DANISH EMISSION INVENTORY FOR INDUSTRIAL PROCESSES

Results of inventories up to 2013

Scientific Report from DCE – Danish Centre for Environment and Energy No. 172 2015

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Data sheet

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Abstract:	This report forms part of the documentation for the emission inventories for industrial processes. The report includes both methodological descriptions for estimating emissions of greenhouse gases and air pollutants and presents the resulting emission data as reported to the United Nations Framework Convention on Climate Change and the United Nations Economic Commission for Europe Convention on Long-Range Transboundary Air Pollution. The results of inventories up to 2013 are included.

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Contents

List of abbreviations

As	Arsenic
BC	Black Carbon
Ca	Calcium
$CaCO_3$	Limestone
CaO	(Burnt) Lime
Cd	Cadmium
CH_4	Methane
CHP	Combined Heat and Power
CKD	Cement Kiln Dust
CLRTAP	Convention on Long-Range Transboundary Air Pollution
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2-eq	CO_2 equivalents, calculated from all GHGs using GWPs
CollectER	Software to support the CORINAIR system
CORINAIR	CORe INventory on AIR emissions
Cr	Chromium
CRF	Common Reporting Format
Cu	Copper
DCE	Danish Centre for Environment and energy
DEA	Danish Energy Agency
DEPA	Danish Environmental Protection Agency
EEA	European Environment Agency
EF	Emission Factor
EMEP	European Monitoring and Evaluation Programme
ENVS	Department of ENVironmental Science, Aarhus University
EU-ETS	European Union Emission Trading Scheme
Gg	Gigagram, 10^9 g
GHG	Greenhouse gas
GWP	Global Warming Potential
HCB	Hexachlorobenzene
HFCs	Hydrofluorocarbons
Hg	Mercury
IE	Included Elsewhere
IEF	Implied Emission Factor
IPCC	Intergovernmental Panel on Climate Change
LKD	Lime Kiln Dust
LPG	Liquefied Petroleum Gas
LRTAP	Long-Range Transboundary Air Pollution
LULUCF	Land Use, Land-Use Change and Forestry
Mg	Megagram, 10^6 g (equals metric ton or tonne)
µg	Microgram, 10^{-6} g
N_2O	Nitrous oxide
NA	Not Applicable
NECD	National Emissions Ceiling Directive
NFR	Nomenclature For Reporting
NH_3	Ammonia
Ni	Nickel
NMVOC	Non-Methane Volatile Organic Compounds
NO	Not Occurring
NO_x	Nitrogen Oxides
Pb	Lead
PCDD/F	PolyChlorinated DibenzoDioxins/Furans
PFCs	Perfluorocarbons
$PM_{2.5}$	Particulate Matter up to 2.5 µm in size

PM_{10}	Particulate Matter up to 10 µm in size
POPs	Persistent Organic Pollutants
QA	Quality Assurance
QC	Quality Control
Se	Selenium
SF_6	Sulphur hexafluoride
SNAP	Selected Nomenclature for Air Pollution
SO_2	Sulphur dioxide
TSP	Total Suspended Particles
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
Zn	Zinc

Preface

DCE - Danish Centre for Environment and Energy, Aarhus University is contracted by the Ministry of the Environment and the Ministry of Climate, Energy and Building to complete emission inventories for Denmark. Department of Environmental Science, Aarhus University is responsible for calculation and reporting of the Danish national emission inventory to EU and the UNFCCC (United Nations Framework Convention on Climate Change) and UNECE CLRTAP (Convention on Long Range Transboundary Air Pollution).

This report forms the documentation of the emission inventories for industrial processes. The report includes both methodological descriptions and emission data. This report contains inventories for the following groups of substances: Greenhouse gasses (CO_2, CH_4, N_2O and F-gasses (HFCs, PFCs, SF_6 and NF_3)), main pollutants (CO, NH_3, NMVOC, NO_x, SO_2), particulate matter (TSP, PM_{10}, $PM_{2.5}$, BC), heavy metals (As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn) and persistent organic pollutants (POPs) (PCDD/F, HCB, PCB and PAHs). The results of inventories up to 2013 are included.

The report is the second version of a sectoral report for industrial processes and has been reviewed externally by Karsten Fuglsang from FORCE Technology. As a result of this review several changes were made to the report; mostly clarifications of the text and tables and elaboration of certain documentation. In addition, suggestions to future improvements have been acknowledged and added to the list of planned improvements, e.g. investigation of particle emissions from the sugar industry and further consideration to the $PM_{2.5}$ emission factor for aluminium smelting.

An updated report will be published in 2017.

Summary

Danish emission inventories are prepared on an annual basis and are reported to the United Nations Framework Convention on Climate Change (UNFCCC or Climate Convention) and to the Kyoto Protocol as well as to the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (LRTAP Convention). Furthermore, a greenhouse gas emission inventory is reported to the European Union (EU) due to the EU – as well as the individual member states – being party to the Climate Convention and the Kyoto Protocol. Inventories also include four pollutants that are estimated for reporting to the European Commission's National Emissions Ceiling Directive (NECD).

The annual Danish emission inventories are prepared by the DCE – Danish Centre for Environment and Energy, Aarhus University. The inventories include the following pollutants relevant to industrial processes: carbon dioxide (CO_2), nitrous oxide (N_2O), hydroflourocarbons (HFCs), perflourocarbons (PFCs), sulphur hexafluoride (SF_6), methane (CH_4), sulphur dioxide (SO_2), nitrogen oxides (NO_x), non-volatile organic compounds (NMVOC), carbon monoxide (CO), particulate matter (PM), ammonia (NH_3), heavy metals (HMs), polyclorinated dibenzodioxins and –furans (PCDD/F), polycyclic aromatic hydrocarbons (PAHs), hexachlorobenzene (HCB) and polychlorinated biphenyls (PCBs). In addition to annual national emissions, the report includes emission data for a number of source categories. Every four years the reporting includes data on the geographical distribution of the emissions, a projection of emissions, data and details of the activity data, e.g. fuel consumption – on which the inventories are based. The next due date is 1 May 2017.

The pollutants listed above correspond to the requirements of the UNFCCC, UNECE and EU to whom the emission inventories are reported. Other pollutants could be relevant for the source categories included in this report for environment impact assessment, but these will fall outside the scope of the emission inventories and will therefore not be included.

The inventories for industrial processes are largely based on official Danish statistics (from Statistics Denmark) and on a set of emission factors for various source categories and technologies. For some source categories the official statistics are supplemented by information from individual plants or from industrial associations. Plant specific emissions for large industrial sources are incorporated into the inventories. This report provides detailed background information on the methodology and references for the input data in the inventory – including activity data and emission factors.

The emission factors are based on either national references or on international guidance documents (EEA, (2004, 2009, 2013); IPCC, (2000, 2006)). The majority of the country-specific emission factors are determined from Danish research reports or calculations based on plant-specific emission data from a considerable number of individual plants. The plant-specific emission factors are provided by plant operators, e.g. in annual environmental reports or in the reports under the EU Emission Trading Scheme (ETS).

Greenhouse gases

An overview of the sources identified is presented in Table 0.1 with an indication of the contribution to the industrial part of the emission of greenhouse gases in 2013. The emissions are extracted from the Common Reporting Format (CRF) tables.

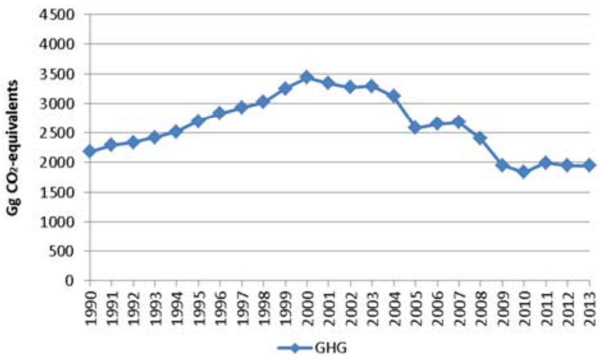
Table 0.1 Overview of industrial greenhouse gas sources (2013).

Process	IPCC Code	Substance	Emission Gg CO_2 eq.	%
Cement production	2A1	CO_2	867.1	45%
Refrigeration and air conditioning	2F1	HFCs, PFCs	711.0	37%
SF_6 from other product use	2G2	SF_6	117.4	6%
Other uses of carbonates	2A4	CO_2	67.2	3%
Foam blowing agents	2F2	HFCs	60.7	3%
Lime production	2A2	CO_2	54.2	3%
Aerosols / Metered dose inhalers	2F4	HFCs	17.7	1%
N_2O from product uses	2G3	N_2O	15.8	1%
Electrical equipment	2G1	SF_6	13.1	1%
Glass production	2A3	CO_2	7.0	0.4%
Other product use	2G4	CO_2, CH_4, N_2O	5.9	0.3%
Other (fibre optics)	2E5	PFCs	3.7	0.2%
Catalysts / fertilisers	2B10	CO_2	1.3	0.1%
Lead production	2C5	CO_2	0.2	0.01%
Iron and steel production	2C1	CO_2	NO	NO
Nitric acid production	2B2	N_2O	NO	NO
Total			1,942.2	100%

NO: Not Occurring

The subsector *Mineral Industry* (2A) constitutes 51 % and *Product Uses as Substitutes for Ozone Depleting Substances (ODS)* (2F) constitutes 41 % of the greenhouse gas emission in 2013 from the *Industrial Processes* sector. *Other Product Manufacture and Use* (2G) constitutes 8 % and the remaining three subsectors *Chemical Industry* (2B), *Metal Industry* (2C) and *Electronics Industry* (2E) each constitutes below 0.2 % of the total industrial process emission of greenhouse gases in 2013. Greenhouse gas emissions from *Metal Industry* (2C) were low in recent years, since the single Danish steel production facility (2C1) was last in operation in 2005. Emissions from *Non-Energy Products from Fuels and Solvent Use* (2D) are not included in this sector report (Fauser, 2010).

The total emission of greenhouse gases (excl. emissions / removals from Land-Use, Land-Use Change and Forestry (LULUCF)) in Denmark in 2013 is estimated to 54.6 Gg CO_2 equivalents, of which industrial processes contribute with 1.94 Gg CO_2 equivalents (3.6 %). The emission of greenhouse gases from industrial processes from 1990-2013 are presented in Figure 0.1.



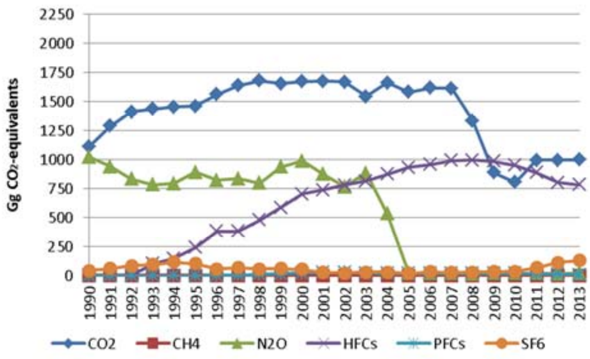


Figure 0.1 Emission of greenhouse gases from industrial processes (CRF Sector 2 excl. 2D solvents) from 1990-2013.

The key categories in the *Industrial Processes* sector - *Cement Production* and *Refrigeration and Air Conditioning* - constitute 1.6 % and 1.3 % respectively of the total national emission of greenhouse gases. The trends in greenhouse gases from the *Industrial Processes* sector / subsectors are presented in Table 0.2 and they will be discussed subsector by subsector below.

Table 0.2 Emission of greenhouse gases from industrial processes.

Year	1990	1995	2000	2005	2010	2011	2012	2013
CO_2 (Gg CO_2)								
A. Mineral Industry	1,078.3	1,417.4	1,627.9	1,564.0	803.7	992.5	993.8	995.4
B. Chemical Industry	0.9	0.9	0.9	1.1	1.1	1.1	1.3	1.3
C. Metal Industry	30.5	38.7	40.9	16.4	0.2	0.2	0.1	0.2
G. Other Product Manufacture and Use	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Total	1,109.7	1,457.1	1,669.9	1,581.7	805.2	994.1	995.5	997.1
CH_4 (Gg CO_2 eq.)								
G. Other Product Manufacture and Use	2.1	2.2	3.0	3.1	2.0	1.8	2.8	2.9
N_2O (Gg CO_2 eq.)								
B. Chemical Industry	1,002.5	868.9	964.7	NO	NO	NO	NO	NO
G. Other Product Manufacture and Use	18.5	20.8	20.9	19.0	19.0	20.8	15.8	18.6
Total	1,021.1	889.7	985.6	19.0	19.0	20.8	15.8	18.6
HFCs (Gg CO_2 eq.)								
E. Electronics Industry	NO	NO	NO	NO	5.3	5.3	1.8	NO
F. Product Uses as Substitutes for Ozone Depleting Substances	NO	242.1	703.1	932.7	944.6	880.1	797.1	782.2
Total	NO	242.1	703.1	932.7	949.9	885.5	798.9	782.2
PFCs (Gg CO_2 eq.)								
E. Electronics Industry	NO	NO	NO	NO	7.3	5.6	3.4	3.7
F. Product Uses as Substitutes for Ozone Depleting Substances	NO	0.6	22.6	18.8	11.4	10.1	8.8	7.1
Total	NO	0.6	22.6	18.8	18.7	15.7	12.2	10.8
SF_6 (Gg CO_2 eq.)								
C. Metal Industry	29.6	34.2	20.3	NO	NO	NO	NO	NO
G. Other Product Manufacture and Use	13.8	68.2	35.8	19.9	35.8	69.4	112.0	130.6
Total	43.4	102.4	56.1	19.9	35.8	69.4[1]	112.0	130.6

[1] The increase in SF_6 emission in 2011-2013 is due to use of SF_6 in windows. The use started in 1991 and there is an expected lifetime of 20 years. At the end of the 20 years lifetime, the SF_6 remaining in the windows is assumed to be emitted.

NO: Not Occurring

The emission of F-gases is documented in the report "Danish consumption and emission of F-gases, Year 2013" (Poulsen, 2015) and will only briefly be described in this report.

Other pollutants

Emissions of air pollution occur in many subsectors under industrial processes. An overview of the emissions of main pollutants (SO_2, NO_x, NMVOC, CO and NH_3) and particulate matter (Total Suspended Particulates (TSP), particles with an aerodynamic diameter of less than 10 µm (PM_{10}) and particles with an aerodynamic diameter of less than 2.5 µm ($PM_{2.5}$)) is shown in Table 0.3 below.

Table 0.3 Emission of main pollutants and particulate matter from industrial processes.

Pollutant	Unit	Sector	1985	1990	1995	2000	2005	2010	2011	2012	2013
SO_2	Gg	2A6 Other mineral products	NE	2.72	2.87	2.76	2.72	1.10	1.25	1.11	1.75
		2B10a Other chemical industry	0.63	0.85	0.62	0.63	0.61	0.12	0.19	0.23	0.18
		2G4 Other product use	0.02	0.03	0.03	0.06	0.06	0.04	0.03	0.05	0.06
		Total	0.65	3.59	3.52	3.45	3.39	1.25	1.48	1.39	1.98
NO_x	Gg	2B2 Nitric acid production	0.63	0.81	0.61	0.41	NO	NO	NO	NO	NO
		2B10a Other chemical industry	0.04	0.04	0.04	0.03	0.03	0.02	0.02	0.02	0.02
		2G4 Other product use	0.04	0.04	0.04	0.06	0.06	0.04	0.04	0.06	0.06
		Total	0.70	0.89	0.69	0.51	0.09	0.06	0.06	0.08	0.08
NMVOC	Gg	2A3 Glass production	IE	0.05	0.05	0.05	0.05	0.03	0.04	0.04	0.04
		2B10a Other chemical industry	0.39	0.39	0.06	0.03	0.03	0.02	0.02	0.02	0.02
		2G4 Other product use	0.08	0.08	0.08	0.10	0.09	0.07	0.06	0.08	0.08
		2H2 Food and beverages industry	4.00	4.04	3.90	3.81	3.98	3.52	3.46	3.44	3.06
		Total	4.48	4.56	4.08	3.99	4.15	3.63	3.58	3.57	3.19
CO	Gg	2A3 Glass production	0.002	0.002	0.002	0.002	0.002	0.001	0.002	0.001	0.001
		2A6 Other mineral products	11.97	11.97	11.93	11.96	12.18	0.01	0.01	0.03	0.01
		2G4 Other product use	1.78	2.29	2.40	3.63	4.08	2.54	2.20	3.70	3.74
		Total	13.76	14.27	14.33	15.59	16.25	2.55	2.21	3.73	3.75
NH_3	Gg	2A3 Glass production	0.22	0.26	0.26	0.23	0.12	0.11	0.11	0.14	0.12
		2A6 Other mineral products	0.30	0.30	0.30	0.29	0.30	0.20	0.19	0.20	0.18
		2B2 Nitric acid production	0.01	0.01	0.06	0.01	NO	NO	NO	NO	NO
		2B10a Other chemical industry	0.01	0.01	0.01	0.01	0.08	0.12	0.02	0.02	0.02
		2G4 Other product use	0.06	0.05	0.05	0.05	0.04	0.04	0.03	0.04	0.04
		2L Other production	NE	0.03	0.03	0.03	0.13	0.09	0.09	0.07	0.06
		Total	0.60	0.66	0.72	0.63	0.67	0.56	0.44	0.47	0.42
TSP	Mg	2A2 Lime production				46.00	35.62	25.20	29.72	34.57	33.40
		2A3 Glass production				137.00	92.00	27.70	43.80	51.50	39.60
		2A6 Other mineral products				71.00	115.00	78.00	77.00	62.00	62.00
		2B2 Nitric acid production				362.00	NO	NO	NO	NO	NO
		2B10a Other chemical industry				19.00	23.00	26.00	6.80	6.00	10.00
		2C1 Iron and steel production				244.40	218.61	148.18	169.64	154.62	157.18
		2C3 Aluminum production				4.41	3.46	0.62	0.75	0.78	0.82
		2C5 Lead production				1.28	1.53	1.44	1.93	1.08	1.27
		2G4 Other product use				412.02	380.40	411.76	361.72	330.73	373.85
		Total				1,297.11	869.62	718.90	691.35	641.27	678.13
PM_{10}	Mg	2A2 Lime production				18.40	14.25	10.08	11.89	13.83	13.36
		2A3 Glass production				123.00	83.30	24.50	39.60	47.00	36.40
		2A6 Other mineral products				63.90	103.50	70.30	69.00	55.60	56.00
		2B2 Nitric acid production				290.00	NO	NO	NO	NO	NO
		2B10a Other chemical industry				15.00	18.00	21.00	5.40	4.80	8.00
		2C1 Iron and steel production				94.02	75.60	46.05	52.52	47.54	48.74
		2C3 Aluminum production				3.09	2.42	0.44	0.53	0.55	0.57
		2C5 Lead production				1.03	1.22	1.15	1.54	0.86	1.02
		2G4 Other product use				315.76	307.36	304.24	267.92	261.67	285.71
		Total				924.19	605.65	477.76	448.40	431.84	449.80
$PM_{2.5}$	Mg	2A2 Lime production				3.68	2.85	2.02	2.38	2.77	2.67
		2A3 Glass production				109.00	73.50	22.30	35.00	41.50	32.30
		2A6 Other mineral products				49.70	80.50	54.76	53.61	43.25	44.00
		2B2 Nitric acid production				217.00	NO	NO	NO	NO	NO
		2B10a Other chemical industry				11.00	14.00	16.00	4.10	3.60	6.00
		2C1 Iron and steel production				32.15	19.66	8.03	9.02	7.94	8.42
		2C3 Aluminum production				1.21	0.95	0.17	0.21	0.21	0.23
		2C5 Lead production				0.51	0.61	0.58	0.77	0.43	0.51
		2G4 Other product use				286.88	285.45	271.99	239.78	240.96	259.26
		Total				711.14	477.52	375.83	344.87	340.65	353.39
BC	Mg	2A2 Lime production				0.02	0.01	0.01	0.01	0.01	0.01

NO: Not occurring, IE: Included elsewhere, NE: Not estimated

Production of nitric acid ceased in Denmark in 2005, which caused a significant decrease in the emissions of NO_x and particulate matter from industrial processes. The CO emission has decreased significantly from the source *Other mineral products*, this is due to a decrease in emissions from the Danish producer of mineral wool caused by the establishment of abatement measures in 2009-2010. In the later years emissions of SO_2 have decreased due to lower production of bricks, tiles and expanded clay products (included in *Other mineral products* (IPCC / CRF Code 2A6)).

The emissions of heavy metals (Arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), selenium (Se) and zinc (Zn)) and persistent organic pollutants (PCDD / F, HCB and PCBs) are shown in the table below.

Table 0.4a Emission of heavy metals and persistent organic pollutants from industrial processes.

Pollutant	Unit	Sector	1990	1995	2000	2005	2010	2011	2012	2013
As	Mg	2A3 Glass production	0.048	0.041	0.052	0.036	0.003	0.003	0.003	0.002
		2C1 Iron and steel production	0.040	0.038	0.040	0.034	0.022	0.025	0.023	0.023
		2C5 Lead production	0.003	0.004	0.003	0.003	0.003	0.004	0.002	0.003
		2G4 Other product use	0.004	0.007	0.010	0.008	0.009	0.008	0.007	0.009
		Total	0.09	0.09	0.10	0.08	0.04	0.04	0.04	0.04
Cd	Mg	2A3 Glass production	0.020	0.017	0.022	0.015	0.001	0.001	0.001	0.001
		2C1 Iron and steel production	0.053	0.035	0.030	0.023	0.012	0.014	0.012	0.013
		2C3 Aluminium production	0.001	0.001	0.001	0.001	0.0002	0.0002	0.0002	0.0002
		2C5 Lead production	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
		2C7c Other metal production	0.004	0.004	0.005	0.005	0.005	0.005	0.005	0.005
		2G4 Other product use	0.001	0.002	0.004	0.003	0.004	0.004	0.003	0.004
		Total	0.08	0.06	0.06	0.05	0.02	0.02	0.02	0.02
Cr	Mg	2A3 Glass production	0.061	0.052	0.066	0.046	0.003	0.004	0.004	0.003
		2C1 Iron and steel production	0.175	0.171	0.112	0.110	0.080	0.092	0.084	0.085
		2G4 Other product use	0.025	0.051	0.080	0.062	0.088	0.077	0.058	0.073
		Total	0.26	0.27	0.26	0.22	0.17	0.17	0.15	0.16
Cu	Mg	2C7c Other metal production	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05
		2G4 Other product use	0.57	1.34	2.16	1.64	2.41	2.10	1.55	1.98
		Total	0.61	1.38	2.21	1.69	2.46	2.15	1.60	2.02
Hg	Mg	2B10a Other chemical industry	0.005	0.005	0.005	0.005	0.001	0.001	0.010	NA
		2C1 Iron and steel production	0.246	0.143	0.063	0.023	0.009	0.009	0.006	0.009
		2G4 Other product use	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001
		Total	0.25	0.15	0.07	0.03	0.01	0.01	0.02	0.01
Ni	Mg	2A3 Glass production	0.039	0.034	0.043	0.030	0.002	0.002	0.002	0.001
		2C1 Iron and steel production	0.89	0.55	0.38	0.27	0.13	0.14	0.12	0.13
		2G4 Other product use	0.04	0.09	0.15	0.11	0.16	0.14	0.11	0.14
		Total	0.97	0.67	0.58	0.41	0.29	0.29	0.23	0.27
Pb	Mg	2A3 Glass production	0.48	0.41	0.33	0.15	0.02	0.03	0.12	0.02
		2C1 Iron and steel production	3.71	2.37	1.40	1.02	0.56	0.64	0.57	0.59
		2C3 Aluminium production	0.005	0.005	0.006	0.004	0.001	0.001	0.001	0.001
		2C5 Lead production	0.34	0.43	0.34	0.40	0.38	0.51	0.28	0.33
		2C7c Other metal production	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07
		2G4 Other product use	2.85	6.64	3.30	2.53	0.04	0.04	0.07	0.07
		Total	7.4	9.9	5.4	4.2	1.1	1.3	1.1	1.1
Se	Mg	2A3 Glass production	0.25	0.21	0.34	0.11	0.02	0.02	0.06	0.02
		2C1 Iron and steel production	0.52	0.45	0.51	0.50	0.36	0.42	0.38	0.39
		2G4 Other product use	0.005	0.005	0.009	0.010	0.005	0.004	0.009	0.009
		Total	0.8	0.7	0.9	0.6	0.4	0.4	0.5	0.4

Table 0.4b Emission of heavy metals and persistent organic pollutants from industrial processes. (Continued)

Pollutant	Unit	Sector	1990	1995	2000	2005	2010	2011	2012	2013
Zn	Mg	2A3 Glass production	0.04	0.03	0.06	0.03	0.03	0.03	0.03	0.00
		2C1 Iron and steel production	12.0	7.0	3.6	1.6	0.5	0.6	0.5	0.5
		2C5 Lead production	0.002	0.003	0.002	0.002	0.002	0.003	0.002	0.002
		2C7c Other Metal production	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6
		2G4 Other product use	0.5	0.9	1.5	1.2	1.5	1.3	1.1	1.4
		Total	13.0	8.5	5.8	3.4	2.7	2.6	2.3	2.5
PAH	Mg	2G4 Other product use	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1
PCDD/F	g	2A2 Lime production	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001
		2A6 Other mineral products	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		2C1 Iron and steel production	12.0	7.5	0.5	0.2	NE	NE	NE	NE
		2C3 Aluminium production	1.1	1.1	1.3	1.0	0.2	0.2	0.2	0.2
		2C5 Lead production	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		2G4 Other product use	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1
		Total	13.3	8.8	2.0	1.4	0.3	0.4	0.4	0.5
HCB	g	2A2 Lime production	1.0	0.8	0.7	0.6	0.4	0.5	0.6	0.5
		2C1 Iron and steel production	1968.2	2297.3	2023.2	804.0	2.9	3.3	3.1	3.1
		2C3 Aluminium production	629.9	649.1	735.3	576.3	104.0	125.2	129.8	136.9
		2C5 Lead production	0.2	0.3	0.2	0.3	0.3	0.4	0.2	0.2
		2G4 Other product use	0.7	0.8	1.3	1.4	0.7	0.6	1.3	1.3
		Total	2,600.0	2,948.3	2,760.8	1,382.6	108.3	130.0	134.9	142.1
PCBs	g	2A2 Lime production	19.2	15.1	13.8	10.7	7.6	8.9	10.4	10.0
		2C1 Iron and steel production	1585.9	1837.1	1628.3	675.0	36.4	41.8	38.2	38.7
		2C3 Aluminium production	107.1	110.3	125.0	98.0	17.7	21.3	22.1	23.3
		2C5 Lead production	5.7	7.3	5.7	6.8	6.4	8.6	4.8	5.7
		2G4 Other product use	1.0	1.1	1.8	2.0	1.0	0.9	1.9	1.9
		Total	1,718.9	1,970.8	1,774.6	792.4	69.1	81.5	77.3	79.5

The closure of the electro steelwork in 2002 with the brief reopening in 2005 as well as the closure of the secondary aluminium plant in 2008 has meant a decrease in emissions of several heavy metal (e.g. Pb, Zn) and POPs (e.g. PCDD/F, HCB and PCBs). Legislation from 2000 and 2007 regulating and eventually forbidding Pb in fireworks has also reduced Pb emissions from *Other product use* substantially.

Sammendrag

De danske emissionsopgørelser udarbejdes og afrapporteres årligt til De Forenede Nationers klimakonvention (UNFCCC) og til Kyotoprotokollen, samt til FN's Økonomiske Kommission for Europas Konvention om Langtransporteret Grænseoverskridende Luftforurening (UNECE LRTAP-konventionen). Ydermere rapporteres de nationale opgørelser af drivhusgasemissioner til EU, da EU, såvel som de enkelte medlemslande, er parter til klimakonventionen samt Kyotoprotokollen. Fire forureningskilder rapporteres til Europakommissionens direktiv om nationale emissionslofter (NECD).

De årlige emissionsopgørelser udarbejdes af DCE – Nationalt Center for Miljø og Energi, Aarhus Universitet. Emissionsopgørelserne inkluderer følgende forureningskomponenter af relevans for industrielle processer: kuldioxid (CO_2), lattergas (N_2O), hydroflourkarboner (HFC), perflourkarboner (PFCer), svovlhexafluorid (SF_6), metan (CH_4), svovldioxid (SO_2), kvælstofoxider (NO_x), andre flygtige organiske forbindelser end metan (NMVOC), kulmonooxid (CO), partikler (PM), ammoniak (NH_3), tungmetaller (HMs), dioxiner og furaner (PCDD/F), polycykliske aromatiske kulbrinter (PAHs), hexachlorbenzen (HCB) and polychlorerede biphenyler (PCBer). Ud over de årlige nationale emissioner indeholder opgørelsen også emissions data for en række kilde kategorier. Hvert fjerde år inkluderer opgørelsen desuden data for den geografiske fordeling af emissioner, en fremskrivning af emissioner, data og detaljer om aktivitets data, f.eks. brændselsforbrug – på hvilke opgørelsen er baseret. Den næste afrapporterings dato for dette er d. 1. maj 2017.

Den ovenstående liste af stoffer svarer til de forpligtigelser Danmark skal efterleve i henhold til UNFCCC, UNECE og EU til hvilke emissionsopgørelserne rapporteres. Andre stoffer kan være relevante for de kildekategorier som er inkluderet i denne rapport, men disse vil ligge uden for opgørelsens formål og vil derfor ikke være inkluderet.

Emissionsopgørelserne for industrielle processer er i vid udstrækning baseret på officielle statistiske oplysninger (fra Danmarks Statistik) kombineret med emissionsfaktorer for forskellige sektorer, processer og teknologier. For nogle sektorer er de officielle statistiske oplysninger suppleret med information direkte fra virksomheder eller brancheorganisationer. Anlægsspecifikke emissioner for større industrielle kilder er indarbejdet i emissionsopgørelsen. Denne rapport beskriver detaljeret de metoder samt inputdata og emissionsfaktorer, der er anvendt i beregningen af emissioner fra industrielle processer.

Emissionsfaktorerne er enten baseret på nationale undersøgelser/målinger eller henviser til internationale retningslinjer, f.eks. EMEP/EEA Guidebook og IPCC Guidelines. Hovedparten af de nationale emissionsfaktorer er baseret på forskningsrapporter eller beregninger baseret på et stort antal målinger på forskellige anlæg. De anlægsspecifikke emissionsfaktorer er tilvejebragt af anlægsejere, f.eks. i forbindelse med udarbejdelsen af grønne regnskaber eller i forbindelse med rapportering under EU's kvotehandelssystem.

Drivhusgasser

En oversigt over relevante kilder er præsenteret i Tabel 0.1 sammen med en indikation af bidraget til den samlede drivhusgasemission fra industrielle processer i 2013.

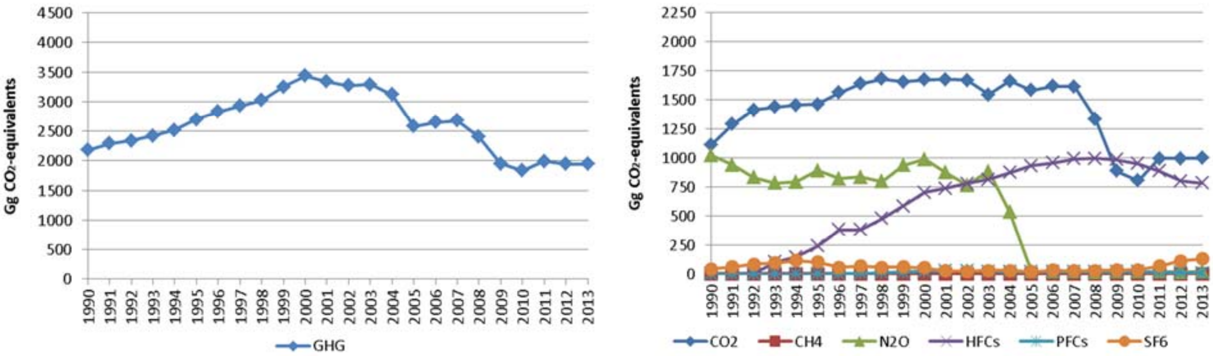
Tabel 0.1 Oversigt over drivhusgas emissionskilder for industrielle processer (2013).

Proces	IPCC kode	Gas	Emission Gg CO_2 ækv.	%
Cement produktion	2A1	CO_2	867,1	45
Køling og aircondition	2F1	HFC, PFCer	711,0	37
SF_6 fra andre produkt anvendelser	2G2	SF_6	117,4	6
Andre anvendelser for karbonater	2A4	CO_2	67,2	3
Opskumning	2F2	HFC	60,7	3
Produktion af brændt kalk	2A2	CO_2	54,2	3
Aerosoler / Dosisinhalatorer	2F4	HFC	17,7	1
N_2O fra andre produkt anvendelser	2G3	N_2O	15,8	1
Elektrisk udstyr	2G1	SF_6	13,1	1
Glas produktion	2A3	CO_2	7,0	0,4
Øvrige produkt anvendelser	2G4	CO_2, CH_4, N_2O	5,9	0,3
Øvrige (fiberoptik)	2E5	PFCer	3,7	0,2
Katalysatorer / gødning	2B10	CO_2	1,3	0,1
Bly produktion	2C5	CO_2	0,2	0,01
Jern og stål produktion	2C1	CO_2	NO	NO
Salpetersyreproduktion	2B2	N_2O	NO	NO
Total			1.942,2	100 %

NO: Forekommer ikke

Samlet udgør mineralsk industri (2A) (cement, tegl, kalk, glas, mv.) 51 % af drivhusgasemissionen i 2013. Produkt anvendelser som erstatning for ozonlagsnedbrydende stoffer (2F) udgør 41 %, andre produkters produktion og anvendelse (2G) udgør 8 % og de resterende tre underkategorier (Kemisk industri (2B), Metal industri (2C) og Elektronisk industri (2E)) udgør hver under 0,2 % af den total drivhusgasemission fra industrielle processer i 2013. Drivhusgasemission fra metal industri har været lav i de seneste år, siden det eneste stålværk i Danmark ikke har været i drift siden 2005. Emissionerne fra Ikke-energi produkter fra brændsel samt solventer (2D) er ikke inkluderet i denne rapport, men kan findes i Fauser (2010).

Den totale drivhusgasemission eksklusive emissioner/optag fra arealanvendelse i 2013 er beregnet til 54,6 Gg CO_2 ækvivalenter, hvoraf industrielle processer bidrager med 1,94 Gg CO_2 ækvivalenter svarende til 3,6 %. Drivhusgasemissionen fra industrielle processer for 1990-2013 er præsenteret i Figur 0.1.



Figur 0.1 Emission af drivhusgasser fra industrielle processer (CRF Sektor 2 uden 2D solventer) for 1990-2013.

De vigtigste kategorier indenfor industrielle processer er cementproduktion samt F-gasser anvendt til køling og aircondition. Disse to kilder udgør henholdsvis 1,6 og 1,3 % af den samlede danske drivhusgasemission. Udviklingen i drivhusgasemissioner fra industrielle processer fordelt på hovedkategorier er præsenteret i Tabel 0.2 nedenfor. Udviklingen er nærmere beskrevet i de enkelte kapitler i rapporten.

Tabel 0.2 Drivhusgas emission fra industrieller processer.

Year	1990	1995	2000	2005	2010	2011	2012	2013
CO_2 (Gg CO_2)								
A. Mineral Industri	1.078,3	1.417,4	1.627,9	1.564,0	803,7	992,5	993,8	995,4
B. Kemisk Industri	0,9	0,9	0,9	1,1	1,1	1,1	1,3	1,3
C. Metal Industri	30,5	38,7	40,9	16,4	0,2	0,2	0,1	0,2
G. Øvrige Produkter Produktion og Anvendelse	0,1	0,1	0,2	0,2	0,2	0,2	0,2	0,2
Total	1.109,7	1.457,1	1.669,9	1.581,7	805,2	994,1	995,5	997,1
CH_4 (Gg CO_2 ækv.)								
G. Øvrige Produkter Produktion og Anvendelse	2,1	2,2	3,0	3,1	2,0	1,8	2,8	2,9
N_2O (Gg CO_2 ækv.)								
B. Kemisk Industri	1.002,5	868,9	964,7	NO	NO	NO	NO	NO
G. Øvrige Produkter Produktion og Anvendelse	18,5	20,8	20,9	19,0	19,0	20,8	15,8	18,6
Total	1.021,1	889,7	985,6	19,0	19,0	20,8	15,8	18,6
HFC (Gg CO_2 ækv.)								
E. Elektronik Industri	NO	NO	NO	NO	5,3	5,3	1,8	NO
F. Produkt Anvendelse som Erstatning for Ozonnedbrydende Stoffer	NO	242,1	703,1	932,7	944,6	880,1	797,1	782,2
Total	NO	242,1	703,1	932,7	949,9	885,5	798,9	782,2
PFCer (Gg CO_2 ækv.)								
E. Elektronik Industri	NO	NO	NO	NO	7,3	5,6	3,4	3,7
F. Produkt Anvendelse som Erstatning for Ozonnedbrydende Stoffer	NO	0,6	22,6	18,8	11,4	10,1	8,8	7,1
Total	NO	0,6	22,6	18,8	18,7	15,7	12,2	10,8
SF_6 (Gg CO_2 ækv.)								
C. Metal Industri	29,6	34,2	20,3	NO	NO	NO	NO	NO
G. Øvrige Produkter Produktion og Anvendelse	13,8	68,2	35,8	19,9	35,8	69,4	112,0	130,6
Total	43,4	102,4	56,1	19,9	35,8	69,4[1]	112,0	130,6

[1] Stigningen i SF_6 emissionen i 2011-2013 skyldes anvendelsen af SF_6 i vinduer. Anvendelsen startede i 1991 og der er en forventet levetid på 20 år. Efter de 20 års levetid, antages det at den resterende mængde SF_6 I vinduerne er udledt.

NO: Forekommer ikke.

Emissionerne af F-gasser er dokumenteret i rapporten " Danish consumption and emission of F-gases, Year 2013" (Poulsen, 2015) og vil kun kortfattet blive beskrevet i denne rapport.

Øvrige luftforurenende stoffer

Emissioner af luftforurening finder sted i mange forskellige underkategorier indenfor industrielle processer. Et overblik af emissionerne af hovedforureningskomponenterne (SO_2, NO_x, NMVOC, CO and NH_3) og partikler ((total støv (TSP), partikler med en diameter under 10 µm (PM_{10}) og partikler med en diameter med en diameter under 2.5 µm ($PM_{2.5}$)) er præsenteret i Tabel 0.3.

Tabel 0.3 Emission af hovedforureningskomponenter og partikler fra industrielle processer.

Gas	Enhed	Sektor	1985	1990	1995	2000	2005	2010	2011	2012	2013
SO_2	Gg	2A6 Øvrige mineralske produkter	NE	2,72	2,87	2,76	2,72	1,10	1,25	1,11	1,75
		2B10a Anden kemisk industri	0,63	0,85	0,62	0,63	0,61	0,12	0,19	0,23	0,18
		2G4 Øvrige produkt anvendelser	0,02	0,03	0,03	0,06	0,06	0,04	0,03	0,05	0,06
		Total	0,65	3,59	3,52	3,45	3,39	1,25	1,48	1,39	1,98
NO_x	Gg	2B2 Salpetersyre produktion	0,63	0,81	0,61	0,41	NO	NO	NO	NO	NO
		2B10a Anden kemisk industri	0,04	0,04	0,04	0,03	0,03	0,02	0,02	0,02	0,02
		2G4 Øvrige produkt anvendelser	0,04	0,04	0,04	0,06	0,06	0,04	0,04	0,06	0,06
		Total	0,70	0,89	0,69	0,51	0,09	0,06	0,06	0,08	0,08
NMVOC	Gg	2A3 Glas produktion	IE	0,05	0,05	0,05	0,05	0,03	0,04	0,04	0,04
		2B10a Anden kemisk industri	0,39	0,39	0,06	0,03	0,03	0,02	0,02	0,02	0,02
		2G4 Øvrige produkt anvendelser	0,08	0,08	0,08	0,10	0,09	0,07	0,06	0,08	0,08
		2H2 Fødevareproduktion	4,00	4,04	3,90	3,81	3,98	3,52	3,46	3,44	3,06
		Total	4,48	4,56	4,08	3,99	4,15	3,63	3,58	3,57	3,19
CO	Gg	2A3 Glas produktion	0,002	0,002	0,002	0,002	0,002	0,001	0,002	0,001	0,001
		2A6 Øvrige mineralske produkter	11,97	11,97	11,93	11,96	12,18	0,01	0,01	0,03	0,01
		2G4 Øvrige produkt anvendelser	1,78	2,29	2,40	3,63	4,08	2,54	2,20	3,70	3,74
		Total	13,76	14,27	14,33	15,59	16,25	2,55	2,21	3,73	3,75
NH_3	Gg	2A3 Glas produktion	0,22	0,26	0,26	0,23	0,12	0,11	0,11	0,14	0,12
		2A6 Øvrige mineralske produkter	0,30	0,30	0,30	0,29	0,30	0,20	0,19	0,20	0,18
		2B2 Salpetersyre produktion	0,01	0,01	0,06	0,01	NO	NO	NO	NO	NO
		2B10a Anden kemisk industri	0,01	0,01	0,01	0,01	0,08	0,12	0,02	0,02	0,02
		2G4 Øvrige produkt anvendelser	0,06	0,05	0,05	0,05	0,04	0,04	0,03	0,04	0,04
		2L Øvrig produktion	NE	0,03	0,03	0,03	0,13	0,09	0,09	0,07	0,06
		Total	0,60	0,66	0,72	0,63	0,67	0,56	0,44	0,47	0,42
TSP	Mg	2A2 Produktion af brændt kalk				46,00	35,62	25,20	29,72	34,57	33,40
		2A3 Glas produktion				137,00	92,00	27,70	43,80	51,50	39,60
		2A6 Øvrige mineralske produkter				71,00	115,00	78,00	77,00	62,00	62,00
		2B2 Salpetersyre produktion				362,00	NO	NO	NO	NO	NO
		2B10a Anden kemisk industri				19,00	23,00	26,00	6,80	6,00	10,00
		2C1 Jern og stål produktion				244,40	218,61	148,18	169,64	154,62	157,18
		2C3 Aluminium produktion				4,41	3,46	0,62	0,75	0,78	0,82
		2C5 Bly produktion				1,28	1,53	1,44	1,93	1,08	1,27
		2G4 Øvrige produkt anvendelser				412,02	380,40	411,76	361,72	330,73	373,85
		Total				1.297,11	869,62	718,90	691,35	641,27	678,13
PM_{10}	Mg	2A2 Produktion af brændt kalk				18,40	14,25	10,08	11,89	13,83	13,36
		2A3 Glas produktion				123,00	83,30	24,50	39,60	47,00	36,40
		2A6 Øvrige mineralske produkter				63,90	103,50	70,30	69,00	55,60	56,00
		2B2 Salpetersyre produktion				290,00	NO	NO	NO	NO	NO
		2B10a Anden kemisk industri				15,00	18,00	21,00	5,40	4,80	8,00
		2C1 Jern og stål produktion				94,02	75,60	46,05	52,52	47,54	48,74
		2C3 Aluminium produktion				3,09	2,42	0,44	0,53	0,55	0,57
		2C5 Bly produktion				1,03	1,22	1,15	1,54	0,86	1,02
		2G4 Øvrige produkt anvendelser				315,76	307,36	304,24	267,92	261,67	285,71
		Total				924,19	605,65	477,76	448,40	431,84	449,80
$PM_{2.5}$	Mg	2A2 Produktion af brændt kalk				3,68	2,85	2,02	2,38	2,77	2,67
		2A3 Glas produktion				109,00	73,50	22,30	35,00	41,50	32,30
		2A6 Øvrige mineralske produkter				49,70	80,50	54,76	53,61	43,25	44,00
		2B2 Salpetersyre produktion				217,00	NO	NO	NO	NO	NO
		2B10a Anden kemisk industri				11,00	14,00	16,00	4,10	3,60	6,00
		2C1 Jern og stål produktion				32,15	19,66	8,03	9,02	7,94	8,42
		2C3 Aluminium produktion				1,21	0,95	0,17	0,21	0,21	0,23
		2C5 Bly produktion				0,51	0,61	0,58	0,77	0,43	0,51
		2G4 Øvrige produkt anvendelser				286,88	285,45	271,99	239,78	240,96	259,26
		Total				711,14	477,52	375,83	344,87	340,65	353,39
BC	Mg	2A2 Produktion af brændt kalk				0,02	0,01	0,01	0,01	0,01	0,01

NO: Forekommer ikke, IE: Inkluderet andetsteds, NE: Ikke estimeret

Produktion af salpetersyre stoppede i Danmark i 2005, hvilket betød en betydelig reduktion af emissioner af NO_x og partikler fra industrielle processer. CO emissionen er reduceret betydeligt fra kategorien 'Andre mineralske produkter'. Reduktionen stammer fra et fald i emissionen fra produktion af stenuld, som skyldes installationen af røggasrensnings udstyr i 2009-2010. Emissionen af SO_2 er i de senere år faldet på grund af en lavere produktion af mursten, tegl og ekspanderede lerprodukter (inkluderet i øvrige mineralske produkter 2A6).

Emissioner af tungmetaller (Arsen (As), kadmium (Cd), Krom (Cr), kobber (Cu), kviksølv (Hg), nikkel (Ni), bly (Pb), selen (Se) and zink (Zn)) og persistente organiske forbindelsers (PCDD/F, HCB og PCBer) er præsenteret i Tabel 0.4.

Tabel 0.4a Emission af tungmetaller og persistente organiske forbindelser fra industrielle processer.

Gas	Enhed	Sektor	1990	1995	2000	2005	2010	2011	2012	2013
As	Mg	2A3 Glas produktion	0,048	0,041	0,052	0,036	0,003	0,003	0,003	0,002
		2C1 Jern og stål produktion	0,040	0,038	0,040	0,034	0,022	0,025	0,023	0,023
		2C5 Bly produktion	0,003	0,004	0,003	0,003	0,003	0,004	0,002	0,003
		2G4 Øvrige produkt anvendelser	0,004	0,007	0,010	0,008	0,009	0,008	0,007	0,009
		Total	0,09	0,09	0,10	0,08	0,04	0,04	0,04	0,04
Cd	Mg	2A3 Glas produktion	0,020	0,017	0,022	0,015	0,001	0,001	0,001	0,001
		2C1 Jern og stål produktion	0,053	0,035	0,030	0,023	0,012	0,014	0,012	0,013
		2C3 Aluminium produktion	0,001	0,001	0,001	0,001	0,0002	0,0002	0,0002	0,0002
		2C5 Bly produktion	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001
		2C7c Anden metal produktion	0,004	0,004	0,005	0,005	0,005	0,005	0,005	0,005
		2G4 Øvrige produkt anvendelser	0,001	0,002	0,004	0,003	0,004	0,004	0,003	0,004
		Total	0,08	0,06	0,06	0,05	0,02	0,02	0,02	0,02
Cr	Mg	2A3 Glas produktion	0,061	0,052	0,066	0,046	0,003	0,004	0,004	0,003
		2C1 Jern og stål produktion	0,175	0,171	0,112	0,110	0,080	0,092	0,084	0,085
		2G4 Øvrige produkt anvendelser	0,025	0,051	0,080	0,062	0,088	0,077	0,058	0,073
		Total	0,26	0,27	0,26	0,22	0,17	0,17	0,15	0,16
Cu	Mg	2C7c Anden metal produktion	0,04	0,04	0,05	0,05	0,05	0,05	0,05	0,05
		2G4 Øvrige produkt anvendelser	0,57	1,34	2,16	1,64	2,41	2,10	1,55	1,98
		Total	0,61	1,38	2,21	1,69	2,46	2,15	1,60	2,02
Hg	Mg	2B10a Anden kemisk industri	0,005	0,005	0,005	0,005	0,001	0,001	0,010	NA
		2C1 Jern og stål produktion	0,246	0,143	0,063	0,023	0,009	0,009	0,006	0,009
		2G4 Øvrige produkt anvendelser	0,001	0,001	0,001	0,001	0,001	0,000	0,001	0,001
		Total	0,25	0,15	0,07	0,03	0,01	0,01	0,02	0,01
Ni	Mg	2A3 Glas produktion	0,039	0,034	0,043	0,030	0,002	0,002	0,002	0,001
		2C1 Jern og stål produktion	0,89	0,55	0,38	0,27	0,13	0,14	0,12	0,13
		2G4 Øvrige produkt anvendelser	0,04	0,09	0,15	0,11	0,16	0,14	0,11	0,14
		Total	0,97	0,67	0,58	0,41	0,29	0,29	0,23	0,27
Pb	Mg	2A3 Glas produktion	0,48	0,41	0,33	0,15	0,02	0,03	0,12	0,02
		2C1 Jern og stål produktion	3,71	2,37	1,40	1,02	0,56	0,64	0,57	0,59
		2C3 Aluminium produktion	0,005	0,005	0,006	0,004	0,001	0,001	0,001	0,001
		2C5 Bly produktion	0,34	0,43	0,34	0,40	0,38	0,51	0,28	0,33
		2C7c Anden metal produktion	0,06	0,07	0,07	0,07	0,07	0,07	0,07	0,07
		2G4 Øvrige produkt anvendelser	2,85	6,64	3,30	2,53	0,04	0,04	0,07	0,07
		Total	7,4	9,9	5,4	4,2	1,1	1,3	1,1	1,1
Se	Mg	2A3 Glas produktion	0,25	0,21	0,34	0,11	0,02	0,02	0,06	0,02
		2C1 Jern og stål produktion	0,52	0,45	0,51	0,50	0,36	0,42	0,38	0,39
		2G4 Øvrige produkt anvendelser	0,005	0,005	0,009	0,010	0,005	0,004	0,009	0,009
		Total	0,8	0,7	0,9	0,6	0,4	0,4	0,5	0,4

Tabel 0.4b Emission af tungmetaller og persistente organiske forbindelser fra industrielle processer. (Fortsat)

Gas	Enhed	Sektor	1990	1995	2000	2005	2010	2011	2012	2013
Zn	Mg	2A3 Glas produktion	0,04	0,03	0,06	0,03	0,03	0,03	0,03	0,00
		2C1 Jern og stål produktion	12,0	7,0	3,6	1,6	0,5	0,6	0,5	0,5
		2C5 Bly produktion	0,002	0,003	0,002	0,002	0,002	0,003	0,002	0,002
		2C7c Anden metal produktion	0,5	0,6	0,6	0,6	0,6	0,6	0,6	0,6
		2G4 Øvrige produkt anvendelser	0,5	0,9	1,5	1,2	1,5	1,3	1,1	1,4
		Total	13,0	8,5	5,8	3,4	2,7	2,6	2,3	2,5
PAH	Mg	2G4 Øvrige produkt anvendelser	0,1	0,1	0,1	0,1	0,1	0,0	0,1	0,1
PCDD/F	g	2A2 Produktion af brændt kalk	0,002	0,002	0,002	0,001	0,001	0,001	0,001	0,001
		2A6 Øvrige mineralske produkter	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
		2C1 Jern og stål produktion	12,0	7,5	0,5	0,2	NE	NE	NE	NE
		2C3 Aluminium produktion	1,1	1,1	1,3	1,0	0,2	0,2	0,2	0,2
		2C5 Bly produktion	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
		2G4 Øvrige produkt anvendelser	0,1	0,1	0,1	0,2	0,1	0,1	0,1	0,1
		Total	13,3	8,8	2,0	1,4	0,3	0,4	0,4	0,5
HCB	g	2A2 Produktion af brændt kalk	1,0	0,8	0,7	0,6	0,4	0,5	0,6	0,5
		2C1 Jern og stål produktion	1968,2	2297,3	2023,2	804,0	2,9	3,3	3,1	3,1
		2C3 Aluminium produktion	629,9	649,1	735,3	576,3	104,0	125,2	129,8	136,9
		2C5 Bly produktion	0,2	0,3	0,2	0,3	0,3	0,4	0,2	0,2
		2G4 Øvrige produkt anvendelser	0,7	0,8	1,3	1,4	0,7	0,6	1,3	1,3
		Total	2.600,0	2.948,3	2.760,8	1.382,6	108,3	130,0	134,9	142,1
PCBer	g	2A2 Produktion af brændt kalk	19,2	15,1	13,8	10,7	7,6	8,9	10,4	10,0
		2C1 Jern og stål produktion	1585,9	1837,1	1628,3	675,0	36,4	41,8	38,2	38,7
		2C3 Aluminium produktion	107,1	110,3	125,0	98,0	17,7	21,3	22,1	23,3
		2C5 Bly produktion	5,7	7,3	5,7	6,8	6,4	8,6	4,8	5,7
		2G4 Øvrige produkt anvendelser	1,0	1,1	1,8	2,0	1,0	0,9	1,9	1,9
		Total	1.718,9	1.970,8	1.774,6	792,4	69,1	81,5	77,3	79,5

Lukningen af elektrostålværket i 2002 med en kort genåbning i 2005 samt lukningen af sekundær aluminiumsproduktion i 2008 har betydet et fald i emissionerne af flere tungmetaller og persistente organiske forbindelser (f.eks. Pb, Zn, PCDD/F, HCB and PCBer). Lovgivning fra 2000 og 2007 der først begrænsede og sidenhen forbød anvendelsen af bly i fyrværkeri har ligeledes reduceret bly emissionerne fra øvrige produkt anvendelser.

1 Introduction

Danish emission inventories are prepared on an annual basis and are reported to the United Nations Framework Convention on Climate Change (UNFCCC or Climate Convention) and to the Kyoto Protocol as well as to the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (LRTAP Convention).

The annual Danish emission inventories are prepared by the DCE – Danish Centre for Environment and Energy, Aarhus University. The inventories include the following pollutants relevant to industrial processes: carbon dioxide (CO_2), nitrous oxide (N_2O), sulphur dioxide (SO_2), nitrogen oxides (NO_x), non-volatile organic compounds (NMVOC), carbon monoxide (CO), particulate matter (PM), ammonia (NH_3), heavy metals (HMs), polyclorinated dibenzodioxins and –furans (PCDD/F), polycyclic aromatic hydrocarbons (PAHs), hexachlorobenzene (HCB) and polychlorinated biphenyls (PCBs).

The pollutants listed above correspond to the requirements of the UNFCCC, UNECE and EU to whom the emission inventories are reported. Other pollutants could be relevant for the source categories included in this report, but these will fall outside the scope of the emission inventories and therefore not be included.

Industrial processes is one of the six main sectors included in emission inventories based on international agreements. The other five sectors are: energy, solvent and product use, agriculture, land-use, land-use change and forestry (LULUCF) and waste.

The aim of this report is to:

- Document the methodologies used for estimating emissions from industrial processes
- Identify possible improvements of the current inventory related to completeness, consistency and accuracy including identifying industrial and product use sources not included in the present emission inventory
- Serve as the basis for QA of the sector through independent review

The present emission inventory includes a number of industrial sources; however, the systematic effort to identify industrial sources of emissions is ongoing. The coverage of sources presented in the EMEP[1]/EEA[2] air pollutant emission inventory guidebook (hereafter the EMEP/EEA guidebook) as well as the IPCC (Intergovernmental Panel on Climate Change) guidelines has been analysed with the purpose of identifying new sources. The industrial sources are included either as area sources or as point sources. Point sources are defined as plants that are treated individually in the inventory, e.g. for cement production and sugar production. Area sources are for categories where there are too many plants or not enough information, e.g. bakeries.

[1] The European Monitoring and Evaluation Programme
[2] European Environment Agency

The base year for emission inventories and reduction targets depends on the actual substance and protocol covering the substance; see Table 1.0.1. Some of the sources are not included in the inventory with complete time series due to missing data. These incomplete time series has as far as possible been completed through collection of the missing data or by introducing relevant emission estimates for the years in question. Improvements to the remaining incomplete time series are planned for the next update of the sector report.

Table 1.0.1 Base year for different pollutants.

Substance		Year
Sulphur dioxide	SO_2	1980
Ammonia Nitrogen oxides Non-Methane VOC	NH_3 NO_x NMVOC	1985
Carbon dioxide Methane Nitrous oxide	CO_2 CH_4 N_2O	1990
Heavy metals	Arsenic – As Cadmium – Cd Chromium – Cr Copper – Cu Mercury – Hg Nickel – Ni Lead – Pb Selenium – Se Zinc – Zn	1990
Persistent organic pollutants (POPs)	Polychlorinated dibenzo dioxins and furans (PCDD/F) Hexachlorobenzene (HCB) Polychlorinated biphenyls (PCBs) Benzo(a)pyrene Benzo(b)fluoranthene Benzon(k)fluoranthene Indeno(1,2,3-cd)pyrene	1990
F-gasses	HFCs PFCs SF_6 NF_3	1995
Particulate matter	Total Suspended Particulates (TSP) PM_{10} $PM_{2.5}$ Black Carbon (BC)	2000

The outline of the report follow the subdivision in sectors as applied in the IPPC guidelines for industrial processes supplemented with industrial sectors of specific relevance for air pollutants. An exception to this is the sector of *Non-Energy Products from Fuels and Solvent Use,* this sector is treated in an individual sector report. The main sectors included in this report are:

- Mineral industry
- Chemical industry
- Metal industry
- Electronics industry
- Product uses as substitutes for ozone depleting substances (ODS)
- Other product manufacture and use
- Other

The consumption of halocarbons and SF_6 (F-gasses) is documented in a separate report (Poulsen, 2015) and are therefore only presented and briefly discussed in this report.

2 Methodology and data sources

The methodologies applied for the inventory of process related emissions are:

- EMEP/EEA guidebook (EMEP/EEA, 2013)
- IPCC guidelines (IPCC, 2000 & 2006)

The main data sources applied in the inventory are:

- National statistics
- Company environmental reports/Reports to Electronic Pollutant Release and Transfer Registry (E-PRTR)
- Company reports to the European Union Emission Trading Scheme (EU-ETS)
- EMEP/EEA guidebook
- IPCC guidelines
- The **C**o-ordinated **E**uropean Programme on **P**articulate **M**atter **E**mission **I**nventories, **P**rojections and Guidance (CEPMEIP)

When considered relevant, emission factors based on information on industrial sector level will be developed. Comments to the different data sources are presented below.

2.1 Company environmental reports

By law, some companies are obligated to report environmental information to the Danish Environmental Protection Agency (DEPA) (DEPA, 2010). The Statutory order specifies the branches of industry that are obligated to report environmental information as well as the contents of the reporting. The reports are made public annually at a website hosted by the DEPA[3].

When plants measure and report emissions of pollutants this information is generally used in the inventory after an assessment of the quality by comparing the emission level to that of previous years as well as comparing an implied emission factor with that of similar plants. Any value that is outside an acceptable range is investigated further and if needed the plant is contacted with a view of verifying the value. If such verification cannot be provided, then the value is not used in the emission inventory.

In general, most information is available regarding the emission of NO_x, SO_2 and TSP. For other pollutants, the information is scarcer.

2.2 EMEP/EEA guidebook

The EMEP/EEA guidebook provides methodologies for estimation of emissions of the following groups of substances:

- Main pollutants: CO, NH_3, NMVOC, NO_x, SO_2
- Particulate matter: TSP, PM_{10}, $PM_{2.5}$, BC
- Heavy metals: As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn

[3] http://www3.mst.dk/Miljoeoplysninger/

- Persistent organic pollutants: PCDD/F, HCB, PCBs, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzon(k)fluoranthene, Indeno(1,2,3-cd)pyrene

The following editions of the guidebook have been used for the present inventory:

- EMEP/EEA air pollutant emission inventory guidebook – 2009 (EMEP/EEA, 2009)
- EMEP/EEA air pollutant emission inventory guidebook 2013 (EMEP/EEA, 2013)

2.3 IPCC guidelines

The IPCC guidelines provide methodologies for estimating emissions of greenhouse gases, i.e.:

- CO_2
- CH_4
- N_2O
- F-gases (HFCs, PFCs, SF_6 and NF_3)

The following editions of the IPCC guidelines have been used for the present inventory:

- Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000), hereafter the IPCC GPG
- 2006 IPCC guidelines for national greenhouse gas inventories (IPCC, 2006), hereafter the 2006 IPCC guidelines

2.4 EU-ETS (European Union - Emission Trading Scheme)

A number of Danish companies are covered by the EU-ETS and are as a consequence hereof obligated to report their emission of CO_2 yearly. The emissions of CO_2 reported to EU-ETS is a subset of the national emission of CO_2 and therefore this reporting can be used to improve the national inventory and to ensure consistency between EU-ETS and the national inventory.

Guidelines for calculating and reporting company specific CO_2 emissions under the EU-ETS have been decided by the EU (EU, 2007). The guidelines present standard methods for plants with small emissions and requirements for developing individual plans for plants with large emissions. The standard methods include default emission factors similar to the default emission factors presented by the IPCC (e.g. for limestone), whereas, the major emitters have to use individual methods to determine the actual composition of raw materials (e.g. purity of limestone or Ca per Mg ratio in dolomite) or the actual CO_2 emission from the specific process.

2.4.1 Description of EU-ETS in the Danish context

About 360 Danish stationary plants are included in the EU-ETS. These plants are within the transformation sector, offshore installations or manufacturing industries. Few of the processes that are included under the EU-ETS are occurring in Denmark and only CO_2 is reported from Danish plants since the potential sources of PFCs (primary aluminium production) and N_2O (production of nitric acid, adipic acid, glyoxal and glyoxilic acid) are not occurring in Denmark. A list of the processes covered by the EU-ETS with an indication of the processes that occur in Denmark is included in Chapter 2.4.2.

2.4.2 Processes covered

The EU-ETS covers a wide range of processes. The full list of activities that could be relevant in terms of industrial processes (IP) is included in Table 2.4.1 below. Indicated in the table are the activities that are relevant in Denmark.

Table 2.4.1 List of activities included in the European Union Emission Trading Scheme (Directive 2009/29/EC)

Activities	Greenhouse gases	Relevant in Denmark
Combustion of fuels in installations with a total rated thermal input exceeding 20 MW (except in installations for the incineration of hazardous or municipal waste)	CO_2	X
Refining of mineral oil	CO_2	X
Production of coke	CO_2	
Metal ore (including sulphide ore) roasting or sintering, including pelletisation	CO_2	
Production of pig iron or steel (primary or secondary fusion) including continuous casting, with a capacity exceeding 2.5 Mg per hour	CO_2	
Production or processing of ferrous metals (including ferro-alloys) where combustion units with a total rated thermal input exceeding 20 MW are operated. Processing includes, inter alia, rolling mills, re-heaters, annealing furnaces, smitheries, foundries, coating and pickling	CO_2	
Production of primary aluminium	CO_2, PFCs	
Production of secondary aluminium where combustion units with a total rated thermal input exceeding 20 MW are operated	CO_2	
Production or processing of non-ferrous metals, including production of alloys, refining, foundry casting, etc., where combustion units with a total rated thermal input (including fuels used as reducing agents) exceeding 20 MW are operated	CO_2	
Production of cement clinker in rotary kilns with a production capacity exceeding 500 Mg per day or in other furnaces with a production capacity exceeding 50 Mg per day	CO_2	X
Production of lime or calcination of dolomite or magnesite in rotary kilns or in other furnaces with a production capacity exceeding 50 Mg per day	CO_2	X
Manufacture of glass including glass fibre with a melting capacity exceeding 20 Mg per day	CO_2	X
Manufacture of ceramic products by firing, in particular roofing tiles, bricks, refractory bricks, tiles, stoneware or porcelain, with a production capacity exceeding 75 Mg per day	CO_2	X
Manufacture of mineral wool insulation material using glass, rock or slag with a melting capacity exceeding 20 Mg per day	CO_2	X
Drying or calcination of gypsum or production of plaster boards and other gypsum products, where combustion units with a total rated thermal input exceeding 20 MW are operated	CO_2	
Production of pulp from timber or other fibrous materials	CO_2	
Production of paper or cardboard with a production capacity exceeding 20 Mg per day	CO_2	X
Production of carbon black involving the carbonisation of organic substances such as oils, tars, cracker and distillation residues, where combustion units with a total rated thermal input exceeding 20 MW are operated	CO_2	
Production of nitric acid	CO_2, N_2O	
Production of adipic acid	CO_2, N_2O	
Production of glyoxal and glyoxylic acid	CO_2, N_2O	
Production of ammonia	CO_2	
Production of bulk organic chemicals by cracking, reforming, partial or full oxidation or by similar processes, with a production capacity exceeding 100 Mg per day	CO_2	
Production of hydrogen (H_2) and synthesis gas by reforming or partial oxidation with a production capacity exceeding 25 Mg per day	CO_2	
Production of soda ash (Na_2CO_3) and sodium bicarbonate ($NaHCO_3$)	CO_2	
Capture of greenhouse gases from installations covered by this Directive for the purpose of transport and geological storage in a storage site permitted under Directive 2009/31/EC	CO_2	
Transport of greenhouse gases by pipelines for geological storage in a storage site permitted under Directive 2009/31/EC	CO_2	
Geological storage of greenhouse gases in a storage site permitted under Directive 2009/31/EC	CO_2	

2.4.3 Survey of companies included

The number of plants included in the EU-ETS in Denmark varies across the years as some new plants have been founded while others have been closed and / or reopened. The largest structural change is the inclusion of waste incineration in the EU-ETS from 2013. This caused an increase in the number of plants covered by the EU-ETS. The reports for the waste incineration plants will be surveyed with a view to improving the inventory for CO_2 emissions from the use of limestone for flue gas desulphurisation in waste incineration plants. All other emissions related to waste incineration are included as combustion emissions and are not addressed in this report.

The plants included in Table 2.4.2 have reported process emissions under the EU-ETS and have been considered in the inventory. In the column 'plant type' the activity relevant for process emissions has been listed. Some plants are included due to exceeding the threshold for combustion installations, but nevertheless they have process emissions related to e.g. mineral wool production or flue gas cleaning. For combustion installations the process emission refers to the CO_2 emission associated with limestone used for flue gas desulphurisation / purification of the sugar.

Table 2.4.2 List of plants included in the European Union Emission Trading Scheme with process emissions in 2013

Plant	Plant type
Shell Raffinaderiet Fredericia	Refining of mineral oil
Aalborg Portland A/S	Production of cement clinker
Grenå Kraftvarmeværk	Combustion installation
Avedøreværket	Combustion installation
Asnæsværket	Combustion installation
Stigsnæsværket	Combustion installation
Vattenfall A/S Amagerværket	Combustion installation
Verdo Production, Energi Randers	Combustion installation
Enstedværket	Combustion installation
Vattenfall A/S Nordjyllandsværket	Combustion installation
Nordic Sugar, Nakskov Sukkerfabrik	Combustion installation
Dalum Papir A/S	Production of paper
Esbjergværket	Combustion installation
Carl Matzens Teglværk A/S	Manufacture of ceramic products
Damolin Fur A/S	Manufacture of ceramic products
Damolin Mors A/S	Manufacture of ceramic products
Saint-Gobain Weber, Hinge	Manufacture of ceramic products
Saint-Gobain Weber, Ølst	Manufacture of ceramic products
Faxe Kalk, Ovnanlægget Stubberup	Production of lime
Gråsten Teglværk	Manufacture of ceramic products
Helligsø Teglværk A/S	Manufacture of ceramic products
Højslev Tegl A/S	Manufacture of ceramic products
Monier A/S	Manufacture of ceramic products
Lundgård Teglværk A/S	Manufacture of ceramic products
Pedershvile Teglværk	Manufacture of ceramic products
Petersen Tegl Egernsund A/S	Manufacture of ceramic products
Wienerberger A/S - Petersminde Teglværk	Manufacture of ceramic products
Pipers Teglværker A/S Gandrup Teglværk	Manufacture of ceramic products
Pipers Teglværker A/S Hammershøj Teglværk	Manufacture of ceramic products
Ardagh Glass Holmegaard A/S	Manufacture of glass including glass fibre
Rockwool A/S Doense	Manufacture of mineral wool
Rockwool A/S, Vamdrup	Manufacture of mineral wool
Saint Gobain Isover A/S	Manufacture of glass including glass fibre
Statoil Raffinaderiet	Refining of mineral oil
Tychsen's Teglværk A/S	Manufacture of ceramic products
Vedstaarup Teglværk A/S	Manufacture of ceramic products
Vesterled Teglværk A/S	Manufacture of ceramic products
Villemoes Teglværk	Manufacture of ceramic products
Vindø Teglværk	Manufacture of ceramic products

2.4.4 Procedure for inclusion of data

The EU-ETS started in 2005 and have had three phases: 2005-2007, 2008-2012 and 2013-2020. The quality of the reported data increased significantly during the first few years and now the data quality in general is excellent.

The information included in the plant reports under the EU-ETS has been used in the inventory for all years where the data are available.

In preparation for the EU-ETS there was a data collection to assess the allocation of emission allowances to the different plants. Therefore, there are data available for some earlier years. These data have also been used in the inventory.

However, since the base year for CO_2 is 1990 there is a challenge in ensuring time series consistency. For some sectors the time series are very consistent as it has been possible to match the different methodologies. For some sectors, e.g. glass production, the time series consistency remains a challenge and is the subject of planned future work.

2.5 CEPMEIP database

The Co-ordinated European Programme on Particulate Matter Emission Inventories, Projections and Guidance (CEPMEIP) was part of the activities aimed at supporting national experts in reporting particulate matter emission inventories. Within this work programme, Netherlands Organisation for Applied Scientific Research (TNO) has compiled an overview of particulate emission estimation methods and applied these in a European emission inventory for particulates for the base year 1995.

TNO compiled information on emission of particulate matter expressed as TSP, PM_{10} and $PM_{2.5}$ from different industrial sectors. The result is organised in a database available online[4]. Emission factors are developed for four pollution levels:

- Low - good / well maintained abatement / BAT
- Medium
- Medium high
- High - low / poor maintained equipment / abatement and old plants

It is not always obvious, where Danish companies should be placed on the scale. In the cases where TSP is known for the Danish companies, they are placed on the scale, and the distribution between TSP, PM_{10} and $PM_{2.5}$ can be found.

[4] http://www.air.sk/tno/cepmeip/

3 Mineral industry

The sector Mineral industry (CRF / NRF 2A) covers the following industries relevant for the Danish air emission inventory:

- Cement production; see section 3.2
- Lime production; see section 3.3
- Glass production; see section 3.4
- Ceramics; see section 3.5
- Other use of soda ash; see section 3.6
- Flue gas desulphurisation; see section 3.7
- Mineral wool production; see section 3.8

3.1 Greenhouse gas emissions

The emission time series for the greenhouse gas emissions from the individual source categories in the mineral industries are presented in Figure 3.1.1. The figure shows that cement production is by far the largest contributor to CO_2 emissions within the mineral industries and that emissions were strongly influenced by the financial crisis in 2007-2009.

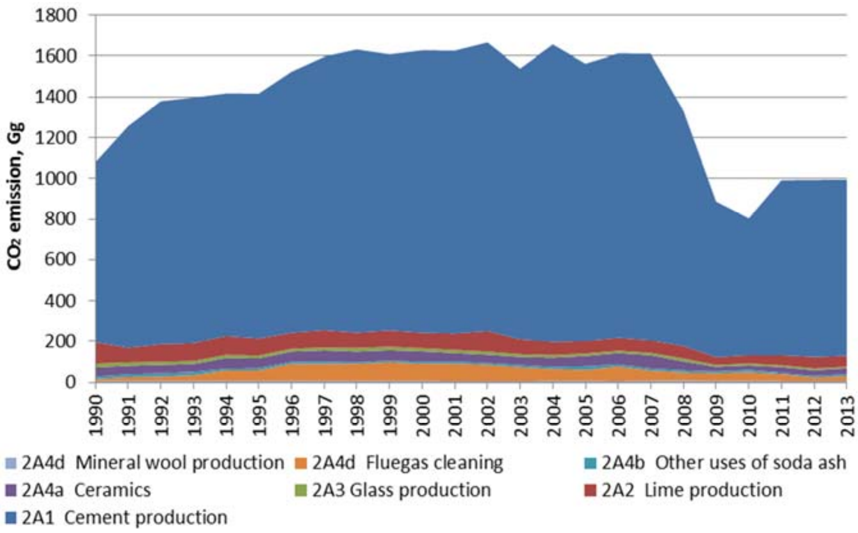


Figure 3.1.1 Emission of CO_2 from the individual source categories compiling *2A Mineral Industry*, Gg.

Greenhouse gas emissions from *Mineral Industry* consist mainly of CO_2 emissions from the production of cement; min. 82 % (1990) to max. 88 % (2004).

Emissions from *Mineral Industry* increased with 48 % from 1990 to the time series peak in 1997 (1598 Gg). The overall development in the CO_2 emission for 1990 to 2013 shows a decrease from 1078 Gg to 995 Gg CO_2, i.e. by 7.7 %.

The increase from 1990 to 1997 can be explained by the increase in the annual cement production. The emission factor has only changed slightly as the distribution between types of cement especially grey / white cement has been almost constant from 1990-1997. The decrease during the latest years may be explained by the decrease in the construction activity.

3.2 Cement production

The production of cement in Denmark is concentrated at one company: Aalborg Portland A/S situated in Aalborg. The following SNAP-codes are covered:

- 03 03 11 Cement
- 04 06 12 Cement (decarbonizing)

Emissions associated with the fuel use are estimated and reported in the energy sector and are therefore not included in this sector report. CO_2 is the only pollutant that is relevant for the cement production process.

3.2.1 Process description

The primary raw materials (i.e. virgin raw materials) are sand, chalk and water. A number of other raw materials are also used in minor amounts. The main products are grey cement (Rapid® cement, Basis® cement and Low Alkali Sulphate Resistant cement) and white cement (Aalborg White®) as well as cement clinker for sale.

The emissions to air from cement production can be explained by the use of different fuels (combustion process), release of CO_2 from calcination, and release of pollutants from fuels and raw materials.

Chalk is extracted from a chalk pit located at the factory ground. The chalk is transported by conveyor belt to a wash mill, where impurities are removed. The chalk is then mixed with water to form chalk slurry. Sand is extracted from the seabed at different locations by dredgers. The sand is transported to the factory and is ground in a sand mill. The main secondary raw materials (i.e. recycled materials) are fly ash, paper pulp, ferro oxide and gypsum from flue gas cleaning. A number of other secondary raw materials are used in minor amounts. The main processes at Aalborg Portland are production of raw meal, clinker production, grinding of clinker and storage of cement.

Aalborg Portland uses a semi-dry process. The first step is production of raw meal. The chalk slurry and the grounded sand are mixed as slurry that is injected into a drier crusher. The raw materials are converted into raw meal that releases CO_2 in the calciner.

In a rotary kiln the material is burned to clinker that afterwards is grounded to cement in the cement mill. During the process, cement kiln dust is recirculated.

Production of cement is a very energy consuming process and a number of different fuels are used e.g. coal, petroleum coke, fuel oil, and alternative fuels (“meat and bone meal”, regenerated oil with low sulphur content, ash residue, asphalt, residue from production of vitamins, sewage sludge, and “CemMiljø fuel”[5]). The company does focus on alternative fuels in order to reduce cost as well as environmental effects (i.e. CO_2 originating from fossil sources). The emissions that are related to combustion are not included in this report.

[5] Produced from non-specified combustible waste (CemMiljø, 2003).

The fuels are injected in the bottom of the rotary kiln whereas the raw materials are injected in the top of the kiln. The product (i.e. cement clinker) are in contact with the fuel and potential pollutants in the fuels may be incorporated in the clinker meaning that the alkaline environment in the rotary kiln acts as a flue gas cleaning system (especially for acid gasses and certain heavy metals).

3.2.2 Methodology

Process emissions are released from the calcination of raw materials (chalk and sand). The overall process for calcination is:

$CaCO_3 \rightarrow CaO + CO_2$

1990-1997

The emission of CO_2 depends on the ratio: white / grey cement and the ratio between three types of clinker used for grey cement: GKL-clinker (rapid cement) / FKH-clinker (basis cement) / SKL-RKL-clinker (low alkali cement).

The emission factor (EF) has been estimated from the loss on ignition determined for the different kinds of clinkers produced, combined with the volumes of grey and white cements produced.

The ratio white / grey cement and the ratio GKL-clinker / FKH-clinker / SKL-RKL-clinker is known from 1990-1997. White cement peaked in 1990 and decreased thereafter. The production of SKL / RKL-clinker peaks in 1991 and decreases hereafter. FKH-clinker is introduced in 1992 and increases to a share of 35 % in 1997. The CO_2 emission is calculated according to the following equation:

$$M_{CO_2} = M_{grey} * \frac{M_{GLK} * EF_{GLK} + M_{FKH} * EF_{FKH} + M_{SKL/RKL} * EF_{SKL/RKL}}{M_{GLK} + M_{FKH} + M_{SKL/RKL}} + M_{white} * EF_{white}$$

M_{grey}	Grey cement	Mg
M_{white}	White cement	Mg
M_{GLK}	GKL clinker (rapid cement)	Mg
M_{FKH}	FHK clinker (basis cement)	Mg
$M_{SKL/RKL}$	SKL/RKL clinker (low alkali cement)	Mg
EF_{white}	CO_2 emission factor	Mg/Mg white cement
EF_{GLK}	CO_2 emission factor	Mg/Mg GLK clinker
EF_{FKH}	CO_2 emission factor	Mg/Mg FKH clinker
$EF_{SKL/RKL}$	CO_2 emission factor	Mg/Mg SKL/RKL clinker

The company has at the same time stated that data until 1997 cannot be improved as there is no further information available.

1998-2004

From 1998-2004 carbonate content of the raw materials has been determined by loss on ignition methodology. Determination of loss of ignition takes into account all the potential raw materials leading to release of CO_2 and omits the Ca-sources leading to generation of CaO in cement clinker without CO_2 release. The applied methodology is in accordance with EU guidelines on calculation of CO_2 emissions (Personal communication with Henrik Møller Thomsen from Aalborg Portland, 17 September 2008).

2005-2013

From the year 2005 the CO_2 emission determined by Aalborg Portland independently verified and reported under the EU-ETS is used in the inventory (Aalborg Portland, 2014a). The reporting to EU-ETS also provides detailed information of alternative fuels used in the production of clinker; see Table 3.2.1.

Table 3.2.1 Alternative fuels used in production of cement clinker (Aalborg Portland 2014a).

Fuel type	Biomass fraction, %
Cemmiljø fuel	30-56
Paper residues	79
Dry wastewater sludge	100
Meat and bone meal	100
Tyre residues	15
Plastic pellet	64

Activity data

Production statistics for cement (given in Total Cement Equivalents, TCE) and clinker production are presented in Table 3.2.2.

Table 3.2.2 Production statistics for cement production (Aalborg Portland 2014a, b and Personal communication with Henrik Møller Thomsen, Aalborg Portland, 17 September 2008).

Year	1990	1991	1992	1993	1994	1995	1996	1997
Mg TCE	1,619,976	1,998,674	2,214,104	2,244,329	2,242,409	2,273,775	2,418,988	2,718,923
Mg clinker[1]	1,406,212	1,811,958	2,089,393	2,117,895	2,192,402	2,353,123	2,481,792	2,486,475
	1998	1999	2000	2001	2002	2003	2004	2005
Mg TCE	2,754,405	2,559,575	2,612,721	2,660,972	2,698,459	2,546,295	2,861,471	2,706,371
Mg clinker	2,462,249	2,387,282	2,452,394	2,486,146	2,508,415	2,363,610	2,611,617	2,520,788
	2006	2007	2008	2009	2010	2011	2012	2013
Mg TCE	2,842,282	2,946,294	2,551,346	1,663,126	1,454,043	1,766,561	1,818,293	1,825,146
Mg clinker	2,632,112	2,706,048	2,269,687	1,493,230	1,313,654	1,582,023	1,628,506	1,612,834

[1] 1990-1997: Amount of clinker produced has not been measured as for 1998-2008. Therefore, the amount of GLK-, FKH-, SKL-/RKL-clinker and white cement is used as an estimate of total clinker production (Personal communication with Henrik Møller Thomsen, Aalborg Portland 17 September 2008).

Emission factors

The calculated implied emission factors (IEF) for the total cement equivalent (TCE) and clinker production are presented in Table 3.2.3.

Table 3.2.3 Implied emission factors for CO_2 for cement production.

Year	1990	1991	1992	1993	1994	1995	1996	1997
IEF Mg CO_2 per Mg TCE[1,2,3]	0.545	0.544	0.539	0.537	0.532	0.529	0.530	0.530
IEF Mg CO_2 per Mg clinker[3,4]	0.628	0.600	0.571	0.569	0.544	0.512	0.517	0.580
	1998	1999	2000	2001	2002	2003	2004	2005
IEF Mg CO_2 per Mg TCE[1,2,3]	0.505	0.529	0.530	0.517	0.529	0.532	0.510	0.504
IEF Mg CO_2 per Mg clinker[3,4]	0.564	0.568	0.565	0.558	0.565	0.563	0.559	0.541
	2006	2007	2008	2009	2010	2011	2012	2013
IEF Mg CO_2 per Mg TCE[1,2,3]	0.491	0.478	0.453	0.460	0.462	0.488	0.479	0.475
IEF Mg CO_2 per Mg clinker[3,4]	0.530	0.520	0.509	0.512	0.512	0.545	0.535	0 538

1) 1990-1997: IEF based on the personal communication with Henrik Møller Thomsen, Aalborg Portland, 2005.
2) 1998-2004: IEF based on the personal communication with Henrik Møller Thomsen, Aalborg Portland, 17 September 2008.
3) 2005-2013: IEF based on emissions reported to EU-ETS (Aalborg Portland, 2014a and previous versions).
4) 1998-2013: IEF based on clinker production statistics provided by Aalborg Portland (2014b).

The IEF for CO_2 from the calcination process is expressed per Mg of cement or clinker and depends on the actual input of chalk/limestone in the process. The IEF will therefore vary as the allocation of different cement/clinker types produced varies. When the implied CO_2 emission factor in 1990 is markedly higher than for the remaining time series it is because the production of white cement was higher in 1990 than for the following years, leading the ratio white/grey cement to be higher for 1990. The share of white cement decreases significantly through the early part of the 1990s causing the IEF to decrease as well. In 1990, 25 % of cement produced was white cement; in 1991-1997 that same share fluctuates around 21 % (20 % in 1992 to 22 % in 1995). As presented in Table 3.2.4, emission factors are higher for white than for grey cement resulting in a higher IEF for 1990. The production of different cement types are shown in the Verification section below (Chapter 3.2.5), see Table 3.2.8.

Table 3.2.4 Emission factors for white cement and (grey) clinkers (Personal communication with Henrik Møller Thomsen, Aalborg Portland, 17 September 2008).

Product	Value	Unit
White cement	0.669	Mg CO_2/Mg white cement
GLK clinker	0.477	Mg CO_2/Mg GLK clinker
FKH clinker	0.459	Mg CO_2/Mg FKH clinker
SKL/RKL clinker	0.610	Mg CO_2/Mg SKL/RKL clinker

For the entire time series, the emission factor (carbon content) has been estimated from the loss on ignition determined for the different kinds of clinkers produced (1990-1997) or different raw materials used (1998-2013). Determination of loss on ignition estimates the CO_2 emissions based on full oxidation of all carbonate materials and omits the Ca-sources leading to generation of CaO in cement clinker without CO_2 release. As a result, there is no need to consider uncalcined cement kiln dust (CKD) not recycled to the kiln. The applied methodology is in accordance with EU guidelines on calculation of CO_2 emissions (Personal communication with Henrik Møller Thomsen from Aalborg Portland, 17 September 2008).

The company reporting to the EU-ETS applies the following emission factors for the most important raw materials used in 2013, similar data are available back to 2006 (Aalborg Portland 2014a) and to a less detailed degree back to 1998 (Aalborg Portland, 2014b).

Table 3.2.5 Emission factors for raw materials.

Raw material	Mg CO_2 per Mg raw material
Limestone	0.44
Magnesium carbonate	0.522
Sand	0.0053-0.0301
Fly ash	0.130
Cement Kiln Dust (CKD)	0.361-0.525
Other	0.0028-0.0268

The emission factors for limestone and magnesium carbonate are in accordance with the stoichiometric factors and the emission factors for the remaining raw materials and CKD are determined by individual yearly analysis.

The emissions of heavy metals were measured in 1997 (Illerup et al., 1999) – see Table 3.2.6. The emission of heavy metals originates from the fuels and the raw materials. In the Danish inventory these emissions together with emissions of CO, NO_x, SO_2, and POPs have been allocated to the combustion part of cement production and are reported in the energy sector.

Table 3.2.6 Emission factors for heavy metals (Illerup et al., 1999).

Pollutant	Unit	Emission factor
As	mg/Mg	20
Cd	mg/Mg	7
Cr	mg/Mg	10
Cu	mg/Mg	10
Hg	mg/Mg	0.06
Ni	mg/Mg	20
Pb	mg/Mg	10
Se	mg/Mg	7
Zn	mg/Mg	50

Emissions of NO_x, SO_2, and CO are continuously measured and reported annually in the environmental report of Aalborg Portland since 2006. Prior to this, emissions are calculated using emission factors derived from information in the environmental reports by Aalborg Portland. For 1990-1995 the same emission factors have been assumed as in 1996.

Emissions of HCB, PCBs, benzo(a)pyrene, benzo(b)flouranthene, benzo(k)fluoranthene and indeno(1,2,3-cd)pyrene are estimated based on the fuel consumption and not the production of cement.

Emissions of particulate matter and PCDD/F are estimated using emission factors expressed per produced amount of clinker.

3.2.3 Emission trends

The emission trend for the CO_2 emission from cement production is presented in Table 3.2.7 and Figure 3.2.1.

Table 3.2.7 CO_2 emission for cement production, Gg.

	1990	1991	1992	1993	1994	1995	1996	1997
CO_2	882.4	1,087.8	1,193.4	1,206.1	1,192.2	1,203.8	1,281.9	1,342.9
	1998	1999	2000	2001	2002	2003	2004	2005
CO_2	1,389.8	1,354.9	1,385.3	1,387.9	1,416.3	1,329.9	1,458.9	1,363.4
	2006	2007	2008	2009	2010	2011	2012	2013
CO_2	1,395.5	1,407.1	1,154.7	764.4	672.2	861.8	871.1	867.1

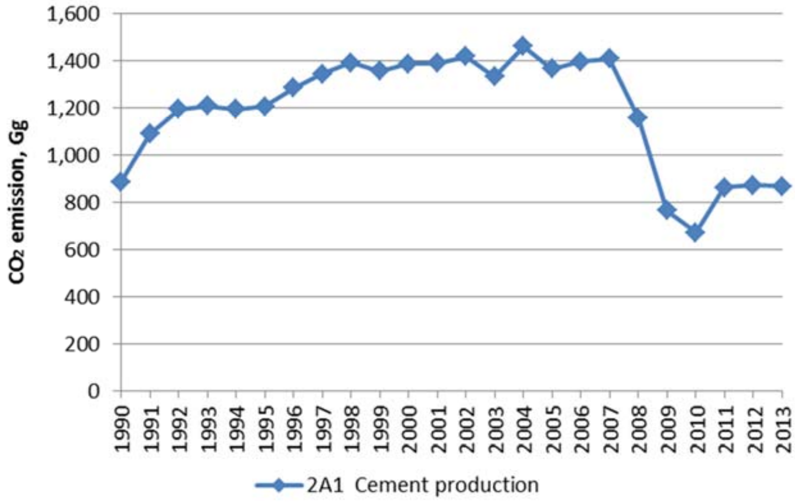


Figure 3.2.1 Emission of CO_2 from cement production.

The increase in CO_2 emission from the production of cement from 1990 to 1997 can be explained by the increase in the annual cement production. The most significant change to occur in the time series is the significant decline in emission from 2007-2010, the decrease is due to reduced production resulting from the economic recession caused by the global financial crisis. The emissions increased in 2011-2013, but the emissions are still far below the pre-recession levels due to lower production. The overall development in the CO_2 emission from 1990 to 2013 is a decrease from 882 to 867 Gg CO_2, i.e. by 1.7 %. The maximum emission occurred in 2004 and constituted 1,459 Gg CO_2; see Figure 3.2.1.

3.2.4 EU-ETS data for cement production

The applied methodology for Aalborg Portland is specified in the individual monitoring plan that is approved by Danish authorities (DEA) prior to the reporting of the emissions. Cement production applies the Tier 3 methodology for calculating the CO_2 emission.

The implied CO_2 emission factor for Aalborg Portland is plant specific and based on the reporting to the EU Emission Trading Scheme (EU-ETS). The EU-ETS data have been applied for the years 2006 – 2013.

The CO_2 emission for cement production is based on measurements of the consumption of calcium carbonate to the calcination process. These measurements fulfil a Tier 3 methodology (± 1.6 %) as defined in the EU decision (EU Commission, 2007). The emission factor is based on continuous measurements with flow meters, density meters, X-ray and CaO analysis. (Aalborg Portland, 2013)

3.2.5 Verification

Information on production, import and export of cement and clinker for the years 1990–1997 were investigated in order to ensure that the Tier 1 method is being implemented in accordance with the IPCC Guidelines (IPCC, 2006).

The supply of cement clinker, grey cement and white cement in Denmark is shown in Table 3.2.8; however, the mass balance is incomplete due to missing information. The missing information may be explained by confidentiality as the statistics can be kept confidential, if there are fewer than three producers.

Table 3.2.8 Production, import, export and supply of cement, Gg (Statistics Denmark, 2014).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cement clinker										
Produced	NAV	NAV	NAV	NAV	NAV	NAV	NAV	139	119	112
Import	0.4	0.3	0.0	0.4	0.2	0.01	0.2	0.03	0.2	0.03
Export	17	45	24	40	189	281	245	139	117	112
Supply	-	-	-	-	-	-	-	-0.1	3	0.04
Portland cement, white										
Produced	412	398	426	492	492	531	576	529	537	563
Import	0	0	0.05	1.2	1.4	0.0	0.0	5.8	3.2	9.9
Export	367	445	481	634	477	473	496	455	638	509
Supply	44	-48	-55	-141	17	58	80	80	-98	64
Portland cement, grey										
Produced	1,244	1,621	1,646	1,778	1,935	2,053	2,052	2,015	2,011	1,859
Import	190	176	256	262	257	272	277	263	222	214
Export	19	449	704	763	829	790	910	766	509	466
Supply	1,414	1,349	1,198	1,277	1,363	1,535	1,419	1,512	1,724	1,607
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cement clinker										
Produced	103	103	153	62	53	43	5	21	16	0.12
Import	0.002	0	4	27	23	31	44	40	42	33
Export	90	99	103	67	54	56	12	10	7	8
Supply	12	4	53	22	21	18	37	51	51	25
Portland cement, white										
Produced	551	532	510	582	679	715	797	722	607	462
Import	11	0.03	0.14	1	5	15	38	19	33	30
Export	546	462	531	507	315	508	745	639	490	422
Supply	17	70	-21	76	369	222	90	102	150	70
Portland cement, grey										
Produced	1,985	2,044	2,035	1,998	2,213	2,166	2,140	2,149	1,932	1,116
Import	238	254	275	191	184	215	235	229	263	177
Export	634	769	731	652	761	732	545	484	443	125
Supply	1,589	1,529	1,578	1,538	1,636	1,650	1,830	1,895	1,751	1,168
	2010	2011	2012	2013						
Cement clinker										
Produced	4	0.03	24	0						
Import	22	27	27	26						
Export	12	3	25	0.05						
Supply	14	24	26	26						
Portland cement, white										
Produced	482	514	496	531						
Import	23	30	30	24						
Export	501	497	499	506						
Supply	3	47	27	50						
Portland cement, grey										
Produced	1,085	1,338	1,321	1,322						
Import	160	214	183	183						
Export	201	251	271	249						
Supply	1,044	1,301	1,233	1,256						

NAV: Personal communication with the single Danish producer of cement makes it clear what it unfortunately is not – and will never be, possible to achieve these data for 1990-1997 (Personal communication with Torben Ahlmann-Laursen, Aalborg Portland, 19 November 2013).

Table 3.2.8 and Table 3.2.2 show the produced amount of cement (grey and white) according to Statistics Denmark and the amount produced according to Aalborg Portland respectively. The two datasets show good agreement in spite of different methodologies. The fluctuations are believed mainly to be caused by changes in stocks, and the overall sum of produced cement only differs 0.6 % (8.2 Gg) through the time series (1990-2013). The most comprehensive activity data is assumed to be the information on yearly produced amount of cement clinker obtained from the Danish producer. A comparison between the two datasets is presented in Table 3.2.9.

Table 3.2.9 Production data for Portland cement as given by Aalborg Portland and Statistics Denmark respectively.

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Aalborg Portland	Gg TCE	1,620	1,999	2,214	2,244	2,242	2,274	2,419	2,719	2,754	2,560
Statistics Denmark	Gg	1,656	2,019	2,072	2,270	2,427	2,584	2,629	2,544	2,548	2,422
Difference	Gg	-36	-21	142	-26	-185	-310	-210	175	207	137
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Aalborg Portland	Gg TCE	2,613	2,661	2,698	2,546	2,861	2,706	2,842	2,946	2,551	1,663
Statistics Denmark	Gg	2,536	2,575	2,545	2,580	2,893	2,881	2,937	2,871	2,539	1,579
Difference	Gg	77	85	154	-34	-31	-174	-95	75	13	85
		2010	2011	2012	2013						
Aalborg Portland	Gg TCE	1,454	1,767	1,818	1,825						
Statistics Denmark	Gg	1,567	1,853	1,817	1,852						
Difference	Gg	-113	-86	1	-27						

The activity data for clinker production provided by the company includes clinker used in cement production while clinker data from Statistics Denmark only includes the amount of clinker sold. The production data for clinker can therefore not be compared.

Table 3.2.10 compares the default emission factor from IPCC (2006) with the measured / calculated implied emission factor for 1992-2013. The average IEF for these years is 0.54 Mg per Mg clinker. The comparison shows good agreement between the two methods.

Table 3.2.10 Comparison of default (Tier 1) and calculated implied (Tier 3) CO_2 emission factors for cement production.

Methodology	Value	Unit	Source
Tier 1	0.52	Mg/Mg clinker	IPCC (2006)
Tier 3[1]	0.51-0.58	Mg/Mg clinker	Aalborg Portland (2014a, b) and Personal communication with Henrik Møller Thomsen from Aalborg Portland (17 September 2008)

[1]1992-2013

1990 and 1991 are both outliers because the production of white cement (EF: 0.669 Mg / Mg) and SKL / RKL clinker (EF: 0.610 Mg / Mg) peeked in these years, resulting in overall IEFs of 0.63 and 0.60 Mg per Mg clinker respectively.

3.2.6 Time series consistency and completeness

Since Denmark only has one cement factory, all data collected from the production are in fact plant specific data.

For 1990-1997, activity data for grey cement production fulfil the Tier 2 methodology while activity data for white cement (20-25 %) only fulfil the Tier 1 methodology (IPCC, 2006). The company has informed that data until 1997 cannot be improved as there is no further information available.

Since 1998, the determination of activity data for cement production has met the requirements of the Tier 3 methodology.

Emission factors have for the entire time series been determined by analysed loss on ignition which fulfil the requirements of the Tier 3 methodology.

The methodology behind the chosen activity data for cement production is therefore not consistent, but CO_2 emission factors are.

The inventory on cement production is considered complete in accordance with IPCC (2006).

3.2.7 Input to emission database (CollectER)

The input data / data sources are presented in Table 3.2.11.

Table 3.2.11 Input data for calculating emissions from cement production.

	Year	Parameter	Comment/Source
Activity data	1985-1996	Grey/white cement	Aalborg Portland/Illerup et al. (1999)
	1997	Cement equivalents	Personal communication with Henrik Møller Thomsen, Aalborg Portland, 17 September 2008)
	1998-2013	Cement equivalents	Aalborg Portland (2014b)
	1998-2013	Clinker produced	Aalborg Portland (2014a) and Personal communication, Henrik Møller Thomsen Aalborg Portland (17 September 2008)
Emissions	1997	Heavy metals	Illerup et al. (1999)
	1985-1996, 1998-2012	Heavy metals	Assumed to be the same per produced amount as in 1997
	1985-1997	CO_2	Personal communication with Henrik Møller Thomsen, Aalborg Portland, 17 September 2008)
	1998-2004	CO_2	Personal communication with Henrik Møller Thomsen from Aalborg Portland (17 September 2008)
	2005-2013	CO_2	Aalborg Portland (2014a)

3.2.8 Future improvements

There are no planned improvements for the process emissions from cement production.

3.3 Lime production

The production of marketed limestone ($CaCO_3$) and lime (also called burned lime or quicklime) (CaO) is located at a few localities: Faxe Kalk (Lhoist group) situated in Faxe, Dankalk A/S situated in Løgstør with limestone quarries/limeworks in Aggersund, Mjels, Poulstrup and Batum.

In addition to the marketed lime production, lime production is also related to production of sugar. Sugar production is concentrated at one company: Nordic Sugar (previously Danisco Sugar A/S) located in Assens, Nakskov and Nykøbing Falster (Danisco Sugar Assens, 2007; Danisco Sugar Nakskov, 2008; Danisco Sugar Nykøbing, 2008; Nordic Sugar Nakskov, 2013; Nordic Sugar Nykøbing, 2013). This lime is produced and consumed by the sugar industry and is therefore also called un-marketed lime.

The following SNAP-codes are covered:

- 03 03 12 Lime (incl. iron and steel and paper pulp industry)
- 04 06 14 Lime (decarbonizing)

The following pollutants are included for the lime production process:

- CO_2
- Particulate matter: TSP, PM_{10}, $PM_{2.5}$, BC
- Persistent organic pollutants: HCB, PCDD/F, PCB

In addition to emissions from marketed lime, only CO_2 from the decarbonizing of un-marketed lime is included in this section. Emissions of NMVOC from sugar refining are presented in Section 9.4 Sugar production and emissions associated with the fuel use are estimated and reported in the energy sector and therefore not included in this report.

3.3.1 Process description

Calculation of CO_2 emissions from oxidation of carbonates follows the general process:

$$M_x(CO_3) + heat \rightarrow M_xO + CO_2$$

and for limestone:

$$CaCO_3 + heat \rightarrow CaO + CO_2$$

Addition of water results in the following reaction:

$$CaO + H_2O \rightarrow Ca(OH)_2$$

The emission of CO_2 results from heating of the carbonates in the lime-kiln. The lime-kilns can be located either at the location for limestone extraction or at the location for use of burned lime.

3.3.2 Methodology

The CO_2 emission from the production of marketed burnt lime has been estimated from the annual production figures registered by Statistics Denmark (see Table 3.3.1) and emission factors.

Plant specific activity data for marketed lime only exist for one company (Faxe Kalk) that constitutes about 66% (2006-2013 average) of the Danish activity; see Table 3.3.1. The plant specific data are available back to 1995. A number of smaller companies account for the remaining of the Danish production.

Since 2006, process CO_2 emissions from Faxe Kalk (i.e. the largest Danish producer) have been calculated by the company and reported to EU-ETS. These calculations are based on the assumption of pure CaO product and are therefore not corrected for impurities. For the sake of consistency, the same method has been applied for the entire time series and for all producers. However, since 2008, Faxe Kalk has measured and included the content of MgO in the process emissions reported to EU-ETS; this causes a slight increase and small fluctuations in the implied emission factor for the recent years (Faxe Kalk, 2013). Faxe Kalk is the only marketed lime producer reported as a point source, but only for 2006-2013.

Total sales statistics for produced sugar is available from Statistics Denmark (2014). Production statistics from the environmental reports are registered each 12 month period going from May 1 - April 30 until 2007/08 and from March 1 – February 28 from 2009/10 (Nordic Sugar Nakskov, 2009; Nordic Sugar Nykøbing, 2009). Therefore, the yearly production does not correspond with the yearly sale registered by Statistics Denmark (2014). The information from Statistics Denmark covers the whole time series and therefore the amount of sugar sold is used as activity data. The company information is only used for calculating the allocation of production/sale between the three point source locations. The consumption of lime is estimated from the production statistics and a number of assumptions: consumption of 0.02 Mg $CaCO_3$ per Mg sugar and precipitation of 90 % CaO resulting in an emission factor at 0.0088 Mg CO_2 per Mg sugar (2 weight% $CaCO_3$ consumption per sugar beets, 10 weight% sugar in sugar beets). The assumptions are based on environmental reports covering the year 2002.

Activity data

Statistics from Statistics Denmark (2014) have been chosen as data source to ensure consistent data throughout the period from 1990. However, after EU-ETS data have become available from 2006; the company specific production data have been included and the data from Statistics Denmark adjust to only cover producers not covered by EU-ETS.

Table 3.3.1 Production of marketed burnt lime, Mg (Statistics Denmark, 2014 and Faxe Kalk, 2014a, b).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Faxe Kalk						46,340			71,480	76,348
Other producers						54,449			17,442	18,829
Total production	127,978	86,222	104,526	106,587	112,480	100,789	95,028	102,587	88,922	95,177
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Faxe Kalk	62,489	70,537	69,827	63,258	64,085	57,302	62,817	57,004	57,812	38,349
Other producers	29,513	25,949	52,814	24,291	13,759	13,937	15,835	18,500	17,169	7,853
Total production	92,002	96,486	122,641	87,549	77,844	71,239	78,652	75,504	74,981	46,202
	2010	2011	2012	2013						
Faxe Kalk	25,623	21,312	29,798	30,293						
Other producers	24,774	38,118	39,338	36,512						
Total production	50,397	59,430	69,136	66,805						

The production of hydrated lime (slaked lime) from burnt lime does not emit any greenhouse gasses, see section 3.2.13.3.1. All burnt lime that is later slaked, is included in the statistics shown in the table above. Adding the production of slaked lime to the activity data, would therefore result in double counting. Dolomitic lime ($CaCO_3MgCO_3$) is not produced in Denmark.

Sugar production statistics and the calculated lime consumption in the sugar industry are presented in Table 3.3.2.

Table 3.3.2 Production of sugar at different locations, Gg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Assens	151.7	152.9	141.2	145.3	148.8	177.7	129.5	146.2	167.1	160.5
Nakskov	202.3	203.9	188.2	193.7	198.4	133.2	172.7	195.0	222.8	214.0
Nykøbing	151.7	152.9	141.2	145.3	148.8	133.2	129.5	146.2	167.1	160.5
Total (Statistics Denmark)	505.7	509.8	470.6	484.3	496.0	444.1	431.8	487.4	557.0	535.1
$CaCO_3$-eq	5.7	5.7	5.3	5.4	5.6	5.0	4.8	5.5	6.2	6.0
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Assens	133.0	168.7	152.4	153.2	135.5	151.9	137.4	0	0	0
Nakskov	177.3	224.9	203.2	204.3	180.7	202.6	183.2	170.2	208.6	222.4
Nykøbing	133.0	168.7	152.4	153.2	135.5	151.9	137.4	159.6	191.6	206.1
Total (Statistics Denmark)	443.2	562.4	508.1	510.8	451.7	506.5	458.0	329.8	400.3	428.4
$CaCO_3$-eq	5.0	6.3	5.7	5.7	5.1	5.7	5.1	3.7	4.5	4.8
	2010	2011	2012	2013						
Assens	0	0	0	0						
Nakskov	137.9	114.7	137.9	140.0						
Nykøbing	124.2	103.3	124.2	125.0						
Total (Statistics Denmark)	262.1	218.1	262.0	265.0						
$CaCO_3$-eq	2.9	2.4	2.9	3.0						

1990-2006: Activity data based on information from Statistics Denmark and distribution between the three plants: 0.3/0.4/0.3.

2007-2009: Production data based on environmental reports from Nakskov and Nykøbing.

2010-2013: Activity data based on information from Statistics Denmark and distribution between the two plants: 0.53/0.47 (distribution calculated from environmental reports from 2005-2009).

Emission factors

The emission factor for calcination of both marketed and non-marketed calcium carbonate is based on stoichiometric relations; the emission factor applied is 0.785 kg CO_2 per kg CaO. The content of MgO in burned lime from Danish producers has been assumed negligible. It is also assumed that the degree of calcination is 100 % and no lime kiln dust (LKD) eludes from the production. Further examples on emission factors are presented in Table 3.3.3.

Table 3.3.3 Emission factors for production or use of carbonate based compounds based on stoichiometric relations.

Raw material			Product		kg CO_2/ kg raw material	kg CO_2/ kg product
Magnesium carbonate		$MgCO_3$	Magnesium oxide	MgO	0.5219	1.0918
Calcium carbonate	Limestone	$CaCO_3$	Lime/Quicklime	CaO	0.4397	0.7848
Calcium magnesium carbonate	Dolomite	$CaCO_3.MgCO_3$	Dolomitic lime	CaO.MgO	0.4773	0.9132
Barium carbonate		$BaCO_3$	Barium oxide	BaO	0.2230	0.2870
Lithium carbonate		Li_2CO_3	Lithium oxide	Li_2O	0.5957	1.4735
Sodium carbonate	Soda ash	Na_2CO_3		Na_2O	0.4152	0.7101

The emission factors for TSP, PM_{10}, and $PM_{2.5}$ are dependent on process conditions including pollution abatement equipment. The emission factors provided by the EMEP/EEA (2009) and CEPMEIP are presented in Table 3.3.4.

Table 3.3.4 Emission factors for TSP, PM_{10}, and $PM_{2.5}$, g per Mg marketed lime.

Level	TSP	PM_{10}	$PM_{2.5}$	Reference	Comment
Low	300	150	30	CEPMEIP	
Medium	500	200	40	CEPMEIP	Applied in Danish inventory
High	1000	300	60	CEPMEIP	
Tier 1	590	240	50	EMEP/EEA, 2009	
Tier 2, uncontrolled	9000	3500	700	EMEP/EEA, 2009	
Tier 2, controlled	400	200	30	EMEP/EEA, 2009	

The emission factors for PM_{10} and $PM_{2.5}$ are assumed to be a fixed fraction of the emission factor for TSP (i.e. 40% and 8% respectively – see **Error! Reference source not found.**).

For the Danish inventory the "medium level" emissions published by CEP-MEIP has been chosen as default as they are assumed to cover an average of small and large plants.

The emission factors used to calculate the BC, HCB, PCDD/F and PCB emissions from lime production are shown in Table 3.3.5 along with their respective sources.

Table 3.3.5 Emission factors for other pollutants for production of marketed lime

Pollutant	Unit	Value	Source
BC	g/Mg	0.18	EMEP/EEA Guidebook (2013)
HCB	mg/Mg	0.01	Nielsen et al. (2013a)
PCDD/F	µg/Mg	0.02	Henriksen et al. (2006)
PCB	mg/Mg	0.15	Nielsen et al. (2013a)

3.3.3 Emission trends

The emission trend for the CO_2 emission from lime production, including sugar production; is presented in Table 3.3.6 and Figure 3.3.1. The emission trend for particles and POPs is presented in Table 3.3.7.

Table 3.3.6 Emission of CO_2 from lime production, Gg.

	1990	1991	1992	1993	1994	1995	1996	1997
Lime production	100.44	67.67	82.03	83.65	88.27	79.10	74.58	80.51
Sugar production	4.66	4.70	4.33	4.46	4.57	4.09	3.98	4.49
Total	105.10	72.36	86.37	88.11	92.84	83.19	78.56	85.00
	1998	1999	2000	2001	2002	2003	2004	2005
Lime production	69.79	74.69	72.20	75.72	96.25	68.71	61.09	55.91
Sugar production	5.13	4.93	4.08	5.18	4.68	4.70	4.16	4.66
Total	74.92	79.62	76.29	80.90	100.93	73.41	65.25	60.57
	2006	2007	2008	2009	2010	2011	2012	2013
Lime production	61.74	59.27	59.01	36.37	39.63	46.71	54.34	52.51
Sugar production	2.17	1.72	2.67	1.92	1.56	2.01	2.24	1.64
Total	63.91	60.99	61.67	38.29	41.18	48.72	56.58	54.15

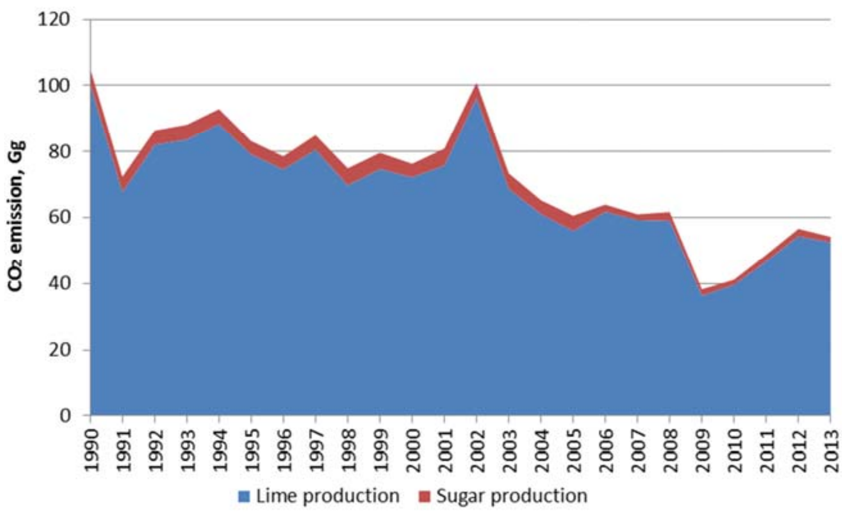


Figure 3.3.1 Emission trends for emission of CO_2 from lime production.

Table 3.3.7 Emission of particles and POPs from marketed lime production.

	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
HCB	g	1.0	0.7	0.8	0.9	0.9	0.8	0.8	0.8	0.7	0.8
PCDD/F	mg	2.3	1.6	1.9	1.9	2.0	1.8	1.7	1.8	1.6	1.7
PCB	g	19.2	12.9	15.7	16.0	16.9	15.1	14.3	15.4	13.3	14.3
	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TSP	Mg	46.0	48.2	61.3	43.8	38.9	35.6	39.3	37.8	37.5	23.1
PM_{10}	Mg	18.4	19.3	24.5	17.5	15.6	14.2	15.7	15.1	15.0	9.2
$PM_{2.5}$	Mg	3.7	3.9	4.9	3.5	3.1	2.8	3.1	3.0	3.0	1.8
BC	Mg	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
HCB	g	0.7	0.8	1.0	0.7	0.6	0.6	0.6	0.6	0.6	0.4
PCDD/F	mg	1.7	1.7	2.2	1.6	1.4	1.3	1.4	1.4	1.3	0.8
PCB	g	13.8	14.5	18.4	13.1	11.7	10.7	11.8	11.3	11.2	6.9
	Unit	2010	2011	2012	2013						
TSP	Mg	25.2	29.7	34.6	33.4						
PM_{10}	Mg	10.1	11.9	13.8	13.4						
$PM_{2.5}$	Mg	2.0	2.4	2.8	2.7						
BC	Mg	0.01	0.01	0.01	0.01						
HCB	g	0.4	0.5	0.6	0.5						
PCDD/F	mg	0.9	1.1	1.2	1.2						
PCB	g	7.6	8.9	10.4	10.0						

There is a peak in the activity data in 2002 causing peaks in the emissions for this year. The activity data are based on the official statistics from Statistics Denmark and there is no immediate explanation for the peak. As there are very few producers in Denmark it will not be possible to obtain more detailed data from Statistics Denmark.

3.3.4 EU-ETS data for lime production

The applied methodology for Faxe Kalk is specified in the individual monitoring plan that is approved by Danish authorities (DEA) prior to the reporting of the emissions. Lime production applies the Tier 2 methodology for the activity data and Tier 3 for the emission factor.

The implied CO_2 emission factor for Faxe Kalk is plant specific and based on the reporting to the EU Emission Trading Scheme (EU-ETS). The EU-ETS data have been applied for the years 2006 – 2013.

The CO_2 emission for lime production is based on sales (± 1.0 %) and measurements of the MgO content in the product (assuming the product is pure CaO / MgO) (Faxe Kalk, 2013).

3.3.5 Verification

For verification, the implied emission factors are calculated and presented in the following table.

Table 3.3.8 Implied emission factors for lime production, Mg CO_2 per Mg $CaCO_3$-eq.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Lime production (marketed)	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785
Sugar production	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785
Overall	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Lime production (marketed)	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.787	0.787
Sugar production	0.785	0.785	0.785	0.785	0.785	0.785	0.750	0.750	0.750	0.750
Overall	0.785	0.785	0.785	0.785	0.785	0.785	0.784	0.784	0.785	0.785
	2010	2011	2012	2013						
Lime production (marketed)	0.786	0.786	0.786	0.786						
Sugar production	0.750	0.750	0.750	0.750						
Overall	0.785	0.784	0.784	0.785						

The emission factor used by the sugar factories in 2006-2013 is only 0.75 kg CO_2 per Mg lime, please refer to Section 3.3.8 Future improvements.

If the simple Tier 2 methodology had been used for the entire time series, instead of partially using EU-ETS data, then the emission from marketed lime production in 2006-2013 would be 1 % (2007) to 16% (2008) lower; average of 2006-2013 is 8 %.

The 2006 IPCC guidelines provide Tier 1 emission factors for lime; see Table 3.3.9.

Table 3.3.9 Basic parameters for calculation of emission factors for lime products.

Lime type	Stoichiometric ratio Mg CO_2/Mg CaO or CaO-MgO	Range of CaO content %	Range of MgO content %	Default value for CaO or CaO-MgO content	Default emission factor Mg CO_2/Mg
High-calcium lime	0.785	93-98	0.3-2.5	0.95	0.75

Since 2008, Faxe Kalk has reported measured emissions factors to EU-ETS. These emission factors take into account the content of MgO and varies from 0.787-0.788 Mg CO2 per Mg lime produced (Faxe Kalk, 2014a), see Table 3.3.8. The measured emission factors show that the MgO content in the product has a negligible impact on the emissions; 0.3 % in average for 2008-2013. It is therefore considered reasonable to ignore this miniscule impurity in favour of increased consistency and the emission factor is hence not adjusted as suggested in Table 3.3.9.

Emissions of TSP at Faxe Kalk A/S, Lhoist Group are presented in Table 3.3.10.

Table 3.3.10 TSP emission factor at Faxe Kalk A/S, Lhoist Group (Faxe Kalk, 2014b).

		2001	2002	2003	2004	2005	2006	2007	2008
Flue gas	m^3	1.58E+08	2.25E+08	2.69E+08	2.71E+08	2.19E+08	2.33E+08	2.11E+08	2.85E+08
TSP concentration	mg TSP/m^3	42	40	31.5	26.1	23	23.8	7	20
TSP emission	Mg	6.64	9.00	8.47	7.07	5.04	5.55	1.48	5.70
Lime production	Mg	70,537	69,827	63,258	64,085	57,302	62,817	57,004	57,812
IEF TSP	g/Mg	94	129	134	110	88	88	26	99

The average emission factor for the years 2001-2008 is 96 g TSP per Mg lime. This figure is very low compared to the chosen emission factor of 500 g TSP per Mg lime from CEPMEIP.

3.3.6 Time series consistency and completeness

The chosen activity data for marketed lime production (entire time series) and non-marketed lime (2006-2013) are consistent. However in the case of lime consumption in the sugar industry in 1990-2005 the activity data (consumption of $CaCO_3$) was calculated from the total produced amount of sugar and an emission factor of 8.8 kg CO_2 per Mg sugar causing an inconsistency.

The applied methodology for calculation of the CO_2 emission from marketed lime is consistent for all producers for 1990-2005. From 2006, the CO_2 emission from the largest Danish producer (Faxe Kalk) is gathered from EU-ETS, but in spite of this, the methodology continues to be consistent until 2008 because Faxe Kalk uses the same emission factor when calculating emissions. In 2008 an inconsistency occurs when emissions reported by Faxe Kalk to EU-ETS begins to takes into account the otherwise negligible amount of MgO in the product, leading to a miniscule increase in the implied emission factor.

The Danish inventory on lime production is considered to be complete.

3.3.7 Input to CollectER

The input data / data sources are presented in Table 3.3.11.

Table 3.3.11 Input data for calculating emissions from production of lime and slaked lime.

	Year	Parameter	Comment/Source
Activity	1990-2013	Production	Danisco Sugar, Nordic Sugar, Statistics Denmark
Emissions	1990-2013	CO_2	Stoichiometric relations combined with product information from one company
	2006-2013	CO_2	Faxe Kalk (2014a)
	2000-2013	TSP, PM_{10}, $PM_{2.5}$	CEPMEIP
	2000-2013	BC	EMEP/EEA (2006)
	1990-2013	HCB, PCB	Nielsen et al. (2013a)
	1990-2013	PCDD/F	Henriksen et al. (2006)

3.3.8 Future improvements

The choice of CEPMEIP as source of the emission factors for particulate matter will be re-evaluated and a change to the latest edition of the EMEP / EEA guidebook will be considered.

Unfortunately, it was not possible to complete improvements to the source category of sugar production for this report; other improvements and the implementation of the 2006 IPCC Guidebook have been prioritised. Planned improvements include:

- It will be attempted to collect activity data on the amount of lime being used as raw material in the sugar production. If this improvement is possible, it will result in increased consistency in the lime production source category (marketed lime and sugar production).
- Further research will focus on the lower emission factor for CO_2 from the un-marketed lime in sugar production in 2006-2013. If possible, the emission factor will be made consistent throughout the time series depending on the findings.

3.4 Glass production

Glass production covers production of:

- Flat glass
- Container glass
- Glass wool

The production of flat glass (SNAP 03 03 14 Flat glass) is concentrated at few European producers and none of these have plants in Denmark. The processes in Denmark are limited to mounting of sealed glazing units. The mounting process is not considered to contribute to emission of pollutants to air in Denmark.

The production of container glass for packaging is concentrated at one company: Ardagh Glass Holmegaard A/S (previously Rexam Glass Holmegaard A/S) and for art industrial glass products: Holmegaard A/S both situated in Fensmark, Næstved. Saint-Gobain Isover situated in Vamdrup produces glass wool. The following SNAP-codes are covered:

- 03 03 15 Container glass
- 03 03 16 Glass wool (except binding)
- 04 06 13 Glass (decarbonising)

The following pollutants are included for the glass production process:

- NMVOC
- CO
- NH_3
- Particulate matter: TSP, PM_{10}, $PM_{2.5}$
- Heavy metals: As, Cd, Cr, Ni, Pb, Se, Zn

Emissions associated with the fuel use are estimated and reported in the energy sector.

3.4.1 Process description

The following descriptions as well as data are based on Holmegaard (2003), Rexam (2002) and Saint-Gobain Isover (2003).

The primary raw materials in glass production are dolomite ($CaMg(CO_3)_2$), feldspar ($(Ca,K,Na)AlSi_2O_8$), limestone ($CaCO_3$), sodium sulphate (Na_2SO_4), pluriol, sand (SiO), recycled glass (cullets), soda ash (Na_2CO_3), and colorants. Cullets constitute 40-50% of the raw materials. For the art industrial glass products a number of additional raw materials are used: aluminium hydrate, barium carbonate, borax, potash (carbonised), kaolin, lithium carbonate, titanium dioxide, and zinc oxide.

The primary constituents of glass are e.g.: SiO_2, Al_2O_3, CaO, MgO, Fe_2O_3, Na_2O, K_2O, BaO, PbO, B_2O_3 etc. where the actual composition depends on the final use of the product. The most common composition of glass for packaging is 60-75% SiO_2, 5-12% CaO, and 10-18% Na_2O (Lenntech).

The products are bottles and glass jars (Rexam Glass Holmegaard) as well as drinking glasses and glass art products (Holmegaard).

Emissions from glass production can be related to use of fuels, release of pollutants from raw materials and recycled glass, and release of CO_2 from use of soda ash.

Glass wool is produced from glass fibres and a binder (that is hardened to bakelite). The glass fibres are produced from sand, soda, limestone, dolomite, and auxiliaries (nephelin, dolomite, rasorite, palfoss, sodium nitrate and manganese dioxide) and also glass waste. The glass waste is crushed on location. The raw materials are mixed and finally mixed with crushed glass. The mixture is melted in an electric furnace. The melted glass is drawn into fibres by a natural gas flame.

The fibres are mixed with binder and formed into wool. The glass wool is hardened in a furnace fired with natural gas. The emission originates from energy consumption and decarbonizing of carbonate based raw materials.

3.4.2 Methodology

For the production of both container glass, art glass and glass wool, the main raw materials are soda ash (Na_2CO_3), dolomite ($CaMg(CO_3)_2$), limestone ($CaCO_3$) and recycled glass (cullets).

Emissions are calculated for each carbonate raw material individually.

Activity data

The activity data for container glass production are presented in Table 3.4.1. Information on consumption of carbon containing raw materials is available from the environmental reports of the plant since 1997 (Ardagh, 2014b) and from EU-ETS since 2006 (Ardagh, 2014a). For the years prior to 1997 the production of glass is based on information contained in Illerup et al. (1999).

Table 3.4.1 Production of container glass, activity data, Mg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Production of glass[1, 2]	164,000	159,000	145,000	140,500	150,200	140,000	140,000	140,000	186,622	197,863
Consumption of soda ash[3]	22,543	19,244	16,945	16,360	16,302	15,195	15,195	15,195	20,258	19,241
Consumption of limestone[3]	18,226	15,559	13,700	13,227	13,180	12,285	12,285	12,285	7,966	8,733
Consumption of dolomite[3]	1,237	1,056	930	898	895	834	834	834	9,522	9,808
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Production of glass[1, 2]	179,541	179,290	160,938	145,186	139,498	125,583	48,179	52,437	130,075	78,596
Consumption of soda ash	16,391	16,668	15,816	14,106	13,611	12,996	12,831	14,060	13,882	8,464
Consumption of limestone	7,739	7,881	7,050	6,347	6,036	5,650	1,325	1,693	9,171	5,383
Consumption of dolomite	9,085	8,920	8,031	7,258	7,036	6,118	5,413	5,462	5,527	3,631
	2010	2011	2012	2013						
Production of glass[1, 2]	86,354	87,923	90,027	68,210						
Consumption of soda ash	8,883	8,843	9,584	6,755						
Consumption of limestone	5,855	5,940	6,095	4,796						
Consumption of dolomite	4,085	4,215	4,267	2,911						

[1] 1990-1997: Illerup et al. (1999).
[2] 1998-2013: Estimated based on 1997 and total consumption of raw materials.
[3] 1990-1996: Estimated based on total production and the consumption of raw materials in 1997.

Only one industrial art glass producer with virgin glass production exists in Denmark; Holmegaard A/S. Emissions from this production is included in the data on container glass above.

The activity data for glass wool production are presented in Table 3.4.2. Information on consumption of carbon containing raw materials is available from the environmental reports of the plant since 1996 (Saint-Gobain Isover, 2014a) and EU-ETS since 2006 (Saint-Gobain Isover, 2014b). For the years prior to 1995/1996 the production of glass wool and consumption of carbonates are estimated.

Table 3.4.2 Production of glass wool, activity data, Mg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Production of glass wool[1]	35,631	35,631	35,631	35,631	35,631	35,631	35,631	34,584	33,630	38,680
Consumption of soda ash[2]	3,566	3,566	3,566	3,566	3,566	3,566	3,589	3,654	3,455	3,095
Consumption of limestone[2]	818	818	818	818	818	818	768	854	831	276
Consumption of dolomite[3]	1,021	1,021	1,021	1,021	1,021	1,021	1,021	1,021	1,021	1,021
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Production of glass wool	39,666	36,983	34,836	37,452	41,350	37,295	42,735	40,995	41,318	33,066
Consumption of soda ash	2,974	2,895	3,300	2,810	3,348	3,639	c	c	c	c
Consumption of limestone	213	369	589	425	530	614	c	c	c	c
Consumption of dolomite[3]	1,021	1,021	1,021	1,021	1,021	1,021	c	c	c	c
	2010	2011	2012	2013						
Production of glass wool	24,899	29,817	26,752	27,894						
Consumption of soda ash	c	c	c	c						
Consumption of limestone	c	c	c	c						
Consumption of dolomite	c	c	c	c						

[1] 1990-1996: Estimated: Assumed constant on the average production from 1997-1999.
[2] 1990-1995: Estimated: Assumed constant on the average consumption from 1996-1998.
[3] 1990-2005: Estimated: Assumed constant on the average consumption from 2006-2008.
c: Confidential.

The time series for activity data for the glass sector are presented in Figure 3.4.1

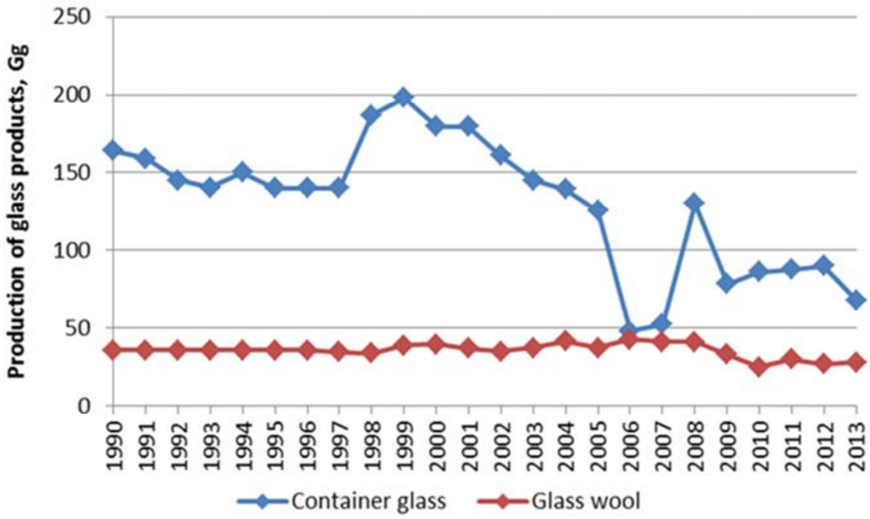


Figure 3.4.1 Activity data for container glass and glass wool production.

The drastic decrease in the calculated production of container glass in 2006 and 2007 is a result of a similar decrease in the consumption of limestone reported to the EU-ETS database. It will be investigated whether the temporary decrease is due to EU-ETS teething troubles or something else.

Both the container glass and glass wool production displays a significant decrease from 2008 to 2010 that can be explained by the financial crises.

Emission factors

The emission factors for the glass industry are a combination of default Tier 2 factors suggested in EMEP/EEA (2013) and calculated implied emission factors based on measurements by the specific industries. The emission factors are supplemented with estimated CO_2 emissions from the calcination of carbonate compounds and some measured emission.

Soda ash is either extracted from natural carbonate bearing deposit (I) or produced from calcium carbonate and sodium chloride (II).

(I) $2\ Na_2CO_3{,}NaHCO_3{,}2H_2O \rightarrow 3Na_2CO_3 + 5H_2O + CO_2$

(II) $CaCO_3 + 2NaCl \rightarrow Na_2CO_3 + CaCl_2$

The CO_2 emission factors from using Na_2CO_3 and other carbonate containing raw materials in production of glass and glass wool, based on stoichiometric relationships, are:

- 0.41492 Mg CO_2/Mg Na_2CO_3
- 0.43971 Mg CO_2/Mg $CaCO_3$
- 0.47732 Mg CO_2/Mg $CaMg(CO_3)_2$
- 0.52197 Mg CO_2/Mg $MgCO_3$

The calcination of all carbonates in all years is assumed to be 100 %.

From 2006 onward the CO_2 emissions are calculated by the companies and reported to EU-ETS (Ardagh, 2014a; Saint-Gobain Isover, 2014a), but the applied emission factors (however rounded) remain the same for the entire time series.

The emission of CO_2 is estimated from the following equation:

$$E_{CO2} = \sum EF_s \times Act_s$$

where:

E_{CO2} is emission of CO_2
EF_s is emission factor for substance *s*
Act_s is consumption of substance *s*

Yearly measurements of the emissions from production of container glass are available in the environmental reports; these provide emissions of TSP (2000-2013), Pb (1997-2013), Se (1997-2013) and Zn (1997-2001) (Ardagh, 2014b and previous years). PM_{10} and $PM_{2.5}$ are estimated from the distribution between TSP, PM_{10} and $PM_{2.5}$ (1/0.9/0.8) provided by EMEP/EEA (2013). Emissions of As, Cd, Cr and Ni are estimated from standard emission factors. Where direct emissions are not available for Pb, Se and Zn; these are also calculated using emission factors. All used emission factors are shown in Table 3.4.3. From 2006, measured particle emissions from the singular Danish container glass producer decrease 90 % due to installation of abatement equipment; all calculated heavy metal emissions are therefore also lowered with 90 % from 2006.

The emission of NH_3 and TSP from the production of glass wool has been measured yearly since 1996 and are available in the company's environmental reports (Saint-Gobain Isover, 2014b). PM_{10} and $PM_{2.5}$ are estimated from the distribution between TSP, PM_{10} and $PM_{2.5}$ (1/0.9/0.8) from EMEP/EEA (2013). NMVOC and CO have been measured for 2007-2013 and 1996-1997 respectively. For the years where no measured emission data are available, emissions are calculated using data on total production and implied emission factors (IEF) based on the available measurements. All used emission factors are shown in Table 3.4.3. Prior to 1996 (where total production is not available) the emissions have been assumed constant at the emission average level of 1996-1998. Since it has not been possible to separate process emissions from the emissions from fuel combustion, the measured/calculated emissions from glass wool production presented here account for the entire production.

Table 3.4.3 Emission factors for production of glass production.

	Container glass production			Glass wool production		
Pollutant	Unit	Value	Source	Unit	Value	Source
NMVOC		-		kg/Mg	1.4	IEF (2007-2009)
CO		IE		kg/Mg	0.1	IEF (1996-1997)
NH_3		-		kg/Mg	7.4	IEF(1996-1998)
TSP	kg/Mg	0.28	Guidebook (2013)	kg/Mg	2.0	IEF (2000-2013)
PM_{10}	kg/Mg	0.25	Guidebook (2013)	kg/Mg	1.8	IEF (2000-2013)
$PM_{2.5}$	kg/Mg	0.22	Guidebook (2013)	kg/Mg	1.6	IEF (2000-2013)
As	g/Mg	0.29	Guidebook (2013)		-	
Cd	g/Mg	0.12	Guidebook (2013)		-	
Cr	g/Mg	0.37	Guidebook (2013)		-	
Ni	g/Mg	0.24	Guidebook (2013)		-	
Pb	g/Mg	2.90	Guidebook (2013)		-	
Se	g/Mg	1.50	Guidebook (2013)		-	
Zn	g/Mg	0.23	Guidebook (2013)		-	

IE: Included elsewhere. It is not possible to separate process and fuel emissions, these process emissions are included in the energy sector.

3.4.3 Emission trend

For the years 2006-2013 information on CO_2 emission has been available in the company reports to the EU-ETS (Ardagh, 2014a and Saint Gobain Isover, 2014a). However, this information is confidential, and data since 2006 can therefore only be presented as total emitted CO_2.

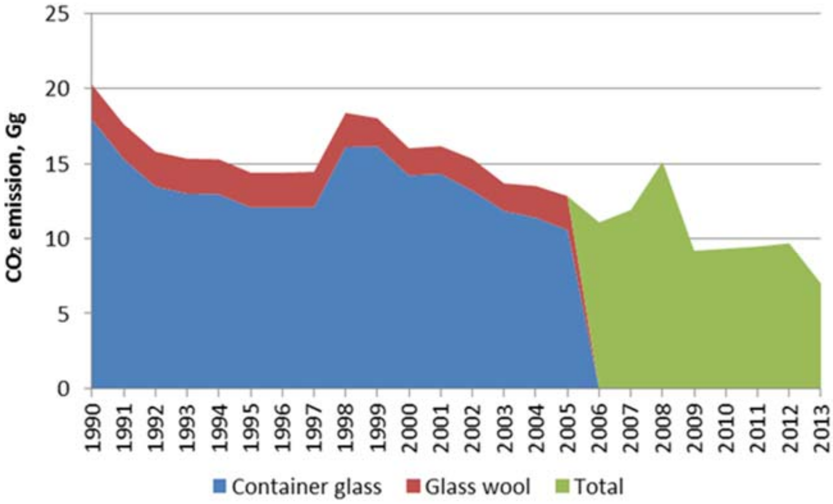


Figure 3.4.2 CO_2 emissions from glass production.

The emission trends from production of container glass and glass wool are presented in Table 3.4.4,.

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Table 3.4.4 Emissions from production of glass.

Pollutant		Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2	Total	Gg	20.2	17.6	15.8	15.3	15.3	14.4	14.4	14.5	18.4	18.0
	- of which container glass	*Gg*	*17.9*	*15.3*	*13.5*	*13.0*	*13.0*	*12.1*	*12.1*	*12.1*	*16.1*	*16.1*
	- of which glass wool	*Gg*	*2.3*	*2.3*	*2.3*	*2.3*	*2.3*	*2.3*	*2.3*	*2.4*	*2.3*	*1.9*
NMVOC	From glass wool	Mg	46.3	46.3	46.3	46.3	46.3	46.3	46.3	45.0	43.7	50.3
CO	From glass wool	Mg	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.8	2.1
NH_3	From glass wool	Mg	262.0	262.0	262.0	262.0	262.0	262.0	224.0	296.0	266.0	268.0
As	From container glass	kg	47.6	46.1	42.1	40.7	43.6	40.6	40.6	40.6	54.1	57.4
Cd	From container glass	kg	19.7	19.1	17.4	16.9	18.0	16.8	16.8	16.8	22.4	23.7
Cr	From container glass	kg	60.7	58.8	53.7	52.0	55.6	51.8	51.8	51.8	69.1	73.2
Ni	From container glass	kg	39.4	38.2	34.8	33.7	36.0	33.6	33.6	33.6	44.8	47.5
Pb	From container glass	kg	475.6	461.1	420.5	407.5	435.6	406.0	406.0	883.0	523.0	562.0
Se	From container glass	kg	246.0	238.5	217.5	210.8	225.3	210.0	210.0	134.0	90.0	218.0
Zn	From container glass	kg	37.7	36.6	33.4	32.3	34.5	32.2	32.2	31.0	49.0	45.0

		Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2	Total	Gg	16.0	16.2	15.3	13.7	13.5	12.8	11.1	11.9	15.1	9.2
	- of which container glass	*Gg*	*14.2*	*14.3*	*13.2*	*11.8*	*11.4*	*10.6*	*c*	*c*	*c*	*c*
	- of which glass wool	*Gg*	*1.8*	*1.9*	*2.1*	*1.8*	*2.1*	*2.3*	*c*	*c*	*c*	*c*
NMVOC	From glass wool	Mg	51.6	48.1	45.3	48.7	53.8	48.5	55.6	58.0	52.0	46.0
CO	From glass wool	Mg	2.1	2.0	1.9	2.0	2.2	2.0	2.3	2.2	2.2	1.8
NH_3	From glass wool	Mg	225.0	190.0	133.0	125.0	124.0	116.0	123.0	109.0	155.0	152.0
TSP	Total	Mg	137.0	144.0	135.0	128.0	122.0	92.0	82.9	53.0	55.2	34.2
	- of which container glass	*Mg*	*26.0*	*25.0*	*21.0*	*26.0*	*23.0*	*7.0*	*0.9*	*1.0*	*1.2*	*1.2*
	- of which glass wool	*Mg*	*111.0*	*119.0*	*114.0*	*102.0*	*99.0*	*85.0*	*82.0*	*52.0*	*54.0*	*33.0*
PM_{10}	Total	Mg	123.0	129.0	122.0	115.0	109.5	83.3	74.8	47.9	50.1	31.1
	- of which container glass	*Mg*	*23.0*	*22.0*	*19.0*	*23.0*	*20.5*	*6.3*	*0.8*	*0.9*	*1.1*	*1.1*
	- of which glass wool	*Mg*	*100.0*	*107.0*	*103.0*	*92.0*	*89.0*	*77.0*	*74.0*	*47.0*	*49.0*	*30.0*
$PM_{2.5}$	Total	Mg	109.0	115.0	108.0	102.0	97.1	73.5	66.7	42.8	43.9	26.9
	- of which container glass	*Mg*	*20.0*	*20.0*	*17.0*	*20.0*	*18.1*	*5.5*	*0.7*	*0.8*	*0.9*	*0.9*
	- of which glass wool	*Mg*	*89.0*	*95.0*	*91.0*	*82.0*	*79.0*	*68.0*	*66.0*	*42.0*	*43.0*	*26.0*
As	From container glass	kg	52.1	52.0	46.7	42.1	40.5	36.4	1.4	1.6	3.9	2.4
Cd	From container glass	kg	21.5	21.5	19.3	17.4	16.7	15.1	0.5	0.5	1.3	0.8
Cr	From container glass	kg	66.4	66.3	59.5	53.7	51.6	46.5	1.9	2.1	5.2	3.1
Ni	From container glass	kg	43.1	43.0	38.6	34.8	33.5	30.1	1.0	1.0	2.6	1.6
Pb	From container glass	kg	330.0	172.0	220.0	272.0	436.0	148.0	12.0	16.0	18.0	18.0
Se	From container glass	kg	340.0	271.0	201.0	234.0	225.0	107.0	59.0	53.0	46.0	25.0
Zn	From container glass	kg	57.0	25.0	38.0	34.0	33.0	29.0	1.0	1.0	3.0	2.0

		Unit	2010	2011	2012	2013
CO_2	Total	Gg	9.3	9.5	9.7	7.0
NMVOC	From glass wool	Mg	32.0	39.0	39.0	37.0
CO	From glass wool	Mg	1.3	1.6	1.4	1.5
NH_3	From glass wool	Mg	108.0	105.0	144.0	119.0
TSP	Total	Mg	27.7	43.8	51.5	39.6
	- of which container glass	*Mg*	*1.7*	*1.8*	*4.5*	*1.6*
	- of which glass wool	*Mg*	*26.0*	*42.0*	*47.0*	*38.0*
PM_{10}	Total	Mg	24.5	39.6	47.0	36.4
	- of which container glass	*Mg*	*1.5*	*1.6*	*4.0*	*1.4*
	- of which glass wool	*Mg*	*23.0*	*38.0*	*43.0*	*35.0*
$PM_{2.5}$	Total	Mg	22.3	35.0	41.5	32.3
	- of which container glass	*Mg*	*1.3*	*1.4*	*3.5*	*1.3*
	- of which glass wool	*Mg*	*21.0*	*33.6*	*38.0*	*31.0*
As	From container glass	kg	2.6	2.6	2.7	2.0
Cd	From container glass	kg	0.9	0.9	0.9	0.7
Cr	From container glass	kg	3.5	3.5	3.6	2.7
Ni	From container glass	kg	1.7	1.8	1.8	1.4
Pb	From container glass	kg	24.0	25.0	116.0	22.0
Se	From container glass	kg	17.0	17.0	60.0	19.0
Zn	From container glass	kg	2.0	2.0	2.0	2.0

c: Confidential

3.4.4 Time series consistency and completeness

CO_2 emissions from glass production (including container glass, art glass and glass wool production) are calculated based on consumption of carbonates and stoichiometric emission factors for the entire time series. However, the source of activity data varies for the time series and it is therefore at present unclear whether or not the time series is consistent. Verification of the activity data will be carried out in the future to ensure the consistency.

Effort has been made to ensure that all glass producers are included in the inventory. Smaller facilities producing art glass do exist in Denmark, but none of these produce their own virgin glass. The source category of glass production is therefore considered to be complete.

3.4.5 Input to CollectER

The environmental report (Saint-Gobain Isover, 2014b) presents energy as well as process related emissions. The process related emissions are used as input along with estimated CO_2 emission from calcination of the raw materials. The TSP emission from both container glass and glass wool production is based on the environmental reports with a distribution between PM_{10} and $PM_{2.5}$ as reported in EMEP / EEA (2013) i.e. 90 % and 80 % of TSP respectively. The input data / data sources are presented in Table 3.4.5.

Table 3.4.5 Input data for calculating emissions from glass production.

	Year	Parameter	Comment/Source
Activity data	1990-1997	Container glass production	Illerup et al. (1999)
	1998-2013	Container glass production	Estimated from consumption of raw materials
	1990-1996	Consumption of raw materials for container glass	Estimated from production
	1997-2013	Consumption of raw materials for container glass	Ardagh (2014b) and earlier
	1990-1997	Glass wool production	Assumed to be average 1997-1999
	1998-2013	Glass wool production	Saint-Gobain Isover (2014b) and earlier
	1990-1995 (1990-2005)	Consumption of raw materials for glass wool	Assumed to be average 1996-1998 (2006-2008 for dolomite)
	1996-2013	Consumption of raw materials for glass wool	Saint-Gobain Isover (2014b) and earlier
Emissions	1990-1996	Pb, Se	Illerup et al. (1999), EMEP/EEA (2013)
	1997-2013	Pb, Se	Ardagh (2014b) and earlier
	2000-2013	TSP	Ardagh (2014b), Saint-Gobain Isover (2014b) and earlier
	2000-2013	PM_{10}, $PM_{2.5}$	Distribution between TSP, PM_{10}, and $PM_{2.5}$ from EMEP/EEA (2013)
	1990-2005	As, Cd, Cr, Ni	EMEP/EEA (2013)
	2006-2013	As, Cd, Cr, Ni	EMEP/EEA (2013), Ardagh (2014b)
	1997-2001	Zn	Ardagh (2014b) and earlier
	1990-1996; 2002-2013	Zn	Calculated from activity data and implied emission factors (IEF) (1997-2001)
	1990-1995	NMVOC, NH_3	Assumed to be average 1996-1998
	1996-2006	NMVOC	Calculated from activity data and IEF (2007-2009)
	2007-2013	NMVOC	Saint-Gobain Isover (2014b) and earlier
	1996-2013	NH_3	Saint-Gobain Isover (2014b) and earlier
	1990-1995	CO	Assumed to be average 1996-1997
	1996-1997	CO	Saint-Gobain Isover (2014b) and earlier
	1998-2013	CO	Calculated from activity data and IEF (1996-1997)
	1990-2005	CO_2	Estimated from consumption of raw materials
	2006-2013	CO_2	EU-ETS (Ardagh, 2014a; Saint-Gobain Isover, 2014a)

3.4.6 Future improvements

Emissions of BC will be added for container glass and glass wool production.

The production figures for container glass are very low for 2006 and 2007, this will be investigated further.

3.5 Ceramics

This section covers production of bricks, tiles (aggregates or bricks/blocks for construction) and expanded clay products for different purposes (aggregates as absorbent for chemicals, cat litter, and for other miscellaneous purposes). The following SNAP codes are covered:

- 04 06 91 Production of bricks
- 04 06 92 Production of expanded clay products

The production of bricks is found all over the country, where clay is available. Producers of expanded clay products are located in the northern part of Jutland.

Emissions associated with the fuel use are estimated and reported in the energy sector.

The following pollutants are covered:

- CO_2
- SO_2
- Persistent organic pollutants: PCDD/F

3.5.1 Process description

During the production of ceramics, the raw materials are collected and finely crushed in successive grinding operations. The ground particles are then fired in a kiln to produce a powder (which may be liquefied). Additives are subsequently added and the ceramic is formed.

The clays used in the production process include small amounts of carbonates, which is oxidised during the process thereby generating CO_2. Also, some of the clays contain significant amounts of sulphur, which is oxidised and released as SO_2 during the process.

The production sites of bricks, tiles and expanded clay products are found all over the country; see Table 3.5.1.

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Table 3.5.1 Producers of clay and expanded clay products.

Product	Company	Location
Bricks and tiles	Vedstårup teglværk	5610 Assens
	Vesterled Teglværk	6400 Sønderborg
	Pipers Teglværk Vindø	9500 Hobro
	Pedershvile teglværk	3200 Helsinge
	Prøvelyst teglværk	2980 Kokkedal
	Lundgård teglværk	7850 Stoholm, Jylland
	Bachmanns teglværk	6400 Sønderborg
	Petersens Tegl Egernsund	6310 Broager
	Orebo Teglværk	4293 Dianalund
	Tychsen's Teglværk	6310 Broager
	Nordtegl	9881 Bindslev
	Ydby Teglværk	7760 Hurup Thy
	Hellingsø Teglværk	7760 Hurup Thy
	Carl Matzens Teglværk	6320 Egernsund
	Gråsten Teglværk	6300 Gråsten
	P.M. Tegl Egernsund	6320 Egernsund
	Pipers Teglværk Gandrup	9362 Gandrup
	Pipers Teglværk Hammershøj	8830 Tjele
	Pipers Teglværk Højslev	7840 Højslev
	Monier Volstrup Teglværk	9300 Sæby
	Villemoes Teglværk	6690 Gørding
Expanded clay products	Saint-Gobain Weber	8900 Randers
	Damolin Mors	7900 Nykøbing Mors
	Damolin Fur	7884 Fur

The expanded clay products are presented in Table 3.5.2.

Table 3.5.2 Products from different producers of expanded clay products.

Company	Location	Products
Damolin	Fur, Nykøbing Mors	Cat litter
		Felicia
		Amigo
		Absorbant
		Absodan
		Sorbix
		Oil Dri
		Moler
		Bentonite
		Perlite
		Vermiculite
Saint-Gobain Weber	Randers, Gadbjerg	Optiroc
		Leca

3.5.2 Methodology

Emission of CO_2 and SO_2 is related to limestone and sulphur content in the raw material respectively, whereas emission of NO_x and other pollutants is related to fuel consumption / process conditions. The NO_x and SO_2 emissions have previously been discussed by DTI (2000). A typical composition of clay used for bricks is presented in Table 3.5.3.

Table 3.5.3 Typical composition of clay used for bricks (Tegl Info, 2004).

	Red bricks	Yellow bricks
Silicic acid (SiO_2)	63.2 %	49.6 %
Aluminium oxide (Al_2O_3)	17.9 %	14.2 %
Iron(III)oxide (Fe_2O_3)	7.1 %	5.1 %
Calcium carbonate ($CaCO_3$)	0.5 %	19.8 %
Magnesium oxide (MgO)	1.3 %	1.4 %
Alkali oxides (e.g. Na_2O, K_2O)	2.9 %	2.9 %
Chemical bound water and organic substances	7.1 %	7.0 %

Since 2006, the producers of ceramics have measured and reported process CO_2 emissions to EU-ETS and production statistics are known from Statistics Denmark (2014) for the entire time series. From these two datasets, implied emission factors are calculated for 2006-2013 and CO_2 emissions are calculated for the years back to 1990.

Activity data

National statistics on production of bricks, tiles and expanded clay products contain a broad range of different products, most of them in units of numbers (no.). The consumption of limestone is therefore used as alternative activity data for these source categories for all pollutants, not just for CO_2.

The production statistics for bricks and expanded clay products (used as surrogate data) from Statistics Denmark (2014) and the consumption of lime in the production (calculated for 1990-2005) are presented in Table 3.5.4.

Table 3.5.4 Statistics for production of bricks and expanded clay products.

	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Bricks											
Produced[1]	million pieces	291.3	291.5	303.6	278.5	389.8	362.7	377.7	419.4	423.3	405.2
Consumed lime[2]	Gg $CaCO_3$	56.8	56.9	59.2	54.3	76.1	70.8	73.7	81.8	82.6	79.1
Expanded clay products											
Produced[1]	Gg	331.8	268.9	282.9	288.3	383.8	340.9	368.1	406.7	324.4	329.4
Consumed lime[2]	Gg $CaCO_3$-eq	37.1	30.0	31.6	32.2	42.9	38.1	41.1	45.4	36.2	36.8
	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Bricks											
Produced[1]	million pieces	414.8	352.0	342.2	342.0	365.4	407.9	465.5	348.9	322.1	226.4
Consumed lime[2]	Gg $CaCO_3$	80.9	68.7	66.8	66.7	71.3	79.6	79.0	86.4	61.8	35.8
Expanded clay products											
Produced[1]	Gg	316.2	232.3	239.7	211.8	281.8	310.9	411.9	504.9	303.9	140.9
Consumed lime[2]	Gg $CaCO_3$-eq	35.3	25.9	26.8	23.7	31.5	34.7	47.5	61.1	36.6	14.7
	Unit	2010	2011	2012	2013						
Bricks											
Produced[1]	million pieces	212.1	222.1	185.4	177.4						
Consumed lime	Gg $CaCO_3$	35.1	46.0	39.7	36.7						
Expanded clay products											
Produced[1]	Gg	157.4	172.3	153.3	139.8						
Consumed lime	Gg $CaCO_3$-eq	13.7	15.1	13.4	23.8						

[1] Statistics Denmark (2014).
[2] 1990-2005: Calculated from production data and the average implied emission factor for 2006-2013.

The consumption of lime in the production of ceramics is also presented in the following figure.

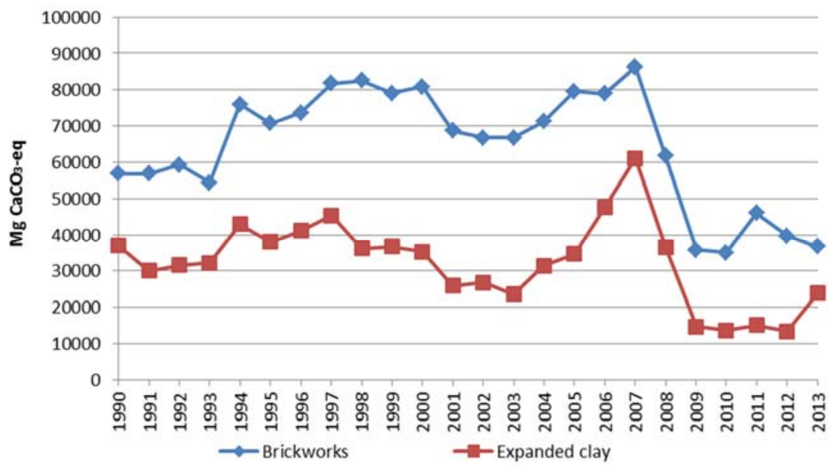

Figure 3.5.1 Consumption of $CaCO_3$ equivalents in the production of ceramics.

Both the brickworks and expanded clay production displays a significant decrease from 2007 to 2009 that can be explained by the financial crises.

Emission factors

The CO_2 emission factor for lime is 0.43971 kg CO_2 per kg $CaCO_3$. The calcination factor is assumed to be 1 for all years and all producers.

For 2006-2013 CO_2 emissions are reported by the brickworks to EU-ETS (confidential reports from approximately 20 brickworks). The reported emissions are calculated from measured lime contents of the raw materials and the stoichiometric emission factor 0.43971 kg CO_2 per kg $CaCO_3$. From the reported emissions implied emission factors are calculated to match the activity data for brickworks using the stoichiometric factors.

Producers of expanded clay products also report CO_2 emissions to EU-ETS for the years 2006-2013 (Damolin, 2014; Saint-Gobain Weber, 2014). The reported emissions are calculated from the difference in C contents measured in the raw materials and products and the stoichiometric emission factor 3.664 kg CO_2 per kg C.

The SO_2 emission factors for the production of bricks and expanded clay products are determined from the individual companies reporting of SO_2 emission (environmental reports) for the years 2009-2011 and the activity for the corresponding years. 2009-2011 were selected as the most complete data sets are available for these years.

The SO_2 emissions attributed to the process have been adjusted for the fuel related emissions as far as possible to derive the process emissions. Five plants were using coal, petroleum coke and residual oil according to EU-ETS reporting. The fuel related SO_2 emission was calculated by using the general EF_{SO2} for the relevant fuels (Nielsen et al., 2015). The applied emission factors are presented in Table 3.5.5.

Table 3.5.5 Applied emission factors for S-containing fuels.

Fuel	Emission factor, g SO_2/GJ
Coal	574
Petroleum coke	605
Residual oil	344

The total emissions of SO_2 from the plants considered were reduced by the amount related to fuel before calculating the emission factor, see Table 3.5.6. However, the emission factor will continuously be improved as a more comprehensive dataset are made available and the influence from fuel contribution will be studied further as not all the environmental reports distinguish clearly between the different emission sources.

The PCDD/F emission factors are calculated from 0.018 µg per Mg product (Henriksen et al., 2006), using the total carbonate consumption (environmental reports), national production statistics (Statistics Denmark) and an assumption of 2 kg per brick.

The applied emission factors for ceramics are presented in Table 3.5.6.

Table 3.5.6 Emission factors for ceramics, units are per Mg $CaCO_3$ equivalent.

	Brickworks		Expanded clay		
Pollutant	Value	Unit	Value	Unit	Source
CO_2	0.44	kg	0.44	kg	Stoichiometric
SO_2	6.5	kg	63.3	kg	Environmental reports*
PCDD/F	0.19	µg	0.17	µg	Henriksen et al. (2006)*

* Some recalculations were necessary to derive the desired units.

3.5.3 Emission trend

Emissions of CO_2, SO_2 and PCDD/F from production of ceramics are presented in Table 3.5.7, Figure 3.5.2 and Figure 3.5.3.

Table 3.5.7 Process emissions from production of ceramics.

Pollutant	Source	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2	Total	Gg	41.3	38.2	39.9	38.1	52.3	47.9	50.5	56.0	52.2	50.9
	Brickworks	Gg	25.0	25.0	26.0	23.9	33.4	31.1	32.4	36.0	36.3	34.8
	Expanded clay	Gg	16.3	13.2	13.9	14.2	18.8	16.7	18.1	20.0	15.9	16.2
SO_2	Total	Gg	2.7	2.3	2.4	2.4	3.2	2.9	3.1	3.4	2.8	2.8
	Brickworks	Gg	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5
	Expanded clay	Gg	2.3	1.9	2.0	2.0	2.7	2.4	2.6	2.9	2.3	2.3
PCDD/F	Total	mg	17.0	15.8	16.5	15.7	21.6	19.8	20.8	23.1	21.7	21.1
	Brickworks	mg	10.7	10.7	11.2	10.2	14.3	13.3	13.9	15.4	15.5	14.9
	Expanded clay	mg	6.3	5.1	5.3	5.4	7.2	6.4	6.9	7.7	6.1	6.2
Pollutant	Source	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2	Total	Gg	51.1	41.6	41.1	39.7	45.2	50.3	55.6	64.8	43.2	22.2
	Brickworks	Gg	35.6	30.2	29.4	29.3	31.3	35.0	34.7	38.0	27.2	15.7
	Expanded clay	Gg	15.5	11.4	11.8	10.4	13.8	15.3	20.9	26.9	16.1	6.5
SO_2	Total	Gg	2.8	2.1	2.1	1.9	2.5	2.7	3.5	4.4	2.7	1.2
	Brickworks	Gg	0.5	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.4	0.2
	Expanded clay	Gg	2.2	1.6	1.7	1.5	2.0	2.2	3.0	3.9	2.3	0.9
PCDD/F	Total	mg	21.2	17.3	17.1	16.6	18.7	20.8	22.9	26.6	17.8	9.2
	Brickworks	mg	15.2	12.9	12.6	12.6	13.4	15.0	14.9	16.3	11.6	6.7
	Expanded clay	mg	6.0	4.4	4.5	4.0	5.3	5.9	8.0	10.3	6.2	2.5
Pollutant	Source	Unit	2010	2011	2012	2013						
CO_2	Total	Gg	21.5	26.8	23.4	26.6						
	Brickworks	Gg	15.4	20.2	17.5	16.1						
	Expanded clay	Gg	6.0	6.6	5.9	10.5						
SO_2	Total	Gg	1.1	1.3	1.1	1.7						
	Brickworks	Gg	0.2	0.3	0.3	0.2						
	Expanded clay	Gg	0.9	1.0	0.8	1.5						
PCDD/F	Total	mg	8.9	11.2	9.7	10.9						
	Brickworks	mg	6.6	8.7	7.5	6.9						
	Expanded clay	mg	2.3	2.5	2.3	4.0						

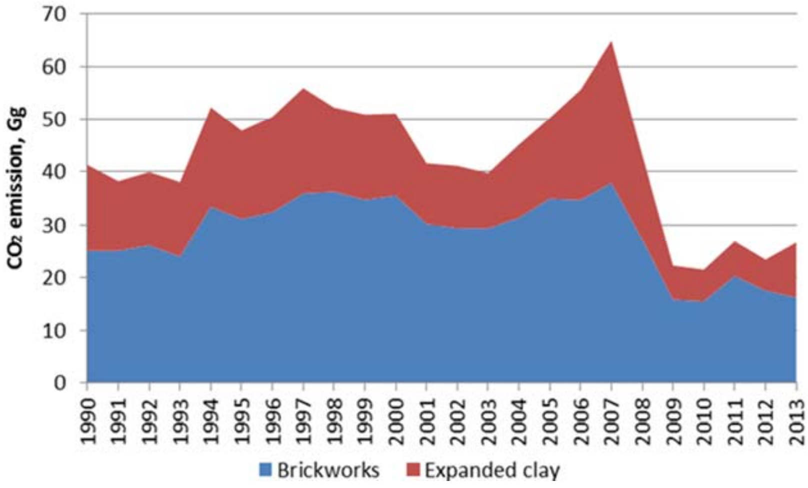

Figure 3.5.2 CO_2 emissions from the production of ceramics divided in the two sources.

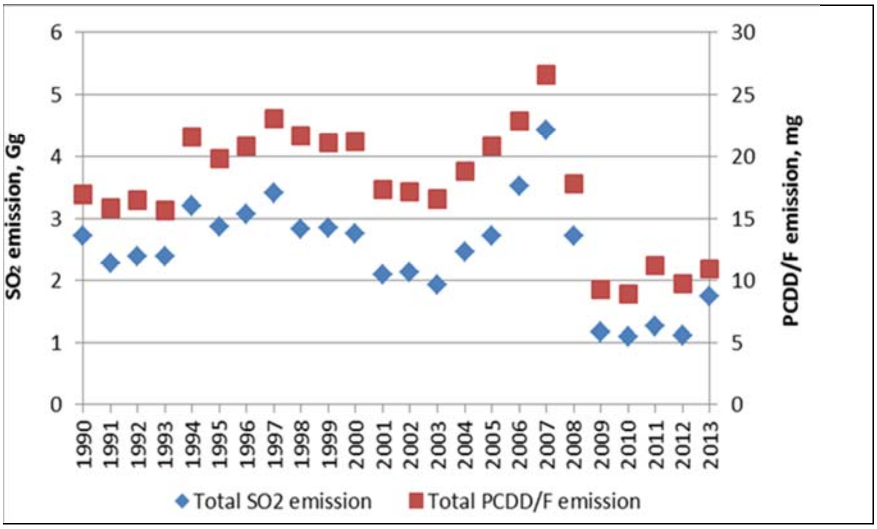

Figure 3.5.3 Total SO_2 and PCDD/F emissions from the production of ceramics.

Emissions from this source category are very dependent on new houses being built as well as old ones being renovated. The significant decline in emissions from 2007-2009 was caused by a reduced production resulting from the economic recession caused by the global financial crisis.

3.5.4 EU-ETS data for ceramics

The applied methodologies for brickworks and expanded clay producers are specified in the individual monitoring plans that are approved by Danish authorities (DEA) prior to the reporting of the emissions. The production of ceramics applies the Tier 2 methodology for calculating the CO_2 emission.

The CO_2 emission for ceramics production is based on measured carbonate content in all raw materials and consumption of the individual carbonate containing raw materials (Tier 2; ± 5.0 %). The implied CO_2 emission factors for the production facilities are based on stoichiometry.

3.5.5 Verification

For 2006-2013 the implied emission factors have been derived from CO_2 emissions reported by the producers of ceramics to EU-ETS (confidential reports from 21 producers) and production statistics (Statistics Denmark, 2014).

The implied emission factor (IEF) for the production of bricks is calculated to 34.8-54.4 kg CO_2 per Mg bricks (average: 42.9 kg CO_2 per Mg product) for 2006-2013 and the IEF for expanded clay products is 38.3-74.9 kg CO_2 per Mg product (average: 49.1 kg CO_2 per Mg product) for the same period. Figure 3.5.4 shows the development of these IEFs for the years 1990-2013. The emission factor for both types of ceramics is 0.43971 Mg CO_2 per Mg $CaCO_3$.

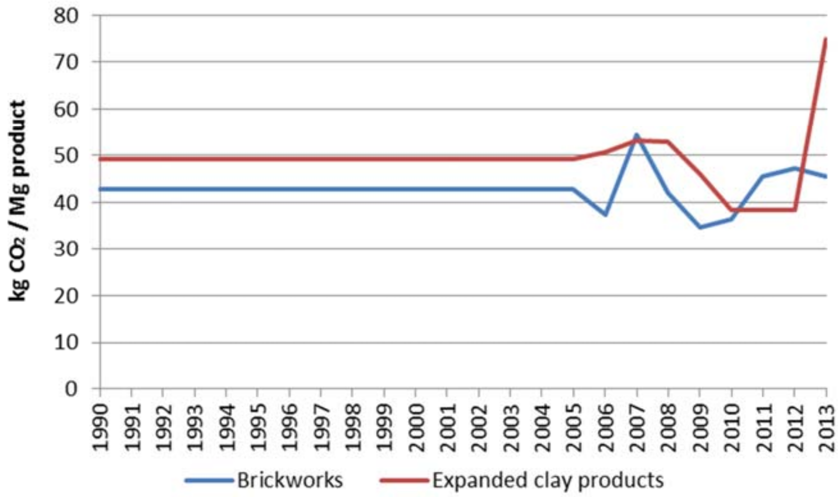

Figure 3.5.4 Development in implied emission factors for CO_2.

Figure 3.5.4 shows fluctuations in the IEFs as would be expected when comparing sale figures from a national statistics with the consumption of raw material in production given by the producers. The major reason for fluctuations in the IEF time series is most likely due to changes in stocks. For 2013, Statistics Denmark (2014) reported a slight decrease in sales of expanded clay products while the producers of these products reported a strong increase in consumption of carbonates; from 13.4 Gg $CaCO_3$-eq in 2012 to 23.8 $CaCO_3$-eq Gg in 2013. This discrepancy causes a strong increase in the IEF for expanded clay products for 2013.

The overall IEF for the source category ceramics has been calculated and is compared with the default Tier 1 IEF calculated using production statistics from Statistics Denmark (2014) and default Tier 1 assumptions from IPCC (2006), see Figure 3.5.5.

The assumptions applied in order to calculate the default Tier 1 IEF are listed in the following (IPCC, 2006):

- Consumption of clay: 1.1 Mg clay per Mg product
- Carbon content in clay: 10 %
- Distribution between carbonates: 85 % limestone / 15 % dolomite
- Order of calcination: 100 %
- Emission factors: 0.43971 Mg CO_2 per Mg limestone and 0.47732 Mg CO_2 per Mg dolomite

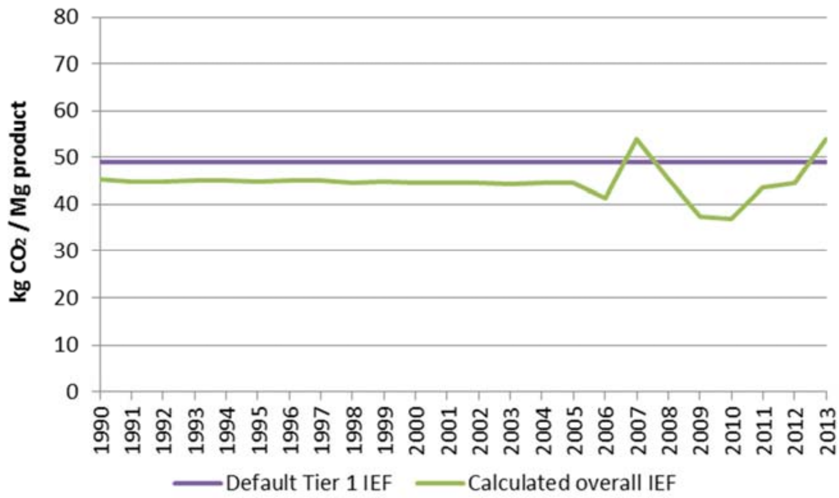

Figure 3.5.5 Development in implied emission factors for CO_2.

The comparison of IEFs shown in Figure 3.5.5 show good agreement considering the rough assumptions listed above the figure.

3.5.6 Time series consistency and completeness

The data sources throughout the time series are not consistent as emissions from 2006-2013 are known and emissions for 1990-2005 are estimated using surrogate data. However, verification of the data confirms that these can be considered being consistent.

The inventory is based on companies reporting to EU-ETS, but clay is also burned in minor scale e.g. ceramic art workshops and school art classes. These minor sources are however considered to be negligible and for all intents and purposes the source category of ceramics is considered to be complete.

3.5.7 Input to CollectER

The actual applied data on production of ceramics are summarised in Table 3.5.8.

Table 3.5.8 Input data for calculating emissions from production of ceramics.

	Year	Parameter	Comment/Source
Activity data	1990-2013	Sale of products	Statistics Denmark; assumptions: 2 kg per brick
	1990-2005	Consumption of carbonates	Calculated from sale statistics and average carbonate consumption per product (2006-2013)
	2006-2013	Consumption of carbonates	Company reports to EU-ETS
Emissions	1990-2005	CO_2	Calculated from consumption of carbonates
	2006-2013	CO_2	Company reports to EU-ETS
	1990-2013	SO_2	EF estimated from environmental reports 2009-2011
	1990-2013	PCDD/F	Calculated using emission factor from Henriksen et al. (2006)

3.5.8 Future improvements

The SO_2 emission factor for bricks and expanded clay products will be improved based on data for recent and coming years.

The time series for production of ceramics will be extended to include 1980-1989.

It will be investigated whether emissions of particulate matter can be included for production of ceramics.

3.6 Other uses of soda ash

This section covers the use of soda ash not related to glass production. The following SNAP code is covered:

- 04 06 19 Other uses of soda ash

3.6.1 Process description

When soda ash (Na_2CO_3) is used in processes where it is heated, it decomposes and CO_2 is released. The reaction is:

$$Na_2CO_3 + heat \rightarrow Na_2O + CO_2$$

There are uses of soda ash that is non-emitting since they do not involve heating of the soda ash, e.g. in soaps and detergents.

3.6.2 Methodology

Emissions from other uses of soda ash (Na_2CO_3) are calculated based on a mass balance using national statistics on import/export and the stoichiometric emission factor. Since no detailed information on the specific uses of soda ash is available, it is assumed in the inventory that all of the apparent consumption leads to emissions. There is no production of soda ash in Denmark.

Activity data

National statistics on import and export and the calculated activity data (supply) are presented in Table 3.6.1.

Table 3.6.1 Statistics for other uses of soda ash, Gg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Import	54.6	55.8	56.4	52.9	42.1	47.6	44.8	46.7	41.2	41.6
Export	0.1	0.0	0.0	0.2	1.1	2.1	1.1	0.0	0.0	0.2
Glass production	26.1	22.8	20.5	19.9	19.9	18.8	18.8	18.8	23.7	22.3
Supply	28.4	33.0	35.9	32.8	21.1	26.7	25.0	27.8	17.5	19.1
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Import	42.0	45.3	41.7	43.1	43.1	59.5	44.1	44.1	41.8	28.0
Export	0.3	0.1	0.9	0.1	0.1	0.0	0.0	0.0	0.0	0.5
Glass production	19.4	19.6	19.1	16.9	17.0	16.6	16.9	18.2	17.8	10.9
Supply	22.3	25.7	21.7	26.1	26.1	42.9	27.1	25.9	24.0	16.6
	2010	2011	2012	2013						
Import	36.5	22.9	31.7	30.2						
Export	0.1	0.1	0.1	0.1						
Glass production	10.7	10.9	11.2	8.2						
Supply	25.7	11.9	20.4	21.9						

The activity data is calculated using the following equation.

$$Supply = Import - Export - Glass\ production$$

Emission factors

The applied emission factor for other uses of soda ash is 0.41492 Mg CO_2 per Mg Na_2CO_3 based on the stoichiometry of the chemical conversion. The calculation assumes a calcination factor of 1.

3.6.3 Emission trend

The emission trend for the CO_2 emission from other uses of soda ash is presented in Figure 3.6.1.

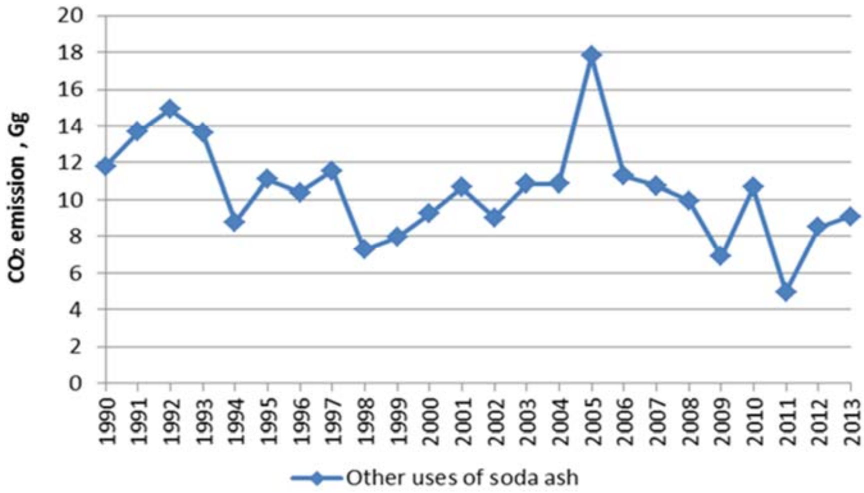

Figure 3.6.1 CO_2 emissions from other uses of soda ash.

Information on the uses of soda ash outside the glass industry is scarce, and descriptions of the trend development are therefore not available.

3.6.4 Verification

Statistical data collected from Statistics Denmark (2014) has been checked against data from Eurostat (2014) for 2000-2013, see Table 3.6.2.

Table 3.6.2 Comparison of statistical data for net import of soda ash, Mg.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Statistics Denmark	41.65	45.25	40.86	43.03	43.07	59.54	44.06	44.04	41.78	27.52	36.41	22.79	31.61	30.12
Eurostat	41.64	45.24	44.30	43.05	38.72	50.35	40.83	44.04	41.78	28.89	31.28	nd	34.86	29.50
Difference	0.01	0.01	-3.44	-0.01	4.36	9.19	3.23	0.00	0.00	-1.37	5.13	nd	-3.25	0.62

nd: No data

The comparison shows good agreement for most years.

3.6.5 Time series consistency and completeness

The same methodology is used for calculating emissions for the entire time series, the source category of other uses of soda ash is therefore considered to be consistent. Calculations are based on a national mass balance and are therefore also considered to be complete. Though it is not possible to document, it is likely that this category is overestimated as it based on a worst case scenario.

3.6.6 Input to CollectER

The actual applied data on other uses of soda ash are summarised in Table 3.6.3.

Table 3.6.3 Input data for calculating emissions from other uses of soda ash.

	Year	Parameter	Comment/Source
Activity data	1990-2013	Import/export statistics	Statistics Denmark
Emissions	1990-2013	CO_2	Calculated using the stoichiometric emission factor

3.6.7 Future improvements

There are no planned improvements for the category of other uses of soda ash.

3.7 Flue gas desulphurisation

Flue gas cleaning systems utilising different technologies are primarily present at major combustion plants i.e. power plants and combined heat and power plants using coal as well as waste incineration plants. The following SNAP code is covered:

- 04 06 18 Limestone and dolomite use - Flue gas cleaning, wet, power plants and waste incineration plants

3.7.1 Process description

Three kinds of flue gas cleaning for acidic gasses are applied in Denmark (Johnsson, 1999):

- Dry flue gas cleaning
- Semi-dry flue gas cleaning
- Wet flue gas cleaning

However, only wet flue gas cleaning leads to process emissions. The only relevant pollutant is CO_2. The chemistry of the wet flue gas cleaning methodologies is presented below.

3.7.2 Methodology

The emission of CO_2 from wet flue gas cleaning can be calculated from the following equation:

$$SO_2\ (g) + ½O_2\ (g) + CaCO_3\ (s) + 2H_2O\ (l) \rightarrow CaSO_4{,}2H_2O\ (s) + CO_2\ (g)$$

The overall equation can be broken down to a number of individual equations. The emission factor is depending on how the process is optimised with the following targets: to achieve high degree of desulphurisation, to reduce the consumption of calcium carbonate, and to produce gypsum of saleable quality. From the equation the emission factors can be calculated to:

- 0.2325 Mg CO_2 / Mg gypsum
- 0.4397 Mg CO_2 / Mg $CaCO_3$

The emission factor for gypsum is used in the inventory when information on calcium carbonate consumption by power plants and waste incineration plants is not available.

Energinet.dk compile environmental information related to energy transformation and distribution. Since the waste incineration plants with desulphurisation are all power producers, these plants are also included in the data from Energinet.dk (2014). Statistics on the generation of gypsum are available from Energinet.dk (2014) for the entire time series. However, for 2006-2013 information on consumption of $CaCO_3$ at the relevant power plants and waste incineration plants has been compiled from EU-ETS and used in the calculation of CO_2 emission from flue gas cleaning.

The consumed amount of limestone is used as activity data for the years where these data are available from EU-ETS (2006-2013). Information on limestone consumption is not available before the implementation of the mandatory environmental reports in 1998.

The consumption of other carbonates than limestone (e.g. dry desulphurisation product (TASP)) is measured by the individual power plants and is added to the limestone consumption in $CaCO_3$-equivalents.

The power plants equipped with wet flue gas cleaning are:

- Amagerværket
- Asnæsværket
- Avedøreværket
- Enstedværket
- Esbjergværket
- Grenå Kraftvarmeværk
- Nordjyllandsværket
- Randersværket (Verdo Produktion A/S)
- Stigsnæsværket

These plants are or have been coal fired CHP plants. As some of the plants are rebuilt to combust biomass instead of coal the need for flue gas desulphurisation will cease (e.g. Enstedværket and Randersværket).

The waste incineration plants identified to be provided with wet fluegas cleaning are:

- Affaldscenter Aarhus
- KARA (Roskilde Forbrænding)
- Kommunekemi
- L90 Affaldsforbrænding
- Odense Kraftvarmeværk
- Reno-Nord
- RenoSyd
- Sønderborg Kraftvarme
- Svendborg Kraftvarme
- Vestforbrænding

Activity data
During the time series this source has increased due to more plants being fitted with desulphurisation. However, since the main use is in coal fired plants, flue gas desulphurisation is decreasing as some of the coal fired power plants are rebuilt to combust biomass and the need for flue gas desulphurisation declines. Since 2006, three of the nine coal fired power plants

have changed to alternative fuels in 2013 and desulphurisation has ceased from these plants.

The Danish waste incineration plants are in general smaller than the coal combustion facilities and owned by smaller companies. Of the approximately 30 waste incineration plants with flue gas desulphurisation only one third uses wet flue gas cleaning.

For 1990-2005 the production of gypsum is used for calculating the CO_2 emission and for 2006-2013 the consumption of $CaCO_3$ is used. The limestone consumption data for the environmental reports (1998-2005) has not been used because this would increase the inconsistency. The applied activity data are presented in Table 3.7.1 and Figure 3.7.1.

Table 3.7.1 Activity data for flue gas desulphurisation, Gg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Gypsum production[1]	41.6	82.0	90.5	121.6	209.4	211.5	348.1	346.7	350.4	381.7
$CaCO_3$ consumption[2]	-	-	-	-	-	-	-	-	199.7	202.2
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Gypsum production[1]	354.3	355.7	331.7	283.4	237.7	220.4	296.4	296.4	215.7	176.4
$CaCO_3$ consumption[2, 3]	209.4	194.6	177.1	168.3	128.3	110.8	156.9	107.4	84.9	85.8
	2010	2011	2012	2013						
Gypsum production[1]	185.8	147.6	100.9	153.3						
$CaCO_3$ consumption[3]	94.0	75.8	41.0	57.9						

[1] Energinet.dk (2014).
[2] 1998-2005: Environmental reports of the individual plants.
[3] 2006-2013: EU-ETS of the individual plants.

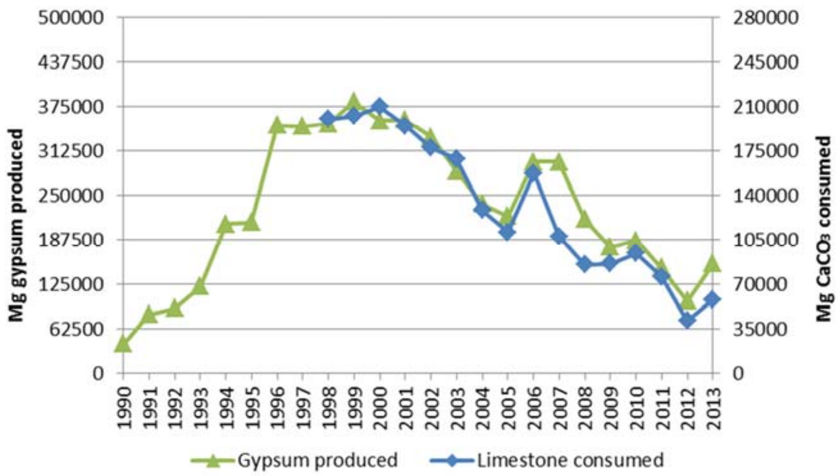

Figure 3.7.1 Activity data for flue gas desulphurisation.

The activity data level varies with the coal consumption that again varies greatly with electricity import / export.

Emission factors

From the chemical reaction equation presented in the "Methodology" section, the stoichiometric emission factor can be calculated to 0.2325 Mg CO_2 per Mg gypsum produced. This emission factor is used in the inventory when information on calcium carbonate consumption by power plants and waste incineration plants is not available from EU-ETS (1990-2005).

The emission factor applied when using limestone consumption as activity data is the stoichiometric emission factor 0.43971 Mg CO_2 per Mg $CaCO_3$ (2006-2013).

3.7.3 Emission trend

The emission trend for CO_2 emitted from flue gas cleaning at CHP plants and waste incineration plants is presented in Table 3.7.2.

Table 3.7.2 Emission of CO_2 from wet flue gas cleaning, Gg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Desulphurisation	9.67	19.06	21.04	28.28	48.69	49.17	80.94	80.61	81.46	88.74
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Desulphurisation	82.38	82.69	77.13	65.89	55.28	51.25	68.99	47.22	37.31	37.74
	2010	2011	2012	2013						
Desulphurisation	41.35	33.33	18.05	25.48						

The CO_2 emission from flue gas desulphurisation in CHP plants increased significantly during the 1990s due to the increased use of wet flue gas desulphurisation. Since then the emissions have decreased due to the decrease in coal consumption.

3.7.4 Verification

Three datasets are available within the time series. Figure 3.7.2 compares emissions based on these different sets of activity data and generally shows a good agreement between the different methodologies.

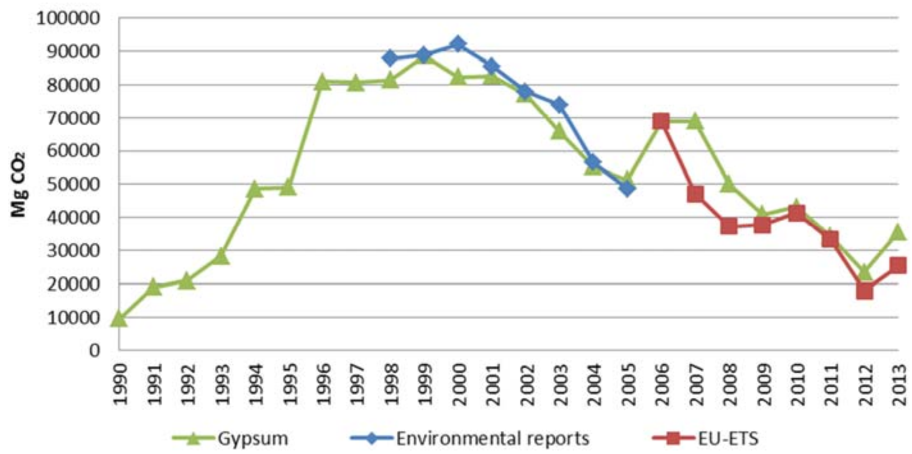

Figure 3.7.2 CO_2 emissions from flue gas desulphurisation calculated with different methodologies; from gypsum production and limestone consumption compiled by environmental reports and EU-ETS respectively.

Emissions calculated from the limestone consumption data provided by the environments reports vary with -5 % (2005) to +12 % (2000) from the emission based on gypsum production. And emissions calculated from the limestone consumption data provided by the EU-ETS vary with up to 31 % (2007) from the emissions based on gypsum production.

3.7.5 Time series consistency and completeness

The methodology for calculating emission from flue gas desulphurisation is inconsistent. However, as proven in the “Verification” section above, there is no gap in the emission data derived from different sources and the emissions are therefore considered to be consistent. The source category is considered to be complete.

3.7.6 Input to CollectER

The input data / data sources are presented in Table 3.7.3.

Table 3.7.3 Input data for calculating emissions from flue gas desulphurisation.

	Year	Parameter	Comment/Source
Activity data	1990-2013	Gypsum generation	Energinet.dk (2014)
	1998-2005	Limestone consumed	Environmental reports
	2006-2013	Limestone consumed	EU-ETS
Emission	1990-2013	CO_2	Estimated by use of stoichiometric emission factor

3.7.7 Future improvements

Further investigation will be put into identifying the desulphurisation methodologies used at waste incineration plants for every year in the time series as some plants might have switched technology since 1990 (i.e. dry / semi-dry / wet).

3.8 Mineral wool production

Rockwool situated at three localities in Denmark: Hedehusene[6], Vamdrup and Øster Doense produces mineral wool. The following SNAP-codes are covered:

- 03 03 18 Mineral wool (except binding)
- 04 06 18 Limestone and dolomite use

Emissions associated with the fuel use are estimated and reported in the energy sector.

The following pollutants are included for the lime production process:

- CO_2
- CO
- NH_3
- Particulate matter: TSP, PM_{10}, $PM_{2.5}$
- Persistent organic pollutants: PCDD / F

The following description, as well as data, is based on an environmental report (Rockwool, 2003).

[6] The melting of minerals (cupola) has been closed down in 2002.

3.8.1 Process description

Mineral wool is produced from mineral fibres and a binder (that is hardened to bakelite). The mineral fibres are produced from stone, bauxite, clay, limestone and cement. In addition to own waste products a number of other waste products are included in the production: aluminium silicate from the iron industry, slags from steelworks, filter dust from cement industry and also used growing media based on mineral wool. The raw materials are melted in a cupola fired by coke and natural gas. The consumption of raw material as well as amount of produced mineral wool is confidential. The energy consumption is reported as electricity (GWh) and fuels (GWh) with a distribution of fuels between coke and natural gas at 60 % / 40 %.

3.8.2 Methodology

Information on emissions from some years has in combination with yearly raw material consumption been used to extrapolate the emissions to other years. The data have been extracted from company reports (Rockwool, 2014b), EU-ETS (Rockwool, 2014a) and reports to PRTR. Implied CO_2 emission factors have been calculated for 2006-2010 and with these emissions are extrapolated back to 1990.

The proxy activity data (i.e. limestone consumed) is calculated from the CO_2 emission. The proxy activity data set is necessary because the Kyoto Protocol, the UNFCCC and the UNECE requires the categories of ceramics, other uses of soda ash, flue gas desulphurisation and mineral wool production to be summarised. When activity data for the source categories ceramics, other uses of soda ash and flue gas desulphurisation are given in $CaCO_3$ equivalents consumed, then activity data for mineral wool production should be given in the same unit.

All calculations are performed for the three factories individually.

Activity data

Data on the produced amount of mineral wool is confidential; however the consumption of raw materials and the consumption of carbonates at the three Danish Rockwool factories are available from the annual environmental reports (Rockwool, 2014b) and EU-ETS (Rockwool, 2014a). The different carbonate raw materials such as lime, waste, bottom ash etc. are added up to the proxy activity data of limestone equivalents consumed presented in Table 3.8.1 and Figure 3.8.1.

The consumption of raw materials is available for 1995-2013 and the consumption of carbonates for 2006-2013. Raw material consumption for 1990-1994 is assumed constant as the average of the years 1995-1999. The consumption of carbonates for 1990-2005 is estimated from the CO_2 emission.

Table 3.8.1 Activity data for mineral wool production, Gg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Consumption of raw materials	195.6	195.6	195.6	195.6	195.6	196.5	188.3	182.2	204.0	207.0
Consumption of $CaCO_3$ equivalents	17.9	17.9	17.9	17.9	17.9	18.0	17.2	16.5	18.6	18.9
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Consumption of raw materials	190.0	174.0	169.0	143.0	172.0	172.0	181.0	205.0	181.0	145.0
Consumption of $CaCO_3$ equivalents	17.3	15.6	15.9	15.0	18.1	18.0	15.5	19.3	22.6	16.5
	2010	2011	2012	2013						
Consumption of raw materials	155.0	146.0	123.0	122.4						
Consumption of $CaCO_3$ equivalents	17.1	16.8	15.0	13.8						

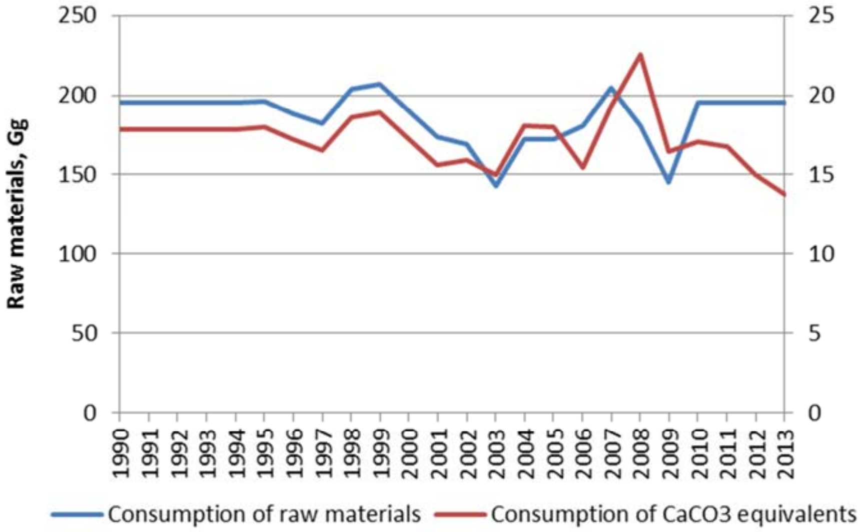

Figure 3.8.1 Activity data for mineral wool production.

The consumption of carbonates at the Doense factory has decreased drastically the last couple of years, while the raw material consumption has only decreased slightly.

Emission factors

From 2006 the CO_2 process emission data have been obtained from the company reports to the EU-ETS (Rockwool, 2014a). For 1990-2005, the CO_2 emission is estimated from the calculated factor of “CO_2 emission per raw material consumption” (average for 2006-2010) and the raw material consumption time series. CO_2 emissions for 1990-1994 are estimated as the constant average of 1995-1999.

Emissions of CO and NH_3 are available for the years 2001, 2004 and 2007-2013 and emissions of particulate matter are available for 1995-2013. The measurements show a strong decrease in CO emissions from the two mineral wool factories in 2009 and 2010 respectively due to installation of abatement equipment. For PCDD/F, the inventory is based on measured emissions from 2004 (Henriksen et al., 2006). PM_{10} and $PM_{2.5}$ are estimated from the TSP emission as 90 % and 70 % of TSP respectively.

Implied emission factors are calculated for all years where measured emissions are available; these are used to estimate emissions for all other years in the time series back to 1990. The implied emission factors are presented in Table 3.8.2

Table 3.8.2 Emission factors for mineral wool production

Pollutant	Unit	Hedehusene	Vamdrup	Doense	Source/Comment
CO_2	Mg/Mg raw material	-	0.047	0.045	IEF calculated for 2006-2010
CO	Mg/Mg raw material	0.089	0.038	0.068	IEF average 2001, 2004, 2007, 2008
NH3	Mg/Mg raw material	0.002	0.001	0.002	IEF average 2001, 2004, 2007-2012
TSP	Mg/Mg raw material	0.0003	0.0005	0.0007	IEF average 2000-2013
PCDD/F	mg/Mg raw material	-	0.0003	0.0003	Henriksen et al. (2006)

3.8.3 Emission trend

The emission trends for emission of CO_2, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$ and PCDD/F from production of mineral wool at three (from 2006 two) locations are presented in Table 3.8.3.

Table 3.8.3 Emissions from production of mineral wool.

	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2	Gg	7.9	7.9	7.9	7.9	7.9	7.9	7.6	7.3	8.2	8.3
CO	Gg	12.0	12.0	12.0	12.0	12.0	11.9	11.5	11.1	12.6	12.7
NH_3	Gg	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
PCDD/F	mg	64.9	64.9	64.9	64.9	64.9	65.3	62.5	60.5	67.6	68.7
	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2	Gg	7.6	6.9	7.0	6.6	7.9	7.9	6.8	8.5	9.9	7.2
CO	Gg	12.0	10.6	11.4	10.3	15.6	11.6	9.1	6.4	6.5	2.4
NH_3	Gg	0.3	0.3	0.3	0.2	0.4	0.3	0.3	0.4	0.2	0.2
TSP	Mg	71	80	81	103	111	115	125	125	111	77
PM_{10}	Mg	64	72	73	86	99	103	113	112	100	70
$PM_{2.5}$	Mg	50	56	57	67	77	80	88	87	77	54
PCDD/F	mg	63	58	56	47	57	57	60	68	60	48
	Unit	2010	2011	2012	2013						
CO_2	Gg	7.5	7.4	6.6	6.0						
CO	Mg	11.0[1]	13.0[1]	31.0[1]	10.0[1]						
NH_3	Gg	0.2	0.2	0.2	0.2						
TSP	Mg	78	77	62	62						
PM_{10}	Mg	70	69	56	56						
$PM_{2.5}$	Mg	55	54	43	43						
PCDD/F	mg	51	48	41	48						

[1] Kindly notice that the unit has changed for CO from 2009 to 2010 due to installation of abatement equipment.

3.8.4 Time series consistency and completeness

The source category of mineral wool production is complete but inconsistent, the inconsistency occurs because emissions for 2006 onward are known (EU-ETS and PRTR) but emissions for 1990-2004 are estimated (with few exceptions.

3.8.5 Input to CollectER

The input data / data sources are presented in Table 3.8.4.

Table 3.8.4 Input data for calculating emissions from mineral wool production

	Year	Parameter	Comment/Source
Activity data	1995-2013	Raw material consumption	Rockwool (2014b)
	2006-2013	Carbonate consumption	Rockwool (2014a)
Emissions	2001, 2004, 2007-2013	CO, NH_3	PRTR
	2000-2013	TSP	Rockwool (2014b), PRTR
	2004	PCDD/F	Henriksen et al. (2006)

3.8.6 Future improvements

There are no planned improvements for the source category of mineral wool production.

4 Chemical industry

The sector Chemical industry (CRF and NRF 2B) covers the following industries relevant for the Danish air emission inventory of greenhouse gases and other air pollutants:

- Nitric and sulphuric acid production; see section 4.2
- Catalyst and fertiliser production; see section 4.2.1
- Pesticide production; see section 4.4
- Production of chemical ingredients; see section 4.5
- Production of tar products; see section 4.6

4.1 Greenhouse gas emissions

The greenhouse gas emission time series for the source categories within Chemical Industry (2B) are presented in Figure 4.1.1 and individually in the subsections below (Sections 4.2 – 4.6). The following figure gives an overview of which source categories that contribute the most to greenhouse emissions throughout the time series.

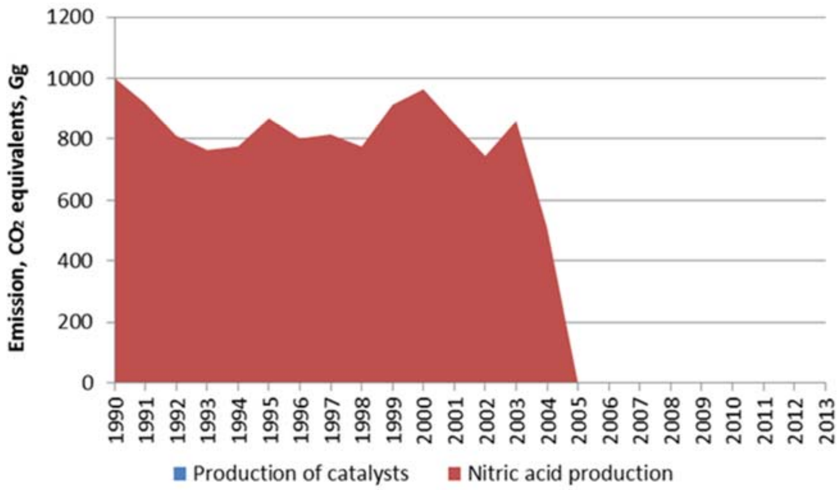

Figure 4.1.1 Emission of CO_2 equivalents from the individual source categories compiling *2B Chemical Industry*, Gg.

Greenhouse gas emissions from *Chemical Industry* are made up almost entirely by N_2O emissions from the production of nitric acid; only 0.1 % (1990-2003) to 0.2 % (2004) stems from the production of catalysts, making the emission invisible in the figure above. The production of nitric acid ceased in the middle of 2004.

4.2 Nitric and sulphuric acid production

The production of sulphuric acid, nitric acid as well as NPK fertilisers has been concentrated at one company; Kemira GrowHow A/S situated in Fredericia (Kemira GrowHow, 2004). The production of sulphuric acid and nitric acid/fertiliser ceased in 1996/7 and in the middle of 2004, respectively. The following SNAP codes are covered:

- 04 04 01 Sulphuric acid
- 04 04 02 Nitric acid

The following pollutants are included for the nitric and sulphuric acid production processes:

- SO_2
- NO_x
- N_2O
- NH_3
- Particulate matter: TSP, PM_{10}, $PM_{2.5}$

4.2.1 Process description

The inputs to the processes are ammonia, potash, raw phosphate, phosphoric acid / sulphuric acid, dolomite, and other unspecified raw materials. The products are fertilisers (nitrogen, phosphate, and potassium), nitric acid, potassium nitrate, phosphates (feedstock for domestic animals). The production facility consists of different plants: nitric acid plant, NPK-plant, potassium nitrate plant, and dicalcium phosphate plant. Up to 1997 sulphuric acid was also produced at Kemira.

A gas turbine and incineration of ammonia supplies the main part of the electricity necessary for the different processes.

Ammonia is incinerated at the nitric acid plant generating nitric acid as well as energy (steam and electricity). The processes are (HNO_3):

(I) $4\ NH_3 + 5\ O_2 \rightarrow 4\ NO + 6\ H_2O$
(II) $2\ NO + O_2 \rightarrow 2\ NO_2$
(III) $3\ NO_2 + H_2O \rightarrow 2\ HNO_3 + NO$

Other reactions:

(IV) $4\ NH_3 + 3\ O_2 \rightarrow 2\ N_2 + 6\ H_2O$
(V) $4\ NH_3 + 4\ O_2 \rightarrow 2\ N_2O + 6\ H_2O$

Air pollutants relevant to be included for fertiliser production are NH_3, N_2O, and NO_x.

The environmental report (Kemira GrowHow, 2004) presents aggregated emissions for the entire facility. This information is supplemented with direct contact to the company.

4.2.2 Methodology

Information on emissions from the production of nitric acid, sulphuric acid and fertiliser is obtained from environmental reports (Kemira GrowHow, 2004), contact to the company (Personal communication with Gert Jacobsen, Technical Sales Support Manager, Process Chemicals, Kemira GrowHow Danmark A/S, 26 September 2005 and previous mail correspondences) as well as information from the county. Emission measurements are available for some years see Table 4.2.1. Implied emission factors are calculated for the years where measurements are available; these implied emission factors are then used to calculate emissions for the remaining years. The following table gives an overview of for which years measured emissions are available for the different pollutants.

Table 4.2.1 Availability of measured process emissions (Kemira GrowHow 2004)

Process	Pollutant	Years
Nitric acid	NH_3	1989-2004
	N_2O	2002
	NO_x	1990, 1994-2002
	TSP	2000-2004
Sulphuric acid	SO_2	1990, 1994-1997

The emission for SO_2 and NO_X for 1991 to 1993 was estimated by using interpolated emission factors and activity data.

Specific information on applied technology is not available; however, the N_2O emission factor measured by the Danish nitric acid plant is in accordance with the default emission factors for medium to high pressure plants presented by IPCC (2006).

The Danish production of sulphuric acid ceased in 1996/7 and the production of nitric acid in Denmark ceased in the middle of 2004 and the company relocated the production to a more modern facility in another country.

Activity data

The activity data regarding production of nitric and sulphuric acids are obtained through personal communication with Gert Jacobsen, Technical Sales Support Manager, Process Chemicals, Kemira GrowHow Danmark A/S, 26 September 2005 and previous mail correspondences and Kemira GrowHow (2004). The data are presented in Table 4.2.2.

Table 4.2.2 Production of nitric and sulphuric acid, Gg.

	1980	1981	1982	1983	1984	1985	1986	1987	1988
Nitric acid	350	350	350	350	350	350	315	357	383
Sulphuric acid	188	188	188	188	188	188	97	126	184
	1989	1990	1991	1992	1993	1994	1995	1996	1997
Nitric acid	402	450	412	364	343	348	390	360	366
Sulphuric acid	215	148	65	58	63	80	102	55	2
	1998	1999	2000	2001	2002	2003	2004		
Nitric acid	348	410	433	382	334	386	229		
Sulphuric acid	NO	NO	NO	NO	NO	NO	NO		

NO: Not occurring

Production of sulphuric acid decreased from approximately 150 to 60 Gg from 1990 to 1996, and production of nitric acid decreased from approximately 450 to 229 Gg from 1990 to 2004. Overall, production of fertiliser decreased from approximately 800 to approximately 400 Gg from 1990 to 2004.

Emission factors

The calculated implied emission factors are presented in Table 4.2.3 together with the standard emission factors given by IPCC (2006) and EMEP/EEA (2013).

Table 4.2.3 Emission factors for production of nitric acid and sulphuric acid in Denmark compared with standard emission factors, kg per Mg produced.

Process	Pollutant	Mean	Range	Standard EF
Nitric acid	NH_3	0.11	0.03 - 0.26	0.01
	N_2O	7.48	-	2-2.5[1]
				5[2]
				7[3]
				9[4]
	NO_x	1.36	0.95 - 1.79	3.5 - 12[5]
				7.5[6]
				3[7]
				0.5[8]
				0.4-0.9[9]
	TSP	0.88	0.84-0.93	
Sulphuric acid	SO_2	2.07	1.40-2.69	3 – 9.1[10]
				3.5[11]
				17[12]

[1] Modern plant with abatement technology (IPCC, 2006).
[2] Atmospheric pressure plant (low pressure) (IPCC, 2006).
[3] Medium pressure combustion plant (IPCC, 2006).
[4] High pressure plant (IPCC, 2006).
[5] Low pressure (EMEP/EEA, 2013).
[6] Medium pressure (EMEP/EEA, 2013).
[7] High pressure (EMEP/EEA, 2013).
[8] Direct strong acid process (EMEP/EEA, 2013).
[9] Modern plant with abatement technology (EMEP/EEA, 2013).
[10] Contact process with intermediate absorption; different gas conditions (EMEP/EEA, 2013).
[11] Wet/dry process with intermediate condensation/absorption (EMEP/EEA, 2013).
[12] Wet contact process (EMEP/EEA, 2013).

The calculated emission factors for both SO_2 and NO_x have decreasing trends.

The emission factors for NO_x and SO_2 (based on actual emissions) are in the low end compared with the standard emission factors, whereas; the factors for NH_3 and N_2O are in the high end.

PM_{10} and $PM_{2.5}$ are estimated from the distribution between TSP, PM_{10} and $PM_{2.5}$ (1/0.8/0.6) from CEPMEIP (Values for ‘Production of nitrogen fertiliser’).

4.2.3 Emission trend

Trends for emissions of NH_3, N_2O, NO_x, SO_2, TSP, PM_{10}, and $PM_{2.5}$ from production of nitric acid and sulphuric acid are presented in Table 4.2.4.

Table 4.2.4 Emissions from nitric and sulphuric acid production.

	Unit	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
NH_3	Mg	12.2	12.2	12.2	12.2	12.2	12.2	11.0	12.4	13.3	14.0
N_2O	Gg	2.62	2.62	2.62	2.62	2.62	2.62	2.35	2.67	2.86	3.01
NO_x	Mg	627	627	627	627	627	627	564	639	686	720
SO_2	Mg	415	415	415	415	415	415	214	278	407	475
	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
NH_3	Mg	12.0	22.0	35.0	49.0	91.0	62.0	62.0	37.0	12.0	24.0
N_2O	Gg	3.36	3.08	2.72	2.56	2.60	2.92	2.69	2.74	2.60	3.07
NO_x	Mg	806	731	640	597	600	612	504	571	419	451
SO_2	Mg	327	151	142	162	215	217	77	3	NO	NO
	Unit	2000	2001	2002	2003	2004					
NH_3	Mg	13.0	30.0	50.0	56.0	33.0					
N_2O	Gg	3.24	2.86	2.50	2.89	1.71					
NO_x	Mg	413	410	397	459	272					
SO_2	-	NO	NO	NO	NO	NO					
TSP	Mg	362	346	310	323	192					
PM_{10}	Mg	290	277	248	258	153					
$PM_{2.5}$	Mg	217	208	186	194	115					

NO: Not occurring

The emission trend for the N_2O emission from nitric acid production is presented in Figure 4.1.1. The trend for N_2O from 1990 to 2003 shows a decrease from 3.4 to 2.9 Gg, i.e. -14 %, and a 41 % decrease from 2003 to 2004. However, the activity and the corresponding emission show considerable fluctuations in the period considered and the decrease from 2003 to 2004 can be explained by the closing of the plant in the middle of 2004.

The emission trends for the air pollutants are presented in Figure 4.2.1. The time series for SO_2 follows the amount of sulphuric acid produced, i.e. the fluctuation follows the activity until the activity ceased in 1997. The same is the case for NO_X from production of nitric acid.

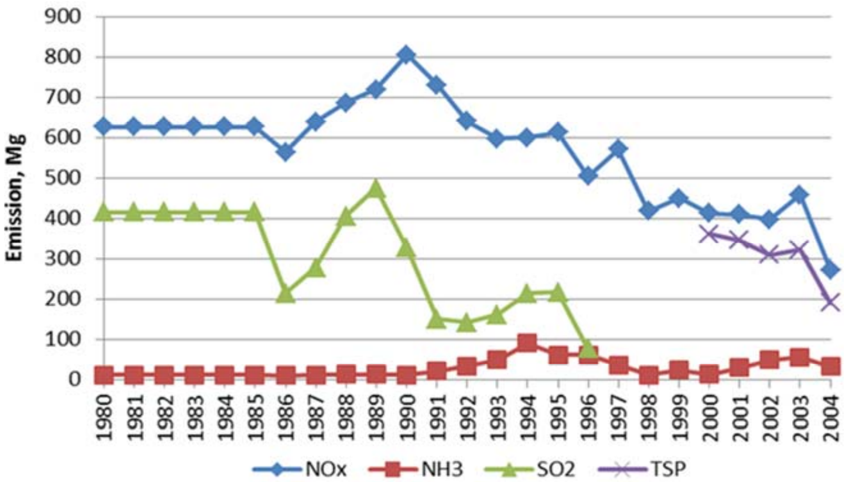

Figure 4.2.1 Emissions from nitric and sulphuric acid production.

4.2.4 Time series consistency and completeness

The applied methodology regarding N_2O is considered to be consistent. The activity data are based on information from the company. The emission factor applied has been constant for the whole time series and is based on measurements performed in 2002. The production equipment has not been changed during the period. The source category of nitric acid production is complete.

4.2.5 Input to CollectER

The input data / data sources are presented in Table 4.2.5.

Table 4.2.5 Input data for calculating emissions from nitric and sulphuric acid production.

	Year	Parameter	Comment/Source
Activity data	1985-2004	HNO_3, H_2SO_4	Kemira GrowHow (2004) and personal communication with Gert Jacobsen, Technical Sales Support Manager, Process Chemicals, Kemira GrowHow Danmark A/S, 26 September 2005 and previous mail correspondences
Emissions	1980-1989	NO_x, SO_2	IEF assumed to be the same as in 1990
	1990, 1994-2002	NO_x, SO_2	Personal communication with Gert Jacobsen, Technical Sales Support Manager, Process Chemicals, Kemira GrowHow Danmark A/S, 26 September 2005 and previous mail correspondences
	1989 (2000)-2004	NH_3, TSP	Kemira GrowHow (2004)
	1980-1988	NH_3	IEF assumed to be the same as in 1989
	2002	N_2O	Personal communication with Gert Jacobsen, Technical Sales Support Manager, Process Chemicals, Kemira GrowHow Danmark A/S, 26 September 2005 and previous mail correspondences
	1980-2001, 2003-4	N_2O	IEF assumed to be the same as in 2002
	2000-2004	PM_{10}, $PM_{2.5}$	Distribution between TSP, PM_{10}, and $PM_{2.5}$ from CEPMEIP

4.2.1 Future improvements

Emissions of BC will be added for nitric acid production.

4.3 Catalyst and fertiliser production

Production of a wide range of catalysts and potassium nitrate (fertiliser) is concentrated at one company: Haldor Topsøe A/S situated in Frederikssund. The following SNAP code is covered:

- 04 04 16 Other: catalysts

The following pollutants are included for the catalyst production process:

- CO_2
- NO_x
- NH_3
- Particulate matter: TSP, PM_{10}, $PM_{2.5}$

4.3.1 Process description

The inputs to the processes are:

- Solid raw materials: salts, oxides, carbonates, intermediates etc. and metals
- Liquid raw materials: acidic and alkaline solutions, dissolved metal salts, methanol etc.
- Gaseous raw materials: ammonia, hydrogen, nitrogen

The products are catalysts for many purposes (for hydro-processing, ammonia, $DeNO_x$, methanol, hydrogen and synthesis gas, sulphuric acid, formaldehyde, and combustion catalysts) and potassium nitrate (fertiliser).

4.3.2 Methodology

The processes involve carbonate compounds i.e. the process leads to emissions of CO_2. The company has estimated the emission of CO_2 from known emission factors for incineration of natural gas and LPG and from information on the raw materials containing carbonate. The contribution from carbonate compounds is estimated to be the difference between the total CO_2 emission reported in the environmental reports (Haldor Topsøe, 2013) and the CO_2 emission from energy consumption reported to EU-ETS (Haldor Topsøe, 2014). Implied emission factors were calculated for 2003-2009 using this method. For the years 1985-1995, the production is estimated as the constant average of the production in 1997-2001. Potential retention of CO_2 in the flue gas cleaning system has not been taken into account.

The emission of NO_X, NH_3 and TSP from production of catalysts and fertilisers is measured yearly from 1996 to 2013 (TSP from 2000 to 2013) (Haldor Topsøe, 2013). The emissions were extrapolated back to 1985. PM_{10} and $PM_{2.5}$ are estimated from the distribution between TSP, PM_{10} and $PM_{2.5}$ (1/0.8/0.6) from CEPMEIP (Values for 'Production of nitrogen fertiliser').

The process-related NO_X emission has been estimated as 80 % of the total NO_X emission; Haldor Topsøe reports this assumption in their environmental report (Haldor Topsøe, 2013). The plant is equipped with $DeNO_x$ flue gas cleaning systems and depending of the efficiency of the cleaning system an emission of NH_3 will occur.

Activity data

The activity data regarding production of catalysts and fertiliser are obtained through environmental reports from Haldor Topsøe. The data are presented in Table 4.3.1.

Table 4.3.1 Production of catalysts and potassium nitrate, Gg (Haldor Topsøe, 2014).

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Catalysts[1]	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0
Potassium nitrate[1]	18.4	18.4	18.4	18.4	18.4	18.4	18.4	18.4	18.4	18.4
Catalysts+KNO_3	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Catalysts[1]	17.0	17.0	16.9	14.4	17.0	17.2	19.5	19.3	15.3	22.0
Potassium nitrate[1]	18.4	18.4	18.8	15.6	18.1	19.2	20.4	21.7	19.6	27.1
Catalysts+KNO_3	35.4	35.4	35.6	30.0	35.1	36.4	39.9	41.0	34.8	49.2
	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Catalysts	23.2	20.3	20.7	28.1	22.5	19.2	22.3	22.9	23.0	
Potassium nitrate	23.3	24.9	27.0	31.4	22.1	24.8	25.3	32.9	33.0	
Catalysts+KNO_3	46.5	45.2	47.7	59.5	44.6	46.4	47.5	55.8	56.0	

[1] Production 1985-1996 assumed to be the average of 1997-2001.

Emission factors

The average calculated CO_2 implied emission factor for 2003-2009 is 0.0241 Mg CO_2 per Mg product; this factor is applied for the entire time series. The CO_2 IEF is presented together with those of NO_x, NH_3 and particles in Table 4.3.2.

Table 4.3.2 Implied emission factors for production of catalysts and potassium nitrate, Mg per Gg product.

Pollutant	CO_2	NO_x	NH_3	TSP	PM_{10}	$PM_{2.5}$
Range	0.02-0.03	0.30-1.76	0.26-3.70	0.11-0.59	0.09-0.48	0.06-0.36
Mean	0.024[1]	0.819[2]	0.933[2]	0.366[3]	0.293[3]	0.220[3]

[1] Average for 2003-2009.
[2] Average for 1985-2013.
[3] Average for 2000-2013.

PM_{10} and $PM_{2.5}$ are estimated from the distribution between TSP, PM_{10} and $PM_{2.5}$ (1/0.8/0.6) from CEPMEIP (Values for 'Production of nitrogen fertiliser').

4.3.3 Emission trend

Trends for emissions of CO_2, NH_3, NO_x, TSP, PM_{10}, and $PM_{2.5}$ from production of catalysts and fertilisers are presented in Table 4.33.

Table 4.3.3 Emissions from catalyst and fertiliser production at Haldor Topsøe, Mg.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
CO_2	853	853	853	853	853	853	853	853	853	853
NH_3	13	13	13	13	13	13	13	13	13	13
NO_x	36	36	36	36	36	36	36	36	36	36
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
CO_2	853	853	859	723	845	877	961	988	840	1185
NH_3	13	13	13	13	9	14	71	43	57	68
NO_x	36	39	40	53	58	34	12	22	16	30
TSP						19	19	19	11	12
PM_{10}						15	15	15	9	10
$PM_{2.5}$						11	11	11	7	7
	2005	2006	2007	2008	2009	2010	2011	2012	2013	
CO_2	1120	1089	1150	1433	1074	1060	1146	1345	1350	
NH_3	79	88	107	111	165	123	20	18	21	
NO_x	30	37	18	19	18	17	21	19	20	
TSP	23	12	25	26	16	26	7	6	10	
PM_{10}	18	10	20	21	13	21	5	5	8	
$PM_{2.5}$	14	7	15	16	10	16	4	4	6	

From 1990 to 2013, the emission of CO_2 from the production of catalysts / fertilisers has increased from 0.9 to 1.4 Gg with maximum in 2008, due to an increase in the activity as well as changes in raw material consumption. The trend for the CO_2 emission from the production of catalysts and fertilisers is presented in Figure 4.3.1.

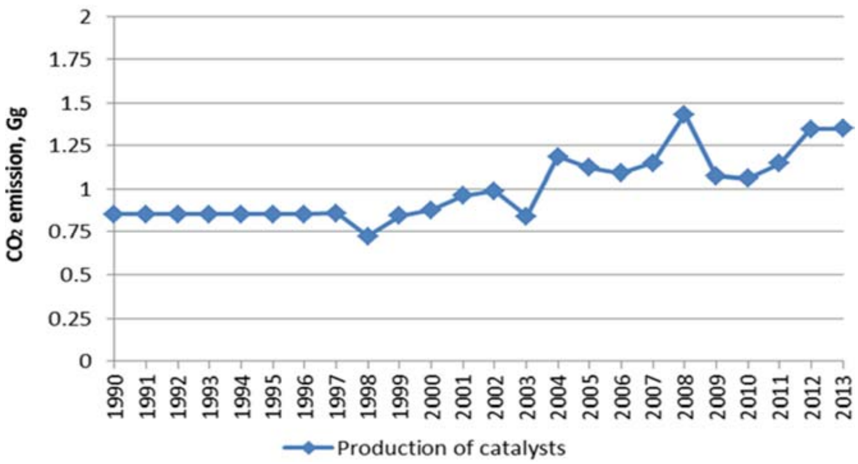

Figure 4.3.1 Emission of CO_2 catalyst/fertiliser production Gg.

The emission of NH_3 shows an increasing trend throughout the '00s; from 14 Mg in 2000 to 165 Mg in 2009; in the same period the IEF fluctuates around the average 0.54 Mg per Gg but shows no trend. For the remaining time series, the NH_3 emission only varies between 9-21 Mg with the exception of 2010 where 123 Mg were emitted.

The emission of NO_X decreases from the end of the '90s to the beginning of the '00s, in spite of the increasing production.

Emissions of NO_x, NH_3 and TSP are shown in Figure 4.3.2.

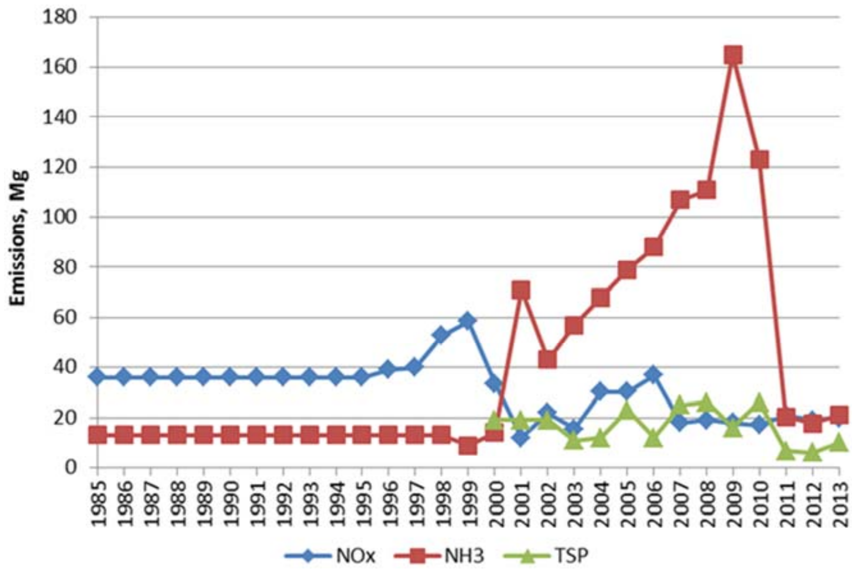

Figure 4.3.2 Emissions from catalyst and fertiliser production.

4.3.4 Time series consistency and completeness

Although activity data are not available for the full time series for this source category, it is still considered to be consistent. The activity data prior to 1996 are estimated as the constant average of the production in 1997-2001 while activity data for 1996 onward are known from the producer. The source category of catalyst production is complete.

4.3.5 Input to CollectER

The input data / data sources are presented in Table 4.3.4.

Table 4.3.4 Input data for calculating emissions from catalysts/fertiliser production.

	Year	Parameter	Comment/Source
Activity	1985-1995	KNO_3, catalysts	Estimated
	1996-2013	KNO_3, catalysts	Haldor Topsøe (2013)
Emissions	1985-1995	CO_2, NO_x, NH_3	Estimated
	1996-2013	CO_2, NO_x, NH_3 TSP	Haldor Topsøe (2013); information on distribution between energy and process related CO_2 as well as NO_x is presented
	2000-2013	PM_{10}, $PM_{2.5}$	Distribution between TSP, PM_{10}, and $PM_{2.5}$ from CEPMEIP

4.3.6 Future improvements

Through contact with the plant, it will be attempted to verify the assumptions on the split between combustion and process emissions for CO_2 and NO_x.

Emissions of BC will be added for catalyst / fertiliser production.

4.4 Pesticide production

The production of pesticides in Denmark is concentrated at one company: Cheminova A / S situated in Harboøre. The following SNAP code is covered:

- 04 05 25 Pesticide production

The following pollutants are included for the pesticide production process:

- SO_2
- NMVOC

Because it is not possible to separate process and fuel emissions reported in the company's environmental reports, SO_2 emissions for this source category includes emissions from fuel consumption.

4.4.1 Process description

Cheminova produce a wide range of pesticides, insecticides and biocides based on organic chemical syntheses. A main group of products are organophosphates and intermediates of organophosphate type to internal as well as external use. Due to the character of the products the identity of the raw materials is often confidential.

The final formulation of the products is often done at affiliated companies in other parts of the world. Secondary products are P fertiliser and regenerated sulphur.

4.4.2 Methodology

The air emissions from Cheminova are measured from a number of sources:

- Exhaust from process plant I (parameters: odour, organic substances (VOC), hydrogen bromide, hydrogen phosphate, hydrogen chloride, hydrogen sulphide and sulphur dioxide)
- Exhaust from process plant II (parameter: hydrogen sulphide)
- Incineration of sewage water from Glyphosat plant (parameters: hydrogen chloride, metals, TOC, TSP, nitrogen oxide, carbon monoxide)
- Sulphur recovery plant ("Claus plant") (parameter: sulphur dioxide and hydrogen sulphide)
- Biological sewage treatment plant, sludge de-watering plant (parameters: odour and organic substances (VOC))
- Combined heat and power plant (parameters: nitrogen oxides, carbon monoxide)

The environmental reports only include some of the emissions and they only present aggregated data. Emissions of SO_2 and NMVOC are measured yearly for 1990-2013 and 1990-2000 respectively.

Activity data

Activity data for the production of pesticides are presented in Table 4.4.1.

Table 4.4.1 Production of pesticides, Mg (Cheminova, 2014).

	1980	1981	1982	1983	1984	1985	1986	1987	1988
Pesticides	20,796	23,914	26,517	33,331	38,924	42,010	42,492	42,781	48,020
	1989	1990	1991	1992	1993	1994	1995	1996	1997
Pesticides	48,342	37,671	39,631	29,764	38,988	41,913	45,320	55,800	56,500
	1998	1999	2000	2001	2002	2003	2004	2005	2006
Pesticides	52,985	64,264	60,284	60,376	55,464	52,849	65,310	53,504	52,575
	2007	2008	2009	2010	2011	2012	2013		
Pesticides	49,796	49,747	37,484	31,000	31,000	31,000	30,000		

Activity data for 1980-1995 are estimated with the production value as surrogate data.

Emission factors

The implied emission factors for pesticide production are presented in Table 4.4.2.

Table 4.4.2 Implied emission factors for pesticide production, Claus process.

	Substance	Interval[1], kg/Mg	Average[2], kg/Mg
Pesticides	SO_2	0.1 – 26.1	4.8
	NMVOC	0.5 - 10.4	2.2

[1] Interval for 1980-2013.
[2] Average only for years where actual emissions and activity data are available; i.e. 1996-2013 and 1996-2000 for SO_2 and NMVOC respectively.

4.4.3 Emission trend

The emission of NMVOC from production of pesticides was reduced significantly from 1990 to 1993 (Cheminova, 2014). The decrease can be explained by introduction of flue gas cleaning equipment rather than any decrease in activity. The emission of SO_2 is from the sulphur regeneration plant (Claus plant).

The emission of NMVOC from production of pesticides is measured yearly from 1990 to 2000 (Cheminova, 2014) and estimated for 2001 to 2013. The implied emission factor based on 2000 data is used for estimation of 2001 to 2013 emissions.

Emissions of NMVOC and SO_2 are presented in Table 4.4.3 and Figure 4.4.1.

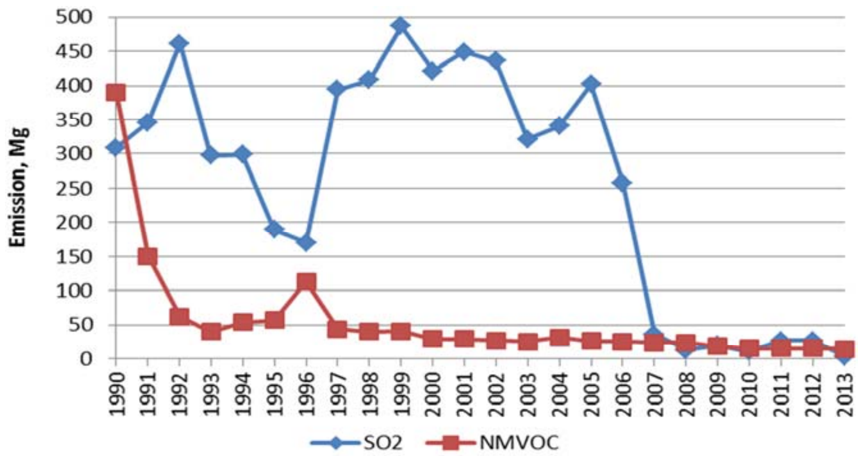

Figure 4.4.1 Emissions of SO_2 and NMVOC from pesticide production.

Table 4.4.3 Emissions from production of pesticides, Mg (Cheminova, 2014).

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
NMVOC	77	89	98	124	144	156	158	159	178	179
SO_2	367	422	468	589	688	742	751	756	848	854
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
NMVOC	390	150	62	40	54	57	113	44	40	41
SO_2	565	644	778	613	638	553	573	632	408	488
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
NMVOC	29	29	27	25	31	26	25	24	24	18
SO_2	422	450	437	322	341	403	258	36	13	20
	2010	2011	2012	2013						
NMVOC	15	15	15	14						
SO_2	11	27	27	4						

4.4.4 Input to CollectER

The input data / data sources are presented in Table 4.4.4.

Table 4.4.4 Input data for calculating emissions from pesticides production.

	Year	Parameter	Comment/Source
Activity data	1980-1995	Total products	Estimated
	1996-2013	Total products	Cheminova (2014)
Emissions	1980-1989; 2001-2013	NMVOC	Estimated using IEF and production data
	1990-2000	NMVOC	Cheminova (2014)
	1980-1989	SO_2	Estimated using IEF and production data
	1990-2013	SO_2	Cheminova (2014)

4.4.5 Future improvements

There are no planned improvements for the source category of pesticide production.

4.5 Production of chemical ingredients

The production of chemical ingredients takes place in a number of different companies. One of the major companies is Danisco Grindsted located in Grindsted (Danisco Grindsted, 2014). The following SNAP code is covered:

- 04 05 00 Production in organic chemical industry

The following pollutants are included for the production process of chemical ingredients:

- NMVOC

4.5.1 Process description

The following description of the production of chemical ingredients is based on the environmental report from the company (Danisco Grindsted, 2010).

The raw materials are primarily natural or nature identical raw materials / substances: vegetable oils, animal fatty acids, glycerine, other organic substances, mineral acidic and alkaline compounds, solvents etc. The products are emulsifiers, stabilisers, flavours, enzymes, antioxidants, pharmaceuticals and preservatives.

The chemical process is not described due to confidentiality.

4.5.2 Methodology

Due to confidentiality no activity data or emission factors are available.

4.5.3 Emission trend

The emission of NMVOC from production of chemical ingredients has been measured from 1997 to 2013 (Danisco Grindsted, 2014). Emissions for 1990-1996 have been estimated. The emission has decreased from 100 to 12 Mg NMVOC in this period. However, no explanation can be given on these conditions, as information on activity is not available. The NMVOC emissions are presented in Table 4.5.1.

Table 4.5.1 Emissions from the production of chemical ingredients, Mg (Danisco Grindsted, 2014).

	1990	1991	1992	1993	1994	1995	1996	1997
NMVOC	100	100	100	100	100	100	100	93
	1998	1999	2000	2001	2002	2003	2004	2005
NMVOC	103	62	40	18	18	15	16	14
	2006	2007	2008	2009	2010	2011	2012	2013
NMVOC	15	17	15	12	12	12	12	12

4.6 Production of tar products

One Danish factory situated in Nyborg produces tar products. The following SNAP code is covered:

- 04 05 27 Production of tar products

The following pollutants are included for the production process of tar products:

- SO_2
- NMVOC
- Heavy metals: Hg

4.6.1 Process description

The description of the process is based on the 2014 environmental report by the company (Koppers, 2014). The company is a chemical plant that refines coal tar. Coal tar is a residual product from degasification of coal at coking plants. The main products of the company are coal tar pitch, carbon black feedstock, creosote oil and naphthalene.

The production facility where the raw material (coal tar) is separated in fractions and refined consists of the following units:

- Tar distillation plant (Distillation of the coal tar)
- Tar acid washer (TAW) plant (Naphthalene oil is washed with sodium hydroxide)
- Naphthalene distillation plant (Distillation of naphthalene oil)
- Storage tanks (Storage of raw materials and finished products with air ventilation and air cleaning)
- Creosote plant (Reduction of the oils crystallising point by cooling and crystallisation)
- Flacking plant (Crystallisation of naphthalene and packaging)
- Loading plant (Loading of distillates and fuel additives)

The majority of the raw material is imported from other European countries. The finished products are exported globally, but the main product, coal tar pitch, is mainly exported to the aluminium industry in Europe, where it is used for production of anodes. Naphthalene is used as a raw material in the chemical industry, creosote oil for wood preservation and carbon black feedstock in the tyre industry.

Intermediates and finished products are kept in storage tanks, which have a total capacity of approximately 100,000 m^3. In the storage tanks some products are kept at temperatures up to 220 ºC to prevent solidification. The only exception is the main part of the naphthalene production, which after purification is crystallised in flakes and is sold as solid naphthalene.

The production takes place in closed system and the storage tanks is run at vacuum to keep releases to the surroundings to a minimum.

The distillation plants are operating around the clock all year with the exception of a few weeks shutdown a year for scheduled maintenance.

4.6.2 Methodology

No activity data are available. The emissions are based on measured emissions reported in the environmental reports from the company (Koppers, 2014). The emissions for the years 1985 – 2004 are assumed to be the same (rounded) as for 2005.

4.6.3 Emission trend

Trends for emissions of NMVOC, SO_2 and Hg from production of tar products are presented in Table 4.6.1.

Table 4.6.1 Emissions from production of tar products, Mg; Hg in kg (Koppers, 2014).

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
SO_2	210	210	210	210	210	210	210	210	210	210
NMVOC	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Hg	NE	NE	NE	NE	NE	4.9	4.9	4.9	4.9	4.9
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
SO_2	210	210	210	210	210	210	210	210	210	210
NMVOC	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Hg	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
	2005	2006	2007	2008	2009	2010	2011	2012	2013	
SO_2	212	122	61	95	93	105	166	203	174	
NMVOC	0.9	1.2	1.0	0.5	2.0	1.3	1.1	1.2	0.6	
Hg	4.9	4.9	4.9	12.1	0.5	1.5	1.4	10.0	0.0	

NE: Not estimated

4.6.4 Future improvements

The emission of SO_2 will be extrapolated back to 1980 to comply with the requirement to have a time series back to the base year.

It will be evaluated whether the assumption to keep emissions constant back in time at the 2005 level is appropriate.

Possible emissions of PAH from the process will be investigated.

5 Metal industry

The processes within metal industry in Denmark in relation to emission of greenhouse gases and other pollutants are:

- Iron and steel production; see section 5.2
- Red bronze production; see section 5.3
- Magnesium production; see section 5.4
- Secondary aluminium production; see section 5.5
- Secondary lead production; see section 5.6

There is no primary production of metals in Denmark and no metallurgical coke production.

5.1 Emissions

The time series for emission of CO_2 from metal industry is presented in Figure 5.1.1 below.

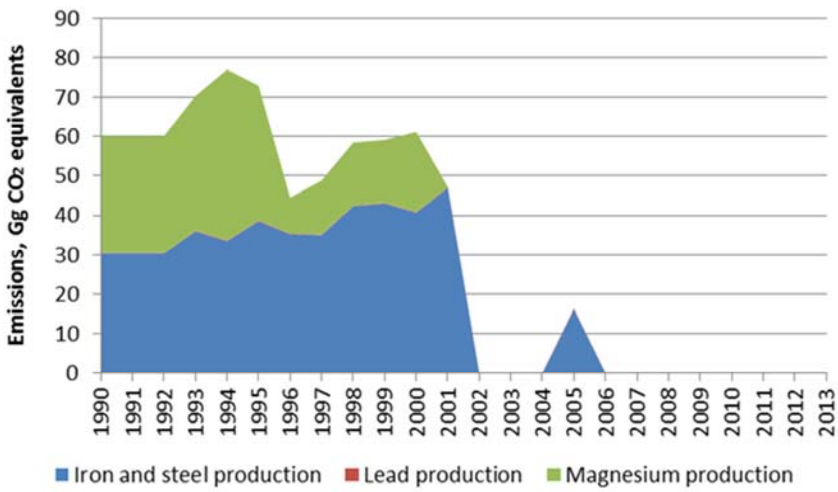

Figure 5.1.1 Emission of greenhouse gasses from the individual source categories compiling *2C Metal Industry*, Gg CO_2 equivalents.

From 1990 to 2001, the CO_2 emission from the electro-steelwork increased by 55 % and from 1990-2000 SF_6 from magnesium production decreased with 32 %. The changes in the greenhouse gas emission is similar to the increase and decrease in the activity as the consumption of metallurgical coke per amount of steel sheets and bars produced has almost been constant during the period and the emission factor for magnesium production is constant throughout the time series.

Greenhouse gas emissions from secondary lead production are miniscule (0.3 % for 1990-2000), but are the only greenhouse gas emissions in the metal industry that occur for the entire time series.

The electro-steelwork was shut down in 2001 and reopened and closed down again in 2005. In 2000, the SF_6 emission from the magnesium production ceased.

Gray iron foundries, aluminium production and red bronze production are active for the entire time series but emit no process greenhouse gas emissions.

An overview of the 2013 emission of particulate matter, heavy metals, and POPs from metal industry is available in Table 5.1.1.

Table 5.1.1 Overview of 2013 emissions from metal production.

	Total emission from metal industries		Fraction of IP*; %	Largest contributor in Metal industries	Emission from largest contributor		Fraction of metal industries, %
TSP	0.16	Gg	19.90	Iron and steel production	0.16	Gg	98.69
HMs	2.86	Mg	43.67	Zn from Other metal production (CRF 2C7c)	0.63	Mg	22.16
POPs	0.21	kg	0.09	HCBs from Aluminium production	0.14	kg	65.78

* IP: The Industrial Processes sector

Iron and steel production comprises three activities; an electric arc furnace (EAF) (until 2001/2002 and in 2005), rolling mills (from 2003) and gray iron foundries (whole time series). The most interesting activity from an air emission perspective is the EAF. After the closing of the EAF, the site has since 2003 been used for rolling steel slabs imported from steelworks in other countries. This change in production results in large changes in activity data and emissions reported for the year 2002. In 2005, the EAF was shortly reopened, which explains the higher activity level this year.

Regarding the steelworks that use iron and steel scrap as raw material, the emissions to a large degree depend on the quality of the scrap. This fact may result in large annual variations for one or more of the heavy metals. This may also be the case for iron foundries, as they also use scrap as raw material, but they have not been subject to the same requirements to analyse emissions of heavy metals to air.

5.2 Iron and steel production

The production of semi-manufactured steel products (e.g. steel sheets/plates and bars) is concentrated at one company: Det Danske Stålvalseværk A/S situated in Frederiksværk. Only two gray iron foundries are still in operation in Denmark, producing a range of products like e.g. cast iron pipes, central heating boilers and flywheels. The following SNAP codes are covered:

- 03 03 03 Gray iron foundries
- 04 02 07 Electric furnace steel plant
- 04 02 08 Rolling mill

The following pollutants are included for the iron and steel production processes:

- CO_2
- Particulate matter: TSP, PM_{10}, $PM_{2.5}$
- Heavy metals: As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn
- Persistent organic pollutants: HCB, PCDD/F, PCB

The steelwork has been closed down in January 2002 and parts of the plant have been re-opened in November 2002. The production of steel sheets/plates was reopened by DanSteel in 2003, the production of steel bars was reopened by DanScan Metal in March 2004, and the electro steelwork was reopened by DanScan Steel in January 2005. The production at DanScan Metal and Steel ceased in the last part of 2005 and in June 2006 DanScan Metal was taken over by Duferco; the future for the electro steelwork (DanScan Steel) is still uncertain and the plant has not been in operation since 2005. The timeline is presented in Figure 5.2.1.

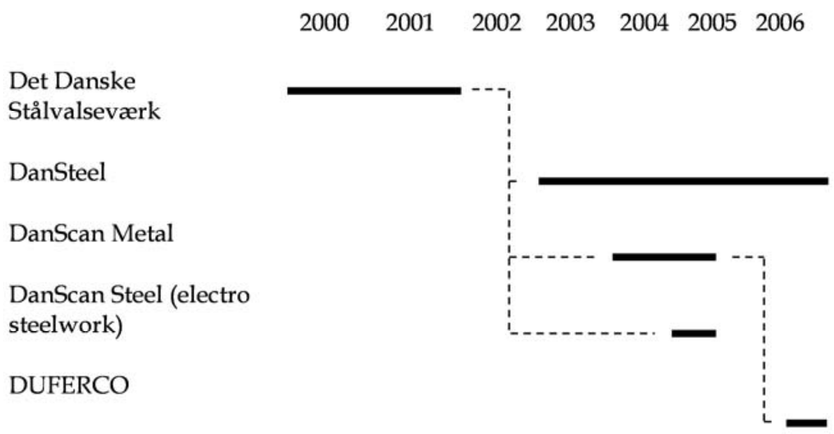

Figure 5.2.1 Timeline for production at the Danish steelwork.

5.2.1 Process description

The primary raw materials in steel production are iron and steel scrap and the secondary raw materials are metallurgical coke, iron, alkali metals, other alloy metals, and oxygen. Trucks, trains or ships deliver the iron and steel scrap. The scrap is controlled before melting in an electric arc furnace. The composition of the molten iron is checked and alloy metals are added depending on the expected quality of the final steel product. The iron is prepared as billets / blooms for bars or slabs for sheets. The final products are made in different rolling mills for bars and sheets, respectively. The cease of the electro steelwork has resulted in import of billets / blooms and slabs for the rolling mills.

The process is presented Figure 5.2.2.

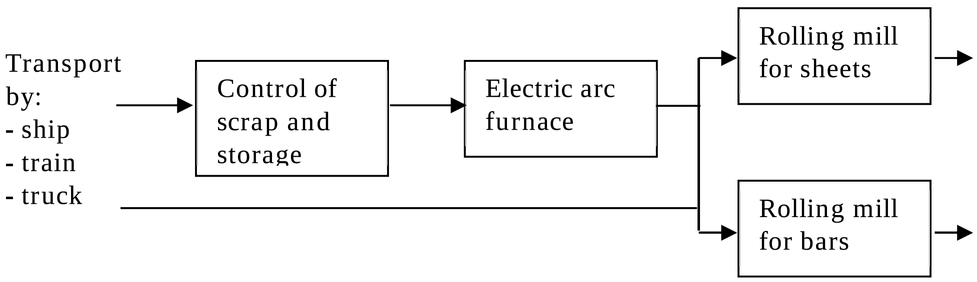

Figure 5.2.2 Overall flow-sheet for ”Det Danske Stålvalseværk” (Stålvalseværket, 2002; DanSteel, 2013).

5.2.2 Methodology

In steel production, metallurgical coke is used in the melting process to reduce iron oxides and to remove impurities. The overall process is:

$$C + O_2 \rightarrow CO_2$$

The emission factors for carbon dioxide from using metallurgical coke in manufacturing of iron and steel scrap is:

- 3.667 Mg CO_2 per Mg C

Different steel qualities contain carbon from <0.25% (iron / unalloyed steel) to >6% (ferrochromium) and some of the metallurgical coke / carbon can be expected to be retained in the steel. However, the scrap can also be expected to contain a certain amount of carbon. Analysis of the data in the environmental declaration for steel sheets or steel bars indicate that all the metallurgical coke is emitted as carbon dioxide as illustrated in Table 5.2.1.

Table 5.2.1 CO_2 balance for production of 1 tonne steel sheets - 2001 (Stålvalseværket, 2002).

	Environmental report	Emission factor (2001)	CO_2-emission (estimated)
Input			
Natural gas	73 Nm^3 (2.92 GJ)	57.25 kg CO_2/GJ	167.17 kg CO_2
Metallurgical coke	18 kg	3.667 kg CO_2/kg C	66.01 kg CO_2
Output			
CO_2	229 kg		233.18 kg

The difference between the reported and the estimated CO_2-emission can be explained by choice of calorific value for natural gas and the CO_2-emission factor for natural gas.

The CO_2 emission from the consumption of metallurgical coke at steelworks has been estimated from the annual production of steel sheets and steel bars combined with the consumption of metallurgical coke per produced amount (Stålvalseværket, 2002). The carbon source is assumed to be coke and all the carbon is assumed to be converted to CO_2 as the carbon content in the products is assumed to be the same as in the iron scrap. The emission factor (consumption of metallurgical coke per Mg of product) has been almost constant from 1994 to 2001; steel sheets: 0.012-0.018 Mg metallurgical coke per Mg and steel bars: 0.011-0.017 Mg metallurgical coke per Mg.

Steel production data for 1990-1991 and for 1993 have been determined with extrapolation and interpolation, respectively and data on the consumption of metallurgical coke for 1990-1992 have been extrapolated.

The emission of heavy metals from iron foundries is based on standard emission factors and yearly production statistics from Statistics Denmark (2014). The emission of TSP and distribution between TSP, PM_{10} and $PM_{2.5}$ is obtained from CEPMEIP. Emission factors for HCB and PCB are obtained from Nielsen et al. (2013a).

Activity data

Statistical data on activities are available in environmental reports from the single Danish steel plant (Stålvalseværket) supplemented with other literature; see Table 5.2.2.

Table 5.2.2 Overall mass flow for Danish steel production, Gg (Stålvalseværket, 2002; DanSteel, 2014).

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Det danske stålvalseværk											
Raw material	Iron and steel scrap	-	630[1]	557	-	673	657	664	735	737	691
Intermediate product	Steel slabs etc.	-	-	599	-	730	654	744	794	800	727
Product	Steel sheets	444	444	444	451	459	478	484	571	514	571
	Steel bars	170	170	170	217	264	239	235	245	238	226
	Products, total	614[2]	614[2]	614	668[3]	722	717	720	816	752	798
DanSteel											
Raw material	Steel slabs										
Product	Steel sheets										
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Det danske stålvalseværk											
Raw material	Iron and steel scrap	731	680				-				
Intermediate product	Steel slabs etc.	803	746				-				
Product	Steel sheets	380	469				-				
	Steel bars	251	256				-				
	Products, total	631	725				250[4]				
DanSteel											
Raw material	Steel slabs				553	600	515	561	635	590	254
Product	Steel sheets				469	506	433	468	520	484	211
		2010	2011	2012	2013						
Det danske stålvalseværk											
Raw material	Iron and steel scrap										
Intermediate product	Steel slabs etc.										
Product	Steel sheets										
	Steel bars										
	Products, total										
DanSteel											
Raw material	Steel slabs	457	490	338	460						
Product	Steel sheets	381	390	275	379						

[1]Jensen & Markussen (1993).
[2]Extrapolation.
[3]Intrapolation.
[4]Assumed

The mass balances/flow sheets presented in the annual environmental reports do not for all years tell about the changes in the stock and therefore the balance cannot be checked off.

Statistical data on production in gray iron foundries are available from Statistics Denmark (2014) since 1998; activity data prior to this year are estimated. The activity data are presented in Table 5.2.3.

Table 5.2.3 Activity data, iron foundries, Gg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Gray iron foundries	103.0	100.4	97.8	95.3	92.7	90.2	87.6	85.1	85.8	86.0
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Gray iron foundries	101.7	94.5	103.0	104.5	113.0	99.9	81.5	72.8	71.4	41.4
	2010	2011	2012	2013						
Gray iron foundries	72.9	83.6	76.4	77.4						

Emission factors

The CO_2 emission factor from use of metallurgical coke in manufacturing of steel from scrap is the stoichiometric ratio 3.667 Mg CO_2 per Mg C.

The applied steel production emission factors for the air pollutants are presented in Table 5.2.4. Regarding the electric arc furnace the emissions for all other pollutants than TSP have been estimated by use of emission factor from literature.

Table 5.2.4 Emission factors for steel production (Environmental reports).

	Unit	Electric Arc Furnace	Rolling Mill
TSP	g/Mg	61-147	6.44
PM_{10}	g/Mg	80 % of TSP[1]	95 % of TSP
$PM_{2.5}$	g/Mg	70 % of TSP[1]	60 % of TSP
As	g/Mg	0.015[1]	-
Cd	g/Mg	0.01-0.08[2]	0.006
Cr	g/Mg	0.1[1]	-
Cu	g/Mg	0.02[1]	-
Hg	g/Mg	0.1-0.4[2]	0.023
Ni	g/Mg	0.4-1.4[2]	0.087
Pb	g/Mg	1.0-5.0[2]	0.087
Zn	g/Mg	3.6-19.0[2]	0.377
HCB	mg/Mg	3.2[3]	-
PCDD/F	mg/Mg	0.8[1]	-
PCB	mg/Mg	2.5[3]	-

[1] EMEP/EEA (2013), Tier 2 no abatement.
[2] Illerup et al. (1999).
[3] Nielsen et al. (2013a).

The applied emission factors for the gray iron foundries are presented in Table 5.2.5.

Table 5.2.5 Emission factors for gray iron foundries.

	Unit	Gray iron foundries
TSP	g/Mg	2000
PM_{10}	g/Mg	30 % of TSP
$PM_{2.5}$	g/Mg	4.5 % of TSP
As	g/Mg	0.3
Cd	g/Mg	0.14
Cr	g/Mg	1.1
Ni	g/Mg	1.3
Pb	g/Mg	7.2
Se	g/Mg	5
Zn	g/Mg	5
HCB	mg/Mg	0.04
PCB	mg/Mg	0.5

5.2.3 Emission trend

The greenhouse gas emission from the steel production is presented in Figure 5.2.3. The production ceased in 2001 and reopened and closed again in 2005; see Figure 5.2.1.

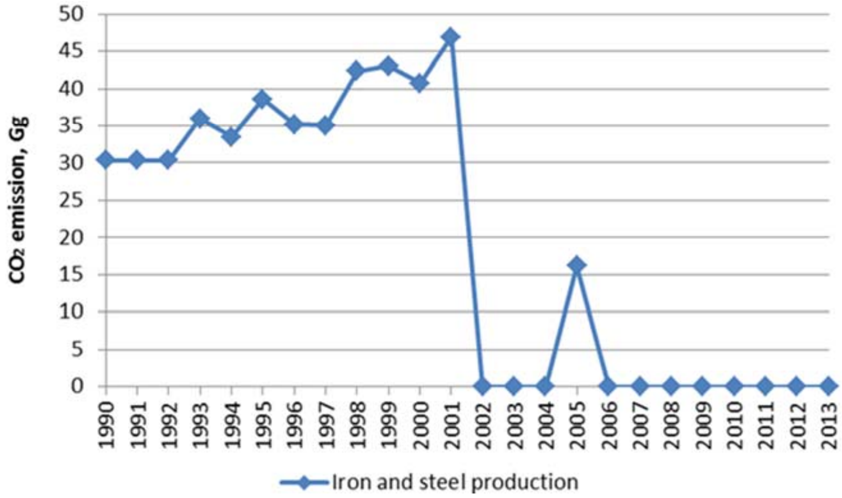

Figure 5.2.3 Emission of greenhouse gasses from the production of steel from scrap.

Emissions from the electro steelwork and rolling mill are presented in Table 5.2.6.

Table 5.2.6a Emissions from the electro steelwork, rolling mill and gray iron foundries.

Pollutant	Process	Unit	1990	1991	1992	1993	1994	1995	1996	1997
CO_2	Electric furnace steel plant	Gg	30.3	30.3	30.3	36.0	33.5	38.5	35.2	35.0
As	Total	kg	40.1	39.3	38.5	38.6	38.6	37.8	37.1	61.8
	Electric furnace steel plant	kg	9.2	9.2	9.2	10.0	10.8	10.8	10.8	12.2
	Gray iron foundries	kg	30.9	30.1	29.3	28.6	27.8	27.1	26.3	49.5
Cd	Total	kg	53.3	53.0	52.6	53.8	38.6	34.2	31.5	45.1
	Electric furnace steel plant	kg	38.9	38.9	38.9	40.4	25.6	21.5	19.2	22.0
	Gray iron foundries	kg	14.4	14.1	13.7	13.3	13.0	12.6	12.3	23.1
Cr	Total	kg	174.7	171.8	169.0	171.6	174.2	171.0	168.4	263.2
	Electric furnace steel plant	kg	61.4	61.4	61.4	66.8	72.2	71.7	72.0	81.6
	Gray iron foundries	kg	113.3	110.4	107.6	104.8	102.0	99.3	96.4	181.6
Cu	Electric furnace steel plant	kg	12.3	12.3	12.3	13.4	14.4	14.3	14.4	16.3
Hg	Electric furnace steel plant	kg	246	246	246	267	144	143	216	204
Ni	Total	kg	891.3	887.9	884.5	862.4	619.4	547.6	473.8	540.9
	Electric furnace steel plant	kg	757.4	757.4	757.4	738.5	498.9	430.2	359.8	326.3
	Gray iron foundries	kg	133.9	130.5	127.1	123.9	120.5	117.4	114.0	214.6
Pb	Total	kg	3,708.5	3,689.8	3,671.1	3,786.6	2,775.4	2,370.4	1,471.3	2,061.4
	Electric furnace steel plant	kg	2,966.9	2,966.9	2,966.9	3,100.5	2,107.9	1,720.4	840.1	872.9
	Gray iron foundries	kg	741.6	722.9	704.2	686.2	667.4	650.0	631.2	1,188.5
Se	Gray iron foundries	kg	515.0	502.0	489.0	476.5	463.5	451.4	438.3	825.4
Zn	Total	kg	12,006.8	11,993.8	11,980.8	12,286.1	8,606.2	6,998.1	7,199.0	7,858.4
	Electric furnace steel plant	kg	11,491.8	11,491.8	11,491.8	11,809.6	8,142.7	6,546.7	6,760.7	7,033.0
	Gray iron foundries	kg	515.0	502.0	489.0	476.5	463.5	451.4	438.3	825.4
HCB	Total	kg	6.1	6.0	5.9	6.0	6.0	5.9	5.8	9.2
	Electric furnace steel plant	kg	2.0	2.0	2.0	2.1	2.3	2.3	2.3	2.6
	Gray iron foundries	kg	4.1	4.0	3.9	3.8	3.7	3.6	3.5	6.6
PCDD/F	Electric furnace steel plant	g	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.7
PCB	Total	kg	53.0	51.7	50.4	49.3	48.2	46.9	45.6	84.6
	Electric furnace steel plant	kg	1.5	1.5	1.5	1.7	1.8	1.8	1.8	2.0
	Gray iron foundries	kg	51.5	50.2	48.9	47.7	46.4	45.1	43.8	82.5

Table 5.2.6b Emissions from the electro steelwork, rolling mill and gray iron foundries. (Continued)

Pollutant	Process	Unit	1998	1999	2000	2001	2002	2003	2004	2005
CO_2	Electric furnace steel plant	Gg	42.3	43.0	40.7	46.9	NO	NO	NO	16.2
TSP	Total	Mg	NE	NE	420.1	425.5	410.2	419.0	455.3	402.6
	Electric furnace steel plant	Mg	NE	NE	41.2	47.5	NO	NO	NO	NO
	Rolling mills	Mg	NE	NE	NO	NO	NO	3.0	3.3	2.8
	Gray iron foundries	Mg	NE	NE	379.0	378.0	410.2	416.0	452.1	399.8
PM_{10}	Total	Mg	NE	NE	146.6	151.4	123.1	127.7	138.7	122.6
	Electric furnace steel plant	Mg	NE	NE	33	38	NO	NO	NO	NO
	Rolling mills	Mg	NE	NE	NO	NO	NO	2.9	3.1	2.7
	Gray iron foundries	Mg	NE	NE	113.7	113.4	123.1	124.8	135.6	120.0
$PM_{2.5}$	Total	Mg	NE	NE	40.1	43.6	18.5	20.5	22.3	19.7
	Electric furnace steel plant	Mg	NE	NE	23.0	26.6	NO	NO	NO	NO
	Rolling mills	Mg	NE	NE	NO	NO	NO	1.8	2.0	1.7
	Gray iron foundries	Mg	NE	NE	17.1	17.0	18.5	18.7	20.3	18.0
As	Total	kg	61.6	60.5	66.3	67.6	61.5	62.4	67.8	60.0
	Electric furnace steel plant	kg	11.3	12.0	9.5	10.9	NO	NO	NO	NO
	Gray iron foundries	kg	50.3	48.5	56.8	56.7	61.5	62.4	67.8	60.0
Cd	Total	kg	43.6	44.3	43.0	45.7	28.7	31.8	34.6	30.5
	Electric furnace steel plant	kg	20.2	21.7	16.4	19.2	NO	NO	NO	NO
	Gray iron foundries	kg	23.5	22.6	26.5	26.5	28.7	29.1	31.6	28.0
	Rolling mills	kg	NO	NO	NO	NO	NO	2.7	2.9	2.5
Cr	Total	kg	259.6	257.7	271.5	280.4	225.6	228.8	248.6	219.9
	Electric furnace steel plant	kg	75.2	79.8	63.1	72.5	NO	NO	NO	NO
	Gray iron foundries	kg	184.5	177.9	208.4	207.9	225.6	228.8	248.6	219.9
Cu	Electric furnace steel plant	kg	15.0	16.0	12.6	14.5	NO	NO	NO	NO
Hg	Total	kg	150.3	119.6	63.1	36.3	NO	10.9	11.7	10.1
	Electric furnace steel plant	kg	150.3	119.6	63.1	36.3	NO	NO	NO	NO
	Rolling mills	kg	NO	NO	NO	NO	NO	10.9	11.7	10.1
Ni	Total	kg	518.6	529.3	498.7	535.8	266.6	311.1	337.8	297.5
	Electric furnace steel plant	kg	300.6	319.0	252.4	290.1	NO	NO	NO	NO
	Gray iron foundries	kg	218.0	210.3	246.3	245.7	266.6	270.4	293.8	259.9
	Rolling mills	kg	NO	NO	NO	NO	NO	40.7	43.9	37.7
Pb	Total	kg	2,010.2	2,019.2	2033.3	2,133.0	1,476.8	1,538.2	1,671.3	1,477.1
	Electric furnace steel plant	kg	802.9	854.7	669.0	772.2	NO	NO	NO	NO
	Gray iron foundries	kg	1,207.4	1,164.6	1364.3	1,360.8	1,476.8	1,497.5	1,627.4	1,439.4
	Rolling mills	kg	NO	NO	NO	NO	NO	40.7	43.9	37.7
Se	Gray iron foundries	kg	838	808.7	947.4	945.0	1,025.5	1,039.9	1,130.1	999.6
Zn	Total	kg	6,386	5,673	4,032	3,556	1,026	1,217	1,321	1,163
	Electric furnace steel plant	kg	5,548	4,864	3,085	2,611	NO	NO	NO	NO
	Gray iron foundries	kg	838	809	947	945	1,026	1,040	1,130	1,000
	Rolling mills	kg	NO	NO	NO	NO	NO	176.7	190.6	163.3
HCB	Total	kg	9.1	9.0	9.6	9.9	8.2	8.3	9.0	8.0
	Electric furnace steel plant	kg	2.4	2.6	2.0	2.3	NO	NO	NO	NO
	Gray iron foundries	kg	6.7	6.5	7.6	7.6	8.2	8.3	9.0	8.0
PCDD/F	Electric furnace steel plant	g	0.6	0.6	0.5	0.6	NO	NO	NO	NO
PCB	Total	kg	85.7	82.9	96.3	96.3	102.6	104.0	113.0	100.0
	Electric furnace steel plant	kg	1.9	2.0	1.6	1.8	NO	NO	NO	NO
	Gray iron foundries	kg	83.8	80.9	94.7	94.5	102.6	104.0	113.0	100.0

NO: Not occurring

NE: Not estimated (basis year for particles is 2000)

Table 5.2.6c Emissions from the electro steelwork, rolling mill and gray iron foundries. (Continued)

Pollutant	Process	Unit	2006	2007	2008	2009	2010	2011	2012	2013
CO_2	-	-	NO	NO	NO	NO	NO	NO	NO	NO
TSP	Total	Mg	329.0	294.6	288.8	167.4	294.0	337.0	307.7	157.2
	Rolling mills	Mg	3.0	3.4	3.1	1.4	2.5	2.5	1.8	2.4
	Gray iron foundries	Mg	326.0	291.2	285.7	166.1	291.6	334.5	305.9	154.7
PM_{10}	Total	Mg	100.7	90.6	88.7	51.1	89.8	102.7	93.5	48.7
	Rolling mills	Mg	2.9	3.2	3.0	1.3	2.3	2.4	1.7	2.3
	Gray iron foundries	Mg	97.8	87.4	85.7	49.8	87.5	100.4	91.8	46.4
$PM_{2.5}$	Total	Mg	16.5	15.1	14.7	8.3	14.6	16.6	14.8	8.4
	Rolling mills	Mg	1.8	2.0	1.9	0.8	1.5	1.5	1.1	1.5
	Gray iron foundries	Mg	14.7	13.1	12.9	7.5	13.1	15.1	13.8	7.0
As	Gray iron foundries	kg	48.9	43.7	42.9	24.9	43.7	50.2	45.9	23.2
Cd	Total	kg	25.5	23.4	22.8	12.8	22.6	25.7	23.0	13.0
	Gray iron foundries	kg	22.8	20.4	20.0	11.6	20.4	23.4	21.4	10.8
	Rolling mills	kg	2.7	3.0	2.8	1.2	2.2	2.3	1.6	2.2
Cr	Gray iron foundries	kg	179.3	160.2	157.1	91.3	160.4	184.0	168.3	85.1
Cu	-	-	NO	NO	NO	NO	NO	NO	NO	NO
Hg	Rolling mills	kg	10.8	12.1	11.2	4.9	8.8	9.0	6.4	8.8
Ni	Total	kg	252.5	234.5	227.7	126.3	222.6	251.3	222.7	133.5
	Gray iron foundries	kg	211.9	189.3	185.7	108.0	189.5	217.4	198.9	100.6
	Rolling mills	kg	40.6	45.2	42.1	18.3	33.1	33.8	23.9	32.9
Pb	Total	kg	1,214.3	1,093.7	1,070.5	616.2	1,082.8	1,238.1	1,125.2	590.0
	Gray iron foundries	kg	1,173.7	1,048.5	1,028.5	597.9	1,049.7	1,204.2	1,101.4	557.1
	Rolling mills	kg	40.6	45.2	42.1	18.3	33.1	33.8	23.9	32.9
Se	Gray iron foundries	kg	815.1	728.1	714.2	415.2	729.0	836.3	764.8	386.9
Zn	Total	kg	991.3	924.3	896.7	494.8	872.6	983.1	868.3	529.5
	Gray iron foundries	kg	815.1	728.1	714.2	415.2	729.0	836.3	764.8	386.9
	Rolling mills	kg	176.3	196.2	182.4	79.6	143.6	146.8	103.5	142.7
HCB	Gray iron foundries	kg	6.5	5.8	5.7	3.3	5.8	6.7	6.1	3.1
PCDD/F	-	-	NO	NO	NO	NO	NO	NO	NO	NO
PCB	Gray iron foundries	kg	81.5	72.8	71.4	41.5	72.9	83.6	76.5	38.7

NO: Not occurring

Due to the change in production process in the beginning of the ‘00s, the emissions (and even more so the implied emission factors) change drastically form 2001 to 2002 and from 2002 to 2003. Please refer to Figure 5.2.1 and Table 5.2.2.

5.2.4 Time series consistency and completeness

The time series for secondary steel production is considered to be consistent as the same methodology has been applied for the whole period. The time series is also considered to be complete.

5.2.5 Input to CollectER

The input data / data sources are presented in Table 5.2.7.

Table 5.2.7 Input data for calculation of emissions from iron and steel production.

	Year	Parameter	Comment/Source
Activity	1992, 1994-2001	Scrap, semi-man. products, final products	Stålvalseværket (2002)
	1990, 1991, 1993	Final products	Estimated with interpolation and extrapolation
	2003-2013	Final products	Environmental reports (Dansteel, 2014)
	1995-2013	Sales statistics for gray iron products	Statistics Denmark (2014)
	1990-1994	Sales statistics for gray iron products	Estimated
Emissions	1992-1997	Heavy metal EFs	Illerup et al. (1999)
	1993-2001	CO_2	Estimated from information on consumption of metallurgical coke (Stålvalseværket, 2002)
	1993-2000	TSP	Stålvalseværket (2002)
	2000-2001	PM_{10}, $PM_{2.5}$	Distribution between TSP, PM_{10}, and $PM_{2.5}$ from EMEP/EEA (2013)

5.2.6 Future improvements

For iron foundries a process description will be elaborated.

Activity data from Statistics Denmark will be used for iron foundries for the whole time series.

Emission factors for iron foundries will be re-examined to ensure that they are properly referenced.

5.3 Red bronze production

This section covers the production of red bronze which is the only ferroalloy (i.e. allied metal) produced in Denmark. The following SNAP code is covered:

- 04 03 06 Allied metal manufacturing

The following pollutants are included for the red bronze production processes:

- Heavy metals: Cd, Cu, Pb, Zn

5.3.1 Process description

No further description is given for red bronze production.

5.3.2 Methodology

Production data is only available for 1990 and 1995-1997, the activity data have therefore been kept constant since 1997. For the years between 1990 and 1995 the activity data have been interpolated. The available production data vary slightly between the years; however, the reference for the data is not clear.

Activity data

The activity data are presented in Table 5.3.1.

Table 5.3.1 Activity data for red bronze production.

	Unit	1990	1995	1996	1997
Red bronze production	Mg	3,895	4,350	4,400	4,532

Emission factors

The applied emission factors are presented in Table 5.3.2 and are all referenced to Illerup et al. (1999).

Table 5.3.2 Emission factors for heavy metals for red bronze production.

Pollutant	Unit	Value
Cd	g/Mg	1
Cu	g/Mg	10
Pb	g/Mg	15
Zn	g/Mg	140

5.3.3 Emission trends

Emissions trends for Cd, Cu, Pb, and Zn from red bronze production are presented in Table 5.3.3.

Table 5.3.3 Emissions from red bronze production, kg.

	1990	1991	1992	1993	1994	1995	1996	1997-2013
Cd	3.9	4.0	4.1	4.2	4.3	4.4	4.4	4.5
Cu	39.0	39.9	40.8	41.7	42.6	43.5	44.0	45.3
Pb	58.4	59.8	61.2	62.5	63.9	65.3	66.0	68.0
Zn	545.3	558.0	570.8	583.5	596.3	609.0	616.0	634.5

5.3.1 Time series consistency and completeness

The time series for red bronze production is consistent, however very little is currently known of this source category's completeness.

5.3.2 Input to CollectER

The input data / data sources are presented in Table 5.3.4.

Table 5.3.4 Input data for calculation of emissions from red bronze production.

	Year	Parameter	Comment/Source
Activity	1990, 1995-1997	Production statistics	Unknown
	1991-1994, 1998-2013	Production statistics	Estimated
Emissions	1990-2013	Heavy metal EFs	Illerup et al. (1999)

5.3.3 Future improvements

It will be investigated whether activity data are available from Statistics Denmark.

A process description for this activity will be elaborated.

5.4 Magnesium production

For the production of magnesium in Denmark the following SNAP-code is covered:

- 04 03 04 Consumption of SF_6 in magnesium foundries

The following pollutants are included for the magnesium production processes:

- SF_6

5.4.1 Process description

There is no primary production of magnesium in Denmark, hence only magnesium casting has taken place. Magnesium casting processes involve handling of molten pure magnesium and / or molten high magnesium content alloys. Molten magnesium may be cast by a variety of methods including gravity casting, sand casting, die casting and others.

All molten magnesium spontaneously burns in the presence of atmospheric oxygen. Production and casting of all magnesium metal therefore requires a protection system to prevent burning. Among the various protection systems commonly used are those that use gaseous components with high GWP values, such as SF_6, which typically escape to the atmosphere.

5.4.2 Methodology

The consumption of SF_6 in the magnesium production is known from Poulsen (2015). The production ceased to use SF_6 in 2000. Activity data can be calculated from the cover gas (SF_6) consumption and the default Tier 1 emission factor is known from IPCC (2006).

A release of 100 % is assumed.

Activity data

Table 5.4.1 presents the calculated activity data.

Table 5.4.1 Activity data for magnesium production, Mg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Production of magnesium	1,300	1,300	1,300	1,500	1,900	1,500	400	600	700	700	891

Emission factors

The applied emission factor is 1 kg SF_6 per Mg produced magnesium (IPCC, 2006).

5.4.3 Emission trends

The greenhouse gas emissions from the production of magnesium are presented in the in **Error! Reference source not found.** below. The consumption of SF_6 ceased in 2000.

5.4.4 Time series consistency and completeness

The time series for magnesium production is considered to be both consistent and complete.

5.4.5 Input to CollectER

The input data / data sources are presented in Table 5.4.2.

Table 5.4.2 Input data for calculation of emissions from magnesium production.

	Year	Parameter	Comment/Source
Activity	1990-2000	Magnesium production	Poulsen (2015)
Emissions	1990-2000	SF_6 emission factor	IPCC (2006)

5.4.6 Future improvements

No improvements are planned for this sector.

5.5 Secondary aluminium production

Two active Danish production sites have been identified for secondary aluminium; “Stena Aluminium” and “Jydsk Aluminium Industri”. The following SNAP code is covered:

- 03 03 10 Secondary aluminium production

The following pollutants are included for the secondary aluminium production:

- Particulate matter: TSP, PM_{10}, $PM_{2.5}$
- Heavy metals: Cd, Pb
- Persistent organic pollutants: HCB, PCDD/F, PCBs

5.5.1 Process description

Secondary aluminium production is when aluminium scraps or aluminium-bearing materials; other than aluminium-bearing concentrates (ores) derived from a mining operation, is processed into aluminium alloys for industrial castings and ingots. The furnace used for melting aluminium scrap depends on the type of scrap and there is a wide variety of scraps and furnaces used. In general for fabrication scrap and cleaner materials, reverbatory and induction furnaces are used. For more contaminated grades of scrap, rotary furnaces, tilting or horizontal furnaces are used. The scrap may also be pre-treated, depending on type of scrap and contamination. Coated scrap, like used beverage cans, is de-coated as an integrated part of the pre-treatment and melting process. The metal is refined either in the holding furnace or in an inline reactor to remove gases and other metals generally in the same way as for primary aluminium. If magnesium needs to be removed, this is done by treatment with chlorine gas mixtures.

The remaining operating Danish plant (Jydsk Aluminium Industri) uses three shaft furnaces and two induction furnaces and only uses clean aluminium and not aluminium scrap. It is difficult to obtain information on the specific technology used at the closed smelter in Denmark. We will try to obtain information from the environmental permit and include a description in future reports.

5.5.2 Methodology

Secondary aluminium industries were identified from a list of companies with the relevant environmental approvals acquired from the Danish Environmental Agency. The largest producer, called Stena Aluminium, accounted for approximately 90 % of the total Danish production until the factory was closed by the end of 2008.

Activity data

The activity data are presented in Table 5.5.1.

Table 5.5.1 Activity data for secondary aluminium production (Stena Aluminium, 2008 and Jydsk Aluminiums Industri, 2014), Gg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Stena Aluminium[1]	30.23	30.23	30.23	30.23	30.23	30.23	25.06	31.79	32.98	28.48
Jydsk Aluminium[2, 3, 4]	1.26	1.26	1.26	1.26	1.74	2.22	2.70	3.00	3.30	3.61
Total	31.49	31.49	31.49	31.49	31.97	32.45	27.76	34.79	36.28	32.08
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Stena Aluminium	32.87	33.38	32.13	26.42	19.56	23.43	31.32	35.12	36.22	NO
Jydsk Aluminium[2]	3.91	4.21	4.51	4.81	5.11	5.42	5.72	6.02	6.07	3.80
Total	36.78	37.59	36.64	31.23	24.67	28.85	37.03	41.14	42.29	3.80
	2010	2011	2012	2013						
Stena Aluminium	NO	NO	NO	NO						
Jydsk Aluminium[2]	5.20	6.26	6.49	6.84						
Total	5.20	6.26	6.49	6.84						

NO: Not occurring.
[1]1990-1995: Calculated average of 1996-2000.
[2]1993, 1996, 2007-2013: Estimated based on information from the environmental reports.
[3]1990-1992: Estimated based on 1993.
[4]1994-1995, 1997-2006: Interpolated.

Emission factors

Emission factors for the production of secondary aluminium are presented in Table 5.5.2.

Table 5.5.2 Emission factors for secondary aluminium production.

Pollutant	Unit	Value	Source
TSP	kg/Mg	0.120	Calculated from Stena (2008), average for 1998-2000
PM_{10}	kg/Mg	0.084	Particle distribution from EMEP/EEA (2013)
$PM_{2.5}$	kg/Mg	0.033	Particle distribution from EMEP/EEA (2013)
Cd	g/Mg	0.032	Calculated from Stena (2008), average for 1998-2000
Pb	g/Mg	0.146	Calculated from Stena (2008), average for 1998-2000
HCB	g/Mg	0.020	Nielsen et al. (2013a)
PCDD/F	mg/Mg	0.035	EMEP/EEA (2013)
PCB	mg/Mg	3.40	Nielsen et al. (2013a)

5.5.3 Emission trends

The emissions from aluminium production are presented in Table 5.5.3.

Table 5.5.3 Emissions from production of secondary aluminium.

	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cd	kg	1.00	1.00	1.00	1.00	1.02	1.03	0.88	1.11	1.16	1.02
Pb	kg	4.60	4.60	4.60	4.60	4.68	4.75	4.06	5.09	5.30	4.69
HCB	kg	0.63	0.63	0.63	0.63	0.64	0.65	0.56	0.70	0.73	0.64
PCDD/F	g	1.10	1.10	1.10	1.10	1.12	1.14	0.97	1.22	1.27	1.12
PCB	kg	0.11	0.11	0.11	0.11	0.11	0.11	0.09	0.12	0.12	0.11
	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TSP	Mg	4.41	4.41	4.41	4.41	4.41	4.41	4.41	4.41	4.41	4.41
PM_{10}	Mg	3.09	3.09	3.09	3.09	3.09	3.09	3.09	3.09	3.09	3.09
$PM_{2.5}$	Mg	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21
Cd	kg	1.17	1.20	1.17	1.00	0.79	0.92	1.18	1.31	1.35	0.12
Pb	kg	5.38	5.50	5.36	4.57	3.61	4.22	5.41	6.01	6.18	0.56
HCB	kg	0.74	0.75	0.73	0.62	0.49	0.58	0.74	0.82	0.85	0.08
PCDD/F	g	1.29	1.32	1.28	1.09	0.86	1.01	1.30	1.44	1.48	0.13
PCB	kg	0.13	0.13	0.12	0.11	0.08	0.10	0.13	0.14	0.14	0.01
	Unit	2010	2011	2012	2013						
TSP	Mg	4.41	4.41	4.41	4.41						
PM_{10}	Mg	3.09	3.09	3.09	3.09						
$PM_{2.5}$	Mg	1.21	1.21	1.21	1.21						
Cd	kg	0.17	0.20	0.21	0.22						
Pb	kg	0.76	0.91	0.95	1.00						
HCB	kg	0.10	0.13	0.13	0.14						
PCDD/F	g	0.18	0.22	0.23	0.24						
PCB	kg	0.02	0.02	0.02	0.02						

5.5.4 Verification

Activity data available from the environmental reports from the largest Danish aluminium producer Stena (2008) have been validated by comparing with sales statistic from Statistics Denmark (2014). These two data sets show good agreement with only smaller fluctuations.

5.5.5 Time series consistency and completeness

The time series for secondary aluminium production is considered to be both consistent and complete.

5.5.6 Input to CollectER

The input data / data sources are presented in Table 5.5.4.

Table 5.5.4 Input data for calculation of emissions from aluminium production.

	Year	Parameter	Comment/Source
Activity	1990-2013	Aluminium production	Stena (2008), Jydsk Aluminiums Industri (2014)
Emissions	1990-2013	Emission factor	Stena (2008), EMEP/EEA (2013), Nielsen et al. (2013a)

5.5.7 Future improvements

An emission factor for BC will be added for secondary aluminium production.

5.6 Secondary lead production

Only one Danish company; Hals Metal, has been identified as producing secondary lead from scrap metal. In addition to Hals Metal, old lead tiles from castles, churches etc. are melted and recast on site during preservation of the many historical buildings in Denmark. The following SNAP code is covered:

- 03 03 07 Secondary lead production

The following pollutants are included for the secondary lead production:

- CO_2
- Particulate matter: TSP, PM_{10}, $PM_{2.5}$
- Heavy metals: As, Cd, Pb, Zn
- Persistent organic pollutants (HCB, PCDD/F, PCBs)

5.6.1 Process description

The process of secondary lead production is usually subdivided as follows: battery breaking and processing (scrap preparation); smelting of battery scrap materials and refining. The Danish plant is recycling e.g. transformers and land and sea cables containing lead. The cables are stripped to isolate the lead and with other lead-bearing materials, it is melted in a furnace and new lead items are casted for sale.

5.6.2 Methodology

Production data from Hals Metal is provided by the company for the entire time series. A clause affected in 2002 meant that Hals Metal could no longer burn cables containing lead. The processing of cables was therefore stopped and the company's activity changed to smelting. This transition resulted in a low activity in 2003.

The activity of recasting lead tiles is not easily found because it is spread out on many craftsmen and poorly regulated. However, an estimate by Lassen et al. (2004) stated that 200-300 Mg lead tiles were recast in 2000. Since the building stock worthy of preservation is constant, it is considered reasonable to also let the activity of recasting of lead tiles be constant.

Activity data

Activity data for secondary lead is shown in Table 5.6.1.

Table 5.6.1 Activity data for secondary lead production (Helle Bjerrum Holm (Hals Metal), personal communication, September 2014 and Lassen et al., 2004), Mg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Hals Metal	540	540	540	750	750	750	540	540	540	540
Lead tiles	250	250	250	250	250	250	250	250	250	250
Total	790	790	790	1000	1000	1000	790	790	790	790
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Hals Metal	540	1080	419	64	520	691	500	670	582	780
Lead tiles	250	250	250	250	250	250	250	250	250	250
Total	790	1330	669	314	770	941	750	920	832	1030
	2010	2011	2012	2013						
Hals Metal	635	938	412	533						
Lead tiles	250	250	250	250						
Total	885	1188	662	783						

Emission factors

The applied emission factors are presented in Table 5.6.2.

Table 5.6.2 Emission factors for secondary lead production.

Pollutant	Value	Unit	Reference
CO_2	0.2	Mg/Mg	IPCC (2006)
TSP	1.63	kg/Mg	EMEP/EEA (2013)
PM_{10}	1.30	kg/Mg	EMEP/EEA (2013)
$PM_{2.5}$	0.65	kg/Mg	EMEP/EEA (2013)
As	3.5	g/Mg	EMEP/EEA (2013)
Cd	1.1	g/Mg	EMEP/EEA (2013)
Pb	426	g/Mg	EMEP/EEA (2013)
Zn	2.6	g/Mg	EMEP/EEA (2013)
HCB	0.3	mg/Mg	Nielsen et al. (2013a)
PCDD/F	8.0	µg/Mg	EMEP/EEA (2013)
PCB	7.3	mg/Mg	Nielsen et al. (2013a)

5.6.3 Emission trends

Emissions from secondary lead production are presented in Table 5.6.3 and for CO_2 also in Figure 5.6.1.

Table 5.6.3 Emissions from production of secondary lead.

	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2	Gg	0.16	0.16	0.16	0.20	0.20	0.20	0.16	0.16	0.16	0.16
As	kg	2.77	2.77	2.77	3.50	3.50	3.50	2.77	2.77	2.77	2.77
Cd	kg	0.87	0.87	0.87	1.10	1.10	1.10	0.87	0.87	0.87	0.87
Pb	kg	336.54	336.54	336.54	426.00	426.00	426.00	336.54	336.54	336.54	336.54
Zn	kg	2.05	2.05	2.05	2.60	2.60	2.60	2.05	2.05	2.05	2.05
HCB	g	0.24	0.24	0.24	0.30	0.30	0.30	0.24	0.24	0.24	0.24
PCDD/F	mg	6.32	6.32	6.32	8.00	8.00	8.00	6.32	6.32	6.32	6.32
PCB	g	5.73	5.73	5.73	7.25	7.25	7.25	5.73	5.73	5.73	5.73
	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2	Gg	0.16	0.27	0.13	0.06	0.15	0.19	0.15	0.18	0.17	0.21
TSP	Mg	1.28	2.16	1.09	0.51	1.25	1.53	1.22	1.50	1.35	1.67
PM_{10}	Mg	1.03	1.73	0.87	0.41	1.00	1.22	0.98	1.20	1.08	1.34
$PM_{2.5}$	Mg	0.51	0.86	0.43	0.20	0.50	0.61	0.49	0.60	0.54	0.67
As	kg	2.77	4.66	2.34	1.10	2.70	3.29	2.63	3.22	2.91	3.61
Cd	kg	0.87	1.46	0.74	0.35	0.85	1.04	0.83	1.01	0.92	1.13
Pb	kg	336.54	566.58	284.99	133.76	328.02	400.87	319.50	391.92	354.43	438.78
Zn	kg	2.05	3.46	1.74	0.82	2.00	2.45	1.95	2.39	2.16	2.68
HCB	g	0.24	0.40	0.20	0.09	0.23	0.28	0.23	0.28	0.25	0.31
PCDD/F	mg	6.32	10.64	5.35	2.51	6.16	7.53	6.00	7.36	6.66	8.24
PCB	g	5.73	9.64	4.85	2.28	5.58	6.82	5.44	6.67	6.03	7.47
	Unit	2010	2011	2012	2013						
CO_2	Gg	0.18	0.24	0.13	0.16						
TSP	Mg	1.44	1.93	1.08	1.27						
PM_{10}	Mg	1.15	1.54	0.86	1.02						
$PM_{2.5}$	Mg	0.58	0.77	0.43	0.51						
As	kg	3.10	4.16	2.32	2.74						
Cd	kg	0.97	1.31	0.73	0.86						
Pb	kg	377.01	506.09	282.01	333.56						
Zn	kg	2.30	3.09	1.72	2.04						
HCB	g	0.27	0.36	0.20	0.23						
PCDD/F	mg	7.08	9.50	5.30	6.26						
PCB	g	6.42	8.61	4.80	5.68						

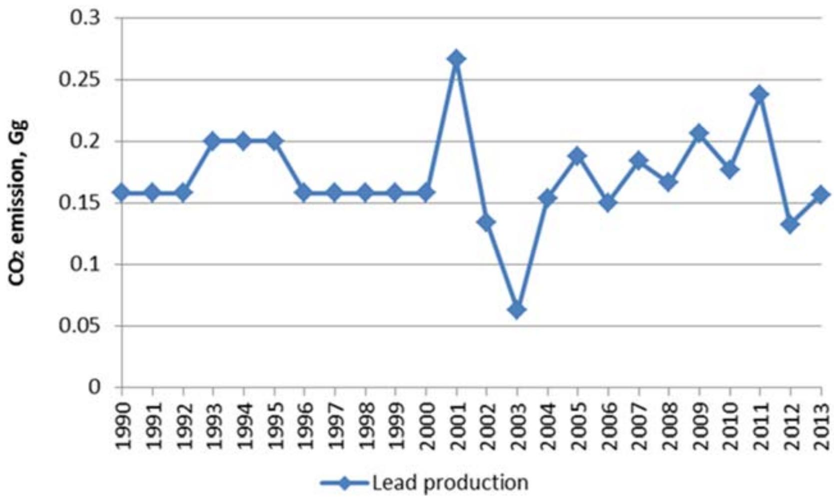

Figure 5.6.1 Emission of greenhouse gasses from secondary lead production.

5.6.4 Time series consistency and completeness

The time series for secondary lead production is considered to be both consistent and complete.

5.6.1 Input to CollectER

The input data / data sources are presented in Table 5.6.4.

Table 5.6.4 Input data for calculation of emissions from lead production.

	Year	Parameter	Comment/Source
Activity	1990-2013	Production data	Helle Bjerrum Holm (Hals Metal), personal communication, September 2014, estimated from Lassen et al. (2004)
Emissions	1990-2013	Emission factors	IPCC (2006), EMEP/EEA (2013), Nielsen et al. (2013a)

5.6.2 Future improvements

There are no planned improvements for this sector.

6 Electronics Industry

The sector Electronics industry (CRF 2E) covers the use of HFCs and PFCs in the production of fibre optics. There is no production of semiconductors (CRF 2E1), TFT flat panels (CRF 2E2) or photovoltaics resulting with use of F-gases (CRF 2E3). No use of HFCs or PFCs as heat transfer fluids (CRF 2E4) occur in Denmark.

As a result the only relevant category in this sector is:

- Other electronics industry (CRF 2E5): Fibre optics; see sections below.

The description of consumption and emission of F-gases given below is based on Poulsen (2015). For further details refer to this report.

6.1 Greenhouse gas emissions

The use of F-gases in the production of fibre optics did not start until 2006 and hence the time series covers the years 2006-2013. The emission time series for Electronics Industry are presented in Figure 6.1.1 and Table 6.1.1.

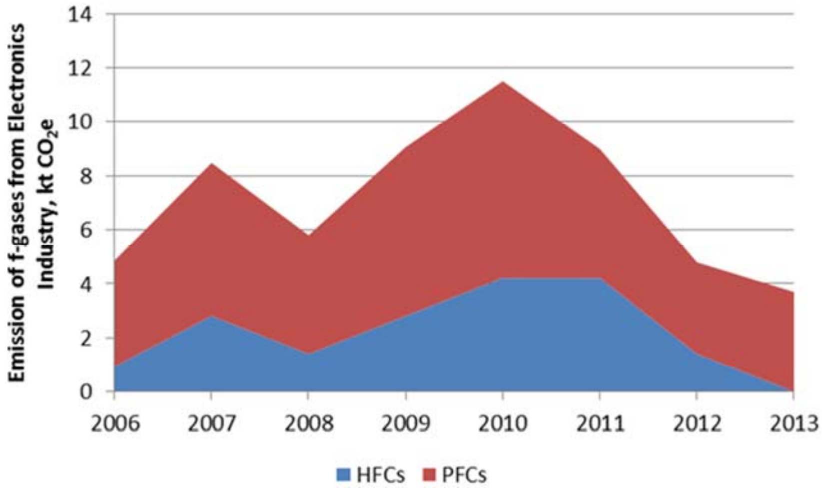

Figure 6.1.1 Emissions of HFCs and PFCs from *Electronics Industry*.

Table 6.1.1 Emission from Electronics industry.

	Unit	2006	2007	2008	2009	2010	2011	2012	2013
HFC-23	Mg	0.08	0.24	0.12	0.24	0.36	0.36	0.12	NO
PFC-14 (CF_4)	Mg	0.25	0.14	0.11	0.36	0.36	0.20	0.18	0.50
PFC-318 (c-C_4F_8)	Mg	0.20	0.45	0.35	0.45	0.45	0.40	0.20	NO
HFC-23	Gg CO_2-eq.	0.94	2.81	1.40	2.81	4.21	4.21	1.40	0.00
PFC-14 (CF_4)	Gg CO_2-eq.	1.86	1.03	0.80	2.34	2.66	1.30	1.33	3.70
PFC-318 (c-C_4F_8)	Gg CO_2-eq.	2.06	4.64	3.61	3.92	4.64	3.48	2.06	0.00
Total	Gg CO_2-eq.	4.86	8.48	5.81	9.06	11.51	8.99	4.79	3.70

6.2 Other electronics industry

The following source category is covered:

- Fibre optics

The following pollutants are included for fibre optics:

- F-gases: HFC-23, PFC-14 (CF_4), PFC-318 ($c\text{-}CF_4F_8$)

6.2.1 Process description

Both HFCs and PFCs are used for technical purposes in Danish optics fibre production. HFC-23 and PFCs (PFC-14 & PFC-318) are used as protection and cleaning gases in the production process.

6.2.2 Methodology

Consumption data are directly available from the importer supplying the gases for producing fibre optics and process specific emission factors are used, hence the methodology corresponds to the IPCC Tier 3 method (IPCC, 2006).

Activity data

The consumption of PFCs from fibre optics production was 0.5 tonnes in 2013. This sector usually uses both PFC-14 and PFC-318 for technical purposes, but in 2013, only PFC-14 has been used. There was no use of HFC-23 in 2013. The consumption data are provided in Table 6.2.1 below.

Table 6.2.1 Consumption of F-gases in production of fibre optics, Mg.

	2006	2007	2008	2009	2010	2011	2012	2013
HFC-23	0.08	0.24	0.12	0.24	0.36	0.36	0.12	NO
PFC-14 (CF_4)	0.25	0.14	0.11	0.36	0.36	0.20	0.18	0.50
PFC-318 ($c\text{-}CF_4F_8$)	0.20	0.45	0.35	0.45	0.45	0.40	0.20	NO

Emission factors

Since both HFC-23 and the PFCs are used as protection and cleaning gases in the production process, the emission factor is defined as 100 per cent release during production.

6.2.3 Time series consistency and completeness

The time series is considered complete and consistent. The estimates are based on information directly from the importer supplying this sector in Denmark.

6.2.4 Future improvements

No improvements are planned for this sector.

7 Product Uses as Substitutes for Ozone Depleting Substances (ODS)

The sector *Product uses as substitutes for ODS* (CRF 2F) includes the following source categories and the following F-gases of relevance for Danish emissions:

- Refrigeration and air conditioning (CRF 2F1): HFC-32, -125, -134a, -152a, -143a, PFC-218 (C_3F_8)
- Foam blowing agents (CRF 2F2): HFC-134a, -152a
- Aerosols (CRF 2F4): HFC-134a
- Solvents (CRF 2F5): PFC-218 (C_3F_8)

It must be noted that the inventories for the years 1990-1994 might not cover emissions of these gases in full. The choice of base-year for these gases under the Kyoto Protocol is 1995 for Denmark.

The description of consumption and emission of F-gases given below is based on Poulsen (2015). For further details refer to this report.

7.1 Greenhouse gas emissions

The emission time series for *Product uses as substitutes for ODS* are presented in Figure 7.1.1 and Table 7.1.1.

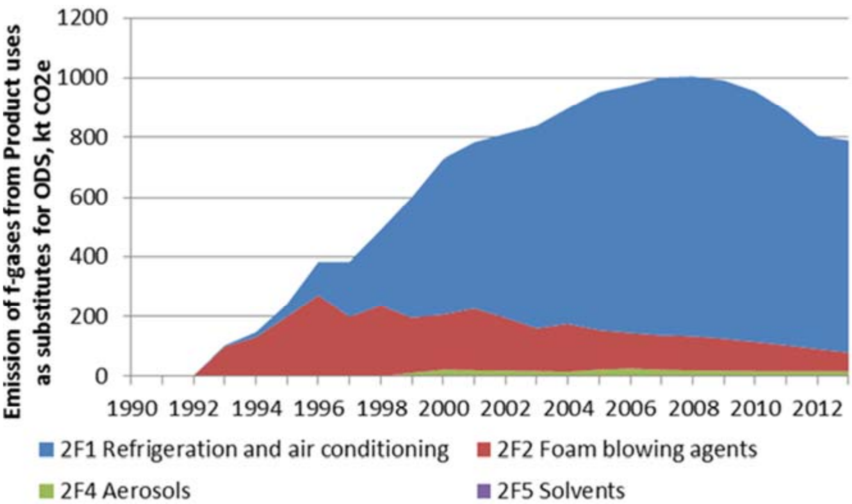

Figure 7.1.1 Emission of F-gases from the individual source categories within Product uses as substitutes for ODS, Gg CO_2-eq.

Table 7.1.1 Emission of F-gases from Product uses as substitutes for ODS, Gg CO_2-eq.

	1990	1995	2000	2005	2010	2011	2012	2013
Refrigeration and air conditioning	NO	43.2	520.8	799.4	841.6	787.6	715.8	711.0
Foam blowing agents	NO	199.5	184.1	130.6	95.9	85.2	72.7	60.7
Aerosols	NO	NO	20.8	23.1	18.4	17.5	17.4	17.7
Solvents	NO	NO	2.4	NO	NO	NO	NO	NO
Total	NO	242.8	728.1	953.1	955.9	890.2	805.9	789.3

7.1.1 General trends

The phase out of F-gases has in particular been effective within the foam blowing sector and refrigeration and air conditioning installations. Regarding foam blowing, there was a stepwise phase-out of HFC-134a used for foam blowing in hard and soft foam production, during the period 2001-2004. In 2006, all foam productions plants in Denmark had substituted HFCs. Especially the phase-out of HFCs in soft foam is significant for the emission in this period.

Since the introduction of taxes on HFCs in 2001, the consumption decreased in 2002-2003, but then the consumption of HFCs for refrigeration purposes increased again. Especially HFC-404a and HFC-134a increased. This increase is explained with other initiatives in Danish legislation, where new refrigeration systems containing HCFC-22 (ODS) was banned from 2001. It caused a boom in refrigeration systems using HFCs during 2002-2004, because the HFC technology was cheap and well proven. The consumption of HFCs for refrigeration changed significantly after 1 January 2007, where new larger HFC installations with charges exceeding 10 kg were banned. Alternative refrigeration technologies based on CO_2, propane / butane and ammonia were then introduced and made available for customers.

There has been no import of PFC-218 (C_3F_8) since 2008, and it is expected that this refrigerant is phased out of the marked. Emissions occur from the existing stock but are naturally decreasing. The use of PFC-218 (C_3F_8) as a solvent only occurred from 2000 to 2002.

A quantitative overview is given below for each of these source categories and each F-gas, showing their emissions in Mg through the times-series.

The emission of HFCs increased rapidly in the 1990s and, thereafter, increased more modestly due to a modest increase in the use of HFCs as a refrigerant and a decrease in foam blowing. The F-gases have been regulated in two ways since 1 March 2001. For some types of use there is a ban on use of the gases in new installations and for other types of use, taxation is in place. These regulations seem to have influenced emissions so that in the latest years a decreasing trend can be observed.

7.2 General methodology

The data for emissions of HFCs and PFCs have been obtained in continuation of the work on previous inventories. The determination includes the quantification and determination of any import and export of HFCs and PFCs contained in products and substances in stock form. This is in accordance with the IPCC guidelines (IPCC, 2006).

For the Danish inventories of F-gases, a Tier 2 bottom-up approach is basically used. In an annex to the F-gas inventory report (Poulsen, 2015), there is a specification of the approach applied for each sub-source category.

The following sources of information have been used:

- Importers, agency enterprises, wholesalers and suppliers
- Consuming enterprises, and trade and industry associations
- Recycling enterprises and chemical waste recycling plants
- Statistics Denmark

- Danish Refrigeration Installers' Environmental Scheme (KMO)
- Previous evaluations of HFCs and PFCs (and SF_6)

Suppliers and / or producers provide consumption data of F-gases. Emission factors are primarily defaults from IPCC (2006), which are assessed to be applicable in a national context. In case of commercial refrigerants and Mobile Air Conditioning (MAC), information from Danish suppliers has been used. The actual amount of F-gas used for refilling is used as an estimate on the actual emission.

Import / export data for sub-source categories where import / export is relevant (MAC, fridges / freezers for households) are quantified on estimates from import / export statistics of products + default values of the amount of gas in the product. The estimates are transparent and described in appendix 3 of Poulsen (2015).

The Tier 2 bottom-up analysis used for determination of emissions from HFCs and PFCs covers the following activities:

- Screening of the market for products in which F-gases are used
- Determination of averages for the content of F-gases per product unit
- Determination of emissions during the lifetime of products and disposal
- Identification of technological development trends that have significance for the emission of F-gases
- Calculation of import and export on the basis of defined key figures, and information from Statistics Denmark on foreign trade and industry information

The determination of emissions of F-gases is based on a calculation of the actual emission. The actual emission is the emission in the evaluation year, accounting for the time lapse between consumption and emission. The actual emission includes Danish emissions from production, from products during their lifetimes and from disposal.

Consumption and emissions of F-gases are, whenever possible, determined for individual substances, even though the consumption of certain HFCs has been very limited. This has been carried out to ensure transparency of evaluation in the determination of GWP values. However, the continued use of a category for *Unspecified mix of HFCs* has been necessary since not all importers and suppliers have specified records of sales for individual substances.

Table 7.2.1 Content (w/w%)[1] of "pure" HFC in HFC-mixtures, used as trade names.

HFC mixtures	HFC-32	HFC-125	HFC-134a	HFC-143a	HFC-152a	HFC-227ea
	%	%	%	%	%	%
HFC-365						8
HFC-401a					13	
HFC-402a		60				
HFC-404a		44	4	52		
HFC-407c	23	25	52			
HFC-410a	50	50				
HFC-507a		50		50		

[1] The mixtures do also contain substances that do not have GWP values and therefore, the substances do not sum up to 100 %.

The substances have been accounted for in the survey according to their trade names, which are mixtures of HFCs used in IPCC (2006). In the transfer to the "pure" substances, the ratios provided in Table 7.2.1 have been used.

The national inventories for F-gases are provided and documented in an annual report (Poulsen, 2015). Furthermore, detailed data and calculations are available and archived in an electronic version. The report contains summaries of methods used and information on sources as well as further details on methodologies.

7.3 Refrigeration and air conditioning

Refrigeration and air conditioning consists of the following subcategories:

- Commercial refrigeration (CRF 2F1a)
- Domestic refrigeration (CRF 2F1b)
- Industrial refrigeration (included under commercial) (CRF 2F1c)
- Transport refrigeration (CRF 2F1d)
- Mobile air-conditioning (CRF 2F1e)
- Stationary air-conditioning (included under commercial) (CRF 2F1f)

The use of HFCs in industrial refrigeration was previously surveyed and the conclusion was that large-scale industrial refrigeration e.g. slaughterhouses, fish factories and medico companies use ammonia based refrigeration units. This is particularly caused by the tax on HFCs in Denmark that makes HFC based refrigeration units with large charges too expensive and furthermore the ban from 2007. Smaller HFC based units will occur in industry, but is then similar to commercial refrigeration units. Since it is not possible to separate small-scale industrial and commercial refrigeration units, all consumption and emissions are reported under commercial refrigeration.

For stationary air-conditioning, the same gases as frequently used in commercial refrigeration are used, e.g. HFC-404a and HFC-407c. It is difficult to estimate the share of these gases going to the different uses as the same suppliers are servicing both types of units. As a consequence the consumption and emissions are reported under commercial refrigeration.

7.3.1 Methodology

For refrigeration and air-conditioning, Denmark uses mainly the Tier 2 top-down approach (Tier 2b). However, for Domestic Refrigeration the methodology is a combination of Tier 2a and 2b. For more information on the applied methodology please refer to Poulsen (2015).

According to Danish law, refrigerators and air-conditioning equipment must be emptied before decommissioning by recovery, reuse or destruction of the remaining gases.

The data collection is described in the Chapter 7.2 General methodology.

Activity data

The activity data expressed as amount of HFCs and PFCs filled into new products, present in operating systems and remaining in products at decommissioning are presented in Table 7.3.1, Table 7.3.2 and Table 7.3.3 respectively.

Table 7.3.1 Filled into new manufactured refrigeration products.

		Unit	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
HFC-32	Commercial	Mg	NO	NO	3.2	3.9	9.2	10.3	9.3	20.5	22.3	23.3
HFC-125	Total	Mg	62.1	61.7	63.2	90.9	121.1	118.3	67.2	112.5	93.6	141.8
	Commercial	Mg	59.3	57.4	58.4	72.1	94.4	106.4	61.7	105.8	89.0	136.4
	Domestic	Mg	0.9	1.8	3.5	6.2	10.6	4.0	2.9	2.0	1.9	2.7
	Transport	Mg	1.9	2.5	1.3	12.6	16.2	7.9	2.6	4.7	2.7	2.7
HFC-134a	Total	Mg	371.9	364.5	363.8	569.7	374.5	468.1	291.8	333.4	267.5	333.5
	Commercial	Mg	104.7	157.2	58.4	222.1	138.2	203.0	127.9	184.9	140.4	216.8
	Domestic	Mg	267.1	200.2	298.3	257.6	205.0	240.4	130.4	115.6	94.3	83.5
	Transport	Mg	0.1	0.1	0.1	1.0	1.4	0.7	2.6	1.0	0.7	0.9
	Mobile A/C	Mg	NO	7.0	7.0	89.0	30.0	24.0	30.9	31.9	32.1	32.4
HFC-143a	Total	Mg	63.4	58.8	62.8	94.4	123.3	121.6	66.7	105.3	80.0	136.6
	Commercial	Mg	60.8	55.1	57.0	73.6	93.1	107.5	60.2	97.4	74.5	130.3
	Domestic	Mg	1.0	2.1	4.2	7.3	12.5	4.7	3.4	2.3	2.2	3.2
	Transport	Mg	1.6	1.6	1.6	13.5	17.7	9.4	3.1	5.6	3.2	3.2
HFC-152a	Commercial	Mg	NO	NO	3.4	2.0	2.0	1.3	0.5	NO	0.0	NO
Unspec. HFCs	Commercial	Gg	29.2	41.8	33.4	31.3	60.5	50.1	33.9	15.7	27.1	29.6
C_3F_8	Commercial	Mg	1.5	3.0	8.0	6.0	6.9	6.3	3.2	1.4	0.5	0.3
		Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	
HFC-32	Commercial	Mg	14.2	16.2	11.6	17.7	11.4	9.7	9.8	9.8	10.1	
HFC-125	Total	Mg	89.6	98.3	75.5	70.3	62.9	60.7	60.0	60.5	61.4	
	Commercial	Mg	84.7	93.5	73.8	66.2	59.8	57.4	56.3	56.8	56.7	
	Domestic	Mg	1.6	1.9	1.3	0.9	0.5	0.6	0.8	0.8	1.3	
	Transport	Mg	3.3	2.9	0.4	3.2	2.6	2.7	2.9	3.0	3.4	
HFC-134a	Total	Mg	250.7	311.9	175.2	201.1	197.8	181.3	201.6	192.6	175.1	
	Commercial	Mg	150.9	213.7	106.0	126.9	135.7	106.5	117.3	124.0	96.0	
	Domestic	Mg	65.7	63.2	33.6	37.7	17.6	6.8	9.3	9.5	11.2	
	Transport	Mg	0.8	0.7	0.4	0.8	0.7	0.7	0.9	0.6	0.6	
	Mobile A/C	Mg	33.3	34.4	35.2	35.7	43.8	67.3	74.1	58.6	67.2	
HFC-143a	Total	Mg	87.2	94.8	73.3	60.2	59.1	58.4	57.7	57.8	57.8	
	Commercial	Mg	81.4	89.1	71.3	55.4	55.4	54.5	53.3	53.4	52.3	
	Domestic	Mg	1.9	2.3	1.6	1.0	0.6	0.8	0.9	0.9	1.5	
	Transport	Mg	3.9	3.4	0.4	3.8	3.0	3.2	3.4	3.5	4.1	
HFC-152a	Commercial	Mg	NO	NO	NO	NO	NO	NO	NO	NO	NO	
Unspec. HFCs	Commercial	Gg	30.3	26.8	75.3	55.5	25.3	43.8	61.6	53.3	72.1	
C_3F_8	Commercial	Mg	0.5	NO	0.1	0.1	NO	NO	NO	NO	NO	

Table 7.3.2 In operating refrigerating systems (average annual stocks).

		Unit	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
HFC-32	Commercial	Mg	NO	NO	3.2	6.7	15.1	23.7	30.5	47.6	64.8	81.2
HFC-125	Total	Mg	73.8	126.9	176.1	247.5	339.9	429.3	432.4	501.4	544.9	631.7
	Commercial	Mg	70.8	120.3	165.8	220.2	291.2	366.9	390.9	456.1	498.1	582.6
	Domestic	Mg	0.9	2.6	6.0	12.0	22.2	25.9	28.4	30.1	31.6	33.9
	Transport	Mg	2.2	4.0	4.3	15.3	26.5	36.6	13.0	15.3	15.2	15.2
HFC-134a	Total	Mg	342.5	552.1	717.2	1110.6	1259.2	1483.5	1623.6	1761.4	1810.2	1925.6
	Commercial	Mg	177.2	310.2	333.0	508.5	581.5	698.9	727.9	815.0	824.7	906.5
	Domestic	Mg	165.2	235.0	372.5	480.2	535.3	624.5	681.0	729.7	767.8	800.3
	Transport	Mg	0.1	0.2	0.3	1.2	2.1	10.8	9.7	9.0	8.1	7.6
	Mobile A/C	Mg	NO	6.7	11.4	120.7	140.3	149.3	205.1	207.6	209.6	211.2
HFC-143a	Total	Mg	74.3	124.4	173.5	248.6	342.8	436.8	435.3	497.4	528.4	612.2
	Commercial	Mg	71.5	118.6	162.9	219.2	289.0	366.0	388.7	445.8	474.7	555.5
	Domestic	Mg	1.0	3.0	7.1	14.2	26.2	30.6	33.6	35.5	37.4	40.1
	Transport	Mg	1.8	2.8	3.4	15.3	27.6	40.2	12.9	16.0	16.4	16.6
HFC-152a	Commercial	Mg	NO	NO	3.3	4.9	6.3	7.0	6.8	6.1	5.5	5.0
Unspec. HFCs	Commercial	Gg	28.8	67.0	93.2	114.7	162.9	196.0	209.8	204.3	210.6	218.7
C_3F_8	Commercial	Mg	1.9	4.7	12.1	16.8	21.9	25.9	26.5	25.3	23.2	21.2

		Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013
HFC-32	Commercial	Mg	87.1	94.4	96.4	104.1	104.9	104.0	103.3	102.3	101.5
HFC-125	Total	Mg	658.6	691.5	698.9	700.5	682.9	624.8	584.6	556.0	523.9
	Commercial	Mg	607.8	639.1	647.9	648.3	631.0	574.1	535.8	510.8	481.7
	Domestic	Mg	35.1	36.6	37.5	38.0	38.1	37.5	36.4	33.8	29.6
	Transport	Mg	15.7	15.8	13.4	14.2	13.8	13.1	12.3	11.3	12.6
HFC-134a	Total	Mg	1957.0	2071.1	2041.6	2008.4	1964.0	1839.1	1835.7	1909.6	1649.2
	Commercial	Mg	909.0	995.0	953.4	917.0	887.4	792.8	685.7	726.8	578.4
	Domestic	Mg	823.9	846.1	853.8	855.2	838.7	810.6	716.6	747.6	629.2
	Transport	Mg	7.1	6.5	5.8	5.6	5.3	5.0	4.9	4.4	4.2
	Mobile A/C	Mg	217.0	223.6	228.6	230.6	232.6	230.7	428.6	430.8	437.3
HFC-143a	Total	Mg	639.1	670.9	678.6	672.8	653.0	587.6	543.5	512.1	475.0
	Commercial	Mg	580.1	609.9	619.1	611.7	592.1	528.1	486.2	459.0	425.4
	Domestic	Mg	41.5	43.3	44.3	44.9	45.0	44.4	43.1	40.0	35.0
	Transport	Mg	17.5	17.8	15.2	16.2	15.8	15.1	14.2	13.1	14.7
HFC-152a	Commercial	Mg	4.5	4.0	3.6	3.3	2.9	2.7	2.4	1.8	1.4
Unspec. HFCs	Commercial	Gg	226.6	230.4	281.5	308.0	302.1	311.6	336.7	352.4	385.7
C_3F_8	Commercial	Mg	19.5	17.6	15.9	14.4	12.9	11.4	10.0	8.1	6.7

Table 7.3.3 Remaining in refrigeration products at decommissioning.

		Unit	2007	2008	2009	2010	2011	2012	2013
HFC-32	Commercial	Mg	NO	NO	NO	NO	NO	0.4	0.4
HFC-125	Total	Mg	0.0	0.0	11.3	51.0	37.8	30.2	39.1
	Commercial	Mg	NO	NO	11.3	50.3	36.4	27.3	34.0
	Domestic	Mg	NO	NO	NO	0.7	1.5	2.9	5.1
HFC-134a	Total	Mg	8.0	46.6	48.7	107.5	210.9	193.4	263.7
	Commercial	Mg	8.0	38.5	32.2	84.5	120.5	133.9	147.4
	Domestic	Mg	NO	8.1	16.5	23.0	90.4	59.4	116.3
HFC-143a	Total	Mg	0.0	0.0	13.0	59.3	43.4	34.6	45.3
	Commercial	Mg	NO	NO	13.0	58.4	41.7	31.1	39.2
	Domestic	Mg	NO	NO	NO	0.9	1.7	3.5	6.1
HFC-152a	Commercial	Mg	NO	NO	NO	NO	NO	NO	NO
Unspec. HFCs	Commercial	Gg	NO	NO	NO	3.4	4.5	3.1	2.5
C_3F_8	Commercial	Mg	NO	NO	0.1	0.2	0.3	0.9	0.6

The first products containing F-gasses are modelled to be decommissioned in 2007. All F-gasses filled into mobile and transport refrigeration are assumed to emit during use, and no F-gasses are therefore remaining at decommissioning from these products.

Emission factors

The applied EFs are presented in Table 7.3.4. The EFs for commercial refrigerators, mobile A/C, and transport refrigeration has been assessed and compared with national conditions (Poulsen, 2003), this has been re-evaluated and the values have been found to still be applicable for Danish conditions (Poulsen, 2015).

Table 7.3.4 Applied EFs for refrigeration and air-condition systems (Poulsen, 2015).

	Assembly, %	Stock, % per annum	Lifetime
Household fridges and freezers	2	1	15 years
Commercial refrigerators	1.5	10	
Mobile air conditioning systems	0.5	33	
Transport refrigeration	0.5	17	6-8 years

Detailed information on the amount of HFCs used for refilling of mobile A/C has been available for 2009 - 2011, and therefore, a new approach has been implemented in the calculation of emissions. HFCs for mobile A/C are only used for refilling, and therefore the amount used for mobile A/C is assumed to be the same as the amount emitted during use (Poulsen, 2015):

Consumption of HFC for MAC = refilled stock = emission

7.3.2 Emission trends

Figure 7.3.1 present the emissions of F-gases from consumption of HFCs and PFCs in refrigeration and air-conditioning systems.

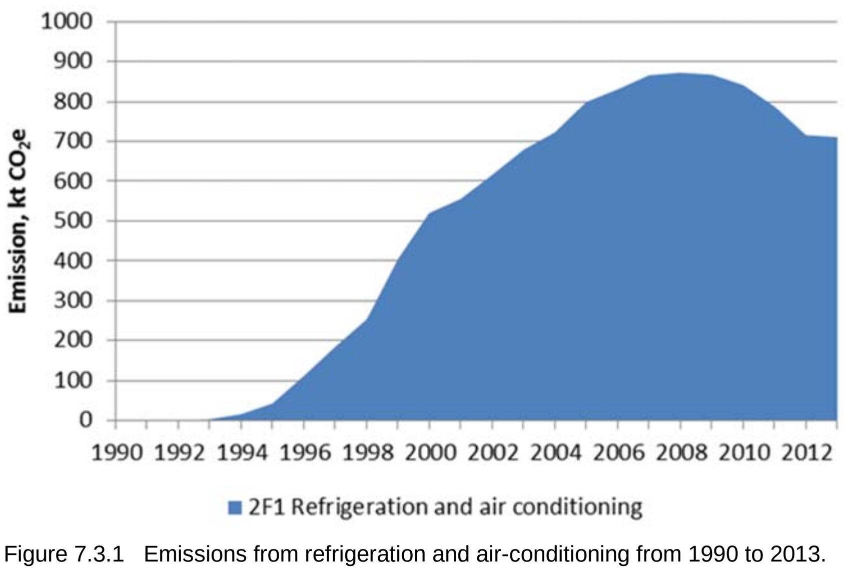

Figure 7.3.1 Emissions from refrigeration and air-conditioning from 1990 to 2013.

F-gas emissions from refrigeration and air-conditioning are dominating the overall emissions from this source. Hence the increasing trend from the early 1990s to 2009 and the subsequent decrease in emissions are explained in Chapter 7.1.

7.3.3 Time series consistency and completeness

The time series is considered complete and consistent.

7.3.4 Future improvements

There are no planned improvements for this source category.

7.4 Foam blowing agents

Foam blowing agents (CRF 2F2) consists of the following processes:

- Closed cells (hard foam)
- Open cells (soft foam)

In Denmark five specific processes have occurred during the time series, i.e. foam in household fridges and freezers (closed cell), soft foam (open cell), joint filler (open cell), foaming of polyether for shoe soles (closed cell) and system foam for panels, insulation etc. (closed cell)

7.4.1 Methodology

The methodology used varies between the different processes. For all processes the methodology corresponds to the Tier 2 level of IPCC (2006). For some processes a bottom-up methodology is applied while for others a top-down approach or a combination of top-down and bottom-up is used. For more information on the details of the applied methodology, please refer to Poulsen (2015).

Activity data

The data collection is described in the Section 7.2 on general methodology.

There is no longer production of HFC-based hard PUR insulation foam in Denmark. This production has been banned in statutory order since 1. January 2006 (MIM, 2002).

Emission factors

The applied emission factors for foam blowing agents are presented in Table 7.4.1.

Table 7.4.1 Applied emission factors for foam blowing agents (Poulsen, 2015).

	Consumption %	Stock %	Lifetime years
Foam in household fridges and freezers (closed cell)	10	4.5	15
Soft foam (open cell)	100[1]		
Joint filler (open cell)	100[1]		
Foaming of polyether for shoe soles (closed cell)	15	4.5	3
System foam	0[2]	-[3]	

[1] 100 % emission during the first year after production.

[2] HFC is used as a component in semi-manufactured goods and emissions first occur when the goods are put into use.

[3] System foam is only produced for export.

System foam is produced in a closed environment and is only produced for export. Therefore, the consumption of HFCs does not contribute to the Danish stock.

The EFs for foam in fridges and freezers, soft foam and joint filler are default values from the 2006 IPCC guidelines (IPCC, 2006). The EFs for foaming of polyether is country-specific, please refer to Poulsen (2015).

The F-gases remaining in products at decommissioning (closed cell products) are destroyed by incineration and hence there is no F-gas emissions related to disposal of these products.

7.4.2 Emission trends

Figure 7.4.1 presents the emissions of F-gases from consumption of HFCs in foam blowing agents.

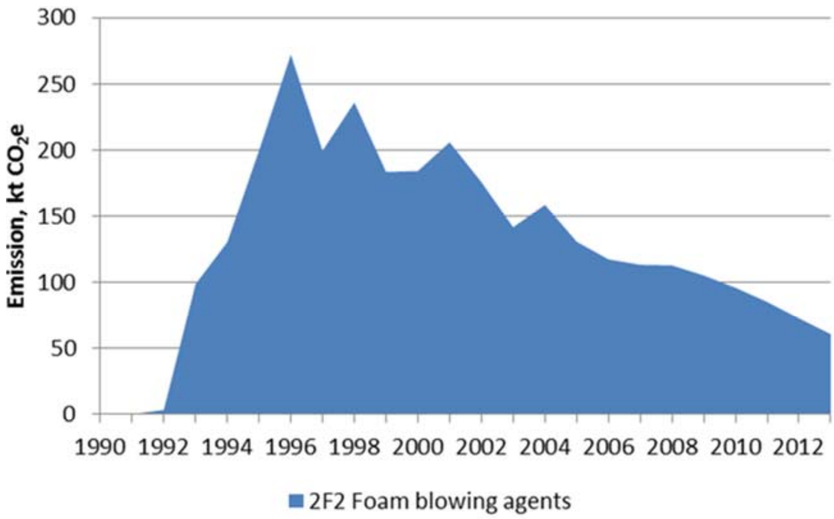

Figure 7.4.1 Emissions from foam blowing agents from 1990 to 2013.

The sharp fluctuations in the time series are caused by fluctuations in the consumption of HFCs in production of soft foam, with an EF of a 100 % in the given year. For the later part of the time series the trend reflects the limited use of HFCs consumed and reflects the emission from the stock of previous use of HFCs.

7.4.3 Time series consistency and completeness

The time series is considered complete and consistent.

7.4.4 Future improvements

There are no planned improvements for this source category.

7.5 Fire protection

No HFCs or PFCs are used in fire protection in Denmark. The use of halogen substituted hydrocarbons has been banned since 1977 (MIM, 1977), this ban is still in place (MIM, 2009).

Halon-1301 has been used in planes, in the military, in server rooms and on ships. New fire protection systems use other technologies, e.g. early fire detection, inert gases or gas mixtures (argon, nitrogen and CO_2) or water vapour. For mobile systems halon-1211 has been replaced with CO_2 or foam fire extinguishers.

7.6 Aerosols

Aerosols (CRF 2F4) consists of HFCs used for:

- Propellant in aerosols
- Metered dose inhalers

7.6.1 Methodology

For HFC use as propellant in aerosol cans the IPCC Tier 2a default methodology is used (IPCC, 2006). A default emission factor of 50 % of the initial charge per year is used for aerosols while an emission factor of 100 % of the initial charge per year is used for metered dose inhalers.

Activity data

The general data collection process is described in the Section 7.2.

Information on propellant consumption is derived from reports on consumption from the only major producers of HFC-containing aerosol sprays in Denmark. The import and export are estimated by the producer.

Emission factors

The applied EF is presented in Table 7.6.1.

Table 7.6.1 Applied EF for aerosols/medical dose inhalers (Poulsen, 2015).

	Consumption/filling	Stock	Lifetime
Aerosols	0 %	50 % first year 50 % second year	2 years
Medical dose inhalers	0 %	100 % in year of application	1 year

7.6.2 Emission trends

Figure 7.6.1 presents the emissions of F-gases from consumption of HFCs in aerosols.

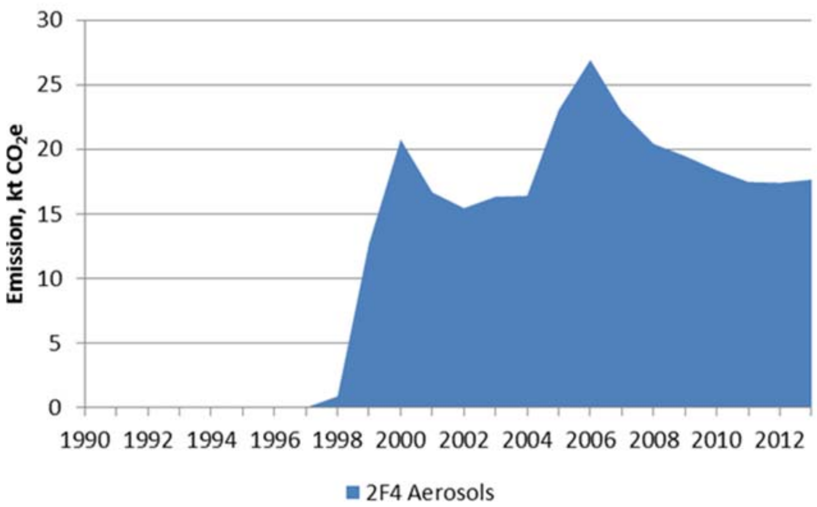

Figure 7.6.1 Emissions from HFCs from aerosols from 1990 to 2013.

Due to the methodology used, the fluctuations in the time series are a result of changes in import, production and export. Baring these fluctuations the emission level has been rather constant at a level between 15 and 20 Gg CO_2 equivalents.

7.6.3 Time series consistency and completeness

The time series is considered complete and consistent.

7.6.4 Future improvements

There are no planned improvements for this source category.

7.7 Solvents

C_3F_8 was used as cleaner from 2000 to 2002 and the use then ceased following the ban in accordance with the Executive Order (MIM, 2002).

7.7.1 Methodology

The methodology used is the IPCC default and the fraction of chemical emitted from solvents in the year of initial use is assumed to be 50 % in line with good practice. The other 50 % is assumed to be emitted in the second year and hence there is no subtraction of any destruction of solvents (IPCC, 2006).

Activity data

The general data collection process is described in the Section 7.2.

Information on consumption of PFCs in liquid cleaners is derived from two importers' sales reports. This is representing 100 % of the Danish consumption.

Emission factors

In accordance with IPCC (2006), the emission factor is 50 % in year 1 and 50 % in year 2.

7.7.2 Emission trends

Figure 7.7.1 presents the emissions of F-gases from consumption of PFCs used as solvents.

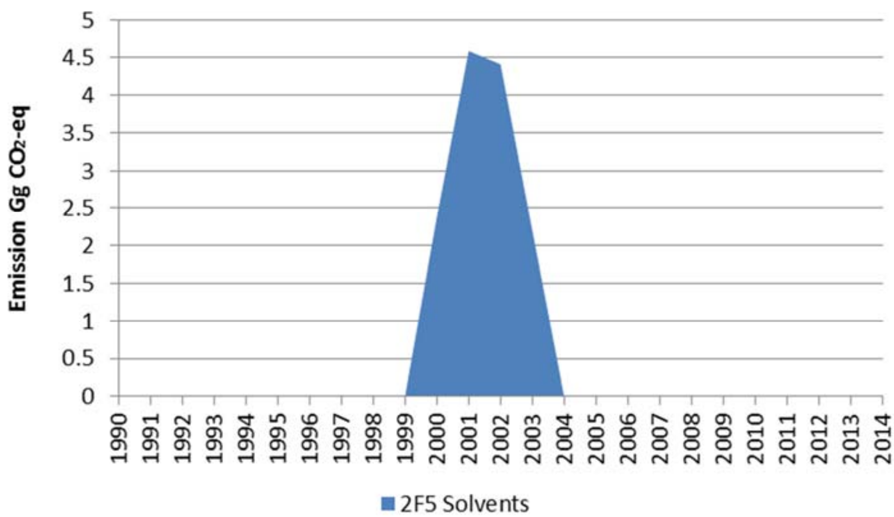

Figure 7.7.1 Emissions from PFCs used as solvents from 1990 to 2013.

As mentioned the use of PFCs as solvent only occurred from 2000 to 2002 and hence emissions only occurred from 2000 to 2003.

7.7.3 Time series consistency and completeness

The time series is considered complete and consistent.

7.7.4 Future improvements

There are no planned improvements for this source category.

8 Other Product Manufacture and Use

The sector *Other Product Manufacture and Use* (CRF 2G) cover the following processes relevant for the Danish air emission inventory:

- Electrical equipment (CRF 2G1); see section 8.2
- SF_6 from other product use (CRF 2G2); see section 8.3
- Medical applications of N_2O (CRF 2G3a); see section 8.4
- N_2O used as propellant for pressure and aerosol products (CRF 2G3b); see section 8.5
- Other product use (CRF 2G4); see section 8.68.6

8.1 Greenhouse gas emissions

The greenhouse gas emission time series for the source categories within *Other Product Manufacture and Use* are presented in Figure 8.1.1 and individually in the subsections below (Sections 8.2 – 8.6). The following figure gives an overview of which source categories that contribute the most throughout the time series. The significant increase in SF_6 emission from 2010 onwards is caused by the disposal of windows containing SF_6. The first windows containing SF_6 were introduced in 1991 and with and estimated lifetime of 20 years, the first disposal emissions occurred in 2011.

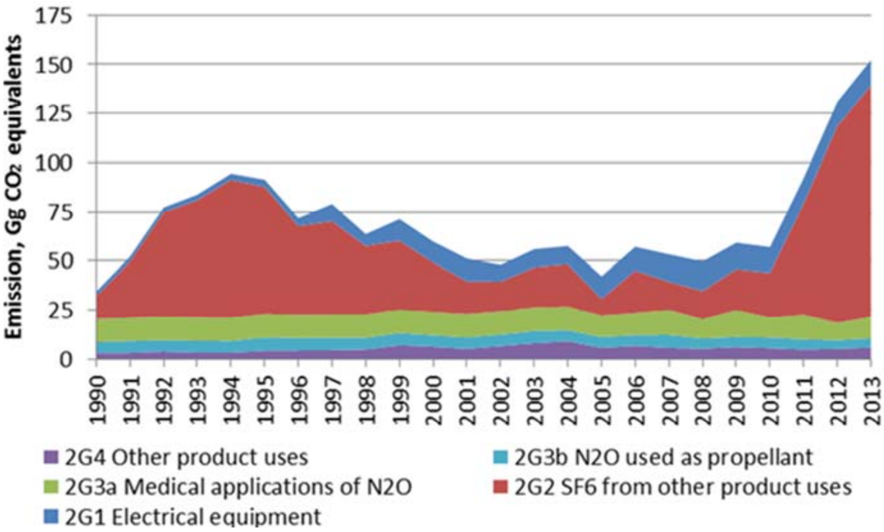

Figure 8.1.1 Emission of CO_2 equivalents from the individual source categories compiling *Other Product Manufacture and Use*, Gg.

8.2 Electrical equipment

Power switches in high-voltage power systems is the only use of SF_6 in electrical equipment in Denmark.

8.2.1 Methodology

The general data collection process for F-gases is described in the Section 7.2.

Power switches are filled or refilled with SF_6, either for new installation or during service and repair. Filling is usually carried out on new installations and a smaller proportion of the consumption of SF_6 is due to refilling.

The methodology uses annual data from importers statistics with detailed information on the use of the gas. It is estimated that 5 % of SF_6 escapes to the atmosphere during filling / refilling. This corresponds to the Tier 3 methodology in IPCC (2006).

No emissions are assumed to result from disposal since the used SF_6 is drawn off from the power switches and re-used internally by the concerned or appropriate disposed through a waste collection scheme.

Activity data

The data collection is described in the Section 7.2.

Information on consumption of SF_6 in high-voltage power switches is derived from importers' sales reports (gas or gas-containing products). The importers account for 100 % of the Danish sales of SF_6.

The electricity sector also provides information on the installation of new plant and thus whether the stock is increasing.

Emission factors

The applied EFs are presented in Table 8.2.1. Special attention has been given to use of SF_6 as insulation in high-voltage plants (Poulsen, 2001; ELTRA, 2004).

Table 8.2.1 Applied EFs for other processes (Poulsen, 2015).

	Consumption	Stock	Lifetime
Insulation gas in high voltage switches	5 %	0.5 %	1

1) Lifetime unknown.

8.2.2 Emission trends

Figure 8.2.1 presents the emissions of SF_6 from electrical equipment.

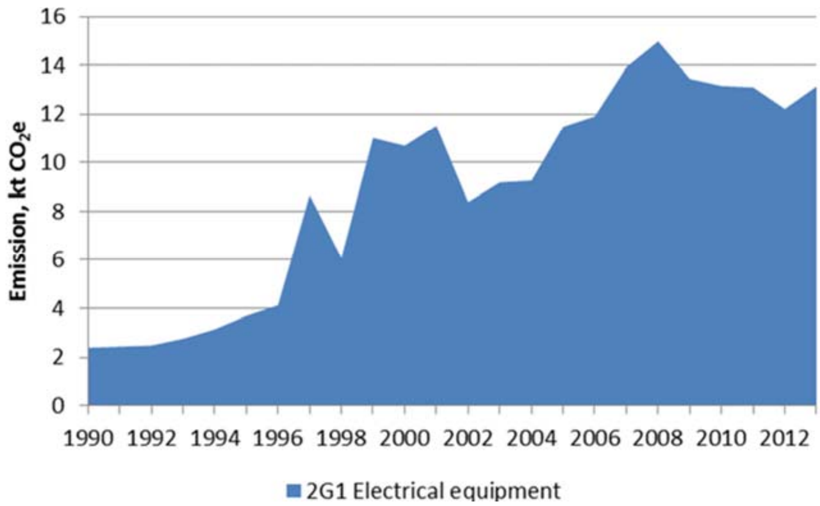

Figure 8.2.1 Emissions from SF_6 from electrical equipment from 1990 to 2013.

The trend shows an increase in emissions from use of SF_6 in electrical equipment. However, significant inter-annual variations occur depending on the specific activity level in a given year.

8.2.3 Time series consistency and completeness

The time series is considered complete and consistent.

8.2.4 Future improvements

There are no planned improvements for this source category.

8.3 SF_6 from other product use

SF_6 from other product use (CRF 2G2) consists of the following subcategories:

- Consumption of SF_6 in running shoes
- Consumption of SF_6 in laboratories

  Consumption of SF_6 in double glazed windows

8.3.1 Methodology

In general a mass balance approach is used for laboratory use of SF_6, this used includes plasma erosion in connection with the manufacture of microchips in clean-room laboratories and to a limited extend purposes of chemical analysis. For double glazed windows and shock-absorption in running shoes a Tier 2 method has been applied and data on the consumption of SF_6 is available from the importers. For double glazed windows the default IPCC methodology is used with country-specific emission factor. For more information, please refer to Poulsen (2015).

Consumption of SF_6 in production of double glazed thermal windows started in 1991 and has been banned since 1 January 2003 (MIM, 2002).

Activity data

The data collection is described in the Section 7.2.

Information on consumption of SF_6 in double glazing is derived from importers' sales reports to the application area. The importers account for 100 % of the Danish sales of SF_6 for double glazing. In addition, the largest producer of windows in Denmark has provided consumption data, with which import information is compared.

The importer has estimated imports to Denmark of SF_6 in training footwear.

The emission from the use of SF_6 in laboratories is 100 % release during consumption.

Emission factors

The applied EFs are presented in Table 8.3.1.

Table 8.3.1 Applied EFs for SF_6 from other product use (Poulsen, 2015).

	Consumption	Stock	Lifetime
Laboratories	100 %		
Insulation gas in double glazed windows	15 %	1 % annual	20 years
Shock-absorbing in Nike Air training footwear	-[1]	-[2]	5 years

[1] No emission from production in Denmark.

[2] Yearly emission has been estimated to 0.11 Mg (Poulsen, 2015).

8.3.2 Emission trends

Figure 8.3.1 presents the emissions of SF_6 from shoes, double glazed windows and laboratories.

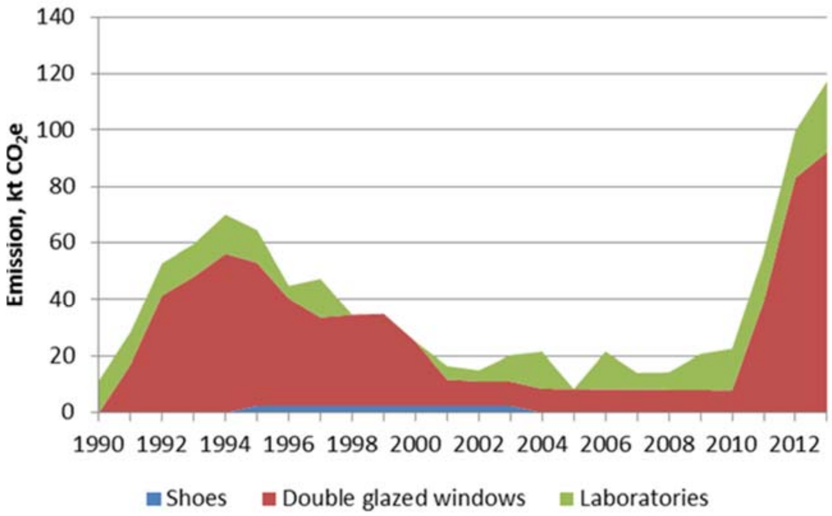

Figure 8.3.1 Emissions from SF_6 from other uses from 1990 to 2013.

The use of SF_6 in double glazed windows was banned in 2002 and the use had decreased in the prior years. The increase in SF_6 emission from 2010 onwards is due to the lifetime of 20 years, i.e. the gas remaining in the windows at this time is assumed to be fully emitted.

8.3.3 Time series consistency and completeness

The time series is considered complete and consistent.

8.3.4 Future improvements

There are no planned improvements for this source category.

8.4 Medical applications of N_2O

The following SNAP-code is covered:

- 06 05 01 Anaesthesia

8.4.1 Methodology

N_2O has been used as anaesthetics for more than a hundred years but has in newer times also had other smaller applications. N_2O in this source category is predominantly used as anaesthesia and a small amount is used as fuel in race cars and in chemical laboratories. However, since consumption cannot be distinguished between these activities it is all reported under anaesthesia.

In the mid-1990s, introduction of air quality limit values for N_2O together with requirements of expensive extraction systems reduced the application of N_2O for anaesthetics at smaller facilities like dentists.

Five companies sell N_2O in Denmark and only one company produces N_2O. N_2O is primarily used in anaesthesia by dentists, veterinarians and in hospitals and in minor use in laboratories, racing cars and in the production of electronics. Due to confidentiality no data on produced amount are available and thus the emissions related to N_2O production are unknown. Sold amounts are obtained from the respective distributors and the produced amount is estimated from communication with the company.

Activity data

Data on total sold and estimated produced N_2O for sale in Denmark is only reliable for the years 2005-2012, activity data for the years 1990-2004 and 2013 have therefore been estimated as the average value of the five following / previous years. Activity data for the time series are presented in Table 8.4.1.

Table 8.4.1 Activity data for N_2O mainly used for medical applications, Mg.

	1990-2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
N_2O consumption	40[1]	37	38	43	33	46	34	42	30	37[2]

1) Calculated: average 2005-2009.

2) Calculated: Average 2008-2012.

Emission factors

An emission factor of 1 is assumed for all uses, meaning 100 % release during consumption.

8.4.2 Emission trends

The emission trend for the N_2O emission from medical applications is presented in Figure 8.4.1 below.

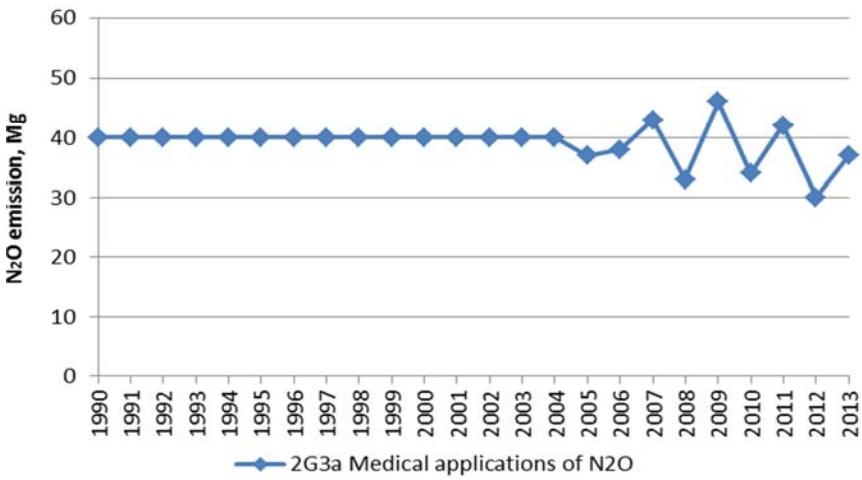

Figure 8.4.1 N_2O emissions from the use of anaesthetics.

8.4.3 Time series consistency and completeness

The methodology is consistent throughout the time series. It is not possible to obtain reliable data prior to 2005, but the source category is considered to be complete though uncertainties going back from 2005 are increasing.

8.4.4 Future improvements

There are no planned improvements for this source category.

8.5 N_2O used as propellant for pressure and aerosol products

The following SNAP-code is covered:

- 06 05 06 Aerosol cans

8.5.1 Methodology

There is a strong tradition of fresh dairy products in Danish culture and while canned whipped cream is popular for e.g. hot beverages in the winter months this product is not that widely used.

There are no statistics on production, import / export and / or sales of canned whipped cream in Denmark and the content of propellant is confidential. The consumption of canned whipped cream is therefore estimated using a country specific methodology where the canned whipped cream sale is estimated as 1 % of the regular cream sale. Further assumptions made include 5 mass% propellant in a can and 100 % release of N_2O.

Activity data

Data on total sold cream and the estimated sale of canned cream are presented in Table 8.5.1.

Table 8.5.1 Consumption of cream in Denmark, Mg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cream[1]	37,378	40,622	39,796	41,387	40,157	46,279	42,854	42,401	40,542	42,488
Canned cream	374	406	398	414	402	463	429	424	405	425
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cream[1]	39,380	39,849	39,525	42,418	38,306	37,333	36,876	45,023	35,019	34,881
Canned cream	394	398	395	424	383	373	369	450	350	349
	2010	2011	2012	2013						
Cream[1]	37,201	35,606	30,408	31,859						
Canned cream	372	356	304	319						

[1] Statistics Denmark (2014)

Emission factors

The applied emission factor is 0.05 Mg N_2O per Mg canned cream sold; i.e. 5 % propellant and 100 % release.

8.5.2 Emission trends

The emission trend for the N_2O emission from canned whipped cream is presented in Figure 8.5.1 below.

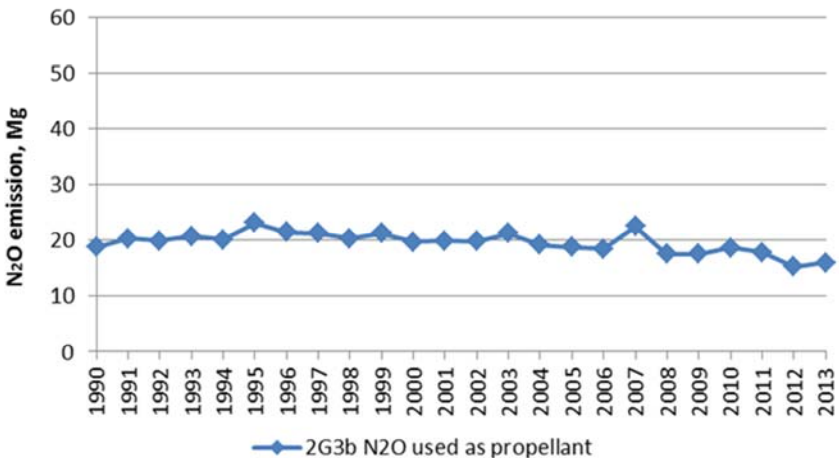

Figure 8.5.1 N_2O emissions from the use of canned whipped cream (Emission 2A from Figure 8.5.2).

8.5.3 Verification

In an attempt to verify the calculated N_2O emissions from canned whipped cream, the same emission is calculated using four assumptions in different combinations. Table 8.5.2 shows the calculated emission for 2012 using the four combinations of assumptions along with the overall assumptions that a can contains 250 ml (250 g) cream and 100 % release of the propellant.

Table 8.5.2 N_2O released as propellant (2012), Gg

	Assumption 1	Assumption 2
	1 can used per household per year	1 % market share of canned cream
Assumption A		
5 % propellant	0.033	0.015
Assumption B		
5 g N_2O per can	0.013	0.005

Using the four assumptions presented in the table above, the time series are calculated; see Figure 8.5.2.

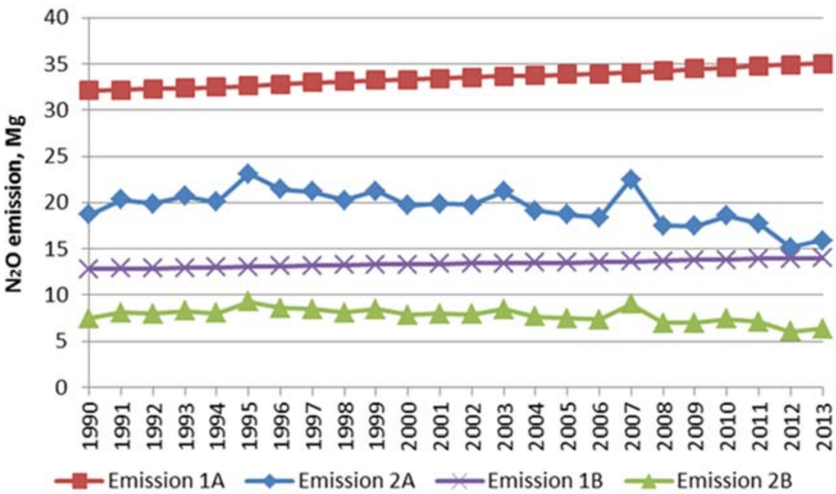

Figure 8.5.2 N_2O emissions from the use of canned whipped cream.

Although the calculated emissions vary over the four estimated scenarios, the emission of N_2O from canned whipped cream is predicted to vary between 5 Mg and 35 Mg. Emission 2A has been chosen as the best estimate and used in Figure 8.5.1.

All four estimates are well below 0.05 % of the national greenhouse gas emissions; in 2012 "Emission 1A" is 0.02 % of nationally emitted CO_2 equivalents (incl. LULUCF).

8.5.4 Time series consistency and completeness

The time series is considered complete and consistent.

8.5.5 Future improvements

There are no planned improvements for this source category.

8.6 Other product use

The use of "other" products currently includes the following SNAP-codes for the Danish inventories:

- 06 06 01 Use of fireworks
- 06 06 02 Use of tobacco
- 06 06 05 Use of charcoal for barbeques

The following pollutants are included for the other product uses:

- CO_2
- CH_4
- N_2O
- SO_2
- NO_x
- NMVOC
- CO
- NH_3
- Particulate matter: TSP, PM_{10}, $PM_{2.5}$
- Heavy metals: As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn
- Persistent organic pollutants: HCB, PCDD/F, PAHs (benzo(a)pyrene, benzo(b)flouranthene, benzo(k)flouranthene, indeno(1,2,3-c-d)pyrene), PCBs

8.6.1 Process description

Use of fireworks

The use of fireworks is in general limited to a short period around New Year's Eve. This section contains calculations of the annual aggregated emissions.

In general fireworks consist of a container of papers and polymers, a propeller in form of black powder and for fireworks like e.g. rockets there is a content of different compounds for colours and effects. Black powder consists of about 75 % oxidizer, most commonly potassium nitrate but also potassium perchlorate or, less commonly, chlorate. The remaining components in black powder are a fuel (carbon), and an accelerant (sulphur). The combustion of black powder commonly produces carbon dioxide, potassium sulphide and nitrogen. (Von Oertzen et al., 2003). Different metal compounds produces different colours and effects, amongst the pollutants included in this inventory Pb, Cu and Zn are the most important.

All imported fireworks must comply with the DS/EN-14035.

Use of tobacco

The combustion of cigarettes and other tobacco products emit a smoke that contributes to the national emissions. Vast amounts of research focusing on the health risks health risks from tobacco smoke are available, but this inventory only focuses on the impact of environmental tobacco smoke (ETS), i.e. releases to air.

Use of charcoal for barbeques

The quality of the charcoal depends on the wood species and the process of production. Charcoal is produced by anaerobic heating of the wood which causes the volatile components in the wood to convert to coke. The heating value for pure dry wood is 19,000 KJ per kg while pure coke has a heating value around 33,000 KJ per kg. The energy content in charcoal is therefore determined by the degree of decomposition of the volatile compounds. (Force Technology).

The product called Heat Beads® BBQ briquettes have won marked shares from regular charcoal for some years now but the use of this product is still relatively small compared to regular coal for barbequing. Heat Beads® consist of a certain blend of hardwood charcoal and mineral carbon made by carbonising brown coal and is therefore emitting some non-biogenic CO_2. Due to confidentiality it is not possible to determine either the marked share of this product or if/how much its composition differs from other products. The amount of non-biogenic CO_2 from barbequing is assumed to be negligible.

8.6.2 Methodology

Use of fireworks

Emissions from fireworks are calculated by multiplying the activity data available from Statistics Denmark (2014) with selected emission factors.

Activity data are collected from Statistics Denmark for the years back to 1988; these data are based on information on import and export. Data for the years 1980-1987 are estimated. The cross-border shopping and use of illegal fireworks are assumed negligible. In collaboration with the Danish Pyrotechnical Association it was decided that any production of fireworks within Denmark is also negligible. It is also assumed that the effect from irregular stock control is negligible.

In November 2004 an accidental explosive burning of vast amounts of fireworks occurred in Denmark. It was estimated that the explosion involved around 284 Mg net explosive mass (NEM). This episode led to a wide evaluation of the laws on use and storage of fireworks (Report Seest, 2005). Since 2005 the amount of total NEM allowed in a single piece of firework has been reduced and the use of fireworks has only been legal to use in the period December 1st to January 5th or with special permission by the local municipality. From 2014 this period was further constricted to only six days (27 December to 1 January).

The heavy metal content in fireworks like Hg, Pb and As and toxic compounds like HCB have been greatly reduced over the last decade and are now legally banned, but there are still cases where trace content of HCB has been detected during random checks (Danish EPA, 2012). Other compounds like Cu have had increasing application in production of fireworks; Cu have to some extent replaced Pb in its uses. Compounds like Ni and Zn are primarily used in alloys; traces of Cd are assumedly caused by contamination of some ingredients since they have no use in fireworks (Miljöförvaltningen, 1999). Compounds that are still widely used in different amounts and for different applications are: S, C, Cu and Cl (resulting in PCDD/F emissions). Furthermore, N and O are widely used in many different combinations of nitrates, oxides, carbonates, sulphates, chlorates and more.

The average NEM content in fireworks is estimated to be 20 % (Report Seest, 2005; Passant et al., 2003; Miljöförvaltningen, 1999).

Use of tobacco

Emissions from use of tobacco are calculated by multiplying activity data with emission factors from literature.

Activity data are collected from Statistics Denmark. It is assumed that cross-border shopping can be regarded as negligible and that all purchased tobacco is smoked within the same year.

Use of charcoal for barbeques

Emissions from barbequing are calculated by multiplying the difference between export and import with selected emission factors.

Activity data for charcoal are gathered from the import/export statistics at Statistics Denmark which are available for all years back to 1988. The consumption data for 1980-1987 are estimated using extrapolation, i.e. linear regression on the 1998-2009 data and assuming that the development represented by this line is fitting for the description of the 1980-1987 data.

Activity data for charcoal collected from Statistics Denmark includes:

- Charcoal, including coal of nutshells or nuts, also agglomerated
- Bamboo, including coal of nutshells or nuts, also agglomerated (except for medical use, charcoal mixed with incense, activated charcoal and charcoal for drawing)
- Charcoal, including coal of nutshells or nuts, also agglomerated (except bamboo, charcoal dosed or packaged as medicines, charcoal mixed with incense, activated charcoal and charcoal for drawing)

It is assumed that the entire quantum of charcoal is combusted the same year as it is imported. It is further more assumed that the cross-border shopping of charcoal is negligible.

In the inventory, the heating factor of 30,000 KJ per kg from the IPCC Guidelines (1996) is accepted.

Activity data

Data on consumption of other products are presented in Table 8.6.1 and Figure 8.6.1.

Table 8.6.1 Activity data for the use of other products, Mg.

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Fireworks	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,041	1,043
Tobacco	13,895	14,051	14,798	13,641	13,859	13,757	13,497	13,052	13,010	12,497
BBQ	1,943	2,440	2,937	3,435	3,932	4,429	4,926	5,424	3,596	7,067
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Fireworks	1,279	1,693	1,830	1,617	1,963	2,998	2,750	2,165	3,524	6,673
Tobacco	12,739	11,951	12,074	11,534	11,409	11,412	11,019	11,163	11,097	11,216
BBQ	7,172	6,199	9,542	7,062	5,997	7,895	10,154	13,488	10,233	10,961
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Fireworks	4,855	3,831	4,738	6,053	8,642	3,684	4,210	4,473	4,369	5,379
Tobacco	11,365	10,915	10,864	11,291	11,073	10,378	10,343	9,786	9,587	9,402
BBQ	13,358	10,897	16,397	20,037	16,211	14,925	19,767	12,151	10,384	11,644
	2010	2011	2012	2013						
Fireworks	5,422	4,731	3,483	4,445						
Tobacco	9,152	8,254	8,172	8,405						
BBQ	7,834	6,719	14,041	14,075						

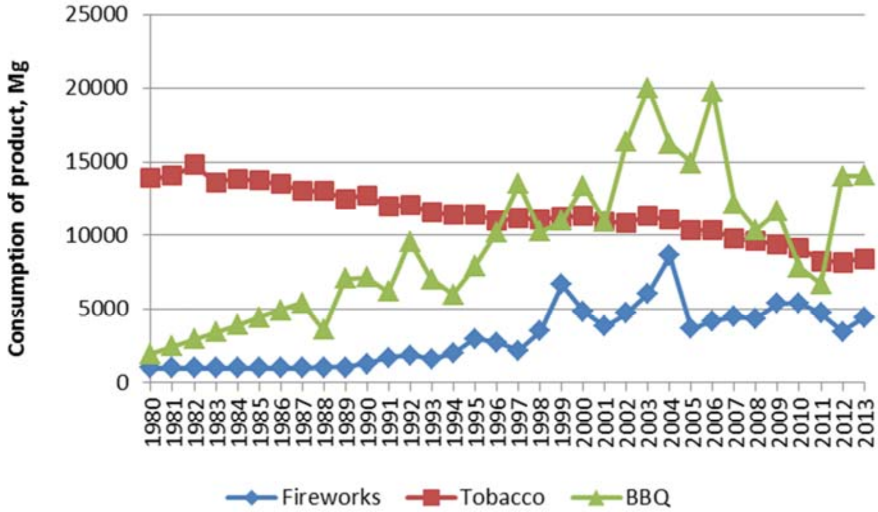

Figure 8.6.1 Activity data for the use of other products.

The consumption of charcoal for BBQs is highly influenced by the summer season weather. The number of smokers has been decreasing throughout the time series. For fireworks, two peaks are visible in the time series, the peak in 1999 is caused by the celebration of the new millennia and the peak in 2004 by the Seest incident where 284 Mg NEM corresponding to a gross weight of about 1,500 Mg of fireworks exploded (Report Seest, 2005). From 2005, the new restrictions put on fireworks (see section 8.6.2) meant a lower general consumption than before 2004, but the increasing trend continued.

Emission factors

Table 8.6.2 shows the selected emission factors for calculating the emissions from fireworks, use of tobacco and combustion of charcoal for barbeques.

Table 8.6.2 Emission factors for other product use.

Compound	Unit	Fireworks	Tobacco	BBQ
CO_2	kg/Mg	43.25 (a)	NA	NA
CH_4	kg/Mg	0.83 (a)	3.19 (e)	6.00(j)[5]
N_2O	kg/Mg	1.94 (a)	0.06 (e)	0.03(j)[5]
SO_2	kg/Mg	1.94 (a)	0.40(e)	3.10 (i)
NO_X	kg/Mg	NAV	1.80(g)	3.00 (j)[5]
NMVOC	kg/Mg	NAV	4.84 (f)	3.00 (j)[5]
CO	kg/Mg	6.90 (a)	55.10(g)	210.0 (j)[5]
NH_3	kg/Mg	NAV	4.15(g)	0.10 (e)
TSP	kg/Mg	39.66 (b)	13.67(g)	3.10 (i)
PM_{10}	kg/Mg	19.83 (b)	13.67(g)	3.10 (i)
$PM_{2.5}$	kg/Mg	13.88 (b)	13.67(g)	3.10 (i)
As	g/Mg	1.33 (c)	0.16 (h)	0.10 (i)
Cd	g/Mg	0.67 (c)	0.02(e)	0.04 (i)
Cr	g/Mg	15.56 (c)	0.35 (h)	0.04 (e)
Cu	g/Mg	444.4 (c)	0.15 (h)	0.15 (e)
Hg	g/Mg	0.06 (d)[1]	0.01(e)	0.07 (i)
Ni	g/Mg	30 (d)	0.03(e)	0.13 (i)
Pb	g/Mg	2200 (d)[2] 666.7 (c)[3] NO[4]	0.64(e)	4.45 (i)
Se	g/Mg	NAV	0.01(e)	0.65 (i)
Zn	g/Mg	260 (d)	1.61(e)	13.90 (i)
HCB	mg/Mg	NAV	NAV	0.10 (e)
PCDD/Fs	ug/Mg	NAV	0.10 (f)	10.50 (k)
Benzo[b]fluoranthene	g/Mg	NAV	0.05 (f)	2.14 (e)
Benzo[k]fluoranthene	g/Mg	NAV	0.05 (f)	1.25 (e)
Benzo[a]pyrene	g/Mg	NAV	0.11 (f)	2.16 (e)
Indeno[1,2,3-cd]pyrene	g/Mg	NAV	0.05 (f)	1.46 (e)
PCB		NAV	NAV	0.13 (e)

NO: Not occurring, NAV: Not available, NA: Not applicable - CO_2 emissions from these sources are biogenic and therefore not relevant, [1] The emission of Hg from fireworks is assumed not to be occurring after the ban in 2002, [2] 1980-1999, [3] 2000-2006, [4] 2007-2009, [5] Calculated from default uncontrolled combustion and a net calorific value of 30 MJ/kg, (a) Netherlands National Water Board (2008), (b) Klimont et al. (2002), (c) Passant et al. (2003), (d) Miljöförvaltningen (1999), (e) Emission factors for wood (111A) combustion in residential plants (1A4b i), SNAP 020200, the energy content used in the calculation is the average of wood pills and wood waste (16.1 GJ/Mg), (f) EMEP/EEA (2013), (g) Martin et al. (1997), (h) Finstad & Rypdal (2003), (i) Environment Australia (1999), (j) IPCC Guidelines (1996), (k) Hansen (2000).

8.6.3 Emission trends

Table 8.6.3 Emissions from other product use.

Pollutant	Unit	1980	1985	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013
SO_2	Mg	13.6	21.2	29.8	34.9	55.4	57.6	73.6	50.3	44.5	50.3	38.5	33.3	53.6	55.6
NO_x	Mg	30.9	38.1	44.5	44.2	60.5	63.5	77.9	54.1	48.4	51.9	40.0	35.0	56.8	57.4
NMVOC	Mg	73.0	79.8	83.1	78.9	95.0	95.0	109.3	83.8	77.5	80.4	67.8	60.1	81.7	82.9
CH_4	Mg	56.8	71.2	84.7	86.2	120.4	125.7	155.0	107.8	96.5	104.3	80.6	70.5	113.2	114.9
CO	Gg	1.2	1.7	2.2	2.3	3.5	3.7	4.7	3.1	2.7	3.0	2.2	1.9	3.4	3.4
CO_2	Mg	43.3	43.3	55.3	129.7	210.0	159.3	182.1	193.5	188.9	232.6	234.5	204.6	150.6	192.3
N_2O	Mg	2.9	2.9	3.5	6.8	10.5	8.2	9.4	9.6	9.4	11.4	11.3	9.9	7.7	9.6
NH_3	Mg	57.8	57.5	53.5	48.1	48.4	44.5	44.8	41.7	40.8	40.1	38.7	34.9	35.2	36.2
TSP	Mg	235.7	241.5	247.1	299.4	389.3	334.3	369.6	348.9	336.5	378.0	364.5	321.3	293.4	334.9
PM_{10}	Mg	215.9	221.7	221.8	240.0	293.1	261.2	286.2	260.2	249.9	271.3	256.9	227.5	224.3	246.7
$PM_{2.5}$	Mg	209.9	215.7	214.2	222.1	264.2	239.3	261.1	233.6	223.9	239.3	224.7	199.4	203.6	220.3
As	kg	3.7	3.9	4.4	6.6	9.5	8.0	9.1	8.7	8.3	9.8	9.4	8.3	7.3	8.6
Cd	kg	1.0	1.0	1.3	2.5	3.9	3.2	3.7	3.6	3.4	4.1	4.0	3.5	3.0	3.6
Cr	kg	20.6	20.6	24.7	51.0	80.1	61.6	69.9	73.5	71.8	87.5	87.9	76.8	57.6	72.7
Cu	Mg	0.4	0.4	0.6	1.3	2.2	1.6	1.9	2.0	1.9	2.4	2.4	2.1	1.6	2.0
Hg	kg	0.3	0.4	0.6	0.8	1.2	1.0	1.3	0.8	0.7	0.8	0.6	0.5	1.0	1.0
Ni	kg	30.7	31.0	39.7	91.3	147.7	112.8	129.2	136.1	132.7	163.2	164.0	143.1	106.6	135.5
Pb	Mg	2.2	2.2	2.9	6.6	3.3	2.5	2.9	0.1	0.1	0.1	0.0	0.0	0.1	0.1
Se	kg	1.4	3.0	4.8	5.2	8.8	9.8	12.9	8.0	6.8	7.6	5.2	4.4	9.2	9.2
Zn	kg	309	344	453	908	1,466	1,182	1,386	1,348	1,296	1,576	1,534	1,337	1,114	1,365
HCB	g	0.2	0.4	0.7	0.8	1.3	1.4	1.9	1.2	1.0	1.1	0.7	0.6	1.3	1.3
PCDD/F	mg	21.8	47.9	76.6	84.0	141.4	157.7	208.6	128.6	110.0	123.2	83.2	71.4	148.3	148.6
Benzo(b)[1]	kg	4.8	10.1	15.9	17.4	29.1	32.4	42.8	26.4	22.7	25.3	17.2	14.7	30.4	30.5
Benzo(k)[2]	kg	3.1	6.2	9.5	10.4	17.2	19.1	25.2	15.6	13.4	15.0	10.2	8.8	17.9	18.0
Benzo(a)[3]	kg	5.7	11.1	16.9	18.3	30.1	33.4	43.8	27.3	23.5	26.2	17.9	15.4	31.2	31.3
Indeno[4]	kg	3.5	7.1	11.0	12.0	20.0	22.3	29.3	18.2	15.6	17.4	11.9	10.2	20.9	20.9
PCB	g	0.3	0.6	1.0	1.1	1.8	2.0	2.6	1.6	1.4	1.6	1.0	0.9	1.9	1.9

[1] Benzo(b)flouranthene, [2] Benzo(k)flouranthene, [3] Benzo(a)pyrene, [4] Indeno(1,2,3-c,d)pyrene

8.6.4 Time series consistency and completeness

The time series is considered to be complete for the included sources, the time series is also consistent.

8.6.5 Future improvements

Other activities not currently included, such as the burning of incense and use of ammunition will be investigated.

An emission factor for black carbon will be added to the relevant product uses.

9 Other industry

The sector *Other industry* (NFR 2H, 2L) cover the following processes relevant for the Danish inventories:

- Beverages production (NFR 2H2); see section 9.2
- Food production / processing (NFR 2H2); see section 9.3
- Sugar production (NFR 2H2), see section 9.4
- Treatment of slaughterhouse waste (NFR 2L); see section 9.5

9.1 Emissions

Non-energy related emissions from beverage, food and sugar productions are NMVOC while treatment of slaughterhouse waste leads to emissions of NH_3.

The emission time series for the NMVOC emissions from the individual source categories in the Other industry sector are presented in Figure 9.1.1. The figure shows that food production (and processing) is by far the largest contributor to industry process emissions of NMVOC followed by beverages production.

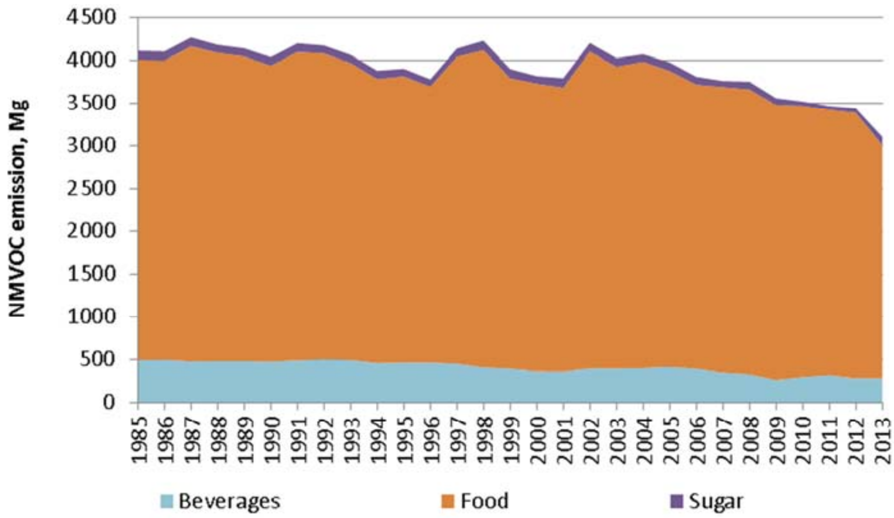

Figure 9.1.1 Emission of NMVOC from the individual source categories compiling NFR *2H Other Industry*.

Treatment of slaughterhouse waste is the only source of NH_3 in the other industry sector. The emissions from slaughterhouse waste are presented in Section 9.5.

9.2 Beverages production

The production of alcoholic beverages is spread out over a large number of different companies of different sizes. The beverage industries included in the inventory are producers of:

- Beer
- White wine
- Red wine
- Malt whisky
- Other spirits

The pollutant relevant for the beverage industry is NMVOC.

9.2.1 Process description

When making any alcoholic beverage, sugar is fermented into ethanol by yeast. The sugar can come from a variety of sources but most often comes from grapes (wine), cereals (beer and some spirits) or other fruits and vegetables. Some pre-processing of the raw materials is often necessary before the fermentation process, e.g. in the production of beer where the barley grain is malted followed by mashing, lautering and boiling before yeast is added to the wort and the fermentation starts.

In the production of spirits, the fermented liquid is then distilled. Alcoholic beverages, particularly spirits and wine, may be stored for a number of years before consumption. However, in Denmark the main production of alcoholic beverages has been beer and spirits with no or very short maturation, which reduces the evaporative emissions.

Emissions may occur during several stages in the production of alcoholic beverages. During the preparation of the starch / sugar source, emissions can occur during the drying of the green malt. Malts are roasted to different degrees depending on the desired colour and specification.

During fermentation, ethanol and other NMVOCs are emitted together with the CO_2 generated by the fermentation as it escapes to the atmosphere. In some cases, the CO_2 can be recovered, thereby also reducing the emission of NMVOC as a result.

During the distillation of fermentation products as well as during maturation NMVOCs evaporate from the distillation column or the stored beverage. During maturation the emission will be proportional to the length of the maturation period.

9.2.2 Methodology

The emission of NMVOC from production of alcoholic beverages is estimated from production statistics (Statistics Denmark, 2014) and standard emission factors from the EMEP / EEA Guidebook (2013).

Activity data

The production statistics for the relevant processes have been aggregated based on data from Statistics Denmark and presented in Table 9.2.1.

Table 9.2.1 Production of beverages (Statistics Denmark, 2014).

	Unit	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Red wine	million l	12	20	12	8	8	10	14	14	12	6
White wine	million l	NO	NO	NO	0.4	0.6	3.2	6.6	6.7	5.9	0.1
Beer	million l	836	879	875	916	922	930	967	978	944	941
Malt whisky	million l	0.2	0.3	0.2	0.2	0.2	0.02	0.01	0.01	0.01	0.01
Other spirits	million l	39	33	31	30	31	33	33	36	37	30
		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Red wine	million l	5	7	11	10	10	5	4	3	2	2
White wine	million l	0.5	0.6	3.5	6.2	6.7	0.3	2.4	2.5	2.2	2.6
Beer	million l	990	959	918	804	821	745	723	820	835	855
Malt whisky	million l	0.003	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other spirits	million l	27	29	29	28	23	24	25	25	24	24
		2005	2006	2007	2008	2009	2010	2011	2012	2013	
Red wine	million l	1	1	0	1	3	4	3	2	4	
White wine	million l	3.1	2.1	1.7	1.1	1.2	4.6	3.6	5.5	8.2	
Beer	million l	868	817	766	647	604	634	659	608	617	
Malt whisky	million l	NO	NO	NO	NO	NO	NO	NO	NO	NO	
Other spirits	million l	26	25	20	25	12	17	21	16	15	

NO: Not occurring.

Emission factors

The emission factors used to calculate the NMVOC emissions from alcoholic beverage production are shown in Table 9.2.2.

Table 9.2.2 Emission factors for NMVOC for production of alcoholic beverages.

Production	Unit	Value	Reference
Red wine	kg/m^3 wine	0.8	EMEP/EEA (2013)
White wine	kg/m^3 wine	0.35	EMEP/EEA (2013)
Beer	kg/m^3 beer	0.35	EMEP/EEA (2013)
Malt whisky	kg/m^3 alcohol	150	EMEP/EEA (2013)
Other spirits	kg/m^3 alcohol	4	EMEP/EEA (2013)

9.2.3 Emission trend

The emission trend for emission of NMVOC from production of beverage is presented in Table 9.2.3.

Table 9.2.3 NMVOC emissions from production of alcoholic beverages, Mg.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Red wine	9.2	16.3	9.7	6.8	6.0	7.7	11.5	10.9	9.8	5.0
White wine	NO	NO	NO	0.1	0.2	1.1	2.3	2.4	2.1	0.03
Beer	292.5	307.7	306.4	320.7	322.6	325.6	338.5	342.1	330.2	329.4
Malt whisky	35.3	37.7	32.6	29.4	23.3	3.3	2.1	2.0	0.9	0.5
Other spirits	154.6	131.6	125.9	119.7	126.0	132.1	133.1	142.4	147.7	119.5
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Red wine	3.9	5.3	8.6	8.0	8.3	4.1	3.4	2.6	1.8	1.4
White wine	0.2	0.2	1.2	2.2	2.3	0.1	0.8	0.9	0.8	0.9
Beer	346.6	335.7	321.3	281.5	287.2	260.9	253.2	287.1	292.3	299.2
Malt whisky	NO	NO	NO	NO	NO	NO	NO	0.2	0.5	0.3
Other spirits	108.6	118.0	115.0	111.7	93.0	95.8	101.7	101.7	97.9	94.5
	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Red wine	0.9	0.5	0.1	1.1	2.6	3.4	2.3	2.0	3.4	
White wine	1.1	0.7	0.6	0.4	0.4	1.6	1.3	1.9	2.9	
Beer	303.8	285.9	268.0	226.6	211.3	221.7	230.6	212.8	215.8	
Malt whisky	0.2	0.2	NO	NO	NO	NO	NO	NO	NO	
Other spirits	105.2	101.5	79.2	99.9	46.2	68.1	83.7	65.1	60.9	

NO: Not occurring.

9.2.4 Future improvements

There are no planned improvements for this source category.

9.3 Food production/processing

The production of food products is spread over a large number of different companies of different sizes. The processes included in the inventory are:

- Bread (rye and wheat)
- Biscuits, cakes and other bakery products
- Poultry frying/curing
- Fish and shellfish frying/curing
- Other meat frying/curing
- Margarine and solid cooking fats
- Coffee roasting

The pollutant relevant for the food industry is NMVOC.

9.3.1 Process description

Food processing may occur in open vessels without forced ventilation, closed vessels with periodic purge ventilation or vessels with continuous controlled discharge to atmosphere. In the larger plants, the discharges may be extremely odorous and consequently emission may be controlled using end-of-pipe abatement (EMEP/EEA, 2013).

Emissions occur primarily from the following sources:

- Cooking of meat, fish and poultry, releasing mainly fats and oils and their degradation products
- Processing of fats and oils to produce margarine and solid cooking fat
- Baking of bread, cakes, biscuits and breakfast cereals
- Processing of meat and vegetable by-products to produce animal feeds
- Roasting of coffee beans

Where cooking or putrefaction is not involved, such as the production of fresh and frozen foods, emissions are considered negligible. Emissions from the pasteurisation of milk and the production of cheeses are also considered negligible (EMEP/EEA, 2013).

9.3.2 Methodology

The emission of NMVOC from production of foods is estimated from production statistics (Statistics Denmark, 2014) and standard emission factors from the EMEP/EEA Guidebook (2013).

Activity data

The production statistics for the relevant processes have been aggregated based on data from Statistics Denmark and presented in Table 9.3.1.

Table 9.3.1 Production of foods and beverages (Statistics Denmark, 2014).

	Unit	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Bread (rye and wheat)	Gg	193	178	179	176	178	190	205	196	208	218
Biscuits, cakes and other bakery products	Gg	119	99	101	101	103	99	123	129	136	138
Poultry curing	Gg	4	5	5	9	12	11	14	16	15	13
Fish and shellfish curing	Gg	35	32	36	38	42	52	48	52	46	40
Other meat curing	Gg	531	503	474	455	439	448	487	457	477	506
Margarine and solid cooking fats	Gg	233	241	260	254	248	233	237	238	221	201
Coffee roasting	Gg	53	53	53	51	54	52	51	56	55	56
		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Bread (rye and wheat)	Gg	231	213	240	247	234	244	271	252	247	256
Biscuits, cakes and other bakery products	Gg	148	164	163	150	131	138	146	151	156	165
Poultry curing	Gg	14	15	16	18	19	24	30	32	33	33
Fish and shellfish curing	Gg	31	40	36	33	35	44	46	44	43	45
Other meat curing	Gg	464	434	443	440	400	393	390	385	400	357
Margarine and solid cooking fats	Gg	199	193	217	227	205	196	178	225	209	211
Coffee roasting	Gg	49	55	53	55	61	56	59	57	51	55
		2005	2006	2007	2008	2009	2010	2011	2012	2013	
Bread (rye and wheat)	Gg	257	270	256	254	267	245	207	233	227	
Biscuits, cakes and other bakery products	Gg	157	149	136	124	115	118	114	109	115	
Poultry curing	Gg	35	38	39	40	50	54	57	63	65	
Fish and shellfish curing	Gg	41	45	39	84	76	73	63	62	67	
Other meat curing	Gg	361	342	318	310	307	303	307	249	241	
Margarine and solid cooking fats	Gg	200	181	191	191	175	180	191	182	146	
Coffee roasting	Gg	37	35	34	35	35	37	23	19	17	

Emission factors

The emission factors used to calculate the NMVOC emissions from food production are shown in Table 9.3.2.

Table 9.3.2 Emission factors for NMVOC for production of alcoholic beverages.

Production	Unit	Value	Reference
Bread (rye and wheat)	kg/Mg bread	4.5	EMEP/EEA (2013)
Biscuits, cakes and other bakery products	kg/Mg product	1	EMEP/EEA (2013)
Meat, fish and poultry	kg/Mg product	0.3	EMEP/EEA (2013)
Margarine and solid cooking fats	kg/Mg product	10	EMEP/EEA (2013)
Coffee roasting	kg/Mg beans	0.55	EMEP/EEA (2013)

9.3.3 Emission trend

The emission trend for emission of NMVOC from production of bread and cookies, meat curing (meat, poultry, fish, and shellfish), production of margarine and solid cooking fats and roasting of coffee is presented in Table 9.3.3.

Table 9.3.3 NMVOC emissions from production of food, Gg.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Bread (rye and wheat)	0.87	0.80	0.81	0.79	0.80	0.85	0.92	0.88	0.94	0.98
Biscuits and other bakery products	0.12	0.10	0.10	0.10	0.10	0.10	0.12	0.13	0.14	0.14
Poultry curing	0.001	0.001	0.001	0.003	0.003	0.003	0.004	0.005	0.005	0.004
Fish and shellfish curing	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01
Other meat curing	0.16	0.15	0.14	0.14	0.13	0.13	0.15	0.14	0.14	0.15
Margarine and solid cooking fats	2.33	2.41	2.60	2.54	2.48	2.33	2.37	2.38	2.21	2.01
Coffee roasting	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Bread (rye and wheat)	1.04	0.96	1.08	1.11	1.05	1.10	1.22	1.13	1.11	1.15
Biscuits and other bakery products	0.15	0.16	0.16	0.15	0.13	0.14	0.15	0.15	0.16	0.17
Poultry curing	0.004	0.004	0.005	0.005	0.006	0.007	0.009	0.009	0.010	0.010
Fish and shellfish curing	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Other meat curing	0.14	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.11
Margarine and solid cooking fats	1.99	1.93	2.17	2.27	2.05	1.96	1.78	2.25	2.09	2.11
Coffee roasting	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Bread (rye and wheat)	1.16	1.22	1.15	1.14	1.20	1.10	0.93	1.05	1.02	
Biscuits and other bakery products	0.16	0.15	0.14	0.12	0.12	0.12	0.11	0.11	0.12	
Poultry curing	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	
Fish and shellfish curing	0.01	0.01	0.01	0.03	0.02	0.02	0.02	0.02	0.02	
Other meat curing	0.11	0.10	0.10	0.09	0.09	0.09	0.09	0.07	0.07	
Margarine and solid cooking fats	2.00	1.81	1.91	1.91	1.75	1.80	1.91	1.82	1.46	
Coffee roasting	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	

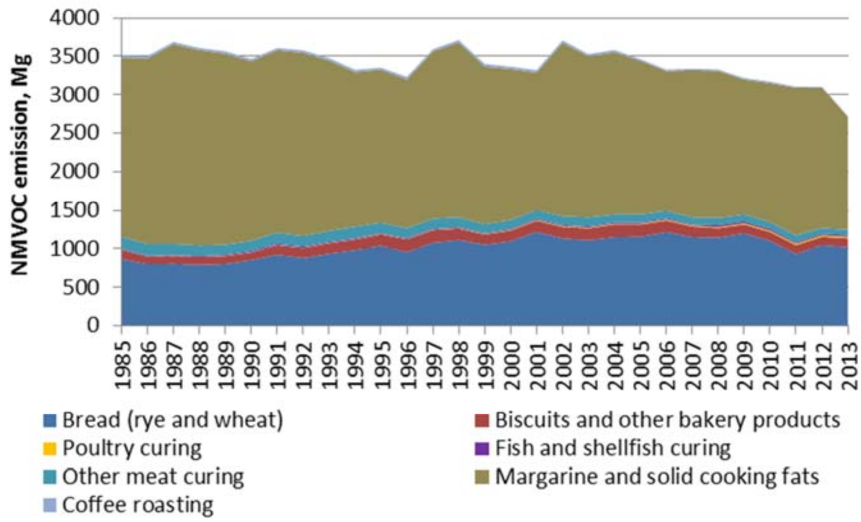

Figure 9.3.1 Emission of NMVOC from the individual source categories compiling NFR *2H2 Food production/processing*.

9.3.4 Future improvements

Other activities not currently included, such as flour production (including potato flour), grain drying feedstuff production and fish meal processing will be investigated further.

9.4 Sugar production

Sugar production is concentrated at one company: Nordic Sugar (previously Danisco Sugar A / S) located in Assens, Nakskov and Nykøbing Falster (Danisco Sugar Assens, 2007; Danisco Sugar Nakskov, 2008; Danisco Sugar Nykøbing, 2008; Nordic Sugar Nakskov, 2013; Nordic Sugar Nykøbing, 2013).

The following SNAP code is covered:

- 04 06 25 Sugar production

The only pollutant relevant to this section on production process of sugar is NMVOC. The CO_2 emissions related to the use of lime in the sugar production are reported in Chapter 3.3. Emissions associated with the fuel use are estimated and reported in the energy sector and are hence not included in this sector report.

9.4.1 Process description

The following description of production processes as well as data are based on environmental reports (Danisco Sugar Assens, 2007; Danisco Sugar Nakskov, 2008; Danisco Sugar Nykøbing, 2008; Nordic Sugar Nakskov, 2013; Nordic Sugar Nykøbing, 2013) combined with a general flow-sheet for production of sugar.

The primary raw material is sugar beets and the secondary raw materials are limestone, gypsum and different chemicals (e.g. sulphur). The primary product is sugar and the by-products are molasses and animal feed.

The sugar beets are delivered to the production site or collected by the company. The first step is to wash and cut up the beets followed by pressing / extraction of sugar juice. The sugar juice is purified by addition of burnt lime (see Section 3.3). Protein compounds are removed by addition of sulphur dioxide. The sugar containing juice is concentrated and finally, the sugar is crystallised. Heat and power is produced on location.

9.4.2 Methodology

Total sales statistics for produced sugar is available from Statistics Denmark (2014). Production statistics from the environmental reports are registered each 12 month period going from 1 May – 30 April until 2007 / 08 and from 1 March – 28 February from 2009 / 10 (Nordic Sugar Nakskov, 2009; Nordic Sugar Nykøbing, 2009). Therefore, the yearly production does not correspond with the yearly sale registered by Statistics Denmark (2014). The information from Statistics Denmark covers the whole time series and therefore the amount of sugar sold is used as activity data.

The production site in Assens closed down in 2006.

Activity data

Production (i.e. sale) statistics for sugar production are presented in Table 9.4.1.

Table 9.4.1 Production of sugar at different locations, Gg (Statistics Denmark, 2014).

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Sugar production	533.2	532.0	522.4	468.1	476.3	505.7	509.8	470.6	484.3	496.0
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Sugar production	444.1	431.8	487.4	557.0	535.1	443.2	562.4	508.1	510.8	451.7
	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Sugar production	506.5	458.0	329.8	400.3	428.4	262.1	218.1	262.0	493.1	

Emission factors

Regarding refining of sugar, the default emission factor for NMVOC has been revised based on company specific measurements obtained from personal communication with Vibeke Vestergaard Nielsen, Danish EPA (9 September 2011). TOC has been measured in order to assess odour issues. The emission of TOC has been used as indicator for NMVOC assuming a conversion factor at: 0.6 kg C/kg NMVOC. The emission factor has been determined to 0.2 kg NMVOC/Mg produced sugar.

9.4.3 Emission trend

The emission trend for emission of NMVOC from production of sugar is presented in Table 9.4.2.

Table 9.4.2 NMVOC emissions from production of sugar, Mg.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
NMVOC	107	106	104	94	95	101	102	94	97	99
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
NMVOC	89	86	97	111	107	89	113	102	102	91
	2005	2006	2007	2008	2009	2010	2011	2012	2013	
NMVOC	101	92	71	93	79	52	44	52	99	

9.4.1 Time series consistency and completeness

The time series is consistent and complete.

9.4.2 Future improvements

There are no planned improvements.

9.5 Treatment of slaughterhouse waste

One company treats slaughterhouse waste: Daka with five departments located in Løsning, Randers, Lunderskov, Ortved, and Nyker. Daka is the result of the merger of Daka and Kambas. The departments in Ortved and Nyker are closed. The following SNAP-code is covered:

- 04 06 17 Other

The pollutant relevant for this source category is NH_3. Emissions related to the consumption of energy are reported under the energy sector and hence is not included in this report.

9.5.1 Process description

The raw materials for the processes are by-products from the slaughterhouses, animals dead from accidents or diseases, and blood. The outputs from the processes are protein and fat products as well as animal fat, meat and bone meal.

The processes involved are e.g. separation, drying and grinding.

The NH_3 emissions and odour from the processing of slaughterhouse waste relates to storage of the raw materials as well as to the drying process.

The information on treatment of slaughterhouse waste is based on Daka (2002; 2004).

9.5.2 Methodology

The emission of NH_3 from treatment of slaughterhouse waste has been calculated from an average emission factor based on measurements from Danish plants (Daka, 2014). Measurements of NH_3 during the years 2002/3 from three locations (Lunderskov, Løsning and Randers) with different product mix have been included in the determination of an emission factor.

The activity data for treatment of slaughterhouse waste are compiled from different sources. Due to changes in the company structure environmental reports are only available for some of the years (Daka, 2014). These environmental reports in combination with environmental reports for one of the merging companies are used to identify the corresponding data in the statistical information from Statistics Denmark (2014).

Activity data

The activity data are presented in Table 9.5.1.

Table 9.5.1 Activity data for treatment of slaughterhouse waste, Gg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Meat/bone meal[1]	128.8	186.1	181.0	209.2	197.8	197.0	191.3	166.6	177.7	201.5
Animal fat[1]	72.1	81.9	85.9	75.8	63.9	54.2	57.7	72.6	72.8	89.2
Blood meal[2]	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.4	11.5
Total	211.9	279.0	277.9	296.0	272.7	262.2	260.0	250.2	261.8	302.2
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Meat/bone meal[1]	198.6	154.0	209.1	227.8	241.6	177.4	161.7	142.6	140.5	116.4
Animal fat[1]	73.4	56.4	108.5	93.8	98.6	90.2	75.6	82.6	84.7	70.9
Blood meal[2]	11.4	9.7	8.9	9.5	10.6	10.2	8.9	10.6	10.0	7.5
Total	283.4	220.1	326.6	331.0	350.7	277.9	246.2	235.8	235.2	194.8
	2010	2011	2012	2013						
Meat/bone meal[1]	104.6	96.3	73.7	78.5						
Animal fat[1]	75.3	77.7	76.2	48.2						
Blood meal[2]	7.5	7.5	7.5	7.5						
Total	187.4	181.5	157.4	134.3						

[1] Statistics Denmark (2014).

[2] Based on environmental reports from Daka (2014) for the years 1998 – 2009 and assumed for the other years.

Emission factors

The emission of NH_3 from treatment of slaughterhouse waste has been calculated from an average emission factor based on measurements from Danish plants (Daka, 2014). Measurements of NH_3 during the years 2002/3 from three locations (Lunderskov, Løsning and Randers) with different product mix have been included in the determination of an emission factor.

Weighted emission factors covering all the products within the sector have been estimated for 2002 and 2003 as well as a weighted emission factor covering 1990-2001. The estimated emission factors are presented in Table 9.5.2.

Table 9.5.2 Emission factors for treatment of slaughterhouse waste.

	EF	1990-2001	2002	2003-2013
NH_3	g/Mg	120[1]	151	475

[1] Weighted average. Daka (2002; 2004)

[2] Weighted yearly average. Daka (2004)

9.5.3 Emission trend

The emission trend for emission of NH_3 from treatment of slaughterhouse waste is presented in Table 9.5.3.

Table 9.5.3 Emission of NH_3 from treatment of slaughterhouse waste, Mg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
NH_3	25.4	33.5	33.4	35.5	32.7	31.5	31.2	30.0	31.4	36.3
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
NH_3	34.0	26.4	49.3	157.2	166.6	132.0	117.0	112.0	111.7	92.5
	2010	2011	2012	2013						
NH_3	89.0	86.2	74.8	63.8						

9.5.1 Future improvements

Other activities not currently included such as production of animal feeds including animal rendering will be investigated.

10 Assessment of completeness

A number of emission sources are not covered by the current emission inventory. At the moment resources are not available to implement all improvements that could be desired for the *Industrial processes* sector. A number of improvements have been described in the previous chapters related to the sources that are currently covered by the inventory and these will be considered together with the possibility of adding new sources to ensure the highest possible overall quality of the inventory.

Some source categories are included in the EMEP/EEA guidebook and the reporting format, but not included in the present inventory. These sources together with an indication of the relevant pollutants are described below. Emission sources that are not currently included in the inventory are also described in the following.

10.1 Source sectors not included

The following four sources are to be included in the 2016 submission of the informative inventory report (IIR) and will thereafter also be included in the next submission of this sectoral report.

10.1.1 Quarrying and mining of minerals

The quarrying and mining of minerals is a potential source of emissions of particulate matter. The required activity data to use the methodology in the EMEP/EEA guidebook are the mass of quarried material. The quarrying of stone, sand and clay is occurring in Denmark, but no activity data have been collected to allow for estimation of the emissions.

10.1.2 Construction and demolition

Emissions associated with the construction and demolition of buildings will be particulate matter. The required activity data to use the methodology in the EMEP/EEA guidebook are the floor space of constructed and demolished buildings. No activity data have been collected to allow for estimation of the emissions.

10.1.3 Storage, handling and transport of mineral products

Particulate matter is the relevant pollutant for storage, handling and transport of mineral products. The methodology in the EMEP/EEA guidebook uses the total amount of mineral products that is stored/handled/transported as the activity data. While the activity does occurs in Denmark, no activity data have been collected.

10.1.4 Wood processing

The processing of wood causes emissions of particulate matter. There is a number of sawmills and other wood processing plants in Denmark, but the activity data have not been collected to allow for an estimation of emissions.

10.2 Activities not included

A number of activities are possible sources of emissions that are not currently included in the emission inventory. The activities described below do not necessarily form and complete list of potential emission sources within industrial processes.

10.2.1 Grain drying and feedstuff production

This activity is part of the food production / processing category. During the drying of grain NMVOC and particular matter is emitted. Production of feed is a source of particulate matter emission and odours.

10.2.2 Barley malting

This activity is part of the beverages category. During the drying / roasting of barley as part of the process for producing beer and some spirits, NMVOC is emitted.

10.2.3 Secondary magnesium smelting

In addition, to emissions of cover gas (SF_6), the secondary magnesium smelting can also be a source of particulate matter emission.

10.2.4 Concrete batching

Concrete batching is a potential emission source of particulate matter and also some heavy metals.

10.2.5 Meat/fish smokehouses

Smoking of fish and meat is a potential source of emissions of particulate matter and PAH.

10.2.6 Yeast manufacturing

Emissions of NMVOC will occur during the fermentation to produce yeast.

11 Uncertainties

Uncertainty estimates include uncertainty with regard to the total emission inventory as well as uncertainty with regard to trends. Uncertainties are reported annually for both greenhouse gases and for other pollutants.

11.1 Methodology

The uncertainty for greenhouse gas emissions have been estimated according to the IPCC Good Practice Guidance (IPCC, 2006). The uncertainty has been estimated by two approaches; Approach 1 and Approach 2. Both approaches are further described in Nielsen et al. (2014).

The Approach 1 calculation is based on a normal distribution and a confidence interval of 95 %.

The input data for the Approach 1 estimate are:

- Emission data for the base year and the latest year
- Uncertainties for emission factors
- Uncertainties for the activity data

The emission source categories applied are listed in Table 11.3.1.

The Approach 2 estimate is a Monte Carlo approach based on a lognormal distribution. The input data for the model is also based on 95 % confidence interval.

The input data for the Approach 2 estimate are:

- Activity data for the base year and the latest year
- Emission factors or implied emission factors (IEF) for the base year and the latest year
- Uncertainties for emission factors for the base year and the latest year. If the same uncertainty is applied for both years, the data can be indicated as statistically dependent or independent
- Uncertainties for the activity data in the base year and the latest year. If the same uncertainty is applied for both years, the data can be indicated as statistically dependent or independent.

11.2 Uncertainty input for greenhouse gases

The source specific uncertainties for industrial processes are presented in Table 11.3.1. The uncertainties are based on IPCC Guidelines (2006) combined with assessment of the individual processes.

Mineral Industry

The single Danish producer of cement has delivered the activity data for production as well as calculated the emission factor based on quality measurements. For activity data, there is a shift in methodology from 1997 to 1998. Prior to 1998 activity data are derived by the Tier 2 (1-2 % uncertainty) methodology for grey cement production and the Tier 1 (<35 % uncertainty) for white cement production (20-25 % of total production), the uncertainty for 1990-1998 it therefore assumed to be 8 %. Activity data have since 1998 fulfilled the Tier 3 methodology and is assumed to have an uncertainty of 1%. The estimation of emission factors fulfils the Tier 3 methodology for the entire time series and uncertainties are therefore assumed to be 2 %. Since uncertainties cannot vary over time in Approach 1, activity data uncertainties are assumed to be 1 % for the entire time series.

The activity data for production of lime, including non-marketed lime in the sugar production, are based on information compiled by Statistics Denmark. Due to the assumption that lime kiln dust (LKD) is collected and recirculated, the uncertainty for the entire time series is assumed to be 5 % for activity data. The emission factor for marketed lime production cover many producers and a variety of high calcium products, assumptions that influence the uncertainty includes the assumptions of no impurities, 100 % calcination and for sugar production also the assumptions on the lime consumption and sugar content in beets. Since 2006 and the introduction of EU-ETS data, the uncertainty decreased as many of the mentioned assumptions were no longer needed, the combined uncertainty for emission factors are estimated to be 8 % and 4 % for the periods 1990-2005 and 2006-2013 respectively. Since uncertainties cannot vary over time in Approach 1, the emission factor uncertainty is assumed to be 4 % for the entire time series.

The uncertainty associated with activity data from glass production (including glass wool production) are low for recent years (EU-ETS data) but higher for historic years (carbonate data were not available for 1990-1996 and were therefore estimated for these years), activity data uncertainties are estimated to be 5 % for 1990 and 1 % for 2013. Since uncertainties cannot vary over time in Approach 1, activity data uncertainties are assumed to be 1 % for the entire time series. Uncertainties associated with the emission factors from glass production are low. Denmark uses the Tier 3 methodology and therefore stoichiometric CO_2 factors, some uncertainty is however connected to assuming a calcination factor of 1, and the overall emission factor uncertainty is therefore estimated to be 2 %.

The activity data for production of ceramics are based on information compiled by Statistics Denmark and EU-ETS. The uncertainty is assumed to be 5 % (Tier 2). The emission factor is based on stoichiometric relations and the assumption of full calcination; the uncertainty is assumed to be 2 %.

The CO_2 emission from other uses of soda ash is calculated based on national statistics (Statistics Denmark, 2014) and the stoichiometric emission factor for soda ash (Na_2CO_3) assuming the calcination factor of 1. Uncertainties are assumed to be 5 % and 2 % for activity data and emission factor respectively.

The category “Other Process Uses of Carbonates” in the Danish inventory includes flue gas desulphurisation and mineral wool production. The activity data uncertainty for flue gas desulphurisation is assumed to be 30 % (see Section 3.7.4 on Verification). For mineral wool the activity data uncertainty is low for recent years (EU-ETS data) but higher for historic years (calculated/estimated), the uncertainties are assumed to be 2% and 30 % respectively. The overall activity data uncertainties for other process uses of carbonates are assumed to be 30 %. The uncertainty of the stoichiometric emission factors for both source categories is assumed to be 2 %.

Chemical Industry

The producers have registered the production of nitric acid during many years and, therefore, the uncertainty is assumed to be 2 %. The measurement of N_2O is problematic and is only carried out for one year. Therefore, the uncertainty is assumed to be 25 %.

The uncertainty for the activity data as well as for the emission factor is assumed to be 5 % for production of catalysts / fertilisers.

Metal Industry

The uncertainty for the activity data and emission factor for CO_2 is assumed to be 5 % and 10 % respectively for production of secondary steel.

The uncertainty for the activity data and emission factor is assumed to be 10 % and 30 % respectively for production of magnesium and 10 % and 50 % respectively for lead production.

Electronics Industry and Product Uses as Substitutes for Ozone depleting Substances

The emission of F-gases is dominated by emissions from refrigeration equipment and therefore, the uncertainties assumed for this sector will be used for all the F-gases. The IPCC propose an uncertainty at 30-40 % for regional estimates. However, Danish statistics have been developed over many years and, therefore the uncertainty on activity data is assumed to be 10 %. The uncertainty on the emission factor is, on the other hand, assumed to be 50 %. The base year for F-gases for Denmark is 1995.

Other Product Manufacture and Use

The uncertainty of N_2O used for medical applications is assumed to be 5-50 % for activity data and 20 % for the emission factor. The activity data uncertainty is highest for historic years and lower for recent years; since uncertainty cannot vary over time in Approach 1 the uncertainty input is here estimated to be 25 % for all years.

The uncertainty of N_2O used as propellant for pressure and aerosol products is estimated to be 100 % for activity data and 150 % for the emission factor.

For "Other product use", the collection of data for quantifying production, import and export of products results in some uncertainty. Some data, like private import (cross-border shopping) of fireworks, are not available due to lack of control on the subject while other lacking data like the composition and marked share of mineral containing charcoal for barbequing are unobtainable due to confidentiality. The uncertainty for activity data for all three product uses is estimated to be 15 %. For emission factors, reliable data are difficult to obtain for other product use categories. Some chosen emission factors apply to countries that are not directly comparable to Denmark, and hereby is introduced an increased uncertainty. The chosen uncertainty input for emission factors for other product use is estimated to be 60 % for all pollutants and all years.

11.3 Uncertainty results for greenhouse gases

All uncertainty input values are discussed in Section 11.2 above. Table 11.3.1 presents the uncertainty inputs and the calculated total uncertainty for Approach 1 for the individual greenhouse gas pollutants.

The calculated Approach 1 uncertainty interval for the overall greenhouse gas emission for the industrial processes sector in 2013 is ± 18.9% and the trend in greenhouse gas emission is 21.6 % ± 16.4 %-age points.

The dominant sources of Approach 1 uncertainty for greenhouse gas emissions in 2013 are emissions of HFCs from refrigeration and air conditioning followed by SF_6 from other SF_6 use and HFCs from foam blowing agents.

Table 11.3.1 Input uncertainties on activity data and emission factors as well as calculated overall trend uncertainties for the different greenhouse gases according to Approach 1 for 2013.

CRF Category	2013 Emission CO_2-eq. Gg	Activity data uncertainty %	Emission factor uncertainty CO_2 %	CH_4 %	N_2O %	HFCs[2] %	PFCs[2] %	SF_6[2] %
2A1 Cement production	867.1	1	2					
2A2 Lime production	54.2	5	4					
2A3 Glass production	7.0	1	2					
2A4a Ceramics	26.6	5	2					
2A4b Other uses of soda ash	9.1	5	2					
2A4d Other process uses of carbonates	31.5	30	2					
2B2 Nitric acid production[1]	NO	2			25			
2B10 Catalysts/fertiliser production	1.3	5	5					
2C1 Iron and steel production	NO	5	10					
2C4 Magnesium production	NO	10						30
2C5 Secondary lead production	0.16	10	50					
2E Electronics industry	3.7	10					50	
2F1 Refrigeration and air conditioning	711.0	10				50	50	
2F2 Foam blowing agents	60.7	10				50		
2F4 Aerosols	17.7	10				50		
2F5 Solvents[3]	NO							
2G1 Electrical equipment	13.1	10						50
2G2 SF_6 from other product use	117.4	10						50
2G3a Medical application	11.0	25			20			
2G3b Propellant for pressure and aerosol products	4.8	100			150			
2G4 Fireworks	2.8	15	60	60	60			
2G4 Tobacco	0.8	15		60	60			
2G4 Barbeques	2.2	15		60	60			
Overall uncertainty in 2013			2.2	47.7	50.5	46.1	37.8	46.1
Trend 1990-2013 (1995-2013)			10.1	-35.7	98.2	-223.0	-1610.9	-27.5
Trend uncertainty			1.7	35.1	1.1	172.2	447.9	27.1

[1] The production closed down in the middle of 2004.

[2] The base year for F-gases is for Denmark 1995.

[3] Uncertainties are not calculated for solvents because this activity occurs in neither 1990 nor 2013.

Table 11.3.2 Approach 2 uncertainties for Industrial Processes.

1990 (1995)			2013			1990-2013 (1995-2013)		
Median	Uncertainty		Median	Uncertainty		Median	Uncertainty	
Emission CO_2 eq, Gg	Lower (-) %	Upper (+) %	Emission CO_2 eq, Gg	Lower (-) %	Upper (+) %	Emission CO_2 eq, Gg	Lower (-) %	Upper (+) %
2490	10	13	1947	15	24	777	35	37

The Approach 2 uncertainties for CO_2 equivalent emission from Industrial Processes is presented in Table 11.3.2. The uncertainty estimates are based on the individual uncertainty inputs as discussed in Section 11.2 above.

11.4 Uncertainty input and results for other pollutants

According to the Good Practice Guidance for LRTAP Emission Inventories (Pulles & Aardenne, 2004) uncertainty estimates should be estimated and reported each year.

With regard to other pollutants, IPCC methodologies for uncertainty estimates have been adopted for the LRTAP Convention reporting activities (Pulles & Aardenne, 2004). The Danish uncertainty estimates are based on the simple Approach 1 estimate.

The uncertainty estimates are based on emission data for the base year and year 2013 as well as on uncertainties for activity data and emission factors aggregated for the entire industrial processes sector. For particulate matter (PM), 2000 is considered to be the base year, but for all other pollutants, the base year is 1990.

The results of the uncertainty analysis for other pollutants are shown in Table 11.4.1 below.

Table 11.4.1 Approach 1 uncertainty estimates for air pollutants 2013.

Pollutant	Uncertainty total emission %	Trend in emission 1990-2013 (2000-2013) %	Uncertainty trend 1990-2013 (2000-2013) %-age points
SO_2	17.95	-45	2.7
NO_x	40.81	-91	5.2
NMVOC	67.75	-30	47.6
CO	100.80	-74	25.1
NH_3	539.80	-36	104.0
TSP	111.34	-48	26.2
PM_{10}	127.74	-51	30.3
$PM_{2.5}$	147.35	-50	34.5
BC	50.04	-27	2.1
As	642.06	-61	190.5
Cd	604.54	-71	80.5
Cr	534.86	-38	162.5
Cu	149.06	225	162.8
Hg	901.08	-96	3.1
Ni	499.57	-72	119.3
Pb	629.58	-85	40.8
Se	933.15	-46	204.1
Zn	336.22	-81	143.5
PCDD/F	544.82	-97	34.5
benzo(b)flouranthene	150.75	92	40.6
benzo(k)flouranthene	150.75	89	40.1
benzo(a)pyrene	150.75	86	39.4
indeno(1,2,3-c,d)pyrene	150.75	90	40.2
HCB	963.65	-95	56.0
PCB	585.76	-95	23.5

12 QA/QC and verification

For greenhouse gases the industrial processes sector is covered by the QA / QC manual guiding the quality work for the Danish greenhouse gas inventory, see Nielsen et al. (2013b) for specific information on the QA / QC plan for the Danish greenhouse gas inventory. For specific information on the implementation of the QA / QC plan for the industrial processes sector, please refer to the National Inventory Report (Nielsen et al., 2014).

Documentation concerning verification of the Danish emission inventories has been published by Fauser et al. (2007). An updated verification report for the Danish emission inventories for GHGs is published in 2013 (Fauser et al., 2013).

This report serves as a key part of the QA of the emission inventory for industrial processes. This report has been externally reviewed by Karsten Fuglsang from FORCE Technology. The comments received have been incorporated in the report or have been listed as future improvements.

13 Source specific planned improvements

A large number of areas have been identified for future improvements. However, the resources are limited and therefore it is necessary to prioritise the improvements. In Table 13.0.1 below; the identified improvements are listed together with an indication of the prioritisation. The improvements have been categorised on a scale from 1-3, where 1 indicates the most urgent need for improvement.

Table 13.0.1 List of identified areas for future improvement.

Main sector	Subsector	Improvement	Priority
Mineral industry	Lime production	The choice of CEPMEIP as source of the emission factors for particulate matter will be re-evaluated and a change to the latest edition of the EMEP/EEA guidebook will be considered.	2
Mineral industry	Lime production	It will be attempted to collect activity data on the amount of lime being used as raw material in the sugar production.	1
Mineral industry	Lime production	Further research will be put into the lower emission factor for CO2 from sugar production in 2006-2013. If possible, the emission factor will be made consistent throughout the time series depending on the findings.	1
Mineral industry	Glass production	Emissions of BC will be added for container glass and glass wool production.	2
Mineral industry	Glass production	The production figures for container glass are very low for 2006 and 2007, this will be investigated further. The activity data have no influence on the GHG emission.	2
Mineral industry	Ceramics	The SO_2 emission factor for bricks and expanded clay products will be improved based on data for recent and coming years.	2
Mineral industry	Ceramics	The time series for production of ceramics will be extended to include 1980-1989.	2
Mineral industry	Ceramics	It will be investigated whether emissions of particulate matter can be included for production of ceramics	3
Mineral industry	Flue gas desulphurisation	Further investigation will be put into identifying the desulphurisation methodologies used at waste incineration plants for every year in the time series as some plants might have switched technology since 1990 (i.e. dry/semi-dry/wet).	2
Chemical industry	Nitric acid production	Emissions of BC will be added for nitric acid production.	2
Chemical industry	Catalyst/fertiliser production	Through contact with the plant, it will be attempted to verify the assumptions on the split between combustion and process emissions for CO_2 and NO_x.	3
Chemical industry	Catalyst/fertiliser production	Emissions of BC will be added for catalyst/fertiliser production.	2
Chemical industry	Production of tar products	The emission of SO_2 will be extrapolated back to 1980 to comply with the requirement to have a time series back to the base year.	3
Chemical industry	Production of tar products	It will be evaluated whether the assumption to keep emissions constant back in time at the 2005 level is appropriate.	2
Chemical industry	Production of tar products	Possible emissions of PAH from the process will be investigated.	3
Metal industry	Iron and steel production	For iron foundries a process description will be elaborated.	3
Metal industry	Iron and steel production	Activity data from Statistics Denmark will be used for iron foundries for the whole time series.	2
Metal industry	Iron and steel production	Emission factors for iron foundries will be re-examined to ensure that they are properly referenced.	2

Continued			
Metal industry	Red bronze production	It will be investigated whether activity data are available from Statistics Denmark.	2
Metal industry	Red bronze production	A process description for this activity will be elaborated.	3
Metal industry	Secondary aluminium production	An emission factor for black carbon will be added for secondary aluminium production.	2
Other product manufacture and use	Other product use	Other activities not currently included, such as the burning of incense and use of ammunition will be investigated.	3
Other product manufacture and use	Other product use	An emission factor for black carbon will be added to the relevant product uses.	2
Other industry	Food production/processing	Other activities not currently included, such as flour production (including potato flour), grain drying, production of animal feeds including animal rendering (seen in conjunction with the activities described in Section 9.5), yeast manufacturing and fish meal processing will be investigated further.	2

An indication of priority 1 means that this is a top-priority and will be carried out within the next 1-2 years. Priority 2 means a time horizon of 1-5 years while the areas for improvement with priority 3 mean that they are depending on additional resources becoming available.

When carrying out improvements related to the sector special attention will be given to the reference documents on best available technology (BREF documents). BREF documents are periodically updated and when new BREF documents are published, the documents will be analysed for information that can be used to improve the Danish emission inventory.

In addition to the areas for improvement identified in the table above, there is also a number of potential emission sources not currently included in the emission inventory. These are documented in Chapter 10.

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DANISH EMISSION INVENTORY FOR INDUSTRIAL PROCESSES

Results of inventories up to 2013

This report forms part of the documentation for the emission inventories for industrial processes. The report includes both methodological descriptions for estimating emissions of greenhouse gases and air pollutants and presents the resulting emission data as reported to the United Nations Framework Convention on Climate Change and the United Nations Economic Commission for Europe Convention on Long-Range Transboundary Air Pollution. The results of inventories up to 2013 are included.

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