DANISH EMISSION INVENTORY FOR INDUSTRIAL PROCESSES

Scientific Report from DCE – Danish Centre for Environment and Energy No. 131 2014

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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 2012 are included.

Keywords: Industrial processes, emissions, UNFCCC, UNECE, emission inventory

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Contents

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) conventions.

This report forms the documentation of the emission inventories for industrial processes. The report includes both methodological descriptions and emission data. The results of inventories up to 2012 are included.

The report is the first version of a sectoral report for industrial processes and has been reviewed externally by Anne Jensen from the Danish Environmental Protection Agency.

An updated report will be published in 2015/2016.

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. Four pollutants (sulphur dioxide, nitrogen oxides, non-methane volatile organic compounds and ammonia) 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), 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 five 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 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 – activity data and emission factors.

The emission factors are based on either national references or on international guidance documents (EEA, (2004, 2009, 2013); IPCC, (1996, 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 2012. The emissions are extracted from the Common Reporting Format (CRF) tables.

Table 0.1 Overview of industrial greenhouse gas sources (2012).

Process	IPCC Code	Substance	Emission ktonne CO_2 eqv.	%
Cement	2A1	CO_2	871	48.6
Refrigeration	2F1	HFCs+PFCs	579	32.4
Other (laboratories, double glaze windows)	2F9	SF_6	105	5.84
Foam blowing	2F2	HFCs	66.2	3.70
Lime	2A2	CO_2	40.2	2.24
Other (lubricants)	2G	CO_2	31.7	1.77
Limestone and dolomite use	2A3	CO_2	25.6	1.43
Other (yellow bricks)	2A7	CO_2	17.5	0.98
Aerosols / Metered dose inhalers	2F4	HFCs	15.8	0.88
Electrical equipment	2F8	SF_6	13.3	0.74
Other (container glass, glass wool)	2A7	CO_2	9.69	0.54
Other (expanded clay products)	2A7	CO_2	5.89	0.33
Other (fibre optics)	2F9	HFCs+PFCs	4.31	0.24
Food and drink	2D2	CO_2	2.24	0.13
Road paving	2A6	CO_2	1.77	0.10
Catalysts / fertilisers	2B5	CO_2	1.41	0.08
Asphalt roofing	2A5	CO_2	0.019	0.001
Iron and steel	2C1	CO_2	NO	NO
Nitric acid	2B2	N_2O	NO	NO
Total			1 791	100

The subsectors *Mineral products* (2A) constitutes 54 % of the emission in 2012, *Consumption of halocarbons (HFCs and PFCs) and SF_6* (2F) constitutes 44 %, *Other, Lubricants* (2G) constitutes 1.8 %, *Chemical industry* (2B) and *Food and Drink* (2D) each constitutes below 1 % of the industrial emission of greenhouse gases. There are no greenhouse gas emissions from *Metal production* (2C) in 2012, since the only electric arc furnace in Denmark was last in operation in 2004. The total emission of greenhouse gases (excl. emissions/removals from Land-Use, Land-Use Change and Forestry (LULUCF)) in Denmark in 2012 is estimated to 51.6 Mt CO_2 equivalents, of which industrial processes contribute with 1.79 Mt CO_2 equivalents (3.5 %). The emission of greenhouse gases from industrial processes from 1990-2012 are presented in Figure 0.1.

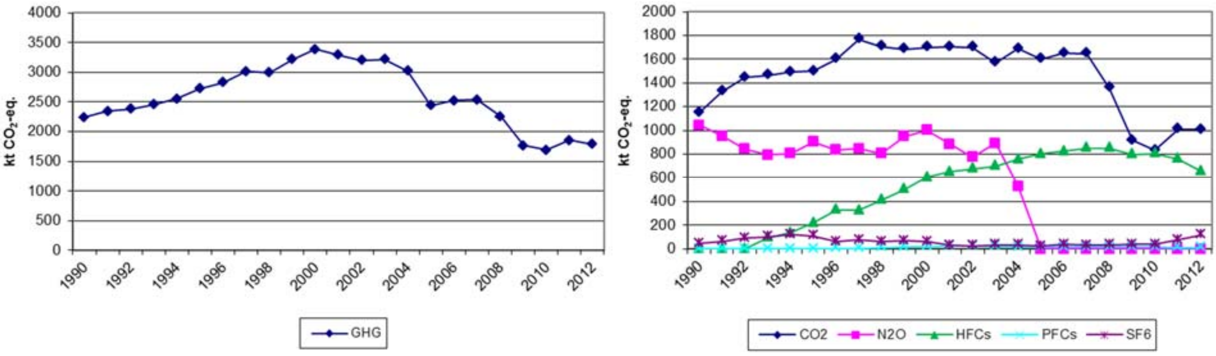


Figure 0.1 Emission of greenhouse gases from industrial processes (CRF Sector 2) from 1990-2012.

The key categories in the industrial processes sector - cement production and refrigeration - constitute 1.69 % and 1.12 % of the total emission of greenhouse gases. The trends in greenhouse gases from the industrial 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 from 1990-2012.

Year	1990	1995	2000	2005	2008	2009	2010	2011	2012
CO_2 (kt CO_2)									
A. Mineral Products	1069	1405	1616	1544	1320	881	796	972	972
B. Chemical Industry	0.80	0.80	0.79	1.06	1.20	1.42	2.12	1.39	1.41
C. Metal Production	28.4	38.6	40.7	15.6	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO
D. Food and Drink	4.45	3.91	3.90	4.46	2.67	1.92	1.56	2.01	2.24
G. Other	49.7	48.8	39.7	37.6	34.0	31.2	33.2	33.2	31.7
Total	1152	1497	1701	1602	1358	915	833	1008	1007
N_2O (kt CO_2 eqv.)									
B. Chemical Industry	1043	904	1004	NO	NO	NO	NO	NO	NO
HFCs (kt CO_2 eqv.)									
F. Consumption of Halocarbons and SF_6	NE	218	607	802	853	799	804	759	657
PFCs (kt CO_2 eqv.)									
F. Consumption of Halocarbons and SF_6	NE	0.50	17.9	13.9	12.8	14.2	13.3	11.1	8.54
SF_6 (kt CO_2 eqv.)									
F. Consumption of Halocarbons and SF_6	44.5	107	58.8	21.8	31.6	36.7	37.9	73.2[1]	118

[1] The increase in SF_6 emission in 2011 and 2012 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 life, the SF_6 remaining in the windows is assumed to be emitted.

The emission of f-gases is documented in the report "The greenhouse gases HFCs, PFCs and SF_6. Danish consumption and emissions, 2012" (Poulsen & Musaeus, 2014) and will not be described further 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), and 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.

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

Year		1985	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012
Pollutant													
SO_2, kt	2 A 7 d Other Mineral products		1.41	1.53	1.52	1.49	1.88	2.02	1.36	0.73	0.76	0.82	0.72
	2 B 5 a Other Chemical industry	0.62	0.85	0.62	0.63	0.61	0.38	0.09	0.15	0.11	0.12	0.19	0.23
		0.62	2.25	2.15	2.15	2.11	2.26	2.11	1.51	0.84	0.88	1.02	0.95
NO_x, kt	2 B 2 Nitric Acid Production	0.63	0.81	0.61	0.41								
	2 B 5 a Other Chemical industry	0.04	0.04	0.04	0.03	0.03	0.04	0.02	0.02	0.02	0.02	0.02	0.02
		0.67	0.84	0.65	0.45	0.03	0.04	0.02	0.02	0.02	0.02	0.02	0.02
NMVOC, kt	2 A 5 Asphalt Roofing	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01
	2 A 6 Road Paving with Asphalt	0.55	0.55	0.55	0.54	0.55	0.55	0.57	0.56	0.54	0.55	0.56	0.55
	2 A 7 d Other Mineral products	0.01	0.06	0.06	0.06	0.06	0.07	0.07	0.06	0.05	0.04	0.05	0.05
	2 B 5 a Other Chemical industry	0.39	0.49	0.16	0.07	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03
	2 D 2 Food and Drink	4.64	4.77	5.03	4.87	4.91	4.69	4.61	4.52	4.36	4.32	4.24	4.13
		5.60	5.88	5.80	5.56	5.57	5.36	5.29	5.19	4.99	4.94	4.88	4.76
CO, kt	2 A 5 Asphalt Roofing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2 A 6 Road Paving with Asphalt	0.24	0.24	0.24	0.22	0.27	0.27	0.35	0.31	0.19	0.23	0.29	0.24
	2 A 7 d Other Mineral products	10.7	10.8	10.8	11.3	8.5	8.2	9.3	8.4	6.6	0.01	0.01	0.03
		11	11	11	12	8.8	8.5	9.7	8.7	6.8	0.24	0.31	0.28
NH_3, kt	2 A 7 d Other Mineral products	0.49	0.53	0.53	0.50	0.33	0.34	0.35	0.37	0.31	0.31	0.29	0.30
	2 B 2 Nitric Acid Production	0.01	0.01	0.06	0.01								
	2 B 5 a Other Chemical industry	0.01	0.01	0.01	0.01	0.08	0.09	0.11	0.11	0.17	0.12	0.02	0.02
	2 G Other production		0.02	0.03	0.03	0.13	0.10	0.11	0.11	0.09	0.09	0.09	0.08
		0.51	0.58	0.63	0.56	0.55	0.52	0.57	0.60	0.57	0.52	0.40	0.39
TSP, t	2 A 2 Lime Production				30	25	27	26	26	17	18	15	19
	2 A 7 d Other Mineral products				208	207	208	177	167	117	106	120	130
	2 B 2 Nitric Acid Production				362	0	0	0	0	0	0	0	0
	2 B 5 a Other Chemical industry				19	23	12	25	26	16	26	7	6
	2 C 1 Iron and Steel Production				244	203	166	149	146	84	148	170	155
	2 C 3 Aluminium Production				32	28	32	36	27	0	0	0	0
	2 C 5 b Lead Production				2	2	2	2	2	2	2	2	2
	2 C 5 d Zinc Production				1	1	1	1	1	1	1	1	1
					898	489	449	417	396	238	301	314	312
PM_{10}, t	2 A 2 Lime Production				15	13	14	13	13	9	9	7	9
	2 A 7 d Other Mineral products				187	187	188	160	151	109	95	107	116
	2 B 2 Nitric Acid Production				290	0	0	0	0	0	0	0	0
	2 B 5 a Other Chemical industry				15	18	10	20	21	13	21	5	5
	2 C 1 Iron and Steel Production				100	63	52	47	46	26	46	53	48
	2 C 3 Aluminium Production				29	25	29	33	25	0	0	0	0
	2 C 5 b Lead Production				1	1	1	1	1	1	1	1	1
	2 C 5 d Zinc Production				1	1	1	1	1	1	1	1	1
					638	308	295	275	258	159	174	175	180
$PM_{2.5}$, t	2 A 2 Lime Production				3	3	3	3	3	2	2	1	2
	2 A 7 d Other Mineral products				149	146	146	123	117	86	74	84	91
	2 B 2 Nitric Acid Production				217	0	0	0	0	0	0	0	0
	2 B 5 a Other Chemical industry				11	14	7	15	16	10	16	4	4
	2 C 1 Iron and Steel Production				34	11	9	9	8	5	8	9	8
	2 C 3 Aluminum Production				13	11	13	15	11	0	0	0	0
	2 C 5 b Lead Production				1	1	1	1	1	1	1	1	1
	2 C 5 d Zinc Production				0	1	1	1	1	1	1	1	1
					428	186	179	165	157	104	101	100	106

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 producers of mineral wool caused by the establishment of abatement measures. Emissions of SO_2 have decreased due to lower production in the later years of bricks, tiles and expanded clay products.

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

Pollutant	Sector	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012
As, t	2 A 7 d Other Mineral products	0.02	0.02	0.004	0.003	0.003	0.004	0.004	0.02	0.003	0.003	0.002
	2 C 1 Iron and Steel Production	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.02	0.03	0.02
		0.05	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03
Cd, t	2 A 7 d Other Mineral products	0.02	0.02	0.002	0.001	0.001	0.002	0.002	0.001	0.001	0.001	0.001
	2 C 1 Iron and Steel Production	0.05	0.06	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	2 C 5 b Lead Production	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	2 C 5 e Other metal production	0.004	0.004	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
		0.08	0.08	0.04	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02
Cr, t	2 A 7 d Other Mineral products	0.39	0.35	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	2 C 1 Iron and Steel Production	0.12	0.11	0.11	0.11	0.09	0.08	0.08	0.05	0.08	0.09	0.08
		0.51	0.46	0.12	0.12	0.10	0.09	0.09	0.05	0.09	0.10	0.09
Cu, t	2 A 7 d Other Mineral products	0.10	0.10	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01
	2 C 5 b Lead Production	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	2 C 5 e Other Metal production	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		0.14	0.15	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Hg, t	2 A 7 d Other Mineral products	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.004
	2 B 5 a Other Chemical industry	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.001	0.005	0.001	0.013
	2 C 1 Iron and Steel Production	0.14	0.16	0.09	0.07	0.01	0.01	0.01	0.00	0.01	0.01	0.01
		0.15	0.18	0.10	0.08	0.02	0.02	0.02	0.01	0.02	0.02	0.02
Ni, t	2 A 7 d Other Mineral products	0.31	0.28	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	2 C 1 Iron and Steel Production	0.41	0.43	0.19	0.21	0.15	0.14	0.13	0.07	0.13	0.14	0.12
		0.72	0.71	0.20	0.22	0.16	0.15	0.15	0.08	0.14	0.15	0.13
Pb, t	2 A 7 d Other Mineral products	1.16	0.88	0.46	0.25	0.12	0.15	0.13	0.11	0.12	0.11	0.19
	2 C 1 Iron and Steel Production	1.41	1.44	1.17	1.06	0.63	0.57	0.56	0.32	0.56	0.64	0.57
	2 C 5 b Lead Production	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	2 C 5 e Other Metal production	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
		2.65	2.39	1.71	1.38	0.83	0.79	0.77	0.50	0.75	0.83	0.84
Se, t	2 A 7 d Other Mineral products	0.33	0.23	0.34	0.11	0.06	0.05	0.05	0.03	0.02	0.02	0.06
	2 C 1 Iron and Steel Production	0.52	0.45	0.51	0.50	0.41	0.36	0.36	0.21	0.36	0.42	0.38
		0.84	0.68	0.85	0.61	0.47	0.42	0.40	0.23	0.39	0.44	0.45
Zn, t	2 A 7 d Other Mineral products	0.16	0.27	0.25	0.17	0.19	0.22	0.20	0.15	0.15	0.14	0.12
	2 C 1 Iron and Steel Production	5.86	6.69	1.90	1.63	0.58	0.56	0.54	0.29	0.51	0.56	0.49
	2 C 5 e Other Metal production	0.55	0.61	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
		6.57	7.57	2.78	2.44	1.41	1.41	1.37	1.07	1.29	1.34	1.24
PCDD/F, g	2 A 2 Lime Production	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.002
	2 A 7 d Other Mineral products	0.01	0.01	0.02	0.07	0.07	0.07	0.07	0.05	0.05	0.05	0.05
	2 C 1 Iron and Steel Production	12.00	7.50	0.52	0.18	NA	NA	NA	NA	NA	NA	NA
	2 C 3 Aluminium Production	1.74	1.74	1.74	0.03	0.03	0.04	0.03	NO	NO	NO	NO
		13.75	9.25	2.29	0.28	0.11	0.11	0.10	0.05	0.05	0.05	0.05
HCB, kg	2 A 2 Lime Production	0.001	0.001	0..001	0.001	0.001	0.001	0.001	0.0005	0.0005	0.0004	0.0005
	2 A 7 d Other Mineral products	NE	0.01	0.01	0.00	0.01	0.01	0.01	0.004	0.005	0.004	0.004

Continued												
	2 C 1 Iron and Steel Production	1.97	2.30	2.02	0.80	0.003	0.003	0.003	0.002	0.003	0.003	0.003
	2 C 3 Aluminium Production	NE	NE	0.64	0.56	0.65	0.72	0.55	NO	NO	NO	NO
	2 C 5 b Lead Production	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
		1.97	2.31	2.67	1.37	0.66	0.74	0.56	0.01	0.01	0.01	0.01
PCBs, kg	2 A 2 Lime Production	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	2 A 7 d Other Mineral products	NE	0.01	0.01	0.00	0.00	0.01	0.005	0.004	0.004	0.004	0.003
	2 C 1 Iron and Steel Production	1.59	1.84	1.63	0.67	0.04	0.04	0.04	0.02	0.04	0.04	0.04
	2 C 3 Aluminium Production	NE	NE	0.11	0.09	0.11	0.12	0.09	NO	NO	NO	NO
	2 C 5 b Lead Production	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
		1.65	1.90	1.79	0.82	0.21	0.21	0.18	0.07	0.09	0.09	0.09

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 and POPs (e.g. Pb, Zn, PCDD/F, HCB and PCBs).

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 (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 (svovldioxid, kvælstofoxider, andre flygtige organiske forbindelser end metan og ammoniak) 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 (HFCs), perflourkarboner (PFCs), svovlhexafluorid (SF_6), svovldioxid (SO_2), kvælstofoxider (NO_x), andre flygtige organiske forbindelser end metan (NMVOC), kulmonooxid (CO), partikler (PM), ammoniak (NH_3), tungmetaller, dioxiner og furaner (PCDD/F), polycykliske aromatiske kulbrinter (PAHs), hexachlorbenzen (HCB) and polychlorerede biphenyler (PCBs).

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/malinger eller henviser til internationale retningslinjer, f.eks. EMEP/EEA Guidebook og IPCC Guidelines. Hovedparten af de nationale emissionsfaktorer er baseret på forskningsrapporter eller beregner 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.

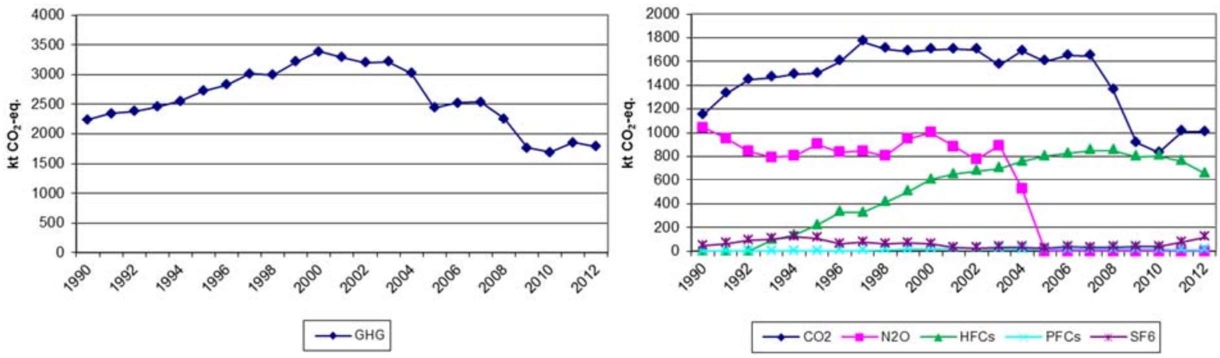
Drivhusgasser

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 2012.

Tabel 0.1 Oversigt over emissionskilder for industrielle processer I 2012.

Proces	IPCC kode	Gas	Emission kton CO_2e.	%
Cementproduktion	2A1	CO_2	871	48,6
Køling og aircondition	2F1	HFCs+PFCs	579	32,4
Andet (laboratorier, termoruder)	2F9	SF_6	105	5,84
Opskumning	2F2	HFCs	66,2	3,70
Produktion af brændt kalk	2A2	CO_2	40,2	2,24
Smøreolie	2G	CO_2	31,7	1,77
Anvendelse af kalksten	2A3	CO_2	25,6	1,43
Teglproduktion	2A7	CO_2	17,5	0,98
Spraydåser/inhalatorer	2F4	HFCs	15,8	0,88
Elektrisk udstyr	2F8	SF_6	13,3	0,74
Produktion af glas og glasuld	2A7	CO_2	9,69	0,54
Produktion af ekspanderet ler	2A7	CO_2	5,89	0,33
Lysledere	2F9	HFCs+PFCs	4,31	0,24
Fødevareproduktion	2D2	CO_2	2,24	0,13
Asfaltering af veje	2A6	CO_2	1,77	0,10
Produktion af katalysatorer	2B5	CO_2	1,41	0,08
Asfaltering af tage	2A5	CO_2	0,019	0,001
Stålproduktion	2C1	CO_2	NO	NO
Salpetersyreproduktion	2B2	N_2O	NO	NO
Total			1 791	100

Samlet udgør mineralske produkter (cement, tegl, kalk, glas) 54 % af drivhusgasemissionen i 2012. F-gasser udgør 44 %, smøreolie udgør 1,8 %, kemisk industri og fødevareindustri udgør hver under 1 % af den total drivhusgasemission fra industrielle processer. Der er ikke nogen drivhusgasemission fra stålproduktion i 2012, da det eneste elektrostålværk i Danmark ikke har været i drift siden 2004. Den totale drivhusgasemission eksklusive emissioner/optag fra arealanvendelse i 2012 er beregnet til 51,6 Mt CO2 ækvivalenter, hvoraf industrielle processer bidrager med 1,79 Mt CO2 ækvivalenter svarende til 3,5 %. Drivhusgasemissionen fra industrielle processer for 1990-2012 er præsenteret i Figur 0.1.



Figur 0.1 Emission af drivhusgasser fra industrielle processer for 1990-2012.

De vigtigste kategorier indenfor industrielle processer er cementproduktion og f-gasser anvendt til køling og aircondition. Disse to kilder udgør henholdsvis 1,69 og 1,12 % 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 Emission af drivhusgaser fra industrielle processer, 1990-2012.

	1990	1995	2000	2005	2008	2009	2010	2011	2012
CO_2 (kt CO_2)									
A. Mineralske produkter	1069	1405	1616	1544	1320	881	796	972	972
B. Kemisk industry	0,80	0,80	0,79	1,06	1,20	1,42	2,12	1,39	1,41
C. Metalproduktion	28,4	38,6	40,7	15,6	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO
D. Fødevareproduktion	4,45	3,91	3,90	4,46	2,67	1,92	1,56	2,01	2,24
G. Andet	49,7	48,8	39,7	37,6	34,0	31,2	33,2	33,2	31,7
Total	1152	1497	1701	1602	1358	915	833	1008	1007
N_2O (kt CO_2e)									
B. Kemisk industry	1043	904	1004	NO	NO	NO	NO	NO	NO
HFCs (kt CO_2e)									
F. Anvendelse af HFC'er, PFC'er og SF6	NE	218	607	802	853	799	804	759	657
PFCs (kt CO_2e)									
F. Anvendelse af HFC'er, PFC'er og SF6	NE	0,50	17,9	13,9	12,8	14,2	13,3	11,1	8,54
SF_6 (kt CO_2e)									
F. Anvendelse af HFC'er, PFC'er og SF6	44,5	107	58,8	21,8	31,6	36,7	37,9	73,2[1]	118

[1] Stigningen i SF_6 emission I 2011 og 2012 skyldes anvendelse af SF6 i termoruder. Anvendelsen startede i 1991 og der antages en levetid på 20 år. Ved skrotning antages det at den resterende mængde SF_6 frigives.

Emissionerne af f-gasser er dokumenteret i rapporten "The greenhouse gases HFCs, PFCs and SF_6. Danish consumption and emissions, 2012" (Poulsen & Musaeus, 2014) og vil ikke blive beskrevet yderligere 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.

		1985	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012
SO_2, kt	2 A 7 d Andre mineralske produkter		1,41	1,53	1,52	1,49	1,88	2,02	1,36	0,73	0,76	0,82	0,72
	2 B 5 a Anden kemisk industri	0,62	0,85	0,62	0,63	0,61	0,38	0,09	0,15	0,11	0,12	0,19	0,23
		0,62	2,25	2,15	2,15	2,11	2,26	2,11	1,51	0,84	0,88	1,02	0,95
NO_x, kt	2 B 2 Salpetersyreproduktion	0,63	0,81	0,61	0,41								
	2 B 5 a Anden kemisk industri	0,04	0,04	0,04	0,03	0,03	0,04	0,02	0,02	0,02	0,02	0,02	0,02
		0,67	0,84	0,65	0,45	0,03	0,04	0,02	0,02	0,02	0,02	0,02	0,02
NMVOC, kt	2 A 5 Asfaltering af tage	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,00	0,01	0,01	0,01
	2 A 6 Asfaltering af veje	0,55	0,55	0,55	0,54	0,55	0,55	0,57	0,56	0,54	0,55	0,56	0,55
	2 A 7 d Andre mineralske produkter	0,01	0,06	0,06	0,06	0,06	0,07	0,07	0,06	0,05	0,04	0,05	0,05
	2 B 5 a Anden kemisk industri	0,39	0,49	0,16	0,07	0,04	0,04	0,04	0,04	0,03	0,03	0,03	0,03
	2 D 2 Fødevareproduktion	4,64	4,77	5,03	4,87	4,91	4,69	4,61	4,52	4,36	4,32	4,24	4,13
		5,60	5,88	5,80	5,56	5,57	5,36	5,29	5,19	4,99	4,94	4,88	4,76
CO, kt	2 A 5 Asfaltering af tage	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	2 A 6 Asfaltering af veje	0,24	0,24	0,24	0,22	0,27	0,27	0,35	0,31	0,19	0,23	0,29	0,24
	2 A 7 d Andre mineralske produkter	10,7	10,8	10,8	11,3	8,5	8,2	9,3	8,4	6,6	0,01	0,01	0,03
		11	11	11	12	8,8	8,5	9,7	8,7	6,8	0,24	0,31	0,28
NH_3, kt	2 A 7 d Andre mineralske produkter	0,49	0,53	0,53	0,50	0,33	0,34	0,35	0,37	0,31	0,31	0,29	0,30
	2 B 2 Salpetersyreproduktion	0,01	0,01	0,06	0,01								
	2 B 5 a Anden kemisk industri	0,01	0,01	0,01	0,01	0,08	0,09	0,11	0,11	0,17	0,12	0,02	0,02
	2 G Øvrige industrielle processer		0,02	0,03	0,03	0,13	0,10	0,11	0,11	0,09	0,09	0,09	0,08
		0,51	0,58	0,63	0,56	0,55	0,52	0,57	0,60	0,57	0,52	0,40	0,39
TSP, t	2 A 2 Produktion af brændt kalk				30	25	27	26	26	17	18	15	19
	2 A 7 d Andre mineralske produkter				208	207	208	177	167	117	106	120	130
	2 B 2 Salpetersyreproduktion				362	0	0	0	0	0	0	0	0
	2 B 5 a Anden kemisk industri				19	23	12	25	26	16	26	7	6
	2 C 1 Jern- og stålproduktion				244	203	166	149	146	84	148	170	155
	2 C 3 Aluminiumsproduktion				32	28	32	36	27	0	0	0	0
	2 C 5 b Blyproduktion				2	2	2	2	2	2	2	2	2
	2 C 5 d Zinkproduktion				1	1	1	1	1	1	1	1	1
					898	489	449	417	396	238	301	314	312
PM_{10}, t	2 A 2 Produktion af brændt kalk				15	13	14	13	13	9	9	7	9
	2 A 7 d Andre mineralske produkter				187	187	188	160	151	109	95	107	116
	2 B 2 Salpetersyreproduktion				290	0	0	0	0	0	0	0	0
	2 B 5 a Anden kemisk industri				15	18	10	20	21	13	21	5	5
	2 C 1 Jern- og stålproduktion				100	63	52	47	46	26	46	53	48
	2 C 3 Aluminiumsproduktion				29	25	29	33	25	0	0	0	0
	2 C 5 b Blyproduktion				1	1	1	1	1	1	1	1	1
	2 C 5 d Zinkproduktion				1	1	1	1	1	1	1	1	1
					638	308	295	275	258	159	174	175	180
$PM_{2.5}$, t	2 A 2 Produktion af brændt kalk				3	3	3	3	3	2	2	1	2
	2 A 7 d Andre mineralske produkter				149	146	146	123	117	86	74	84	91
	2 B 2 Salpetersyreproduktion				217	0	0	0	0	0	0	0	0
	2 B 5 a Anden kemisk industri				11	14	7	15	16	10	16	4	4
	2 C 1 Jern- og stålproduktion				34	11	9	9	8	5	8	9	8
	2 C 3 Aluminiumsproduktion				13	11	13	15	11	0	0	0	0
	2 C 5 b Blyproduktion				1	1	1	1	1	1	1	1	1
	2 C 5 d Zinkproduktion				0	1	1	1	1	1	1	1	1
					428	186	179	165	157	104	101	100	106

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 forbedret procesteknologi. Emissionen af SO_2 er faldet på grund af lavere produktion af tegl og ekspanderede lerprodukter.

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 PCBs) er præsenteret i Tabel 0.4.

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

		1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012
As, t	2 A 7 d Andre mineralske produkter	0.02	0.02	0.004	0.003	0.003	0.004	0.004	0.02	0.003	0.003	0.002
	2 C 1 Jern- og stålproduktion	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.02	0.03	0.02
		0.05	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03
Cd, t	2 A 7 d Andre mineralske produkter	0.02	0.02	0.002	0.001	0.001	0.002	0.002	0.001	0.001	0.001	0.001
	2 C 1 Jern- og stålproduktion	0.05	0.06	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	2 C 5 b Blyproduktion	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	2 C 5 e Øvrig metalproduktion	0.004	0.004	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
		0.08	0.08	0.04	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02
Cr, t	2 A 7 d Andre mineralske produkter	0.39	0.35	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	2 C 1 Jern- og stålproduktion	0.12	0.11	0.11	0.11	0.09	0.08	0.08	0.05	0.08	0.09	0.08
		0.51	0.46	0.12	0.12	0.10	0.09	0.09	0.05	0.09	0.10	0.09
Cu, t	2 A 7 d Andre mineralske produkter	0.10	0.10	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01
	2 C 5 b Blyproduktion	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	2 C 5 e Øvrig metalproduktion	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		0.14	0.15	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Hg, t	2 A 7 d Andre mineralske produkter	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.004
	2 B 5 a Anden kemisk industri	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.001	0.005	0.001	0.013
	2 C 1 Jern- og stålproduktion	0.14	0.16	0.09	0.07	0.01	0.01	0.01	0.00	0.01	0.01	0.01
		0.15	0.18	0.10	0.08	0.02	0.02	0.02	0.01	0.02	0.02	0.02
Ni, t	2 A 7 d Andre mineralske produkter	0.31	0.28	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	2 C 1 Jern- og stålproduktion	0.41	0.43	0.19	0.21	0.15	0.14	0.13	0.07	0.13	0.14	0.12
		0.72	0.71	0.20	0.22	0.16	0.15	0.15	0.08	0.14	0.15	0.13
Pb, t	2 A 7 d Andre mineralske produkter	1.16	0.88	0.46	0.25	0.12	0.15	0.13	0.11	0.12	0.11	0.19
	2 C 1 Jern- og stålproduktion	1.41	1.44	1.17	1.06	0.63	0.57	0.56	0.32	0.56	0.64	0.57
	2 C 5 b Blyproduktion	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	2 C 5 e Øvrig metalproduktion	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
		2.65	2.39	1.71	1.38	0.83	0.79	0.77	0.50	0.75	0.83	0.84
Se, t	2 A 7 d Andre mineralske produkter	0.33	0.23	0.34	0.11	0.06	0.05	0.05	0.03	0.02	0.02	0.06
	2 C 1 Jern- og stålproduktion	0.52	0.45	0.51	0.50	0.41	0.36	0.36	0.21	0.36	0.42	0.38
		0.84	0.68	0.85	0.61	0.47	0.42	0.40	0.23	0.39	0.44	0.45
Zn, t	2 A 7 d Andre mineralske produkter	0.16	0.27	0.25	0.17	0.19	0.22	0.20	0.15	0.15	0.14	0.12
	2 C 1 Jern- og stålproduktion	5.86	6.69	1.90	1.63	0.58	0.56	0.54	0.29	0.51	0.56	0.49
	2 C 5 e Øvrig metalproduktion	0.55	0.61	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
		6.57	7.57	2.78	2.44	1.41	1.41	1.37	1.07	1.29	1.34	1.24
PCDD/F, g	2 A 2 Produktion af brændt kalk	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.002
	2 A 7 d Andre mineralske produkter	0.01	0.01	0.02	0.07	0.07	0.07	0.07	0.05	0.05	0.05	0.05
	2 C 1 Jern- og stålproduktion	12.00	7.50	0.52	0.18	NA	NA	NA	NA	NA	NA	NA
	2 C 3 Aluminiumsproduktion	1.74	1.74	1.74	0.03	0.03	0.04	0.03	NO	NO	NO	NO
		13.75	9.25	2.29	0.28	0.11	0.11	0.10	0.05	0.05	0.05	0.05

		1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012
Continued												
HCB, kg	2 A 2 Produktion af brændt kalk	0.001	0.001	0..001	0.001	0.001	0.001	0.001	0.0005	0.0005	0.0004	0.0005
	2 A 7 d Andre mineralske produkter	NE	0.01	0.01	0.00	0.01	0.01	0.01	0.004	0.005	0.004	0.004
	2 C 1 Jern- og stålproduktion	1.97	2.30	2.02	0.80	0.003	0.003	0.003	0.002	0.003	0.003	0.003
	2 C 3 Aluminiumsproduktion	NE	NE	0.64	0.56	0.65	0.72	0.55	NO	NO	NO	NO
	2 C 5 b Blyproduktion	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
		1.97	2.31	2.67	1.37	0.66	0.74	0.56	0.01	0.01	0.01	0.01
PCBs, kg	2 A 2 Produktion af brændt kalk	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	2 A 7 d Andre mineralske produkter	NE	0.01	0.01	0.00	0.00	0.01	0.005	0.004	0.004	0.004	0.003
	2 C 1 Jern- og stålproduktion	1.59	1.84	1.63	0.67	0.04	0.04	0.04	0.02	0.04	0.04	0.04
	2 C 3 Aluminiumsproduktion	NE	NE	0.11	0.09	0.11	0.12	0.09	NO	NO	NO	NO
	2 C 5 b Blyproduktion	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
		1.65	1.90	1.79	0.82	0.21	0.21	0.18	0.07	0.09	0.09	0.09

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 PCBs).

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).

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 other product use, agriculture, land-use, land-use change and forestry 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
- Identify industrial 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, a systematic effort to identify industrial sources of emissions has not been performed. 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.

The base year for emission inventories and reduction targets depends on the actual substance and protocol covering the substance; see Table 1.1. Some of the sources are not included in the inventory with complete time series due to missing data. These incomplete time series will as far as possible be completed through collecting of the missing data or by introducing relevant emission estimates for the years in question.

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

Table 1.1 Base year for different pollutants.

Substance		Year
Sulphur dioxide	SO_2	1980
Ammonia	NH_3	
Nitrogen oxides	NO_x	1985
Non-Methane VOC	NMVOC	
Carbon dioxide	CO_2	
Methane	CH_4	1990
Nitrous oxide	N_2O	
Heavy metals	Arsenic – As Cadmium – Cd Chromium – Cr Copper – CuMercury – 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
Particulate matter	Total Suspended Particulates (TSP) PM_{10} $PM_{2.5}$	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. The main sectors are:

- Mineral industry
- Chemical industry
- Metal industry
- Other industry
- Production of halocarbons and SF_6
- Consumption of halocarbons and SF_6
- Other

Production of halocarbons and SF_6 is not relevant for Denmark and consumption of halocarbons and SF_6 is documented in a separate report (Poulsen & Musaeus, 2014).

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, 1996, 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 other 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 more scarce.

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}, $PM_{2.5}$, Black Carbon (BC)
- Heavy metals: As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn
- Persistent organic pollutants: PCDD/F, HCB, PCBs, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzon(k)fluoranthene, Indeno(1,2,3-cd)pyrene

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

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

- EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EMEP/CORINAIR, 2004)
- EMEP/EEA air pollutant emission inventory guidebook – 2009 (EMEP/EEA, 2009)
- EMEP/EEA air pollutant emission inventory guidebook 2013 (EMEP/EEA, 2013)

In future inventories, work will be undertaken to update references to the earlier editions of the guidebook with the most recent edition.

2.3 IPCC guidelines

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

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

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

- Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1996), hereafter the 1996 IPCC guidelines
- 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

From the 2015 reporting all references to the 1996 IPCC guidelines and the IPCC GPG will be updated to 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 is included in Table 2.1 below. Indicated in the table are the activities that are relevant in Denmark.

Table 2.1 List of activities included in the European Union Emission Trading Scheme.

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 tonnes 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 tonnes per day or in other furnaces with a production capacity exceeding 50 tonnes 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 tonnes per day	CO_2	X
Manufacture of glass including glass fibre with a melting capacity exceeding 20 tonnes 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 tonnes per day	CO_2	X
Manufacture of mineral wool insulation material using glass, rock or slag with a melting capacity exceeding 20 tonnes 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 tonnes 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 tonnes per day	CO_2	
Production of hydrogen (H_2) and synthesis gas by reforming or partial oxidation with a production capacity exceeding 25 tonnes 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 plants have closed while others have been opened. 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 2.2 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 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.

Table 2.2 List of plants included in the European Union Emission Trading Scheme with process emissions in 2012.

Plant	Plant type
Shell Raffinaderiet Fredericia	Refining of mineral oil
Aalborg Portland A/S	Production of cement clinker
Vattenfall A/S Fynsværket	Combustion installation
Grenå Kraftvarmeværk	Combustion installation
Studstrupværket	Combustion installation
Avedøreværket	Combustion installation
Asnæsværket	Combustion installation
Stigsnæsværket	Combustion installation
Vattenfall A/S Amagerværket	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
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
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. flue gas desulphurisation at waste incineration plants, 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 can 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 products (CRF and NRF 2A) cover the following industries relevant for the Danish air emission inventory:

- Cement production; see section 3.1
- Lime production; see section 3.2
- Limestone and dolomite use; see section 3.3
- Asphalt roofing; see section 3.4
- Road paving with asphalt; see section 3.5
- Other; see section 3.6

3.1 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)

3.1.1 Process description

The primary raw materials (e.g. virgin raw materials) are sand, chalk and water. A number of 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 be 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. The sand is ground in a sand mill. The main secondary raw materials (e.g. 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, 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 carbon dioxide (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 low-S oil, 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 (e.g. CO_2 originating from fossil sources). The emissions that are related to combustion are not included in this report.

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 i.e. the alkaline environment in the rotary kiln acts as a flue gas cleaning system (especially for acid gasses and certain heavy metals).

3.1.2 Methodology

The overall process for calcination is:

$$CaCO_3 \rightarrow CaO + CO_2$$

The emission factor for CO_2 from the calcination process expressed per tonne of cement depends on the actual input of chalk/limestone in the process. The company has stated an emission factor at 0.538 tonne CO_2 per tonne product (Aalborg Portland, 1999.

The supply of cement clinker, grey and white cement in Denmark is shown in Table 3.1. However, the mass balance is incomplete due to missing information. The missing information may probably be explained by confidentiality as the statistics can be kept confidential, if there are fewer than three producers.

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

Table 3.1 Production, import, export and supply of cement, tonne (Statistics Denmark, 2013).

Year		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cement clinker[1]	Prod.	NI	NI	NI	NI	NI	NI	NI	139 062	119 465	111 916
	Import	404	271	29	448	176	8	150	11	221	NI
	Export	17 038	42 708	23 574	40 419	185 167	186 979	213 703	NI	NI	NI
	Supply	-16 634	-42 438	-23 545	-39 971	-184 991	-186 971	-213 552	139 073	119 686	111 916
Portland cement, white	Prod.	411 653	397 831	426 133	492 276	492 117	531 215	576 030	529 109	536 629	562 833
	Import	NI	NI	48	830	1406	24	43	729	3197	9906
	Export	91 132	179 759	141 990	NI	NI	NI	NI	NI	NI	NI
	Supply	320 521	218 072	284 191	493 106	493 523	531 239	576 073	529 838	539 826	572 739
Portland cement, grey	Prod.	1 244 256	1 621 448	1 645 948	1 778 189	1 935 319	2 052 705	2 052 498	2 014 868	2 011 073	1 859 299
	Import	115 452	173 512	115 739	73 531	NI	NI	NI	NI	NI	NI
	Export	19 387	212 624	377 494	468 692	405 560	332 390	232 873	NI	NI	NI
	Supply	1 340 321	1 582336	1 384 192	1 383 028	1 529 759	1 720 315	1 819 625	2 014 868	2 011 073	1 859 299

Year		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cement clinker[1]	Prod.	102 719	102 571	152 636	61 909	52 758	42 691	5499	21 209	16 092	122
	Import	NI	NI	3555	27 199	22 688	31 331	43 523	39 776	42 480	32 444
	Export	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
	Supply	102 719	102 571	156 191	89 108	75 446	74 022	49 022	60 985	58 572	32 566
Portland cement, white	Prod.	551 072	531 696	509 946	581 914	679 434	714 626	796 870	722 310	607 143	462 377
	Import	8299	30	135	830	5288	15 438	16 566	18 670	33 082	29 423
	Export	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
	Supply	559 371	531 726	510 081	582 744	684 722	730 064	813 436	740 980	640 225	491 800
Portland cement, grey	Prod.	1 984 976	2 043 787	2 034 823	1 998 341	2 213 346	2 165 928	2 140 262	2 149 092	1 931 679	1 116 237
	Import	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
	Export	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
	Supply	1 984 976	2 043 787	2 034 823	1 998 341	2 213 346	2 165 928	2 140 262	2 149 092	1 931 679	1 116 237

Year		2010	2011	2012
Cement clinker[1]	Prod.	3819	25	24 256
	Import	21 391	29 106	24 442
	Export	NI	NI	NI
	Supply	25 210	29 131	48 698
Portland cement, white	Prod.	481 507	514 389	495 886
	Import	24 152	28 414	24 645
	Export	NI	NI	NI
	Supply	505 659	542 803	520 531
Portland cement, grey	Prod.	1 085 117	1 338 415	1 321 447
	Import	159 923	213 930	182 473
	Export	NI	NI	NI
	Supply	1 245 040	1 552 345	1 503 920

Cement clinker for sale.

NI No information.

Production statistics and implied emission factors are presented in Table 3.2. Description on how the CO_2 emission has been determined is given below the table.

Table 3.1 Production statistics and implied emission factors for CO_2 for cement production.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Tonnes TCE[6]	1 619 976	1 998 674	2 214 104	2 244 329	2 242 409	2 273 775	2 418 988	2 718 923	2 754 405	2 559 575
Tonnes clinker	NI	NI	NI	NI	NI	NI	NI	NI	2 462 249	2 387 282
Tonnes clinker + white cement[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	-	-
EF tonnes CO_2 per tonnes TCE[2]	0.545	0.544	0.539	0.537	0.532	0.529	0.530	0.530	0.505	-
EF tonnes CO_2 per tonnes TCE[3]	-	-	-	-	-	-	-	-	0.505	0.529
EF tonnes CO_2 per tonnes TCE[4]	-	-	-	-	-	-	-	-	-	-
EF tonnes CO_2 per tonnes clinker[4,5]	*0.628*	0.600	0.571	0.569	0.544	0.512	0.517	0.580	0.564	0.568

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Tonnes TCE[6]	2 612 721	2 660 972	2 698 459	2 546 295	2 861 471	2 706 371	2 842 282	2 946 294	2 551 346	1 663 126
Tonnes clinker	2 452 394	2 486 146	2 508 415	2 363 610	2 611 617	2 520 788	2 632 112	2 706 048	2 269 687	1 493 230
Tonnes clinker + white cement[1]	-	-	-	-	-	-	-	-	-	-
EF tonnes CO_2 per tonnes TCE[2]	-	-	-	-	-	-	-	-	-	-
EF tonnes CO_2 per tonnes TCE[3]	0.530	0.517	0.529	0.532	0.510	-	-	-		
EF tonnes CO_2 per tonnes TCE[4]	-	-	-	-	-	0.504	0.491	0.478		
EF tonnes CO_2 per tonnes clinker[4,5]	0.565	0.558	0.565	0.563	0.559	0.541	0.530	0.520	0.509	0.512

Year	2010	2011	2012
Tonnes TCE[6]	1 454 043	1 766 561	1 818 293
Tonnes clinker	1 313 654	1 582 023	1 628 506
Tonnes clinker + white cement[1]	-	-	-
EF tonnes CO_2 per tonnes TCE[2]	-	-	-
EF tonnes CO_2 per tonnes TCE[3]	-	-	-
EF tonnes CO_2 per tonnes TCE[4]	-	-	-
EF tonnes CO_2 per tonnes clinker[4,5]	0.512	0.545	0.535

[1] 1990-1997: Amount of clinker produced has not been measured as for 1998-2008. Therefore, the amount of GKL- (rapid cement), FHK- (basis cement), SKL-/RKL- (low alkali cement) clinker and white cement is used as estimate of total clinker production.

[2] 1990-1997: EF based on information provided by Aalborg Portland, 2005.

[3] 1998-2004: EF based on information provided by Aalborg Portland (Aalborg Portland, 2008).

[4] 2005-2012: EF based on emissions reported to EU-ETS (Aalborg Portland, 2013a and previous versions).

[5] 1998-2012: EF based on clinker production statistics provided by Aalborg Portland (Aalborg Portland, 2013c).

[6] Aalborg Portland (2013b).

EF Emission factor.

NI No information.

1990-1997

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 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/FHK-clinker/SKL-RKL-clinker. The ratio white/grey cement is known from 1990-1997 with maximum in 1990 and thereafter decreasing. The ratio: GKL-clinker/FHK-clinker/SKL-RKL-clinker is known from 1990-1997. 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.

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

M_{grey}	Grey cement	Tonne
M_{white}	White cement	Tonne
M_{GLK}	GKL clinker (rapid cement)	Tonne
M_{FKH}	FHK clinker (basis cement)	Tonne
$M_{SKL/RKL}$	SKL/RKL clinker (low alkali cement)	Tonne
EF_{white}	CO_2 emission factor	0.669 tonne CO_2/tonne white cement
EF_{GLK}	CO_2 emission factor	0.477 tonne CO_2/tonne GLK clinker
EF_{FKH}	CO_2 emission factor	0.459 tonne CO_2/tonne FKH clinker
$EF_{SKL/RKL}$	CO_2 emission factor	0.610 tonne CO_2/tonne 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 (Aalborg Portland, 2008).

2005-2012

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, 2013a). The reporting to EU-ETS also provides detailed information of alternative fuels used in the production of clinker; see Table 3.3.

Table 3.3 Alternative fuels used in production of cement clinker (Aalborg Portland 2013a).

Fuel type	Biomass fraction, %
Cemmiljø fuel	30-56
Paper residues	79
Dry wastewater sludge	100
Meat and bone meal	100
Tyre residues	15
Wood waste	100
Garden waste	100
Glycerine	100

The company reporting to the EU ETS applies the following EFs for the most important raw materials (Aalborg Portland 2013a):

Table 3.4 Emission factors for raw materials.

Raw material	tonne CO_2 per tonne raw material
Limestone	0.44
Magnesium carbonate	0.522
Sand	0.0088-0.0367
Fly ash	0.140
Cement Kiln Dust (CKD)	0.396-0.525

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

The CO_2 implied emission factor in 1990 is markedly higher than for the remaining time-series. This is caused by a very high share of white cement produced in this year. The share of white cement decreases significantly through the early part of the 1990s causing the implied emission factor 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).

The emissions of heavy metals are measured in 1997 (Illerup et al., 1999) – see Table 3.5. 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 3.5 Emission factors for heavy metals (Illerup et al., 1999).

As	mg/tonne	20
Cd	mg/tonne	7
Cr	mg/tonne	10
Cu	mg/tonne	10
Hg	mg/tonne	0.06
Ni	mg/tonne	20
Pb	mg/tonne	10
Se	mg/tonne	7
Zn	mg/tonne	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. The references for the emission factors are unclear and will be investigated further.

3.1.3 Emission trends

The emission trend for the CO_2 emission from cement production is presented in Table 3.6.

Table 3.6 CO_2 emission for cement production, tonne.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2	882 402	1 087 816	1 192 336	1 206 093	1 192 196	1 203 777	1 282 064	1 441 029	1 389 830	1 354 876
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2	1 385 260	1 387 852	1 416 300	1 329 911	1 458 926	1 363 377	1 395 466	1 407 086	1 154 749	764 407
Year	2010	2011	2012							
CO_2	672 224	861 805	871 083							

The increase in CO_2 emission is most significant for the production of cement until 2007; followed by a significant decline from 2007-2010 due to reduced production resulting from the economic recession caused by the global financial crisis. The emissions increased in 2011 and 2012, but the emissions are still far below the pre-recession levels. The overall development in the CO_2 emission from 1990 to 2012 is a decrease from 882 to 871 kt CO_2, i.e. by 1.3 %. The maximum emission occurred in 2004 and constituted 1 459 kt CO_2; see Figure 3.1. The increase from 1990 to 1997 can be explained by the increase in the annual cement production.

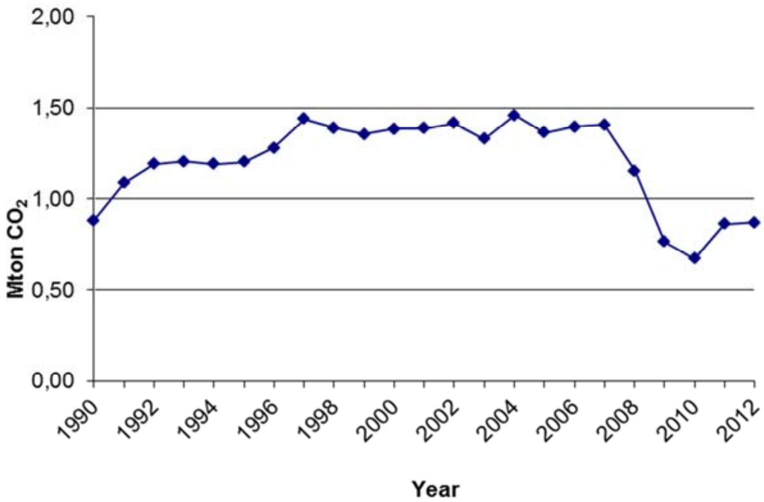


Figure 3.1 Emission of CO_2 from cement production.

3.1.4 Input to emission database (CollectER)

The input data/data sources are presented in Table 3.7.

Table 3.7 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	Aalborg Portland (1998)
	1998-2012	Cement equivalents	Aalborg Portland (2013b)
	1998-2012	Clinker produced	Aalborg Portland (2008; 2013c)
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	Henrik M. Thomsen, Aalborg Portland/Aalborg Portland (2003)
	1998-2004	CO_2	Aalborg Portland (2008)
	2005-2012	CO_2	Aalborg Portland (2013a)

3.1.5 Future improvements

The company is proposed to be contacted regarding new emission measurements of heavy metals.

It will be considered to estimate emissions of all POPs using emission factors based on the clinker production rather than the fuel consumption data.

The emission factors for particulate matter and PCDD/F will be assessed and properly referenced.

3.2 Lime production

The production of limestone and lime/burned lime/quicklime is located at a few localities: Faxe Kalk (Lhoist group) situated in Faxe, Scandinavian Calcium Oxide ApS situated in Støvring, dankalk A/S situated in Løgstør with limestone quarries/limeworks in Aggersund, Mjels, Poulstrup and Batum. 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 relevant for the lime production process:

- CO_2
- TSP
- PM_{10}
- $PM_{2.5}$

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

Use of limestone in other processes can also result in emission of CO_2. Table 3.8 presents different Danish producers, different products and product quality/chemical composition.

Table 3.8 Danish producers of lime products.

Producer	Product	Purity[1]
dankalk A/S[2]	Lime	96.5% CaO
	Hydrated lime	86.7% $Ca(OH)_2$, 1.4% H_2O
Faxe Kalk A/S[3]	Lime	94-96% CaO
(Lhoist Group)	Hydrated lime	91% $Ca(OH)_2$, 0.8% H_2O
	Slaked lime	91% $Ca(OH)_2$, 25/35% H_2O
Scandinavian Calcium	Lime	ni
Oxide Aps	Hydrated lime	ni

[1] Purity given in product data sheets.
[2] dankalk A/S.
[3] Faxe Kalk (2003).
ni no information.

The chemical composition for lime (average for different products), hydrated lime (average for different products) and slaked lime are used for calculation of a correction factor taking into account the content of impurities etc.

Consumption of limestone in specific processes - with emission of CO_2 - will be described in relation to the processes. The relevant processes are:

- Flue gas cleaning at combined heat and power (CHP) plants; see section 3.3.1
- Container glass; see section 3.6.1
- Glass wool; see section 3.6.2
- Mineral wool; see section 3.3.2
- Sugar refining; see section 0

3.2.1 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.

3.2.2 Methodology

Activity data

The CO_2 emission from the production of burnt lime (quicklime) as well as hydrated lime (slaked lime) has been estimated from the annual production figures, registered by Statistics Denmark – see Table 3.9 and emission factors.

Table 3.9 Statistics for production of lime and slaked lime, tonne (Statistics Denmark, 2013).

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Lime	127 978	86 222	104 526	106 587	112 480	100 789	95 028	102 587	88 922	95 177
Slaked lime	27 686	27 561	23 821	17 559	14 233	15 804	13 600	12 542	8 445	7 654
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Lime	92 002	96 486	122 641	87 549	77 844	71 239	78 652	75 504	74 981	46 202
Slaked lime	8 159	9 012	12 006	11 721	12 532	13 839	13 731	14 028	12 326	12 842
Year	2010	2011	2012							
Lime	50 397	59 430	69 136							
Slaked lime	11 173	13 264	13 388							

Plant specific activity data only exist for one company (Faxe Kalk) that constitutes about 75% of the Danish activity; see Table 3.10. The plant specific data are available back to 1995.

Table 3.10 Production statistics for Faxe Kalk/Lhoist Group, tonne (Faxe Kalk, 2013b).

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Lime						46 340			71 480	76 348
Slaked lime						12 354			6 912	7 544
Total production (total lime)							87 431	99 239		
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Lime	62 489	70 537	69 827	63 258	64 085	57 302	62 817	57 006	57 812	38 349
Slaked lime	8 053	8 053	11 610	11 255	12 710	13 731	13 593	12 276	12 283	12 715
Year	2010	2011	2012							
Lime	25 623	21 312	29 798							
Slaked lime	11 785	10 267	10 403							

Statistics Denmark has initially been chosen as data source to ensure consistent data throughout the period from 1990, however, after EU-ETS data has become available from 2006, the company specific production data has been included in order to adjust the data from Statistics Denmark only to cover producers not covered by EU-ETS.

Emission factors

Emission factors are developed for:

- CO_2
- TSP
- PM_{10}
- $PM_{2.5}$

The emission factors for calcination of carbonates are based on stoichiometric relations. Examples on emission factors are presented in Table 3.11.

Table 3.11 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
			Hydrated lime/slaked lime	$Ca(OH)_2$		0.5940
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 applied emission factor for high-calcium lime is 0.7857 kg CO_2 per kg high-calcium lime produced. This is based on a simplified stoichiometric calculation and will be changed to the emission factor shown in Table 3.11 in the 2015 inventory submission.

The applied emission factor for hydrated lime is 0.541 kg CO_2 per kg hydrated lime. The emission factor is calculated from company information on composition of hydrated lime (Faxe Kalk, 2003).

The 2006 IPCC guidelines provide Tier 1 emission factors for lime, hydraulic lime, and dolomitic lime; see Table 3.12. Dolomitic lime is not produced in Denmark.

Table 3.12 Basic parameters for calculation of emission factors for lime products.

Lime type	Stoichiometric ratio tonne CO_2/tonne CaO or CaO.MgO	Range of CaO content %	Range of MgO content %	Default value for CaO or CaO.MgO content	Default emission factor tonne CO_2/tonne
High-calcium lime	0.785	93-98	0.3-2.5	0.95	0.75
Dolomitic lime	0.913	55-57	38-41	0.95 or 0.85	0.86 or 0.77
Hydraulic lime	0.785	65-92	na	0.75	0.59

The emission factors for TSP, PM_{10}, and $PM_{2.5}$ are based on process conditions including pollution abatement equipment. Emission factors based on one Danish plant are compared with emission factors provided by the guidebook below.

Emissions of TSP at Faxe Kalk A/S, Lhoist Group are presented in Table 3.13.

Table 3.13 TSP emission factor at Faxe Kalk A/S, Lhoist Group (Faxe Kalk, 2013b).

Year		2000	2001	2002	2003	2004	2005	2006	2007	2008
Flue gas	m^3	nd	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	42	40	31.5	26.1	23	23.8	7	20
TSP emission	g	nc	6.64E+06	9.00E+06	8.47E+06	7.07E+06	5.04E+06	5.55E+06	1.48E+06	5.70E+06
Activity	tonne	70 542	78 590	81 437	74 513	76 795	71 033	76 410	69 282	70 095
EF TSP	g/tonne	nc	84.4	111	114	92.1	70.9	72.6	21.3	81.3

nd Not detected.
nc Not calculated.
ni No information.

The average emission factor for the years 2001-2008 is 80.9 g TSP/tonne lime. The emission factors for PM_{10} and $PM_{2.5}$ is assumed to be a fixed fraction of the emission factor for TSP (e.g. 50% and 10% respectively – see Table 3.14).

The emission factors provided by the EMEP/EEA guidebook and CEPMEIP are presented in Table 3.14.

Table 3.14 Emission factors for TSP, PM_{10}, and $PM_{2.5}$, g per tonne lime.

Level	TSP	PM_{10}	$PM_{2.5}$	Reference	Comment
Low	300	150	30	CEPMEIP	Applied in Danish inventory
Medium	500	200	40	CEPMEIP	
Medium high	500	200	40	CEPMEIP	
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	

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

3.2.3 Emission trends

The emission trend for the emission of CO_2 is presented in Table 3.15 and Figure 3.2. The emission trend for TSP, PM_{10}, and $PM_{2.5}$ is presented in Table 3.3.

Table 3.2 Emission of CO_2 from lime production, tonne.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Lime	100 552	67 745	82 126	83 745	88 376	79 190	74 663	80 603	69 866	74 781
Slaked lime	14 978	14 911	12 887	9499	7700	8550	7358	6785	4569	4141
Total	115 530	82 655	95 013	93 245	96 076	87 740	82 021	87 388	74 435	78 921
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Lime	72 286	75 809	96 359	68 787	61 162	55 972	61 797	59 323	58 913	36 301
Slaked lime	4414	4875	6495	6341	6780	7487	7428	7589	6668	6948
Total	76 700	80 685	102 854	75 128	67 942	63 459	69 225	66 913	65 581	43 248

Year	2010	2011	2012
Lime	39 597		
Slaked lime	6045		
Total	45 642	29 818	40 166

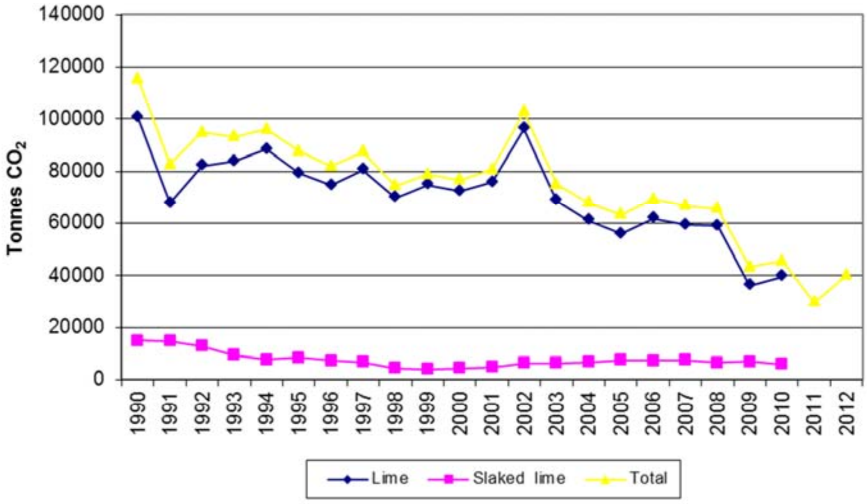


Figure 3.1 Emission trends for emission of CO_2 from production of lime and slaked lime.

Table 3.3 Emission of TSP, PM_{10}, and $PM_{2.5}$ from lime production, tonne.

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TSP	30.0	31.6	40.4	29.8	27.1	25.5	27.7	26.9	26.2	17.7
PM_{10}	15.0	15.8	20.2	14.9	13.6	12.8	13.9	13.4	13.1	8.86
$PM_{2.5}$	3.00	3.16	4.04	2.98	2.71	2.55	2.77	2.69	2.62	1.77

Year	2010	2011	2012
TSP	18.5	21.8	24.8
PM_{10}	9.2	10.9	12.4
$PM_{2.5}$	1.8	2.2	2.5

3.2.4 Input to CollectER

The input data/data sources are presented in Table 3.17.

Table 3.17 Input data for calculating emissions from production of lime and slaked lime.

	Year	Parameter	Comment/Source
Emissions	1990-2012	CO_2	Stoichiometric relations combined with product information from one company
	2011-2012	CO_2	Faxe Kalk (2013a)
	2000-2012	TSP, PM_{10}, $PM_{2.5}$	CEPMEIP

3.2.5 Future improvements

EU-ETS data for the years 2006 to 2010 will be included.

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.

Currently, an emission of PCDD/F has been estimated and reported for lime production. However, the basis of the emission factor is unclear. In literature there also is no indication that there are process emissions of PCDD/F from lime production. Therefore, this will be corrected in future submissions.

3.3 Limestone and dolomite use

The sub-sector *Limestone and dolomite use* cover the following processes relevant for the Danish air emission inventory:

- Flue gas cleaning at coal fired plants; see 3.3.1
- Flue gas cleaning at waste incineration plants; see section 3.3.1
- Production of mineral wool; see section 3.3.2

3.3.1 Flue gas cleaning

Flue gas cleaning systems utilising different technologies are primarily present at major combustion plants i.e. power plants, combined heat and power plants 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

Basically, the activity data are the consumed amount of limestone. However, this information is only partly available especially before implementation of the mandatory environmental reports. Implementation of the EU-ETS has facilitated the collection of activity data as some of the plants in question are included in the ETS.

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

The chemistry of the wet flue gas cleaning methodologies is presented below.

Wet flue gas cleaning

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

$$SO_2\ (g) + \tfrac{1}{2}O_2\ (g) + CaCO_3\ (s) + 2H_2O\ (l) \rightarrow CaSO_4{,}2H_2O\ (s) + CO_2\ (g)$$

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 desulphurization, to reduce the consumption of calcium carbonate, and to produce gypsum of saleable quality. From the equation the emission factor can be calculated to:

- 0.2325 tonne CO_2/tonne gypsum

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

Activity data - i.e. generation of gypsum - for power plants and waste incineration plants respectively have to be obtained from different statistics. The Danish power plants (via the system responsible company) are unified in Energinet.dk, which compile environmental information related to energy transformation and distribution. Regarding waste incineration no statistics deals with generation of gypsum, however, combination of statistics on amount of waste incinerated, distribution of flue gas cleaning types, and generation of gypsum per incinerated amount of waste can be used to estimate the amount of gypsum generated from waste incineration.

Power plants

The power plants equipped with wet flue gas cleaning are:

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

The majority of these plants is or has 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.

The applied activity data: production of gypsum as well as consumption of limestone and TASP is shown in Table 3.18.

The emission factor applied when using limestone consumption as activity data is the stoichiometric emission factor presented in Table 3.11.

Table 3.4 Activity data for flue gas cleaning at CHP; produced amount of gypsum as well as consumed amount of lime and TASP, tonne.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Gypsum prod.[1]	41 600	82 000	90 480	121 647	209 405	211 479	348 110	346 704	350 356	381 659
Limestone cons.[2]									193 677	193 361
TASP cons.[2]									0	0

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Gypsum prod.[1]	354 316	355 669	331 729	283 392	237 748	220 426	296 417			
Limestone cons.[2]	194 718	176 387	160 148	151 784	111 534	89 892	133 523	92 124	67 984	68 893
TASP cons.[2]	26 122	45 579	40 735	33 049	33 240	51 829	57 061	43 099	24 455	21 925

Year	2010	2011	2012
Gypsum prod.[1]			
Limestone cons.[2]	79 017	61 795	26 895
TASP cons.[2]	25 663	16 765	18 830

1 Energinet.dk (2007).

2 Environmental reports for the power plants.

Waste incineration

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

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

Information on generation of gypsum at waste incineration plants do not appear explicit in the Danish waste statistics (Miljøstyrelsen, 2012), however, the total amount of waste products generated can be found in the statistics. Distribution and development in flue gas cleaning systems at waste incineration plants from 1990 until now is presented in Table 3.19.

Table 3.19 Distribution of flue gas cleaning systems in waste incineration plants.

	Other processes	Dry flue gas cleaning	Semi-dry flue gas cleaning	Wet flue gas cleaning
1990[1]	0.79	0.09	0.10	0.02
1996[1]	0.02	0.16	0.32	0.50
2000[2]	0	0.06	0.24	0.70

1 Illerup et al. (1999).

2 Nielsen & Illerup (2003).

Information on distribution of flue gas cleaning systems has to be combined with information on generation of waste from the different cleaning systems; see Table 3.20.

Table 3.20 Generation of waste per amount of incinerated waste, tonne/tonne waste (Hjelmar & Hansen, 2002).

	Dry flue gas cleaning	Semi-dry flue gas cleaning	Wet flue gas cleaning
Fly ash	0.01-0.03	0.01-0.03	0.01-0.03
Residue including fly ash	0.02-0.05	0.015-0.04	
Gypsum			0.001-0.003

Table 3.21 present the amount of waste incinerated, the amount of waste incinerated at plants with flue gas cleaning, wet process, and amount of gypsum generated calculated by the factors presented in Table 3.19 and Table 3.20. A linear increase of generation of gypsum has been assumed for the years where no data is available.

Table 3.21 Activity data for flue gas cleaning at CHP; amount of waste incinerated, - with wet flue gas cleaning, produced amount of gypsum as well as consumed amount of limestone, tonne.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Waste incinerated	1 809 790						2 507 000		2 740 000	
- with wet flue gas cleaning	42 700						1 261 884		1 915 808	
Gypsum produced[1]	85.4	*492*	898	*1305*	*1711*	*2117*	2524	*3178*	3832	*4058*
Limestone consumed[2]										
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Waste incinerated	3 064 000		3 344 000	3 287 000	3 437 000	3 473 000	3 489 000	3 584 000	3 590 000	3 590 000
- with wet flue gas cleaning	2 142 349		2 338 125	2 298 270	2 403 150	2 428 322	2 439 509	2 505 933	2 510 128	2 510 128
Gypsum produced[1]	4285	*4480*	4676	4597	4806	4857	4879	5012	5020	5020
Limestone consumed[2]								12 215	12 807	11 581
Year	2010	2011	2012							
Waste incinerated										
- with wet flue gas cleaning										
Gypsum produced[1]										
Limestone consumed[2]	12 098	12 903	12 791							

Emission trend

The emission trend for CO_2 emitted from flue gas cleaning at CHP plants not combusting waste is presented in Table 3.22. Figure 3.3Figure 3.3 compare emissions based on different sets of activity data and show a good correlation between the different methodologies.

Table 3.22 Emission of CO_2 from wet flue gas cleaning at CHP, tonne.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Calculated from gypsum	9 672	19 065	21 037	28 283	48 687	49 169	80 935	80 609	81 458	88 736
Calculated from lime/TASP									85 160	85 021
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Calculated from gypsum	82 378	82 693	77 127	65 889	55 276	51 249	68 917			
Calculated from lime/TASP	87 915	81 566	74 000	69 646	51 965	44 084	63 728	44 297	32 043	32 221
Year	2010	2011	2012							
Calculated from gypsum										
Calculated from lime/TASP	37 001	28 646	13 482							

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.

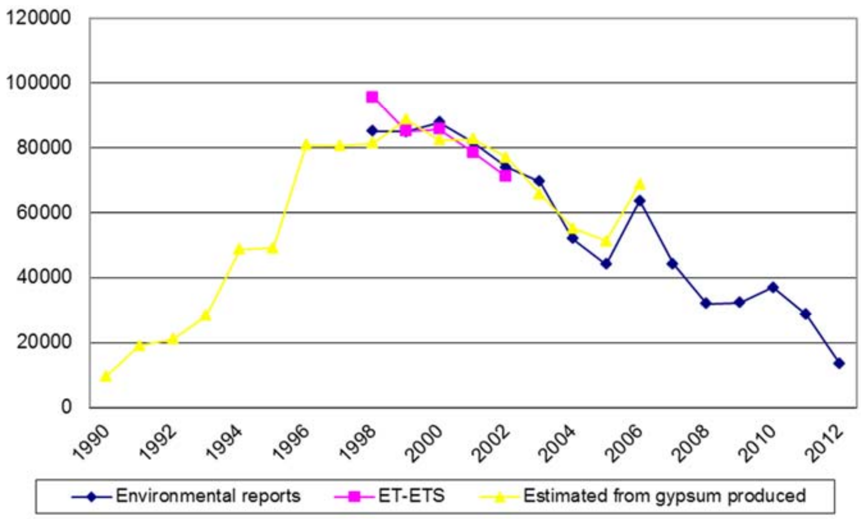


Figure 3.3 Emission trends for emission of CO_2 from flue gas cleaning at CHP. The CO_2 emissions are calculated with different methodologies.

The emission trend for CO_2 emitted from flue gas cleaning at waste incineration plants is presented in Table 3.23 and Figure 3.4.

Table 3.23 Emission of CO_2 from wet flue gas cleaning at waste incineration plants, tonne.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Calculated from gypsum	19.9	114	209	303	398	492	587	739	891	944
Calculated from lime										

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Calculated from gypsum	996	1042	1087	1069	1117	1129	1134	1165	1167	1167
Calculated from lime								5371	5631	5092

Year	2010	2011	2012
Calculated from gypsum	1167		
Calculated from lime	5320	5673	5624

Figure 3.4 shows a significant difference between the two applied methodologies as the emission trend based on information in environmental reports are approximately five times as high as the emission trend based on incinerated waste/gypsum produced.

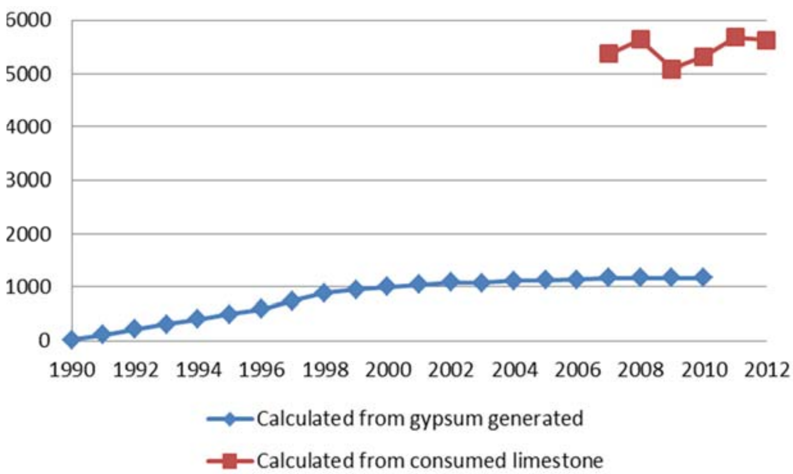


Figure 3.4 Emission trends for emission of CO_2 from flue gas cleaning at waste incineration plants.

A part of an explanation may be that e.g. KommuneKemi (incinerating hazardous waste) is not included in the statistics on incinerated waste in general. Furthermore, it is not always clear whether the waste incineration plants use limestone ($CaCO_3$), burnt lime or hydraulic lime ($CaO/Ca(OH)_2$) in their flue gas cleaning equipment.

Input to CollectER

The input data/data sources are presented in Table 3.24.

Table 3.24 Input data for calculating emissions from flue gas desulphurisation.

	Year	Parameter	Comment/Source
Activity data	1990, 1994, 1996, 1998, 2000, 2002-2004	Waste incinerated	Illerup et al. (1999); Miljøstyrelsen (2012)
	1990, 1996, 2000	Flue gas cleaning system	Illerup et al. (1999); Nielsen & Illerup (2003).
		Gypsum generation	Hjelmar & Hansen (2002)
	1990-2006	Gypsum generation, power plants	Energinet.dk (2007)
	2007-2012	Limestone consumed	Environmental reports from waste incineration plants
	1998-2012	Limestone consumed	Environmental reports from CHP
Emission	1990-2004	CO_2	Estimated by use of stoichiometric emission factor

Future improvements

The environmental reports for previous years will be further analysed in order to establish better information on the character of the flue gas cleaning systems and thereby the consumption of lime/limestone.

Also, alternative methods will be investigated, e.g. developing a factor for limestone consumption per tonne of waste incinerated and applying this factor to the years when limestone consumption is not available.

3.3.2 Mineral wool

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

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

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 %.

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

Methodology

Information on emissions from some years has in combination with yearly energy consumption been used to extrapolate the emissions to other years. The data have been extracted from company reports (Rockwool, 2013b) and reports to PRTR. EF_{CO2} has been established from preliminary company reporting to Danish Energy Agency (DEA, 2004) and energy consumption. From 2006 the CO_2 emission has been obtained from the company reports to the EU ETS (Rockwool, 2013a).

Measured emissions of NMVOC, CO, NH_3 and particulate matter are available for the whole time-series (base year to latest historic year). For PCDD/F, the inventory is based on measured emissions since 2004, before that the emission is calculated based on emission factors for the fuel consumption.

Emission trend

The emission trends for emission of CO_2, CO, NH_3, TSP, PM_{10}, and $PM_{2.5}$ from production of mineral wool at three (from 2006 two) locations are presented in Table 3.25.

Table 3.5 Emissions from production of mineral wool, tonne.

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
CO_2										
CO						10 750	10 750	10 750	10 750	10 750
NH_3						265	265	265	265	265
NMVOC						12.5	12.5	12.5	12.5	12.5
TSP										
PM_{10}										
$PM_{2.5}$										

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
CO	10 750	10 750	10 750	10 750	10 750	10 750	10 233	10 817	11 665	11 886
NH_3	265	265	265	265	265	265	251	265	286	292
NMVOC	12.5	12.5	12.5	12.5	12.5	12.5	11.8	12.4	13.4	13.7
TSP										
PM_{10}										
$PM_{2.5}$										

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2	4000	4000	4000	3996	4806	6334	2595	2250	3036	3805
CO	11 281	10 590	9163	8137	9218	8514	8178	9322	8382	6625
NH_3	272	254	225	209	239	219	214	244	219	157
NMVOC	12.6	11.8	10.5	9.95	11.4	10.3	10.2	11.7	10.4	8.17
TSP	71	80	81	103	111	115	125	124	112	82.8
PM_{10}	64.0	71.0	73.0	92.0	99.9	104	113	112	101	77.8
$PM_{2.5}$	50.0	56.0	57.0	72.0	77.7	80.7	88.0	86.0	78.0	62.0

Year	2010	2011	2012
CO_2	3837	6809	4142
CO	11.2	13.1	32.0
NH_3	203	190	157
NMVOC	8.65	8.32	7.54
TSP	78.2	76.6	78.1
PM_{10}	70.4	67.3	68.6
$PM_{2.5}$	54.7	53.8	54.8

Input to CollectER

The input data/data sources are presented in Table 3.26.

Table 3.26 Input data for calculating emissions from mineral wool production.

	Year	Parameter	Comment/Source
Activity data	1996-2012	Energy consumption	Rockwool (2013b)
Emissions			
	2000-2012	TSP	Rockwool (2013), PRTR
	2000-2012	PM_{10}, $PM_{2.5}$	Distribution between TSP, PM_{10}, and $PM_{2.5}$ from CEPMEIP

Future improvements

The environmental reports/PRTR shows significant variation in CO emission. The time series will be verified by contact to the company.

3.4 Asphalt roofing

Roof covering with asphalt materials can be found all over the country. The following SNAP-codes are covered:

- 04 06 10 Roof covering with asphalt materials

3.4.1 Process description

No further description is given for use of roof covering with asphalt containing materials.

3.4.2 Methodology

The indirect emission of CO_2 from asphalt roofing, resulting from the atmospheric oxidation of NMVOC to CO_2, has been estimated from statistics compiled by Statistics Denmark and default emission factors. The use is calculated as:

Use = Production + Import - Export

The default emission factors, together with the calculated emission factor for CO_2, are presented in Table 3.27. The supply of roof covering material containing asphalt is presented in Table 3.27.

Table 3.27 Default emission factors for application of asphalt products.

		Asphalt roofing
CH_4	g per tonne	0
CO	g per tonne	10
NMVOC	g per tonne	80
Carbon content fraction of NMVOC	%	0.8
Indirect CO_2	kg per tonne	0.250

Table 3.28 Supply of roof material containing asphalt, tonne (Statistics Denmark, 2013).

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Roof covering material						75 468	75 468	75 468	75 468	75 468
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Roof covering material	75 468	85 034	69 094	72 945	82 073	81 829	95 971	75 334	104 009	105 605
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Roof covering material	128 028	99 715	69 583	73 925	80 466	95 794	94 311	98 814	100 509	62 127
Year	2010	2011	2012							
Roof covering material	65 753	85 942	75 510							

The activity data before 1990 are not available. Therefore, the 1990 value has been applied for 1985-1989.

3.4.3 Emission trend

The emission trends for CO, CO_2, and NMVOC from use of roof covering materials with asphalt are presented in Table 3.29.

Table 3.29 Emissions from asphalt roofing, tonne.

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
CO_2						18.9	18.9	18.9	18.9	18.9
CO						0.75	0.75	0.75	0.75	0.75
NMVOC						6.04	6.04	6.04	6.04	6.04
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2	18.9	21.3	17.3	18.2	20.5	20.5	24.0	18.8	26.0	26.4
CO	0.75	0.85	0.69	0.73	0.82	0.82	0.96	0.75	1.04	1.06
NMVOC	6.04	6.80	5.53	5.84	6.57	6.55	7.68	6.03	8.32	8.45
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2	32.0	24.9	17.4	18.5	20.1	23.9	23.6	24.7	25.1	15.5
CO	1.28	1.00	0.70	0.74	0.80	0.96	0.94	0.99	1.01	0.62
NMVOC	10.2	7.98	5.57	5.91	6.44	7.66	7.54	7.91	8.04	4.97
Year	2010	2011	2012							
CO_2	16.4	21.5	18.9							
CO	0.66	0.86	0.76							
NMVOC	5.26	6.88	6.04							

3.4.4 Input to CollectER

The input data/data sources are presented in Table 3.30.

Table 3.30 Input data for calculating emissions from asphalt roofing.

	Year	Parameter	Comment/Source
Activity	1990-2012	Production, import, export	Statistics Denmark
Emissions	1990-2012	NMVOC, CO, CO_2	EMEP/CORINAIR (2004) and IPPC (1997)

3.4.5 Future improvements

The emission factors are currently not referenced. The emission factors will be reinvestigated using the latest edition of the EMEP/EEA guidebook as well as other available literature.

A process description for asphalt roofing will be elaborated.

3.5 Road paving with asphalt

Road paving with asphalt is an activity that can be found all over the country and especially in relation to establishing new roads. The following SNAP-code is covered:

- 04 06 11 Road paving with asphalt.

3.5.1 Process description

The raw materials for construction of roads are prepared on one of the plants located near the locality of application due to limitations in transport distance. The asphalt concrete is mixed and brought to the locality of application on a truck. The asphalt concrete is used at high temperature and this condition reduces the potential transport distance.

Roads are constructed by a number of different layers:

- a load bearing layer (e.g. course gravel)
- an adhesive layer (liquefied asphalt e.g. "cutback" asphalt or asphalt emulsion)
- a wearing coarse (e.g. hot mix asphalt concrete)

Different qualities of "cutback" asphalt (e.g. asphalt dissolved in organic solvents/petroleum distillates) and asphalt emulsion contains different kinds and amounts of solvent. Cutback asphalt contains 25-45 %v/v solvent e.g. heavy residual oil, kerosene-type solvent, naphtha or gasoline solvent.

3.5.2 Methodology

The indirect emission of CO_2 from asphalt roofing and road paving has been estimated from statistics compiled by Statistics Denmark and default emission factors. The use is calculated as:

Use = Production + Import - Export

The default emission factors, together with the calculated emission factor for CO_2, are presented in Table 3.31.

Table 3.31 Default emission factors for application of asphalt products.

Pollutant	Unit	Road paving with asphalt	Use of cutback asphalt
CH_4	g per tonne	5	0
CO	g per tonne	75	0
NMVOC	g per tonne	15	64 935
Carbon content fraction of NMVOC	%	0.667	0.667
Indirect CO_2	kg per tonne	0.168	159

Statistics covering production, import and export of asphalt products can be found in Statistics Denmark as well as in statistics compiled be the industrial organisation for the asphalt industry (Asfaltindustrien). For consumption of asphalt products for road paving the statistics from Statistic Denmark shows high fluctuations compared to the statistics from the industrial organisation.

Table 3.3Table 3.32 presents the consumption of asphalt for road paving by the members of the industrial organisation for the asphalt industry. The asphalt consumption includes three different types e.g. asphalt concrete as well as cutback asphalt or asphalt emulsion. The adhesive products are not mentioned explicitly in the statistics from the industrial organisation.

Table 3.32 Consumption of asphalt for road paving.

Year	PA (Pulverised asphalt) tonne	AB (Concrete asphalt) tonne	GAB (Gravel asphalt concrete) tonne	Total tonne
1990	750 000	750 000	1 700 000	3 200 000
1991	750 000	750 000	1 700 000	3 200 000
1992	850 000	600 000	1 900 000	3 350 000
1993	700 000	750 000	2 050 000	3 500 000
1994	750 000	750 000	1 650 000	3 150 000
1995	750 000	800 000	1 700 000	3 250 000
1996	600 000	1 000 000	1 650 000	3 250 000
1997	550 000	800 000	1 900 000	3 250 000
1998	550 000	800 000	1 500 000	2 850 000
1999	500 000	950 000	1 650 000	3 100 000
2000	500 000	800 000	1 650 000	2 950 000
2001	450 000	750 000	1 400 000	2 600 000
2002	450 000	750 000	1 400 000	2 600 000
2003	500 000	750 000	1 400 000	2 650 000
2004	600 000	1 000 000	1 600 000	3 200 000

Consumption in 1990 is assumed to be the same as in 1991. Table 3.33 presents the activity data applied in the inventory. Until 2003 the data are based on information from Asfaltindustrien and from 2004 from Statistics Denmark.

Table 3.33 Supply of asphalt for road paving, tonne (Asfaltindustrien & Statistics Denmark).

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Asphalt						3 200 000	3 200 000	3 200 000	3 200 000	3 200 000
Cut back asphalt						7700	7700	7700	7700	7700

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Asphalt	3 200 000	3 200 000	3 350 000	3 500 000	3 150 000	3 250 000	3 250 000	3 250 000	2 850 000	3 100 000
Cut back asphalt	7700	7700	7700	7700	7700	7700	7700	7700	7700	7700

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Asphalt	2 950 000	2 600 000	2 600 000	2 650 000	3 700 688	3 649 200	3 644 540	4 640 756	4 135 232	2 500 645
Cut back asphalt	7700	7700	7700	7700	7700	7700	7700	7700	7700	7700

	2010	2011	2012
Asphalt	3 005 146	3 883 436	3 222 505
Cut back asphalt	7700	7700	7700

3.5.3 Emission trend

The emission trends for CO, CO_2, CH_4, and NMVOC from use of asphalt for road paving is presented in Table 3.34.

Table 3.34 Emissions from road paving with asphalt, tonne.

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
CO_2						1762	1762	1762	1762	1762
CH_4						16.0	16.0	16.0	16.0	16.0
CO						240	240	240	240	240
NMVOC						548	548	548	548	548
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2	1762	1762	1787	1812	1754	1770	1770	1770	1703	1745
CH_4	16.0	16.0	16.8	17.5	15.8	16.3	16.3	16.3	14.3	15.5
CO	240	240	251	263	236	244	244	244	214	233
NMVOC	548	548	550	552	547	549	549	549	543	546
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2	1720	1661	1661	1670	1846	1837	1837	2004	1919	1644
CH_4	14.8	13.0	13.0	13.3	18.5	18.2	18.2	23.2	20.7	12.5
CO	221	195	195	199	278	274	273	348	310	188
NMVOC	544	539	539	540	556	555	555	570	562	538
Year	2010	2011	2012							
CO_2	1729	1877	1766							
CH_4	15.0	19.4	16.1							
CO	225	291	242							
NMVOC	545	558	548							

3.5.4 Input to CollectER

The input data/data sources are presented in Table 3.35.

Table 3.35 Input data for calculating emissions from road paving with asphalt.

	Year	Parameter	Comment/Source
Activity	1990-2012	Production, import, export	Asfaltindustrien Statistics Denmark
Emissions	1990-2012	NMVOC, CO, CH_4, CO_2	

3.5.5 Future improvements

The activity data will be further investigated, especially the use of cutback asphalt.

The Danish asphalt plants will be investigated as well as the mass balance for bituminous materials appearing in the Danish energy statistics (Danish Energy Agency, 2013).

The emission factors will be reassessed and properly referenced.

3.6 Other mineral industries

The sub-sector Other cover the following processes relevant for the Danish air emission inventory:

- Glass production; see section 3.6.1
- Glass wool production; see section 3.6.2
- Production of yellow bricks; see section 3.6.3
- Expanded clay products; see section 3.6.4

3.6.1 Glass production

Glass production covers production of:

- Flat glass
- Container glass

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.

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. The following SNAP-codes are covered:

- 03 03 15 Container glass
- 04 06 13 Glass (decarbonizing)

Process description

The following description is based on Holmegaard (2003) and Rexam Glass Holmegaard (2002).

The primary raw materials 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.

Methodology

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 emission factors for carbon dioxide from using Na_2CO_3 and other carbonate containing raw materials in production of virgin glass, based on stoichiometric relationships, are:

- 0.4152 tonne CO_2/tonne Na_2CO_3
- 0.4397 tonne CO_2/tonne $CaCO_3$

- 0.4773 tonne CO_2/tonne $CaMg(CO_3)_2$
- 0.2230 tonne CO_2/tonne $BaCO_3$
- 0.5957 tonne CO_2/tonne Li_2CO_3

The activity data are presented in Table 3.36. Information on consumption of carbon containing raw materials is available from the environmental reports of the plant since 1997. For the years prior to 1997 the production of glass is based on information contained in Illerup et al. (1999).

Table 3.36 Production of glass, activity data, tonne.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Production of glass	164 000	159 000	145 000	140 500	150 200	140 000	140 000	140 000	140 000	140 000
Consumption of soda ash	ni	ni	ni	ni	ni	ni	ni	15 195	16 206	19 241
Consumption of limestone	ni	ni	ni	ni	ni	ni	ni	12 285	6 373	8 733
Consumption of dolomite	ni	ni	ni	ni	ni	ni	ni	834	7 617	9 808
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Production of glass	150 000	154 000	154 000	154 000	154 000	154 000	150 000	150 000	150 000	100 000
Consumption of soda ash	16 391	16 668	15 816	14 106	13 611	12 996	12 407	13 587	13 349	7934
Consumption of limestone	7739	7881	7050	6347	6036	5650	6839	8420	9145	5089
Consumption of dolomite	9085	8920	8031	7258	7036	6118	5434	5583	5829	3359
Year	2010	2011	2012							
Production of glass	110 000	110 000	110 000							
Consumption of soda ash	8495	8474	9313							
Consumption of limestone	5594	5743	5980							
Consumption of dolomite	3906	4097	4428							

ni no information.

The applied emission factors are a combination of standard factors suggested in EMEP/CORINAIR, CEPMEIP database and specific emission factors reported by Illerup et al. (1999). The emission factors are supplemented with estimated CO_2 emissions from the calcination of carbonate compounds and the actual emission of Pb, Se, and Zn as reported in Rexam Glass Holmegaard (2002). The TSP emission factor is based on the environmental report with a distribution between PM_{10} and $PM_{2.5}$ as reported in the CEPMEIP database i.e. 0.2 kg/tonne, 0.18 kg/tonne, and 0.16 kg/tonne for TSP, PM_{10}, and $PM_{2.5}$ respectively (CEPMEIP).

Emission trend

The emission trends for CO_2, Pb, Se, Zn, TSP, PM_{10}, and $PM_{2.5}$ from production of container glass are presented in Table 3.37.

Table 3.37 Emissions from production of glass, tonnes; heavy metals in kg.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2	15 580	13 780	12 640	12 280	13 050	12 240	12 110	12 109	13 163	16 506
Pb	1164						658	883	418	562
Se	328						196	134	72	218
Zn	164						56	31	39	45
TSP										
PM_{10}										
$PM_{2.5}$										
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2	14 541	14 640	13 496	12 109	11 661	10 798	10 750	12 007	12 344	7134
Pb	330	172	220	272	436	148	12	16	18	18
Se	340	271	201	234	225	117	59	53	46	25
Zn	57	25	25	25	25	25	25	25	25	25
TSP	26	25	21	26	23	7.0	0.9	1.0	1.2	1.2
PM_{10}	23	23	19	23	21	6.3	0.8	0.9	1.1	1.1
$PM_{2.5}$	21	20	17	21	18	5.6	0.7	0.8	1.0	1.0

Year	2010	2011	2012
CO_2	7850	7998	8608
Pb	24	25	116
Se	17	17	60
Zn	25	25	25
TSP	1.7	1.8	4.5
PM_{10}	1.5	1.6	4.1
$PM_{2.5}$	1.4	1.4	3.6

ni: no information.

Input to CollectER

The input data/data sources are presented in Table 3.38.

Table 3.38 Input data for calculating emissions from glass production.

	Year	Parameter	Comment/Source
Activity data	1990-1997	Glass	Illerup et al. (1999)
	1998-2000	Glass	Estimated
	2001	Glass	Estimated from consumption of raw materials
	2002-2012	Glass	Assumed
	1997-2012	Consumption of raw materials	Ardagh Holmegaard Glass (2013b)
Emissions	1990,1997	Pb, Se, Zn	Measurements; Illerup et al. (1999)
	1991-1996	Pb, Se, Zn	Interpolated from 1990 and 1997 figures; see Illerup et al. (2003)
	1997-2012	Pb, Se, Zn, TSP	Rexam Glass Holmegaard (2013b)
	1990	CO_2	Estimated using a fixed emission factor of 95 kg per tonne
	1991-1996	CO_2	Estimated based on production and the implied emission factor in 1997
	1997-2005	CO_2	Estimated from consumption of raw materials
	2006-2012	CO_2	EU-ETS (Ardagh Glass Holmegaard (2013a)
	2000-2012	PM_{10}, $PM_{2.5}$	Distribution between TSP, PM_{10}, and $PM_{2.5}$ from CEPMEIP

Future improvements

The methodology for estimating CO_2 emissions for the years prior to 1997 will be reassessed.

It will be investigated whether there is glass production at other plants in Denmark. Data from Statistics Denmark will be investigated and contact made to the glass industry.

3.6.2 Glass wool

Saint-Gobain Isover situated in Vamdrup produces glass wool. The following SNAP codes are covered:

- 03 03 16 Glass wool (except binding)
- 04 06 13 Glass (decarbonizing)

Process description

The following description as well as data is based on an environmental report (Saint-Gobain Isover, 2003).

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.

Methodology

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

The emission factors for carbonate containing substances are presented in Table 3.11. The activity for production of glass wool is presented in Table 3.39. Data on the consumption of raw materials are available from 1996 onwards and used for estimating CO_2 emissions. Production numbers are only available from 1998 onwards. For the years 1990-1997 the production has been assumed to be on the same level as in 1998.

Table 3.39 Production of glass wool, tonne.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Production of glass wool	33 630	33 630	33 630	33 630	33 630	33 630	33 630	33 630	33 630	38 680
Consumption of soda ash	ni	ni	ni	ni	ni	nii	3589	3654	3455	3095
Consumption of limestone	ni	ni	ni	ni	ni	nii	768	854	831	276
Consumption of dolomite[1]	ni	ni	ni	ni	ni	nii	ni	ni	ni	ni
Year	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	2974	2895	3300	2810	3348	3639	3720	4112	3940	c
Consumption of limestone	213	369	589	425	530	614	592	700	625	c
Consumption of dolomite[1]	nii	ni	ni	ni	ni	ni	ni	ni	ni	c
Year	2010	2011	2012							
Production of glass wool	24 899	29 817	26 752							
Consumption of soda ash	c	c	c							
Consumption of limestone	c	c	c							
Consumption of dolomite[1]	c	c	c							

1 Dolomite is used as raw material but is not mentioned in the environmental reports.

ni no information.

c confidential.

Measured emission data for NH_3 and TSP are available in the environmental reports back to 1996. Prior to 1996 the emissions have been assumed constant at the emission level in 1996.

Prior to 2010 emissions of NMVOC and CO are calculated using emission factors of 1300 g per tonne and 53 g per tonne, respectively. The emission factors are not referenced.

Emission trend

The emission trend for CO_2, NH_3, TSP, PM_{10}, $PM_{2.5}$ from production of glass wool is presented in Table 3.40. For the years information 2006-2012 information on CO_2 emission has been available in the company reports to the EU ETS (Saint Gobain Isover, 2013a), however this information is confidential and therefore not presented.

Table 3.40 Emissions from production of glass wool, tonnes.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2	1827	1827	1827	1827	1827	1827	1827	1892	1799	1406
NMVOC	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
CO	2	2	2	2	2	2	2	2	2	2
NH_3	224	224	224	224	224	224	224	296	266	268
TSP										
PM_{10}										
$PM_{2.5}$										

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2	1328	1364	1629	1353	1623	1780	1804/c	2014/c	1910/c	c
NMVOC	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
CO	2	2	2	2	2	2	2	2	2	2
NH_3	225	190	133	125	124	116	123	109	155	152
TSP	111	119	114	102	99	85	82	52	54	33
PM_{10}	100	107	103	92	89	77	74	47	49	30
$PM_{2.5}$	78	83	80	71	69	60	57	36	38	23

Year	2010	2011	2012
CO_2	c	c	c
NMVOC	32	39	39
CO	1	2	1
NH_3	108	105	144
TSP	26	42	47
PM_{10}	23	38	42
$PM_{2.5}$	18	29	33

nini no information.

c confidential - information on CO_2 emission is obtained from EU-ETS reports.

NE not estimated

From the confidential data in EU-ETS reports (Saint-Gobain Isover, 2013a) it appears that dolomite is used as raw material as well as limestone and soda ash, however, the environmental reports do not mention dolomite as a raw material. The calculated emission of CO_2 for the years before 2006 may therefore be underestimated.

Input to CollectER

The environmental report (Saint-Gobain Isover, 2013b) 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; see section 3.2, Table 3.11 for emission factors for different raw materials. The TSP emission is based on the environmental report with a distribution between PM_{10} and $PM_{2.5}$ as reported in CEPMEIP database i.e. 0.2 kg/tonne, 0.18 kg/tonne, and 0.16 kg/tonne for TSP, PM_{10}, and $PM_{2.5}$ respectively (CEPMEIP). The input data/data sources are presented in Table 3.41.

Table 3.41 Input data for calculating emissions from glass wool production.

	Year	Parameter	Comment/Source
Activity	1990-1997	Glass wool production	Assumed constant to 1998
	1998-2012	Glass wool production	Saint-Gobain Isover (2013b)
	1996-2012	Consumption of raw materials	Saint-Gobain Isover (2013b and earlier)
Emissions	1990-1995		Emissions assumed
	1996-2002	NH_3, TSP	Saint-Gobain Isover (2013b)
	1996-2008	CO_2	Estimated from consumption of raw materials
	2006-2012	CO_2	Emission based on EU-ETS reports (Saint-Gobain Isover, 2013a)
	2000-2012	PM_{10}, $PM_{2.5}$	Distribution between TSP, PM_{10}, and $PM_{2.5}$ from CEPMEIP

Future improvements

Consumption of dolomite during the years 1990 – 2005 will be investigated and included in the inventory, if possible.

The emission factors used for NMVOC and CO will be further investigated. The particle size distribution currently used will be compared with the particle size distribution in the latest edition of the EMEP/EEA guidebook.

The activity data for years before 1998 (production data) and 1996 (raw material consumption) will be further investigated.

3.6.3 Bricks and tiles

Process description

This section covers production of bricks and tiles (aggregates or bricks/blocks for construction).

The following SNAP code is covered:

- 04 06 91 Production of yellow bricks

The following pollutants are covered:

- CO_2
- SO_2

The production of yellow bricks is found all over the country, where clay is available. Producers of expanded clay products are mostly located in Jutland; see Table 3.42.

Table 3.42 Producers of clay and expanded clay products.

Product	Company	Location
Bricks and tiles	Vedstårup teglværk	5610 Assens
	Vindø teglværk	9500 Hobro
	Pedershvile teglværk	3200 Helsinge
	Stoffers teglværk	6400 Sønderborg
	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
	Thy Tegl	7760 Hurup Thy
	Hellingsø Teglværk	7760 Hurup Thy
	Carl Matzens Teglværk	6320 Egernsund
	Gråsten Teglværk	6300 Gråsten
	P.M. Tegl Egernsund	6320 Egernsund
	Gandrup Teglværk (Pipers Teglværker)	9362 Gandrup
	Pipers Teglværker	7840 Højslev
	Villemoes Teglværk	6690 Gørding

Methodology

The potential emissions from production of bricks:

- CO_2
- SO_2

Emission of CO_2 and SO_2 is related to limestone and sulphur content in the raw material 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 3.43.

Table 3.43 Typical composition of clay used for different kinds of 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 %

Emission factor (CO_2)

The content of $CaCO_3$ in the raw material and a number of other factors determine the colour of bricks and tiles. In the present estimate, the average content of $CaCO_3$ in clay has been assumed to be 18 % (the $CaCO_3$ content in clay for bricks varies from e.g. 0.5 % in clay for red bricks and 19.8 % in clay for yellow bricks (Tegl Info, 2004)). The emission factor for limestone (0.44 kg CO_2 per kg $CaCO_3$) has been used to calculate the emission factor for yellow bricks: 79 kg CO_2 per Mg yellow bricks. For verification of the emission factor for yellow bricks, see Figure 3.5. The figure shows the emission calculated from the applied emission factors and activity data from Statistics

Denmark (2012) compared with individual CO_2 emission of CO_2 reported to Danish Energy Agency by the companies for preparation of the national allocation plan for EU-ETS.

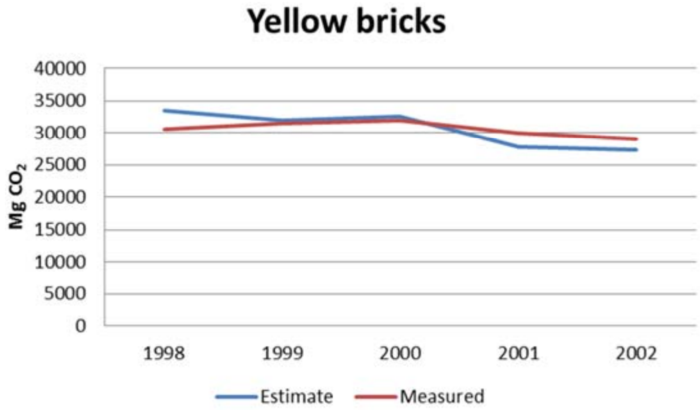


Figure 3.5 Estimated and "measured" CO_2 emission from tile-/brickworks and from production of expanded clay products; "measured" means information provided to the Danish Energy Agency by the individual companies according to the rules outlined under the EU ETS (DEA, 2004).

Figure 3.5Figure 2.5 shows a very good agreement between the estimation methodology applied from 1990 to 2005 and the measured/estimated emissions reported to the EU ETS for the years 1998 to 2002 for yellow bricks.

For 2006-2012 emission factors have been derived from CO_2 emissions reported by the brickworks under the EU ETS (confidential reports from approximately 20 brickworks) and production statistics (Statistics Denmark, 2013). The emission factors are calculated to 72.8-108.9 kg CO_2 per tonne yellow bricks (average: 86 kg CO_2 per tonne product). Figure 3.6 shows the default EF compared with the development in the implied EF for the years 1990-2012.

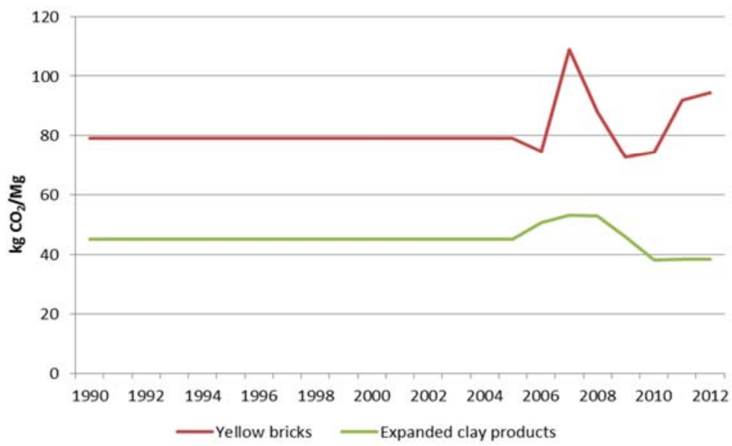


Figure 3.6 Development in implied emission factors.

For the 2012 inventory the CO_2 implied emission factor was calculated to 94.3 kg CO_2 per tonne product

Emission factor (SO_2)

The emission of SO_2 depends on the sulphur content of the raw material. The EF for SO_2 is determined from the individual companies reporting of SO_2 emission (environmental report) for the years 2008-2010 and actual activity (from Statistics Denmark) for the corresponding years. These years were selected as the most complete datasets were available for these years.

The SO_2 emissions attributed to the process has been adjusted for the fuel related emissions as far as possible. 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., 2014a). The applied EFs are presented in Table 3.44.

Table 3.6 Applied emission factors for S-containing fuels.

Fuel	EF (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 EF. However, the EF 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.

For the 2012 inventory the SO_2 implied emission factor has been calculated to 1.3 kg SO_2 per tonne product.

Production statistics for yellow bricks and expanded clay products are obtained from Statistics Denmark (2013); see Table 3.45. The CO_2 emission from the production of bricks and tiles has been estimated from information on annual production registered by Statistics Denmark. The data available from Statistics Denmark is in 1000 brick produced; this is converted to mass by assuming an average weight of 2 kg per brick. Furthermore, the activity data applied in the inventory is for the production of yellow bricks, therefore the data from Statistics Denmark is further corrected for the amount of yellow bricks and tiles. This amount is unknown and, therefore, it is assumed that 50 % of the production of bricks and tiles are yellow.

Table 3.45 Production of yellow bricks, tonnes (Statistics Denmark, 2013).

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Yellow bricks	291 348	291 497	303 629	278 534	389 803	362 711	377 652	419 431	423 254	405 241
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Yellow bricks	414 791	351 955	342 179	341 981	365 388	407 940	465 504	348 928	322 137	226 363
Year	2010	2011	2012							
Yellow bricks	212 051	222 144	185 398							

Emission trend

Emissions of CO_2 and SO_2 from production of yellow bricks are presented in Table 3.52, 3.46 and Figure 3.7.

Table 3.46 Process emissions from production of yellow bricks (tonne).

Year		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Yellow bricks	CO_2	23 016	23 028	23 987	22 004	30 794	28 654	29 835	33 135	33 437	32 014
	CO_2[1]	-	-	-	-	-	-	-	-	-	-
	SO_2	391	391	407	373	523	486	506	562	568	543
Year		**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Yellow bricks	CO_2	32 768	27 804	27 032	27 016	28 866	32 227	-	-	-	-
	CO_2[1]	-	-	-	-	-	-	34 757	37 995	28 392	16 483
	SO_2	556	472	459	459	490	547	624	468	432	304
Year		**2010**	**2011**	**2012**							
Yellow bricks	CO_2	-	-	-							
	CO_2[1]	15 751	20 430	17 488							
	SO_2	284	298	249							

[1] CO_2 emission from company reporting to EU-ETS.

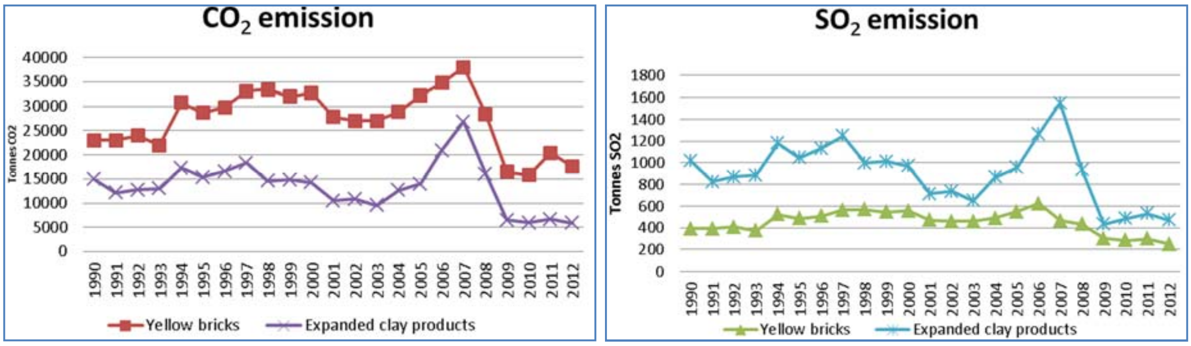


Figure 3.7 CO_2 and SO_2 emissions from production of yellow bricks.

Input to CollectER

The actual applied data on production of yellow bricks and tiles are summarised in Table 3.47.

Table 3.47 Input data for calculating emissions from production of bricks and tiles.

	Year	Parameter	Comment/Source
Activity data	1990-2012	Bricks	Statistics Denmark; assumptions: 2 kg per brick and 50 % yellow bricks
Emissions	1990-2005	CO_2	EF estimated from average $CaCO_3$ content in yellow bricks
	2006-2012	CO_2	Company reports to EU-ETS
	1990-2012	SO_2	EF estimated from environmental reports 2008-2010

Future improvements

The SO_2 emission factor will be improved based on additional data for coming years. Also, the emission of SO_2 will be extrapolated back to 1980.

The assumptions made to convert the activity data will be further investigated as will the exclusion of CO_2 emissions from the production of red bricks and tiles prior to 2006.

3.6.4 Production of expanded clay products

Process description

This section covers production of expanded clay products for different purposes (aggregates as absorbent for chemicals, cat litter, and for other miscellaneous purposes).

The following SNAP code is covered:

- 04 06 92 Expanded clay products

The following pollutants are covered:

- CO_2
- SO_2

The production sites of expanded clay products are mostly located in Jutland; see Table 3.48.

Table 3.48 Producers of expanded clay products.

Product	Company	Location
Expanded clay products	Optiroc	8900 Randers
	Dansk Leca	8900 Randers
	Damolin Mors	7900 Nykøbing Mors
	Damolin Fur	7884 Fur

The expanded clay products are presented in Table 3.49.

Table 3.49 Products from different producers of expanded clay products.

Company	Location	Products
Damolin (moler products)	Fur	Cat litter
	Nykøbing Mors	Felicia
		Amigo
		Absorbant
		Absodan
		Sorbix
		Oil Dri
		Industry
		Moler
		Bentonite
		Perlite
		Vermiculite
Dansk Leca (expanded clay products)	Gadbjerg	"Bloksten"
	Randers	"Letklinker"
Optiroc/Maxit (expanded clay products)	Ølst	"Bloksten"
		"Letklinker"
		"Mørtel" (tør/våd)
Skamol (moler products)		Bricks and blocks

Methodology

The potential process emissions from production of expanded clay products are:

- CO_2
- SO_2

Process emissions of CO_2 and SO_2 are related to limestone and sulphur content in the raw material whereas emission of NO_x is related to fuel consumption/process conditions. The NO_x and SO_2 emissions have previously been discussed by DTI (2000).

Emission factor (CO_2)

For expanded clay products the emission factor 45 kg CO_2 per tonne product has been applied for the years prior to 2006. This emission factor is based on the average implied emission factor for 2006 to 2012 derived from CO_2 emission data from the EU ETS and production data from Statistics Denmark. For verification of the emission factor for expanded clay products, see Figure 3.8. The figure shows the emission calculated from the applied emission factors and activity data from Statistics Denmark (2013) compared with individual CO_2 emission of CO_2 reported to Danish Energy Agency by the companies for preparation of the national allocation plan for EU-ETS.

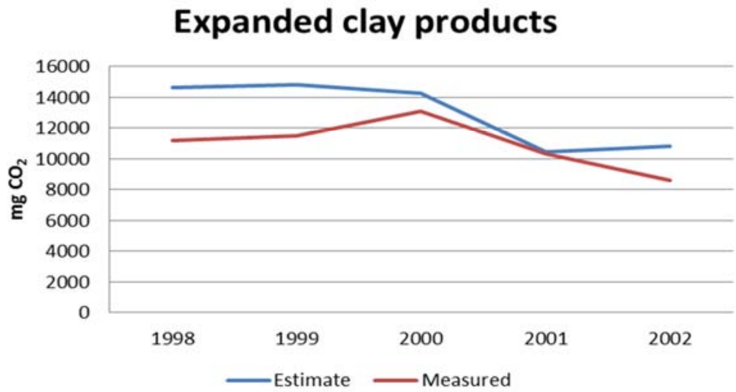


Figure 3.8 Estimated and "measured" CO_2 emission from production of expanded clay products; "measured" means information provided to the Danish Energy Agency by the individual companies according to the rules outlined by EU-ETS (DEA, 2004).

The consistency between the estimation methodology for expanded clay products applied from 1990 to 2005 and the measured/estimated emissions reported to EU-ETS is not perfect and will be considered further in future submissions.

For 2006-2012 emission factors have been derived from CO_2 emissions reported by the producers of expanded clay products to EU-ETS (confidential reports from approximately four producers of expanded clay products) and production statistics (Statistics Denmark, 2012). The emission factors are calculated to 38.1-52.9 kg CO_2 per Mg expanded clay (average: 45 kg CO_2 per tonne product). Figure 3.9Figure 3.9 shows the default EF compared with the development in implied EF for the years 2006-2012.

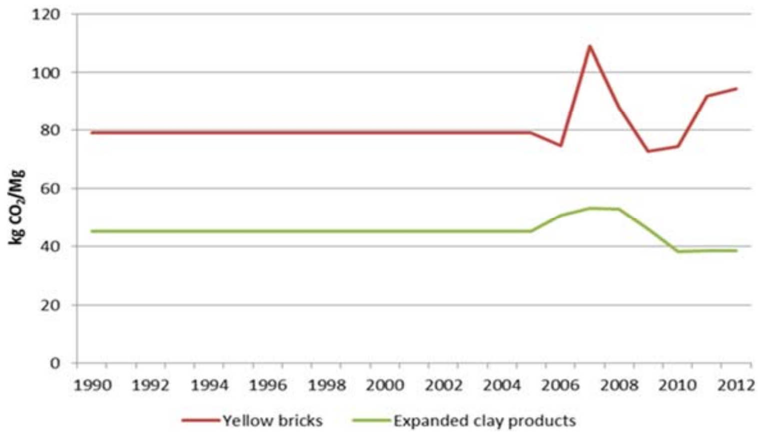


Figure 3.9 Development in implied emission factors.

For the 2012 inventory the CO_2 implied emission factor has been calculated to 38.4 kg CO_2 per tonne product

Emission factor (SO_2)

The emission of SO_2 depends on the sulphur content of the raw material. The EF for SO_2 is determined from the individual companies reporting of SO_2 emissions in the environmental reports for the years 2009-2010 for expanded clay products and production data from Statistics Denmark for the corresponding years. These years were selected as the most complete datasets were available for these years.

The SO_2 emissions attributed to the process have been adjusted for the fuel related emissions as far as possible. Five plants were using coal, petcoke 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., 2014a). The applied EFs are presented in Table 3.50.

Table 3.50 Applied EF for S-containing fuels.

Fuel	EF (g SO_2/GJ)
Coal	574
Petroleum coke	605
Residual oil	344

The total emission of SO_2 was reduced by the amount related to fuel combustion before calculating the EF. However, the EF will continuously be improved as a more comprehensive dataset becomes available and the influence from fuel contribution will be studied further as not all the environmental reports distinguish clearly between the different emission sources.

For the 2012 inventory the SO_2 implied emission factor has been calculated to 3.1 kg SO_2 per tonne product.

Production statistics for expanded clay products are obtained from Statistics Denmark (2013); see Table 3.51.

Table 3.51 Production of expanded clay products, tonne (Statistics Denmark, 2013).

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Expanded clay products	331 760	268 871	282 920	288 310	383 768	340 881	368 080	406 716	324 413	329 393
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Expanded clay products	316 174	232 289	239 664	211 794	281 828	310 901	411 869	504 925	303 948	140 915
Year	2010	2011	2012							
Expanded clay products	157 378	172 263	153 305							

Emission trend

Emissions of CO_2 and SO_2 from production of expanded clay products are presented in Table 3.52 and Figure 3.10.

Table 3.52 Process emissions from production of expanded clay products, tonne.

Year		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Expanded clay products	CO_2	14 929	12 099	12 731	12 974	17 270	15 340	16 564	18 302	14 599	14 823
	CO_2[1]	-	-	-	-	-	-	-	-	-	-
	SO_2	1019	826	869	886	1179	1047	1131	1249	997	1012
Year		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Expanded clay products	CO_2	14 228	10 453	10 785	9 531	12 682	13 991	-	-	-	-
	CO_2[1]	-	-	-	-	-	-	20 896	26 878	16 077	6478
	SO_2	971	714	736	651	866	955	1265	1551	934	433
Year		2010	2011	2012							
Expanded clay products	CO_2	-	-	-							
	CO_2[1]	5997	6632	5889							
	SO_2	483	529	471							

[1] CO_2 emission from company reporting to EU-ETS.

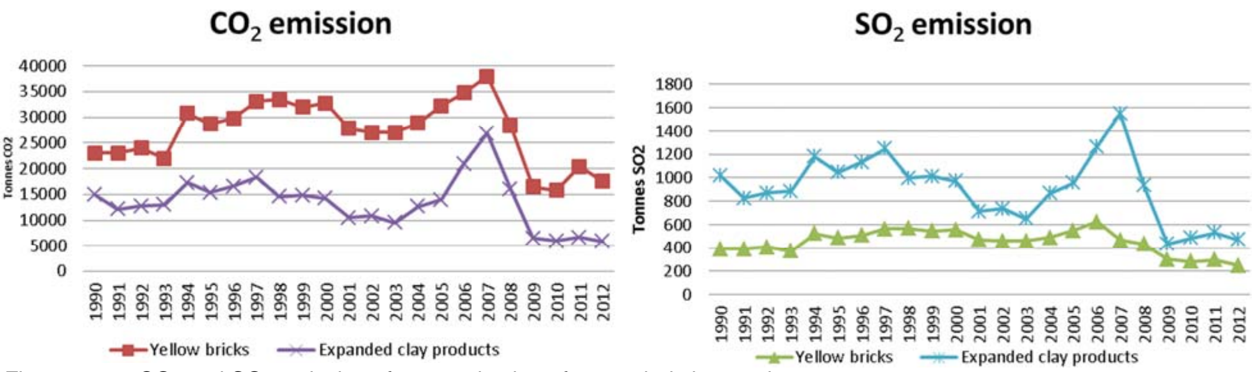


Figure 3.10 CO_2 and SO_2 emissions from production of expanded clay products.

Input to CollectER

The actual applied data on production of expanded clay products are summarised in Table 3.53.

Table 3.53 Input data for calculating emissions from production of expanded clay products.

	Year	Parameter	Comment/Source
Activity data	1990-2012	Expanded clay products	Statistics Denmark
Emissions	1990-2005	CO_2	Average EF derived from EU ETS data
	2006-2012	CO_2	Company reports to EU-ETS
	1990-2012	SO_2	EF estimated from environmental reports 2009-2010

Recommendations to future improvements

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

4 Chemical industry

The processes within chemical industry in Denmark in relation to emission of greenhouse gasses and other air pollutants are:

- Production of nitric and sulphuric acid production; see section 4.1
- Production of catalysts / fertilisers; see section 0
- Production of pesticides; see section 4.3
- Production of chemical ingredients; see section 4.4
- Production of tar products; see section 4.5

4.1 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). Up to 1997 sulphuric acid was produced at Kemira and in 2004 the rest of the production stopped. The following SNAP codes are covered:

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

4.1.1 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.

4.1.2 Methodology

Standard emission factors given by IPCC (1997) and EMEP/CORINAIR (2004) are presented in Table 4.1 together with the Danish values.

Table 4.1 Emission factors for production of nitric acid in Denmark compared with standard emission factors (kg per tonne).

	Mean	Range	Standard EF
NH_3	0.103	0.027 - 0.261	0.01
N_2O	7.476	-	<2[1]
			4 - 5[2]
			6 - 7.5[3]
NO_x	1.356	0.95 - 1.79	3 - 12[4]
			7.5[5]
			3[6]
			5[7]
SO_2	1.985	1.40-2.69	<1 - 6.6[8]
			3.3[9]
			17[10]

[1] Modern, integrated plant, Norway (IPCC, 1996).
[2] Atmospheric pressure plant, Norway (IPCC, 1996).
[3] Medium pressure plant, Norway (IPCC, 1996).
[4] Low pressure (EMEP/CORINAIR, 2004).
[5] Medium pressure (EMEP/CORINAIR, 2004).
[6] High pressure (EMEP/CORINAIR, 2004).
[7] Direct strong acid process (EMEP/CORINAIR, 2004).
[8] Contact process with intermediate absorption; different gas conditions (EMEP/CORINAIR, 2004).
[9] Wet/dry process with intermediate condensation/absorption (EMEP/CORINAIR, 2004).
[10] Wet contact process (EMEP/CORINAIR, 2004).

The information on emissions is obtained from environmental reports (Kemira GrowHow, 2005), contact to the company as well as information from the former county. Information on emissions of NH_3 and N_2O is available for 1996-2002 and 2002 respectively. For the remaining years emission factors based on 1996 and 2002, respectively, has been used. The emission factors for NO_x and SO_2 (based on actual emissions) are in the low end whereas the factors for NH_3 and N_2O are in the high end.

The applied activity data for production of nitric acid and sulphuric acid are presented in Table 4.2.

Table 4.2 Production of nitric acid and sulphuric acid, tonne (Kemira GrowHow, 2005).

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Sulphuric acid						188 000	97 000	126 000	184 000	215 000
Nitric acid						350 000	315 000	357 000	383 000	402 000
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Sulphuric acid	148 000	65 000	58 000	63 000	80 000	102 000	55 000	2000	0	0
Nitric acid	450 000	412 000	364 000	343 000	348 000	390 000	360 000	366 000	348000	410 000
Year	2000	2001	2002	2003	2004					
Sulphuric acid	0	0	0	0	0					
Nitric acid	433 000	382 000	334 000	386 000	229 000					

The emissions of SO_2, NO_X, NH_3 and TSP from production of sulphuric acid, nitric acid and fertiliser are measured yearly or estimated, from 1985 to 2004

(TSP from 2000 to 2004) (Kemira GrowHow, 2005). 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 emission for SO_2 and NO_X for 1991 to 1993 was estimated by using interpolated emission factors and activity data. Production of sulphuric acid ceased in 1997 and production of nitric acid ceased in 2004. The emission factor for SO_2 fluctuated and the emission factor for NO_X decreased from 1990 to 2004. Production of sulphuric acid decreased from approximately 150 000 to 60 000 tonnes from 1990 to 1996, and production of nitric acid decreased from approximately 450 000 to 229 000 tonnes from 1990 to 2004. Overall, production of fertiliser decreased from approximately 800 000 to approximately 395 000 tonnes from 1990 to 2004.

The implied emission factors are shown in Table 4.3.

Table 4.3 Implied emission factors for production of nitric acid and sulphuric acid.

Process	Pollutant	kg/tonne	EMEP/EEA Tier 2 (2009) kg/tonne
Sulphuric acid	SO_2	1.4-2.7	1.0-20
Nitric acid	NO_x	1.0-1.8	0.01-20

4.1.3 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 4.4.

Table 4.4 Emissions from nitric and sulphuric acid production, tonne.

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
NH_3						12	11	12	13	14
N_2O						2617	2355	2669	2863	3005
NO_x						627	564	639	686	720
SO_2						415	214	278	407	475
TSP										
PM_{10}										
$PM_{2.5}$										

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
NH_3	12	22	35	49	91	62	62	37	12	24
N_2O	3364	3080	2721	2564	2602	2916	2691	2736	2602	3065
NO_x	806	731	640	597	600	612	504	571	419	451
SO_2	327	151	142	162	215	217	77	3	0	0
TSP										
PM_{10}										
$PM_{2.5}$										

Year	2000	2001	2002	2003	2004
NH_3	13	30	50	56	33
N_2O	3237	2856	2497	2886	1712
NO_x	413	410	397	459	272
SO_2	0	0	0	0	0
TSP	362	346	310	323	192
PM_{10}	290	277	248	258	153
$PM_{2.5}$	217	208	186	194	115

4.1.4 Input to CollectER

The input data/data sources are presented in Table 4.5.

Table 4.5 Input data for calculating emissions from nitric and sulphuric acid production.

	Year	Parameter	Comment/Source
Activity data	1985-1994	HNO_3, H_2SO_4	Kemira GrowHow
	1995-2001	HNO_3, H_2SO_4	Oluf Nielsen, Mette Christensen, Sussie Björch, Kemira GrowHow
	1998-2004	HNO_3	Kemira GrowHow (2004)
Emissions	1991-1993	NO_x, SO_2	Assumed to be the same as in 1994
	1990, 1994, 1995-2002	NO_x, SO_2	Oluf Nielsen, Mette Christensen, Sussie Björch, Mogens Bjerre, Kemira GrowHow
	1998-2004	NH_3, TSP	Kemira GrowHow (2004)
	2002	NO_x, N_2O	Mogens Bjerre, Kemira GrowHow
	1990-2001, 2003-4	N_2O	Assumed to be the same per produced amount as in 2002
	2000-2004	PM_{10}, $PM_{2.5}$	Distribution between TSP, PM_{10}, and $PM_{2.5}$ from CEPMEIP

4.2 Catalyst/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

4.2.1 Process description

The inputs to the processes are:

- Solid raw materials: salts, oxides, 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).

4.2.2 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, 2013b) and the CO_2 emission from energy consumption reported to EU-ETS (Haldor Topsøe, 2013a). Potential retention of CO_2 in the flue gas cleaning system has not been taken into account.

The emission of NH_3, NO_X and TSP from production of catalysts and fertilisers is measured yearly from 1996 to 2012 (TSP from 2000 to 2012) (Haldor Topsøe, 2013b). The emissions from 1990-1995 were extrapolated. 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. The plant is equipped with $DeNO_x$ flue gas cleaning systems and depending of the efficiency of the cleaning system emission of NH_3 will occur. The emission of NH_3 shows an increasing trend and varies between 13 and 165 tonnes from 1990 to 2012 with the maximum of 165 tonnes in 2009. In the same period, the production of catalysts and fertilisers increased from approximately 33 000 to 45 000 tonnes.

The activity data applied for production of catalysts and potassium nitrate are presented in Table 4.6.

Table 4.6 Production of catalysts and potassium nitrate (tonne) (HaldorTopsøe, 2013b).

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Catalysts						-	-	-	-	-
Potassium nitrate						-	-	-	-	-
Catalysts+KNO_3[1]						32 296	32 296	32 296	32 296	32 296
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Catalysts	-	-	-	-	-	-	-	16 864	14 420	16 986
Potassium nitrate	-	-	-	-	-	-	-	18 772	15 596	18 074
Catalysts+KNO_3[1]	32 296	32 296	32 296	32 296	32 296	32 296	32 296	35 636	30 016	35 060
	2000	2001	2002	2003	2004	2005				
Catalysts	17 197	19 478	19 300	15 256	22 035	23 185	20 314	20 712	28 125	22 504
Potassium nitrate	19 193	20 408	21 699	19 581	27 143	23 271	24 876	27 006	31 356	22 059
Catalysts+KNO_3	32 296	32 296	32 296	32 296	32 296	32 296	32 296	35 636	30 016	35 060
	2010	2011	2012							
Catalysts	20 480	22 250	22 917							
Potassium nitrate	25 920	25 289	32 899							
Catalysts+KNO_3	46 400	47 539	55 816							

[1] Production 1985-1995 assumed to be the same as in 1996.

The implied emission factors for production of catalysts and potassium nitrate are presented in Table 4.7.

Table 4.1 Implied emission factors for production of catalysts and potassium nitrate.

Process	Pollutant	kg/tonne	EMEP/EEA (2009) kg/tonne
Catalysts, potassium nitrate	NO_x	0.3-1.8	-
	NH_3	0.4-3.7	-

4.2.3 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 4.8.

Table 4.8 Emissions from catalyst and fertiliser production at Haldor Topsøe, tonne.

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
CO_2										
NH_3						13	13	13	13	13
NO_x						36	36	36	36	36
TSP										
PM_{10}										
$PM_{2.5}$										
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2	800	800	800	800	800	800	285	1517	563	581
NH_3	13	13	13	13	13	13	13	13	13	9
NO_x	36	36	36	36	36	36	39	40	53	58
TSP										
PM_{10}										
$PM_{2.5}$										
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2	788	911	262	533	896	1062	1466	1348	1198	1419
NH_3	14	71	43	57	68	79	88	107	111	165
NO_x	34	12	22	16	30	30	37	18	19	18
TSP	19	19	19	11	12	23	12	25	26	16
PM_{10}	15	15	15	9	10	18	10	20	21	13
$PM_{2.5}$	11	11	11	7	7	14	7	15	16	10
	2010	2011	2012							
CO_2	2119	1389	1407							
NH_3	123	20	18							
NO_x	17	21	19							
TSP	26	6.8	6.0							
PM_{10}	21	5.4	4.8							
$PM_{2.5}$	16	4.1	3.6							

4.2.4 Input to CollectER

The input data/data sources are presented in Table 4.9.

Table 4.9 Input data for calculating emissions from catalysts/fertiliser production.

	Year	Parameter	Comment/Source
Activity	1985-1995	KNO_3, catalysts	Assumed
	1996-2012	KNO_3, catalysts	Haldor Topsøe (2013b)
Emissions	1990-1995	CO_2, NO_x, NH_3.	Assumed
	1996-2012	CO_2, NO_x, NH_3. TSP	Haldor Topsøe (2013b); information on distribution between energy and process related CO_2 as well as NO_x is presented
	2000-2012	PM_{10}, $PM_{2.5}$	Distribution between TSP, PM_{10}, and $PM_{2.5}$ from CEPMEIP

4.2.5 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.

4.3 Pesticide production

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

4.3.1 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.

4.3.2 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 do only include some of the above mentioned emissions and they do only present aggregated data. The production of pesticides is presented in Table 4.10.

Table 4.10 Production of pesticides, tonne (Cheminova, 2013).

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Pesticides[1]						55 800	55 800	55 800	55 800	55 800
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Pesticides[1]	55 800	55 800	55 800	55 800	55 800	55 800	55 800	56 500	52 985	64 264
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Pesticides	60 284	60 376	55 464	52 849	65 310	53 504	52 575	49 796	49 747	37 484
Year	2010	2011	2012							
Pesticides	30 977	31 000	31 000							

[1] The production 1985-1995 is assumed to be the same as in 1996.

The implied emission factors for pesticide production are presented in Table 4.11.

Table 4.11 Implied emission factors for pesticide production.

Process	Substance	kg/tonne	EMEP/EEA (2009) kg/tonne
Pesticides, Claus process[1]	SO_2	7.0	-
	NMVOC	0.5-2.0	-

[1] Average 1997-2005.

4.3.3 Emission trend

Trends for emissions of NMVOC and SO_2 from production of pesticides are presented in Table 4.12.

Table 4.12 Emissions from production of pesticides (tonne) (Cheminova, 2013).

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
NMVOC						390	390	390	390	390
SO_2										
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
NMVOC	390	150	62	40	54	57	113	44	40	41
SO_2	309	346	461	297	299	189	170	394	408	487
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
NMVOC	29	29	27	25	31	26	25	24	24	18
SO_2	421	449	436	321	340	402	258	36	13	20
Year	2010	2011	2012							
NMVOC	15	15	15							
SO_2	11	27	27							

4.3.4 Input to CollectER

The input data/data sources are presented in Table 4.13.

Table 4.13 Input data for calculating emissions from pesticides production.

	Year	Parameter	Comment/Source
Activity data	1990-1995	Total products	Extrapolated
	1996-2012	Total products	Cheminova (2013)
Emissions	1985-1989	NMVOC	Assumed same level as in 1990
	1990-2000	NMVOC	Cheminova (2006)
	1990-2012	SO_2	Process emissions calculated as difference between published emissions and energy related emissions (Cheminova, 2006)
	2001-2012	NMVOC	EF based on emissions from previous years

4.3.5 Future improvements

Emissions of SO_2 will be extrapolated back to 1980 to complete the time-series to the base year.

4.4 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, 2004). The following SNAP code is covered:

- 04 05 00

4.4.1 Process description

The following description of the production of chemical ingredients is based on the environmental report from the company (Danisco Grindsted, 2013).

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.

4.4.2 Methodology

No activity data available.

4.4.3 Emission trend

Trends for emissions of NMVOC from production of chemical ingredients are presented in Table 4.14.

Table 4.14 Emission from production of chemical ingredients, tonne.

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

4.5 Production of tar products

4.5.1 Process description

No further description is given for production of tar products.

4.5.2 Methodology

No activity data are available. The emissions are based on measured emissions reported in the environmental reports from the company (Koppers, 2013). The emissions for the years 1985 – 2004 are assumed to be the same as for 2005.

4.5.3 Emission trend

Trends for emissions of NMVOC, SO_2, and Hg from production of tar products are presented in Table 4.15.

Table 4.15 Emissions from production of tar products, tonne; Hg in kg.

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
NMVOC						0.9	0.9	0.9	0.9	0.9
SO_2						210	210	210	210	210
Hg										
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
NMVOC	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
SO_2	210	210	210	210	210	210	210	210	210	210
Hg	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
NMVOC	0.9	0.9	0.9	0.9	0.9	0.93	1.18	1.03	0.46	2.00
SO_2	210	210	210	210	210	212	122	55	136	88
Hg	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	0.5
Year	2010	2011	2012							
NMVOC	1.30	1.05	1.21							
SO_2	105	166	203							
Hg	4.8	1.5	13							

4.5.4 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.

A process description will be elaborated.

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 5.1
- Red bronze production; see section 5.2
- Secondary aluminium production; see section 5.3
- Secondary lead production; see section 5.4
- Secondary zinc production; see section 5.5

5.1 Iron and steel production

5.1.1 Steel work

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. The following SNAP codes are covered:

- 04 02 07 Electric furnace steel plant
- 04 02 08 Rolling mill

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 5.1.

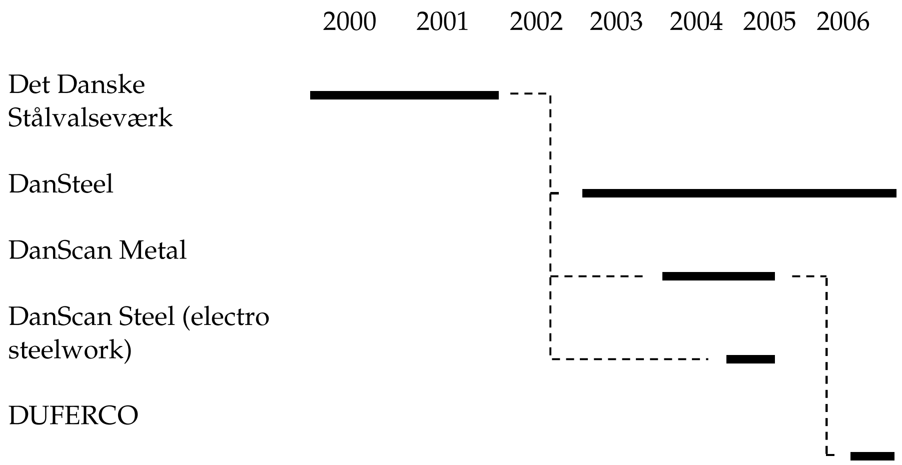


Figure 5.1 Timeline for production at the Danish steelwork.

Process description

The primary raw materials 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 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.

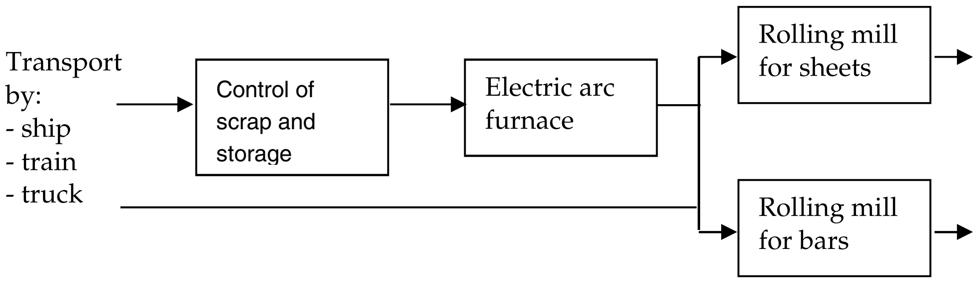


Figure 5.2 Overall flow-sheet for "Det Danske Stålvalseværk" (Stålvalseværket, 2002; DanSteel, 2013).

Methodology

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 tonnes CO_2/tonne 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 5.1.

Table 5.1 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 be choice of calorific value for natural gas and the CO_2 emission factor for natural gas.

Statistical data on activities are available in environmental reports from the single Danish plant (Stålvalseværket) supplemented with other literature; see Table 5.2.

Table 5.2 Overall mass flow for Danish steel production, 1,000 tonne (Stålvalseværket, 2002; Dansteel, 2013).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Iron and steel scrap[4]	-	630[1]	557	-	673	657	664	735	737	691
Steel slabs etc.[4]	-	-	599	-	730	654	744	794	800	727
Steel sheets[4]	444	444	444	452	459	478	484	571	514	571
Steel bars[4]	170	170	170	217	264	239	235	245	235	226
Products, total[4, 6]	614[2]	614[2]	614	669[3]	723	717	719	816	749	798
Steel slabs[5]										
Steel sheets[5, 6]										

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Iron and steel scrap[4]	731	680	-			-				
Steel slabs etc.[4]	803	746	-			-				
Steel sheets[4]	380	465	-			-				
Steel bars[4]	251	256	-			-				
Products, total[4, 6]	631	721	-			250[7]				
Steel slabs[5]				552	600	515	561	635	590	254
Steel sheets[5, 6]				469	506	433	468	520	483	211

	2010	2011	2012
Iron and steel scrap[4]			
Steel slabs etc.[4]			
Steel sheets[4]			
Steel bars[4]			
Products, total[4, 6]			
Steel slabs[5]	457	490	338
Steel sheets[5, 6]	381	390	275

[1] Jensen & Markussen (1993).

[2] Extrapolation.

[3] Intrapolation.

[4] Stålvalseværket

[5] Dansteel (2013).

[6] Input to CollectER.

[7] Assumed.

The applied emission factors are presented in Table 5.3. Regarding the electric arc furnace the emissions have been estimated by use of EF from Illerup et al. (1999).

Table 5.3 Emission factors for PM, heavy metals and POPs for iron and steel

		Electric Arc Furnace	Rolling Mill
TSP	g/tonne	-	6.44
PM_{10}	g/tonne	-	6.12
$PM_{2.5}$	g/tonne	-	3.86
Cd	g/tonne	-	0.00579
Hg	g/tonne	-	0.0232
Ni	g/tonne	-	0.0869
Pb	g/tonne	-	0.089
Zn	g/tonne	-	0.377
HCB	mg/tonne	3.2	-
PCBs	mg/tonne	2.5	-

Emission trend

Emissions of TSP, PM_{10}, $PM_{2.5}$, Cd, Hg, Ni, Pb, Zn, HCB, and PCBs are presented in Table 5.4.

Table 5.1 Emissions from the electro steelwork and rolling mill, PM in tonne, heavy metals and POPs in kg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
TSP										
PM_{10}										
$PM_{2.5}$										
Cd	38.7	38.7	38.7	42.1	45.5	45.2	42.0	30.0	38.1	2.43
Hg	136	136	136	148	160	158	147	84.0	60.6	49.5
Ni	272	272	272	296	320	318	294	228	111.9	86.1
Pb	673	673	673	733	792	786	728	636	373	667
Zn	5346	5346	5346	5821	6295	6243	5782	5022	2416	2121
HCB	1.96	1.96	1.96	2.14	2.31	2.29	2.12	2.61	2.40	2.55
PCBs	1.54	1.54	1.54	1.67	1.81	1.79	1.66	2.04	1.87	1.99
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TSP	41.0	93.0	0	3.02	3.26	2.79	3.01	3.35	3.12	1.36
PM_{10}	39.0	88.0	0	2.87	3.09	2.65	2.86	3.18	2.96	1.29
$PM_{2.5}$	25.0	56.0	0	1.81	1.95	1.67	1.80	2.01	1.87	0.81
Cd	20.0	36.0	0	2.71	2.93	2.51	2.71	3.01	2.80	1.22
Hg	90.0	184	0	10.9	11.7	74.0	10.8	12.1	11.2	4.90
Ni	60.0	123	0	40.7	43.9	80.2	40.6	45.2	42.1	18.3
Pb	440	871	0	40.7	43.9	339	40.6	45.2	42.1	18.3
Zn	1390	2786	0	177	191	1129	176	196	182	79.6
HCB	2.02	2.31	0	0	0	0.80	0	0	0	0
PCBs	1.58	1.80	0	0	0	0.63	0	0	0	0
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
TSP	2.46	2.51	1.77							
PM_{10}	2.33	2.38	1.68							
$PM_{2.5}$	1.47	1.50	1.06							
Cd	2.21	2.26	1.59							
Hg	8.84	9.04	6.37							
Ni	33.1	33.8	23.9							
Pb	33.1	33.8	23.9							
Zn	144	147	103							
HCB	0	0	0							
PCBs	0	0	0							

Input to CollectER

The input data/data sources are presented in Table 5.5.

Table 5.2 Input data for calculation of emissions from steel production.

	Year	Parameter	Comment/Source
Activity	1991	Iron and steel scrap	Jensen & Markussen (1993)
	1992, 1994-2001	Scrap, semi-man. products, final products	Stålvalseværket (2002)
	1990, 1991, 1993	Final products	Estimated with intrapolation and extrapolation
	2003-2013	Final products	Environmental reports (Dansteel, 2013)
Emissions	1990-2001, 2005	HM	Illerup et al. (1999)
	1994-2001	CO_2	Estimated from information on consumption of metallurgical coke (Stålvalseværket, 2002)
	2000-2001	TSP	Stålvalseværket (2002)
	2000-2001	PM_{10}, $PM_{2.5}$	Distribution between TSP, PM_{10}, and $PM_{2.5}$ from CEPMEIP

5.1.2 Grey iron foundries

Process description

No further description is given for iron foundries.

Methodology

Statistical data on production in grey iron foundries are available from different sources. The activity data applied in CollectER were initially based on the statistics from The Association of Danish Foundries (DSBF) combined with information from Statistics Denmark (2013); see Table 5.6.

Table 5.6 Activity data, iron foundries, tonne.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Statistics Denmark						98 209	86 379	95 380	95 809	89 654
DSBF	92 764	97 251	76 577	65 734	70 170	94 195	74 459	85 367	85 845	86 225
Input in CollectER	103 000	100 400	97 800	95 300	92 700	90 200	87 600	85 100	85 800	86 000
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Statistics Denmark	101 698	94 454	103 031	104 470	113 025	99 910	81 453	72 778	71 389	41 388
DSBF	96 467	89 567	87 297	87 271	90 604	87 262	78 565	74 130	NI	NI
Input in CollectER	101 698	94 454	103 031	104 470	113 025	99 910	81 453	72 778	71 389	41 388
	2010	2011	2012							
Statistics Denmark	72 864	83 565	76 426							
DSBF	NI	NI	NI							
Input in CollectER	72 864	83 565	76 426							

According to DSBF the statistic cover 80-90% of the production at Danish foundries. However, the statistics from DSBF were not available from 2008 onwards. Therefore, activity data from Statistics Denmark were applied and until now from 2000 – 2012.

Table 5.7 Emission factors for PM, heavy metals and POPs for grey iron foundries.

TSP	g/tonne	2000
PM_{10}	g/tonne	600
$PM_{2.5}$	g/tonne	90
As	g/tonne	0.3
Cd	g/tonne	0.14
Cr	g/tonne	1.1
Ni	g/tonne	1.3
Pb	g/tonne	7.2
Se	g/tonne	5
Zn	g/tonne	5
HCB	mg/tonne	0.04
PCBs	mg/tonne	0.5

Emission trend

Emissions of TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Ni, Pb, Se, Zn, HCB, and PCBs from iron foundries are presented in Table 5.8.

Table 5.8 Emissions from iron foundries, PM in tonne, heavy metals and POPs in kg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
TSP										
PM_{10}										
$PM_{2.5}$										
As	30.9	30.1	29.3	28.6	27.8	27.1	26.3	25.5	25.7	25.8
Cd	14.4	14.1	13.7	13.3	13.0	12.6	12.3	11.9	12.0	12.0
Cr	113	110	108	105	102	99.2	96.4	93.6	94.4	94.6
Ni	134	131	127	124	121	117	114	111	112	112
Pb	742	723	704	686	667	649	631	613	618	619
Se	515	502	489	477	464	451	438	426	429	430
Zn	515	502	489	477	464	451	438	426	429	430
HCB	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.003
PCBs	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TSP	203	189	206	209	226	200	163	146	143	82.8
PM_{10}	61.0	56.7	61.8	62.7	67.8	59.9	48.9	43.7	42.8	24.8
$PM_{2.5}$	9.15	8.50	9.27	9.40	10.2	8.99	7.33	6.55	6.43	3.72
As	30.5	28.3	30.9	31.3	33.9	30.0	24.4	21.8	21.4	12.4
Cd	14.2	13.2	14.4	14.6	15.8	14.0	11.4	10.2	10.0	5.79
Cr	112	104	113	115	124	110	89.6	80.1	78.5	45.5
Ni	132	123	134	136	147	130	106	94.6	92.8	53.8
Pb	732	680	742	752	814	719	586	524	514	298
Se	508	472	515	522	565	500	407	364	357	207
Zn	508	472	515	522	565	500	407	364	357	207
HCB	0.004	0.004	0.004	0.004	0.005	0.004	0.003	0.003	0.003	0.002
PCBs	0.05	0.05	0.05	0.05	0.06	0.05	0.04	0.04	0.04	0.02
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TSP	146	167	153							
PM_{10}	43.7	50.1	45.9							
$PM_{2.5}$	6.56	7.52	6.88							
As	21.9	25.1	22.9							
Cd	10.2	11.7	10.7							
Cr	80.2	91.9	84.1							
Ni	94.7	109	99.4							
Pb	525	602	550							
Se	364	418	382							
Zn	364	418	382							
HCB	0.003	0.003	0.003							
PCBs	0.04	0.04	0.04							

5.1.3 Future improvements

The methodology for calculating CO_2 emissions from steel production will be updated to take into account the 2006 IPCC guidelines.

All emission factors for steel production as well as iron foundries will be reviewed and clear references provided.

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.

5.2 Allied metal manufacturing

The following SNAP code is covered:

- 04 03 06 Allied metal manufacturing

5.2.1 Process description

No further description is given for Allied metal manufacturing.

5.2.2 Methodology

The activity data have been kept constant since 1997 at 4532 tonnes. For the years between 1990 and 1997 the activity data vary slightly between the years, however, the reference for the data is not clear.

The applied emission factors are presented in Table 5.9 and are all referenced to Illerup et al. (1999).

Table 5.9 Emission factors for heavy metals for Allied metal manufacturing.

Cd	g/tonne	1
Cu	g/tonne	10
Pb	g/tonne	15
Zn	g/tonne	140

5.2.3 Emission trends

Emissions trends for Cd, Cu, Pb, and Zn from ferroalloy production are presented in Table 5.10.

Table 5.10 Emissions from allied metal manufacturing, kg.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cd	3.90	3.99	4.08	4.17	4.26	4.35	4.40	4.53	4.53	4.53
Cu	39.0	39.9	40.8	41.7	42.6	43.5	44.0	45.3	45.3	45.3
Pb	58.4	59.9	61.2	62.6	63.9	65.3	66.0	68.0	68.0	68.0
Zn	545	559	571	584	596	609	616	634	634	634
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cd	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53
Cu	45.3	45.3	45.3	45.3	45.3	45.3	45.3	45.3	45.3	45.3
Pb	68.0	68.0	68.0	68.0	68.0	68.0	68.0	68.0	68.0	68.0
Zn	634	634	634	634	634	634	634	634	634	634
Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Cd	4.53	4.53	4.53							
Cu	45.3	45.3	45.3							
Pb	68.0	68.0	68.0							
Zn	634	634	634							

5.2.4 Future improvements

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

A process description for this activity will be elaborated.

5.3 Secondary aluminium production

The following SNAP code is covered:

- 03 03 10 Secondary aluminium production

5.3.1 Process description

No further description is given for secondary aluminium production.

5.3.2 Methodology

The activity data are obtained from Statistics Denmark. The Danish plant was closed in 2008; see Table 5.11.

Table 5.11 Activity data for secondary aluminium production.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Secondary aluminium	-	-	-	-	-	26 859	26 289	33 101	34 329	33 581
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Secondary aluminium	32 147	32 553	30 538	23 736	20 202	27 760	32 412	36 190	27 495	-

The applied emission factors are presented in Table 5.12.

Table 5.12 Emission factors for particulate matter and PCDD/F for secondary aluminium production.

TSP	g/tonne	1000
PM_{10}	g/tonne	900
$PM_{2.5}$	g/tonne	405
PCDD/F	µg/tonne	1

5.3.3 Emission trends

The emissions of TSP, PM_{10}, $PM_{2.5}$, and PCDD/F are presented in Table 5.13.

Table 5.13 Emissions from production of secondary aluminium, PCDD/F in grams and PM in tonne.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
PCDD/F	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74
TSP										
PM_{10}										
$PM_{2.5}$										
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
PCDD/F	1.74	0.03	0.03	0.02	0.02	0.03	0.03	0.04	0.03	0
TSP	32.1	32.6	30.5	23.7	20.2	27.8	32.4	36.2	27.5	0
PM_{10}	28.9	29.3	27.5	21.4	18.2	25.0	29.2	32.6	24.7	0
$PM_{2.5}$	13.0	13.2	12.4	9.61	8.18	11.2	13.1	14.7	11.1	0

5.3.4 Future improvements

Update EFs in accordance with the 2013 version of the EMEP/EEA guidebook.

Check whether the production of secondary aluminium occurred prior to 1995.

A process description for secondary aluminium production will be elaborated.

5.4 Secondary lead production

The following SNAP code is covered:

- 03 03 07 Secondary lead production

5.4.1 Process description

No further description is given for secondary lead production.

5.4.2 Methodology

A constant activity rate has been used in the inventory. For all years a production of 5000 tonnes has been assumed.

The applied emission factors are presented in Table 5.14.

Table 5.14 EF for PM, heavy metals, and POPs for secondary lead production.

TSP	g/tonne	300
PM_{10}	g/tonne	285
$PM_{2.5}$	g/tonne	150
Cd	g/tonne	0.017
Cu	g/tonne	0.22
Pb	g/tonne	1.75
HCB	mg/tonne	0.3
PCBs	mg/tonne	7.25

5.4.3 Emission trends

The emissions of TSP, PM_{10}, $PM_{2.5}$, Cd, Cu, Pb, HCB, and PCBs are presented in Table 5.15.

Table 5.15 Emissions from production of secondary lead, PM in tonne, heavy metals and POPs in kg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
TSP										
PM_{10}										
$PM_{2.5}$										
Cd	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Cu	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Pb	8.75	8.75	8.75	8.75	8.75	8.75	8.75	8.75	8.75	8.75
HCB	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
PCBs	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TSP	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
PM_{10}	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
$PM_{2.5}$	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Cd	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Cu	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Pb	8.75	8.75	8.75	8.75	8.75	8.75	8.75	8.75	8.75	8.75
HCB	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
PCBs	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04

	2010	2011	2012
TSP	1.50	1.50	1.50
PM_{10}	1.43	1.43	1.43
$PM_{2.5}$	0.75	0.75	0.75
Cd	0.09	0.09	0.09
Cu	1.10	1.10	1.10
Pb	8.75	8.75	8.75
HCB	0.002	0.002	0.002
PCBs	0.04	0.04	0.04

5.4.4 Future improvements

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

The EFs will be evaluated taking into account the 2013 edition of the EMEP/EEA guidebook. The possibility of CO_2 emissions from the process as indicated in the 2006 IPCC guidelines will be investigated.

A process description will be elaborated for secondary lead production.

5.5 Secondary zinc production

The following SNAP code is covered:

- 03 03 08 Secondary zinc production

5.5.1 Process description

No further description is given for secondary zinc production

5.5.2 Methodology

The activity data have been kept constant since 2004. For 2000-2003 the activity data vary, however, the data are not referenced. No activity data are included in the emission database for years prior to 2000.

The applied emission factors are presented in Table 5.16.

Table 5.16 Emission factors for PM for secondary zinc production.

TSP	g/tonne	500
PM_{10}	g/tonne	400
$PM_{2.5}$	g/tonne	300

5.5.3 Emission trends

The trends for emission of TSP, PM_{10}, and $PM_{2.5}$ from production of secondary zinc are presented in Table 5.17.

Table 5.17 Emissions from production of secondary zinc, tonne.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
TSP										
PM_{10}										
$PM_{2.5}$										
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TSP	0.63	0.63	0.61	0.58	1.22	1.22	1.22	1.22	1.22	1.22
PM_{10}	0.50	0.50	0.49	0.47	0.97	0.97	0.97	0.97	0.97	0.97
$PM_{2.5}$	0.38	0.38	0.36	0.35	0.73	0.73	0.73	0.73	0.73	0.73
Year	2010	2011	2012							
TSP	1.22	1.22	1.22							
PM_{10}	0.97	0.97	0.97							
$PM_{2.5}$	0.73	0.73	0.73							

5.5.4 Future improvements

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

The emission factors will be evaluated taking into account the 2013 edition of the EMEP/EEA guidebook. The possibility of CO_2 emissions from the process as indicated in the 2006 IPCC guidelines will be investigated.

A description of the process for secondary zinc production will be elaborated.

6 Other industry

Other production covers the following processes:

- Beer, wine and spirits; see section 6.1
- Food; see section 6.2
- Sugar; see section 6.2.5

6.1 Beer, wine and spirits production

The production of alcoholic beverages is spread over a large number of different companies of different sizes. The processes included in the inventory are:

- Production of beer
- Production of spirit
- Production of ethanol, technical

Production of wine is not currently included in the inventory.

The following SNAP codes are covered:

- 04 06 07 Beer
- 04 06 08 Spirits

6.1.1 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 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.

6.1.2 Methodology

The production statistics for the relevant processes have been aggregated based on data from Statistics Denmark and presented in Table 6.1. Data before 1990 are not available and therefore the activity level for 1985-1989 has been assumed to be equal to 1990.

Table 6.1 Production of beer and spirits, 1000 l (Statistics Denmark).

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Beer						930 405	930 405	930 405	930 405	930 405
Spirits						8026	8026	8026	8026	8026
Ethanol, technical						12 977	12 977	12 977	12 977	12 977
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Beer	930 405	967 177	977 541	943 504	941 020	990 321	959 132	918 055	804 354	820 502
Spirits	8026	79332	7474	7472	3874	7823	7303	6687	6596	5969
Ethanol, technical	12 977	13 444	16 936	18 245	20 204	19 338	22 190	22 056	21 336	17 276
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Beer	745 492	723 311	820 242	835 184	854 988	868 041	816 890	765 789	647 402	603 797
Spirits	5893	5861	6240	6379	5943	5518	5018	4140	2976	2721
Ethanol, technical	18 059	19 556	19 183	18 097	17 686	20 780	20 336	15 663	19 195	15 896
Year	2010	2011	2012							
Beer	633 535	658 995	608 021							
Spirits	3173	6067	5784							
Ethanol, technical	13 827	14 846	10 486							

The emission of NMVOC from production of alcoholic beverages is estimated from production statistics (Statistics Denmark) and standard emission factors from the EMEP/EEA Guidebook (EMEP/EEA, 2009); see Table 6.2.

Table 6.2 Emission factors for NMVOC for production of alcoholic beverages.

Beverage	kg NMVOC/1 000 l	Reference
Beer	0.35	EMEP/EEA (2009)
Spirits	4	EMEP/EEA (2009)
Ethanol, technical	4	EMEP/EEA (2009)

6.1.3 Emission trend

The emission trend for emission of NMVOC from production of beverage is presented in Table 6.3.

Table 6.3 NMVOC emissions from production of alcoholic beverages, tonne NMVOC.

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Beer						326	326	326	326	326
Spirits						32.1	32.1	32.1	32.1	32.1
Ethanol, technical						51.9	51.9	51.9	51.9	51.9
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Beer	326	339	342	330	329	347	336	321	282	287
Spirits	32.1	31.7	29.9	29.9	15.5	31.3	29.2	26.7	26.4	23.9
Ethanol, technical	51.9	53.8	67.7	73.0	80.8	77.4	88.8	88.2	85.3	69.1
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Beer	261	253	287	292	299	304	286	268	227	211
Spirits	23.6	23.4	25.0	25.5	23.8	22.1	20.1	16.6	11.9	10.9
Ethanol, technical	72.2	78.2	76.7	72.4	70.7	83.1	81.3	62.7	76.8	63.6
Year	2010	2011	2012							
Beer	222	231	213							
Spirits	12.7	24.3	23.1							
Ethanol, technical	55.3	59.4	41.9							

6.1.4 Input to CollectER

The input data/data sources are presented in Table 6.4.

Table 6.4 Input data for calculating emissions from production of alcoholic beverages.

	Year	Parameter	Comment/Source
Activity data	1985-1989	Production	Assumed same level as 1990
	1990-2012	Production	Statistics Denmark
Emission factors	1985-2012	NMVOC	EMEP/EEA (2009)

6.1.5 Future improvements

The activity data for years prior to 1990 will be assessed.

The production of wine will be investigated for possible inclusion in the emission inventory.

It will be investigated whether it is possible to separate the production of spirits into categories depending on whether the spirit is matured or not.

6.2 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:

- Biscuits, cookies and bakery products
- Bread (rye and wheat)
- Meat - slaughtering and processing
- Poultry - slaughtering and processing
- Fish and shellfish - processing
- Margarines and solid fats
- Coffee roasting

The following SNAP codes are covered:

- 04 06 05 Bread
- 04 06 27 Meat (fish etc. frying/curing)

- 04 06 98 Margarine and solid cooking fats
- 04 06 99 Coffee roasting

6.2.1 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 sugar beet and cane and the subsequent refining of sugar
- 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)

6.2.2 Methodology

The production statistics for the relevant processes have been aggregated based on data from Statistics Denmark and presented in Table 6.5. Data before 1990 are not available for all sub-sources and therefore the activity level for 1985-1989 has been assumed at the same level as 1990 for these categories.

Table 6.5 Production statistics for production of bread and cookies, meat curing (meat, poultry, fish, and shellfish), production of margarine and solid cooking fats, roasting of coffee, tonne.

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Biscuits, cookies and other bakery products						100 000	100 000	100 000	100 000	100 000
Bread (rye and wheat)						190 000	190 000	190 000	190 000	190 000
Meat						1 381 400	1 457 000	1 452 500	1 453 000	1 435 000
Poultry						114 700	115 400	113 000	116 800	128 000
Fish and shellfish						1 650 000	1 650 000	1 650 000	1 650 000	1 650 000
Solid fats and oils						230 000	230 000	230 000	230 000	230 000
Coffee, not roasted, not decaff., supply						50 000	50 000	50 000	50 000	50 000
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Biscuits, cookies and other bakery products	98 574	123 393	128 792	135 796	138 136	148 247	163 634	162 958	149 580	130 944
Bread (rye and wheat)	189 562	205 111	195 648	207 987	217 932	230 762	212 701	239 621	247 309	234 153
Meat	1477700	1549400	1664300	1795000	1796600	1758800	1756200	1782700	1880500	1 884 900
Poultry	131 400	138 900	155 100	167 300	172 500	173 000	170 100	175 900	190 500	202 400
Fish and shellfish	1 643 648	1 940 020	2 247 327	1 927 206	2 228 849	2 360 076	1 934 419	2 137 490	1 905 973	1 812 459
Solid fats and oils	230 705	236 014	237 921	221 026	200 548	198 274	193 380	217 120	226 929	204 485
Coffee, not roasted, not decaff., supply	52 086	50 588	55 725	55 126	55 235	48 870	55 097	52 177	55 169	60 243
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Biscuits, cookies and other bakery products	138 488	145 566	150 596	156 018	165 139	157 214	148 683	136 397	124 170	115 496
Bread (rye and wheat)	244 060	270 707	252 163	246 639	255 813	257 444	270 493	256 265	254 373	266 886
Meat	1 864 000	1 957 600	2 002 500	1 997 600	2 051 500	2 009 400	1 958 200	2 016 100	1 912 800	1 785 300
Poultry	201 700	216 100	217 600	199 700	192 900	187 500	171 100	172 400	176 200	168 800
Fish and shellfish	1 926 516	1 895 372	1 838 940	1 500 075	1 508 929	1 348 424	1 235 158	1 046 152	984 407	1 054 914
Solid fats and oils	195 679	178 171	225 037	208 980	210 337	200 170	181 654	191 405	191 082	175 192
Coffee, not roasted, not decaff., supply	55 617	58 947	56 857	51 009	54 638	36 555	34 549	33 121	33 643	33 933
Year	2010	2011	2012							
Biscuits, cookies and other bakery products	117 500	114 486	109 310							
Bread (rye and wheat)	244 753	207 316	232 768							
Meat	1 877 000	1 934 400	1 807 000							
Poultry	186 500	187 000	141 800							
Fish and shellfish	1 066 548	911 624	614 576							
Solid fats and oils	180 214	191 455	186 235							
Coffee, not roasted, not decaff., supply	34 190	22 178	17 676							

The emission of NMVOC from production of food is estimated from production statistics (Statistics Denmark, 2013; Danish AgriFish Agency, 2013) and standard emission factors from the EMEP/EEA guidebook (EMEP/EEA, 2009); see Table 6.6.

Table 6.6 Emission factors for NMVOC for food production/processing.

Food	kg NMVOC/tonne	Reference
Meat, fish and poultry	0.3	EMEP/EEA (2009)
Margarine and solid cooking fats	10	EMEP/EEA (2009)
Cakes, biscuits and breakfast cereals	1	EMEP/EEA (2009)
Bread	4.5	EMEP/EEA (2009)
Coffee roasting	0.55	EMEP/EEA (2009)

6.2.3 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 6.7.

Table 6.7 Emission of NMVOC from production of bread and cookies, meat curing (meat, poultry, fish, and shellfish), production of margarine and solid cooking fats, roasting of coffee, tonne.

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Biscuits, cookies and other bakery products						100	100	100	100	100
Bread (rye and wheat)						855	855	855	855	855
Meat						414	437	436	436	431
Poultry						34.4	34.6	33.9	35.0	38.4
Fish and shellfish						495	495	495	495	495
Solid fats and oils						2300	2300	2300	2300	2300
Coffee, not roasted, not decaffeinated, supply						27.5	27.5	27.5	27.5	27.5
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Biscuits, cookies and other bakery products	98.6	123	129	136	138	148	164	163	150	131
Bread (rye and wheat)	853	923	880	936	981	1038	957	1078	1113	1054
Meat	443	465	499	539	539	528	527	535	564	565
Poultry	39.4	41.7	46.5	50.2	51.8	51.9	51.0	52.8	57.2	60.7
Fish and shellfish	493	582	674	578	669	708	580	641	572	544
Solid fats and oils	2307	2360	2379	2210	2005	1983	1934	2171	2269	2045
Coffee, not roasted, not decaffeinated, supply	28.6	27.8	30.6	30.3	30.4	26.9	30.3	28.7	30.3	33.1
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Biscuits, cookies and other bakery products	138	146	151	156	165	157	149	136	124	115
Bread (rye and wheat)	1098	1218	1135	1110	1151	1158	1217	1153	1145	1201
Meat	559	587	601	599	615	603	587	605	574	536
Poultry	60.5	64.8	65.3	59.9	57.9	56.3	51.3	51.7	52.9	50.6
Fish and shellfish	578	569	552	450	453	405	371	314	295	316
Solid fats and oils	1957	1782	2250	2090	2103	2002	1817	1914	1911	1752
Coffee, not roasted, not decaffeinated, supply	30.6	32.4	31.3	28.1	30.1	20.1	19.0	18.2	18.5	18.7

Year	2010	2011	2012
Biscuits, cookies and other bakery products	118	114	109
Bread (rye and wheat)	1101	933	1047
Meat	563	580	542
Poultry	56.0	56.1	42.5
Fish and shellfish	320	273	184
Solid fats and oils	1802	1915	1862
Coffee, not roasted, not decaffeinated, supply	18.8	12.2	9.72

6.2.4 Input to CollectER

The input data/data sources are presented in Table 6.8.

Table 6.1 Input data for calculating emissions from food production/processing.

	Year	Parameter	Comment/Source
Activity data	1985-1989	Production	Assumed same level as 1990
	1990-2012	Production	Statistics Denmark (2013), Danish AgriFish Agency (2013)
Emission factors	1985-2012	NMVOC	EMEP/EEA (2009)

6.2.5 Future improvements

The activity data for years prior to 1990 will be assessed.

It will be investigated whether the bread production can be subdivided to allow for the application of more disaggregated emission factors.

Other activities not currently included, such as grain drying, production of animal feeds including animal rendering (seen in conjunction with the activities described in Chapter 7.2) and fish meal processing will be investigated further.

6.3 Sugar production

The production of sugar 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

6.3.1 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 the beets and cutting up and pressing/extraction follow this process. The sugar juice is purified by addition of burnt lime. Protein compounds are removed by addition of sulphur dioxide. Burnt lime and sulphur dioxide is produced on location by burning limestone in a lime kiln and burning of sulphur in a sulphur-kiln. Surplus of lime is precipitated by the carbon dioxide from the lime kiln resulting in generation of lime sludge.

The sugar containing juice is concentrated and finally, the sugar is crystallised. Heat and power is produced on location.

6.3.2 Methodology

Production statistics for production of sugar are available in the environmental reports for the years 1996-2012, however, each 12 month period going from May 1 - April 30 (Danisco Sugar Assens, 2007; Danisco Sugar Nakskov, 2008; Danisco Sugar Nykøbing, 2008; Nordic Sugar Nakskov, 2013; Nordic Sugar Nykøbing, 2013). Therefore, the yearly production does not correspond with the yearly sale registered by Statistics Denmark (Statistics Denmark, 2013). During nine years (1996-2004) the sale is 4.8% above the production. The information from Statistics Denmark covers the whole period and therefore the amount of sugar for sale is used as activity data. The company information is used for calculating the allocation of production/sale between the three locations; see Table 6.9.

Table 6.9 Production of sugar at different locations, tonne.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Assens	151 713	152 933	141 182	145 278	148 797	133 243	129 545	146 230	167 087	160 523
Nakskov	202 284	203 910	188 243	193 704	198 396	177 657	172 727	194 974	222 782	214 031
Nykøbing	151 713	152 933	141 182	145 278	148 797	133 243	129 545	146 230	167 087	160 523
Total (Statistics Denmark)	505 709	509 776	470 608	484 259	495 991	444 143	431 818	487 434	556 955	535 077
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Assens	132 957	168 709	152 419	153 237	135 503	151 941	137 400	0	0	0
Nakskov	177 276	224 946	203 225	204 316	180 671	202 588	183 200	170 244	208 639	222 352
Nykøbing	132 957	168 709	152 419	153 237	135 503	151 941	137 400	159 567	191 622	206 094
Total (Statistics Denmark)	443 189	562 364	508 063	510 791	451 677	506 471	458 001	356 740	465 995	394 779
	2010	2011	2012							
Assens	0	0	0							
Nakskov	137 880	114 728	137 856							
Nykøbing	124 192	103 337	124 170							
Total (Statistics Denmark)	262 072	218 065	262 026							

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 environmental reports from Nakskov and Nykøbing

2010-2012: 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).

The CO_2 emission from the refining of sugar is estimated from production statistics for sugar and a number of assumptions: consumption of 0.02 tonne $CaCO_3$ per tonne sugar and precipitation of 90 % CaO resulting in an emission factor at 0.0088 tonne CO_2 per tonne sugar (consumption: 2 % $CaCO_3$ per tonne sugar beets, 10 % sugar in sugar beets). The assumptions are based on environmental reports covering the year 2002.

However, from the year 2006-2012 the CO_2 emission compiled by the company for EU-ETS is used in the inventory (Nordic Sugar, 2013). During the preliminary work to establish the EU ETS in Denmark the relevant companies reported energy and process related CO_2 emissions for the years 1998-2002 (DEA, 2004). Based on the process CO_2 emissions and statistical information (Statistics Denmark, 2013) the actual emission factors were determined to respectively 0.0048, 0.0038, 0.0046, 0.0039, and 0.0051 tonne CO_2 per tonne product (average: 0.0044).

Regarding NMVOC, the default EF has been revised based on company specific measurements obtained from Nielsen (2011). TOC has been measured in order to solve 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/tonne produced sugar.

6.3.3 Emission trend

The emission trend for emission of CO_2 and NMVOC from production of sugar is presented in Table 6.10.

Table 6.10 Emissions from production of sugar, tonne.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2	4450	4486	4141	4261	4365	3908	3800	4289	4901	4709
NMVOC	101	102	94.1	96.9	99.2	88.8	86.4	97.5	111	107
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2	3900	4949	4471	4495	3975	4457	2172	1720	2665	1921
NMVOC	88.6	112	102	102	90.3	101	91.6	66.0	80.1	85.7
Year	2010	2011	2012							
CO_2	1557	2013	2241							
NMVOC	52.4	43.6	52.4							

6.3.4 Input to CollectER

The input data/data sources are presented in Table 6.11.

Table 6.11 Input data for calculating emissions from sugar production.

	Year	Parameter	Comment/Source
Activity	1990-2012	Production	Danisco Sugar, Nordic SugarStatistics Denmark
Emissions	1990-2012	NMVOC	EF based on Nielsen (2011)

6.3.5 Future improvements

The activity data for years prior to 1990 will be assessed in order to report emissions of NMVOC back to the base year (1985).

The CO_2 EF for years prior to the EU ETS will be further investigated.

7 Other

The category Other include the following two processes:

- Consumption of lubricants; see section 7.1
- Treatment of slaughterhouse waste; see section 0

7.1 Consumption of lubricants

7.1.1 Process description

Lubricants are used in different sectors but primarily in stationary and mobile engines. During the use an amount of lubricant will be oxidised and hence emitted as CO_2. Emissions from the disposal of lubricants, i.e. by incineration of waste oil are included in the energy sector. Emissions of other pollutants based on the oxidation during use are already included in the emission factors for these sources and hence not included here to avoid double counting. The following SNAP code is covered:

- 06 06 04 Lubricants

7.1.2 Methodology

The emission of CO_2 from oxidation of lubricants during use is calculated according to the following formula:

$$E_{CO2} = LC \bullet CC_{\text{lub}} \bullet ODU_{\text{lub}} \bullet 44/12$$

where:

E_{CO2} = emission of CO_2
LC = consumption of lubricants
CC = carbon content of lubricant
ODU = amount of lubricant oxidised during use

In the calculation the following default values have been applied: CC = 20.1 kg C per GJ and ODU = 0.2 (IPCC, 2006). Based on the formula the emission factor for CO_2 can be calculated:

$$EF_{CO2} = 14.74\ kg\ CO_2\ \ per\ GJ$$

The activity data applied for consumption of lubricant oil are presented in Table 7.1.

Table 7.1 Statistics for consumption of lubricant oil (GJ) (Danish Energy Agency, 2013).

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Lubricant oil	3 372 217	3 314 973	3 264 706	3 225 940	3 184 949	3 313 653	3 316 595	3 198 524	3 042 820	2 898 014
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Lubricant oil	2 693 097	2 611 003	2 704 486	2 512 466	2 559 981	2 550 139	2 543 749	2 574 168	2 307 173	2 115 977
Year	2010	2011	2012							
Lubricant oil	2 250 868	2 150 308	2 150 308							

7.1.3 Emission trend

The emission trend for emission of CO_2 from consumption of lubricants is presented in Table 7.2.

Table 7.2 Emission of CO_2 from oxidation of lubricant oil during use.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Tonne CO_2	49 706	48 863	48 122	47 550	46 946	48 843	48 887	47 146	44 851	42 717
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Tonne CO_2	39 696	38 486	39 864	37 034	37 734	37 589	37 495	37 943	34 008	31 189
Year	2010	2011	2012							
Tonne CO_2	33 178	31 696	31 696							

7.1.4 Input to CollectER

A summary of input data/data sources are presented in Table 7.3.

Table 7.3 Input data for calculating emissions from the use of lubricants.

	Year	Parameter	Comment/Source
Activity data	1990-2012	GJ consumed lubricant	Danish Energy Agency (2013)
Emission factor	1990-2012	CO_2	EF calculated from IPCC (2006)

7.2 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 information on treatment of slaughterhouse waste is based on Daka (2002; 2004).

7.2.1 Process description

The raw materials for the processes are by-products from the slaughterhouse, animals dead from accident or disease, 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 emissions from the processes are related to the consumption of energy and emissions of e.g. NH_3. The last-mentioned emissions are related to storage of the raw materials as well as to the drying process.

7.2.2 Methodology

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, 2013). 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 (2013). The activity data are presented in Table 7.4.

Table 7.4 Activity data for treatment of slaughterhouse waste, tonne.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Meat/bone meal[1]	128 789	186 145	181 009	209 191	197 800	197 034	191 335	166 633	177 669	201 511
Animal fat[1]	62 178	73 030	76 098	72 244	58 298	54 178	57 674	72 586	72 753	89 244
Blood meal[2]	11000	11 000	11 000	11 000	11 000	11 000	11 000	11 000	11 400	11 500
Total	201 967	270 175	268 107	292 435	267 098	262 212	260 009	250 219	261 822	302 255
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Meat/bone meal[1]	198 568	58 971	142 100	227 753	241 566	177 388	118 049	142 577	140 502	116 412
Animal fat[1]	73 436	56 393	108 505	93 794	98 570	90 234	75 598	82 648	84 700	70 889
Blood meal[2]	11 400	9700	8900	9500	10 600	10 230	8905	10 621	10 045	7482
Total	283 404	125 064	259 505	331 047	350 736	277 852	202 552	235 846	235 247	194 783
Year	2010	2011	2012							
Meat/bone meal[1]	104 622	96 251	73 717							
Animal fat[1]	75 285	77 740	77 740							
Blood meal[2]	7 482	7 482	7 482							
Total	187 389	181 473	158 939							

[1] Statistics Denmark (2013).

[2] Based on environmental reports from Daka (2013) for the years 1998 – 2009 and assumed for the other years.

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, 2013). 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 7.5.

Table 7.5 Emission factors for treatment of slaughterhouse waste (daka 2002; 2004).

	EF	1990-2001	2002	2003-2012
NH_3	g/tonne	120	151	475

7.2.3 Emission trend

The emission trend for emission of NH_3 from treatment of slaughterhouse waste is presented in Table 7.6.

Table 7.6 Emission of NH_3 from treatment of slaughterhouse waste, tonne.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
NH_3	24.2	32.4	32.2	35.1	32.1	31.5	31.2	30.0	31.4	36.3
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
NH_3	34.0	31.9	47.9	157	167	132	96.4	112	112	92.5
Year	2010	2011	2012							
NH_3	89.0	86.2	75.5							

7.2.4 Input to CollectER

A summary of input data/data sources are presented in Table 7.7.

Table 7.1 Input data for calculating emissions from treatment of slaughter waste.

	Year	Parameter	Comment/Source
Activity	1990-2012	Meat and bone meal, animal fat	Statistics Denmark (2013)
	1998-2008	Blood meal	Daka (2009)
Emission factors	1990-2001	NH_3	Weighted average. Daka (2002; 2004)
	2002-20012	NH_3	Weighted yearly average. Daka (2004)

8 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 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 sectors are included in the EMEP/EEA guidebook and the reporting format, but not included in the inventory. These sources together with an indication of the relevant pollutants are included below. Also included are emission sources that are not currently included in the inventory.

8.1 Source sectors not included

8.1.1 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.

8.1.2 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.

8.1.3 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 occurs in Denmark, no activity data have been collected.

8.1.4 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.

8.2 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 an exhaustive list of potential emission sources within industrial processes.

8.2.1 Grain drying

This activity is part of the food production/processing category. During the drying of grain NMVOC is emitted.

8.2.2 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.

8.2.3 Wine production

This activity is part of the beverages category. During the fermentation and maturation, NMVOC is emitted.

8.2.4 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.

8.2.5 Concrete batching

Concrete batching is a potential emission source of particulate matter and also some heavy metals.

8.2.6 Meat/fish smokehouses

Smoking of fish and meat is a potential source of emissions of particulate matter, NMVOC and PAH.

8.2.7 Yeast manufacturing

Emissions of NMVOC will occur during the fermentation to produce yeast.

9 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.

9.1 Methodology

9.1.1 Greenhouse gases

The uncertainty for greenhouse gas emissions have been estimated according to the IPCC Good Practice Guidance (IPCC, 2000). The uncertainty has been estimated by two approaches; Tier 1 and Tier 2. Both approaches are further described in Nielsen et al. (2014b).

The Tier 1 approach is based on a normal distribution and a confidence interval of 95 %.

The input data for the Tier 1 approach 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 9.1.

The Tier 2 approach 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 Tier 2 approach 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

The same emission source categories and emission data have been applied for both approaches.

Table 9.1 Uncertainty rates for activity data and emission factors for greenhouse gases.

		Activity data uncertainty	Emission factor uncertainty				
			CO_2	N_2O	HFCs	PFCs	SF_6
2A1	Cement production	1	2				
2A2	Lime production	5	5				
2A3	Limestone and dolomite use	5	5				
2A5	Asphalt roofing	5	25				
2A6	Road paving with asphalt	5	25				
2A71	Glass production	5	2				
2A72	Yellow bricks	5	2				
2A73	Expanded clay	5	2				
2B5	Catalysts/Fertilizers, Pesticides and Sulphuric acid	5	5				
2B2	Nitric acid production	2		25			
2C1	Iron and steel production	5	5				
2D2	Food and Drink	5	5				
2F	Consumption of HFC	10			50		
2F	Consumption of PFC	10				50	
2F	Consumption of SF6	10					50
2G	Other: Lubricants	2	5				

The producer has delivered the activity data for production of cement as well as calculated the emission factor based on quality measurements. The uncertainties on activity data and emission factors are assumed to be 1 % and 2 %, respectively.

The activity data for production of lime and bricks are based on information compiled by Statistics Denmark. Due to the many producers and the variety of products, the uncertainty is assumed to be 5 %. The emission factor is partly based on stoichiometric relations and partly on an assumption of the number of yellow bricks. The combined uncertainty is assumed to be 5 %.

The producers of glass and glass wool have registered the consumption of - raw materials containing carbonate. The uncertainty is assumed to be 5 %. The emission factors are based on stoichiometric relations and, therefore, uncertainty is assumed to be 2 %.

The producer has 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 and iron and steel production.

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.

9.1.2 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 Tier 1 approach.

The uncertainty estimates are based on emission data for the base year and year 2012 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 uncertainty rates are shown in Table 9.2 below.

Table 9.2 Uncertainty rates for activity data and emission factors for air pollutants.

	Activity data uncertainty	Emission factor uncertainty
SO_2	2	20
NO_x	2	50
NMVOC	50	50
CO	2	50
NH_3	2	1000
TSP	2	50
PM_{10}	2	50
$PM_{2.5}$	2	50
Arsenic	2	1000
Cadmium	2	1000
Chromium	2	1000
Copper	2	1000
Mercury	2	1000
Nickel	2	1000
Lead	2	1000
Selenium	2	1000
Zinc	2	1000
PCDD/F	2	1000

9.2 Results of the uncertainty estimates for GHGs

The Tier 1 uncertainty estimates for industrial processes emission inventories are shown in Table 9.3. The Tier 2 uncertainty estimates are shown in Table 9.4 and Table 9.5.

The Tier 1 uncertainty interval for greenhouse gas is estimated to be ± 19.0 % and trend in greenhouse gas emission is -29.0 % and ± 13.0 %-age points. The dominant sources of uncertainty for greenhouse gas emissions in 2012 are emissions of HFCs and SF_6 followed by cement production.

Table 9.3 Danish greenhouse gas emission uncertainty estimates, Tier 1 approach, 2012.

Pollutant	Uncertainty, %	Trend 1990-2012, %	Trend uncertainty, %-age points
GHG	± 19.0	-29.0	± 13.0
CO_2	± 2.0	-12.6	± 1.2
HFCs	± 51	+202	± 43
PFCs	± 51	+1600	± 240
SF_6	± 51	+9.8	± 16

The Tier 2 uncertainty for CO_2 emission from industrial processes and consumption of F-gases is presented in Table 9.4 and Table 9.5. The uncertainty estimates are based on the same individual uncertainties as applied for the Tier 1 uncertainty estimates.

Table 9.4 Tier 2 uncertainty estimates for CO_2 emissions from industrial processes.

		1990			2012			1990-2012		
		Median	Uncertainty (%)		Median	Uncertainty (%)		Median	Uncertainty (%)	
		Emission	Lower	Upper	Emission	Lower	Upper	Emission	Lower	Upper
			(-)	(+)		(-)	(+)		(-)	(+)
CO_2	ktonne	2195	10	13	1007	2.0	1.9	1182	9.2	12

Table 9.5 Tier 2 uncertainty estimates for F-gas emissions from industrial processes.

		1995			2012			1995-2012		
		Median	Uncertainty (%)		Median	Uncertainty (%)		Median	Uncertainty (%)	
		Emission	Lower	Upper	Emission	Lower	Upper	Emission	Lower	Upper
			(-)	(+)		(-)	(+)		(-)	(+)
CO_2 eqv.	ktonne	292	22	33	793	25	37	-414	-60	-33

9.3 Results of the uncertainty estimates for other pollutants

The results of the uncertainty analysis for other pollutants are shown in Table 9.6 below.

Table 9.6 Danish air pollution emission uncertainty estimates, Tier 1 approach, 2012.

	Uncertainty, %	Trend, %	Trend uncertainty, %
SO_2	20	-58	1.2
NO_x	50	-98	0.1
NMVOC	71	-18	57.7
CO	50	-97	0.1
NH_3	1000	-27	2.1
TSP	50	-65	1.0
PM_{10}	50	-72	0.8
$PM_{2.5}$	50	-75	0.7
Arsenic	1000	-50	1.4
Cadmium	1000	-78	0.6
Chromium	1000	-82	0.5
Copper	1000	-60	1.1
Mercury	1000	-84	0.4
Nickel	1000	-82	0.5
Lead	1000	-68	0.9
Selenium	1000	-47	1.5
Zinc	1000	-81	0.5
Dioxins	1000	-100	0.0

10 QA/QC and verification

For greenhouse gases the industrial processes sector are covered by the QA/QC manual guiding the quality work for the Danish greenhouse gas inventory, see Nielsen et al. (2013) 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., 2014b).

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 Anne Jensen from the Danish Environmental Protection Agency. The comments received have been incorporated in the report or have been listed as future improvements.

11 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 11.1 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 11.1 List of identified areas for future improvement.

Main sector	Subsector	Improvement	Priority
Mineral industry	Cement production	The company is proposed to be contacted regarding new emission measurements of heavy metals.	2
Mineral industry	Cement production	The emission factors for NO_x, SO_2 and CO will be assessed for the period prior to 2006.	2
Mineral industry	Cement production	It will be considered to estimate emissions of all POPs using emission factors based on the clinker production rather than the fuel consumption data.	2
Mineral industry	Lime production	EU-ETS data for the years 2006 to 2010 will be included.	1
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	Currently, an emission of PCDD/F has been estimated and reported for lime production. However, the basis of the emission factor is unclear; also there are there any indications in literature that there are process emissions of PCDD/F from lime production. Therefore, this will be corrected in future submissions.	1
Mineral industry	Limestone use – flue gas desulphurisation	The environmental reports for previous years will be further analysed in order to establish better information on the character of the flue gas cleaning systems and thereby the consumption of lime/limestone.	2
Mineral industry	Limestone use – flue gas desulphurisation	Also, alternative methods will be investigated, e.g. developing a factor for limestone consumption per tonne of waste incinerated and applying this factor to the years when limestone consumption is not available.	1
Mineral industry	Limestone use – mineral wool production	The environmental reports/PRTR shows significant variation in CO emission. The time series will be verified by contact to the company.	2
Mineral industry	Asphalt roofing	The emission factors are currently not referenced. The emission factors will be reinvestigated using the latest edition of the EMEP/EEA guidebook as well as other available literature.	2
Mineral industry	Asphalt roofing	A process description for asphalt roofing will be elaborated.	3
Mineral industry	Road paving	The activity data will be further investigated, especially the use of cutback asphalt.	2
Mineral industry	Road paving	The Danish asphalt plants will be investigated as well as the mass balance for bituminous materials appearing in the Danish energy statistics (Danish Energy Agency, 2013).	3
Mineral industry	Road paving	The emission factors will be reassessed and properly referenced.	2
Mineral industry	Glass production	The methodology for estimating CO_2 emissions for the years prior to 1997 will be reassessed.	1
Mineral industry	Glass production	It will be investigated whether there is glass production at other plants in Denmark. Data from Statistics Denmark will be investigated and contact made to the glass industry.	1
Mineral industry	Glass wool production	Consumption of dolomite during the years 1990 – 2005 will be investigated and included in the inventory, if possible.	1

Continued			
Mineral industry	Glass wool production	The emission factors used for NMVOC and CO will be further investigated. The particle size distribution currently used will be compared with the particle size distribution in the latest edition of the EMEP/EEA guidebook.	2
Mineral industry	Glass wool production	The activity data for years before 1998 (production data) and 1996 (raw material consumption) will be further investigated.	2
Mineral industry	Brick and tiles	The SO_2 emission factor will be improved based on additional data for coming years. Also, the emission of SO_2 will be extrapolated back to 1980.	2
Mineral industry	Brick and tiles	The assumptions made to convert the activity data will be further investigated as will the exclusion of CO_2 emissions from the production of red bricks and tiles prior to 2006.	1
Mineral industry	Expanded clay products	The SO_2 emission factor will be improved based on data for recent and coming years.	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	Pesticide production	Emissions of SO_2 will be extrapolated back to 1980 to complete the time-series to the base year.	3
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	A process description will be elaborated.	3
Metal industry	Iron and steel production	The methodology for calculating CO_2 emissions from steel production will be updated to take into account the 2006 IPCC guidelines.	1
Metal industry	Iron and steel production	All emission factors for steel production as well as iron foundries will be reviewed and clear references provided.	2
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
Metal industry	Allied metal manufacturing	It will be investigated whether activity data are available from Statistics Denmark.	2
Metal industry	Allied metal manufacturing	A process description for this activity will be elaborated.	3
Metal industry	Secondary aluminium production	Update EFs in accordance with the 2013 version of the EMEP/EEA guidebook.	2
Metal industry	Secondary aluminium production	Check whether the production of secondary aluminium occurred prior to 1995.	2
Metal industry	Secondary aluminium production	A process description for secondary aluminium production will be elaborated.	3
Metal industry	Secondary lead production	It will be investigated whether more accurate activity data are available from Statistics Denmark.	1
Metal industry	Secondary lead production	The EFs will be evaluated taking into account the 2013 edition of the EMEP/EEA guidebook. The possibility of CO_2 emissions from the process as indicated in the 2006 IPCC guidelines will be investigated.	1
Metal industry	Secondary lead production	A process description will be elaborated for secondary lead production.	3
Metal industry	Secondary zinc production	It will be investigated whether more accurate activity data are available from Statistics Denmark.	1
Metal industry	Secondary zinc production	The emission factors will be evaluated taking into account the 2013 edition of the EMEP/EEA guidebook. The possibility of CO_2 emissions from the process as indicated in the 2006 IPCC guidelines will be investigated.	1
Metal industry	Secondary zinc production	A description of the process for secondary zinc production will be elaborated.	3

Continued			
Other industry	Beer, wine and spirits	The activity data for years prior to 1990 will be assessed.	3
Other industry	Beer, wine and spirits	The production of wine will be investigated for possible inclusion in the emission inventory.	2
Other industry	Beer, wine and spirits	It will be investigated whether it is possible to separate the production of spirits into categories depending on whether the spirit is matured or not.	3
Other industry	Food production/processing	The activity data for years prior to 1990 will be assessed.	3
Other industry	Food production/processing	It will be investigated whether the bread production can be subdivided to allow for the application of more disaggregated emission factors.	2
Other industry	Food production/processing	Other activities not currently included, such as grain drying, production of animal feeds including animal rendering (seen in conjunction with the activities described in Chapter 0) and fish meal processing will be investigated further.	2
Other industry	Sugar production	The activity data for years prior to 1990 will be assessed in order to report emissions of NMVOC back to the base year (1985).	3
Other industry	Sugar production	The CO_2 EF for years prior to the EU ETS will be further investigated.	1

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). Also, 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 8.

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DANISH EMISSION INVENTORY FOR INDUSTRIAL PROCESSES

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 2012 are included.

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