been included since the system was introduced.

7.1.1.2 INDUSTRIAL ACTIVITIES

The scope of EU ETS was extended in 2013 with emissions of nitrous oxide and perfluorocarbons from some specific activities and some new industrial activities. Nitrous oxide is emitted from one installation producing nitric acid and perfluorocarbons from Sweden´s only producer of primary aluminium.

7.1.1.3 AVIATION

International and domestic aviation was included in EU ETS in 2012. But the European Commission adopted, pending a global market-based mechanism addressing international aviation emissions, a temporary exemption for flights to and from third countries until the end of 2016. As a result of the adoption of a resolution by ICAO on a global measure (Corsia), EU has decided to maintain the reduced present scope (intra-EEA flights) from 2017 onwards.

7.1.2 Monitoring and reporting

Emissions in EU ETS shall be monitored and reported according to EU Regulation 601/2012[175]. The regulation is directly valid in all the Member States. Emissions have to be reported yearly, in the end of March the year after the year of emissions. Emission reports shall be verified by an accredited verifier before submitted to EPA by using the ETS Reporting Tool (ERT). The number of tonne of carbon dioxide equivalents is also notified in the Union Registry.

7.1.3 Emissions in the ETS in relation to emissions in the greenhouse gas inventory

In Table A8:1.2 below, emissions 2008-2022 of fossil CO_2 together with N_2O and PFC emissions for 2013-2022 in the ETS and non-ETS, distributed on different CRT categories, are shown. The results are uncertain and should be interpreted

[175] COMMISSION REGULATION (EU) No 601/2012 of 21 June 2012 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council

with caution since the ETS data are sometimes difficult to allocate to CRT categories. Also, ETS data are only partially used within the inventory, so the share of ETS emissions for each CRT category does not mean that ETS emissions are included in the inventory to this extent. The results should be seen as an approximation[176].

[176] Helbig et al. 2022

Table A8:1.2. Emissions of greenhouse gases (kt CO_2 equivalents) in the ETS and non-ETS, second and third trading period 2008 – 2012 and 2013 – 2022.

	Sector	Second trading period (kt CO_2 eq)					Third trading period (kt CO_2 eq)								Fourth trading period (kt CO_2 eq)		Change 08-22	
		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	kt CO_2 eq	
ETS	1.A.1	8 093	8 589	10 893	8 398	7 884	9 352	8 690	8 327	8 895	8 672	9 109	7 634	7 303	8 812	8 222	129	2%
	1.A.2	6 059	4 483	5 630	5 321	4 669	4 547	4 426	4 686	4 442	4 615	4 596	4 605	4 140	4 285	4 034	-2 026	-33%
	1.A.3					524	526	524	511	553	553	530	476	198	192	305		
	1.B	858	863	824	834	836	698	773	822	640	801	825	536	445	9*	12*	-846	-99%
	1 Energy	***15 010***	***13 935***	***17 347***	***14 553***	***13 913***	***15 122***	***14 412***	***14 346***	***14 530***	***14 640***	***15 061***	***13 251***	***12 086***	***13 299***	***12 573***	***-2 437***	***-16%***
	2.A	1 991	1 696	1 898	1 934	2 000	1 918	1 846	1 992	2 009	1 982	2 027	1 756	1 679	1 652	1 617	-374	-19%
	2.B	535	469	635	635	613	756	741	669	781	759	744	723	388	725	C	C	C
	2.C	2 538	1 387	2 772	2 726	2 163	2 852	2 827	2 725	3 100	2 914	2 673	3 621	2 733	2 984	3 183	645	25%
	2.D	0	0	0	0	0	0	0	0	0	0	1	1	1	1	C	C	C
	2.H	7	5	8	7	7	11	10	9	10	12	14	10	10	8	C	C	C
	2 Industrial Processes	***5 070***	***3 557***	***5 314***	***5 301***	***4 783***	***5 536***	***5 424***	***5 394***	***5 899***	***5 666***	***5 460***	***6 112***	***4 810***	***5 370***	***5 389***	***319***	***6%***
	TOTAL	**20 081**	**17 492**	**22 661**	**19 854**	**18 696**	**20 659**	**19 836**	**19 740**	**20 429**	**20 306**	**20 520**	**19 363**	**16 896**	**18 669**	**17 962**	**-2 118**	**-11%**
Total (ETS+ Non-ETS)	1.A.1	10 076	10 466	12 965	10 604	10 206	9 757	8 855	8 647	9 387	9 077	9 524	8 134	7 549	9 077	8 677	-1 398	-14%
	1.A.2	9 011	7 357	8 595	7 954	7 403	7 047	6 877	7 010	6 796	6 702	6 821	6 828	6 174	6 283	6 014	-2 997	-33%
	1.A.3	21 420	21 049	21 145	20 769	19 596	19 134	18 711	18 818	18 115	17 703	17 142	16 864	15 479	15 515	14 002	-7 418	-35%
	1.A.4	3 747	3 489	3 742	3 357	3 142	2 957	2 813	2 716	2 554	2 479	2 297	2 341	2 281	2 312	2 125	-1 622	-43%
	1.A.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	1.B	942	940	895	900	912	764	831	877	694	853	873	583	495	51*	50*	-892	-95%
	1 Energy	***45 196***	***43 302***	***47 342***	***43 585***	***41 260***	***39 659***	***38 087***	***38 068***	***37 546***	***36 813***	***36 657***	***34 749***	***31 978***	***33 239***	***30 868***	***-14 328***	***-32%***
	2.A	1 994	1 698	1 901	1 937	2 003	1 920	1 850	1 994	2 012	1 984	2 030	1 757	1 681	1 656	1 620	-374	-19%
	2.B	937	889	1 066	789	786	899	862	785	915	893	898	933	525	942	C	C	C
	2.C	3 441	1 857	3 455	3 307	2 851	2 863	2 840	2 743	3 121	2 926	2 673	3 633	2 744	2 997	3 185	-256	-7%
	2.D	476	414	442	417	488	495	483	440	450	447	412	372	328	383	C	C	C
	2.F	1 092	1 088	1 067	1 041	1 024	1 015	1 040	1 059	1 077	1 041	986	936	888	849	811	-281	-26%
	2.G	143	141	139	115	112	100	107	116	107	138	113	110	110	108	104	-39	-27%
	2.H	94	87	92	88	92	91	92	90	91	96	98	99	100	98	C	C	C
	2 Industrial Processes	***8 177***	***6 175***	***8 162***	***7 695***	***7 357***	***7 384***	***7 275***	***7 227***	***7 772***	***7 526***	***7 210***	***7 839***	***6 377***	***7 034***	***6 924***	***-1 253***	***-15%***
	3 Agriculture	***6 655***	***6 431***	***6 520***	***6 498***	***6 405***	***6 471***	***6 546***	***6 556***	***6 522***	***6 638***	***6 452***	***6 474***	***6 568***	***6 452***	***6 513***	***-142***	***-2%***
	5 Waste	***2 378***	***2 267***	***2 133***	***2 022***	***1 877***	***1 760***	***1 611***	***1 488***	***1 403***	***1 341***	***1 243***	***1 139***	***1 076***	***999***	***944***	***-1 434***	***-60%***

	TOTAL (excl LULUCF)	**62 406**	**58 174**	**64 157**	**59 800**	**56 900**	**55 274**	**53 519**	**53 340**	**53 243**	**52 318**	**51 563**	**50 201**	**46 000**	**47 733**	**45 388**	**-17 018**	**-27%**
Share ETS of Total	1.A.1	80%	82%	84%	79%	77%	96%	98%	96%	95%	96%	96%	94%	97%	97%	95%		
	1.A.2	67%	61%	66%	67%	63%	65%	64%	67%	65%	69%	67%	67%	67%	68%	67%		
	1.B	91%	92%	92%	93%	92%	91%	93%	94%	92%	94%	94%	92%	90%	18%	24%		
	1 Energy	***33%***	***32%***	***37%***	***33%***	***34%***	***38%***	***38%***	***38%***	***39%***	***40%***	***41%***	***38%***	***38%***	***40%***	***41%***		
	2.A	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%		
	2.B	57%	53%	60%	80%	78%	84%	86%	85%	85%	85%	83%	78%	74%	77%	C		
	2.C	74%	75%	80%	82%	76%	100%	100%	99%	99%	100%	100%	100%	100%	100%	100%		
	2.D	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	C		
	2.H	7%	6%	9%	8%	8%	12%	11%	9%	11%	13%	15%	10%	10%	9%	C		
	2 Industrial Processes	***62%***	***58%***	***65%***	***69%***	***65%***	**75%**	**75%**	**75%**	**76%**	**75%**	**76%**	**78%**	**75%**	**76%**	***78%***		
	TOTAL (excl LULUCF)	**32%**	**30%**	**35%**	**33%**	**33%**	**37%**	**37%**	**37%**	**38%**	**39%**	**40%**	**39%**	**37%**	**39%**	**40%**		

*: Due to confidentiality reasons all refinery emissions for 2021 and 2022 are reported in CRT 1.A.1.B in the GHG inventory.

The trends for emissions of greenhouse gases (expressed as CO_2 equivalents) reported in ETS and reported in the UNFCCC inventory are shown in Figure A8.1 below. Please note that the definition of what emissions are included in the ETS has been broadened in the second and further in the third trading period.

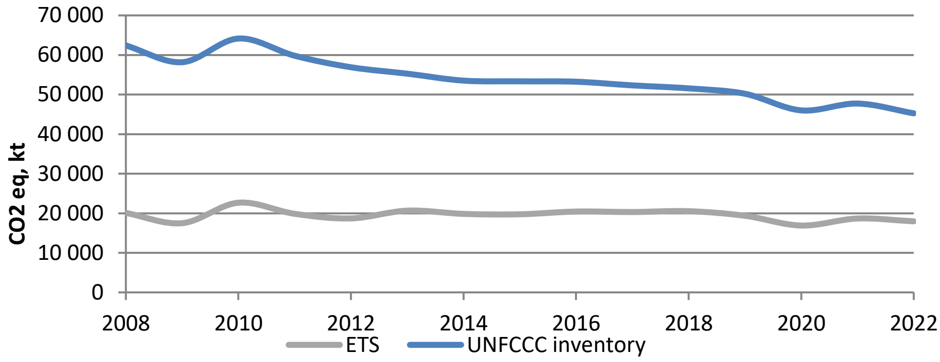

Figure A8.1. Emissions of greenhouse gases in ETS and reported to the UNFCCC 2008 – 2022 (kt CO_2 equivalents). LULUCF not included.

7.1.3.1 COMPARISONS OF DATA IN THE GHG INVENTORY AND EU ETS IN SWEDEN

Ever since the Swedish national allocation plan was prepared in 2004, Sweden has performed a number of studies to compare data in the two systems and improve the greenhouse gas (GHG) inventory[177]. One result of the studies is that for a number of plants in the energy and industrial process sectors, data from the EU ETS is used in the GHG inventory since it is convenient and the quality is considered higher than that from data sources used in earlier submissions.

In Sweden, emissions from the systems need to be compared on plant level and not on a total or sector-based level, since the EU ETS does not cover all plants in the GHG inventory.

During 2008, a study aiming to review and when necessary, update reported process related CO_2 emissions in CRT 2.A, 2.B.5.b, 2.C.1.a and 2.C.1.e was performed. Comparisons of UNFCCC reported CO_2 emissions and EU ETS data were made to secure that all facilities included in the EU ETS were included in the inventory and that all in EU ETS included process related CO_2 emissions were covered by the inventory. The comparison resulted in adjustments of CO_2 emissions reported in 2.A.3, 2.A.4.a, 2.C.1.a and 2.C.1.e. Information in the EU

[177] Nyström, A-K (2007).

Backman, H. and Gustafsson, T. (2006).

Cooper, D. and Nyström, A-K. (2005).

Gustafsson, T., Lidén, M. and Nyström, A-K., (2005).

Ivarsson, A-K., Kumlin, A., Lidén, M. and Olsson, B. (2004).

ETS is however not sufficient enough to be the base for reporting of CO_2 emissions in all CRT 2 sub-sectors. To be able to report correct activity data and corresponding CO_2 emissions to UNFCCC, other sources of information are needed. In the Swedish inventory, information from the facilities' environmental reports, from industry trade associations or by direct contact with the facilities is important for the compilation of the inventory.

7.1.3.2 GENERAL DIFFERENCES

Not all of the plants in the GHG inventory are included in the EU ETS, due to the definitions used in EU ETS. For combustion plants for instance, only installations with a rated thermal input exceeding a certain limit are included in EU ETS, but in the GHG inventory, all plants are included[178].

In the GHG inventory, emissions are separated in energy and industrial process emissions and into different subsectors (CRT codes). In the EU ETS, there is a similar system, but a number of plants that are reported in specific industrial CRT sectors in the GHG inventory are included as a combustion installation in the EU ETS and are hence included in the Energy sector. That is for instance the case for chemical producers and pulp and paper producers. Some technical units in food industry and engineering industry are also included in the EU ETS as combustion plants in the Energy sector.

7.1.3.3 DEFINITIONS OF ENERGY AND INDUSTRIAL PROCESS EMISSIONS

When comparing data with emissions from the use of raw materials, the definitions and the interpretation of the IPCC Guidelines results in different categorization of energy and process related emissions in the two systems.

For instance, emissions from catalytic cracking in oil refineries are reported as process related in the EU ETS, while in the GHG inventory they are reported in the energy sector in the sub-sector fugitive emissions, CRT 1.B. Due to confidentiality reasons, all refinery emissions for 2021 and 2022 are reported in CRT 1.A.1.B in the GHG inventory.

Primary iron and steel works calculate and report their emissions according to a mass balance approach in the EU ETS, whereas in the GHG inventory, emissions are reported in several different sectors (CRT codes) in line with the interpretation of the IPCC guidelines.

[178] For further information of the completeness, see each sector section in the National Inventory Report.

7.1.3.4 DIFFERENCES IN THE ENERGY SECTOR

7.1.3.4.1 Differences on plant level

The quarterly fuel statistics is the main activity data source for emissions from stationary combustion in the Swedish inventory, as described in Annex 2, section 2.1.1. Data is reported quarterly from the plants and might have to be estimated if data is not available. EU ETS data, on the other hand, are reported after the year ends for all sectors and is in addition verified by an independent accredited verification body. Type and amounts of fuels reported to the quarterly fuel statistics from a facility sometimes differ from the corresponding data reported to EU ETS, which leads to differences on plant level.

Plant-level comparisons between EU ETS data and quarterly fuel statistics were made in a SMED study in 2012. The most common reason for differences on plant level was found to be different amounts of fuels reported to the quarterly fuel statistics and EU ETS, respectively. In a few cases, the differences showed to be rather large. This was in turn generally caused by the different definitions of working unit (responding unit in energy statistics) and installation/facility (reporting unit in EU ETS). This means that a working unit reporting to the fuel statistics can include several facilities as defined in EU ETS, or only parts of a facility, i.e. there is not a 1:1 relationship between units in the two data sources. A systematic (but small) difference is diesel oil used for stationary combustion in the vehicle industry, which is reported to the energy statistics but not to EU ETS.[179]

7.1.3.4.2 Different aggregations of microdata in the Energy sector

The reporting unit for the quarterly fuel statistics survey in the heat and electricity sector (CRT 1.A.1.a), is not installation or working unit, but by company and municipality. Identifying energy consumption and emissions for specific plants in that sector is therefore in many cases not possible. Furthermore, some reporting units may include both large combustion installations included in the EU ETS system and smaller installations not included in the EU ETS system, and hence it is currently not possible to specify which fuel consumptions reported to the quarterly fuel statistics that are included in the EU ETS.

7.1.3.4.3 Only parts of plants included in the ETS

Combustion of municipal solid waste was not included in the EU ETS in the two first periods (2005-2007 and 2008-2012), while it is included in the GHG inventory. In the third and fourth periods, fossil CO_2 emissions from plants combusting of municipal solid fuels are included. Due to this, the EU ETS share of emissions in CRT 1A1 is much larger (between 94 - 98%) for the third and fourth periods than in the second period (between 77 - 84%).

[179] Gerner, 2012.

Especially in the first trading period, it was not uncommon that only parts of the installations in a certain facility were included in EU ETS. For instance, the plants with the largest emissions within the Chemical industries sector (CRT 1.A.2.c) were only partly included in the EU ETS in the first trading period.

7.1.3.5 FUEL CLASSIFICATION, EMISSION FACTORS AND NCVS

In the EU ETS, the plants in some cases use plant specific emission factors and NCVs, while in the GHG inventory, NCVs and CO_2 emission factors are in many cases general and yield good estimates on national level. Hence, they are to some extent not representative on plant level.

Another smaller problem in the GHG inventory is that unconventional fuels are grouped together into for instance “other non-specific fuels” which leads to high uncertainties on plant level since the emission factors are not specific for a certain fuel. Besides, some of those unconventional fuels are incorrectly classified. In the EU ETS, some of these fuels are often partly biogenic and should hence be classified as "Other biomass" in the GHG inventory.

7.1.3.6 DIFFERENCES IN THE INDUSTRIAL PROCESS SECTOR

7.1.3.7 ONLY PARTS OF PLANTS INCLUDED IN THE ETS

In the EU ETS, not all activities within a facility may be included. As an example, production of calcium carbide can be mentioned. For carbide production, only the lime producing part of the production of calcium carbide is included (CRT 2.A.2).

7.1.3.7.1 Facilities not included

Some industries, that are important in the GHG inventory, are not covered in the EU ETS. For instance, non-iron metal production and aluminium production were not included before emission year 2013.

7.1.3.8 USE OF ETS DATA IN CRT 1

The use of activity data from ETS in CRT 1 is summarized in Table A8:1.3.

Table A8:1.3. Summary of the use of activity data in CRT 1 from ETS.

Year	CRT	Facilities
2005	1A1b, 1B2C21	Four refineries, including one hydrogen production plant
2006	1A1b, 1A2e, 1B2A1,1B2C21	Four refineries, including two hydrogen production plants, and one sugar production plant
2007	1A1b, 1B2A1, 1B2C21	Five refineries, including two hydrogen production plants.
2008-2020	1A1b, 1A2c, 1A2g, 1B2A1, 1B2C21	Five refineries including two hydrogen production plants, three cement factories and one chemical industry
2021-2022	1A1b, 1A2c, 1A2g	Five refineries including two hydrogen production plants, three cement factories and one chemical industry

For the hydrogen production plants, CO_2 emissions reported in the EU ETS system are used in the GHG inventory. This is also the case for all emissions from combustion and flaring of refinery gas and methane-based gas mixtures in 2008 and later.

7.1.4 References Annex 8:1

Backman, H. and Gustafsson, T. (2006). Verification of activity data within the energy sector for the reporting to the UNFCCC, EU Monitoring Mechanism, CLRTAP and the EU NEC Directive using data from the EU Emission Trading Scheme. SMED report 76:2006..

Cooper, D. and Nyström, A-K. (2005). Use of data from the EU emission trading scheme for reporting to EU Monitoring Mechanism, UNFCCC and CLRTAP. SMED report 74:2005.

Helbig, T., Josefsson Ortiz, C., Danielsson, H. 2022. Särredovisning av utsläpp av fossil CO_2 inom respektive utanför ETS, submission 2023, SMED memorandum 2022.

Gerner, 2012. SMED Report No 127, 2012. Jämförelse av industrins förbränningsutsläpp rapporterade till ETS respektive beräknade till klimatrapporteringen. (Comparison of industrial combustion emissions reported to ETS and calculated in the GHG inventory).

Gustafsson, T., Lidén, M. and Nyström, A-K., (2005). Användning av data från utsläppshandelssystemet för svensk internationell utsläppsrapportering. Delprojekt 1 Underlag till beslut om datakällor för rapporteringarna. SMED report 66:2005.

Ivarsson, A-K., Kumlin, A., Lidén, M. and Olsson, B. (2004). Dataunderlag för Sveriges nationella fördelningsplan I EU:s system för handel med utsläppsrätter. SMED report.

Nyström, A-K (2007). Study of differences in plant data between the Energy Statistics and the EU Emission Trading Scheme. SMED report 78:2007.

7.2 Annex 8.2: Normal-year correction of greenhouse gas emissions

In the UNFCCC Reporting Guidelines on Annual Inventories, Parties are encouraged to give information on application of adjustments as it is regarded as important information in relation to the monitoring of emission and removal trends, and the performance of national policies and measures.

The Swedish weather conditions vary a great deal from year to year. Temperature, solar radiation and wind influence the amount of energy needed to heat buildings in order to maintain normal indoor temperatures. Precipitation affects the quantity of water flowing in watercourses and hence the potential for generating electric energy using hydropower. Hydropower accounts for almost half of all Swedish electricity production.

Sweden has developed a normal-year correction method which makes it possible to adjust actual fossil CO_2-emissions in Sweden for a specific year to the fossil CO_2-emissions which should have taken place in a climatic "normal" year. The method is based on three different models; the first one for electricity production for the years 1990-2008, the second for production of heating for 1990-2008 and the third for production of heating and electricity for 2009-2020.

The two models for 1990-2008 are based on climatic "normal" year period 1991 – 2020. The model used to calculate the need for heating, depending on weather, is described in more detail in Persson (2004)[180] and later further elaborated in detail by Profu (2006)[181]. The second model for normal-year corrections of CO_2 emissions from electricity production, including hydropower and weather information, is described by Holmberg & Axelsson (2006)[182]. The third model for 2009-2021, EPOD [183], calculates the optimal fuel mixture for electricity and heating at a given time-period for a given need of electricity and heating at one of the four geographical areas in Sweden. This model balances energy need and energy supply and minimizes a cost function which leads to that the production type with the lowest operation price is used. The model takes also into account differences in weather conditions at four geographical areas in Sweden. The model estimates the actual energy use and the energy use if the weather conditions were normal. In submission 2022, the EPOD model was revised and improved by using a new "normal" year temperature as average of the temperature between 1991 to

[180] Persson C. Normalårskorrigering av Sveriges utsläpp av fossil CO_2 från uppvärmning. Summary in English. Rapportserie SMED och SMED&SLU, Nr 1. 2004

[181] Normalårskorrigering av fjärrvärmebränslen. Rapport till Naturvårdsverket. Profu AB 2006.

[182] Holmberg J. & Axelsson J. Kortfattad metodbeskrivning – Normalårskorrigering av el. SwedPower. 2006

[183] Metod för normalårskorrigering – av bränsleanvänding inom fjärrvärmeproduktionen -Uppdaterad version. Rapport till Naturvårdsverket. Profu AB i Göteborg 2022.

2020 (before the average of 1965-1991 was used). The new “normal” temperature is warmer than the previous used. This led to that the “true” years were colder relative to the reference and to larger corrections in especially cold years but also for years close to the “normal” year since it is now colder than the normal year and the correction is increased for those years also.

The differences between these estimates are applied on the AD of the GHG-inventory. The reason for using three different methods for estimating the normal-year corrections is because the new model EPOD is a projection model and works better for recent and future years. The methods used for the years 1990 to 2008 are based on earlier methods suitable for those years. There are thus time series consistency problems in using these three models. The three models are however using the same sources to estimate the actual and normal estimated energy use[184]. The normal-year correction of household heating is not included but will be investigated for inclusion in coming submissions.

Actual and normal-year corrected fossil CO_2 emissions caused by production of heating and electricity for 1990-2021 is shown in Figure A8.2. The normal-year corrected emissions are higher than the actual emissions because of warm weather and lower fuel use except for five years (1996, 2010, 2012, 2013 and 2021).

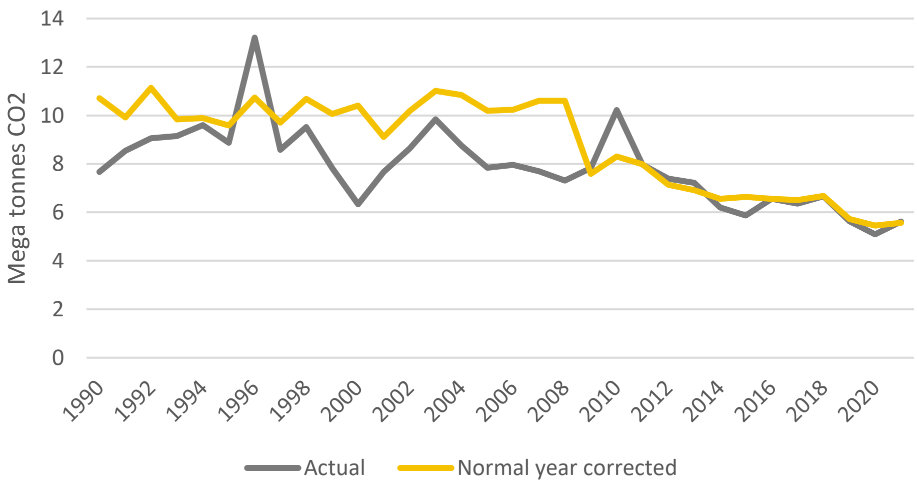

Figure A8.2. Actual and normal year corrected fossil CO_2 emissions for heating of buildings and electricity production in Sweden for the years 1990-2021.

[184] Ortiz C. & Verbova M. Föreslå ny metod för normalårskorrifering. PM SMED. 2019

7.2.1 References Annex 8:2

Persson C. Normalårskorrigering av Sveriges utsläpp av fossil CO_2 från uppvärmning. Summary in English. Rapportserie SMED och SMED&SLU, Nr 1. 2004

Normalårskorrigering av fjärrvärmebränslen. Rapport till Naturvårdsverket. Profu AB 2006.

Holmberg J. & Axelsson J. Kortfattad metodbeskrivning – Normalårskorrigering av el. SwedPower. 2006

Ortiz C. & Verbova M. Föreslå ny metod för normalårskorrifering. PM SMED. 2019

Metod för normalårskorrigering – av bränsleanvänding inom fjärrvärmeproduktionen -Uppdaterad version. Rapport till Naturvårdsverket. Profu AB i Göteborg 2022.

Metodutveckling för normalårskorrigering– av bränsleanvänding inom fjärrvärmeproduktionen. Rapport till Naturvårdsverket. Profu AB i Mölndal 2021.

7.3 Annex 8:3: Environmental reporting system

In Sweden, approximately 6,000 “environmental hazardous activities” must have a permit to operate. Such activities are conducted on a real estate and result, or may result, in discharges or other disturbances to the environment, e.g., water and air pollution or noise. The number includes activities regulated in EC-directives, e.g., under the Industrial Emissions Directive (IED)[185] and Seveso directive[186].

According to Chapter 9 of the Environmental Code (SFS 1998:808)[187] permits must be obtained for the establishment, operation and in some cases modification of environmentally hazardous activities on a certain scale. The structures and operations for which permits must be obtained are covered by two ordinances:

- Ordinance on Environmental Licensing (SFS 2013:251)[188]
- Ordinance on Environmentally Hazardous Activities and the Protection of Public Health (SFS 1998:899)[189]

For permitting procedures the Code divides competence between the regional administrations and the Environmental Courts. Permits are granted by the Environmental Courts and the Environmental Permitting Committees (EPC). The EPC is a special function at the County Administrative Board (CAB). There are 21 EPCs, one in each county, and five Environmental Courts. The allocation of licensing tasks between the EPCs and the Courts is regulated in the Ordinance on Environmental Licensing. For activities that entail a significant environmental impact (classed as A-activities in the list and totalling less than 400), the proponent must apply for a permit to the Court. For activities with less impact on the environment (classed as B-activities in the list and totally around 5,500) the proponent must apply for a permit to the CAB.

Rules on the operator's responsibility for self-monitoring and environmental reports are given in Chapter 26 of the Environmental Code. All operations regulated by permit must return an annual environmental report. All activities and measures that require permission or notification are subject to the Ordinance on Operators’ self-monitoring (SFS 1998:901)[190]. The requirements concerning environmental reports

[185] Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control)

[186] Directive 2003/105/EC of the European Parliament and of the Council of 16 December 2003 amending Council Directive 96/82/EC on the control of major-accident hazards involving dangerous substances.

[187] SFS 1998:808. Miljöbalken

[188] SFS 2013:251, Miljöprövningsförordning

[189] SFS 1998:899, Förordning om miljöfarlig verksamhet och hälsoskydd

[190] SFS 1998:901, Förordning om verksamhetsutövares egenkontrol

are given in the regulation on environmental reports (NFS 2016:8)[191] issued by the Swedish Environmental Protection Agency (Swedish EPA). The environmental report consists of three parts:

- Administrative information about the facility.
- Text section (for example, a description of the facility and the processes, the use of energy, chemicals and raw materials, emissions and conditions in the permit).
- Emission declaration (for example, production data, fuel consumption data, emission data and, information on how emission data have been determined i.e., measured, calculated or estimated).

The data in the environmental reports often originates from measurements or mass balances. The use of default emission factors is limited.

All environmental reports have to be submitted electronically via the Swedish Portal for Environmental Reporting (SMP)[192].

The environmental reporting system is essential to the credibility of the self-monitoring. The authority checks the operator performance, asks for additional measures and monitoring. The operator is obliged to keep themselves informed about the activity's impact on the environment. This is done by initiating studies and measurements, or by other means. The operator should also have routines for responding to new knowledge and new information, e.g. by taking appropriate counter-measures.

7.3.1 References Annex 8:3

Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control). https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:334:0017:0119:en:PDF 2021-12-02

Directive 2003/105/EC of the European Parliament and of the Council of 16 December 2003 amending Council Directive 96/82/EC on the control of major-accident hazards involving dangerous substances. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32003L0105&from=EN 2021-12-02

NFS 2016:8, Naturvårdsverkets föreskrifter om miljörapport. https://www.naturvardsverket.se/lagar-och-regler/foreskrifter-och-allmanna-rad/2016/nfs-20168/ 2021-12-02

[191] NFS 2016:8, Naturvårdsverkets föreskrifter om miljörapport https://www.naturvardsverket.se/Documents/foreskrifter/nfs2016/nfs-2016-8.pdf 2018-12-13

[192] Svenska Miljörapporteringsportalen. https://smp.lansstyrelsen.se

SFS 1998:808. Miljöbalk. https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/miljobalk-1998808_sfs-1998-808 2020-11-25

SFS 2013:251, Miljöprövningsförordning. http://www.riksdagen.se/sv/Dokument-Lagar/Lagar/Svenskforfattningssamling/_sfs-2013-251/ 2014-12-18

SFS 1998:899, Förordning om miljöfarlig verksamhet och hälsoskydd. http://www.riksdagen.se/sv/Dokument-Lagar/Lagar/Svenskforfattningssamling/Miljotillsynsforordning-2011_sfs-1998-899/ 2014-12-18

SFS 1998:901, Förordning om verksamhetsutövares egenkontrol. http://www.riksdagen.se/sv/Dokument-Lagar/Lagar/Svenskforfattningssamling/Forordning-1998901-om-verks_sfs-1998-901/ 2014-12-18

Svenska Miljörapporteringsportalen. https://smp.lansstyrelsen.se 2014-12-18

7.4 Annex 8:4: Global Warming Potentials (100 year time horizon)

Greenhouse gas	GWP
Carbon dioxide (CO_2)	1
Methane (CH_4)	28
Nitrous oxide (N_2O)	265
Hydrofluorocarbons (HFCs)	
HFC-23 (CHF_3)	12 400
HFC-32 (CH_2F_2)	677
HFC-41 (CH_3F)	116
HFC-43-10mee ($CF_3CHFCHFCF_2CF_3$)	1 650
HFC-125 (C_2HF_5)	3 170
HFC-134 ($C_2H_2F_4$ (CHF_2CHF_2))	1 120
HFC-134a ($C_2H_2F_4$ (CH_2FCF_3))	1 300
HFC-143 ($C_2H_3F_3$ (CHF_2CH_2F))	328
HFC-143a ($C_2H_3F_3$ (CF_3CH_3))	4 800
HFC-152 (CH_2FCH_2F)	16
HFC-152a ($C_2H_4F_2$ (CH_3CHF_2))	138
HFC-161 (CH_3CH_2F)	4
HFC-227ea (C_3HF_7)	3 350
HFC-236cb ($CH_2FCF_2CF_3$)	1 210
HFC-236ea (CHF_2CHFCF_3)	1 330
HFC-236fa ($C_3H_2F_6$)	8 060
HFC-245ca ($C_3H_3F_5$)	716
HFC-245fa ($CHF_2CH_2CF_3$)	858
HFC-365mfc ($CH_3CF_2CH_2CF_3$)	804
Perfluorocarbons	
Perfluoromethane – PFC-14 (CF_4)	6 630
Perfluoroethane – PFC-116 (C_2F_6)	11 100
Perfluoropropane – PFC-218 (C_3F_8)	8 900
Perfluorobutane – PFC-3-1-10 (C_4F_{10})	9 200
Perfluorocyclobutane – PFC-318 (c-C_4F_8)	9 540
Perfluouropentane – PFC-4-1-12 (C_5F_{12})	8 550
Perfluorohexane – PFC-5-1-14 (C_6F_{14})	7 910
Perfluorodecalin – PFC-9-1-18b ($C_{10}F_{18}$)	7 190
Perfluorocyclopropanec (c-C_3F_6)	9 200
Sulphur hexafluoride (SF_6)	
Sulphur hexafluoride (SF_6)	23 500
Nitrogen trifluoride (NF_3)	
Nitrogen trifluoride (NF_3)	16 100
Hydrofluoroolefins	
HFO-1234yf ($C_3H_2F_4$)	<1

More chemicals and associated GWP values for the 100 year time horizon can be found at:
https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter08_FINAL.pdf

7.5 Annex 8:5: Reporting of CO_2 uptake in concrete

7.5.1 Introduction

Concrete is the single most important building material in society, and is used for a variety of products, such as houses, bridges, tunnels, roads, and other major and minor construction products, etc. The production of clinker, which is normally the main constituent in cement for concrete, requires high temperature and is therefore very energy intensive. The fuels used globally are mainly coal, oil and pet coke (from oil refining), but also fuels made from residues, such as waste oil, solvents, plastic, and waste tires are used. The latter case represents the situation for Sweden.

In the production of cement, carbon dioxide is formed from the combustion of the fuels needed in the production (cement kiln), ~40%, and also from the calcination of the limestone, ~60%, e.g. according to the schematic reaction below:

$CaCO_3 + \text{heat} \rightarrow CaO + CO_2$

These calcination reactions are not permanent but reversible. This means that CO_2 is absorbed into the concrete by a process referred to as carbonation. In principle, the same amount of CO_2 driven off in the cement kiln can be taken up in the concrete by carbonation. However, the amount of CO_2 that will be taken up by carbonation in reality depends on several factors. The carbonation process is a slow process that can last for many years. The time aspect is thus an important issue. The availability of CO_2 for the concrete is also crucial. The concrete must be exposed to the CO_2 in the air to be able to carbonate. The transport of CO_2 molecules into the concrete is thus also an important factor. For example, if the concrete is crushed after the use phase, the exposed surface will increase, and the carbonation rate will thus increase considerably.

Carbonation in cement and concrete is thus an important aspect to take into account in greenhouse gas emissions and sinks estimations and reporting. The 2006 IPCC guidelines acknowledge that free lime potentially can re-absorb atmospheric CO_2. However, the guidelines does not contain methodologies for calculation of carbonation. This may be considered a shortcoming in these methodologies, which can lead to less accurate results. A rough estimate is that the use of concrete today accounts for about 5% to 7% of the world's carbon dioxide emissions.

Against this background, it is therefore important to find solid methodologies to calculate CO_2 uptake due to carbonation from the use of cement and concrete. The following section represents a first step towards such calculations.

7.5.2 CO_2 uptake calculations in concrete

The chemical mechanisms for CO_2 uptake in concrete and the corresponding calculations of uptake are complex and considerable research exists around this as carbonation also affects the corrosion resistance of the iron reinforcement bars and thus also the durability of many concrete structures. Therefore, only an overview of the calculation methods that are applicable in this case is made here. Reference is made to the IVL report on carbonation (Stripple H. et al., 2018) where many other references are also available for further in-depth study of the topic.

The CO_2 uptake in concrete occurs in the use phase of the concrete product, in waste handling and in secondary use of old concrete. The uptake can be considered as a share of the CO_2 driven off in the calcination. Figure A8.3 illustrates this principle.

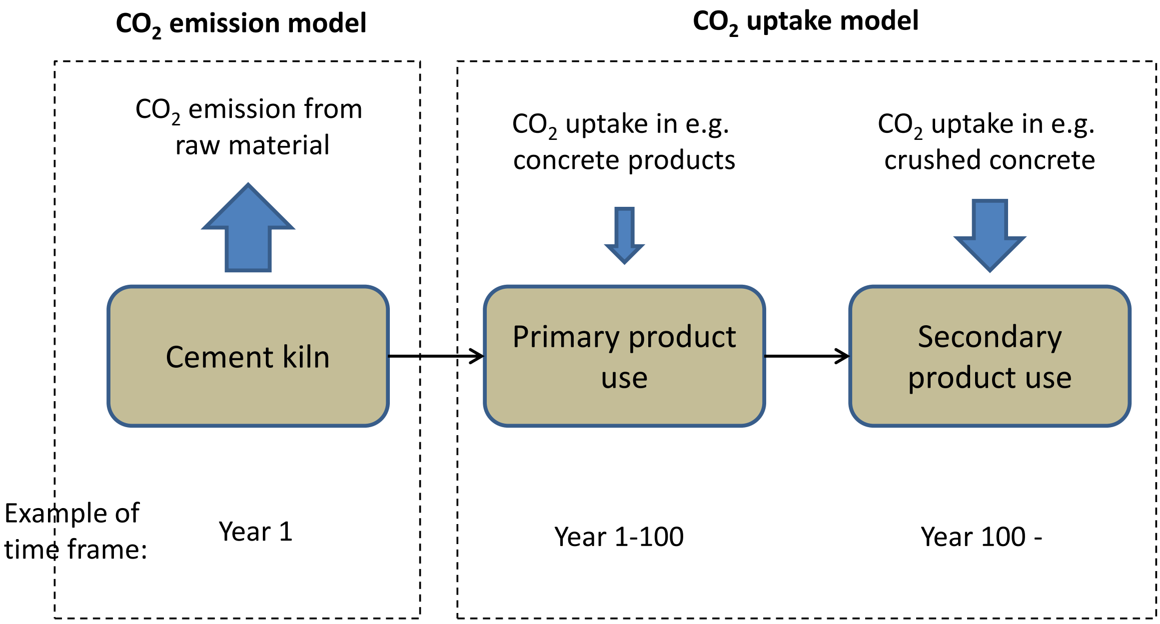

Figure A8.3. Schematic figure showing the CO_2 balance in cement containing products over a certain period of time.

By knowing the total yearly use of cement clinker and its use in different product categories, the CO_2 uptake areas can be estimated. The yearly use of cement clinker in a country can be calculated as (cement clinker production-clinker export+clinker import). From the uptake areas, the yearly CO_2 uptake over the years can be calculated. The calculations can be rather complicated, also taking into account the square-root of time reduction of carbonation rate and the effect of different environment for the concrete surfaces. Different calculation alternatives and simplifications are thus proposed in Stripple et al. (2018). The alternatives are referred to as Tier 1, Tier 2 and Tier 3, where Tier 1 is the simplest of methods and can used as a first approximation. Tier 1 has also been used for the calculations of Sweden's reporting of CO_2 uptake in concrete below.

7.5.2.1 TIER 1 CALCULATION OF CO_2 UPTAKE IN CONCRETE

Use stage

The annual uptake in the use stage can be estimated as 0.20×(the estimated emissions from calcination of annual use of cement clinker).

If the mortar for rendering applications, in total, amount to more than 10% but less than 30% of the cement consumption, the annual uptake factor in the use stage can be estimated at: 0.20 + 0.0115(MR - 10), where MR is the mortar percentage for rendering.

End-of-Life stage and secondary use

Annual uptake in the end-of-life stage and secondary use can be estimated at (0.02 + 0.01)×(the reported emission from calcination of consumed cement clinker)

Alternatively, the following estimation can be done in the end-of-life stage and the secondary use.

- If the annual amount of concrete being taken out of service and processed on a recycling plant is known, the CO_2 uptake in the end-of-life stage can be calculated to 10 kg CO_2/m^3 concrete.
- If the annual amount of crushed concrete, entering the secondary use as unbound material, is known, the uptake can be calculated to 10 kg CO_2/m^3 concrete.

7.5.3 Swedish CO_2 uptake in concrete

Here, Sweden's total annual uptake of CO_2 in concrete was calculated using the Tier 1 method described in the previous section. Calculations have been made for all years from 1990 to 2019. The results from the calculations are presented in Table 1. Table 2 shows the calculation process for the different calculation steps as well as the input data used in the calculations. National statistics data have been used for clinker production in Sweden, CO_2 emissions from the calcination process in clinker production as well as import and export statistics for cement and clinker. These data have a relatively good reliability and CO_2 that is driven off from the raw meal in the clinker production is also well known. This should mean that the calculation basis is good. However, the uncertainties in the assumptions made in the Tier 1 carbonation method, where it is assumed that about 23% of CO_2 from the calcination of used clinker in Sweden carbonates during the use phase of the concrete products or in the end-of-life/secondary use phase, would however be greater. Therefore, it is natural that the Tier 1, which is a simplified calculation method, is subject to some uncertainties.

As shown in the table, the CO_2 uptake varies considerably from year to year. This is a consequence of the calculation method, which is based on the clinker used each year. In reality, the CO_2 uptake is relatively constant because the uptake takes place on the surfaces of all the concrete. The “Share of annual CO_2 calcination emissions in Sweden (%)” is also lower than 23% due to the net export of cement from

Sweden, where emissions from production have been included but the CO_2 uptake takes place outside Sweden.

A comparison with Sweden's total CO_2 emissions and with Sweden's total CO_2 uptake in the LULUCF sector has also been made. As shown in Table 2, the CO_2 uptake in concrete is, in the order of magnitude, below 1% of the total national Swedish CO_2 emissions and also of the CO_2 uptake in the LULUCF sector.

CO_2 uptake in concrete (Tables A8:5.1a, A8:5.1b) is expected to increase in the future due to, for example, increasing amounts of demolition concrete and an actively increased uptake of CO_2 in end-of-life and secondary use of concrete.

Table A8:5.1a. Total Swedish CO_2 uptake in cement-containing products 1990-2019.

Year	Total CO_2 uptake in cement-containing products Tier 1 (ktonne)	Year	Total CO_2 uptake in cement-containing products Tier 1 (ktonne)
1990	267	2005	197
1991	227	2006	222
1992	178	2007	242
1993	153	2008	271
1994	138	2009	192
1995	172	2010	228
1996	151	2011	247
1997	123	2012	252
1998	158	2013	228
1999	168	2014	222
2000	157	2015	240
2001	176	2016	266
2002	154	2017	298
2003	160	2018	304
2004	174	2019	305

Table A8:5.1b. CO_2 uptake calculations for concrete with comparison of uptake in LULUCF sector and total Swedish fossil-based CO_2 emissions.

Year	National clinker production in Sweden (ktonne)	CO2 emissions from clinker calcination process in Sweden (ktonne)	Import cement/clinker (as ktonne clinker)	Export cement/clinker (as ktonne clinker)	Net, import-export clinker (ktonne)	Clinker use in Sweden (ktonne)	Adjusted CO2 calcination emissions based on clinker use in country (ktonne)	Tier 1 CO2 uptake factor, primary use (%)	Uptake of CO2, primary use (ktonne)	Tier 1 CO2 uptake factor, secondary use (%)	Uptake of CO2, secondary use (ktonne)	Tier 1 CO2 uptake factor, end-of-life (%)	Uptake of CO2, end-of-life (ktonne)	Total CO2 uptake in cement-containing products Tier 1 (ktonne)	Share of annual CO2 calcination emissions in Sweden (%)	LULUCF sink, CO2 (ktonne) 1)	Share of LULUCF sink (%)	National total Swedish CO2 emissions (ktonne) 1)	Share of national total Swedish CO2 emissions (%)
1990	2 348	1233	122	262	-140	2208	1159	20	232	1	12	2	23	267	22%	36 236	0.7%	57 349	0.5%
1991	2 099	1102	100	315	-215	1884	989	20	198	1	10	2	20	227	21%	35 332	0.6%	57 707	0.4%
1992	2 007	1054	120	657	-537	1470	772	20	154	1	8	2	15	178	17%	35 172	0.5%	57 451	0.3%
1993	2 011	1056	120	865	-745	1266	665	20	133	1	7	2	13	153	14%	31 095	0.5%	57 493	0.3%
1994	2 043	1073	120	1018	-898	1145	601	20	120	1	6	2	12	138	13%	33 393	0.4%	59 954	0.2%
1995	2 405	1263	120	1101	-981	1424	748	20	150	1	7	2	15	172	14%	36 273	0.5%	59 366	0.3%
1996	2 255	1184	142	1144	-1002	1253	658	20	132	1	7	2	13	151	13%	38 677	0.4%	63 303	0.2%
1997	2 047	1075	148	1172	-1024	1023	537	20	107	1	5	2	11	123	11%	39 378	0.3%	58 213	0.2%
1998	2 105	1105	130	927	-797	1308	687	20	137	1	7	2	14	158	14%	39 980	0.4%	58 697	0.3%
1999	2 116	1111	140	865	-725	1391	730	20	146	1	7	2	15	168	15%	39 324	0.4%	55 820	0.3%
2000	2 389	1254	145	1232	-1087	1302	684	20	137	1	7	2	14	157	13%	41 507	0.4%	54 684	0.3%
2001	2 472	1298	187	1200	-1013	1459	766	20	153	1	8	2	15	176	14%	42 708	0.4%	55 617	0.3%
2002	2 372	1245	189	1281	-1092	1279	672	20	134	1	7	2	13	154	12%	42 296	0.4%	56 573	0.3%
2003	2 235	1173	190	1097	-907	1328	697	20	139	1	7	2	14	160	14%	39 843	0.4%	57 161	0.3%
2004	2 386	1252	205	1148	-943	1442	757	20	151	1	8	2	15	174	14%	33 642	0.5%	56 476	0.3%
2005	2 457	1313	221	1073	-852	1605	858	20	172	1	9	2	17	197	15%	33 916	0.6%	53 853	0.4%
2006	2 660	1439	250	1124	-874	1786	967	20	193	1	10	2	19	222	15%	44 071	0.5%	53 674	0.4%
2007	2 493	1337	285	818	-533	1960	1051	20	210	1	11	2	21	242	18%	42 232	0.6%	52 941	0.5%
2008	2 644	1395	300	713	-413	2231	1177	20	235	1	12	2	24	271	19%	43 149	0.6%	50 856	0.5%
2009	2 336	1260	240	1032	-792	1544	833	20	167	1	8	2	17	192	15%	43 506	0.4%	47 231	0.4%
2010	2 454	1322	348	965	-617	1836	990	20	198	1	10	2	20	228	17%	46 817	0.5%	53 042	0.4%
2011	2 544	1359	419	955	-536	2009	1073	20	215	1	11	2	21	247	18%	45 486	0.5%	49 167	0.5%
2012	2 769	1477	391	1104	-713	2056	1096	20	219	1	11	2	22	252	17%	46 040	0.5%	46 692	0.5%
2013	2 599	1390	404	1150	-746	1853	991	20	198	1	10	2	20	228	16%	44 106	0.5%	45 086	0.5%
2014	2 602	1394	434	1237	-803	1799	964	20	193	1	10	2	19	222	16%	42 667	0.5%	43 338	0.5%
2015	2 826	1524	414	1303	-889	1937	1045	20	209	1	10	2	21	240	16%	43 645	0.6%	43 337	0.6%
2016	2 847	1534	441	1144	-703	2143	1155	20	231	1	12	2	23	266	17%	46 472	0.6%	42 973	0.6%
2017	2 768	1467	462	785	-323	2445	1296	20	259	1	13	2	26	298	20%	44 749	0.7%	42 307	0.7%
2018	2 958	1607	426	951	-525	2433	1322	20	264	1	13	2	26	304	19%	43 740	0.7%	41 766	0.7%
2019	2 539	1 349	584	627	-44	2496	1326	20	265	1	13	2	27	305	23%	1) From submission 2020			

7.5.4 References Annex 8:5

Stripple H. Gustafsson, T. CO_2 uptake in cement-containing products - Background and calculation models for IPCC implementation, IVL report B 2309 (2018).

Stripple, H., Gustafsson, T., Skårman, T. Reporting of CO_2 uptake in concrete – Swedish reporting to the National Inventory Report (NIR) – submission 2020. IVL report C 456 (2019).