EMISSION INVENTORY FOR FUGITIVE EMISSIONS FROM FUEL IN DENMARK

Scientific Report from DCE – Danish Centre for Environment and Energy No. 173 2015

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Data sheet

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Abstract: This report presents the methodology and data used in the Danish inventory of fugitive emissions from fuels for the years until 2013. The inventory of fugitive emissions includes CO_2, CH_4, N_2O, SO_2, NO_x, NMVOC, CO, particulate matter, black carbon, heavy metals, dioxin and PAHs. In 2013 the total Danish emission of greenhouse gasses was 54 584 Gg CO_2 equivalents. Fugitive emissions from fuels account for 387 Gg CO_2 equivalents or approximately 1 %. The major part of the fugitive emissions are emitted as CO_2 (61 %) mainly from flaring in upstream oil and gas production. The major source of fugitive CH_4 emission is production of oil and gas in the North Sea, refining of oil and loading of oil onto ships both offshore and onshore. The fugitive emissions of NMVOC originate for the major part from oil and gas production, loading of ships, transmission and distribution of oil, and to a less degree from natural gas and fugitive emissions from gas stations. The total Danish emission of NMVOC in 2013 is 114 Gg. Fugitive emissions account for 9 Gg, which corresponds to 8 %. Time series for emissions are presented for the years 1990-2013, except for particulate matter where the time series covers 2000-2013.

Keywords: Fugitive emissions, emission inventory, emission factors, activity data, oil, gas, flaring

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List of abbreviations

As	Arsenic
BC	Black Carbon
Cd	Cadmium
CH_4	Methane
CLRTAP	Convention on Long-Range Transboundary Air Pollution
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2-eq	CO2 equivalents, calculated from all GHGs using GWPs
CollectER	Software to support the CORINAIR system
CORINAIR	CORe INventory on AIR emissions
Cr	Chromium
CRF	Common Reporting Format
Cu	Copper
DCE	Danish Centre for Environment and energy
DEA	Danish Energy Agency
DEPA	Danish Environmental Protection Agency
EEA	European Environment Agency
EF	Emission Factor
EMEP	European Monitoring and Evaluation Programme
ENVS	Department of ENVironmental Science, Aarhus University
EU-ETS	European Union Emission Trading Scheme
Gg	Gigagram, 10^9 g
GHG	Greenhouse gas
GWP	Global Warming Potential
HCB	Hexachlorobenzene
HFCs	Hydrofluorocarbons
Hg	Mercury
IE	Included Elsewhere
IEF	Implied Emission Factor
IPCC	Intergovernmental Panel on Climate Change
LRTAP	Long-Range Transboundary Air Pollution
LULUCF	Land Use, Land-Use Change and Forestry
Mg	Megagram, 10^6 g (equals metric ton or tonne)
µg	Microgram, 10^{-6} g
N_2O	Nitrous oxide
NA	Not Applicable
NECD	National Emissions Ceiling Directive
NFR	Nomenclature For Reporting
NH_3	Ammonia
Ni	Nickel
NMVOC	Non-Methane Volatile Organic Compounds
NO	Not Occurring
NO_x	Nitrogen Oxides
Pb	Lead
PCDD/F	PolyChlorinated DibenzoDioxins/Furans
PFCs	Perfluorocarbons

$PM_{2.5}$	Particulate Matter up to 2.5 µm in aerodynamic diameter
PM_{10}	Particulate Matter up to 10 µm in aerodynamic diameter
POPs	Persistent Organic Pollutants
QA	Quality Assurance
QC	Quality Control
Se	Selenium
SF_6	Sulphur hexafluoride
SNAP	Selected Nomenclature for Air Pollution
SO_2	Sulphur dioxide
TSP	Total Suspended Particles
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
Zn	Zinc

Preface

The Danish Centre for Environment and Energy (DCE), Aarhus University prepares the national inventories of emissions to the air and carries out the reporting to the UNFCCC (United Nations Framework Convention Climate Change) and to the UNECE CLRTAP (United Nations Economic Commission for Europe Convention on Long-range Transboundary Pollutants) on an annual basis. Furthermore, the greenhouse gas emission inventory is reported to the EU monitoring mechanism and the Kyoto Protocol, while the air pollution inventory forms the basis of the reporting under the NEC directive (National Emission Ceilings for certain atmospheric pollutants).

This report summarises the methods and data foundation used for quantification of fugitive emissions from fuels. Fugitive emissions from non-fuel sources e.g. agricultural operations, are not included in the fugitive sector. It includes the latest updates and improvements to the emission inventory of fugitive emissions. Data given in this report is based on the national emission inventory for the year 2013, which are described in full in Denmark's National Inventory Report 2015 (Nielsen et al., 2015a) and Denmark's Informative Inventory Report 2015 (Nielsen et al., 2015b).

This report updates the version published in 2009 (Plejdrup et al., 2009). The 2009 report was reviewed by an external expert not involved with the preparation of the inventory to allow for an independent peer review as part of the QA activities. The expert was Anette Holst from Statoil Refinery, Kalundborg, Denmark. Her recommendations have been incorporated into this report.

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- A/S Dansk Shell, Shell-Refinery, Lis Rønnow Rasmussen
- Aalborg Gasforsyning, Andreas Bech Jensen
- HMN Naturgas, in particular Søren K. Andersen
- NGF Nature energy, in particular Hanne Mochau
- DONG Oil Pipe A/S – DONG Energy, Stine B. Bergmann

Summary

The Danish Centre for Environment and Energy (DCE), Aarhus University prepares the national inventories of emissions to the air and carries out the reporting to the UNFCCC (United Nations Framework Convention Climate Change) and to the UNECE CLRTAP (United Nations Economic Commission for Europe Convention on Long-range Transboundary Pollutants) on an annual basis. Furthermore, the greenhouse gas emission inventory is reported to the EU monitoring mechanism and the Kyoto Protocol, while the air pollution inventory forms the basis of the reporting under the NEC directive (National Emission Ceilings for certain atmospheric pollutants).

The national emission inventories covers five sectors as defined in the international guidelines and reporting templates (IPCC, 2000; IPCC, 2006; EMEP/EEA, 2013). “Fugitive emisisons from fuels” is a sub-sector in the Energy sector. This report document the metodologies use in the emission inventory for fugitive emissions from fuels, including information on activity data, emission factors and emissions for the timeseries 1990-2013. This report updates the version published in 2009 (Plejdrup et al., 2009).

The fugitive sector covers emissions from extraction, handling, storage, transmission and distribution of solid, liquid, and gaseous fuels, and from flaring and venting. Among the major sources in the fugitive sector is offshore installations in upstream oil and gas production, and the refineries.

The total Danish GHG emission in 2013 is 54 584 kt CO_2 equivalents (CO_2 eqv.) excluding Land use, Land use change and forestry (LULUCF). In the same year the GHG emission from the energy sector is 41 005 kt CO_2-eqv., corresponding 75 %. The majority of the GHG emissions is in the energy sector and stem from fuel combustion in energy industries and transport. The fugitive sector accounts for 0.94 % of the GHG emissions from the energy sector as a whole.

Besides the greenhouse gases CO_2, CH_4 and N_2O the inventory on fugitive emissions from fuels also includes emissions of sulphur dioxide (SO_2), nitrogen oxide (NO_x), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO), particulate matter (PM), black carbon (BC), heavy metals (HM), and persistent organic pollutants (POPs). Emissions of particulate matter are estimated in three size fractions; total suspended particulate matter (TSP) and particles with an aerodynamic diameter less than 10 µm (PM_{10}) and less than 2.5 µm ($PM_{2.5}$). The fugitive sector contribute 9.9 % , 8.1 % and 5.0 % to the national total emissions of BC, NMVOC and SO_2, respectively. For the remaining pollutants the fugitive sector contributed only little to the national total (< 1 %).

Sammendrag

DCE - Nationalt Center for Miljø og Energi, Aarhus Universitet udarbejder de nationale opgørelser af emissioner til luft, og varetager årlig rapportering til UNFCCC (United Nations Framework Convention Climate Change) og til UNECE CLRTAP (United Nations Economic Commission for Europe Convention on Long-range Transboundary Pollutants). Desuden rapporteres emissionsopgørelsen for drivhusgasser til EU's monitoringsmekanisme og til Kyotoprotokollen, mens emissions-opgørelsen for luftforurening rapporteres til NEC direktivet (direktivet om nationale emissionslofter for visse luftforurenende stoffer).

De nationale emissionsopgørelser omfatter fem sektorer, jf. definitionerne i internationale retningslinjer og rapporteringsskabeloner (IPCC, 2000; IPCC, 2006; EMEP/EEA, 2013). "Flygtige emissioner fra brændsler" er en under-sektor i energisektoren. Denne rapport dokumenterer metoderne, der anvendes i opgørelsen for flygtige emissioner, herunder information om aktivitetsdata, emissionsfaktorer og emissioner for tidsserien 1990-2013. Denne rapport er en opdatering af den tidligere versionen publiseret i 2009 (Plejdrup et al., 2009).

Sektoren flygtige emissioner omfatter udvinding, håndtering, lagring, transmission og distribution af faste, flydende og gasformige brændsler, samt fra flaring og venting. Blandt de vigtigste i sektoren er platformene på Nordsøen til udvinding af olie og gas, samt raffinaderier.

Den samlede danske emission af drivhusgasser i 2013 er 54.584 kt CO_2 ækvivalenter (CO_2-ækv.) eksklusiv LULUCF-sektoren (Land use, Land use change and forestry, som dækker emissioner og optag forårsaget af ændringer i arealanvendelse og ændringer af skovarealer). I samme år er drivhusgasemissionen fra energisektoren 41.005 kt CO_2-ækv., svarende til 75 %. Hovedparten af drivhusgasemissionen i energisektoren stammer fra brændselsforbrug til energiproduktion og til transport. Flygtige emissioner udgør 0,94 % af den samlede drivhusgasemission fra energisektoren.

Udover drivhusgasserne CO_2, CH_4 and N_2O omfatter emissions-opgørelsen for sektoren flygtige emissioner fra brændsler også svovldioxid (SO_2), kvælstofilter (NO_x), andre flygtige kulbrinter end metan (NMVOC), kulilte (CO), partikler (PM), sod (BC), tungmetaller (HM) og persistente organiske forbindelser (POP'er). Partikelemissioner estimeres for tre størrelsesfraktioner; total mængde luftbårne partikler (TSP), partikler med en aerodynamisk diameter mindre end 10 µm (PM_{10}) og mindre end 2,5 µm ($PM_{2,5}$). Flygtige emissioner udgør 9,9 %, 8,1 % og 5,0 % af den totale nationale emission af hhv. BC, NMVOC og SO_2.

1 Total Danish emissions, international conventions and reduction targets

The Danish emission inventories follow the IPCC Guidelines (IPCC, 2006) and IPCC Good practice guidance (IPCC, 2000). The inventories are based on the European programme for emission inventories, the CORINAIR system, which includes methodology, structure and software. The emission data are stored in a MS Access database, from where it is transferred to the reporting formats. The methodology is outlined in the EMEP/EEA Guidebook (EMEP/EEA, 2013).

In the national inventory the emissions are organised in six categories, according to the reporting formats for the Convention on Long-range Transboundary Pollutants (UNECE CLRTAP) and the United Nations Framework Convention Climate Change (UNFCCC). These categories cover emissions from Energy, Industrial Processes and Product Use, Agriculture, Land use - Land use change and forestry, Waste, and Other. The Danish emission database is organized according to the Selected Nomenclature for Air Pollution (SNAP) as defined in the CORINAIR system. The emission inventories are prepared from a complete emission database based on the SNAP sectors. Aggregation to the sector codes used for both the CLRTAP in accordance with the Nomenclaure for Reporting (NFR) and the UNFCCC in accordance with the Common Reporting Format (CRF) is based on a correspondence list between SNAP and NFR or CRF sectors. Data presented in the present report are based on the Danish emission inventories 2015 including emissions for the year 2013.

Documentation reports for the National Emission Inventory 2015 are published on the homepage for The Danish Centre for Environment and Energy (DCE), Aarhus University, as are annual updated figures on emissions and emission factors:
http://envs.au.dk/videnudveksling/luft/emissioner/emissioninventory/
Furthermore, the data reported to the UNFCCC, CLRTAP and the EU Monitoring Mechanism can be found on the EIONET homepage: http://cdr.eionet.europa.eu/dk/Air_Emission_Inventories.

1.1 International conventions and reduction targets

Denmark is a Party to two international conventions with regard to air emissions; the CLRTAP (the Geneva Convention) and the UNFCCC (the climate convention). Denmark has ratified the UNFCCC without territorial exceptions for Greenland and the Faroe Islands, and the national reporting to UNFCCC therefore includes the entire Kingdom of Denmark. The information contained in this report only relates to Denmark.

CLRTAP is a framework convention and has expanded to cover eight protocols:

1. EMEP Protocol, 1984 (Geneva).
2. Protocol on the Reduction of Sulphur Emissions, 1985 (Helsinki).

3. Protocol concerning the Control of Emissions of Nitrogen Oxides, 1988 (Sofia).
4. Protocol concerning the Control of Emissions of Volatile Organic Compounds, 1991 (Geneva).
5. Protocol on Further Reduction of Sulphur Emissions, 1994 (Oslo).
6. Protocol on Heavy Metals, 1998 (Aarhus) and its 2012 amended version.
7. Protocol on Persistent Organic Pollutants (POPs), 1998 (Aarhus) and its 2009 amended version.
8. Protocol to Abate Acidification, Eutrophication and Ground-level Ozone, 1999 (Gothenburg) and its 2012 amended version.

The Climate Convention is a framework convention from 1992. The objective of the convention is “to achieve (…) stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.” The convention does not hold obligations concerning reduction of emissions but encourage the parties to reduce the emissions of greenhouse gases to their 1990 level. An important point is that the Parties to the convention are obligated to make national inventories of anthropogenic emissions of sources and removals by sinks of greenhouse gases.

The Kyoto Protocol is a protocol to the Climate Convention. The Kyoto Protocol sets legally binding emission targets and timetables for the following greenhouse gases: CO_2, CH_4, N_2O, HFCs, PFCs and SF_6 (expanded to also cover NF_3 for the second commitment period (2013-2020). The greenhouse gas emissions of the pollutants are combined to CO_2-equivalents, which can be summarized to produce total greenhouse gas (GHG) emissions. Denmark (including Greenland, excluding the Faroe Islands) is a Party to the Kyoto Protocol and was obligated to reduce the emission of GHG in the first commitment period (2008-2012) by 8 % compared to the base year emission level (1990 for CO_2, CH_4 and N_2O and 1995 for the F-gases). EU is also a Party to the Climate Convention with an individual reduction obligation of 8 %. The 15 EU countries (EU-15) that compose EU as a Party to the Kyoto Protocol have distributed this reduction obligation among themselves according to the Burden Sharing Agreement. Hereby, the countries have obligated themselves to submit emission data to the EU monitoring mechanism for CO_2 and other greenhouse gases. According to the Burden Sharing Agreement Denmark (excluding Greenland and the Faroe Islands) was obligated to reduce its GHG emission be 21 % in 2008-2012 according to the emission in the base year.

For EU-15 the 8 % commitment has been achieved by a wide margin. On average for the period 2008-2012, annual emissions (without LULUCF and the use of Kyoto mechanism) were 11.8 % below base year levels (http://ec.europa.eu/clima/policies/g-gas/index_en.htm). Denmark has reduced national emissions excluding LULUCF by 15 % on average for the period 2008-2012, the remaining part of the emissions reduction commitment being fulfilled through credits from LULUCF under the Kyoto Protocol (article 3.3 and 3.4), Clean Development Mechanism (CDM) projects (projects in developing countries that have no reduction commitments under the Kyoto Protocol) and Joint Implementation projects (JI) (project located in a country with a reduction commitment of its own).

For the second commitment period, the EU has a target of 20 % reduction compared to the base year. The reduction commitment within the EU distinguishes between the emissions covered by the EU Emission Trading System (ETS) and the non-ETS emissions. For the ETS there is a reduction of 24 % in allowances. For the non-ETS emissions each Member State has a separate target set out in the Effort Sharing Decision, (ESD) (Decision No 406/2009/EC). In the ESD, Denmark has a reduction commitment of 20 % in 2020 compared to the emission level in 2005.

In accordance with the Kyoto Protocol, Denmark's base year emissions include the emissions of CO_2, CH_4 and N_2O in 1990 in CO_2 equivalents and Denmark has chosen 1995 as the base year for the emissions of HFCs, PFCs and SF_6 and NF_3.

1.2 Total Danish emissions

The national Danish emissions in 2013 as reported to the conventions are summarised in Table 1.1, 1.2, 1.3 and 1.4. The emissions are aggregated on sector level according to the reporting formats.

Table 1.1 GHG emission 2013 as reported to UNFCCC (Nielsen et al. 2015a).

Sector	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3	Total GHG
				kt CO2e				
Energy	40 172	432	401	NA	NA	NA	NA	41 005
Industrial Processes and Product Use	1 187	3	19	782	11	131	NO	2 133
Agriculture	246	5 387	4 514	NA	NA	NA	NA	10 148
Land Use, Land-Use Change and Forestry	2 311	7	73	NA	NA	NA	NA	2 390
Waste	16	1 084	197	NA	NA	NA	NA	1 298
Denmark Total excl. LULUCF	41 622	6 906	5 132	782	11	131	0	54 584
Denmark Total incl. LULUCF	43 959	6 913	5 204	782	11	131	NA,NO	56 974

NA: Not applicable, NO: Not occuring

Table 1.2 Danish emissions of other air pollutants in 2013 as reported to CLRTAP (Nielsen et al., 2015b).

	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO
Sector					kt				
Energy	109.30	43.78	11.11	2.58	18.63	20.20	22.61	4.96	330.89
Industrial Processes and Product Use	0.08	32.24	1.98	0.42	0.35	0.45	0.68	0.00	4.00
Agriculture	14.40	38.25	0.01	70.53	2.01	11.31	65.72	0.02	2.75
Waste	0.08	0.16	0.54	0.78	0.24	0.24	0.24	0.00	1.16
Total	123.86	114.43	13.64	74.32	21.24	32.21	89.25	4.99	338.80

Table 1.3 Danish emissions of other air pollutants in 2013 as reported to CLRTAP (Nielsen et al., 2015b).

	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
Sector					t				
Energy	8.63	0.55	0.34	0.33	1.31	40.72	3.94	1.07	46.05
Industrial Processes and Product Use	1.08	0.02	0.01	0.04	0.16	2.02	0.27	0.42	2.53
Agriculture	0.04	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00
Waste	1.85	0.00	0.00	0.00	0.01	0.06	0.01	0.00	7.21
Total	11.60	0.58	0.35	0.37	1.49	42.81	4.22	1.49	55.80

Table 1.4 Danish emissions of other air pollutants in 2013 as reported to CLRTAP (Nielsen et al., 2015b).

Sector	Dioxin g I-Teq	Benzo(a) pyrene Mg	Benzo(b) fluoranthene Mg	Benzo(k) fluoranthene Mg	Indeno(1,2, 3-cd)pyrene Mg	HCB kg	PCBs kg
Energy	15.67	2.07	2.25	0.84	1.35	2.44	39.92
Industrial Processes and Product Use	0.45	0.03	0.03	0.02	0.02	0.14	0.08
Agriculture	0.03	0.13	0.13	0.05	0.05	0.13	0.00
Waste	5.63	0.04	0.06	0.04	0.07	0.01	0.02
Total	21.77	2.28	2.47	0.96	1.48	2.72	40.02

2 Fugitive emissions to the air

Coal mining is not occurring in Denmark and this has been the case for the entire time-series. Also, there is no solid fuel transformation processes such as coke or charcoal production in Denmark. Consequently, the only fugitive emissions related to solid fuels are emissions in connection with the storage and handling.

In contrast to solid fuels, Denmark has a large domestic production of oil and gas. All production takes place offshore west for Jutland in the North Sea. In addition to the offshore activities, there are two operating refineries in Denmark (a third refinery closed in 1996). Town gas production in Denmark is based on natural gas for the time series considered in the emission inventory and is occurring in a few of the densely populated areas in Denmark.

The total Danish GHG emission in 2013 was 54 584 kt CO_2 equivalents (CO_2 eqv.) excluding Land use, Land use change and forestry (LULUCF) and 56 974 kt CO_2 eqv. including LULUCF.

To give an impression of the quantities of the GHG emissions on both national and sector level, the emissions of CO_2, CH_4 and N_2O are given in Table 2.1 as well as the total GHG emission. Furthermore, the percentage of the national total is included in the table.

Table 2.1 National and fugitive emissions of CO_2, CH_4 N_2O and GHG in 2013, and the fugitive emissions share of national total emissions.

	National* emission	Fugitive emission	Fugitive/national* emission
	kt CO_2 eqv	kt CO_2 eqv	%
CO_2	41 622	238	0.6
CH_4	6 906	107	1.6
N_2O	5 132	41	0.8
GHG	54 584	387	0.7

*excluding LULUCF

"Fugitive emissions from fuels" is a subsector under the energy sector which accounts for 0.94 % of the GHG emissions from the energy sector as a whole. The majority of the GHG emissions in the energy sector stem from fuel combustion in energy industries and transport (see Table 2.2). Fugitive emissions from fuels arise from extraction, handling, storage, transmission and distribution of solid, liquid, and gaseous fuels. Also, flaring is an important source for fugitive emissions from fuels. Among the facilities that contribute to the fugitive emissions are the oil and gas production facilities in the North Sea, gas storage and treatment plants and refineries. Furthermore, transmission pipelines and distribution networks are sources of fugitive emissions.

Table 2.2 Emissions of greenhouse gases in the Energy sector in 2013.

CRF category	CO_2		CH_4		N_2O		GHG	
	Gg	% of total	Mg	% of total	Mg	% of total	Gg CO_2-eqv.	% of total
1A1	18 768.21	46.7	140.05	32.5	97.75	24.4	19 006.01	46.4
1A2	4 134.88	10.3	9.31	2.2	51.08	12.7	4 195.26	10.2
1A3	11 801.93	29.4	12.48	2.9	124.52	31.0	11 938.94	29.1
1A4	4 989.80	12.4	161.96	37.5	84.16	21.0	5 235.92	12.8
1A5	239.06	0.6	0.37	0.1	2.54	0.6	241.97	0.6
1B1	NO	0	NO	0	NO	0	NO	0
1B2	238.33	0.6	107.40	24.9	41.13	10.3	386.86	0.9
Sum	40 172.21		431.56		401.19		41 004.96	

Emissions of F-gases (HFCs, PFCs, SF_6, and NF_3) are only applicable to the industrial processes and product use sector, and therefore the total fugitive GHG emission from fuels, expressed as CO_2 equivalents, refers to the sum of CO_2, CH_4 and N_2O emissions multiplied by their individual global warming potentials (GWP) of 1, 25 and 298, respectively, as given in the Working Group I Report of IPCC Fourth Assessment Report (IPCC, 2007).

Flaring, the largest contributior being flaring offshore in upstream oil and gas production, is by far the major source of CO_2 in the fugitive sector. The CO_2 emission from flaring makes up 61 % of the total GHG emission in the fugitive sector.

The major sources of fugitive emissions of CH_4 are extraction of oil and gas, refining of oil, transport of oil in pipelines, loading of oil onto ships, and flaring. The CH_4 emission makes up 28 % of the total GHG emission in the fugitive sector.

Fugitive emissions of N_2O are dominated by flaring in oil and gas extraction, making up 99.9 % of the total fugitive N_2O emission in 2013. The N_2O emission makes up 11 % of the total GHG emission in the fugitive sector.

Besides the greenhouse gases CO_2, CH_4 and N_2O the inventory on fugitive emissions from fuels also includes emissions of sulphur dioxide (SO_2), nitrogen oxide (NO_x), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO), particulate matter (PM), black carbon (BC), heavy metals (HM), and persistent organic pollutants (POPs). Emissions of particulate matter are estimated in three size fractions; total suspended particulate matter (TSP) and particles with an aerodynamic diameter less than 10 µm (PM_{10}) and less than 2.5 µm ($PM_{2.5}$).

To give an impression of the quantities of emissions of air pollutants on both national and sector level, the emissions of NO_x, CO, NMVOC, SO_2, $PM_{2.5}$ and BC are given in Table 2.3. Furthermore, the percentage of the national total is included in the table. The fugitive sector has only minor emissions of NO_x, CO, and PM compared to the total Danish emissions of these components (Table 2.3).

Table 2.3 Emissions of selected air pollutants in the fugitive sector and national total emission, and share of fugitive to national total emissions.

	Fugitive emission	National emission	Fugitive/national emission
	kt	kt	%
NO_x	0.12	124	0.1
CO	0.21	339	0.1
NMVOC	9.24	114	8.1
SO_2	0.68	14	5.0
$PM_{2.5}$	0.03	21	0.2
BC	0.50	5	9.9

Refining of oil products is the major source of fugitive emissions of SO_2, while NO_x and CO mainly come from flaring at refineries and upstream oil and gas production facilities. The fugitive emissions of NMVOC originate predominantly from refining of oil products, production of oil and natural gas, service stations and oil loading and unloading activities from ships. The only source of PM emissions in the Fugitive emissions from fuels sector is storage of solid fuels, due to dust from stockpiles of coal for use in power and heating plants.

The energy fugitive sector is an important source of NMVOC, BC and SO_2 (see Table 2.4). The main sources for NMVOC in the fugitive sector are refineries contributing 60 %, onshore activities (loading of ships and transport of oil in pipelines and storage of raw oil in tanks) contributing 14 % and offshore activities (exploration, extraction and loading of ships) contributing 10 %. Fugitive SO_2 emissions are predominantly from sulphur recovery (76 %) and flaring in refineries (24 %). Storage of coal is the major source of fugitive emissions of particles and BC (approximately 99 % and 99.9 %, respectively).

Table 2.4 Emissions of selected air pollutants in the Energy sector in 2013.

CRF	SO_2		NO_x		NMVOC		BC	
category	Gg	% of total	Gg	% of total	Gg	% of total	Gg	% of total
1A1	3.62	32.6	20.92	19.1	1.37	3.1	0.40	8.0
1A2	2.83	25.4	12.45	11.4	1.34	3.1	0.51	10.3
1A3	1.41	12.7	52.52	48.0	9.87	22.5	1.05	21.1
1A4	2.51	22.5	21.77	19.9	21.59	49.3	2.47	49.7
1A5	0.07	0.6	1.51	1.4	0.38	0.9	0.04	0.8
1B1	NO	0	NOx	0	NO	0	0.50	10.0
1B2	0.68	6.2	0.12	0.1	9.24	21.1	0.00	0.0
Sum	11.11		109.30		43.78		4.96	

NO: Not occuring

The major source of emission of particles in the fugitive sector is dust from storage of coal (approximately 99 %). It must be noted that the CH_4 emission from post-mining of coal (storage and transport) should be accounted for in the emission inventory of the mining countries according to the IPCC Guidelines and is therefore not included in the Danish emission inventory.

3 Methodology

According to the IPCC sector definitions the category *fugitive emissions from fuels* is a sub-category under the main category Energy (Sector 1). The category *fugitive emissions from fuels* (Sector 1B) is segmented into sub-categories covering emissions from solid fuels (coal mining and handling (1B1a), solid fuel transformation (1B1b), other (1B1c)) and from oil and natural gas (oil (1B2a), natural gas (1B2b), venting and flaring (1B2c) and other (1B2d)). The sub-sectors relevant for the Danish emission inventory are shortly described below according to Danish conditions:

- 1B1a Fugitive emission from solid fuels: Emissions from solid fuels are only relevant for the Danish national emission inventories in the case of emissions of particulate matter and black carbon from the handling and storage of coal. Other components are not occurring, as these emissions should be included in the inventory for the nation housing the coalmines.
- 1B2a Fugitive emissions from oil includes emissions from offshore activities in oil production, transport and storage of oil, refineries, and service stations.
- 1B2b Fugitive emissions from natural gas includes emissions from offshore activities in gas production, transmission and distribution of natural gas. Emissions from gas storage are included under transmission.
- 1B2c Venting and flaring includes flaring in upstream oil and gas production, venting and flaring in gas storage and treatment plants, and flaring in refineries. In Denmark venting of gas in offshore activities and refineries is assumed to be negligible as controlled venting enters the gas flare system. Venting occur in gas storage and transmission for part of the timeseries.

Activity data, emission factors and emissions are stored in the Danish emission database on SNAP sector categories (Selected Nomenclature for Air Pollution). In Table 3.1 the corresponding SNAP codes and IPCC sectors relevant to fugitive emissions are shown. Further, the table holds the SNAP names for the SNAP codes and the overall activity (e.g. oil and natural gas)

Table 3.1 Overview of the SNAP codes and the corresponding IPCC sources relevant for fugitive emissions.

SNAP code	SNAP name	IPCC sector	Activity
040101	Petroleum products processing	1 B 2 a 4	Oil
040103	Other processes in petroleum industries	1 B 2 a 4	Oil
040104	Storage and handling of petroleum product in refinery	1 B 2 a 4	Oil
050103	Storage of solid fuel	1 B 1 a	Coal (storage)
050201	Landbased activities	1 B 2 a 3	Oil
050202	Offshore activities	1 B 2 a 2 / 1 B 2 a 3	Oil
050204	Exploration of oil	1 B 2 a 1	Oil
050303	Offshore activities	1 B 2 b 2	Natural gas
050304	Exploration of gas	1 B 2 b 1	Natural gas
050503	Service stations (including refuelling of cars)	1 B 2 a 5	Oil
050601	Pipelines	1 B 2 b 4	Natural gas (transmission)
050603	Distribution networks	1 B 2 b 5	Natural gas (distribution)
050699	Venting in gas storage	1 B 2 c 2 1 ii	Venting
090203	Flaring in oil refinery	1 B 2 c 2 i	Flaring
090206	Flaring in oil and gas extraction	1 B 2 c 2 ii	Flaring
090298	Flaring in gas storage	1 B 2 c 2 ii	Flaring
090299	Flaring in gas transmission and distribution	1 B 2 c 2 ii	Flaring

Note: IPCC sector and activity is only given for categories included in the Danish emission inventory.

Table 3.2 summarizes the Danish fugitive emissions in 2013 for selected pollutants. The methodologies, activity data and emission factors used for calculation are described in the following chapters.

Table 3.2 Summary of the Danish fugitive emissions in 2013.

IPC category	Sector	Pollutant	Emission	Share of total fugitive *
1.B.1.a	Storage of solid fuel	TSP	742.767	99%
1.B.1.a	Storage of solid fuel	PM_{10}	297.107	99%
1.B.1.a	Storage of solid fuel	$PM_{2.5}$	29.711	88%
1.B.1.a	Storage of solid fuel	BC	495.178	100%
1.B.2.a.1	Exploration of oil	SO_2	<0.001	0%
1.B.2.a.1	Exploration of oil	NO_x	0.002	0%
1.B.2.a.1	Exploration of oil	NMVOC	0.002	0%
1.B.2.a.1	Exploration of oil	CH_4	0.013	0%
1.B.2.a.1	Exploration of oil	CO	0.002	0%
1.B.2.a.1	Exploration of oil	CO_2	3040.930	1%
1.B.2.a.1	Exploration of oil	N_2O	0.002	0%
1.B.2.a.1	Exploration of oil	TSP	<0.001	0%
1.B.2.a.1	Exploration of oil	PM_{10}	<0.001	0%
1.B.2.a.1	Exploration of oil	$PM_{2.5}$	<0.001	0%
1.B.2.a.1	Exploration of oil	BC	<0.001	0%
1.B.2.a.2	Production and transport of oil	NMVOC	2297.201	25%
1.B.2.a.2	Production and transport of oil	CH_4	775.444	18%
1.B.2.a.2	Production and transport of oil	CO_2	5.168	0%
1.B.2.a.4	Petroleum products processing	SO_2	517.000	76%
1.B.2.a.4	Petroleum products processing	NMVOC	5574.600	60%
1.B.2.a.4	Petroleum products processing	CH_4	619.400	14%
1.B.2.a.5	Service stations	NMVOC	724.633	8%
1.B.2.b.1	Exploration of gas	SO_2	<0.001	0%

Continued				
1.B.2.b.1	Exploration of gas	NO_x	<0.001	0%
1.B.2.b.1	Exploration of gas	NMVOC	<0.001	0%
1.B.2.b.1	Exploration of gas	CH_4	0.001	0%
1.B.2.b.1	Exploration of gas	CO	<0.001	0%
1.B.2.b.1	Exploration of gas	CO_2	0.288	0%
1.B.2.b.1	Exploration of gas	N_2O	<0.001	0%
1.B.2.b.1	Exploration of gas	TSP	<0.001	0%
1.B.2.b.1	Exploration of gas	PM_{10}	<0.001	0%
1.B.2.b.1	Exploration of gas	$PM_{2.5}$	<0.001	0%
1.B.2.b.1	Exploration of gas	BC	<0.001	0%
1.B.2.b.2	Production of gas	NMVOC	428.064	5%
1.B.2.b.2	Production of gas	CH_4	1787.520	42%
1.B.2.b.2	Production of gas	CO_2	65.856	0%
1.B.2.b.4	Transmission of gas	NMVOC	3.600	0%
1.B.2.b.4	Transmission of gas	CH_4	16.138	0%
1.B.2.b.4	Transmission of gas	CO_2	0.473	0%
1.B.2.b.5	Distribution of gas	NMVOC	44.001	0%
1.B.2.b.5	Distribution of gas	CH_4	122.275	3%
1.B.2.b.5	Distribution of gas	CO_2	3.551	0%
1.B.2.c.1.ii	Venting in gas storage	NMVOC	18.383	0%
1.B.2.c.1.ii	Venting in gas storage	CH_4	53.292	1%
1.B.2.c.1.ii	Venting in gas storage	CO_2	1.140	0%
1.B.2.c.2.i	Flaring in oil refinery	SO_2	165.700	24%
1.B.2.c.2.i	Flaring in oil refinery	NO_x	15.318	12%
1.B.2.c.2.i	Flaring in oil refinery	NMVOC	22.368	0%
1.B.2.c.2.i	Flaring in oil refinery	CH_4	5.309	0%
1.B.2.c.2.i	Flaring in oil refinery	CO	51.788	24%
1.B.2.c.2.i	Flaring in oil refinery	CO_2	14688.889	6%
1.B.2.c.2.i	Flaring in oil refinery	N_2O	0.138	0%
1.B.2.c.2.i	Flaring in oil refinery	TSP	0.260	0%
1.B.2.c.2.i	Flaring in oil refinery	PM_{10}	0.260	0%
1.B.2.c.2.i	Flaring in oil refinery	$PM_{2.5}$	0.260	1%
1.B.2.c.2.i	Flaring in oil refinery	BC	0.065	0%
1.B.2.c.2.ii	Flaring in gas storage, transmission and distribution	SO_2	0.011	0%
1.B.2.c.2.ii	Flaring in gas storage, transmission and distribution	NO_x	1.361	1%
1.B.2.c.2.ii	Flaring in gas storage, transmission and distribution	NMVOC	0.371	0%
1.B.2.c.2.ii	Flaring in gas storage, transmission and distribution	CH_4	0.618	0%
1.B.2.c.2.ii	Flaring in gas storage, transmission and distribution	CO	1.605	1%
1.B.2.c.2.ii	Flaring in gas storage, transmission and distribution	CO_2	2319.806	1%
1.B.2.c.2.ii	Flaring in gas storage, transmission and distribution	N_2O	0.001	0%
1.B.2.c.2.ii	Flaring in gas storage, transmission and distribution	TSP	0.036	0%
1.B.2.c.2.ii	Flaring in gas storage, transmission and distribution	PM_{10}	0.036	0%
1.B.2.c.2.ii	Flaring in gas storage, transmission and distribution	$PM_{2.5}$	0.036	0%
1.B.2.c.2.ii	Flaring in gas storage, transmission and distribution	BC	0.007	0%
1.B.2.c.2.iii	Flaring in oil and gas extraction	SO_2	1.150	0%
1.B.2.c.2.iii	Flaring in oil and gas extraction	NO_x	106.452	86%
1.B.2.c.2.iii	Flaring in oil and gas extraction	NMVOC	128.547	1%

Continued				
1.B.2.c.2.iii	Flaring in oil and gas extraction	CH_4	915.824	21%
1.B.2.c.2.iii	Flaring in oil and gas extraction	CO	160.821	75%
1.B.2.c.2.iii	Flaring in oil and gas extraction	CO_2	218203.891	92%
1.B.2.c.2.iii	Flaring in oil and gas extraction	N_2O	137.882	100%
1.B.2.c.2.iii	Flaring in oil and gas extraction	TSP	3.642	0%
1.B.2.c.2.iii	Flaring in oil and gas extraction	PM_{10}	3.642	1%
1.B.2.c.2.iii	Flaring in oil and gas extraction	$PM_{2.5}$	3.642	11%
1.B.2.c.2.iii	Flaring in oil and gas extraction	BC	0.670	0%
1.B.1.a	Storage of solid fuel	TSP	742.767	99%
1.B.1.a	Storage of solid fuel	PM_{10}	297.107	99%
1.B.1.a	Storage of solid fuel	$PM_{2.5}$	29.711	88%
1.B.1.a	Storage of solid fuel	BC	495.178	100%
1.B.2.a.1	Exploration of oil	SO_2	<0.001	0%
1.B.2.a.1	Exploration of oil	NO_x	0.002	0%
1.B.2.a.1	Exploration of oil	NMVOC	0.002	0%
1.B.2.a.1	Exploration of oil	CH_4	0.013	0%
1.B.2.a.1	Exploration of oil	CO	0.002	0%
1.B.2.a.1	Exploration of oil	CO_2	3040.930	1%
1.B.2.a.1	Exploration of oil	N_2O	0.002	0%
1.B.2.a.1	Exploration of oil	TSP	<0.001	0%
1.B.2.a.1	Exploration of oil	PM_{10}	<0.001	0%
1.B.2.a.1	Exploration of oil	$PM_{2.5}$	<0.001	0%
1.B.2.a.1	Exploration of oil	BC	<0.001	0%
1.B.2.a.2	Production and transport of oil	NMVOC	2297.201	25%
1.B.2.a.2	Production and transport of oil	CH_4	775.444	18%
1.B.2.a.2	Production and transport of oil	CO_2	5.168	0%

3.1 Methods of calculation

The following chapters give descriptions on the methods of calculation used in the Danish emission inventory.

3.1.1 Fugitive emissions from solid fuels

The emissions of PM and BC from storage of coal are estimated on the basis of the imported amount of coal (equation 3.1).

Equation 3.1

$$E_{coal\_storage} = EMF_{coal\_storage} \cdot I_{coal}$$

where $EMF_{coal\_storage}$ is the emission factor for storage of coal in coal piles and I_{coal} is the amount of coal imported in the actual year.

3.1.2 Fugitive emissions from oil

The emissions from oil derive from offshore activities in oil production, transport and storage of oil, service stations and refineries. Emissions from offshore activities include emissions from exploration, extraction and offshore loading of ships. Transport and storage covers emissions from the raw oil terminal and onshore loading of ships. In the case of service stations emissions from reloading of tankers and refuelling of vehicles are included. The emissions from refineries derive from petroleum products processing (oil refining). Emissions from flaring in refineries are included in the chapters concerning flaring (Chapter 3.1.4, 3.2.6, 3.3.9 and 3.4.6). The total emission can be expressed as:

Equation 3.2

$$E_{total} = E_{exploration} + E_{extraction} + E_{loading\ of\ ships} + E_{oil\ tanks} + E_{service\ stations} + E_{refineries}$$

Fugitive emissions from exploration of oil

Exploration of oil and gas in the North Sea involves the drilling and preparion of exploration and appraisal wells (E/A wells), which leads to fugitive emissions. The oil and gas operators provide information to the DEA for each exploration drilling, including volume of oil and gas extracted. All oil and gas from exploration drilling is flared on-site. Oil and gas composition is available for most drillings. As calorific values and densities are not available per drilling, data from a gas test in 1992 are applied.

Fugitive emissions from extraction of oil

The methodology for calculation of emissions from oil and gas extraction in the North Sea is based on the amount of produced oil multiplied with standard emission factors from the 2006 IPCC Guidelines (IPCC, 2006).

Loading of ships

Fugitive emissions of CH_4 and NMVOC from loading of ships include the transfer of oil from storage tanks or directly from the well into ships. The activity also includes losses during transport. When oil is loaded, hydrocarbon vapour will be displaced by oil, and new vapour will be formed, both leading to emissions. The emissions from ships are calculated by equation 3.3.

Equation 3.3

$$E_{loading\ of\ ships} = EMF_{offshore\ loading} \cdot L_{offshore\ loading} + EMF_{onshore\ loading} \cdot L_{onshore\ loading}$$

where EMF is the emission factor for loading of ships offshore and onshore and L is the amount of oil loaded.

Oil terminal

The main part of the raw oil produced in the North Sea is transported to the danish raw oil terminal via pipeline (on average 85 % per year). The remaining part is loaded to ships offshore. The CH_4 and NMVOC emissions from the oil terminal, covering storage and handling of raw oil, are given in the environmental reports for the raw oil terminal from DONG Oil Pipe A/S for 2013 (DONG Oil Pipe A/S, 2014). An implied emission factor is calculated for use in the reporting template on the basis of the amount of oil transported in pipelines according to equation 3.4.

Equation 3.4

$$IEF_{tanks} = \frac{E_{tanks}}{T_{oil}}$$

where IEF_{tanks} is the implied emission factor for storage of raw oil in tanks, E_{tanks} is the emission and T_{oil} is the amount of oil transported in pipelines.

Service stations

NMVOC emissions from service stations are estimated as outlined in equation 3.5.

Equation 3.5

$$E_{service\ stations} = (EMF_{reloading} \cdot T_{fuel}) + (EMF_{refuelling} \cdot T_{fuel})$$

where $EMF_{reloading}$ is the emission factor for reloading of tankers to storage tanks at the service stations, $EMF_{refuelling}$ is the emission factor for refuelling of vehicles, and T_{fuel} is the amount of gasoline used for road transport. The emission calculation is dependent on true vapour pressure (TVP), which again is dependent on the reid vapour pressure (RVP) and the temperature.

Oil refining

When oil is processed in refineries, part of the volatile organic compounds (VOC) is emitted to the atmosphere. VOC emissions from the oil refinery process include non-combustion emissions from handling and storage of feedstock (raw oil), from the petroleum product processing and from handling and storage of products. VOC emissions are provided by the refineries. Only one of the two refineries has made a split between NMVOC and CH_4. For the other refinery it is assumed that 10 % of the VOC emission is CH_4 (Hjerrild & Rasmussen, 2014).

Both the non-combustion processes including product processing and sulphur recovery plants emit SO2. For descriptions regarding fugitive emissions of SO2 and other pollutants from refining, please refer to the Danish Informative Inventory Report (Nielsen et al., 2015b).

Both the non-combustion processes including product processing and sulphur recovery emit SO_2. The SO_2 emissions are calculated by the refineries based on oil balance, measured sulphur content in products and fuels, flow measurements in sulphur recovery plants and key figures in environmental approvals.

Emissions from flaring in refineries are included under “Flaring”. Emissions related to process furnaces in refineries are included in stationary combustion with the relevant emission factors.

3.1.3 Fugitive emissions from gas

The emissions from gas derive from offshore activities in gas production, transmission of natural gas, and distribution of natural gas and town gas. Emissions from venting and flaring in gas transmission and distribution, and venting and flaring in gas treatment and storage are included in the chapters concerning flaring (Chapter 3.1.4, 3.2.6, 3.3.9 and 3.4.6). The total emission can be expressed as:

Equation 3.6

$$E_{total} = E_{exploration} + E_{extraction} + E_{transmission} + E_{distribution}$$

Fugitive emissions from exploration of gas

Exploration of oil and gas in the North Sea involves the drilling and preparation of exploration and appraisal wells (E/A wells), which leads to fugitive emissions. The oil and gas operators provide information to the DEA for each exploration drilling, including volume of oil and gas extracted. All oil and gas from exploration drilling is flared on-site. Oil and gas composition is available for most drillings. As calorific values and densities are not available per drilling, data from a gas test in 1992 are applied.

Fugitive emissions from extraction of gas

The methodology for calculation of emissions from extraction of gas is based on the amount of produced natural gas multiplied with standard emission factors from the 2006 IPCC Guidelines (IPCC, 2006).

Transmission and distribution of gas

The fugitive emission from transmission, storage and distribution of natural gas is based on information from the gas companies. Gas transmission is handeled by one company, natural gas distribution is handeled by three companies and town gas distribution is handeled by two companies (in earlier years another two companies handeled town gas distribution). All transmission and distribution companies deliver data on the transported amount, and the length and material of the pipeline systems.

Calculations of the NMVOC emissions are based on the CH_4 emission and the gas quality measured by Energinet.dk (Table 3.9) according to equation 3.7.

Equation 3.7

$$E_{NMVOC} = E_{CH_4} \times \left(w_{NMVOC} \ / \ w_{CH_4} \right)$$

where w_{NMVOC} is the weight-% NMVOC and w_{CH4} is the weight-% CH_4 according to the gas quality of the current year.

The fugitive losses from pipelines are only given for some companies, here among the transmission company. The available distribution data are used for the remaining companies too. Emissions are calculated from the fugitive losses from transmission and distribution pipelines due to the annual average gas quality for natural gas transmitted in Denmark measured by Energinet.dk (Energinet.dk 2014c). The same approach is used for town gas, which is natural gas admixed 49 % - 50 % ambient air. Town gas make only a small contribution to the total gas distribution (approximately 0.5 % of the total distribution in energy units).

Calculations of emissions from distribution of town gas are based on data from the distribution companies on distribution losses. At present, there are two areas with town gas distribution and corresponding distribution companies. Two other companies in different areas were closed in 2004 and 2006, and it has not been possible to collect data for all years in the timeseries. The emissions have been calculated for the years with available data and the distribution loss for the first year with data has been applied for the previous years in the time series. Data are missing for the later years (1996-2003) for one of the distribution companies. The distribution amount is assumed to decrease linearly to zero over these years, and the share (distribution loss/distribution amount) is assumed equal to the value for 1995.

3.1.4 Flaring

Emissions from flaring are estimated from the amount of gas flared offshore (7 installations), in gas treatment/storage plants (1/2 plants), in refineries (2 plants), and in gas transmission (1 company), storage and distribution (5 companies), combined with corresponding emission factors. From 2006 data on flaring in upstream oil and gas production is given in the reports for the European Union Greenhouse Gas Emission Trading System (EU ETS) and thereby flaring can be split to the individual production units. Before 2006 only the total flared amount is available from DEA. Flaring in refineries and in gas transmission, storage and distribution are given in annual environmental reports from the relevant companies and plants.

3.2 Activity data

The following chapters give descriptions of activity data used for calculation of fugitive emissions from fuels in the Danish emission inventory.

3.2.1 Coal Storage

The activity data are the imported amount of coal converted from energy units to mass using the calorific value of coal (DEA 2014c). The coal import fluctuates between years in the time series with an overall decreasing trend. In 2013 the imported amount was 4 952 Gg (Figure 3.1) which is an increase compared to 2012.

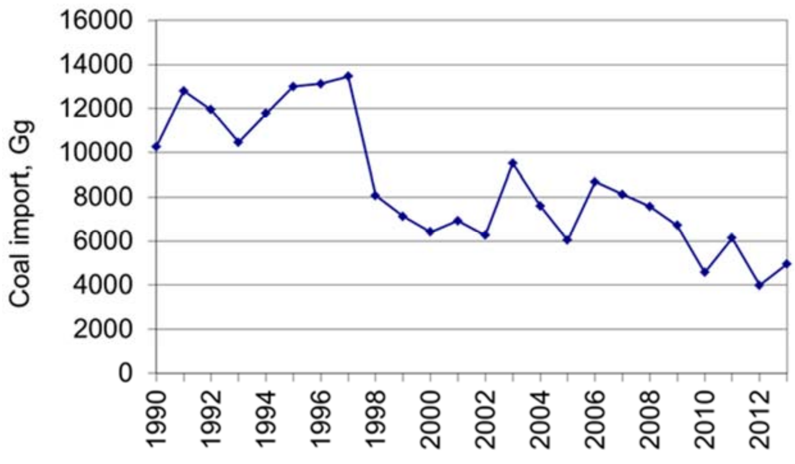

Figure 3.1 Amounts of imported coal.

3.2.2 Extraction of oil and gas and loading of ships

Activity data used in the calculations of the emissions from oil and gas exploration and production, and loading of ships onshore and offshore are shown in Table 3.3. Data are based on information provided by the Danish Energy Agency (DEA 2014a,b) and from the environmental reports from DONG Oil Pipe A/S (2014).

Table 3.3 Activity data for 2013.

Activity, unit *	Value	Data source
Extracted gas, Sm^3	1 242	DEA 2014a
Extracted oil, Nm^3	102	DEA 2014a
Produced gas, 10^6 Nm^3	4 704	DEA 2014b
Produced oil, 10^3 m^3	10 185	DEA 2014b
Oil loaded offshore, 10^3 m^3	1 116	DEA 2014b
Oil loaded onshore, 10^3 m^3	6 100	DONG Oil Pipe A/S 2014
Density of crude oil, tonnes/m^3	0.86	DEA 2014b

*1 Nm^3 = 1.0549 Sm^3

Exploration of oil and gas fluctuates significantly between years. The largest oil amounts are seen for 1990, 2002 and 2005, while relatively large gas amounts are seen for more years of the time series. Explored amounts are shown in Figure 3.2a and Figure 3.2b.

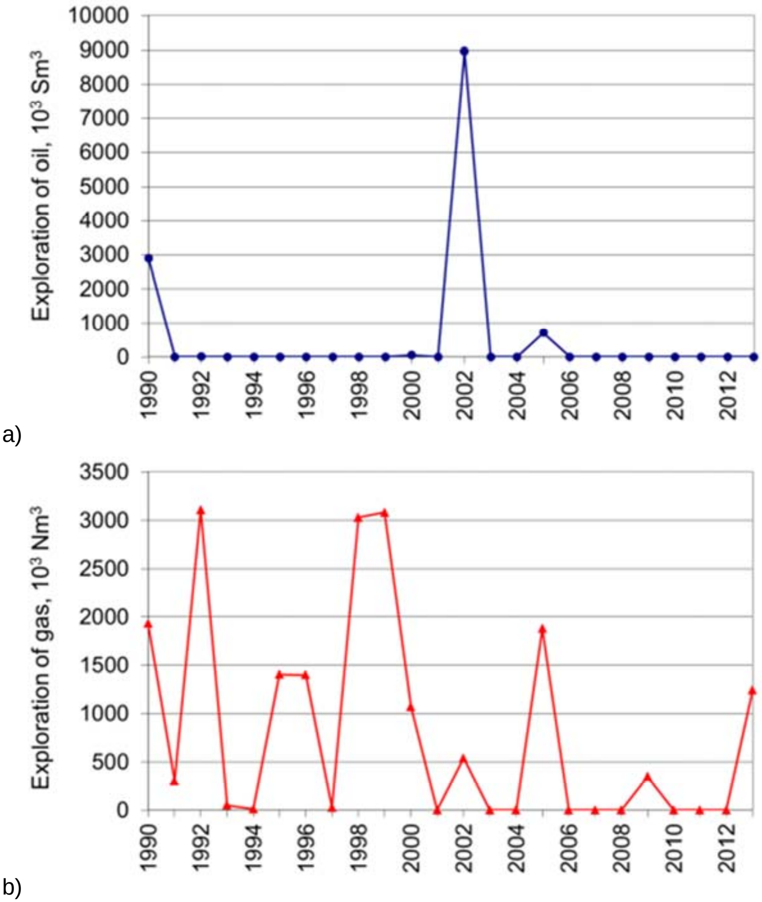

Figure 3.2 Exploration of oil (a) and gas (b) in the Danish part of the North Sea.

As seen in Figure 3.3 the production of oil and gas in the North Sea has generally increased in the years 1990-2004, and since 2004 the production has decreased. Five major platforms were completed in 1997-1999, which is the main reason for the great increase in the oil production in the years 1998-2000.

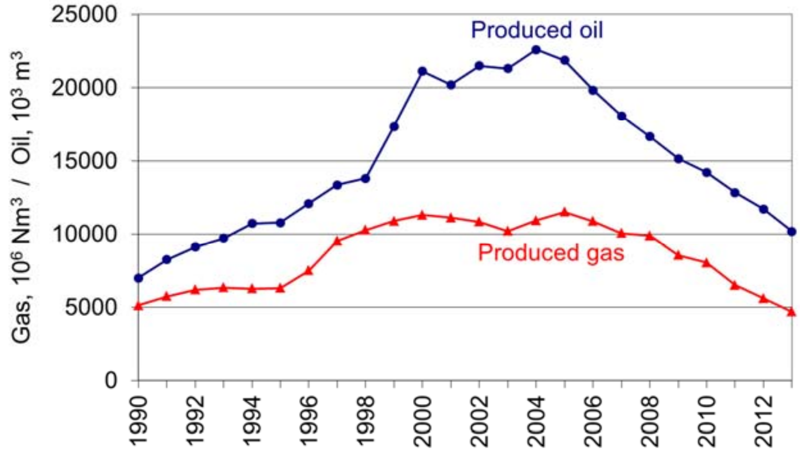

Figure 3.3 Production of oil and gas in the Danish part of the North Sea.

The amount of oil loaded offshore and onshore on ships (Figure 3.4) roughly follows the trend of the oil and gas production (Figure 3.3). Before 1999 all produced oil was send to land via pipeline, and still the major part (85 % in 2013) is tranported to the raw oil terminal via the pipeline and subsequently loaded to ships onshore.

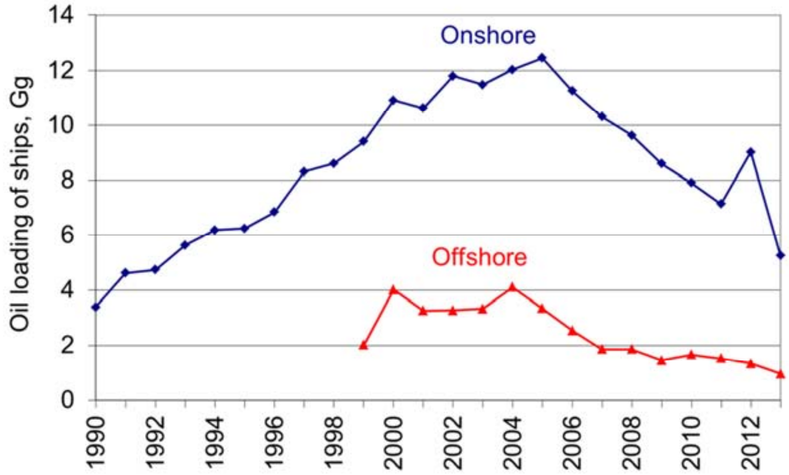

Figure 3.4 Onshore and offshore loading of ships.

3.2.3 Oil refining

Data on the amount of crude oil processed in the two Danish refineries are given by the refineries in their annual environmental reports (A/S Dansk Shell, 2014 and Statoil A/S, 2014). Until 1996 a third refinery was in operation, and its closure lead to a decrease in the crude oil amount from 1996 to 1997. Data are shown in Figure 3.5. In 2013 the amount of crude oil being processed was 7 179 Gg.

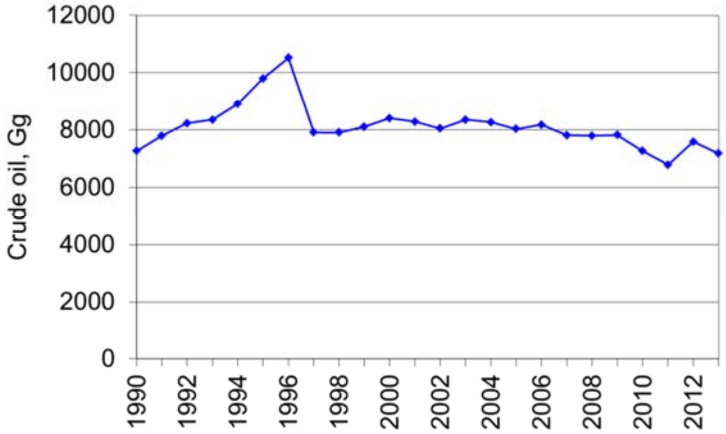

Figure 3.5 Processed crude oil in Danish refineries.

3.2.4 Service stations

The Danish energy statistics holds data on the sale of gasoline that is the basis for estimating emissions of NMVOC from service stations. The gasoline sales shows an increase from 1990-1998 and a decreasing trend since 1999 as shown in Figure 3.6. Eventhough the annual milage driven in gasoline cars has increased by 30 % from 1999 to 2013, the gasoline sale has decreased, due to more energy efficient cars. The gasoline sale is 1 339 Gg in 2013.

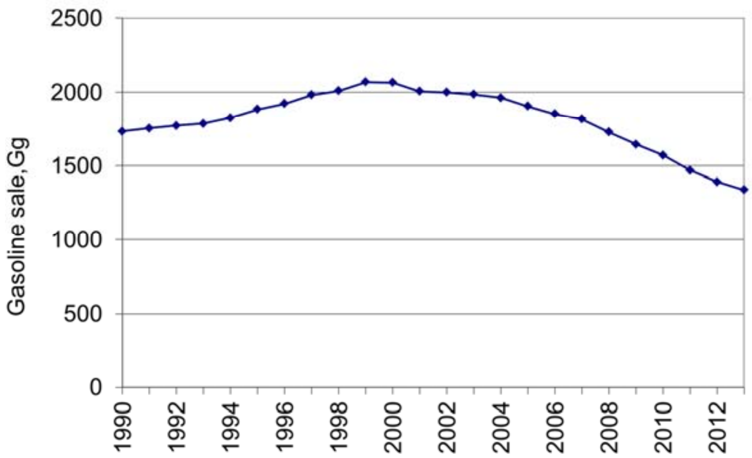

Figure 3.6 Gasoline sales in Denmark.

3.2.5 Transmission, storage and distribution of gas

The activity data used in the calculation of the emissions from natural gas are shown in Table 3.4. Transmission rates for 1990-1998 refer to annual environmental reports for DONG Energy. In 1999-2006 transmission rates refer to the Danish Gas Technology Centre (Karll 2002, 2003, 2004, 2005; Oertenblad 2006, 2007). From 2008 onwards transmission rates refer to Energinet.dk (2014b). Transmission losses for 1991-1999 are based on annual environmental reports of DONG Energy. The average “loss per transmission amount” for 1991-1995 is applied for 1990. From 2005 onwards transmission losses are given by Energinet.dk. The average for 2005-2010 is applied for the years 2000-2004.

Distribution rates for 1990-1998 are estimated from the Danish energy statistics. Distribution rates are assumed to equal total Danish consumption rate minus the consumption rates of sectors that receive gas at high pressure. The following consumers are assumed to receive high pressure gas: town gas production companies, production platforms and power plants. In 1999-2006 distribution rates refer to DONG Energy / Danish Gas Technology Centre / Danish gas distribution companies (Karll 2002, 2003, 2004, 2005; Oertenblad 2006, 2007). Since 2007 the distribution rates are given by the companies. Distribution rates for town gas are based on the available data from the Danish town gas distribution companies of which two are closed down today. Distribution losses for 1990-2000 are based on annual environmental reports of DONG Energy. For 2000-2006 the average losses for the gas distribution companies are used. From 2007 data on distribution losses available from the companies are used.

Table 3.4 Activity data on transmission and distribution of gas for selected years of the time series. Town gas is included in distribution.

	1990	1995	2000	2005	2010	2011	2012	2013
Transmission, Mm^3	2 739	4 689	7 079	7 600	7 462	6 181	5 365	4 886
Distribution of natural gas, Mm^3	1 714	3 054	3 181	3 265	3 416	2 933	2 728	2 634
Distribution of town gas, Mm^3	35	35	34	32	22	21	24	28

In 2013 the gas transmission rate was 4 886 Mm^3 and the distribution rate was 2 662 Mm_n^3, hereof 28 Mm_n^3 town gas (Figure 3.7). The variation over the time series mainly owes to variations in the winter temperature and to the variation of import / export of electricity from Norway and Sweden. As Denmark is a net exporter of natural gas, the transmission rate is less than the production rate, as part of the produced natural gas is exported through the NOGAT pipeline system. The decrease in 2007 and 2009 (Table 3.7) are caused by the completion of greater construction works and rerouting of a major pipeline. In preparation for construction work on a new compressor station, there has been laid a number of new line valve stations in 2011. Before this work could be done, larger amounts of natural gas were vented to drain the pipes. Therefore emissions from transmission of natural gas are significantly higher in 2011. Likewise, distribution rates depend on the annual number and extent of excavations and maintenance works, but also on difference between the calendar year and the meter reading year might influence the annual variations.

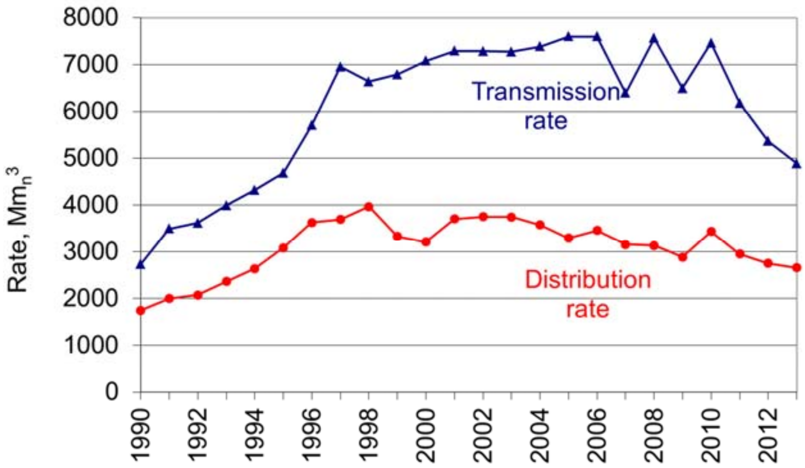

Figure 3.7 Rates for transmission and distribution of gas. Distribution covers both natural gas and town gas.

Data on the transmission pipelines excluding offshore pipelines and on the distribution network are given by Energinet.dk, DGC and the distribution companies concerning length and material. The length of the transmission pipelines is approximately 900 km. Because the distribution system in Denmark is relatively new most of the distribution network is made of plastic (PE). In 2013 the length of the distribution network was around 20 000 km. The major part is made of plastic (approximately 90 %) and the remaining part is made of steel. For this reason the fugitive emission is negligible under normal operating conditions as the distribution system is basically tight with no fugitive losses. However, the plastic pipes are vulnerable and therefore most of the fugitive emissions from the pipes are caused by losses due to excavation damages, and construction and maintenance activities performed by the gas companies. These losses are either measured or estimated by calculation in each case by the gas companies. About 5 % of the distribution network is used for town gas. This part of the network is older and the fugitive losses are larger. The fugitive losses from this network are associated with more uncertainty as it is estimated as a percentage (15 %) of the meter differential. This assumption is based on expert judgement from one of the town gas companies (Jensen, 2008). It must be noted that two town gas distribution companies have been closed in recent years (one in 2004 and another in 2006). At present there are only two town gas distribution companies left, and therefore the data availability is scarce.

3.2.6 Venting and flaring

Venting

In Denmark there are two natural gas storage facilities. Both are obligated to make an environmental report on annual basis. Data on gas input and withdrawal are included and were 891 Mm^3 and 650 Mm^3 in 2013, respectively. Venting and flaring at the gas storage plants are included in the inventory. Venting of gas is assumed to be not occurring in extraction and in refineries as controlled venting enters the gas flare system. Venting rates in gas storage facilities are shown in Figure 3.8. For the years 1990-1993 venting only occurred at the gas treatment plant. From 1994 onwards venting also occur at one of two gas storage plants. As venting rates are not available for the gas treatment plant for the years 1990-1993, the average for 1994-1998 is used.

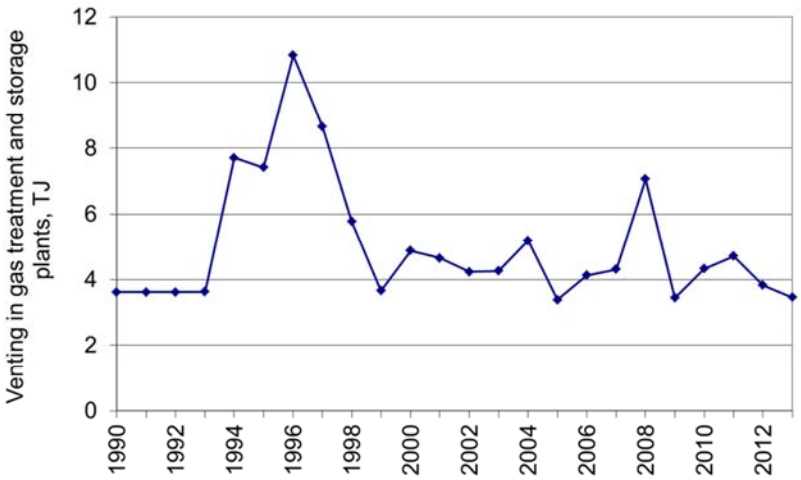

Figure 3.8 Amount vented in gas treatment and storage plants.

Flaring

Flaring rates for the two Danish refineries are given in their environmental reports and in additional data provided by the refineries directly to DCE. From 2006 flaring amounts are given in the EU ETS reporting. Data are not available for the years 1990-1995. The flaring amount for 1996 has been adopted for the previous years. Flaring rates are shown in Figure 3.9.

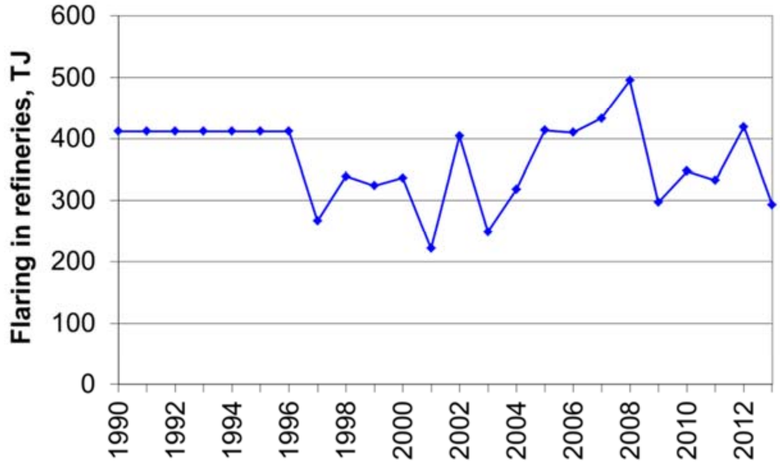

Figure 3.9 Amount flared in refineries (annual environmental reports from A/S Dansk Shell and Statoil A/S).

Amounts flared in upstream oil and gas production (in the following refered as offshore flaring) are given in Denmark's oil and gas production (DEA 2014b) while flaring in treatment/storage plants are given in DONG Energy's environmental reports (Dong Energy, 2014a,b; Energinet.dk 2014a). Flaring rates are shown in Figure 3.10 and 3.11.

Offshore flaring amounts have been decreasing over the last 10 years period in accordance with the decrease in production as seen in Figure 3.3. Further, there is focus on reduction of the amount being flared for environmental reasons.

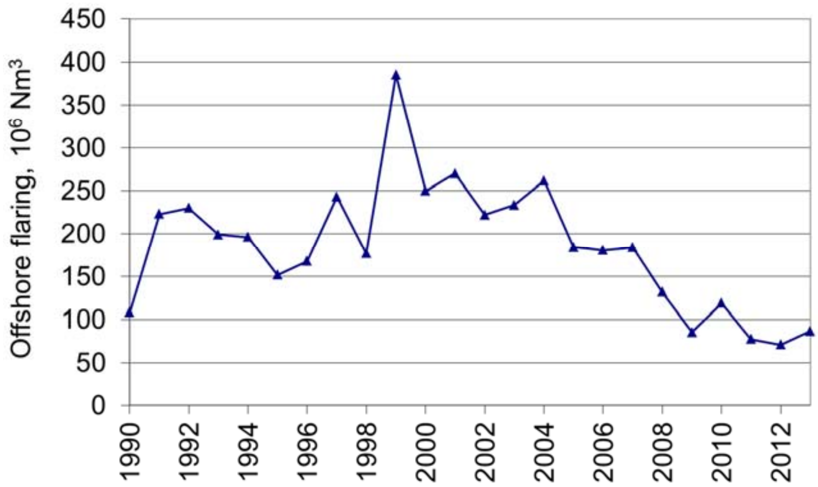

Figure 3.10 Amounts of gas flared in offshore exploration.

Flaring rates in gas treatment and gas storage plants are not available before 1994. The mean value for 1994-1998 has been adopted as basis for the emission calculation for the years 1990-1993. The large amount of flared gas in 2007 owe to a larger maintenance work at the gas treatment plant. Flaring rates are shown in Figure 3.11.

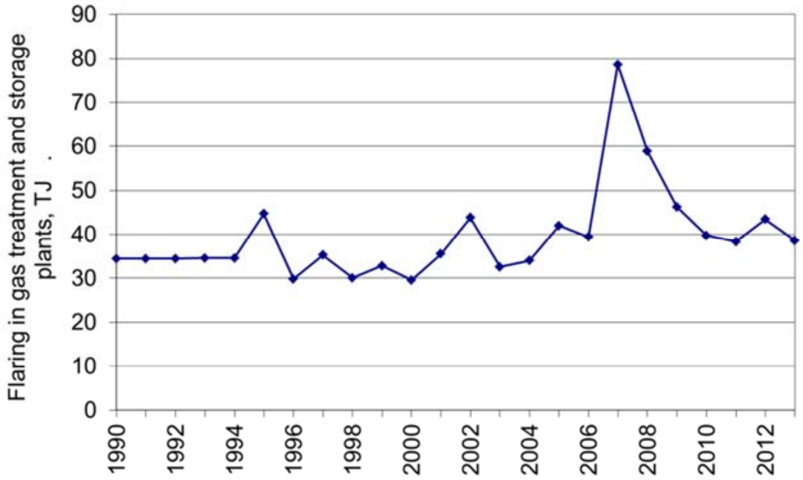

Figure 3.11 Amount flared in gas treatment and storage plants.

3.3 Emission factors

The following chapters give descriptions on emission factors used for calculation of fugitive emissions from fuels in the Danish emission inventory.

3.3.1 Coal storage

Emissions of particulate matter (PM) from coal storage are estimated using emission factors from the Coordinated European Particulate Matter Emission Inventory Program, CEPMEIP (Visschedijk et al., 2004). The emission factors are listed in Table 3.5.

Table 3.5 Emission factors used to estimate particulate emissions from coal storage.

Emission factor	TSP	PM_{10}	$PM_{2.5}$
Emission factor, g per Mg	150	60	6

3.3.2 Exploration of oil and gas

Annual implied CO_2 emission factors for exploration of gas are based on composition data for explored oil and gas. Separate composition data are available for the exploration and appraisal wells (E/A wells), except for a few E/A wells, for which the composition for the latest E/A well is used for emission calculation. For all other pollutants, emissions from exploration are calculated from the same emission factors that are used for offshore flaring. The emission factors, which are based on DEPA 2006, IPCC 2006 and EMEP/EEA 2013, are listed in Table 3.11.

3.3.3 Extraction of oil and gas

Standard emission factors from the 2006 IPCC Guidelines (IPCC 2006) are used to calculate emissions from extraction of oil and gas. The emission factors are listed in Table 3.6.

3.3.4 Oil terminal

Implied emission factors are calculated annually for NMVOC based on emission provided in the environmental reports for the raw oil terminal (DONG Oil Pipe A/S, 2014). The implied emission factor for 2013 is listed in Table 3.6.

Table 3.6 Emission factors for extraction of oil and gas.

	CO_2	CH_4	NMVOC	Reference
Extraction of oil, Gg/1000m^3	4.30E-08	5.90E-07	7.40E-07	IPCC 2006
Extraction of gas, Gg/Mm3	1.40E-05	3.80E-04	9.10E-05	IPCC 2006
Oil terminal, g/Mg oil	0.54	77.6	62.0	IPCC 2006, DONG Oil Pipe A/S 2014

3.3.5 Loading of ships

In the EMEP/EEA Guidebook standard emission factors for different countries are given (EMEP/EEA, 2013). In the Danish emission inventory the Norwegian emission factors are used for estimation of fugitive emissions from loading of ships onshore and offshore for the years 1990-2009. During 2009 new emission reducing technologies (Vapour Recovery Unit) were installed at the crude oil terminal. Measurements carried out at the terminal before and after installation show a decrease of emissions from loading of ships of 21 % for CH_4 and 25 % for NMVOC. The reduced emission factors used for 2010 onwards are listed in Table 3.7.

Table 3.7 Emission factors for loading of ships onshore and offshore.

	CH_4, fraction of loaded		NMVOC, fraction of loaded	
	1990-2009	2010 onwards	1990-2009	2010 onwards
Ships offshore *	0.00005	0.00005	0.001	0.001
Ships on-shore **	0.00001	0.0000079	0.0002	0.00015

* EMEP/EEA, 2013.

** EMEP/EEA, 2013; Miljøcenter Odense, 2010.

3.3.6 Oil refining

The refineries provide information on consumption of fuel gas and fuel oil. The calorific values are given by the refineries in the reporting for EU ETS since 2006. Before 2006 the calorific values given by the refineries were used when available. When not available standard calorific values from the Danish Energy Agency combined with the conversion factor between fuel gas and fuel oil given by the refinery were used for calculation.

Emissions of SO_2, NO_x and VOC are given by the refineries. Only one of the two refineries has made a split between NMVOC and CH_4. For the other refinery it is assumed that 10 % of the VOC emission is CH_4 and the remaining 90 % is NMVOC (Hjerrild & Rasmussen, 2014).

Flaring in refineries is a significant fugitive emission source to emissions of SO_2. In 1990-1993 emissions from petroleum product processing were included in emissions from flaring in refineries (1B2c). From 1994 the data delivery format was changed, which made it possible to split the emissions into contributions from flaring and processing, respectively. Emissions from processing are from 1994 included in NFR category 1B2a iv.

3.3.7 Service stations

The NMVOC emission from service stations is calculated by use of different emission factors for the time series as shown in Table 3.8.

In 1994 the emission factors for NMVOC from service stations were investigated by Fenhann and Kilde (1994) for 1990 and 1991, individually. In 1995 Stage I control measures were made obligatory, and the emission factor from the 2013 EMEP/EEA Guidebook (EMEP/EEA, 2013) is applied from 1995 and onwards. Linear interpolation is applied for the years 1992-1994.

Fenhann and Kilde (1994) also include NMVOC emission factors for refuelling for the years 1990, 1991, 1992, and 1993. The same value is given for the three years, and this emission factor is applied for the years 1994-1995, when the first legal acts on emission reduction from service stations came into force. From 2005 the refuelling emission factor is based on the 2013 EMEP/EEA Guidebook (EMEP/EEA, 2013). An abatement rate of 85 % is given in the 2013 EMEP/EEA Guidebook, while 60 % was given in the 2006 EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2006). The Danish requirement is 85 % abatement under optimal conditions, but 70 % under regular conditions (Danish Ministry of the Environment, 2011). Based on this, 70 % abatement is applied in the emission calculations. Linear interpolation is used from 1996-2004.

Table 3.8 Emission factors used for estimating NMVOC from service stations.

Year	Reloading of tankers, kg NMVOC per tonnes gasoline	Refuelling of vehicles, kg NMVOC per tonnes gasoline	Sum of reloading and refuelling, kg NMVOC per tonnes gasoline	Source
1990	1.28	1.52	2.80	Fenhann & Kilde,1994
1991	0.64	1.52	2.16	Fenhann & Kilde,1994
1992	0.49	1.52	2.01	Interpolation / Fenhann & Kilde,1994
1993	0.35	1.52	1.87	Interpolation / Fenhann & Kilde,1994
1994	0.20	1.52	1.72	Interpolation / Fenhann & Kilde,1994
1995	0.05	1.52	1.57	EMEP/EEA 2013 / Fenhann & Kilde,1994
1996	0.05	1.42	1.47	EMEP/EEA 2013 / interpolation
1997	0.05	1.31	1.37	EMEP/EEA 2013 / interpolation
1998	0.05	1.21	1.26	EMEP/EEA 2013 / interpolation
1999	0.05	1.11	1.16	EMEP/EEA 2013 / interpolation
2000	0.05	1.00	1.06	EMEP/EEA 2013 / interpolation
2001	0.05	0.90	0.95	EMEP/EEA 2013 / interpolation
2002	0.05	0.80	0.85	EMEP/EEA 2013 / interpolation
2003	0.05	0.69	0.75	EMEP/EEA 2013 / interpolation
2004	0.05	0.59	0.64	EMEP/EEA 2013 / interpolation
2005 onwards	0.05	0.49	0.54	EMEP/EEA 2013

3.3.8 Transmission, storage and distribution of gas

The fugitive emissions from transmission, storage and distribution of natural gas are based on data on gas losses from the companies and on the average annual natural gas composition given by Energinet.dk (Table 3.9).

For distribution of town gas the emission factor is reduced due to the admixture of 50 % atmospheric air to the natural gas.

Table 3.9 Annual gas composition, lower heating value and density for Danish natural gas (Energinet.dk).

		Unit	1990	2000	2005	2010	2011	2012	2013
Methane	CH_4	molar-%	90.92	86.97	88.97	89.95	89.10	88.84	89.82
Ethane	C_2H_6	molar-%	5.08	6.88	6.14	5.71	5.98	6.11	5.65
Propane	C_3H_8	molar-%	1.89	3.17	2.50	2.19	2.36	2.44	2.00
i-Butane	i-C_4H_{10}	molar-%	0.36	0.43	0.40	0.37	0.37	0.37	0.32
n-Butane	n-C_4H_{10}	molar-%	0.50	0.61	0.55	0.54	0.55	0.54	0.46
i-Petane	i-C_5H_{12}	molar-%	0.14	0.11	0.11	0.13	0.13	0.13	0.11
n-Petane	n-C_5H_{12}	molar-%	0.10	0.08	0.08	0.08	0.09	0.08	0.08
n-Hexane and heavier hydrocarbons	C_{6+}	molar-%	0.09	0.06	0.05	0.06	0.06	0.06	0.05
Nitrogen	N_2	molar-%	0.31	0.34	0.29	0.31	0.37	0.36	0.55
Carbon dioxide	CO_2	molar-%	0.60	1.35	0.90	0.66	0.98	1.06	0.96
Lower heating value	LHV	MJ/m^3_n	39.176	40.154	39.671	39.461	39.507	39.548	39.988
Density	ρρ	kg/m^3_n	0.808	0.846	0.825	0.816	0.824	0.827	0.814

3.3.9 Venting and flaring

Venting

Emissions of CH_4 and NMVOC from venting are given in the environmental reports for the gas storage plants (DONG Energy, 2014a; Energinet.dk, 2014a). CO_2 emissions from venting are calculated from country specific emission factors based on annual natural gas composition published by Energinet.dk.

Flaring in refineries

The composition of fuel gas is given for 2008 by one of the two refineries. As the composition for fuel gas is markedly different than the composition of natural gas, which has been used in earlier year’s calculations, the same fuel gas composition is used in calculations for both the Danish refineries.

The CH_4 and NMVOC emission factor based on these data are applied for both refineries for the entire time series. The CO_2 emission factor is based on the refineries reporting to the EU ETS for the years 2006 and onwards. Before 2006 corresponding data are not available, and the average of CO_2 emission factors for 2006-2010 for each refinery is applied. The emission factor applied for N_2O is based on OLF (1993) for flaring in oil and gas extraction as no value are given for flaring in refineries.

NO_x emissions are provided by one refinery. Emission factors from the EMEP/EEA Guidebook (2013) are used to calculate emissions of CO and for NO_x where plant specific data are not available. Emission factors for the remaining pollutants are taken from the 2013 EMEP/EEA Guidebook. The emission factors are listed in Table 3.10.

Table 3.10 Emission factors for flaring in refineries.

Pollutant	Emission factor	Unit	Source
NO_x	32.2	g per GJ	Country specific
NMVOC	76.4	g per GJ	Country specific
CH_4	18.1	g per GJ	Country specific
CO	177	g per GJ	EMEP/EEA, 2013
CO_2 *	47.47 / 54.49	kg per GJ	Country specific
N_2O	0.47	g per GJ	OLF, 1993
TSP	0.89	g per GJ	EMEP/EEA, 2013
PM_{10}	0.89	g per GJ	EMEP/EEA, 2013
$PM_{2.5}$	0.89	g per GJ	EMEP/EEA, 2013
BC	0.22	g per GJ	EMEP/EEA, 2013
As	0.3	mg per GJ	EMEP/EEA, 2013
Cd	0.7	mg per GJ	EMEP/EEA, 2013
Cr	3	mg per GJ	EMEP/EEA, 2013
Cu	2	mg per GJ	EMEP/EEA, 2013
Hg	0.09	mg per GJ	EMEP/EEA, 2013
Ni	4	mg per GJ	EMEP/EEA, 2013
Pb	2	mg per GJ	EMEP/EEA, 2013
Se	0.42	mg per GJ	EMEP/EEA, 2013
Zn	26	mg per GJ	EMEP/EEA, 2013
Dioxin	0.5	ng I-TEQ per GJ	EMEP/EEA, 2013
Benzo(b)fluoranthene	1.14	µg per GJ	EMEP/EEA, 2013
Benzo(k)fluoranthene	0.63	µg per GJ	EMEP/EEA, 2013
Benzo(a)pyrene	0.67	µg per GJ	EMEP/EEA, 2013
Indeno(1,2,3-c,d)pyrene	0.63	µg per GJ	EMEP/EEA, 2013

* The CO_2 emission factor is based on the refineries reports for ETS and is plant specific.

Flaring offshore

The emission factors for offshore flaring are shown in Table 3.11. Since 2006 the CO_2 emission factor is calculated according to the reporting under the EU ETS. Corresponding data are not available for earlier years and therefore the CO_2 emission factor is assumed to follow the same time series as for natural gas combusted in stationary combustion plants. The emission factor for N_2O is based on IPCC (2006) for flaring in gas production, recalculated to g N_2O / m^3 gas flared, based on the production and flaring amounts in the years 2009-2013. The emission factor for CH_4 is based on OLF (1993). The NO_x emission factor is based on the conclusion in a Danish study of NO_x emissions from offshore flaring carried out by the Danish Environmental Protection Agency (DEPA, 2006). The recommended NO_x emission factor (0.0015 tonnes NO_x per tonnes gas) corresponds well with the emission factors used to estimate NO_x emission in other countries with oil production in the North Sea (Netherlands: approximately 0.0014 tonnes NO_x per tonnes gas and United Kingdom: approximately 0.0013 tonnes NO_x per tonnes gas (DEPA, 2006)). Emission factors for all other pollutants are based on the 2013 EMEP/EEA Guidebook (2013).

Table 3.11 Emission factors for offshore flaring.

Pollutant	Emission factor	Unit	Source
SO_2	0.013	g per Nm^3	EMEP/EEA, 2013
NO_x	1.227	g per Nm^3	DEPA, 2006
NMVOC	1.482	g per Nm^3	EMEP/EEA, 2013
CH_4	10.56	g per Nm^3	OLF, 1993
CO	1.854	g per Nm^3	EMEP/EEA, 2013
CO_2	2.516	kg per Nm^3	Country specific
N_2O	1.598	g per Nm^3	IPCC, 2006
TSP	0.042	g per Nm^3	EMEP/EEA, 2013
PM_{10}	0.042	g per Nm^3	EMEP/EEA, 2013
$PM_{2.5}$	0.042	g per Nm^3	EMEP/EEA, 2013
BC	0.008	g per Nm^3	EMEP/EEA, 2013
As	0.006	mg per Nm^3	EMEP/EEA, 2013
Cd	>0.001	mg per Nm^3	EMEP/EEA, 2013
Cr	>0.001	mg per Nm^3	EMEP/EEA, 2013
Cu	>0.001	mg per Nm^3	EMEP/EEA, 2013
Hg	0.005	mg per Nm^3	EMEP/EEA, 2013
Ni	>0.001	mg per Nm^3	EMEP/EEA, 2013
Pb	0.084	mg per Nm^3	EMEP/EEA, 2013
Se	0.001	mg per Nm^3	EMEP/EEA, 2013
Zn	>0.001	mg per Nm^3	EMEP/EEA, 2013
Dioxin	0.024	ng I-TEQ per Nm^3	EMEP/EEA, 2013
Benzo(b)fluoranthene	0.040	µg per Nm^3	EMEP/EEA, 2013
Benzo(k)fluoranthene	0.040	µg per Nm^3	EMEP/EEA, 2013
Benzo(a)pyrene	0.026	µg per Nm^3	EMEP/EEA, 2013
Indeno(1,2,3-c,d)pyrene	0.040	µg per Nm^3	EMEP/EEA, 2013

Emissions from flaring in gas treatment and storage plants are calculated from the same emission factors, which are used for offshore flaring. Only difference is the CO_2 emission factor for the years from 2006 onwards. The emission factors used for the plants are based on the same data source, the reporting for EU ETS, but the values are different than for offshore flaring. The gas that are flared in the treatment and storage plants are natural gas with the same composition as natural gas distributed in Denmark. Therefore, the emission factors in the EU ETS reports are the same as the one calculated on basis of the gas composition given by Energinet.dk.

3.4 Emissions

The following chapters give an overview of emissions from sources in the fugitive sector in the Danish emission inventory.

3.4.1 Coal storage

The emission from storage of coal is 743 Mg TSP in 2013 (297 Mg PM_{10} and 30 Mg $PM_{2.5}$). The coal consumption and the related emissions vary from year to year mainly due to the extent of electricity import/export and temperature variations (Table 3.12). Note that PM is only included in the inventory from 2000 due to the reporting requirements.

Table 3.12 PM_{10} from storage of solid fuels for selected years of the time series.

	2000	2005	2010	2011	2012	2013
TSP, Mg	962	905	686	920	597	743
PM_{10}, Mg	385	362	274	368	239	297
$PM_{2.5}$, Mg	38	36	27	37	24	30

3.4.2 Extraction of oil and gas and loading of ships

CO_2, CH_4 and NMVOC emissions from exploration and extraction of oil and gas, and from loading of ships are listed in Table 3.13, Table 3.14 and Table 3.15, along with emissions from the oil terminal given in the environmental reports from DONG Oil Pipe (2014). A degassing system has been established at the crude oil terminal leading to reduced VOC emissions from storage and handling. The degassing system has been in operation since the summer of 2009 and measurements of VOC emissions were carried out in September 2009 after a period with constant operation. The CH_4 and NMVOC emission factor from the oil terminal has decreased by 16 % and 38 %, respectively, from 2008 to 2009 and further by 18 % and 61 % from 2009 to 2010.

Table 3.13 CO_2 (Mg) from activities related to production of oil and gas.

CO_2, Mg	1990	1995	2000	2005	2010	2011	2012	2013
Exploration of oil	4.7	3.4	2.6	4.6	NO	NO	NO	3
Exploration of gas	8.2541	0.0004	0.1646	2.0577	NO	NO	NO	0.0003
Extraction of oil	0.0003	0.0005	0.0009	0.0009	0.0006	0.0006	0.0005	0.0004
Extraction of gas	0.072	0.088	0.158	0.161	0.113	0.091	0.079	0.066
Oil terminals	0.003	0.005	0.008	0.009	0.006	0.006	0.005	0.005

Table 3.14 CH_4 (Mg) from activities related to production of oil and gas.

CH_4, Mg	1990	1995	2000	2005	2010	2011	2012	2013
Exploration of oil	0.02	0.015	0.011	0.02	NO	NO	NO	0.013
Exploration of gas	30.54	0.002	0.591	7.53	NO	NO	NO	0.001
Extraction of oil	4	6	12	13	8	8	7	6
Extraction of gas	1952	2402	4300	4379	3061	2474	2134	1788
Onshore loading of ships	34	62	109	125	63	56	71	41
Offshore loading of ships	NO	NO	201	167	83	76	67	48
Oil terminals	783	1209	1700	2100	984	822	766	680

Table 3.15 NMVOC (Mg) from activities related to extraction of oil and gas.

NMVOC, Mg	1990	1995	2000	2005	2010	2011	2012	2013
Exploration of oil	0.0029	0.0021	0.0016	0.0028	NO	NO	NO	0.0018
Exploration of gas	4.2867	0.0002	0.083	1.0569	NO	NO	NO	0.0002
Extraction of oil	5.2	8	15.6	16.2	10.5	9.5	8.7	7.5
Extraction of gas	467	575	1 030	1 049	733	593	511	428
Onshore loading of ships	678	1 249	2 183	2 494	1 187	1 071	1 355	787
Offshore loading of ships	NO	NO	4021	3 337	1 658	1 525	1 332	960
Oil terminal	1 726	2 664	4 000	4 500	763	638	594	543

3.4.3 Oil refining

CH_4 and NMVOC emissions from oil refining at the Danish refineries are listed for selected years of the time series in Table 3.16. Further, the emissions of SO_2 from oil refining and sulphur recovery in refineries are shown. The emission of SO_2 has shown a pronounced decrease since 1990 because of technical improvements at the refineries. Note that SO_2 from refining and recovery prior to 1994 was summarised and reported as an area source in category 1B2a vi, and that SO_2 from oil refining from 2001 are included in stationary combustion.

Table 3.16 Emissions of NMVOC and SO_2 from oil refining and SO_2 from sulphur recovery in refineries.

	1990[1]	1995	2000	2005[2]	2010[2]	2011[2]	2012[2]	2013[2]
CH_4 emission, Mg	435	592	503	416	609	609	616	619
NMVOC, Mg	4 072	5 500	4 530	3 742	5 477	5 479	5 543	5 575
SO_2, oil refining, Mg		585	178					
SO_2, sulphur recovery, Mg	3 335	2 437	803	347	981	1150	881	517

[1] Prior to 1994 SO_2 emissions from oil refining and sulphur recovery are reported as area sources in category 1B2a vi.

[2] From 2001 SO_2 emissions from oil refining are included in stationary combustion.

3.4.4 Service stations

Emissions from service stations are calculated using the emission factors in Table 3.8 and the sales of gasoline given by the Danish energy statistics. The NMVOC emissions are listed in Table 3.17.

Table 3.17 Emissions of NMVOC from service stations for selected years of the time series.

	1990	1995	2000	2005	2010	2011	2012	2013
NMVOC, Mg	4 856	2 965	2 616	1 031	851	796	754	725

3.4.5 Transmission, storage and distribution of gas

Emissions from distribution of town gas show large decreases in 2003 and 2005 due to the closure of two distribution networks, leaving only another two companies still in operation.

Emissions of CH_4 and NMVOC from transmission of natural gas and distribution of natural gas and town gas are shown in Table 3.18 and Table 3.19.

Table 3.18 CH_4 emission from transmission of natural gas and distribution of natural gas and town gas for selected years.

CH_4, Mg	1990	1995	2000	2005	2010	2011	2012	2013
Transmission	190	597	86	141	26	171	14	16
Distribution, natural gas	56	99	49	66	37	49	71	64
Distribution, town gas	202	211	176	176	106	106	75	58

Table 3.19 NMVOC emission from transmission, storage of natural gas and distribution of natural gas and town gas for selected years of the time series.

NMVOC emission, Mg	1990	1995	2000	2005	2010	2011	2012	2013
Transmission	41	135	26	36	6	43	4	4
Distribution, natural gas	12	22	15	17	9	12	18	14
Distribution, town gas	683	700	680	587	53	50	39	30

3.4.6 Venting and flaring

Venting

Venting is limited to the gas storage plants and the emissions are of minor importance. Compared to the total fugitive emissions in 2013, venting contribute 0.2 % for NMVOC, 1.2 % for CH_4 and < 0.01 % for CO_2.

Flaring in refineries

Emissions for selected years and components are shown in Table 3.20. One refinery was shut down in 1996 leading to larger emissions in 1990-1996. Technical improvements of the sulphur recovery system at one of the two Danish refineries lead to a decrease of SO_2 emissions from 1996-1998. The large emissions from 2005 and onwards owe to shut-downs due to maintenance and accidents. Further, construction and initialisation of new facilities and problems related to the ammonium thiosulphate (ATS) plant at one refinery has led to increased emissions. In 2007 the capacity of the ATS plant was increased followed by commissioning difficulties.

Table 3.20 Emissions from flaring in refineries.

Emission, Mg	1990	1995	2000	2005	2010	2011	2012	2013
SO_2 [1]	943	203	51	296	326	271	175	166
NO_x,	13	13	11	26	19	18	23	15
NMVOC	31	31	26	32	27	25	32	22
CH_4	7	7	6	8	6	6	8	5
CO	73	73	60	73	62	59	74	52
CO_2	23	23	19	23	19	19	22	17

[1] In 1990-1993 emissions from petroleum product processing were included in flaring in refineries due to the data delivery form. From 1994 emissions from petroleum product processing are given in 1B2a iv.

Flaring offshore

The time series for the emission of CO_2 from offshore flaring fluctuates due to the fluctuations in the fuel rate and to a minor degree due to the CO_2 emission factor. As shown in Figure 3.12, there was a marked increase in the amount of offshore flaring in 1997 and especially in 1999. The increase in 1997 was due to the new Dan field and the completion of the Harald field. The increase in 1999 was due to the opening of the three new fields Halfdan, Siri and Syd Arne.

The CO_2 emission factor is based on gas quality measurements. From 2006 the CO_2 emission factors and calorific values for flare gas are given at installation level in the EU ETS. This information is incorporated in the inventory for the years 2006-2007 for part of the offshore installations, and from 2008 and onwards for all installations. This has led to an increase of the CO_2 emission factor. The average of the emission factors for 2008-2010 is adopted for 1990-2007. Fuel rate and CO_2 emission are shown in Figure 3.12.

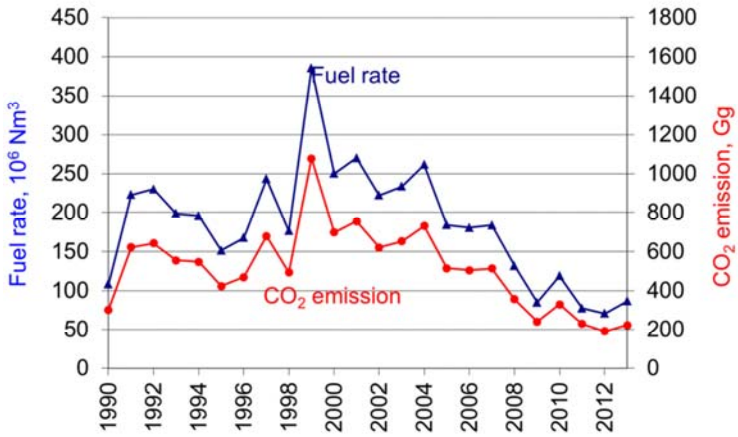

Figure 3.12 Fuel rate and CO_2 emission from offshore flaring of gas.

The emissions from offshore flaring are estimated from the same set of emission factors for all years in the time series and the variations reflect only the variations in the flared amounts. Emissions of selected components from flaring in oil and gas extraction including offshore flaring are shown in Table 3.21. Flaring in gas storage and gas transmission and distribution only contribute little to the emissions from flaring, and are not included in Table 3.21.

Table 3.21 Emissions from flaring in oil and gas extraction.

Emission, Mg	1990	1995	2000	2005	2010	2011	2012	2013
SO_2	1	2	3	2	2	1	1	1
NO_x	133	186	307	226	146	95	87	106
NMVOC	160	225	371	273	177	115	105	129
CH_4	1 142	1 602	2 641	1 946	1 258	819	749	916
CO	201	281	464	342	221	144	132	161

4 Uncertainties and time-series consistency

4.1 Methodology

Two sets of uncertainty estimates are made for the Danish emission inventory. A simple approach (error propagation) is applied for all pollutants, and in addition a detailed approach (Monte Carlo simulation) is applied for greenhouse gases. The two approaches are consistent with the guidance provided in the 2006 IPCC Guidelines and the 2013 EMEP/EEA Guidebook. Uncertainty estimates are made for emissions in the base year (Tier 2), in the latest inventory year (Tier 1 and Tier 2) and for the emission trend for the corresponding time series (Tier 1 and Tier 2).

The most comprehensive uncertainty analysis is made for GHGs, where the analysis is based on activity data uncertainties and emission factor uncertainties on SNAP level. For the remaining pollutants the analysis is carried out for aggregated data for the IPCC category 1 B - Fugitive Emissions from Fuels. Base year refers to 2000 for particulate matter and BC and to 1990 for the remaining pollutants.

4.2 Input data

4.2.1 GHGs

The Tier 1 uncertainty model is based on emission data, uncertainty levels for activity data and uncertainty levels for emission factors for base year and latest inventory year. The Tier 2 model is based on activity data and emission factors for the same years and the same uncertainty levels as in Tier 1. Activity data, emission factors and emission data, are described in Chapters 3.2, 3.3 and 3.4.

The uncertainty levels used in the uncertainty models are based on different sources, e.g. IPCC Guidelines, EMEP/EEA Guidebook and reports under the EU ETS. Further, some of the uncertainty levels are given as DCE assumptions. DCE assumptions are based on source and/or plant specific uncertainty levels for part of the SNAP category and assumptions for the remaining sources and/or plants in the category.

Input data are aggregated on SNAP level. Estimates are made for the greenhouse gases CO_2, CH_4 and N_2O both separately and in total (GHGs). Uncertainty levels for activity data and emission factors are listed in Table 4.1.

Table 4.1 Uncertainty levels for activity rates and emission factors.

Pollutant	Source	Activity data uncertainty level, %	Emission factor uncertainty level, %
CO_2	Exploration, oil	2 D	10 D
CO_2	Offshore activities, oil	2 D	100 I
CO_2	Land based activities, oil	2 D	40 S
CO_2	Exploration, gas	2 D	10 D
CO_2	Offshore activities, gas	2 D	100 S
CO_2	Transmission of natural gas	15 G	2 Q
CO_2	Distribution of natural gas	25 G, D	10 Q, D
CO_2	Venting in gas storage	15 G, D	2 Q
CO_2	Flaring, refinery gas	11 E	2 E
CO_2	Flaring, natural gas	7.5 E	2 E
CH_4	Exploration, oil	2 D	125 D
CH_4	Off-shore activities, oil	2 D	100 I
CH_4	Land based activities, oil	2 D	40 S
CH_4	Petroleum product processing	1 E, D	125 D
CH_4	Exploration, gas	2 D	125 D
CH_4	Off-shore activities, gas	2 D	100 I
CH_4	Transmission of natural gas	15 G	2 Q
CH_4	Distribution of natural gas	25 G, D	10 Q, D
CH_4	Venting in gas storage	15 G, D	2 Q
CH_4	Flaring, refinery gas	11 E	15 H, D
CH_4	Flaring, natural gas	7.5 E	125 G
N_2O	Exploration, oil	2 D	500 D
N_2O	Exploration, gas	2 D	500 D
N_2O	Flaring, refinery gas	11 E	500 I
N_2O	Flaring, natural gas	7.5 E	500 I

D: DCE assumption.
I: IPCC Good Practice Guidance (default value).
S: Statistisk Sentralbyrå, Statistics Norway, 2008.
E: EU Emission Trading Scheme (EU ETS).
G: EMEP/EEA Guidebook, 2013.
H: Holst, 2009 and Statoil A/S, 2010.
Q: Annual gas quality, Energinet.dk.

The CO_2 emission factors for flaring offshore and in refineries and the CO_2 and CH_4 emission factors for natural gas transmission, distribution and venting, are the most accurate as they are calculated on basis of gas composition measurements. Emissions factors for flare gas are available in the EU-ETS reporting while emissions factors for natural gas are published by Energinet.dk.

The calculation of CO_2 emissions from exploration of oil and gas is based on information on oil and gas quality for most drillings. As the uncertainty levels of the measurements are not available, the double of the uncertainty for flaring in oil and gas extraction (before EU ETS standards) has been used.

The CO_2 emission factor for extraction of oil and gas is based on standard emission factors from IPCC (2006) and the corresponding uncertainties of 100 % are applied in the uncertainty analysis.

The uncertainty level for the emission factor for fugitive CH_4 emissions from refineries is dominated by a large uncertainty for one refinery. Further, measurements of fugitive emissions from the refineries are only available for one and two years, respectively, and these measurements indicate larger emissions than earlier estimates. As more measurements become available the uncertainty level is expected to decrease.

The emission factors for loading of ships are given as quality C in EMEP/EEA (2013), corresponding an uncertainty level of 50-200 %. The lower level is assumed to be most plausible for Danish conditions.

For onshore activities, the emission factor uncertainty corresponds to the uncertainty for onshore loading by Statistics Norway (Statistisk Sentralbyrå, 2008), and the same uncertainty level is assumed for the CH_4 emission factor for onshore activities.

According to IPCC (2006) the emission factor for N_2O is the least reliable. An uncertainty level of 500 % is adopted in the Danish uncertainty model for all fugitive sources (exploration and flaring of oil and gas).

The Tier 2 uncertainty model is based on Monte Carlo simulations and the input uncertainty levels are given for the 95 % confidence interval assuming a log-normal distribution. The input uncertainty levels are the same as those used in the Tier 1 uncertainty model (Table 4.1).

4.2.2 Non-GHGs

The uncertainty rates are based on the EMEP/EEA emission inventory guidebook (2013), on uncertainty estimates from companies and on estimates and assumptions by DCE. The applied uncertainty levels for activity data and emission factors are given in Table 4.2.

Table 4.2 Uncertainty levels for activity data and emission factors.

	Activity Data Uncertainty level, %	Emission Factor Uncertainty level, %
SO_2	10	25
NO_x	8	125
NMVOC	2	125
CO	8	125
TSP	2	50
PM_{10}	2	50
$PM_{2.5}$	2	50
BC	2	100
As	8	500
Cd	8	500
Cr	8	500
Cu	8	500
Hg	8	500
Ni	8	500
Pb	8	500
Se	8	500
Zn	8	500
Benzo(b)fluoranthe	8	500
Benzo(k))fluoranthe	8	500
Benzo(a)pyrene	8	500
Indeno(1,2,3-c,d)pyrene	8	500

4.3 Results

4.3.1 GHGs

The results of the Tier 1 uncertainty model for 2013 are shown in Table 4.3. In 2013 N_2O has the largest uncertainty for the total emission followed by CH_4 and CO_2. Due to the emission trend N_2O has the largest uncertainty followed by CO_2 and CH_4. The estimated uncertainty for the total GHG emission is 107 % and the GHG emission trend is -25 % ± 8 %-point.

Table 4.3 Uncertainty estimates for total emissions and emission trends from the Tier 1 uncertainty model.

	Emission, Gg CO_2 eqv Base year	Emission, Gg CO_2 eqv 2013	Uncertainty, % Lower and upper (±)	Trend 1990-2013, %	Uncertainty, % Lower and upper (±)
CO_2	341	238	7	-30	7
CH_4	123	107	53	-12	7
N_2O	53	41	999	-22	30
GHG	516	387	107	-25	8

Table 4.4 show the results from the Tier 2 uncertainty model for 1990 and 2013. The overall emission uncertainty in 2013 is -19 / +74 %. The Tier 2 trend estimate is -26 % -18 / +13 %-point.

Table 4.4 Uncertainty estimates for total emissions in 1990 and 2013 and for the emission trends from the Tier 2 uncertainty model.

	1990			2013			1990-2013		
	Median emission Gg CO_2 eqv	Uncertainty, % Lower (-)	Uncertainty, % Upper (+)	Median emission Gg CO_2 eqv	Uncertainty, % Lower (-)	Uncertainty, % Upper (+)	Median trend, %	Uncertainty, % Lower (-)	Uncertainty, % Upper (+)
CO_2	341	15	18	238	7	7	-3	24	3
CH_4	131	37	71	39	93	779	-34	63	72
N_2O	50	91	743	115	37	72	-78	47	40
GHG	539	20	68	402	19	74	-26	18	13

Tier 1 and Tier 2 emissions and uncertainties are shown together in Figure 4.1. The figures show that the emissions and median emissions from Tier 2 are very similar. Further, the uncertainty estimates are in the same range for Tier 1 and Tier 2. The N_2O uncertainty is left out of Figure 4.1 b as the N_2O uncertainties are much higher than for CO_2 and CH_4. It must be noted that the uncertainty models, especially the Tier 1 model, are not suitable for very large uncertainty levels and therefore the uncertainty estimates for N_2O may only be seen as an indicator for a large uncertainty while the uncertainty estimates are less accurate. The Tier 2 model has been developed to be more suitable for very large uncertainties, as it is possible to apply truncation for uncertainties. This has been included in the uncertainty calculation for fugitive emissions in case of N_2O, as the uncertainty level for the emission factors is 500 %. A truncation of 1 000 % has been applied to ensure that the emission factor interval is within an order of magnitude as given in IPCC Good Practice Guidance.

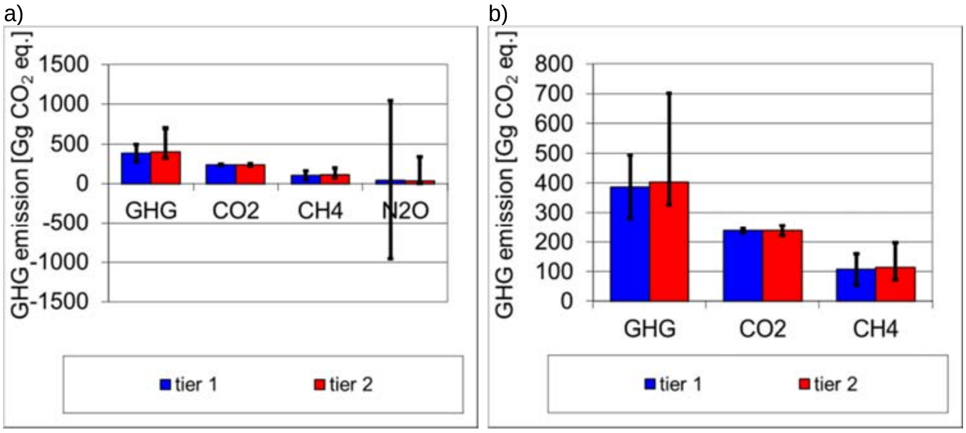

Figure 4.**1** Emissions and uncertainty estimates from the Tier 1 and Tier 2 models; a) GHG, CH_4, CO_2 and N_2O, b) as figure a, but without N_2O.

4.3.2 Non-GHGs

The uncertainty model estimates uncertainties for both the emission levels and the trends. The uncertainty on the emission levels for SO_2, NO_x, NMVOC and CO are 27 %, 125 %, 125 % and 125 %, respectively.

For PM the uncertainty is 50 %, for BC the uncertainty is 100 % and for HM and PAHs the uncertainty is 500 %. The individual uncertainty estimates for the fugitive emission inventory are shown in Table 4.5.

Table 4.5 Estimated emission uncertainty and trend uncertainty for fugitive emissions. The trend refers to the years 1990-2013 for all pollutants except PM where the trend refers to 2000-2013.

	Emission uncertainty %	Trend uncertainty %
SO_2	27	2
NO_x	125	9
NMVOC	125	2
CO	125	8
TSP	50	2
PM_{10}	50	2
$PM_{2.5}$	50	2
BC	100	2
As	500	8
Cd	500	8
Cr	500	8
Cu	500	8
Hg	500	8
Ni	500	8
Pb	500	8
Se	500	8
Zn	500	8
Benzo(b) fluoranthe	500	8
Benzo(k) fluoranthe	500	8
Benzo(a) pyrene	500	8
Indeno(1,2,3-c,d)pyrene	500	8

5 Quality Assurance and Quality Control (QA/QC)

5.1 The Danish QA/QC plan

The elaboration of a formal QA / QC plan started in 2004 (Sørensen et al., 2005), and an updated version is available (Nielsen et al., 2013). The plan describes the concepts of quality work and definitions of sufficient quality, critical control points and a list of Points of Measuring (Figure 5.1).

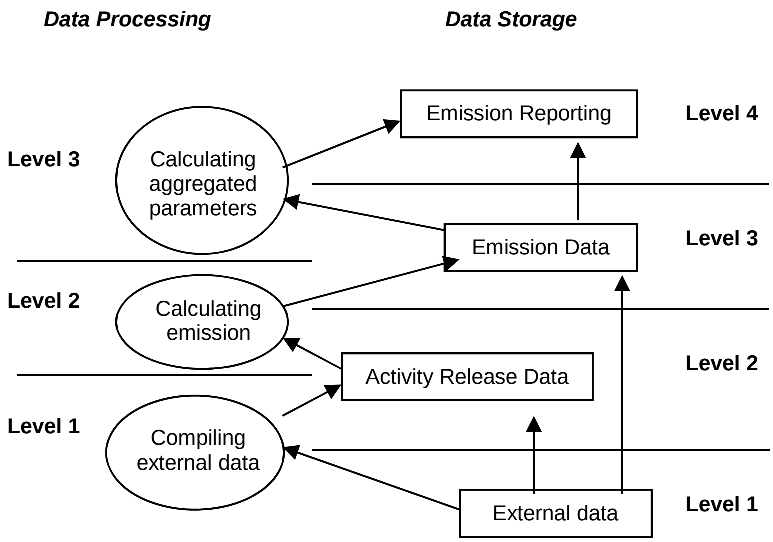

Figure 5.1 The general data structure for the Danish emission inventory (Nielsen et al., 2013).

Data storage level 1

Data storage level 1 refers to the data collected by DCE before any processing or preparing.

The uncertainty of the external data is not quantified but it is assumed that the level of uncertainty is relatively small except for the emissions from the refineries. All external data are stored in the inventory file system or in hard copy and are available for all members of the inventory staff. It is aimed to make formal agreements on data delivery. Part of the data on Danish fugitive emissions is made available due to legal obligations, here among the energy statistics, EU ETS reports and the environmental accounts. There are no formal agreements on data delivery with the refineries regarding supplemental data and the gas distribution companies. The latter was in earlier years reported to the Technical Association of the European Natural Gas Industry, Marcogaz, by the Danish Gas Technology Centre.

Data Processing Level 1

Data processing level 1 refers to the processing of the collected data before it can be incorporated in the emission calculation.

The methodological approach is consistent with the international guidelines as described in the previous chapters in this report. Time-series for activity data on SNAP level as well as emission factors are incorporated in the procedure to identify errors in the incoming data and in the calculation procedure. During the calculation process, numerous controls are in place to ensure correctness, e.g. sum checks of the various stages in the calculation procedure. There are direct links between the external datasets, the calculation process and the input data used on Data Storage level 2.

Data storage level 2

Data storage level 2 refers to storage of data that have been processed.

To ensure a correct connection between data on level 1 to data on level 2, different controls are in place, e.g. control of sums and random tests. The same procedure is applied every year in order to minimise the risk of data import errors.

Data Processing level 2

Data processing level 2 refers to calculation of emissions. The calculations are incorporated in the model for the fugitive sector, which is stored in MS Excel in the Danish inventory file system.

Data Storage level 3

Data Storage level 3 refers to the emission data either given directly in or calculated from the data in Data Storage level 1. The emissions are stored in MS Excel on both source level and aggregated on SNAP level for export to the overall inventory storage system.

5.2 Sector specific QA/QC procedures for fugitive emissions

The model for the fugitive sector is created in MS Excel. Separate models are set up for 1) oil and gas production, 2) flaring offshore, 3) gas transmission and distribution, and 4) coal storage and service stations.

The models cover Data storage level 1-3 and Data processing level 1-2, as they hold both activity data, emission factors/implied emission factors and calculated/direct emissions. Input data to the Danish emission inventory database system is collected in separate worksheets to allow for easy data transfer.

A list of QA/QC tasks are performed directly in relation to the fugitive emission part of the Danish emission inventories. The following procedures are carried out to ensure the data quality:

- The emission from the large point sources (refineries, gas treatment and gas storage plants) is compared with the emission reported the previous year.
- Annual environmental reports are kept for subsequent control of plant-specific emission data.
- Checks of data transfer are incorporated in the fugitive emission models, e.g. sum checks.
- Verification of activity data from external data when data are available through more data sources (offshore fuel and flaring rates).
- Data sources are incorporated in the fugitive emission models.
- A manual log table in the emission databases is applied to collect information about recalculations.

- Comparison with the inventory of the previous year. Any major changes are verified.
- Total emission, when aggregated to reporting tables, is compared with totals based on SNAP source categories (control of data transfer).
- Checking of time series. Significant dips and jumps are controlled and explained.
- Country specific emission factors are compared to standard emission factors in the EMEP/EEA Guidebook (EMEP/EEA, 2013) and the IPCC Guidelines (IPCC, 2006).

Data deliveries

Table 5.1 lists the external data deliveries used for the inventory of fugitive emissions. Further the table holds information on the contacts at the data delivery companies.

Table 5.1 List of external data sources.

Category	Data description	Activity data, emission factors or emissions	Reference	Contact(s)	Data agreement/ Comment
Exploration of oil and gas	Dataset for extraction of oil and gas, including amounts and composition	Activity data	The Danish Energy Agency	Jan H. Andersen	Data agreement
Production of oil and gas	Gas and oil production. Dataset for production of oil, gas and number of platforms. Amounts of offshore loading of ships	Activity data	The Danish Energy Agency	Jan H. Andersen	Legal basis for data provision
Offshore flaring	Flaring offshore in oil and gas extraction (ETS data)	Activity data	The Danish Energy Agency	Dorte Maimann	Data agreement
Service stations	Data on gasoline sales from the Danish energy statistics	Activity data	The Danish Energy Agency	Jane Rusbjerg	Data agreement
Gas transmission	Natural gas from the transmission company, sales and losses (meter differences)	Activity data	Energinet.dk	Christian Friberg B. Nielsen	Legal basis for data provision
Onshore activities	Amounts of oil transport in pipeline and onshore loading to ships. Emissions from storage of raw oil in the terminal	Activity data and emission data	DONG Olierør A/S	Stine B. Bergmann	No formal data agreement
Gas distribution	Natural gas from the distribution company, sales and losses (meter differences)	Activity data	Naturgas Fyn, HMN Aalborg Forsyning	Hanne Mochau, Søren K. Andersen Andreas Bech Jensen	No formal data agreement
Air emissions from refinery	Fuel consumption and emission data	Activity data and emission data	Statoil A/S, A/S Danish Shell	Anette Holst, Lis Rønnow Rasmussen	No formal data agreement
Storage and treatment of gas	Environmental reports from plants defined as large point sources (Lille Torup, Stenlille, Nybro)	Activity data	Various plants		Legal basis for data provision
Emission factors	Emission factors origin from a large number of sources	Emission factors	See chapter regarding emission factors		

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EMISSION INVENTORY FOR FUGITIVE EMISSIONS FROM FUEL IN DENMARK

This report presents the methodology and data used in the Danish inventory of fugitive emissions from fuels for the years until 2013. The inventory of fugitive emissions includes CO_2, CH_4, N_2O, SO_2, NOx, NMVOC, CO, particulate matter, black carbon, heavy metals, dioxin and PAHs. In 2013 the total Danish emission of greenhouse gasses was 54 584 Gg CO_2 equivalents. Fugitive emissions from fuels account for 387 Gg CO_2 equivalents or approximately 1 %. The major part of the fugitive emissions are emitted as CO_2 (61 %) mainly from flaring in upstream oil and gas production. The major source of fugitive CH_4 emission is production of oil and gas in the North Sea, refining of oil and loading of oil onto ships both offshore and onshore. The fugitive emissions of NMVOC originate for the major part from oil and gas production, loading of ships, transmission and distribution of oil, and to a less degree from natural gas and fugitive emissions from gas stations. The total Danish emission of NMVOC in 2013 is 114 Gg. Fugitive emissions account for 9 Gg, which corresponds to 8 %. Time series for emissions are presented for the years 1990-2013, except for particulate matter where the time series covers 2000-2013.

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