# DANISH EMISSION INVENTORIES FOR STATIONARY COMBUSTION PLANTS

## Inventories until 2018

Scientific Report from DCE – Danish Centre for Environment and Energy No. 424 2021

AARHUS UNIVERSITY
DCE – DANISH CENTRE FOR ENVIRONMENT AND ENERGY

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# Data sheet

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Abstract: Emission inventories for stationary combustion plants are presented and the methodologies and assumptions used for the inventories are described. The pollutants considered are $SO_2$, $NO_x$, NMVOCs, $CH_4$, CO, $CO_2$, $N_2O$, $NH_3$, particulate matter, black carbon, heavy metals, PCDD/Fs, HCB, PCBs and PAHs. The $CO_2$ emission from stationary combustion was 54.8 % lower in 2018 than in 1990 and the total greenhouse gas emission was 53.9 % lower than in 1990. However, fluctuations in the emission level for $CO_2$ are large as a result of electricity import/export. A considerable decrease of the $SO_2$, $NO_x$ and heavy metal emissions is mainly a result of decreased emissions from large power plants and waste incineration plants. The PM emissions increased until 2007 and decreased after 2007. The increase until 2007 was caused by the increased wood combustion in residential plants. However, the PM emission factors have decreased for this emission source category due to installation of modern stoves and boilers. The stabilisation of wood consumption in residential plants in 2007-2014 has resulted in a decrease of PM emission from stationary combustion between 2007 and 2014. The PCDD/F emission decreased until 1999 due to improved flue gas cleaning on waste incineration plants. In recent years, residential wood combustion is the largest emission source.

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# Contents

# List of abbreviations

| | |
|---|---|
| As | Arsenic |
| BAT | Best Available Techniques |
| BC | Black Carbon |
| BKB | Brown Coal Briquettes |
| BREF | BAT Reference Document |
| Cd | Cadmium |
| $CH_4$ | Methane |
| CHP | Combined Heat and Power |
| CLRTAP | Convention on Long-Range Transboundary Air Pollution |
| CO | Carbon Monoxide |
| $CO_2$ | Carbon Dioxide |
| $CO_2$ eq | Carbon dioxide equivalents |
| CORINAIR | CORe INventory on AIR emissions |
| Cr | Chromium |
| CRF | Common Reporting Format applied for greenhouse gas emission reporting |
| Cu | Copper |
| DEA | Danish Energy Agency |
| DEPA | Danish Environmental Protection Agency |
| dl-PCB | dioxine like - polychlorinated biphenyl |
| EEA | European Environment Agency |
| EMEP | European Monitoring and Evaluation Programme |
| EU ETS | EU Emission Trading Scheme |
| GHG | Greenhouse Gas |
| HCB | Hexachlorobenzene |
| Hg | Mercury |
| HM | Heavy metals |
| I-Teq | International Toxic Equivalents for dioxins and furans |
| IEF | Implied Emission Factor |
| IIR | Informative Inventory Report |
| IPCC | Intergovernmental Panel on Climate Change |
| KCA | Key Category Analysis |
| LPG | Liquefied Petroleum Gas |
| LRTAP | Long-Range Transboundary Air Pollution |
| LULUCF | Land Use, Land-Use Change and Forestry |
| $N_2O$ | Nitrous Oxide |
| NCV | Net Calorific Value |
| NECD | European Commissions National Emissions Ceiling Directive |
| NFR | Nomenclature for Reporting applied for emission reporting for the LRTAP Convention |
| $NH_3$ | Ammonia |
| Ni | Nickel |
| NIR | National Inventory Report |
| NMVOCs | Non-Methane Volatile Organic Compounds |
| $NO_x$ | Nitrogen Oxides |
| PAH | Polycyclic Aromatic Hydrocarbons |
| Pb | Lead |
| PCB | Polychlorinated biphenyl |
| PCDD/-F | Poly Chlorinated Dibenzo Dioxins and Furans |
| PM | Particulate Matter |
| $PM_{10}$ | Particulate Matter < 2.5 µm |

| | |
|---|---|
| $PM_{2.5}$ | Particulate Matter < 10 µm |
| POP | Persistent Organic Pollutant |
| Se | Selenium |
| SNAP | Selected Nomenclature for Air Pollution |
| $SO_2$ | Sulphur dioxide |
| TSP | Total Suspended Particulates |
| UHC | Unburned hydrocarbons |
| UNECE | United Nations Economic Commission for Europe |
| Zn | Zinc |

# Preface

On behalf of the Danish Ministry of Climate, Energy and Utilities, the Danish Centre for Environment and Energy (DCE), Aarhus University, is responsible for the calculation and reporting of the Danish national emission inventory. The inventories are reported to EU and the UNFCCC (United Nations Framework Convention on Climate Change) and to the UNECE CLRTAP (Convention on Long Range Transboundary Air Pollution) conventions.

A draft version of this report has not been available for comments by the ministries, and no steering group or external partners have been writing or commenting on the report. However, the report has been externally reviewed, see below.

This report forms part of the documentation for the emission inventories for stationary combustion plants. The report includes both methodology and emission data. The results of inventories up to 2018 are included. The report updates the seven reports published in 2004, 2006, 2007, 2009, 2010, 2014 and 2018.

In addition to the national approach emission data for stationary combustion, this report also includes three data sets for greenhouse gases (GHG) that are reported to EU:

- The reference approach
- Verification based on Eurostat data
- Comparison of the sum of EU ETS data and the national approach data

The sector reports are reviewed by external national experts. The external national reviews forms a vital part of the QA activities for the emission inventories for stationary combustion required in IPCC Guidelines (IPCC, 2006). This year, Jytte Boll Illerup from The Danish Environmental Protection Agency has reviewed the report, mainly the chapters related to emissions and emission factors.

The 2004, 2006, 2009, 2014 and 2018 updates of this report were reviewed by Jan Erik Johnsson from the Technical University of Denmark, Bo Sander from Elsam Engineering, Annemette Geertinger from FORCE Technology, Vibeke Vestergaard Nielsen, DCE - Danish Centre for Environment and Energy, Aarhus University and energy experts from the Danish Energy Agency. Internal review of this report was performed by Ole-Kenneth Nielsen.

# Summary

Danish emission inventories are prepared on an annual basis and are reported to the United Nations Framework Convention on Climate Change (UNFCCC or Climate Convention) and to the Kyoto Protocol. Furthermore, a greenhouse gas emission inventory is reported to the European Union (EU) due to the EU – as well as the individual member states – being party to the Climate Convention and the Kyoto Protocol.

Danish emission inventories for non-GHGs are prepared on an annual basis and are reported to the UNECE-Convention on Long-Range Transboundary Air Pollution (LRTAP) and EU Directive 2016/2284 on the reduction of national emissions of certain atmospheric pollutants.

Five pollutants (sulphur dioxide, nitrogen oxides, non-methane volatile organic compounds, ammonia and particulate matter with an aerodynamic diameter below 2.5 µm) are estimated for reporting to the European Commission's National Emissions Ceiling Directive (NECD).

The inventories include the following pollutants relevant to stationary combustion: carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), sulphur dioxide ($SO_2$), nitrogen oxides ($NO_x$), non-volatile organic compounds (NMVOCs), carbon monoxide (CO), particulate matter (PM), black carbon (BC), ammonia ($NH_3$), heavy metals (HMs), polyclorinated dibenzodioxins and –furans (PCDD/Fs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and hexachlorobenzene (HCB).

The inventories for stationary combustion are based on the Danish energy statistics and on a set of emission factors for various source categories, technologies and fuels. Plant-specific emissions for large combustion sources are incorporated into the inventories. This report provides detailed background information on the methodology and references for the input data in the inventory - energy statistics and emission factors.

The emission factors are based either on national references or on international guidebooks (EEA, 2016[1]; IPCC, 2006). The majority of the country-specific emission factors are determined from Danish legislation, Danish research reports, or calculations based on plant-specific emission data from a considerable number of large point sources. The plant-specific emission factors are provided by plant operators, e.g. in PRTR data, other annual environmental reports or in the EU Emission Trading Scheme (EU ETS).

In the inventory for the year 2018, 74 stationary combustion plants are specified as large point sources. The point sources include large power plants, waste incineration plants, industrial combustion plants and petroleum refining plants. The fuel consumption of these large point sources corresponds to 51 % of the overall fuel consumption of stationary combustion.

The fuel consumption for stationary combustion plants has decreased since 1990. However, the fuel consumption fluctuates due to variation in the im-

[1] Or EEA (2019) or former updates of the Guidebook.

port/export of electricity from year to year. In 2018, the total fuel consumption was 19 % lower than in 1990 and the fossil fuel consumption was 49 % lower than in 1990. The use of coal and oil has decreased whereas the use of natural gas, waste and biomass has increased.

In 2018, stationary combustion accounted for 32.5 % of the national emission of GHGs (including LULUCF) and 42 % of the $CO_2$ emission.

Stationary combustion plants account for more than 50 % of the national emission (2018) for the following pollutants: $SO_2$, $PM_{2.5}$, BC, the heavy metals As, Cd, Cr, Hg and Se, HCB, PCDD/Fs, PCBs and PAHs. Furthermore, the emission from stationary combustion plants accounts for more than 10 % of the national emission for the following pollutants: $NO_x$, NMVOC, CO, TSP, $PM_{10}$ and the heavy metals Ni, Pb and Zn. Stationary combustion plants account for less than 10 % of the national emission of $CH_4$, $N_2O$, $NH_3$ and the heavy metal Cu.

Public electricity and heat production is the most important stationary combustion emission source for $CO_2$, $CH_4$ and $N_2O$, $SO_2$, $NO_x$, Hg, Se, HCB and PCBs.

Residential plants is the most important stationary combustion emission source for NMVOCs, CO, $NH_3$, particulate matter, BC, Cd, Cr, Cu, Pb, Zn, PAHs and PCDD/Fs. Wood combustion in residential plants is the predominant emission source.

Industrial plants are the main emission sources for $SO_2$, As and Ni.

$CO_2$ is the most important greenhouse gas accounting for 97.3 % of the greenhouse gas emission ($CO_2$ eq.) from stationary combustion. The greenhouse gas (GHG) emission trend follows the $CO_2$ emission trend closely. Both the $CO_2$ and the total greenhouse gas emission are lower in 2018 than in 1990, $CO_2$ is 54.8 % lower and greenhouse gas emissions are 53.9 % lower. However, fluctuations in the GHG emission level are large. The fluctuations in the time series are mainly a result of electricity import/export but also of outdoor temperature variations from year to year that results in fluctuations in the fuel consumption for space heating.

The $CH_4$ emission from stationary combustion was 54 % higher in 2018 than in 1990. The emission increased until 1996 and decreased after 2004. This time series is related to the considerable number of lean-burn gas engines installed in CHP plants in Denmark during the 1990s. The decline in later years is due to structural changes in the Danish electricity market, which means that the fuel consumption in gas engines has been decreasing.

The $N_2O$ emission from stationary combustion has increased by 18% from 1990 to 2018. However, fluctuations in emission level due to electricity import/export are considerable.

$SO_2$ emission from stationary combustion plants has decreased by 96 % since 1990. The considerable emission decrease is mainly a result of the reduced emission from public electricity and heat production plants due to installation of desulphurisation technology and the use of fuels with lower sulphur content. These improvements are a result of sulphur tax laws, legislation concerning sulphur content of fuels, emission ceilings for large power plants and lower emission limit values for several plant categories.

The $NO_x$ emission from stationary combustion plants has decreased by 76 % since 1990. The reduced emission is largely a result of the reduced emission from Public electricity and heat production due to installation of low $NO_x$ burners, selective catalytic reduction (SCR) units and selective non-catalytic reduction (SNCR) units. The installation of the technical improvements was launched by legislation including emission ceilings for large power plants, lower emission limits for several plant categories and $NO_x$ tax laws. The fluctuations in the emission time series follow fluctuations in electricity import/export.

In 2018, the wood consumption in residential plants was 4.6 times the 1990 level. The increase mainly took place between 1990 and 2007. Residential wood combustion is a major emission source for NMVOCs, CO, $NH_3$, PM, BC, dioxins (PCDD/Fs), some heavy metals and PAHs. A change of technology (installation of modern stoves and boilers) has caused decreasing emission factors.

The NMVOC emissions from stationary combustion plants has decreased by 10 % from 1990. The emission increased until 2007 and decreased after 2007. The increased emission is mainly a result of the increasing wood consumption in residential plants and of the increased use of lean-burn gas engines in CHP plants. The decrease in 2007-2014 is a result of lower emission from residential wood combustion and the low number of operation hours for the lean burn gas engines.

The CO emission from stationary combustion has decreased 33 % since 1990. The time series for CO from stationary combustion plants follow the time series for CO emission from residential plants. The increase of wood consumption in residential plants in 1999-2007 is reflected in the time series for CO emission. The decreased emission in 2007-2018 is a result of implementation of improved residential wood combustion technologies and the fact that the rapid increase of wood consumption until 2007 have stopped.

The time series for PM emission from stationary combustion plants follows the time series for PM emission from residential plants. The emission of TSP, $PM_{10}$ and $PM_{2.5}$ was 1 %, 5 % and 4 % lower in 2018 than in 1990. The PM emissions increased until 2007 and decreased after 2007. The increase until 2007 was caused by the increased wood combustion in residential plants. However, the PM emission factors have decreased for this emission source category due to installation of modern stoves and boilers. The stabilisation of wood consumption in residential plants in 2007-2014 has resulted in a decrease of PM emission from stationary combustion between 2007 and 2014. Residential wood combustion is the main emission source for BC.

The emission of PAHs has decreased since 1990, mainly after 2007. This is also a result of the time series for combustion of wood in residential plants.

Emissions of all heavy metals have decreased considerably (18 % - 92 %) since 1990. Emissions have decreased despite increased incineration of waste. This has been possible due to installation and improved performance of gas cleaning devices in waste incineration plants and also in large power plants, the latter being a further important emission source.

The PCDD/F emissions has decreased 39 % since 1990 mainly due to installation of dioxin filters in waste incineration plants. The emission from residential plants has increased due to increased wood consumption in this source category.

The HCB emission has decreased 79 % since 1990 mainly due to improved flue gas cleaning in waste incineration plants.

The dl-PCB emissions have decreased 63 % since 1990. The decrease is mainly a result of the flue gas cleaning devices that have been installed in waste incineration plants for dioxin reduction.

The uncertainty interval for the Danish greenhouse gas emission from stationary combustion is estimated to be ±2.3 % and the trend in greenhouse gas emissions is -53.9 % ± 1.0 %-age points.

As part of the EU review of the reported GHG emission data, EU performs for each member state a comparison of Eurostat energy data in terms of TJ with energy data provided in the CRF. The largest differences between the two approaches have been explained. The calorific value (LCV) for coal applied in the Eurostat data are not in agreement with the average LCV for coal applied in the Danish energy statistics. In addition, the fuel consumption for transport between mainland Denmark and Greenland and the Faroe Islands is not included in the reporting to Eurostat whereas it is considered domestic in the Danish emission inventory.

The verified emission data reported under EU ETS Directive 2003/87/EC have been compared to the Danish emission inventory for GHGs. The verified $CO_2$ emissions add up to 43 % of the total $CO_2$ emission reported in the Danish emission inventory.

# Sammenfatning

Opgørelser over de samlede danske luftemissioner rapporteres årligt til klimakonventionen (United Nation Framework Convention on Climate Change, UNFCCC) og Kyotoprotokollen samt til UNECE konventionen om langtransporteret grænseoverskridende luftforurening (UNECE Convention on Long-Range Transboundary Air Pollution, der forkortes LRTAP Convention). Endvidere rapporteres drivhusgasemissionen til EU, fordi EU – såvel som de enkelte medlemslande – har ratificeret klimakonventionen og Kyotoprotokollen. Der udarbejdes også opgørelser til rapportering til Europakommissionens NEC (National Emissions Ceiling) direktiv.

De danske emissioner opgøres og rapporteres af DCE – Nationalt Center for Miljø og Energi ved Aarhus Universitet (AU). Emissionsopgørelserne omfatter følgende stoffer af relevans for stationær forbrænding: $CO_2$, $CH_4$, $N_2O$, $SO_2$, $NO_x$, NMVOC, CO, partikler (PM), black carbon (BC), $NH_3$, tungmetaller (HM), dioxiner (PCDD/F), PAH, PCB og HCB.

Emissionsopgørelserne for stationære forbrændingsanlæg (ikke mobile kilder) er baseret på den danske energistatistik og på et sæt emissionsfaktorer for forskellige sektorer, teknologier og brændsler. Anlægsspecifikke emissionsdata for store anlæg, som fx kraftværker, indarbejdes i opgørelserne. Denne rapport giver detaljeret baggrundsinformation om den anvendte metode samt referencer for de data der ligger til grund for opgørelsen – energistatistikken og emissionsfaktorerne.

Emissionsfaktorerne stammer enten fra danske referencer eller fra internationale guidebøger (EEA, 2016[2] og IPCC, 2006) udarbejdet til brug for denne type emissionsopgørelser. De danske referencer omfatter miljølovgivning, danske rapporter samt middelværdier baseret på anlægsspecifikke emissionsdata fra et betydeligt antal større værker. Anlægsspecifikke emissionsfaktorer oplyses af anlægsejere, bl.a. i PRTR data, grønne regnskaber og $CO_2$-kvoteindberetninger.

I emissionsopgørelsen for 2018 er 74 stationære forbrændingsanlæg defineret som punktkilder. Punktkilderne omfatter: Kraftværker, decentrale kraftvarmeværker, affaldsforbrændingsanlæg, industrielle forbrændingsanlæg samt raffinaderier. Brændselsforbruget for disse anlæg udgør 51 % af det samlede brændselsforbrug for stationære forbrændingsanlæg.

Brændselsforbruget til stationære forbrændingsanlæg har været faldende siden 1990. Variationen i årlig import/eksport af el medvirker til at brændselsforbruget til stationære forbrændingsanlæg varierer meget fra år til år. I 2018 var det samlede brændselsforbrug 19 % lavere end i 1990, mens det fossile brændselsforbrug var 49 % lavere end i 1990. Forbruget af kul og olie er faldet, mens forbruget af naturgas, affald og biobrændsler er steget.

I 2018 stammede 32.5 % af den samlede danske emission af drivhusgasser fra stationær forbrænding. For $CO_2$ var andelen fra stationær forbrænding 42 %.

[2] Og EEA (2019) samt tidligere opdateringer af EEA Guidebook.

For følgende stoffer udgør emissionen fra stationær forbrænding over 50 % af den nationale emission: $SO_2$, $PM_{2.5}$, BC, tungmetallerne As, Cd, Cr, Hg og Se, HCB, dioxin, PCB og PAH. Endvidere udgør emissionen over 10 % for $NO_x$, NMVOC, CO, TSP, $PM_{10}$, Ni, Pb og Zn. Stationær forbrænding bidrager med mindre end 10 % af den nationale emission af $CH_4$, $N_2O$, $NH_3$ og Cu.

For stationær forbrænding, er el- og varmeproducerende værker den betydeligste emissionskilde for $CO_2$, $CH_4$, $N_2O$, $SO_2$, $NO_x$, Hg, Se, HCB og PCB.

Emissioner fra kedler, brændeovne mv. i forbindelse med beboelse er den betydeligste emissionskilde for NMVOC, CO, $NH_3$, partikler, BC, Cd, Cr, Cu, Pb, Zn, dioxin og PAH. Det er især forbrænding af træ, som bidrager til disse emissioner.

Industrielle anlæg er den største emissionskilde for $SO_2$, As og Ni.

$CO_2$ udgjorde i 2018 97.3 % af den samlede drivhusgasudledning fra stationær forbrænding. Tidsserien for drivhusgasemissionen følger tidsserien for $CO_2$-emissionen ganske tæt. Både $CO_2$-emissionen og den samlede drivhusgasemission fra stationær forbrænding var lavere i 2018 end i 1990. $CO_2$-emissionen var 54.8 % lavere og drivhusgasemissionen var 53.9 % lavere. Emissionerne fluktuerer dog betydeligt, primært pga. variationerne i import/eksport af el men også som resultat af varierende udetemperatur og deraf følgende variationer i brændselsforbruget til rumopvarmning.

$CH_4$-emissionen fra stationær forbrænding var 54 % højere i 2018 end i 1990. Emissionen steg frem til 1996 og faldt igen fra 2004. Stigningen skyldes primært, at der i 1990'erne blev installeret et betydeligt antal gasmotorer på decentrale kraftvarmeværker. De senere år er emissionen dog faldet som følge af de ændrede afregningsregler i henhold til det frie elmarked, som har resulteret i færre driftstimer for gasmotorerne.

Emissionen af $N_2O$ var 18 % højere i 2018 end i 1990. Emissionen af $N_2O$ fluktuerer som følge af variationerne i brændselsforbruget for stationær forbrænding, der er en følge af den varierende import/eksport af el.

$SO_2$-emissionen fra stationær forbrænding er faldet med 96 % siden 1990. Den store reduktion er primært et resultat af installering af afsvovlingsanlæg fra el- og fjernvarmeproducerende anlæg samt brug af brændsler med lavere svovlindhold. Dette er sket på baggrund af en indført svovlafgift, grænseværdier for svovlindhold i brændsler, $SO_2$-kvoter for centrale kraftværker samt lavere emissionsgrænseværdier.

$NO_x$-emissionen fra stationær forbrænding er faldet med 76 % siden 1990. Reduktionen er primært et resultat af, at emissionen fra el- og fjernvarmeproducerende anlæg er faldet som følge af, at der benyttes lav-$NO_x$-brændere på flere anlæg, og at der er idriftsat $NO_x$-røggasrensning på flere store kraftværker. Baggrunden herfor er emissionsloft for de centrale kraftværker, lavere emissionsgrænseværdier for flere anlægstyper og $NO_x$-afgift. $NO_x$-emissionen fluktuerer som følge af variationen i import/eksport af el.

Mængden af træ forbrændt i villakedler og brændeovne var i 2018 4.6 gange så højt som i 1990. Den store stigning skete i 1990 til 2007 hvorefter forbruget er stabiliseret. Dette har stor betydning for tidsserierne for en række emissionskomponenter for hvilke netop træ, anvendt i villakedler/brændeovne, er en væsentlig emissionskilde: NMVOC, CO, $NH_3$, partikler, BC, dioxin nogle metaller og PAH. Emissionen fra nyere brændeovne/-kedler er lavere end for de ældre, idet forbrændingsteknologien er forbedret, og stigningen i emissioner er således lavere end stigningen i brændselsforbruget.

CO-emissionen fra stationær forbrænding er faldet 33 % siden 1990. Tidsserien for emissionen af CO fra stationær forbrænding følger tidsserien for CO fra husholdninger. Det øgede forbrug af træ i brændeovne og –kedler i 1999 – 2007 reflekteres i tidsserien for CO-emission. Faldet i CO-emission fra 2007 til 2018 er et resultat af bedre teknologi i nyere brændeovne samt at brændeforbruget er stabiliseret fra 2007 og frem.

Emissionen af NMVOC fra stationær forbrænding er faldet 10 % siden 1990. Emissionen steg indtil 2007 og faldt derefter frem til 2014. Stigningen skyldes primært øget brændeforbrug i brændeovne og øget anvendelse af gasmotorer. Faldet i emission fra 2007-2014 er et resultat af forbedret forbrændingsteknologi i brændeovnene samt færre driftstimer for gasmotorerne.

Tidsserierne for emissionen af partikler følger tidsserierne for partikelemissionen fra træ anvendt i husholdninger (brændeovne og –kedler). Emissionen af TSP, $PM_{10}$ og $PM_{2.5}$ er faldet henholdsvis 1 %, 5 % og 4 % siden år 1990. Emissionen steg indtil 2007 og faldt efter 2007. Stigningen indtil 2007 hænger sammen med det øgede forbrug af træ i husholdninger. Emissionsfaktorerne er dog faldet i forbindelse med udskiftning til nyere anlæg. Efter 2007, er emissionen faldet igen som følge af installering af flere nyere brændeovne og kedler. Emissionsgrænseværdien i Brændeovnsbekendtgørelsen og grænseværdien for svanemærkede brændeovne er sat ned flere gange.

Forbrænding af træ i husholdninger er den primære emissionskilde for BC.

Emissionen af de forskellige PAH'er er faldet siden 1990, primært efter 2007. Dette er ligeledes et resultat af tidsserien for forbrænding af træ i husholdninger.

Tungmetalemissionerne er faldet 18 % - 92 % siden 1990. Emissionen er faldet trods en øget forbrænding af affald. Reduktionen er et resultat af den forbedrede røggasrensning på affaldsforbrændingsanlæg og på kraftværker.

Emissionen af dioxin var 39 % lavere i 2018 end i 1990. Dette fald skyldes primært installering af dioxinrensningsanlæg på affaldsforbrændingsanlæg som alle affaldsforbrændingsanlæg iht. Forbrændingsbekendtgørelsen[3] skulle idriftsætte senest i 2005. Emissionen fra husholdninger er steget siden 1990 på grund af det øgede forbrug af træ i husholdninger.

HCB-emissionen er faldet 79 % siden 1990, primært på grund af forbedret røggasrensning på affaldsforbrændingsanlæg.

PCB-emissionen er faldet 63 % siden 1990. Faldet er et resultat af forbedret dioxinrensning på affaldsforbrændingsanlæggene.

[3] Bekendtgørelse om anlæg der forbrænder affald, Bekendtgørelse 162 af 11. marts 2003.

Emissionen af drivhusgasser er bestemt med en usikkerhed på ±2,3 %. Drivhusgasemissionen er siden 1990 faldet 53,9 % ± 1,0 %-point.

Som en del af et EU review af de danske emissionsopgørelser, foretages en sammenligning af de rapporterede data og data baseret på Eurostats data. Denne sammenligning er vist i rapporten og de væsentligste forskelle er forklaret. I den danske opgørelse anvendes to forskellige brændværdier for kul afhængig af type, men i rapporteringen til Eurostat er data baseret på den ene brændværdi. Dette giver en væsentlig forskel for kul. Derudover er brændselsforbruget til transport mellem Danmark og henholdsvis Færøerne og Grønland er ikke inkluderet i rapporteringerne til Eurostat. Dette brændselsforbrug er imidlertid inkluderet under indenrigsluftfart/søfart i de danske emissionsopgørelser.

Summen af $CO_2$-kvotedata rapporteret under EU Direktivet 2003/87/EC er blevet sammenholdt med de danske emissionsopgørelser for drivhusgasser på sektorniveau. Samlet set udgør kvotedata 43 % af den samlede danske $CO_2$-emission.

# 1 Introduction

## 1.1 Definition of stationary combustion and subsectors

In the Danish emission database, all activity rates and emissions are defined in SNAP sector categories (Selected Nomenclature for Air Pollution) according to the CORINAIR system[4]. The emission inventories are prepared from a complete emission database based on the SNAP sectors. Aggregation to the CRF / NFR sector codes is based on a correspondence list between SNAP and CRF / NFR enclosed in Annex 3A-1. Stationary combustion is defined as combustion activities in the SNAP sectors 01-03, not including SNAP 0303.

Emissions from industrial processes e.g. calcination are not included in stationary combustion. Fugitive emissions from fuels are not included in stationary combustion.

Stationary combustion plants are included in the emission source subcategories:

- 1A1 Energy, Fuel combustion, Energy industries
  - 1A1a Public electricity and heat production
  - 1A1b Petroleum refining
  - 1A1c Oil and gas extraction
- 1A2 Energy, Fuel combustion, Manufacturing industries and construction
  - 1A2a Iron and steel
  - 1A2b Non-ferrous metals
  - 1A2c Chemicals
  - 1A2d Pulp, paper and print
  - 1A2e Food processing, beverages and tobacco
  - 1A2f Non-metallic minerals
  - 1A2 g viii Other manufacturing industry
- 1A4 Energy, Fuel combustion, Other sectors
  - 1A4a i Commercial / institutional plants
  - 1A4b i Residential plants
  - 1A1c i Agriculture / forestry

The emission and fuel consumption data included in tables and figures in this report only include emissions originating from stationary combustion plants of a given CRF sector. The consumption of fuel for military use in stationary combustion plants has been included in Commercial / institutional plants.

## 1.2 Emission share from stationary combustion

Table 1 gives an overview of the emission share from stationary combustion compared to national total. Main emission sources are discussed in chapter 3 and 4.

[4] Including some additional SNAP added for industrial combustion.

Table 1 Emission share from stationary combustion compared to national total, 2018.

| Pollutant | Emission share |
|---|---|
| GHG total | 32.5 % |
| $CO_2$ | 42 % |
| $CH_4$ | 3.6 % |
| $N_2O$ | 3.9 % |
| $SO_2$ | 58% |
| $NO_x$ | 26% |
| NMVOC | 13% |
| CO | 45% |
| $NH_3$ | 2.9% |
| TSP | 13% |
| $PM_{10}$ | 41% |
| $PM_{2.5}$ | 69% |
| BC | 50% |
| As | 58% |
| Cd | 83% |
| Cr | 74% |
| Cu | 1.3% |
| Hg | 81% |
| Ni | 43% |
| Pb | 17% |
| Se | 75% |
| Zn | 39% |
| HCB | 50% |
| PCDD/F | 81% |
| Benzo(a)pyrene | 93% |
| Benzo(b)fluoranthene | 89% |
| Benzo(k)fluoranthene | 87% |
| Indeno(123cd)pyrene | 86% |
| PCB | 83% |

## 1.3 Key Categories for GHGs

Key Category Analysis (KCA) approach 1 and approach 2 for the years 1990 and 2018 and for the trend 1990-2018 for Denmark has been carried out in accordance with the IPCC Guidelines (IPCC, 2006). Table 2 shows the 26 stationary combustion key categories. The table is based on the analysis including LULUCF. Detailed key category analysis is shown in the National Inventory Report, Chapter 1.5 (Nielsen et al., 2020).

The $CO_2$ emissions from stationary combustion are key categories for all the major fuels. In addition, $CH_4$ from residential wood combustion and from straw combustion in agriculture/residential plants are key categories in the approach 2 analysis. Finally, due to the relatively high uncertainty for $N_2O$, emission factors the $N_2O$ emission from a number of emission sources are also key categories in the approach 2 analysis.

Table 2 Key categories[5], stationary combustion.

| | | | Approach 1 | | | Approach 2 | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1990 | 2018 | 1990-2018 | 1990 | 2018 | 1990-2018 |
| Energy | 1A Stationary combustion, Coal, ETS data, $CO_2$ | $CO_2$ | | Level | Trend | | | Trend |
| Energy | 1A Stationary combustion, Coal, no ETS data, $CO_2$ | $CO_2$ | Level | Level | Trend | Level | | Trend |
| Energy | 1A Stationary combustion, Fossil waste, ETS data, $CO_2$ | $CO_2$ | | Level | Trend | | | Trend |
| Energy | 1A Stationary combustion, Fossil waste, no ETS data, $CO_2$ | $CO_2$ | Level | Level | | | | |
| Energy | 1A Stationary combustion, Petroleum coke, ETS data, $CO_2$ | $CO_2$ | | Level | Trend | | | |
| Energy | 1A Stationary combustion, Petroleum coke, no ETS data, $CO_2$ | $CO_2$ | Level | | Trend | | | |
| Energy | 1A Stationary combustion, Residual oil, ETS data, $CO_2$ | $CO_2$ | | Level | Trend | | | |
| Energy | 1A Stationary combustion, Residual oil, no ETS data, $CO_2$ | $CO_2$ | Level | | Trend | | | Trend |
| Energy | 1A Stationary combustion, Gas oil, $CO_2$ | $CO_2$ | Level | Level | Trend | Level | | Trend |
| Energy | 1A Stationary combustion, Kerosene, $CO_2$ | $CO_2$ | Level | | Trend | | | |
| Energy | 1A Stationary combustion, LPG, $CO_2$ | $CO_2$ | | Level | | | | |
| Energy | 1A1b Stationary combustion, Petroleum refining, Refinery gas, $CO_2$ | $CO_2$ | Level | Level | Trend | | | |
| Energy | 1A Stationary combustion, Natural gas, onshore, $CO_2$ | $CO_2$ | Level | Level | Trend | | Level | Trend |
| Energy | 1A1c_ii Stationary combustion, Oil and gas extraction, Off shore gas turbines, Natural gas, $CO_2$ | $CO_2$ | Level | Level | Trend | | | |
| Energy | 1A4b_i Stationary combustion, Residential wood combustion, $CH_4$ | $CH_4$ | | | | Level | Level | Trend |
| Energy | 1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion, $CH_4$ | $CH_4$ | | | | Level | Level | |
| Energy | 1A1 Stationary Combustion, Solid fuels, $N_2O$ | $N_2O$ | | | | Level | Level | Trend |
| Energy | 1A1 Stationary Combustion, Gaseous fuels, $N_2O$ | $N_2O$ | | | | Level | Level | Trend |
| Energy | 1A1 Stationary Combustion, Waste, $N_2O$ | $N_2O$ | | | | | | Trend |
| Energy | 1A1 Stationary Combustion, Biomass, $N_2O$ | $N_2O$ | | | | | Level | Trend |
| Energy | 1A2 Stationary Combustion, Solid fuels, $N_2O$ | $N_2O$ | | | | | Level | Trend |
| Energy | 1A2 Stationary Combustion, Liquid fuels, $N_2O$ | $N_2O$ | | | | Level | Level | Trend |
| Energy | 1A2 Stationary Combustion, Gaseous fuels, $N_2O$ | $N_2O$ | | | | | Level | Trend |
| Energy | 1A4 Stationary Combustion, Liquid fuels, $N_2O$ | $N_2O$ | | | | Level | | Trend |
| Energy | 1A4 Stationary Combustion, Gaseous fuels, $N_2O$ | $N_2O$ | | | | | Level | Trend |
| Energy | 1A4b_i Stationary Combustion, Residential wood combustion, $N_2O$ | $N_2O$ | | | | | Level | Trend |

[5] For Denmark, not including Greenland & Faroe Island. Based on the KCA including LULUCF.

# 2 Fuel consumption data

In 2018, the total fuel consumption for stationary combustion plants was 407 PJ of which 236 PJ was fossil fuels and 171 PJ was biomass. Fuel consumption distributed according to the stationary combustion subcategories is shown in Figure 1 and Figure 2. The majority - 52 % - of all fuels is combusted in the source category, Public electricity and heat production. Other source categories with high fuel consumption are Residential and Industry.

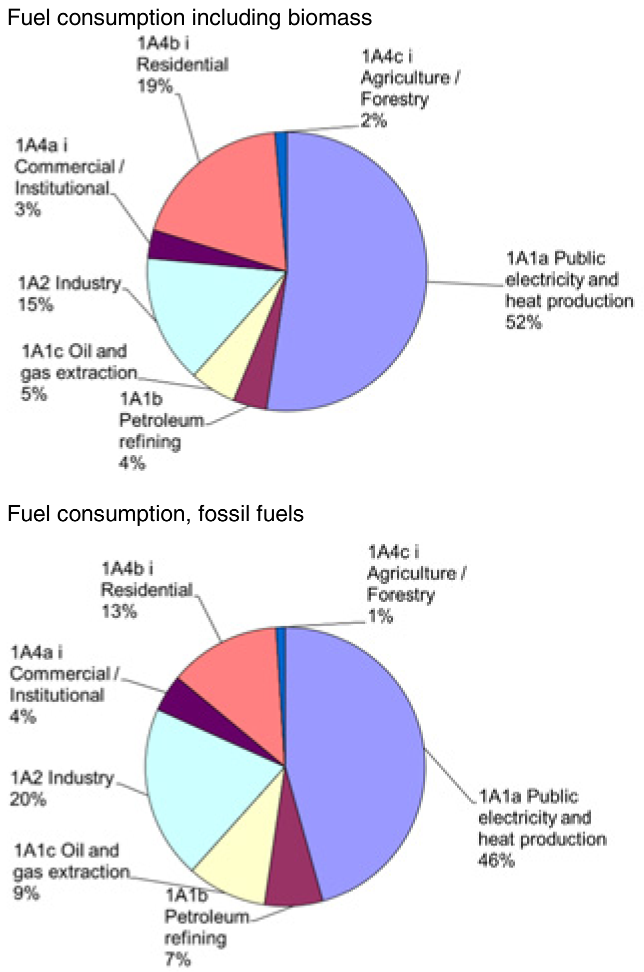
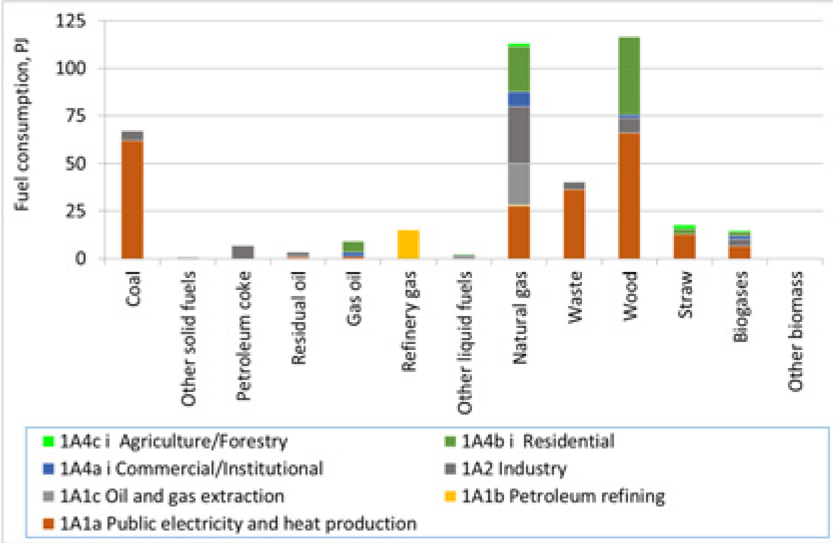



Figure 1 Fuel consumption of stationary combustion source categories, 2018. Based on DEA (2019a).

Coal, natural gas and wood are the most utilised fuels for stationary combustion plants. Coal is mainly used in power plants, natural gas is used in power plants and in decentralised combined heat and power (CHP) plants, as well as in industry, residential plants and offshore gas turbines (see Figure 2). Wood is mainly applied for public electricity and heat production and in residential plants.

Detailed fuel consumption rates are shown in Annex 2.



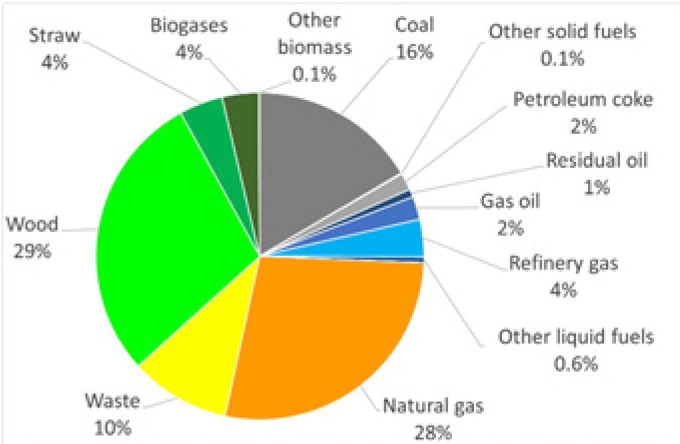




Figure 2 Fuel consumption of stationary combustion 2018, disaggregated to fuel type. Based on DEA (2019a).

Time series for fuel consumption for stationary combustion plants are presented in Figure 3. The fuel consumption for stationary combustion was 19 % lower in 2018 than in 1990, while the fossil fuel consumption was 49 % lower and the biomass fuel consumption 4.2 times the level in 1990.

The consumption of natural gas, waste and biomass has increased since 1990 whereas the consumption of coal and oil has decreased.

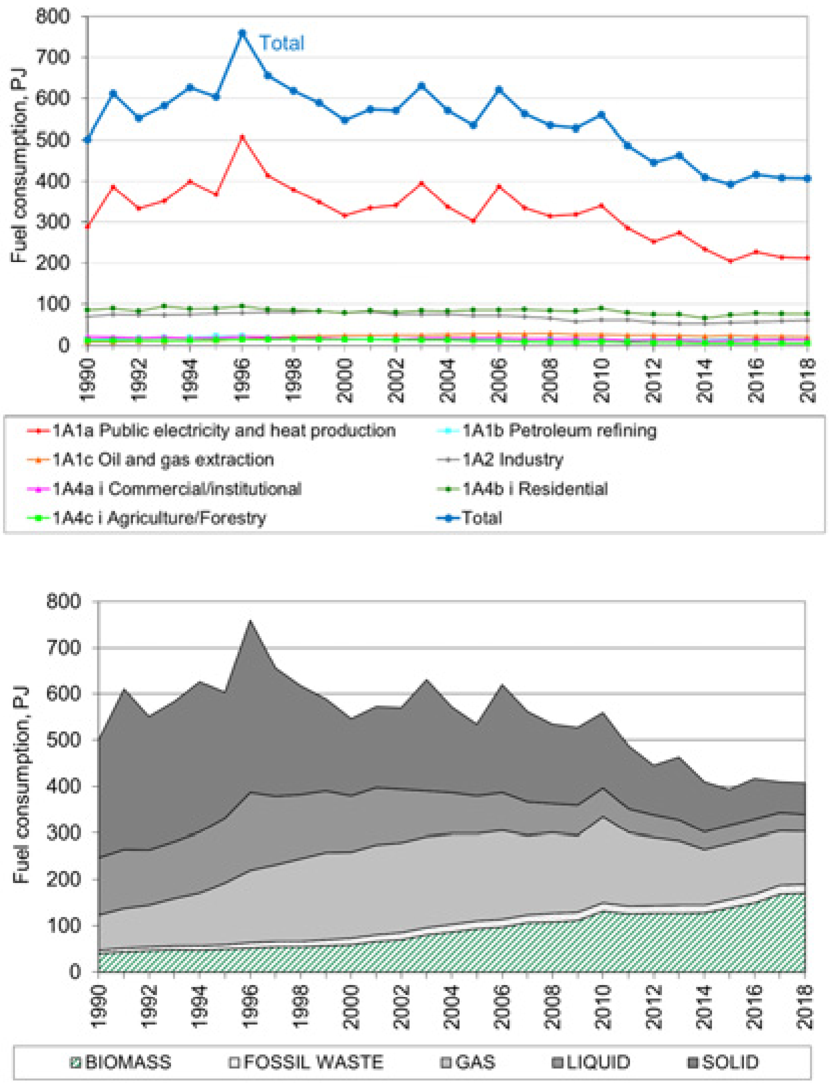



Figure 3 Fuel consumption time series, stationary combustion. Based on DEA (2019a).

The fluctuations in the time series for fuel consumption are mainly a result of electricity import/export, but also of outdoor temperature variations from year to year. This, in turn, leads to fluctuations in emission levels. The fluctuations in electricity trade, fuel consumption, $CO_2$ and $NO_x$ emission are illustrated and compared in Figure 4. In 1990, the Danish net electricity import was large causing relatively low fuel consumption, whereas the fuel consumption was high in 1996 and 2003 due to a large net electricity export. In 2018, the net electricity import was 19 PJ, whereas there was a 16 PJ net electricity import in 2017. The large net electricity export that occurs some years is a result of low rainfall in Norway and Sweden causing insufficient hydropower production in both countries.

The Danish electricity production is highly dependent on the electricity trade with especially Sweden and Norway. Denmark has a number of central coal-fuelled power plants that consists of a number of blocks. These do not under normal conditions, operate at max load, i.e. there is free capacity for peak situations. In addition, there are blocks, which are mothballed but can be reopened in situations where there is a significant increase in the electricity demand.

To be able to follow the national energy consumption, the Danish Energy Agency (DEA) produces a correction of the observed fuel consumption and $CO_2$ emission without random variations in electricity import/export and in ambient temperature. This fuel consumption trend is also illustrated in Figure 4. The estimates are based on DEA (2016d) and updated data (DEA, 2019d). The corrections are included here to explain the fluctuations in the time series for fuel rates and emissions.

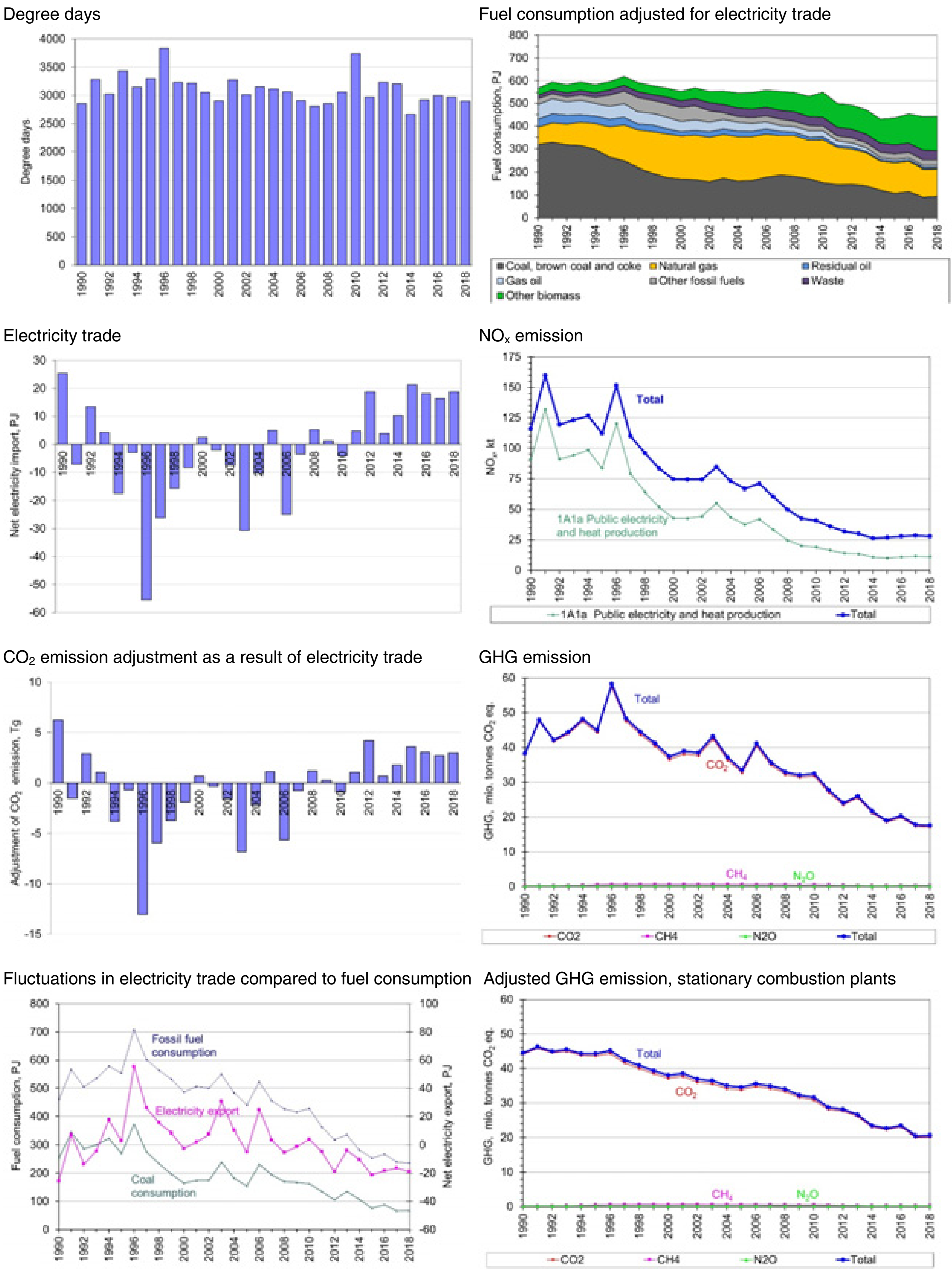



Figure 4 Comparison of time series fluctuations for net electricity import, fuel consumption, $CO_2$ emission and $NO_x$ emission. Based on DEA (2019a).

Fuel consumption time series for the subcategories to stationary combustion are shown in Figure 5, 6 and 7.

Fuel consumption for Energy industries fluctuates due to electricity trade as discussed above. The fuel consumption in 2018 was 20 % lower than in 1990 and the fossil fuel consumption was 51 % lower. The fluctuation in electricity production is based on fossil fuel consumption in the subcategory Public electricity and heat production. The energy consumption in Oil and gas extraction is mainly natural gas used in gas turbines in the offshore industry. The biomass fuel consumption in Energy industries in 2018 added up to 105 PJ, which is 6.5 times the level in 1990 and 1 % lower than in 2017.

The fuel consumption in Industry was 13 % lower in 2018 than in 1990 (Figure 6) and the fossil fuel consumption was 25 % lower. The fuel consumption in industrial plants decreased considerably after 2006 as a result of the financial crisis. The fuel consumption has increased again since 2014. The biomass fuel consumption in Industry in 2018 added up to 13 PJ, which is 2.2 times the consumption in 1990.

The fuel consumption in Other sectors decreased 19 % since 1990 (Figure 7) and increased 0.5 % since 2017. The fossil fuel consumption decreased 57 % since 1990. The biomass fuel consumption in Other sectors in 2018 added up to 52 PJ, which is 2.8 times the consumption in 1990 and a 3 % increase since 2017. Wood consumption in residential plants in 2018 was 2.8 times the consumption in year 2000 and 4.6 times the consumption in 1990.

Time series for subcategories are shown in Chapter 5.

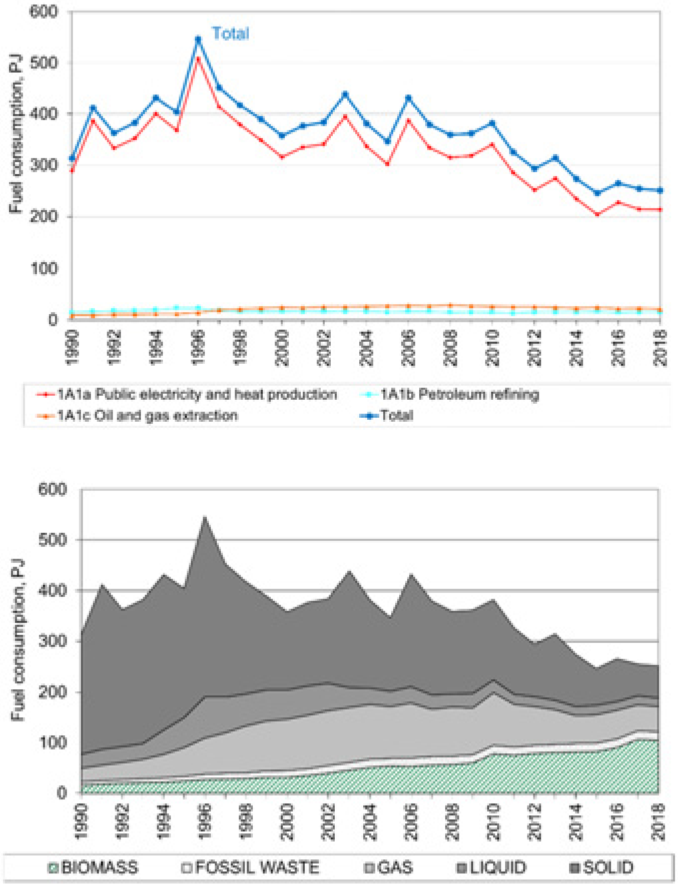


Figure 5 Fuel consumption time series for subcategories - 1A1 Energy industries.

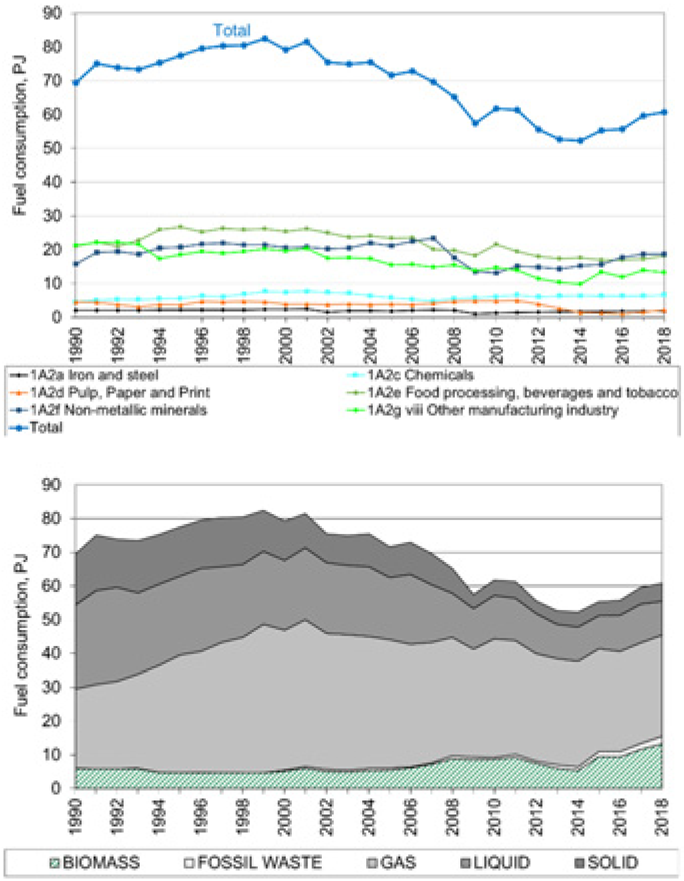


Figure 6 Fuel consumption time series for subcategories - 1A2 Industry.

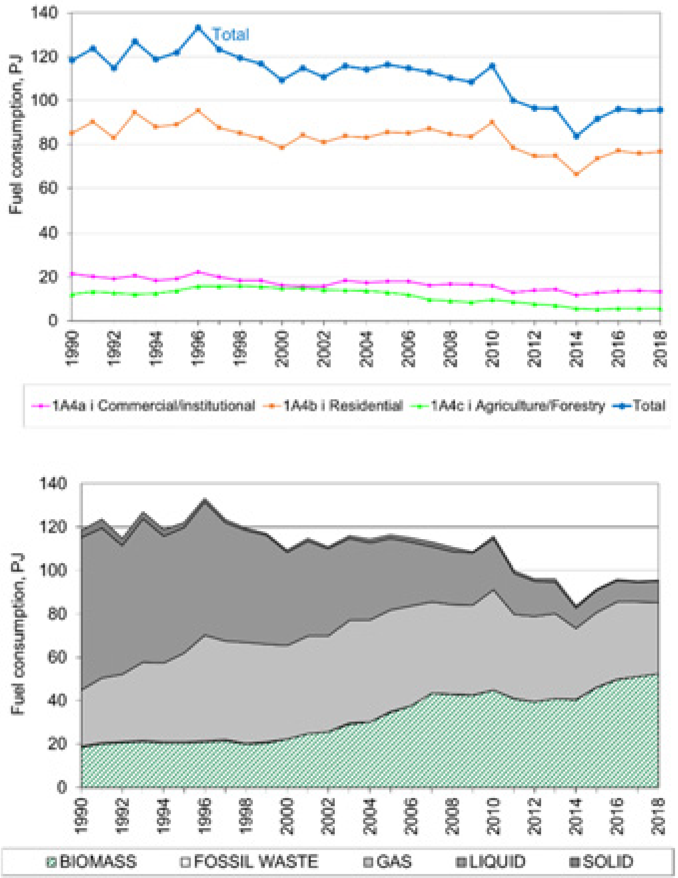



Figure 7 Fuel consumption time series for subcategories - 1A4 Other sectors.

# 3 Emissions of greenhouse gases

## 3.1 Greenhouse gas emission

The greenhouse gas emissions from stationary combustion are listed in Table 3. The emission from stationary combustion accounted for 32.5 % of the national greenhouse gas emission (including LULUCF) in 2018.

The $CO_2$ emission from stationary combustion plants accounts for 42 % of the national $CO_2$ emission (including LULUCF). The $CH_4$ emission from stationary combustion plants accounts for 3.6 % of the national $CH_4$ emission and the $N_2O$ emission for 3.9 % of the national $N_2O$ emission.

Table 3 Greenhouse gas emission, 2018 [1)].

| | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|
| | kt $CO_2$ equivalent | | |
| 1A1 Fuel combustion, Energy industries | 11264 | 112 | 86 |
| 1A2 Fuel combustion, Manufacturing industries and construction[1)] | 3275 | 22 | 55 |
| 1A4 Fuel combustion, Other sectors [1)] | 2620 | 130 | 70 |
| Emission from stationary combustion plants | 17159 | 264 | 211 |
| Emission share for stationary combustion (LULUCF included) | 42% | 3.6% | 3.9% |

[1)] Only stationary combustion sources of the category is included.

$CO_2$ is the most important greenhouse gas accounting for 97.3 % of the greenhouse gas emission ($CO_2$ equivalents) from stationary combustion. $CH_4$ accounts for 1.5 % and $N_2O$ for 1.2 % of the greenhouse gas emission ($CO_2$ equivalents) from stationary combustion (Figure 8).

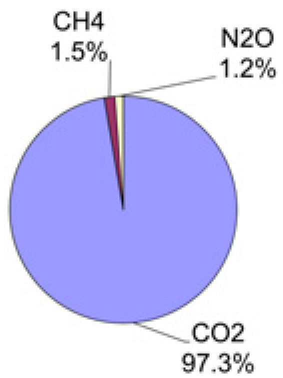



Figure 8 Greenhouse gas emissions from stationary combustion ($CO_2$ equivalents), contribution from each pollutant.

Figure 9 shows the time series of greenhouse gas emissions ($CO_2$ equivalents) from stationary combustion. The development of the greenhouse gas emission follows the $CO_2$ emission development very closely. Both the $CO_2$ and the total greenhouse gas emission are lower in 2018 than in 1990, $CO_2$ is 54.8 % lower and greenhouse gas emissions are 53.9 % lower. However, fluctuations in the GHG emission level are large.

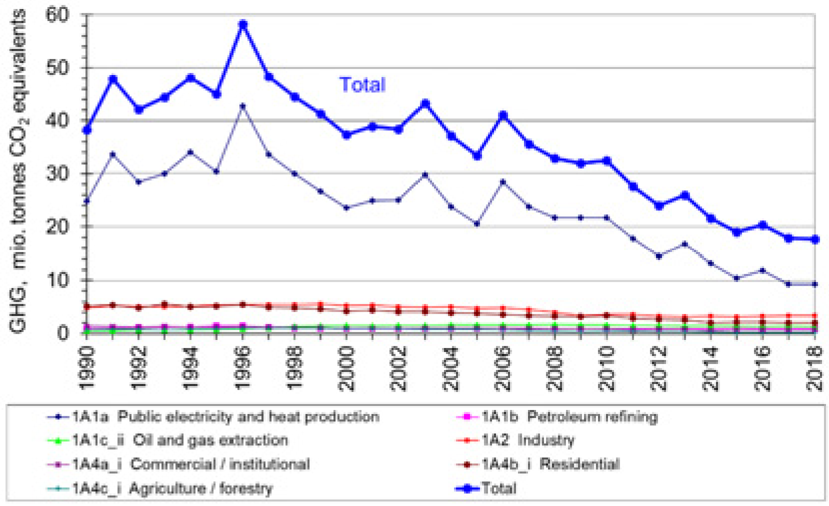



Figure 9 GHG emission time series for stationary combustion.

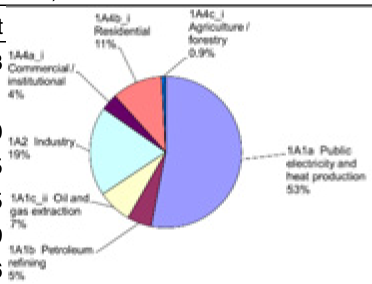
The fluctuations in the time series are largely a result of electricity import / export, but also of outdoor temperature variations from year to year. The fluctuations follow the fluctuations in fuel consumption discussed in Chapter 2. As mentioned in Chapter 2, the Danish Energy Agency estimates a correction of the observed $CO_2$ emission without random variations in electricity imports / exports and in ambient temperature. The greenhouse gas emission corrected for electricity import / export and ambient temperature has decreased by 55.6 % since 1990, and the $CO_2$ emission by 54.4 %. These data are included here to explain the fluctuations in the emission time series.

## 3.2 $CO_2$

The carbon dioxide ($CO_2$) emission from stationary combustion plants is one of the most important sources of greenhouse gas emissions. Thus, the $CO_2$ emission from stationary combustion plants accounts for 42 % of the national $CO_2$ emission (LULUCF included). Table 4 lists the $CO_2$ emission inventory for stationary combustion plants for 2018. Public electricity and heat production accounts for 53 % of the $CO_2$ emission from stationary combustion. This share is somewhat higher than the fossil fuel consumption share for this category, which is 46 % (Figure 10). This is due to a large share of coal in this category. Other large $CO_2$ emission sources are Industry[6], Residential plants and Oil and gas extraction. These are the source categories, which also account for a considerable share of fuel consumption.

Table 4 $CO_2$ emission from stationary combustion plants, 2018[1)].

| | $CO_2$, kt |
|---|---|
| 1A1a Public electricity and heat production | 9113 |
| 1A1b Petroleum refining | 891 |
| 1A1c Oil and gas extraction | 1260 |
| 1A2 Industry | 3275 |
| 1A4a Commercial/institutional | 615 |
| 1A4b Residential | 1849 |
| 1A4c Agriculture/forestry | 156 |
| Total | 17159 |



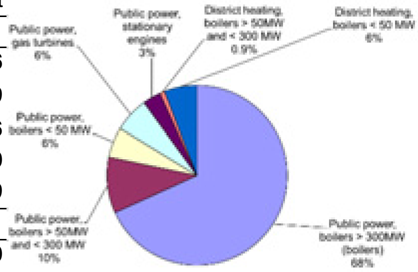

[1)] Only emissions from stationary combustion plants in the categories are included.

[6] Includes only stationary combustion, whereas $CO_2$ from industrial processes e.g. calcination in cement production is included elsewhere.

In the Danish inventory, the source category Public electricity and heat production is further disaggregated. The $CO_2$ emission from each of the subcategories is shown in Table 5. The largest subcategory is power plant boilers >300MW.

Table 5 $CO_2$ emission from subcategories to 1A1a Public electricity and heat production.

| SNAP | SNAP name | $CO_2$, kt |
|---|---|---|
| 0101 | Public power | |
| 010101 | Combustion plants ≥ 300MW (boilers) | 6216 |
| 010102 | Combustion plants ≥ 50MW and < 300 MW (boilers) | 919 |
| 010103 | Combustion plants <50 MW (boilers) | 496 |
| 010104 | Gas turbines | 570 |
| 010105 | Stationary engines | 299 |
| 0102 | District heating plants | |
| 010202 | Combustion plants ≥ 50MW and < 300 MW (boilers) | 80 |
| 010203 | Combustion plants <50 MW (boilers) | 534 |




$CO_2$ emission from combustion of biomass fuels is not included in the total $CO_2$ emission data, because biomass fuels are considered $CO_2$ neutral. The $CO_2$ emission from biomass combustion is reported as a memo item in the Climate Convention reporting. In 2018, the $CO_2$ emission from biomass combustion from stationary combustion was 18 408 kt.

In Figure 10, the fuel consumption share (fossil fuels) is compared to the $CO_2$ emission share disaggregated to fuel origin. Due to the higher $CO_2$ emission factor for coal than oil and gas, the $CO_2$ emission share from coal combustion is higher than the fuel consumption share. Coal accounts for 29 % of the fossil fuel consumption and for 37 % of the $CO_2$ emission. Natural gas accounts for 48 % of the fossil fuel consumption and for 38 % of the $CO_2$ emission.

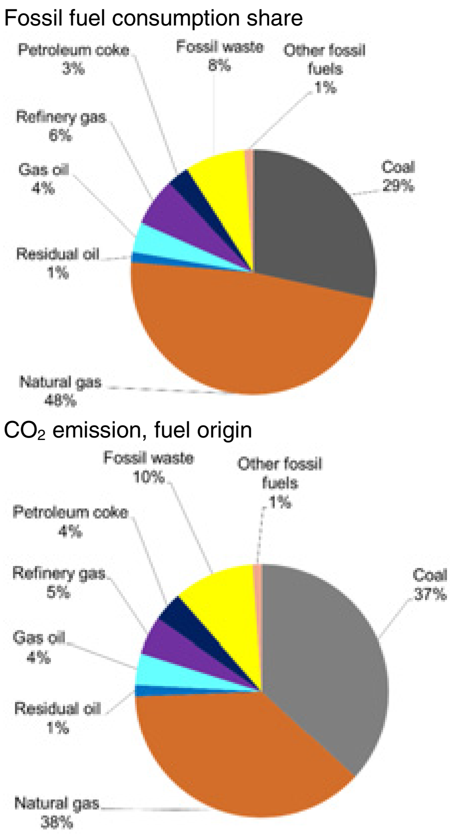



Figure 10 $CO_2$ emission, fuel origin.

The time series for $CO_2$ emission is provided in Figure 11. Despite a decrease in fuel consumption of 19 %[7] since 1990, the $CO_2$ emission from stationary combustion has decreased by 55 % because of the change of fuel type used.

The fluctuations in total $CO_2$ emission follow the fluctuations in $CO_2$ emission from Public electricity and heat production (Figure 11) and in coal consumption (Figure 4). The fluctuations are a result of electricity import / export as discussed in Chapter 2.

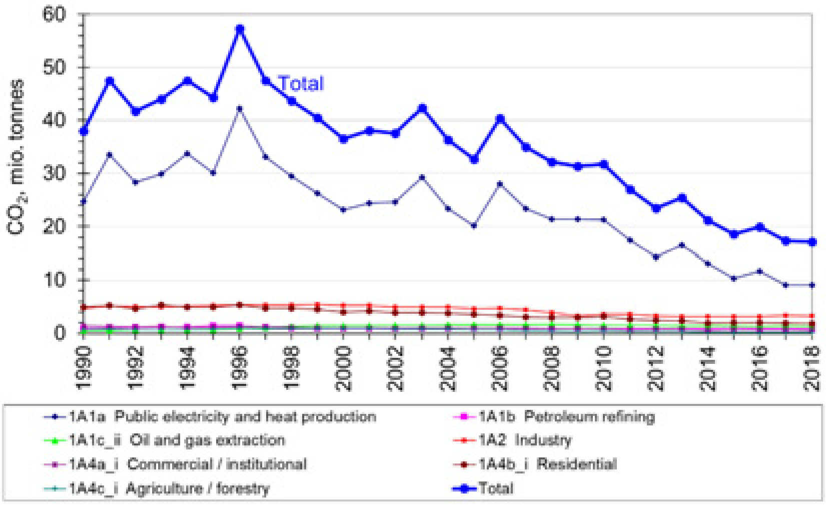


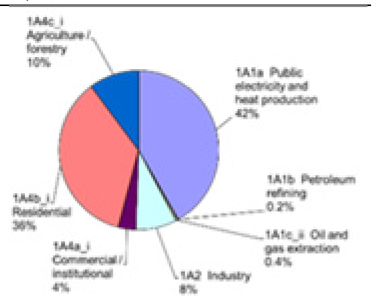

Figure 11 $CO_2$ emission time series for stationary combustion plants.

## 3.3 $CH_4$

The methane ($CH_4$) emission from stationary combustion plants accounts for 3.6 % of the national $CH_4$ emission. Table 6 lists the $CH_4$ emission inventory for stationary combustion plants in 2018. Public electricity and heat production accounts for 42 % of the $CH_4$ emission from stationary combustion. The emission from residential plants adds up to 36 % of the emission.

Table 6 $CH_4$ emission from stationary combustion plants, 2018[1)].

| | $CH_4$, tonnes |
|---|---|
| 1A1a Public electricity and heat production | 4406 |
| 1A1b Petroleum refining | 18 |
| 1A1c Oil and gas extraction | 37 |
| 1A2 Industry | 878 |
| 1A4a Commercial/institutional | 376 |
| 1A4b Residential | 3769 |
| 1A4c Agriculture/forestry | 1072 |
| Total | 10556 |




[1)] Only emission from stationary combustion plants in the source categories is included.

The $CH_4$ emission factor for reciprocating gas engines is much higher than for other combustion plants due to the continuous ignition / burn-out of the gas. Lean-burn gas engines have an especially high emission factor. A considerable number of lean-burn gas engines are in operation in Denmark and in 2018, these plants accounted for 49 % of the $CH_4$ emission from stationary combustion plants (Figure 12). Most engines are installed in CHP plants and the fuel

[7] The consumption of fossil fuels has decreased 49 %.

used is either natural gas or biogas. Residential wood combustion is also a large emission source accounting for 27 % of the emission in 2018.

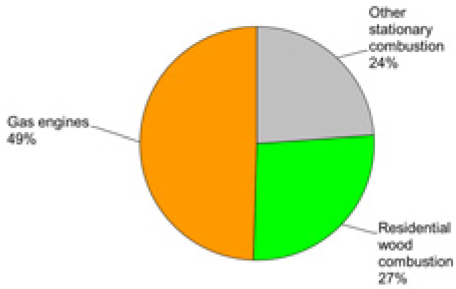



Figure 12 $CH_4$ emission share for gas engines and residential wood combustion, 2018.

Figure 13 shows the time series for $CH_4$ emission. The $CH_4$ emission from stationary combustion was 54 % higher in 2018 than in 1990. The emission increased until 1996 and decreased after 2004. This time series is related to the considerable number of lean-burn gas engines installed in CHP plants in Denmark during the 1990s. Figure 14 provides time series for the fuel consumption rate in gas engines and the corresponding increase of $CH_4$ emission. The decline in later years is due to structural changes in the Danish electricity market, which means that the fuel consumption in gas engines has been decreasing.

The $CH_4$ emission from residential plants has increased since 1990 due to increased combustion of biomass in residential plants. The consumption of wood in residential plants has increased but the emission factor for residential wood combustion has decreased due to implementation of new improved stoves and boilers. Combustion of wood accounted for 74 % of the $CH_4$ emission from residential plants in 2018.

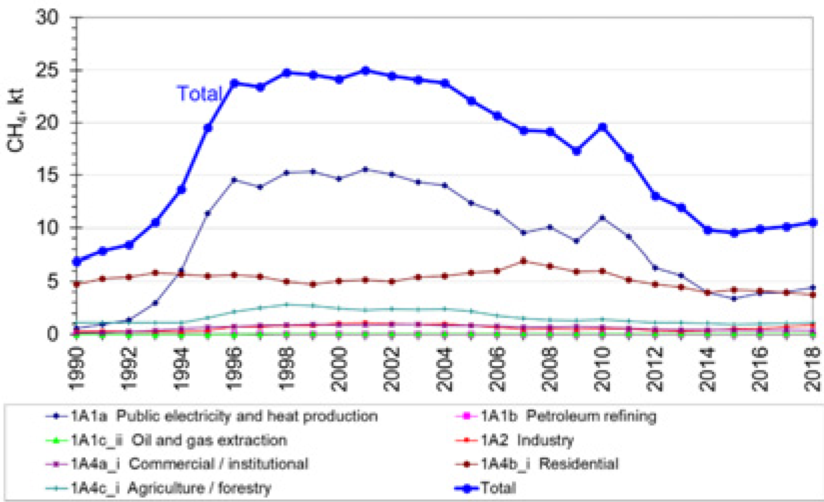
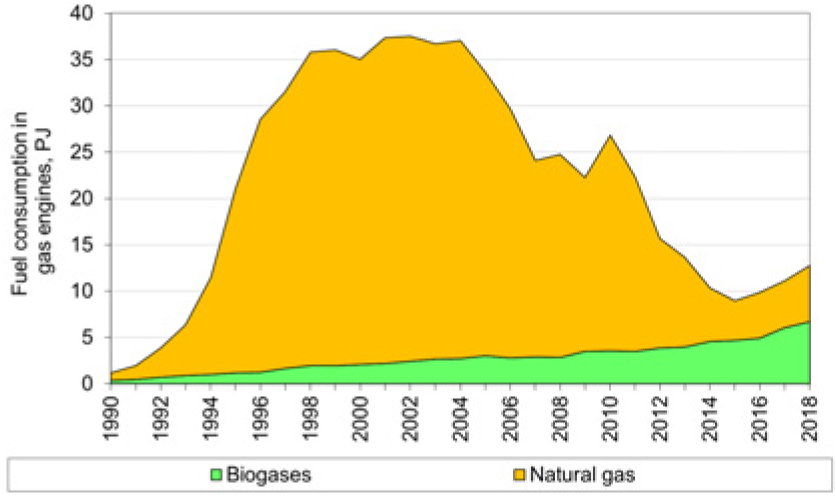



Figure 13 $CH_4$ emission time series for stationary combustion plants.



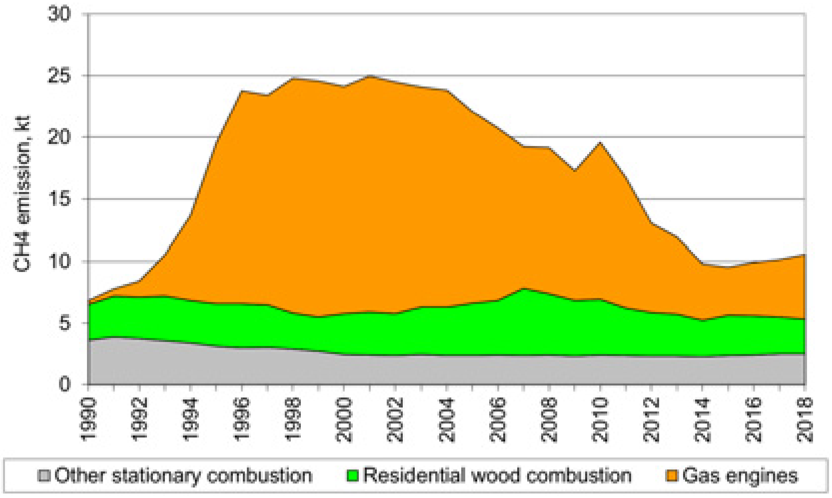



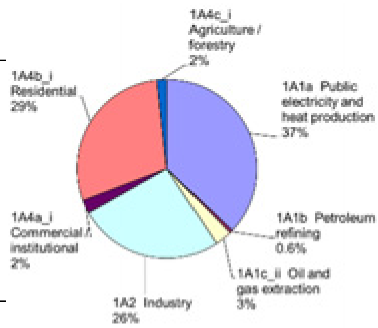

Figure 14 Time series for a) fuel consumption in gas engines and b) $CH_4$ emission from gas engines, residential wood combustion and other plants.

## 3.4 $N_2O$

The nitrous oxide ($N_2O$) emission from stationary combustion plants accounts for 3.9 % of the national $N_2O$ emission. Table 7 lists the $N_2O$ emission inventory for stationary combustion plants in the year 2018. Public electricity and heat production accounts for 37 % of the $N_2O$ emission from stationary combustion.

Table 7 $N_2O$ emission from stationary combustion plants, 2018[1].

| | $N_2O$, tonnes |
|---|---|
| 1A1a Public electricity and heat production | 263 |
| 1A1b Petroleum refining | 4 |
| 1A1c Oil and gas extraction | 22 |
| 1A2 Industry | 185 |
| 1A4a Commercial/institutional | 17 |
| 1A4b Residential | 205 |
| 1A4c Agriculture/forestry | 12 |
| Total | 708 |




[1] Only emission from stationary combustion plants in the source categories is included.

Figure 15 shows the time series for $N_2O$ emission. The $N_2O$ emission from stationary combustion has increased by 18% from 1990 to 2018, but again fluctuations in emission level due to electricity import / export are considerable.

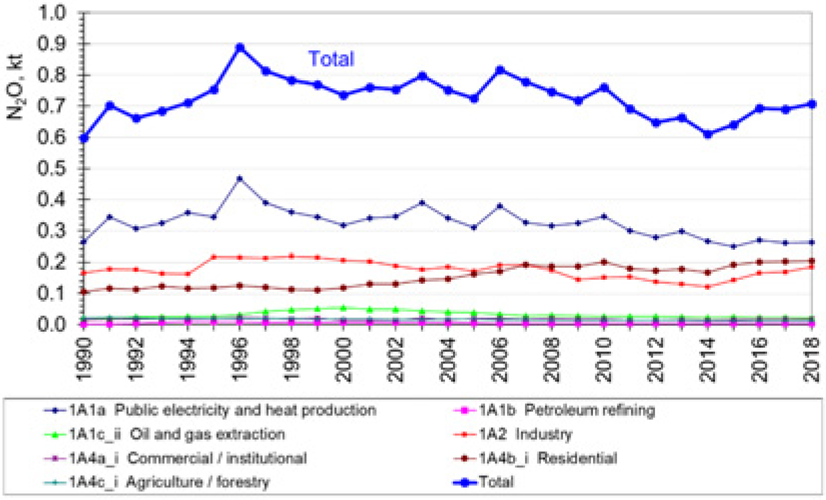



Figure 15 $N_2O$ emission time series for stationary combustion plants.

# 4 Emissions of other pollutants

## 4.1 $SO_2$

Stationary combustion is the most important emission source for $SO_2$ accounting for 58 % of the national emission. Table 8 presents the $SO_2$ emission inventory for the stationary combustion subcategories.

The largest emission sources are Public electricity and heat production and Industry each accounting for 38 % of the emission from stationary combustion.

For Public electricity and heat production, the $SO_2$ emission share is however lower than the fuel consumption share for this source category, which is 52 %. This is a result of effective flue gas desulphurisation equipment installed in power plants combusting coal. In the Danish inventory, the source category Public electricity and heat production is further disaggregated. Figure 16 shows the $SO_2$ emission from Public electricity and heat production on a disaggregated level. District heating boilers < 50 MW and Power plants >300$MW_{th}$ are the main emission sources, accounting for 39 % and 36 % of the emission.

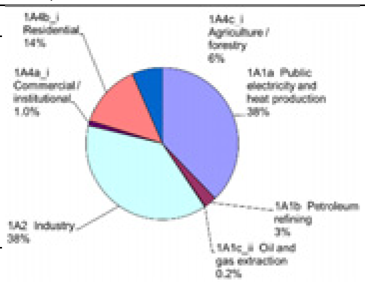
The $SO_2$ emission from industrial plants adds up to 38 % of the emission from stationary combustion, a remarkably high emission share compared with fuel consumption. The main emission sources in the industrial category are combustion of coal and emissions from the cement industry, mineral wool industry and sugar production plants. Until year 2000, the $SO_2$ emission from the industrial category only accounted for a small part of the emission from stationary combustion, but due to reduced emissions from power plants, the share has now increased.

The time series for $SO_2$ emission from stationary combustion is shown in Figure 17. The $SO_2$ emission from stationary combustion plants has decreased by 96 % since 1990 and 99 % since 1980. The large emission decrease is mainly a result of the reduced emission from Public electricity and heat production, made possible due to installation of desulphurisation plants and due to the use of fuels with lower sulphur content. Despite the considerable reduction in emission from Public electricity and heat production plants, these still account for 38 % of the emission from stationary combustion, as mentioned above. The emission from other source categories also decreased considerably since 1990. Time series for subcategories are shown in Chapter 5.

The emission of $SO_2$ has decreased since 2005, but the emission level has steadied since 2014.

Table 8 $SO_2$ emission from stationary combustion plants, 2018[1)].

| | | $SO_2$, t |
|---|---|---|
| 1A1a | Public electricity and heat production | 2363 |
| 1A1b | Petroleum refining | 168 |
| 1A1c | Oil and gas extraction | 9 |
| 1A2 | Industry | 2389 |
| 1A4a | Commercial/institutional | 65 |
| 1A4b | Residential | 853 |
| 1A4c | Agriculture/forestry | 408 |
| Total | | 6256 |




1) Only emission from stationary combustion plants in the source categories is included.

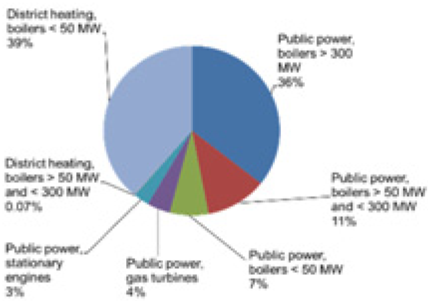



Figure 16 Disaggregated $SO_2$ emissions from 1A1a Public electricity and heat production.

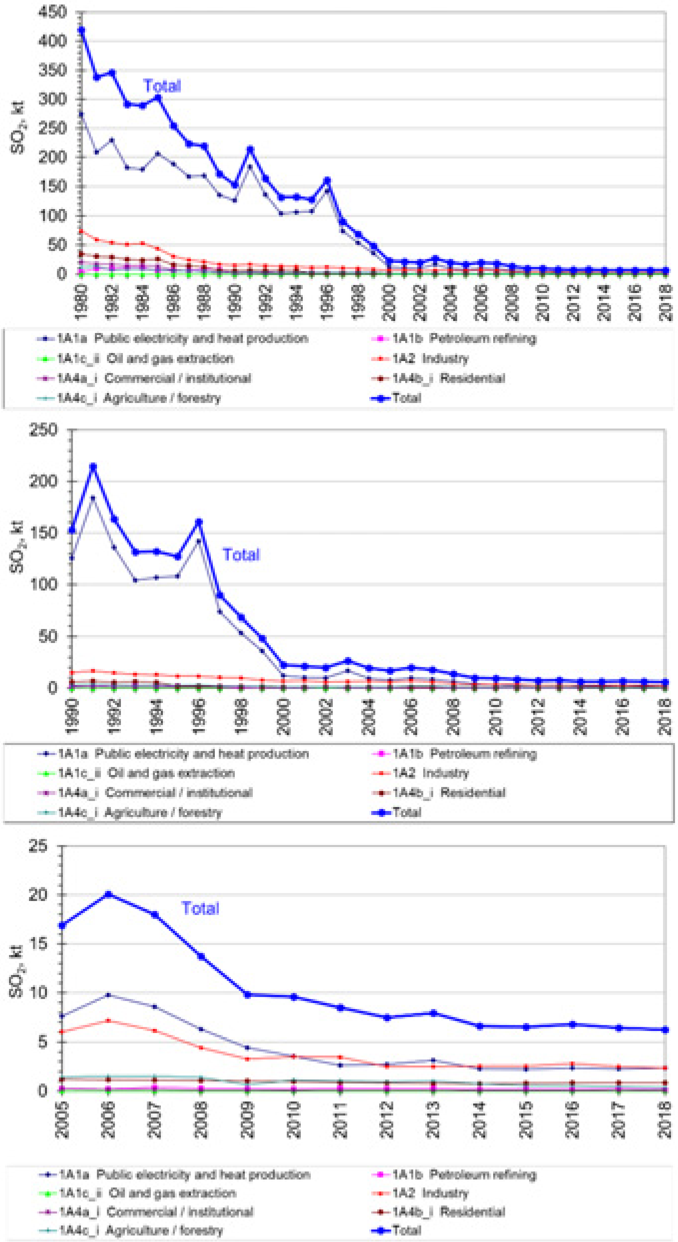



Figure 17 $SO_2$ emission time series for stationary combustion.

## 4.2 $NO_x$

Stationary combustion accounts for 26% of the national $NO_x$ emission. Table 9 shows the $NO_x$ emission inventory for stationary combustion subcategories.

Public electricity and heat production is the largest emission source accounting for 40 % of the emission from stationary combustion plants. The emission from Public power boilers > 300 $MW_{th}$ accounts for 18 % of the emission in this subcategory, Public power boilers 50-300 MW for 24 % and District heating < 50MW for 22%.

Industrial combustion plants are also an important emission source accounting for 21 % of the emission. The main industrial emission source is cement production, which accounts for 42 % of the emission from industrial plants.

Residential plants account for 16 % of the $NO_x$ emission. The fuel origin of this emission is mainly wood accounting for 70 % of the residential plant emission.

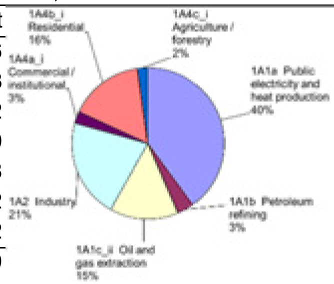
Oil and gas extraction, which is mainly offshore gas turbines accounts for 15 % of the $NO_x$ emission.

Time series for $NO_x$ emission from stationary combustion are shown in Figure 18. $NO_x$ emission from stationary combustion plants has decreased by 76 % since 1990 and 81 % since 1985. The reduced emission is largely a result of the reduced emission from Public electricity and heat production due to installation of low $NO_x$ burners, selective catalytic reduction (SCR) units and selective non-catalytic reduction (SNCR) units. The fluctuations in the time series follow the fluctuations in Public electricity and heat production, which, in turn, result from electricity trade fluctuations.

The emission has also decreased considerably since 2005, see Figure 18.

Table 9 $NO_x$ emission from stationary combustion plants, 2018[1).

| | | $NO_x$, t |
|---|---|---|
| 1A1a | Public electricity and heat production | 11196 |
| 1A1b | Petroleum refining | 988 |
| 1A1c | Oil and gas extraction | 4092 |
| 1A2 | Industry | 5950 |
| 1A4a | Commercial/institutional | 708 |
| 1A4b | Residential | 4452 |
| 1A4c | Agriculture/forestry | 622 |
| Total | | 28009 |




1) Only emission from stationary combustion plants in the source categories is included.

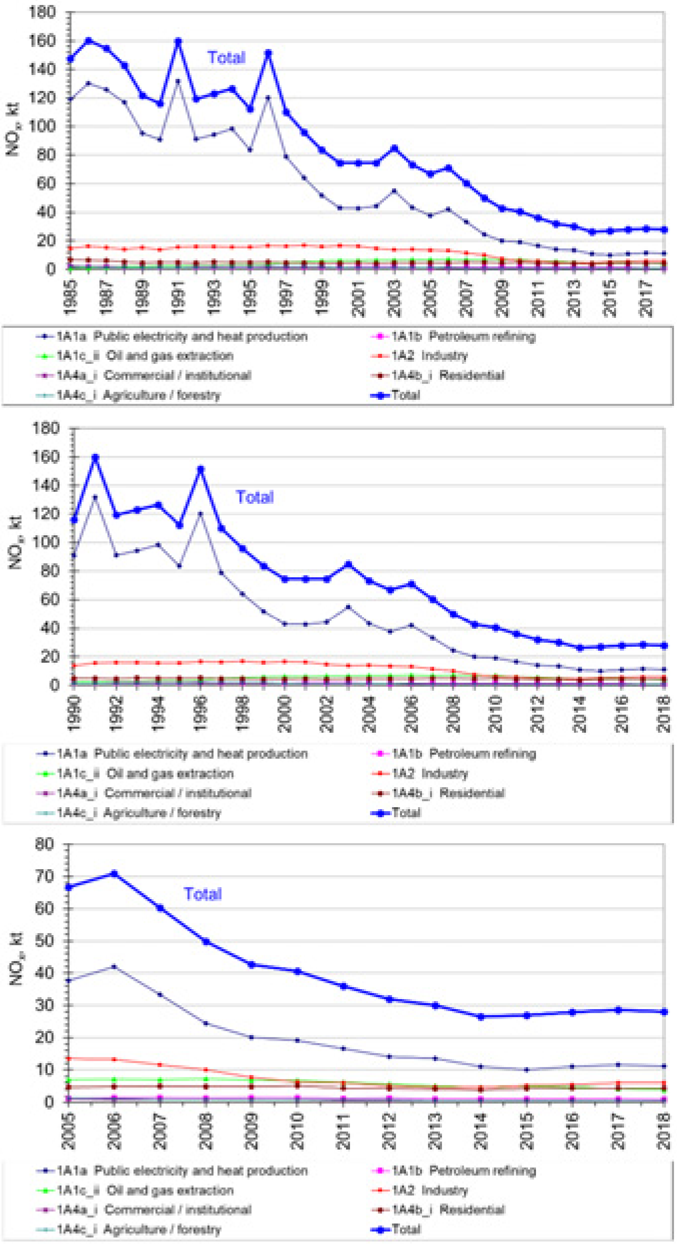



Figure 18 $NO_x$ emission time series for stationary combustion.

## 4.3 NMVOC

Stationary combustion plants account for 13 % of the national NMVOC emissions. Table 10 presents the NMVOC emission inventory for the stationary combustion subcategories.

Residential plants are the largest emission source accounting for 75 % of the emission from stationary combustion plants. For residential plants NMVOCs is mainly emitted from wood and straw combustion, see Figure 19.

Public electricity and heat production is also a considerable emission source, accounting for 7 % of the emission. Lean-burn gas engines have a relatively high NMVOC emission factor and are the most important emission source in this subcategory (see Figure 19). The gas engines are either natural gas or biogas fuelled.

Agricultural plants accounted for 9 % of the emission in 2018. Combustion of straw was the main emission source in this category.

The time series for NMVOC emissions from stationary combustion is shown in Figure 20. The emission has decreased by 10 % from 1990 and 20 % from 1985. The emission increased until 2007 and decreased after 2007. The increased emission is mainly a result of the increasing wood consumption in residential plants and of the increased use of lean-burn gas engines in CHP plants. The decrease in after 2007-2014 is a result of lower emission from residential wood combustion and the low number of operation hours for the lean burn gas engines.

The emission from residential plants has decreased 2 % since 1990.

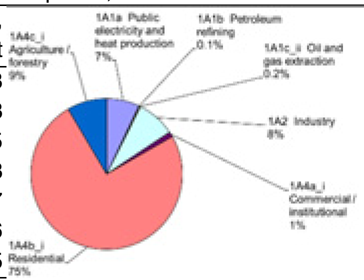
The emission from straw combustion in farmhouse boilers has decreased (42 %) over this period due to both a decreasing emission factor and decrease in straw consumption in this source category. The emission from most other fuels has also decreased.

However, the NMVOC emissions from residential wood combustion was 27 % higher in 2018 than in 1990 due to increased wood consumption. The emission factor has decreased since 1990 due to installation of modern stoves and boilers with improved combustion technology. The use of wood in residential boilers and stoves was relatively low in 1998-99 resulting in a lower emission level.

The consumption of wood in residential plants increased until 2007. The improved technology that has been implemented in residential wood combustion has led to lower emission factors and thus decreasing NMVOC emissions since 2007.

Table 10 NMVOC emissions from stationary combustion plants, 2018[1)].

| | | NMVOC, t |
|---|---|---|
| 1A1a | Public electricity and heat production | 1073 |
| 1A1b | Petroleum refining | 23 |
| 1A1c | Oil and gas extraction | 35 |
| 1A2 | Industry | 1253 |
| 1A4a | Commercial/institutional | 167 |
| 1A4b | Residential | 11406 |
| 1A4c | Agriculture/forestry | 1295 |
| Total | | 15251 |




1) Only emission from stationary combustion plants in the categories is included.

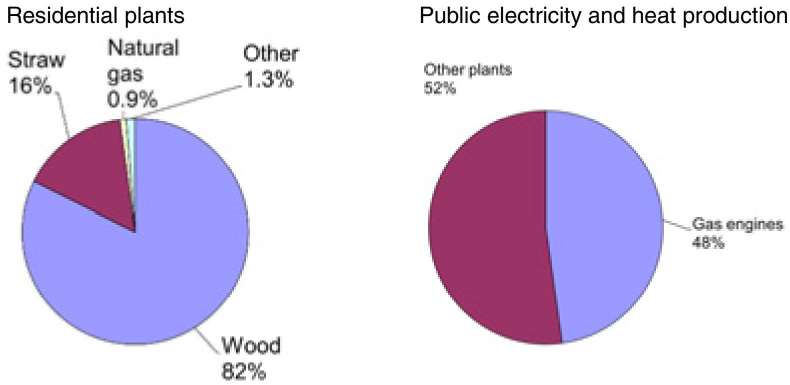



Figure 19 NMVOC emissions from Residential plants and from Public electricity and heat production, 2018.

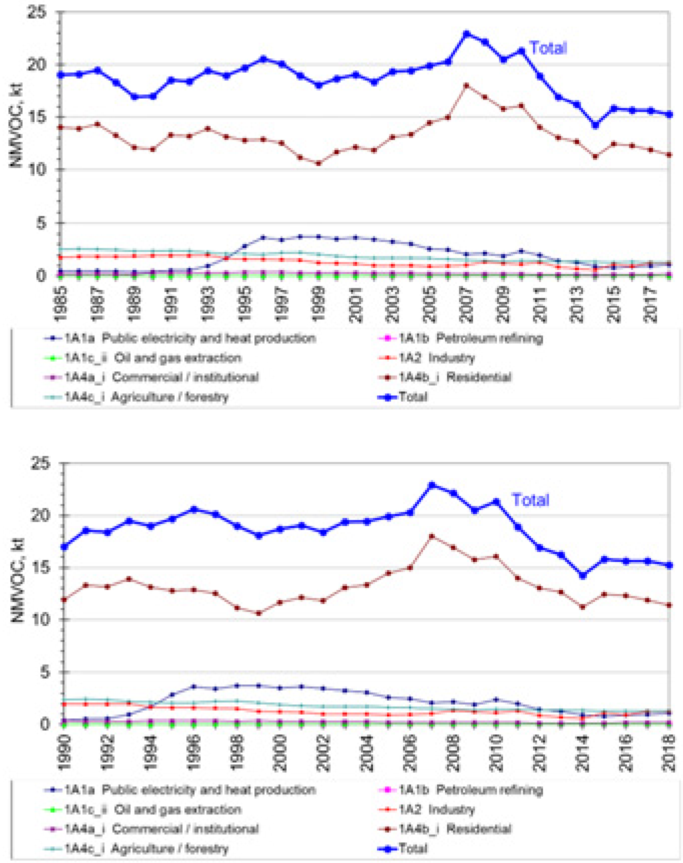



Figure 20 NMVOC emission time series for stationary combustion.

## 4.4 CO

Stationary combustion accounts for 45 % of the national CO emission. Table 11 presents the CO emission inventory for stationary combustion subcategories.

Residential plants are the largest emission source, accounting for 75 % of the emission. Wood combustion accounts for 92 % of the emission from residential plants, see Figure 21. This is in spite of the fact that the fuel consumption share is only 54 %. Combustion of straw is also a considerable emission source whereas the emission from other fuels used in residential plants is almost negligible.

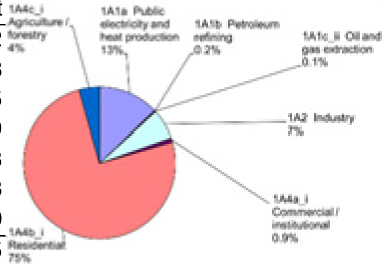
The time series for CO emission from stationary combustion is shown in Figure 22. The emission has decreased by 33 % from 1990 and 39 % from 1985. The time series for CO from stationary combustion plants follow the time series for CO emission from residential plants.

The increase of wood consumption in residential plants in 1999-2007 is reflected in the time series for CO emission. The consumption of wood in residential plants in 2018 was 4.6 times the 1990 level. The decreased emission in 2007-2018 is a result of implementation of improved residential wood combustion technologies and the fact that the rapid increase of wood consumption until 2007 have stopped.

Both consumption and CO emission factor have decreased for residential straw combustion plants since 1990.

Table 11 CO emission from stationary combustion plants, 2018[1)].

| | | CO, t |
|---|---|---|
| 1A1a | Public electricity and heat production | 13722 |
| 1A1b | Petroleum refining | 198 |
| 1A1c | Oil and gas extraction | 105 |
| 1A2 | Industry | 6799 |
| 1A4a | Commercial/institutional | 928 |
| 1A4b | Residential | 79753 |
| 1A4c | Agriculture/forestry | 4630 |
| Total | | 106135 |




[1)] Only emission from stationary combustion plants in the source categories is included.

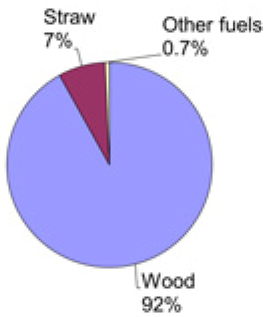
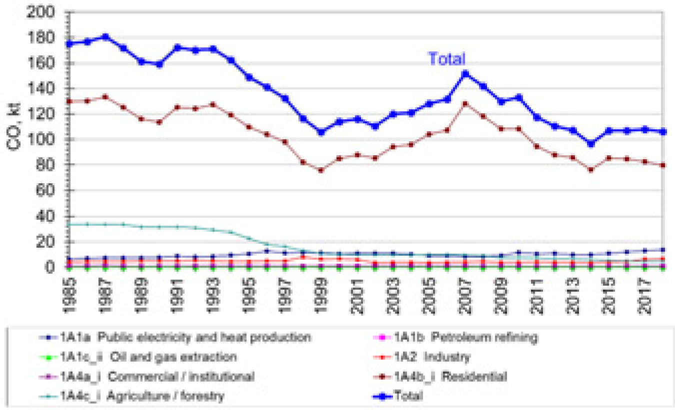
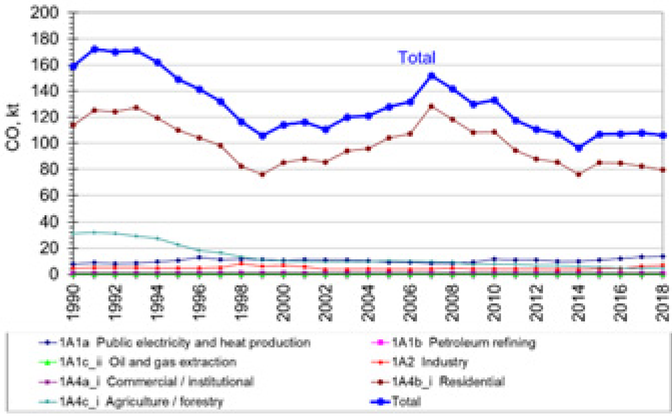



Figure 21 CO emission sources, Residential plants, 2018.

Stationary combustion, 1985-2018




Stationary combustion, 1990-2018




1A4b Residential plants, fuel origin

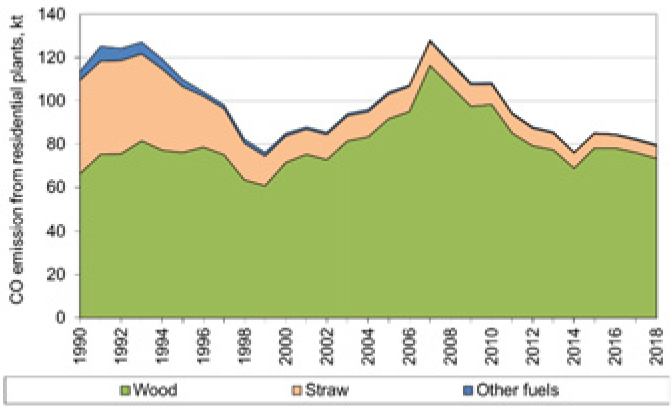



Figure 22 Time series for CO emission for stationary combustion and fuel consumption for residential plants.

## 4.5 $NH_3$

Stationary combustion plants accounted for 2.9 % of the national $NH_3$ emission in 2018.

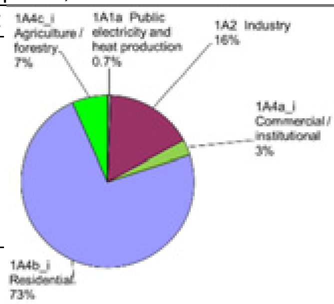
The $NH_3$ emission from non-residential plants is small and default emission factors are only available for biomass combustion in EEA Guidebook (EEA, 2016). However, based on national references the $NH_3$ emission from waste incineration has been included in the Danish inventory.

Table 12 shows the $NH_3$ emission inventory for the stationary combustion subcategories. Residential plants account for 73 % of the emission. Wood combustion accounts for 87 % of the emission from residential plants.

The time series for $NH_3$ emission is presented in Figure 23. The $NH_3$ emission has increased 56 % from 1990.

Table 12 $NH_3$ emission from stationary combustion plants, 2018[1)].

| | | $NH_3$, t |
|---|---|---|
| 1A1a | Public electricity and heat production | 15 |
| 1A1b | Petroleum refining | - |
| 1A1c | Oil and gas extraction | - |
| 1A2 | Industry | 361 |
| 1A4a | Commercial/institutional | 65 |
| 1A4b | Residential | 1613 |
| 1A4c | Agriculture/forestry | 147 |
| Total | | 2200 |




1) Only the emission from stationary combustion plants in the source categories is included.

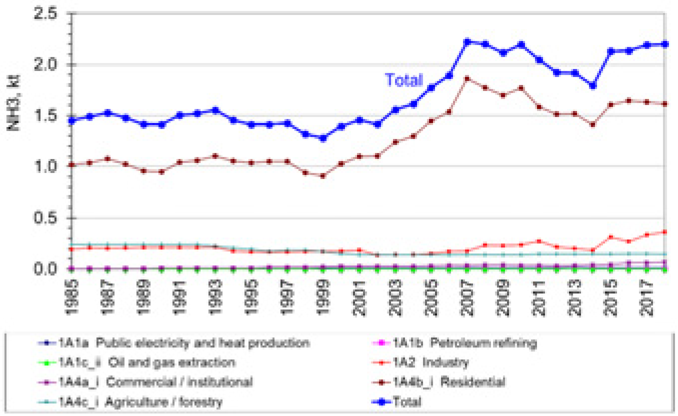



Figure 23 $NH_3$ emission time series, stationary combustion plants.

## 4.6 Particulate matter (PM)

TSP from stationary combustion accounts for 13 % of the national emission. The emission shares for $PM_{10}$ and $PM_{2.5}$ are 41 % and 69 %, respectively.

PM emission data include condensable particles if data references including condensable are available.

Table 13 and Figure 24 show the PM emission inventory for the stationary combustion subcategories. Residential plants are the largest emission source accounting for 85 % of the $PM_{2.5}$ emission from stationary combustion plants.

The primary sources of PM emissions are:

- Residential boilers, stoves and fireplaces combusting wood.
- Farmhouse / residential boilers combusting straw.
- Wood combusted in non-residential plants.
- Power plants primarily combusting coal.

The PM emission from wood combusted in residential plants is the predominant source. Thus, 69 % of the $PM_{2.5}$ emission from stationary combustion is emitted from residential wood combustion. This corresponds to 50 % of the national emission. Figure 25 shows the fuel consumption and the $PM_{2.5}$ emission of residential plants. Wood combustion accounts for 86 % of the $PM_{2.5}$ emission from residential plants in spite of a wood consumption share of 54 %.

Emission inventories for PM are reported for the years 1990-2018. The time series for PM emission from stationary combustion is shown in Figure 26. The time series for PM emission from stationary combustion plants follows the time series for PM emission from residential plants. The emission of TSP, $PM_{10}$ and $PM_{2.5}$ was 1 %, 5 % and 4 % lower in 2018 than in 1990.

The PM emissions increased until 2007 and decreased after 2007. The increase until 2007 was caused by the increased wood combustion in residential plants. However, the PM emission factors have decreased for this emission source category due to installation of modern stoves and boilers. The stabilisation of wood consumption in residential plants in 2007-2014 has resulted in a decrease of PM emission from stationary combustion between 2007 and 2014.

Table 13 PM emission from stationary combustion plants, 2018[1)].

| | | TSP, t | $PM_{10}$, t | $PM_{2.5}$, t |
|---|---|---|---|---|
| 1A1a | Public electricity and heat production | 695 | 508 | 388 |
| 1A1b | Petroleum refining | 94 | 90 | 88 |
| 1A1c | Oil and gas extraction | 2 | 1 | 1 |
| 1A2 | Industry | 312 | 223 | 149 |
| 1A4a | Commercial/institutional | 235 | 232 | 218 |
| 1A4b | Residential | 10183 | 9731 | 9556 |
| 1A4c | Agriculture/forestry | 891 | 887 | 884 |
| Total | | 12411 | 11672 | 11284 |

1) Only emission from stationary combustion plants in the source categories is included.

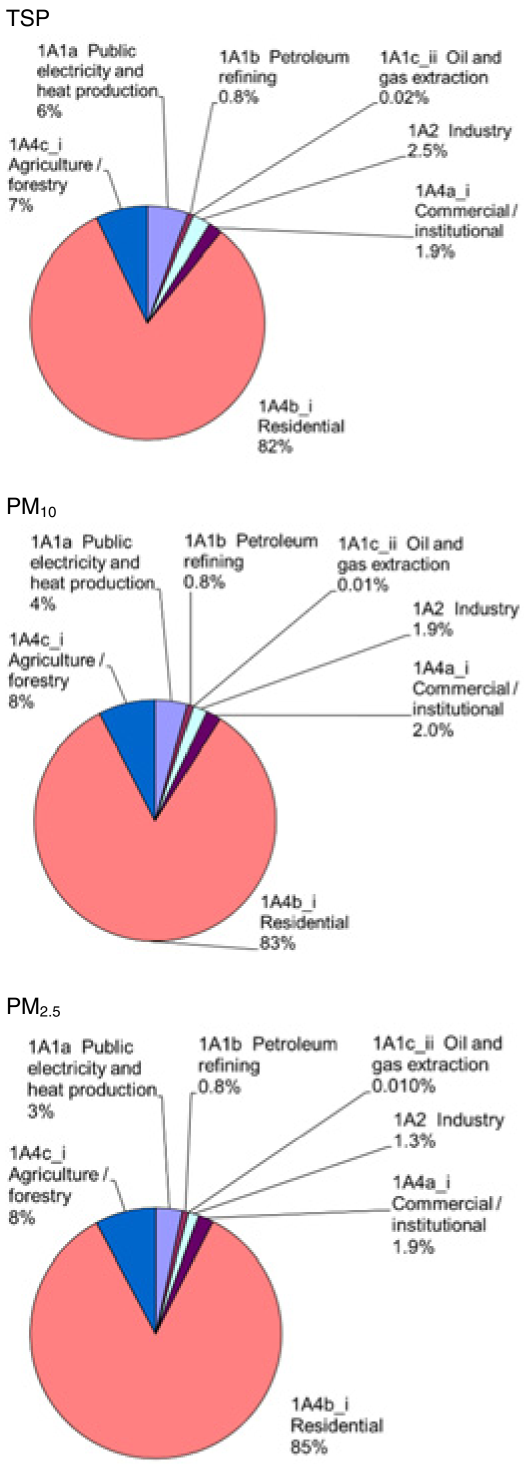



Figure 24 PM emission sources, stationary combustion plants, 2018.

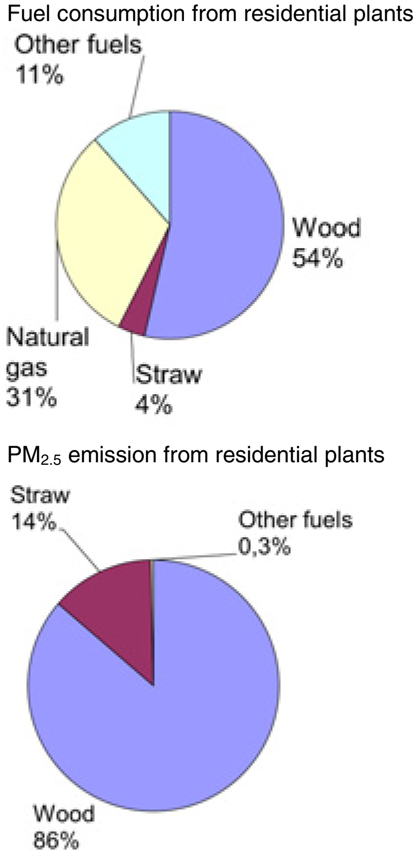



Figure 25 Fuel consumption and $PM_{2.5}$ emission from residential plants.

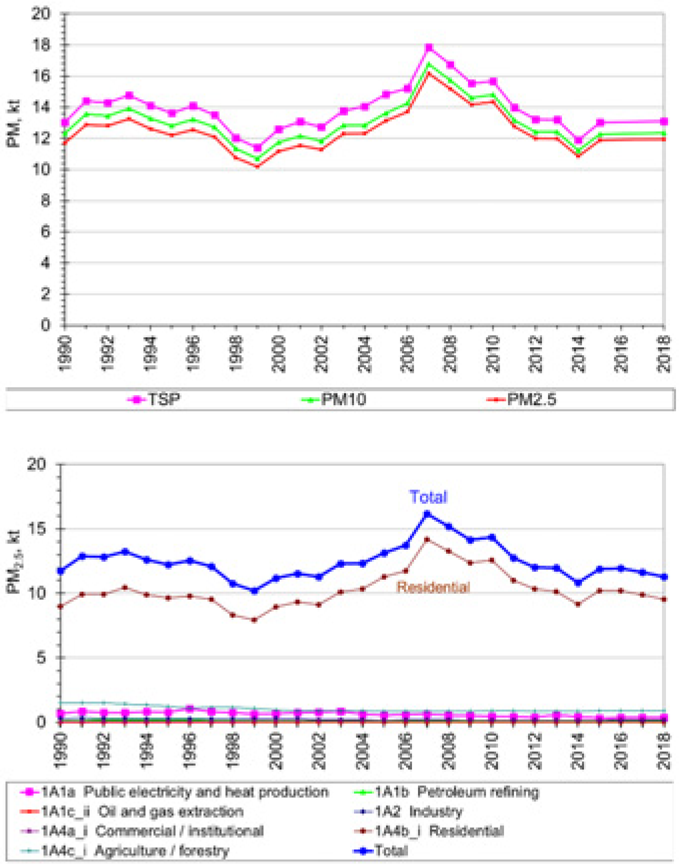



Figure 26 PM emission time series for stationary combustion.

## 4.7 Black carbon (BC)

Black carbon (BC) from stationary combustion accounted for 50 % of the national emission in 2018. Residential combustion is the main emission source accounting for 72 % of the emission from stationary combustion. Residential wood combustion is the main emission source accounting for 61 % of the emission from residential plants. Plants in Agriculture / forestry account for 19 % of the emission.

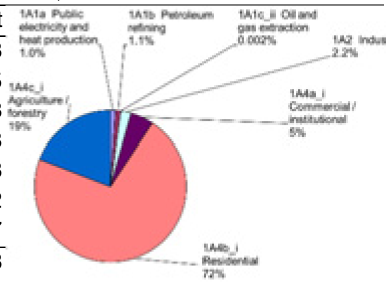
Table 14 shows the BC emission inventory for the stationary combustion subcategories.

The BC emission factors are estimated as fractions of the $PM_{2.5}$ emission factor. The fractions depend on both fuel and sector, see Chapter 7.11.

BC emissions are reported for year 1990 onwards. Figure 27 shows time series for BC emission.

Table 14 BC emission from stationary combustion plants, 2018[1)].

| | BC, t |
|---|---|
| 1A1a Public electricity and heat production | 13 |
| 1A1b Petroleum refining | 15 |
| 1A1c Oil and gas extraction | 0.03 |
| 1A2 Industry | 28 |
| 1A4a Commercial/institutional | 63 |
| 1A4b Residential | 922 |
| 1A4c Agriculture/forestry | 247 |
| Total | 1288 |




1) Only emission from stationary combustion plants in the source categories is included.

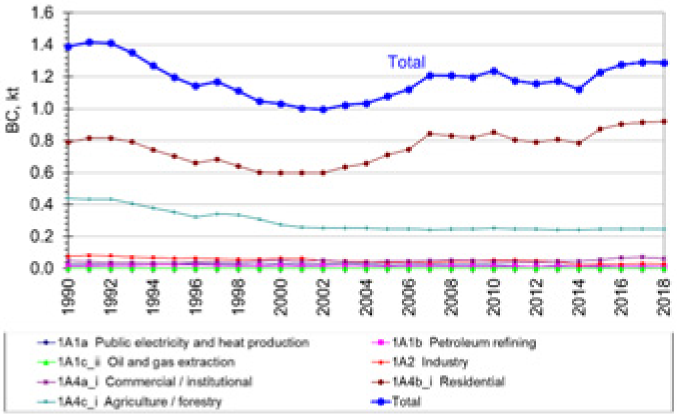



Figure 27 BC emission time series for stationary combustion.

## 4.8 Heavy metals

Stationary combustion plants are among the most important emission sources for heavy metals. The emission share for stationary combustion compared to national total is shown for each metal in Table 15.

Table 15 and Figure 28 present the heavy metal emission inventory for the stationary combustion subcategories. The source categories Public electricity and heat production, Residential and Industry are the main emission sources. The emission share for waste incineration plants has decreased considerably since the year 2000 due to installation of new improved flue gas cleaning technology that was initiated based on lower emission limit values in Danish legislation (DEPA, 2011).

Table 15 Heavy metal emissions from stationary combustion plants, 2018[1)].

| | As, kg | Cd, kg | Cr, kg | Cu, kg | Hg, kg | Ni, kg | Pb, kg | Se, kg | Zn, kg |
|---|---|---|---|---|---|---|---|---|---|
| 1A1a Public electricity and heat production | 43 | 24 | 138 | 136 | 120 | 214 | 320 | 267 | 370 |
| 1A1b Petroleum refining | 7 | 11 | 42 | 35 | 1 | 150 | 29 | 7 | 415 |
| 1A1c Oil and gas extraction | 3 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| 1A2 Industry | 72 | 27 | 92 | 113 | 63 | 678 | 493 | 92 | 981 |
| 1A4a Commercial/institutional | 1 | 1 | 5 | 5 | 2 | 8 | 6 | 1 | 11 |
| 1A4b Residential | 11 | 572 | 1014 | 265 | 28 | 92 | 1189 | 22 | 22543 |
| 1A4c Agriculture/forestry | 2 | 27 | 51 | 19 | 4 | 9 | 103 | 10 | 1094 |
| Total | 138 | 661 | 1341 | 573 | 220 | 1151 | 2139 | 399 | 25414 |
| Emission share from stationary combustion | 58% | 83% | 74% | 1% | 81% | 43% | 17% | 75% | 39% |

1) Only emission from stationary combustion plants in the source categories is included.

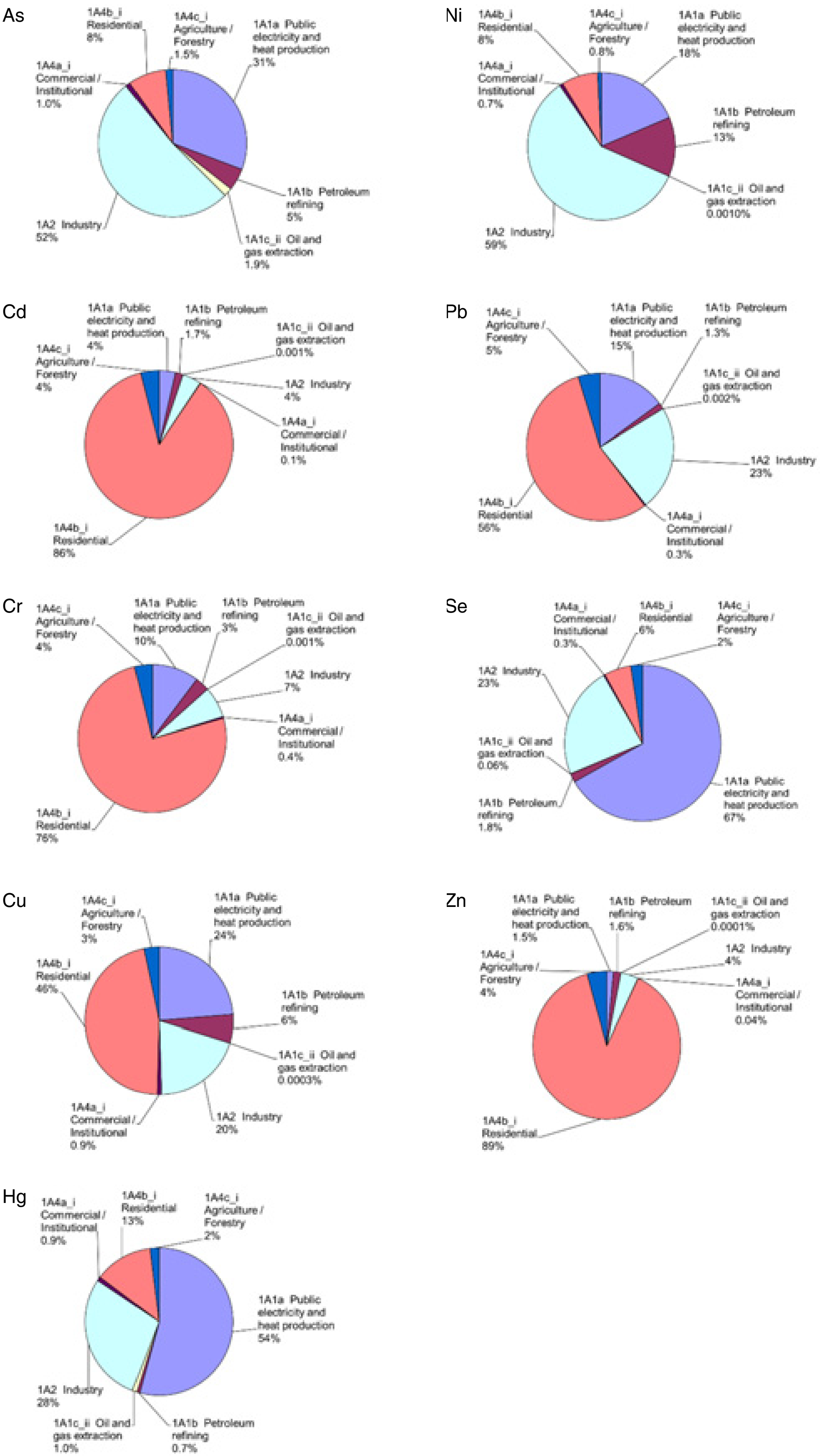



Figure 28 Heavy metal emission sources, stationary combustion plants, 2018.

The time series for heavy metal emissions are provided in Figure 29. Emissions of all heavy metals have decreased considerably (18 % - 92 %) since 1990, see Table 16. Emissions have decreased despite increased incineration of waste. This has been possible due to installation and improved performance of gas cleaning devices in waste incineration plants and also in large power plants, the latter being a further important emission source. The Zn and Cd emission decrease only 18 % and 37 % respectively. The smaller decrease compared to other HMs is due to a relatively high emission share from residential wood combustion even in 1990.

For Cd, Cr, Pb and Zn the main emission source in recent years was residential plants, mainly from residential wood combustion. Thus, in recent years the time series for Cd, Cr, Pb and Zn follow the time series for residential wood combustion.

Table 16 Decrease in heavy metal emissions from 1990 to 2018.

| Pollutant | As | Cd | Cr | Cu | Hg | Ni | Pb | Se | Zn |
|---|---|---|---|---|---|---|---|---|---|
| Decrease since 1990, % | 88 | 37 | 76 | 84 | 92 | 92 | 86 | 90 | 18 |

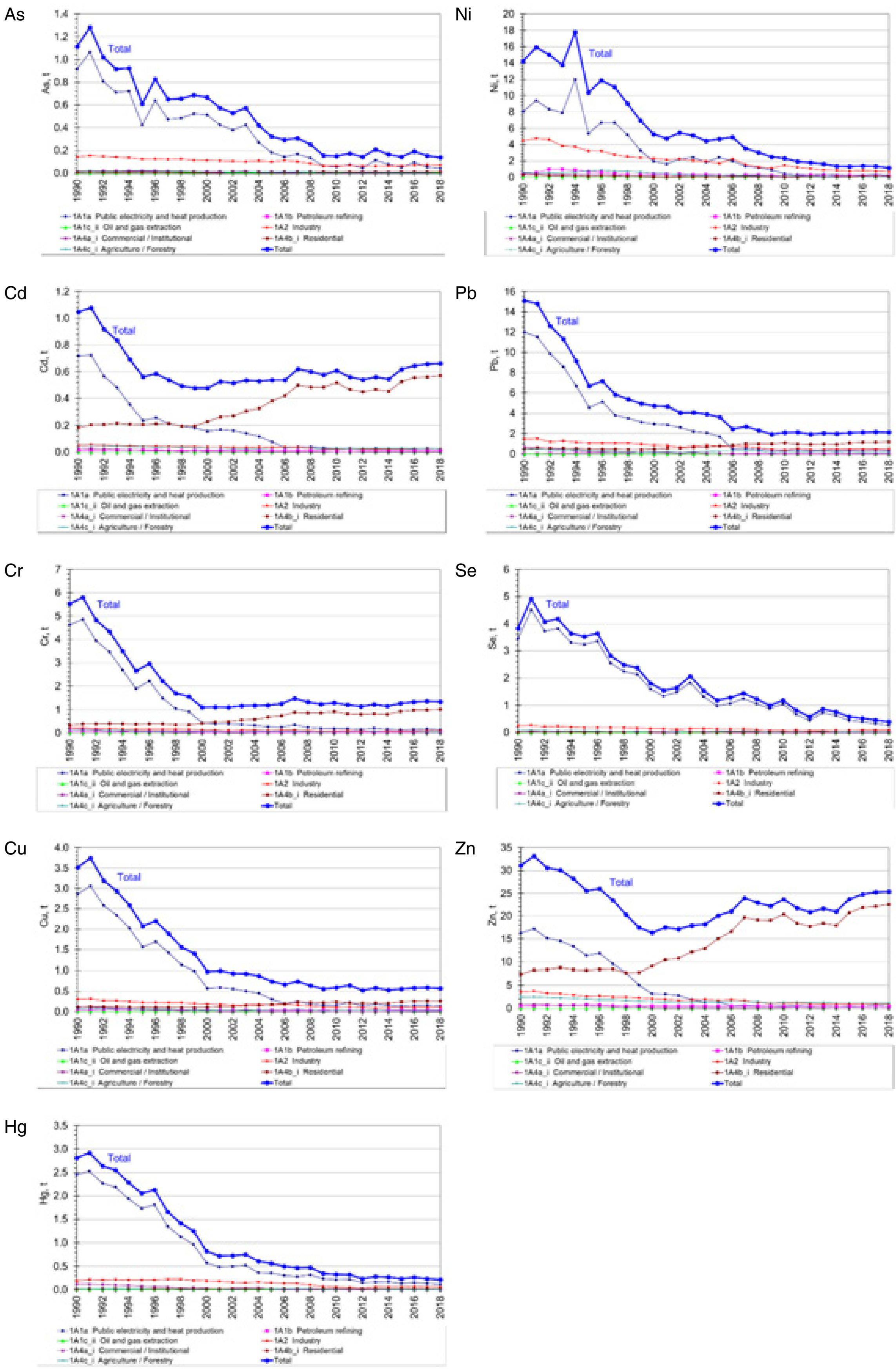



Figure 29 Heavy metal emission time series, stationary combustion plants.

## 4.9 Polycyclic aromatic hydrocarbons (PAH)

Stationary combustion plants accounted for more than 86 % of the PAH emissions in 2018.

Table 17 and Figure 30 present the PAH emissions inventories for the stationary combustion subcategories. Residential combustion is the largest emission source accounting for more than 75 % of the emission. Combustion of wood is the predominant source, accounting for more than 97 % of the PAH emissions from residential plants, see Figure 31.

The time series for PAH emissions are presented in Figure 32. The time series for wood combustion in residential plants is also provided in Figure 32. The wood combustion in residential plants has increased whereas the emission factors have decreased due to installation of new residential wood combustion units.

Table 17 PAH emissions from stationary combustion plants, 2018[1).]

| | Benzo(a)-pyrene, kg | Benzo(b)-fluoranthene, kg | Benzo(k)-fluoranthene, kg | Indeno (1,2,3-c,d) pyrene, kg |
|---|---|---|---|---|
| 1A1a Public electricity and heat production | 10 | 43 | 30 | 7 |
| 1A1b Petroleum refining | 0 | 0 | 0 | 0 |
| 1A1c Oil and gas extraction | 0 | 0 | 0 | 0 |
| 1A2 Industry | 1 | 16 | 16 | 5 |
| 1A4a Commercial/institutional | 295 | 388 | 129 | 210 |
| 1A4b Residential | 1686 | 1591 | 1045 | 921 |
| 1A4c Agriculture/forestry | 83 | 95 | 30 | 77 |
| Total | 2074 | 2134 | 1250 | 1219 |
| Emission share from stationary combustion | 93% | 89% | 87% | 86% |

1) Only emission from stationary combustion plants in the source categories is included.

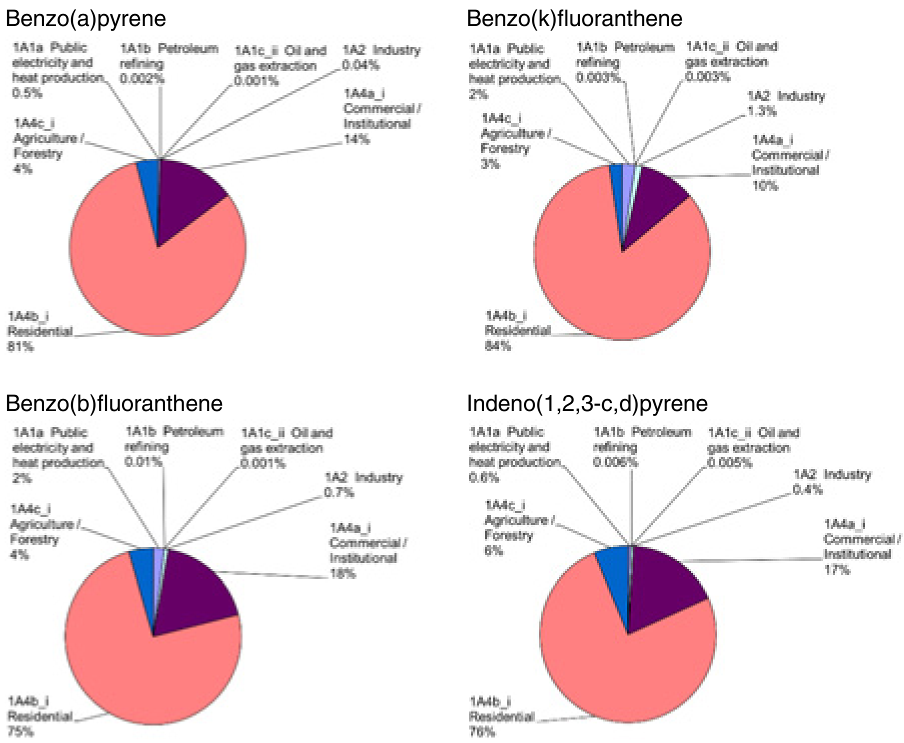



Figure 30 PAH emission sources, stationary combustion plants, 2018.

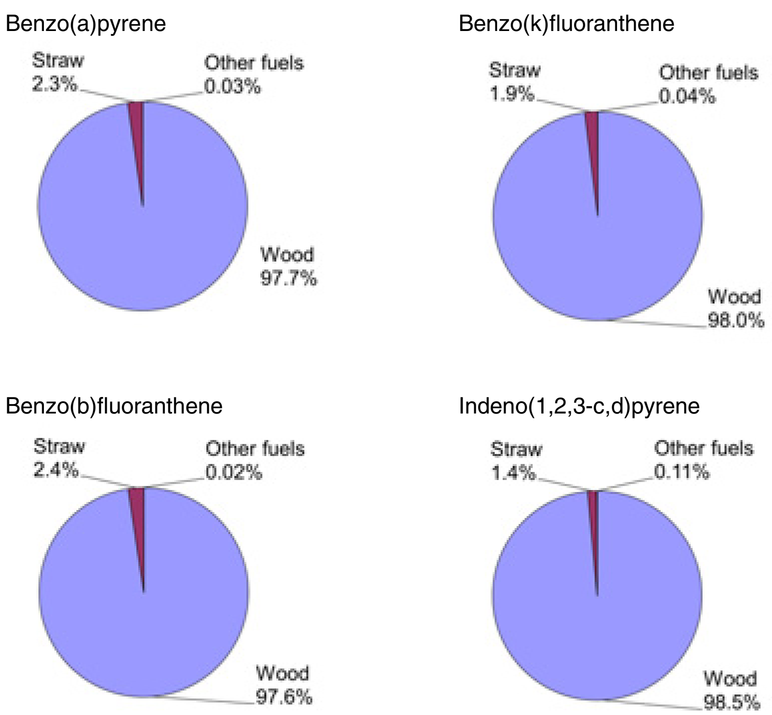



Figure 31 PAH emissions from residential combustion plants (stationary), fuel origin.

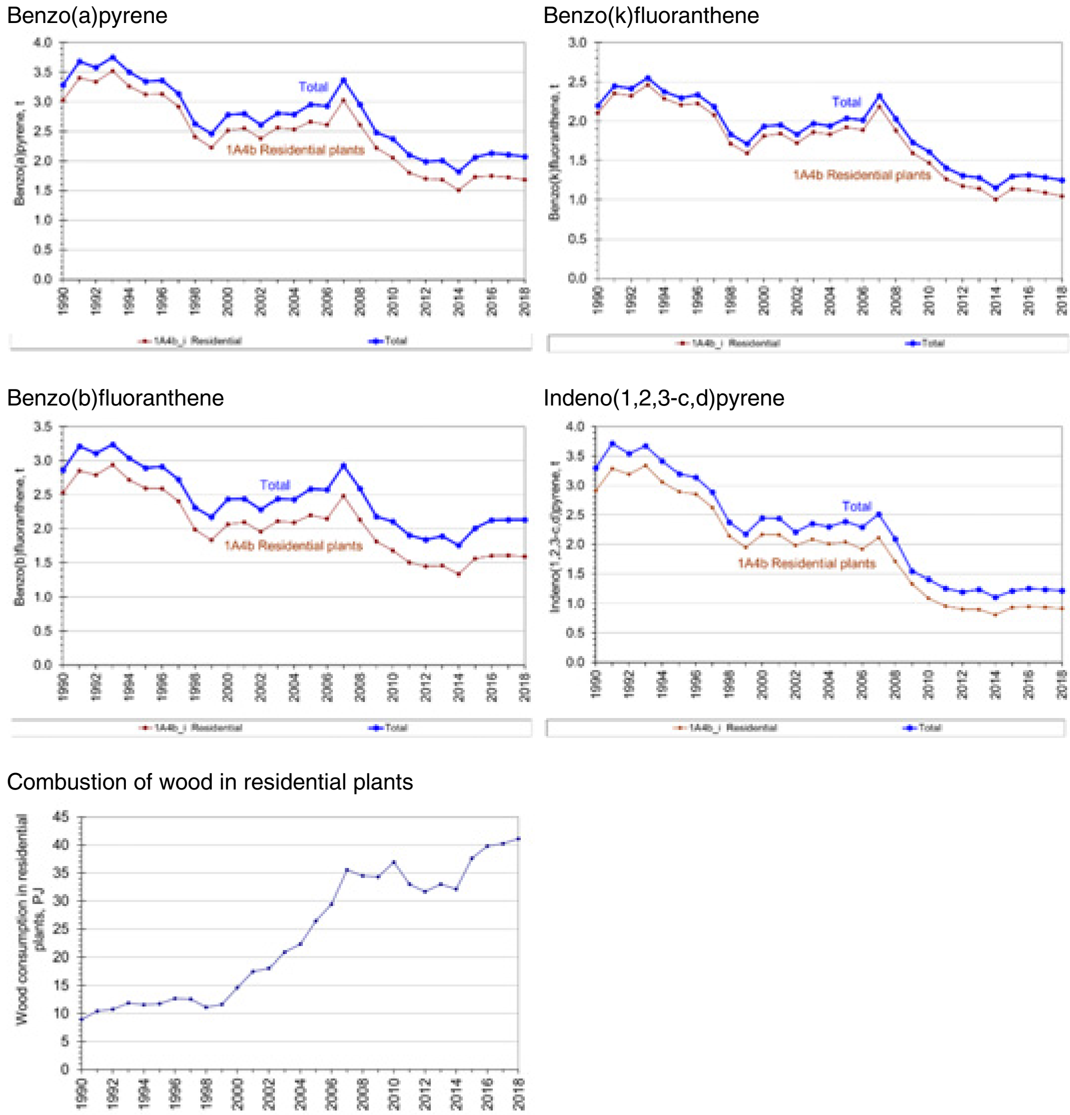



Figure 32 PAH emission time series, stationary combustion plants. Comparison with wood consumption in residential plants.

## 4.10 Polychlorinated dibenzodioxins and -furans (PCDD/F)

Stationary combustion plants accounted for 81 % of the national emission of polyclorinated dibenzodioxins and –furans (PCDD/F) in 2018.

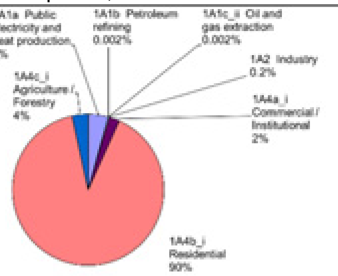
Table 18 presents the PCDD/F emission inventories for the stationary combustion subcategories. In 2018, the emission from residential plants accounted for 90 % of the emission. Combustion of wood is the predominant source accounting for 94 % of the emission from residential plants (Figure 33).

The time series for PCDD/F emissions are presented in Figure 34. The PCDD/F emissions have decreased 39 % since 1990 mainly due to installation of dioxin filters in waste incineration plants.

The emission from residential plants has increased due to increased wood consumption in this source category. The dioxin emission factors for residential wood combustion are dependent on the wood origin but independent of stove technology (Chapter 6.13). Thus, the dioxin emissions from residential wood combustion has not decreased similar to e.g. the PM and PAH emissions due to implementation of new improved stoves and boilers.

Table 18 PCDD/F emissions from stationary combustion plants, 2018[1)].

| | | PCDD/ F, g I-teq |
|---|---|---|
| 1A1a | Public electricity and heat production | 1.24 |
| 1A1b | Petroleum refining | 0.001 |
| 1A1c | Oil and gas extraction | 0.001 |
| 1A2 | Industry | 0.07 |
| 1A4a | Commercial/institutional | 0.65 |
| 1A4b | Residential | 26.05 |
| 1A4c | Agriculture/forestry | 0.99 |
| Total | | 29.00 |




1) Only emission from stationary combustion plants in the source categories is included.

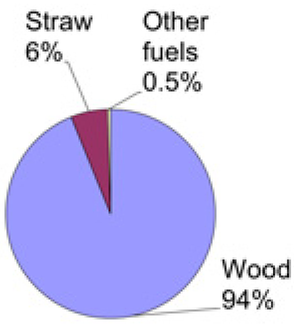



Figure 33 PCDD/F emissions from residential plants, fuel origin.

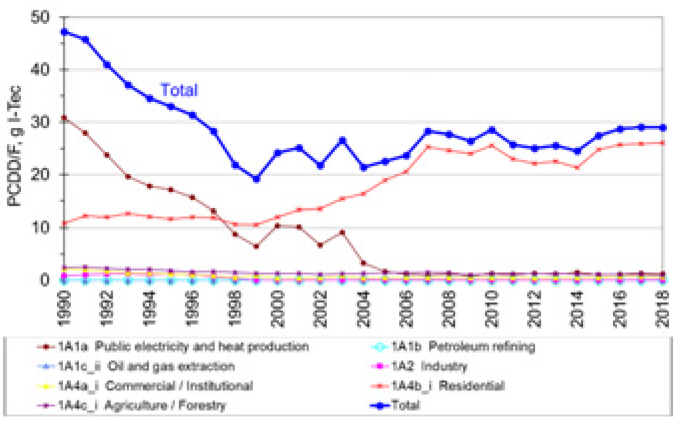



Figure 34 PCDD/F emission time series, stationary combustion plants.

## 4.11 Hexachlorobenzene (HCB)

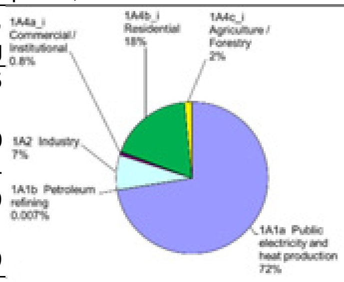
Stationary plants accounted for 50 % of the estimated national emission of hexachlorobenzene (HCB) in 2018.

Table 19 shows the HCB emission inventory for the stationary combustion subcategories. Public electricity and heat production account for 72 % of the emission. Residential plants account for 18 % of the emission.

The time series for HCB emission is presented in Figure 35. The HCB emission has decreased 79 % since 1990 mainly due to improved flue gas cleaning in waste incineration plants. The high emission from residential plants in 1990-1995 is related to combustion of coal in residential plants.

Table 19 HCB emission from stationary combustion plants, 2018[1)].

| | HCB, kg |
|---|---|
| 1A1a Public electricity and heat production | 0.905 |
| 1A1b Petroleum refining | 0.0001 |
| 1A1c Oil and gas extraction | 0.0000 |
| 1A2 Industry | 0.094 |
| 1A4a Commercial/institutional | 0.009 |
| 1A4b Residential | 0.221 |
| 1A4c Agriculture/forestry | 0.019 |
| Total | 1.249 |




1) Only the emission from stationary combustion plants in the source categories is included.

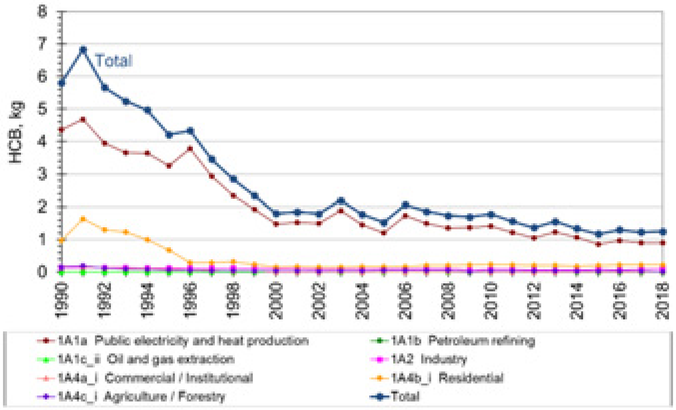



Figure 35 HCB emission time series, stationary combustion plants.

## 4.12 Polychlorinated biphenyls (PCB)

Polychlorinated biphenyls (PCBs) can be emitted in any chemical process involving chloride and organic carbon or emitted due to incomplete combustion of PCBs in fuel (waste incineration). In Denmark, waste with high levels of PCBs is only incinerated in plants with permission to incinerate this waste fraction, as it requires a high combustion temperature.

Different references for PCBs emissions are not directly comparable because some PCB emission data are reported for individual PCB congeners, some as a sum of a specified list of PCB congeners and some PCB emission data are reported as toxic equivalence (teq) based on toxicity equivalence factors (TEF) for 12 dioxin-like PCB congeners. The emission measurements reported by Thistlethwaite (2001a and 2001b) show that the emission of non-dioxin-like PCBs is high compared to the emission of dioxin-like PCBs.

Furthermore, teq values based on TEF are reported as $WHO_{2005}$-teq or $WHO_{1998}$-teq. This difference is however typically less than 50%[8].

For stationary combustion, the emission inventory is a sum of dioxin-like PCBs (dl-PCBs) emission, no teq values applied.

Stationary plants accounted for 83 % of the estimated national PCB emissions in 2018.

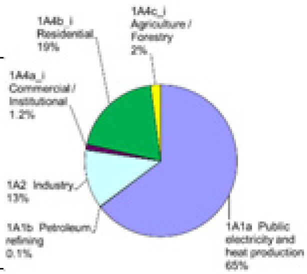
[8] Data have been compared for a few datasets in which each dioxin-like PCB congeners were specified.

Table 20 shows the dl-PCB emission inventory for the stationary combustion subcategories. Public electricity and heat production accounted for 65 % of the emission in 2018. Residential plants accounted for 19 % of the emission.

The time series for dl-PCB emissions are presented in Figure 36. The dl-PCB emissions have decreased 63 % since 1990. The decrease is mainly a result of the flue gas cleaning devices that have been installed in waste incineration plants for dioxin reduction.

Table 20 PCB emissions from stationary combustion plants, 2018[1).]

| | PCB, kg |
|---|---|
| 1A1a Public electricity and heat production | 0.282 |
| 1A1b Petroleum refining | 0.000 |
| 1A1c Oil and gas extraction | 0.000 |
| 1A2 Industry | 0.055 |
| 1A4a Commercial/institutional | 0.005 |
| 1A4b Residential | 0.084 |
| 1A4c Agriculture/forestry | 0.010 |
| Total | 0.436 |




1) Only the emission from stationary combustion plants in the source categories is included.

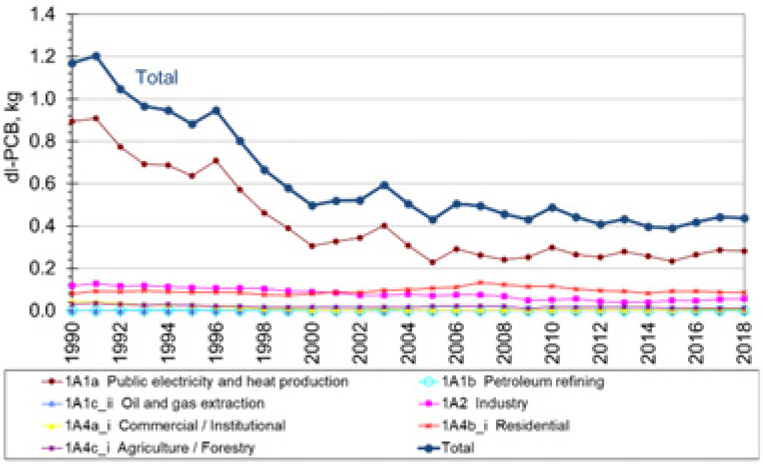



Figure 36 PCB emission time series, stationary combustion plants.

# 5 Trend for subsectors

In addition to the data for stationary combustion, this chapter presents and discusses data for each of the subcategories in which stationary combustion is included. Time series are presented for fuel consumption and emissions.

## 5.1 1A1 Energy industries

The emission source category 1A1 Energy industries consists of the subcategories:

- 1A1a Public electricity and heat production
- 1A1b Petroleum refining
- 1A1c Oil and gas extraction

Figure 37-42 present time series for the Energy industries. Public electricity and heat production is the largest subcategory accounting for the main part of all emissions. Time series are discussed below for each subcategory.

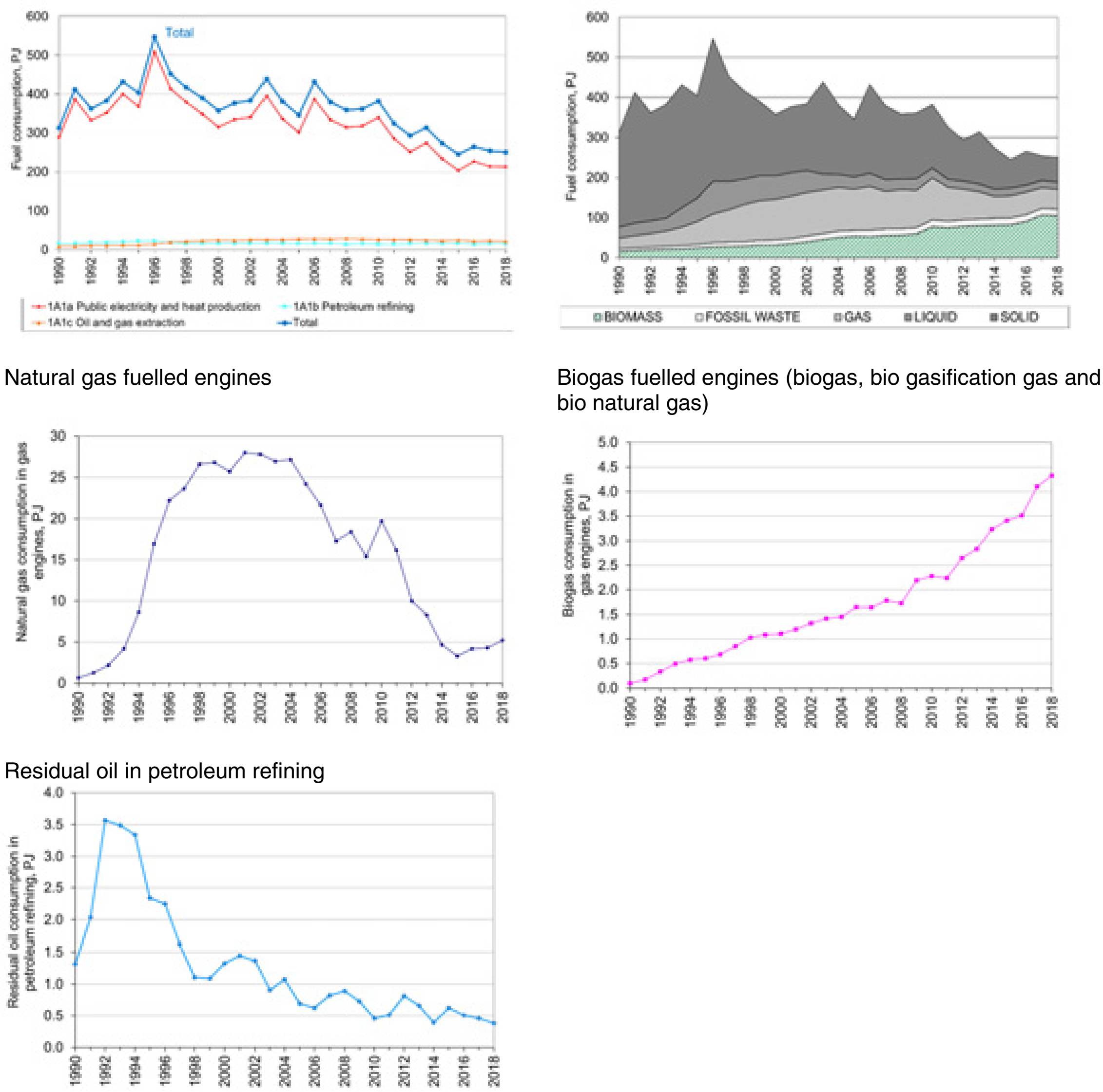



Figure 37 Time series for fuel consumption, 1A1 Energy industries.

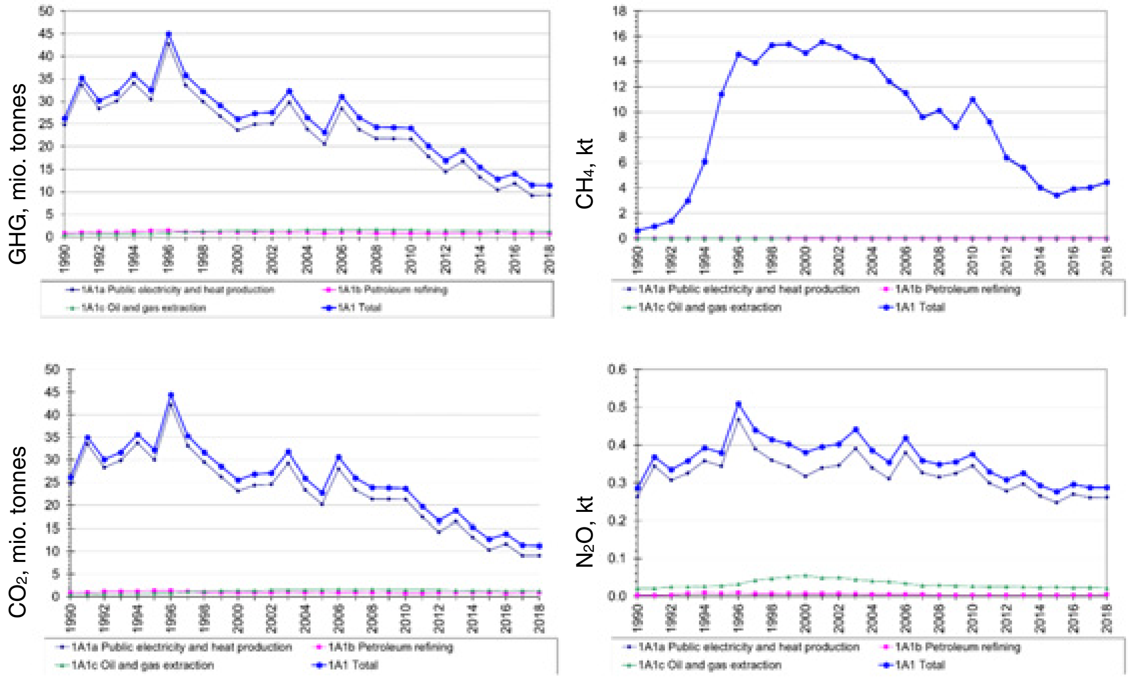



Figure 38 Time series for greenhouse gas emissions, 1A1 Energy industries.

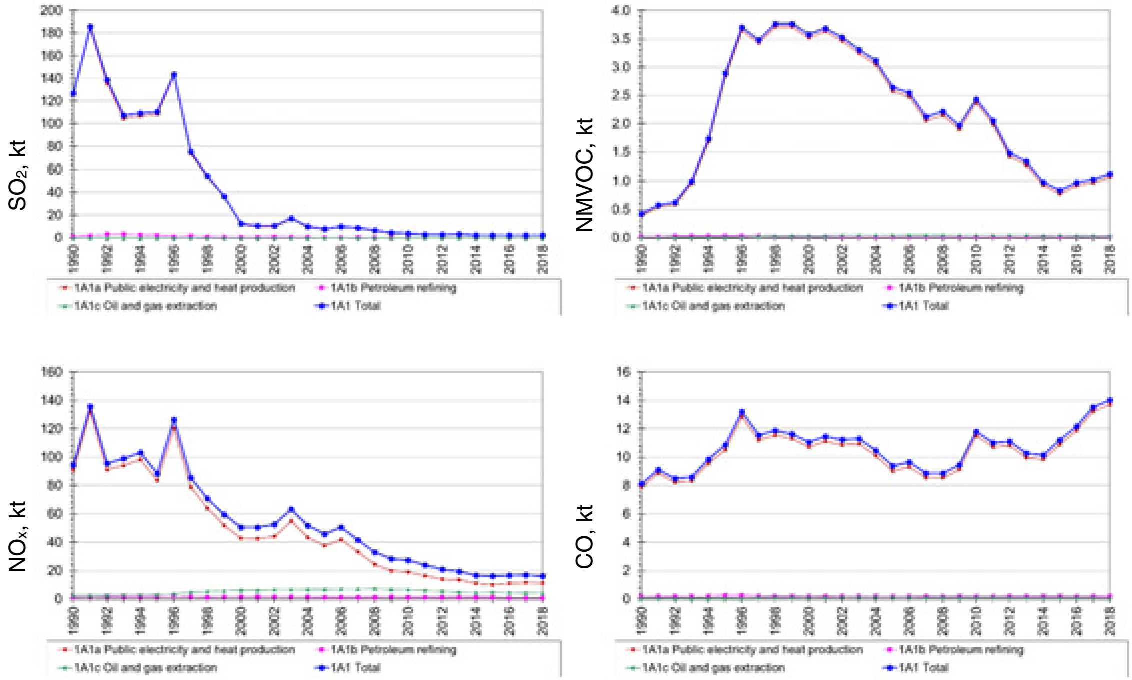



Figure 39 Time series for emission of $SO_2$, $NO_x$, NMVOCs and CO, 1A1 Energy industries.

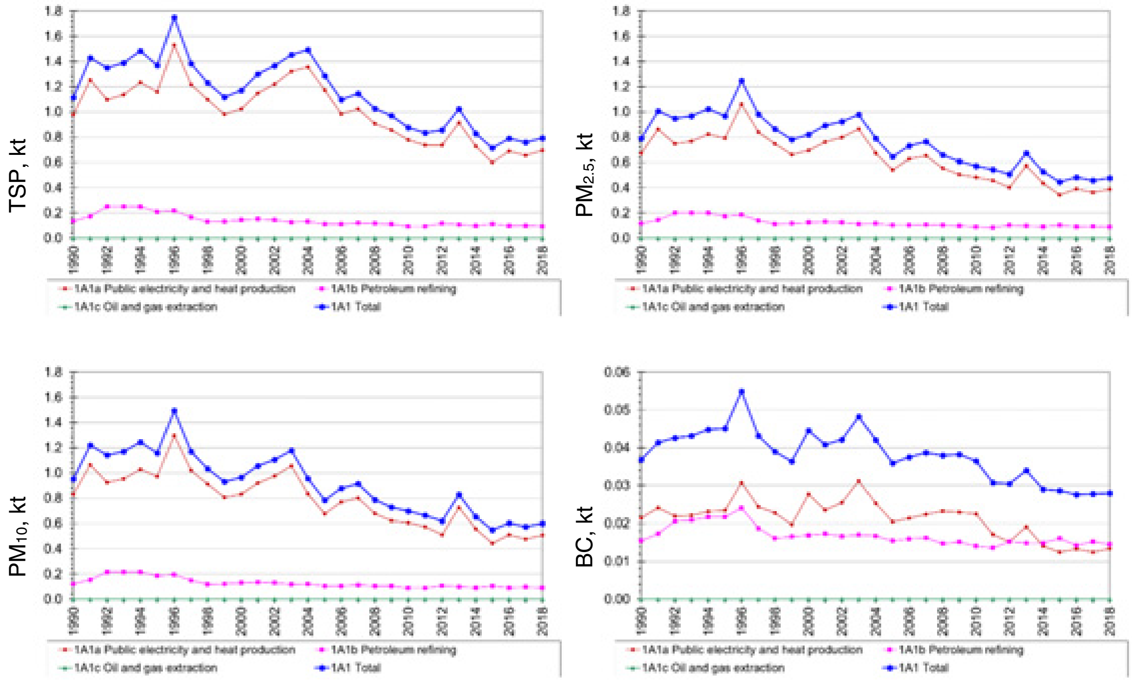



Figure 40   Time series for PM and BC emission, 1A1 Energy industries.

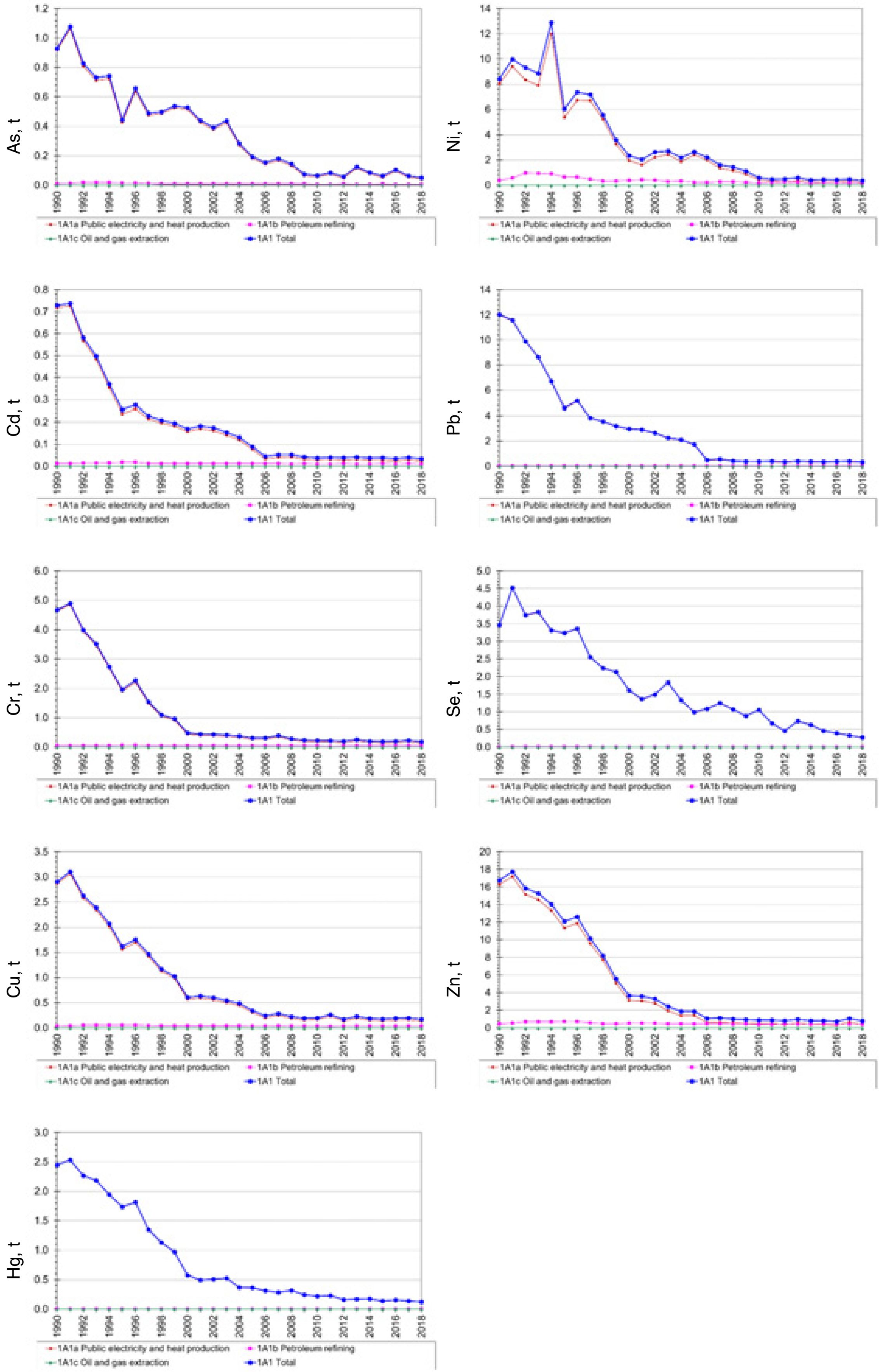



Figure 41 Time series for HM emissions, 1A1 Energy industries.

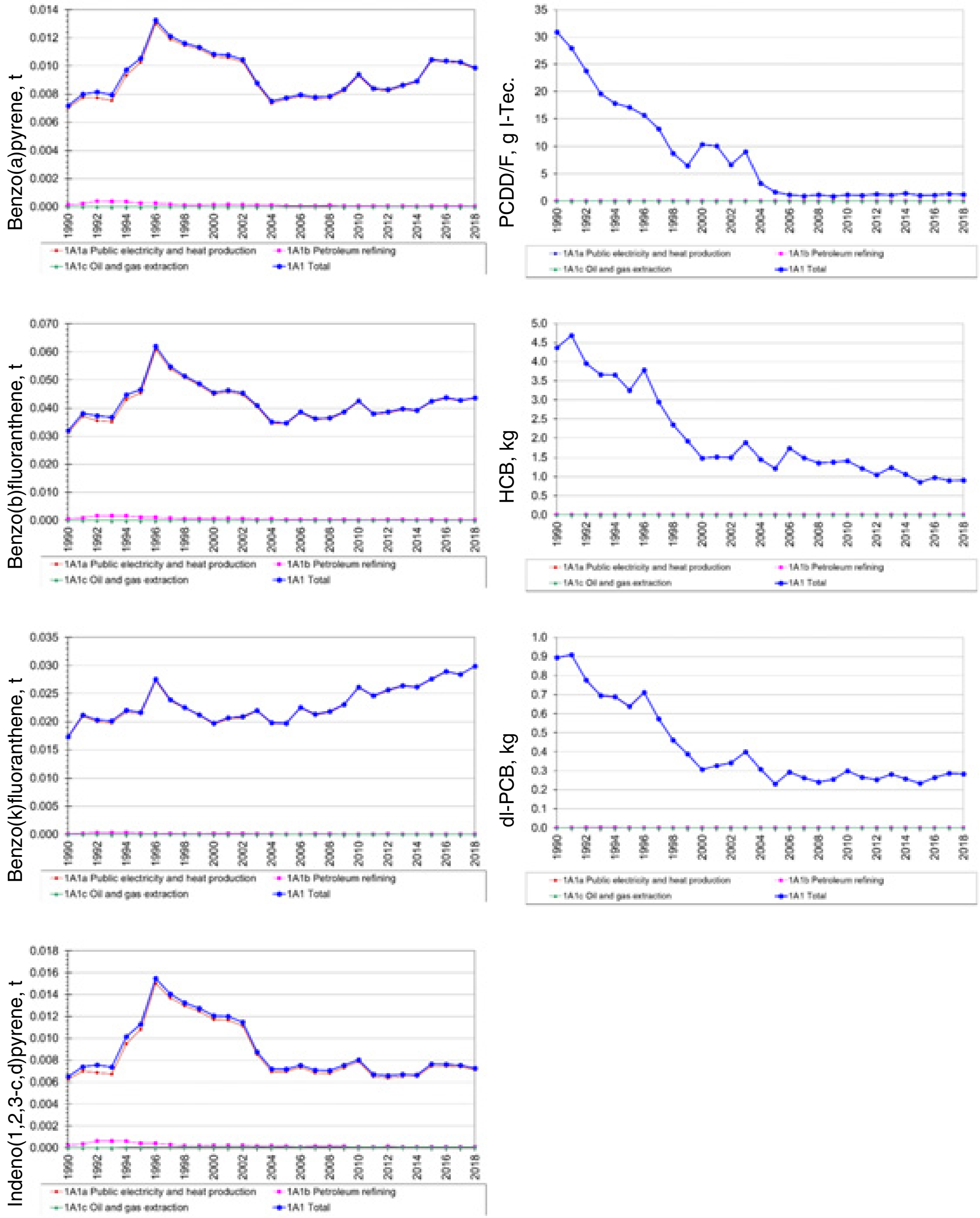



Figure 42 Time series for emission of PAH, PCDD/Fs, HCB and dl-PCBs, 1A1 Energy industries.

### 5.1.1 1A1a Public electricity and heat production

Public electricity and heat production is the largest source category regarding both fuel consumption and greenhouse gas emissions for stationary combustion. Figure 43 and Figure 44 show the time series for fuel consumption and emissions.

The fuel consumption in public electricity and heat production was 26 % lower in 2018 than in 1990. In addition to fuel type changes, the total fuel consumption is also influenced by the fact that the Danish wind power production has increased.

As discussed in Chapter 2, the fuel consumption fluctuates mainly because of electricity trade. Coal is the fuel that is affected the most by the fluctuating electricity trade.

Coal is the main fuel in the source category even in years with electricity import. The coal consumption in 2018 was 74 % lower than in 1990. Natural gas is also an important fuel and the consumption of natural gas increased in 1990-2000 but has decreased since 2010. A considerable part of the natural gas is combusted in gas engines (Figure 37). The consumption of waste and biomass has increased.

The $CO_2$ emission was 63 % lower in 2018 than in 1990. This decrease – in spite of only a 26 % decrease in fuel consumption - is a result of the change of fuel types used.

The $CH_4$ emission increased until the mid-nineties as a result of the considerable number of lean-burn gas engines installed in CHP plants in Denmark in this period. The decline after 2004 is due to structural changes in the Danish electricity market, which means that the fuel consumption in gas engines has been decreasing (Figure 37). The emission in 2018 was 7.4 times the 1990 emission level.

The $N_2O$ emission in 2018 was 1 % lower than the 1990 emission level. The emission fluctuates similar to the fuel consumption.

The $SO_2$ emission has decreased 98 % from 1990 to 2018. This decrease is a result of both lower sulphur content in fuels and installation and improved performance of desulphurisation plants. The emission was 4 % higher in 2018 than in 2017.

The $NO_x$ emission has decreased 88 % since 1990 due to installation of low $NO_x$ burners, selective catalytic reduction (SCR) units and selective non-catalytic reduction (SNCR) units. The fluctuations in time series follow the fluctuations in fuel consumption and electricity trade. The $NO_x$ emission was 3 % lower in 2018 than in 2017.

The emission of NMVOCs in 2018 was 2.7 times the emission in 1990. The emission increased until 1996 and decreased after 2002. This is a result of the large number of gas engines installed in Danish CHP plants. The decreasing emission after 2004 is results of the decreasing fuel consumption for natural gas engines (Figure 37). In addition, the NMVOC emission factor for engines decreased in 1995-2007 due to introduction of an emission limit value for unburned hydrocarbon[9] (DEPA, 2005).

The CO emission was 74 % higher in 2018 than in 1990. The fluctuations follow the fluctuations of the fuel consumption. In addition, the emission from gas engines is considerable. The increase in later years is caused by an increase in the use of biogas fuelled gas engines.

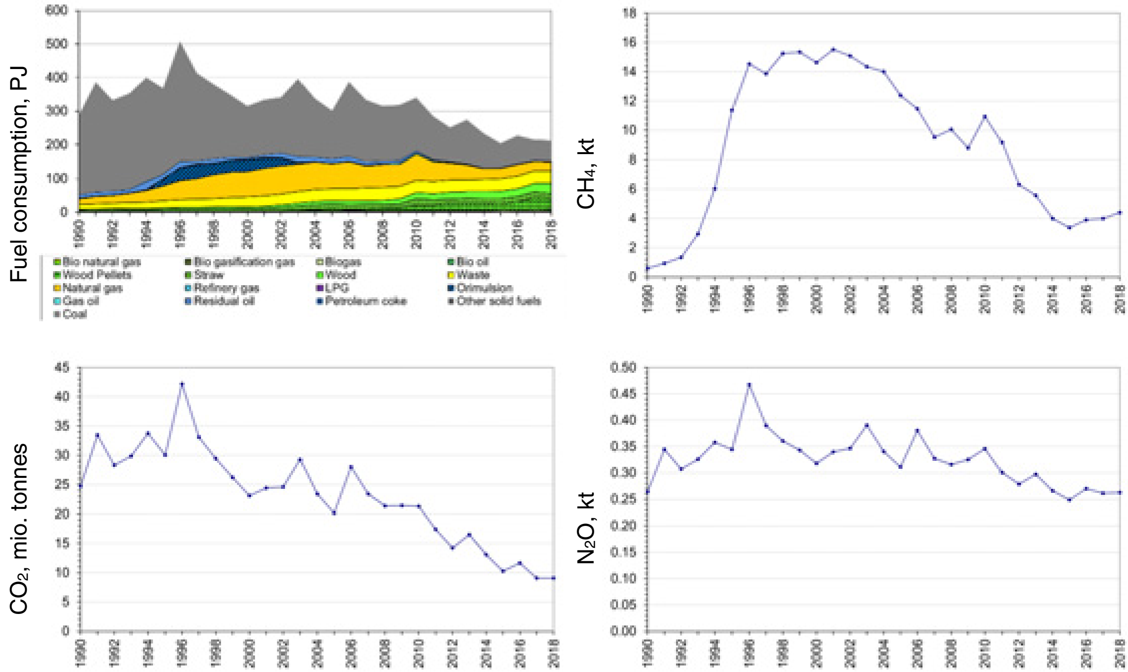



Figure 43 Time series for fuel consumption and GHG emissions from 1A1a Public electricity and heat production.

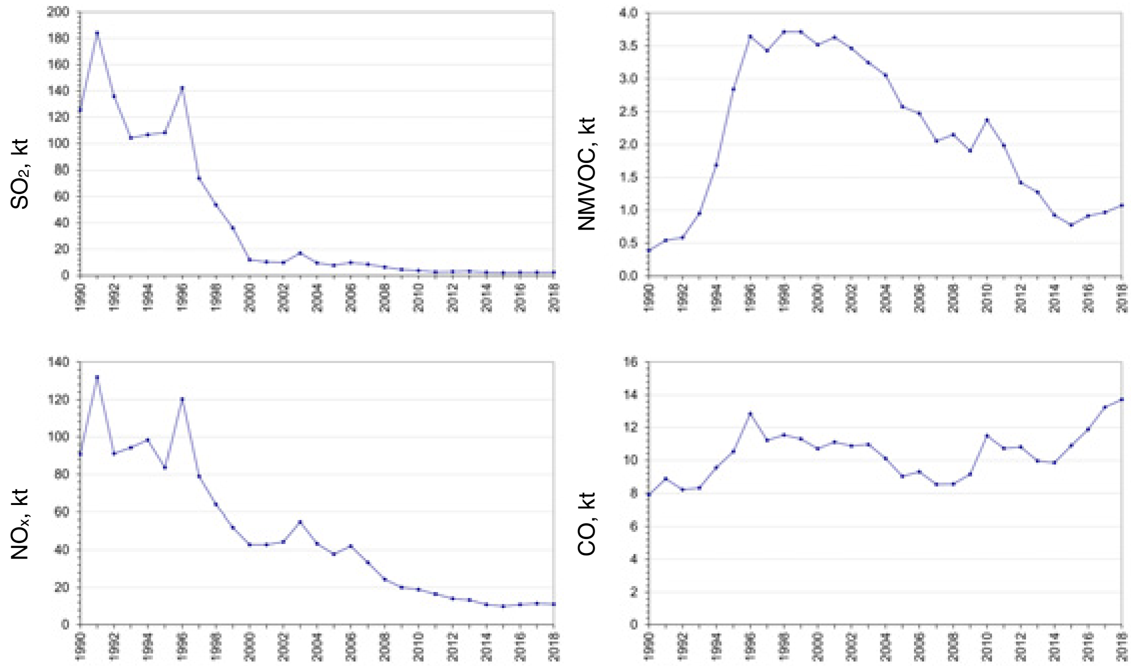



Figure 44 Time series for fuel consumption and for emission of $SO_2$, $NO_x$, NMVOCs and CO from 1A1a Public electricity and heat production.

[9] Including methane.

### 5.1.2 1A1b Petroleum refining

Petroleum refining is a small source category regarding both fuel consumption and emissions for stationary combustion. There are presently two refineries operating in Denmark. Figure 45 and Figure 46 shows the time series for fuel consumption and emissions.

The significant decrease in both fuel consumption and emissions in 1996 is a result of the closure of a third refinery.

The fuel consumption has increased 4 % since 1990 and the $CO_2$ emission has decreased 2 %.

The $CH_4$ emission has increased 1 % since 1990 and decreased 1 % since 2017. The reduction in $CH_4$ emission from 1995 to 1996 is caused by the closure of a refinery.

The $N_2O$ emission was 83 % higher in 2018 than in 1990. The emission increased in 1993 as a result of the installation of a gas turbine in one of the refineries (DEA, 2019b).

The $N_2O$ emission factor for the refinery gas fuelled gas turbine has been assumed equal to the emission factor for natural gas fuelled turbines and thus the emission factor have been decreasing since 2001. The time series for the emission factor cause the decreasing $N_2O$ emission since 2001.

The emission of $SO_2$ has shown a pronounced decrease (86 %) since 1990, mainly because decreased consumption of residual oil (71 %) also shown in Figure 37. The increase in $SO_2$ emission in 1990-1992 also follows the residual oil consumption. The $NO_x$ emission in 2018 was 29 % lower in 2018 than in 1990. Since 2005, data for both $SO_2$ and $NO_x$ are plant-specific data stated by the refineries.

The NMVOC emission time series follows the time series for fuel consumption.

A description of the Danish emission inventory for fugitive emissions from fuels is given in Plejdrup et al. (2015).

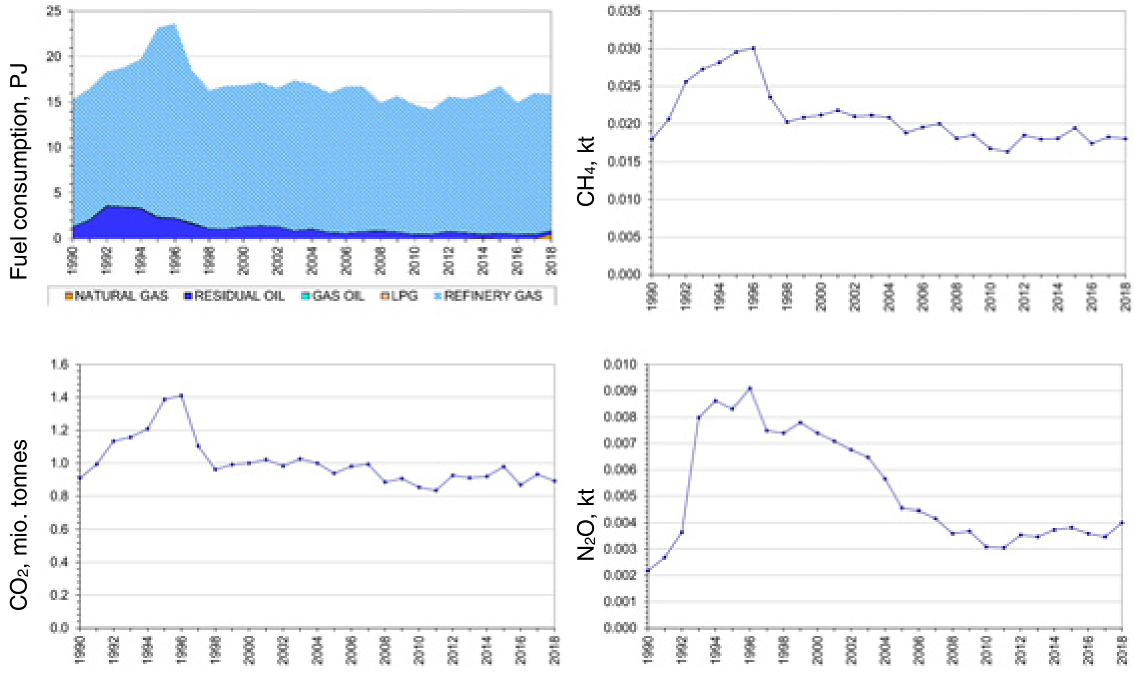



Figure 45 Time series for fuel consumption and GHG emissions from 1A1b Petroleum refining.

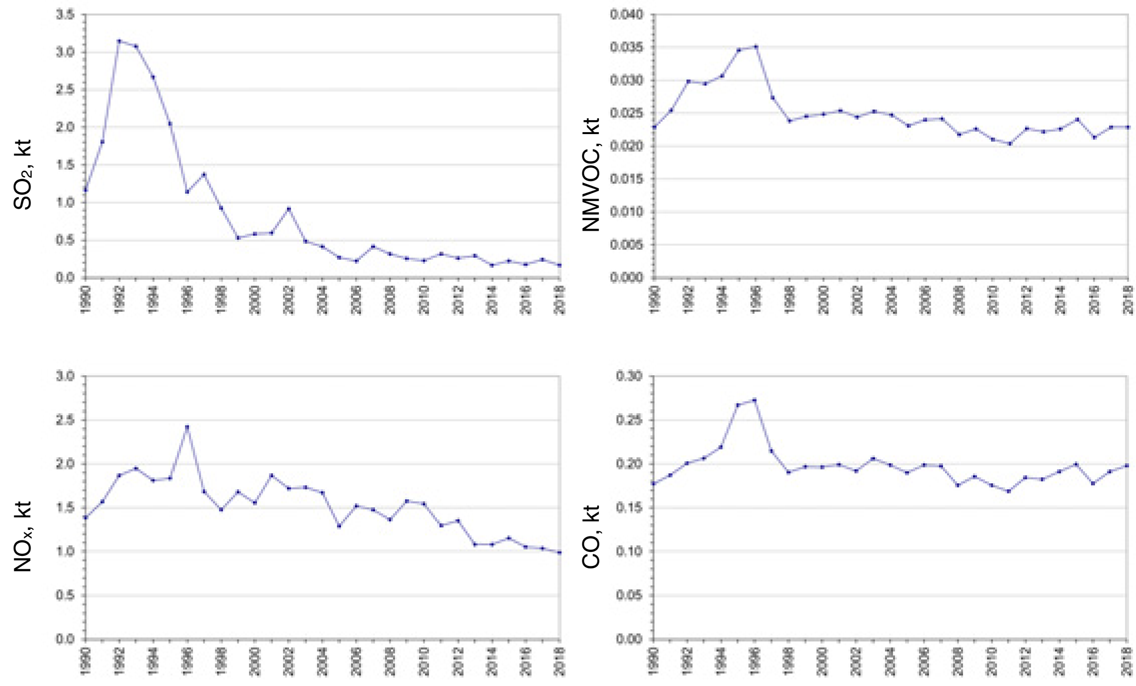



Figure 46 Time series for emission of $SO_2$, $NO_x$, NMVOCs and CO from 1A1b Petroleum refining.

### 5.1.3 1A1c Oil and gas extraction

The source category Oil and gas extraction comprises natural gas consumption in the offshore industry and in addition a small consumption in the Danish gas treatment plant[10]. Gas turbines are the main plant type.

Fugitive emissions from fuels are not included in the sector. Venting and flaring are included in the sector 1B2c Venting and flaring.

Figure 47 and Figure 48 show the time series for fuel consumption and emissions.

The fuel consumption in 2018 was 2.3 times the consumption in 1990. The fuel consumption has decreased since 2008. The $CO_2$ emission follows the fuel consumption and the emission in 2018 was 2.3 times the emission in 1990.

The time series for $N_2O$ emission follows the decreasing emission factor for gas turbines applied in CHP plants.

The emissions follow the increase of fuel consumption.

The decrease of CO emission in 2005 – 2007 is a result of a lower emission factor. This decrease of emission factor is valid for gas turbines in cogeneration plants, but might not be valid for offshore gas turbines. However, the same emission factors have been assumed for CO emission due to the lack of data from offshore gas turbines.

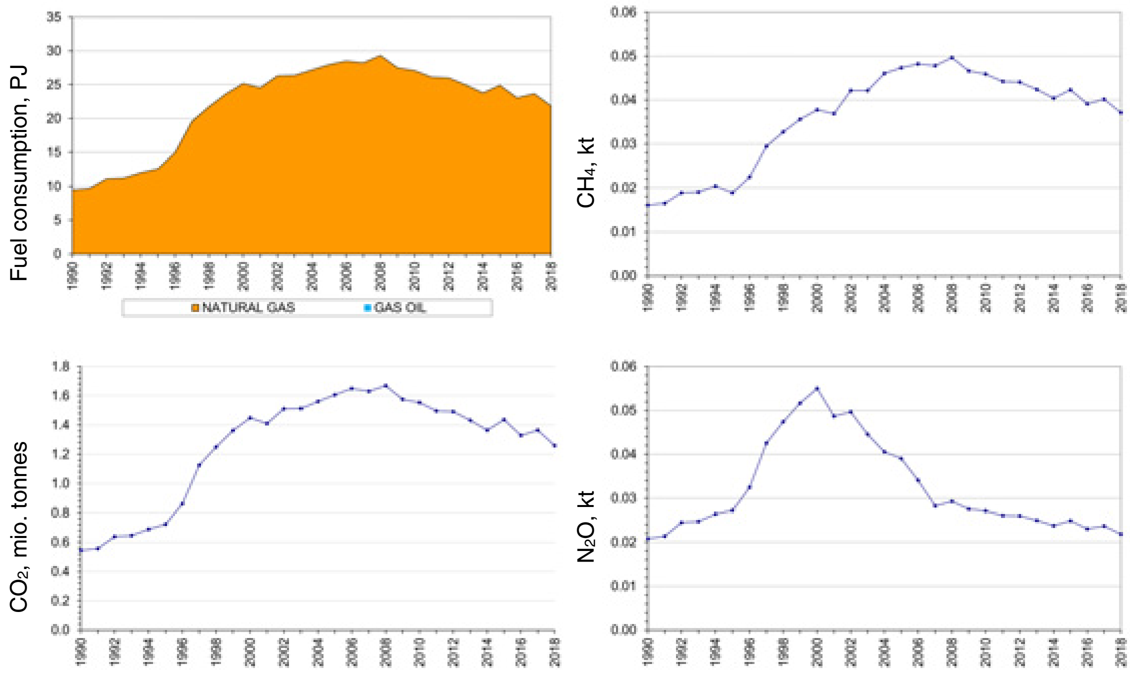



Figure 47 Time series for fuel consumption and GHG emissions from 1A1c Oil and gas extraction.

[10] Nybro.

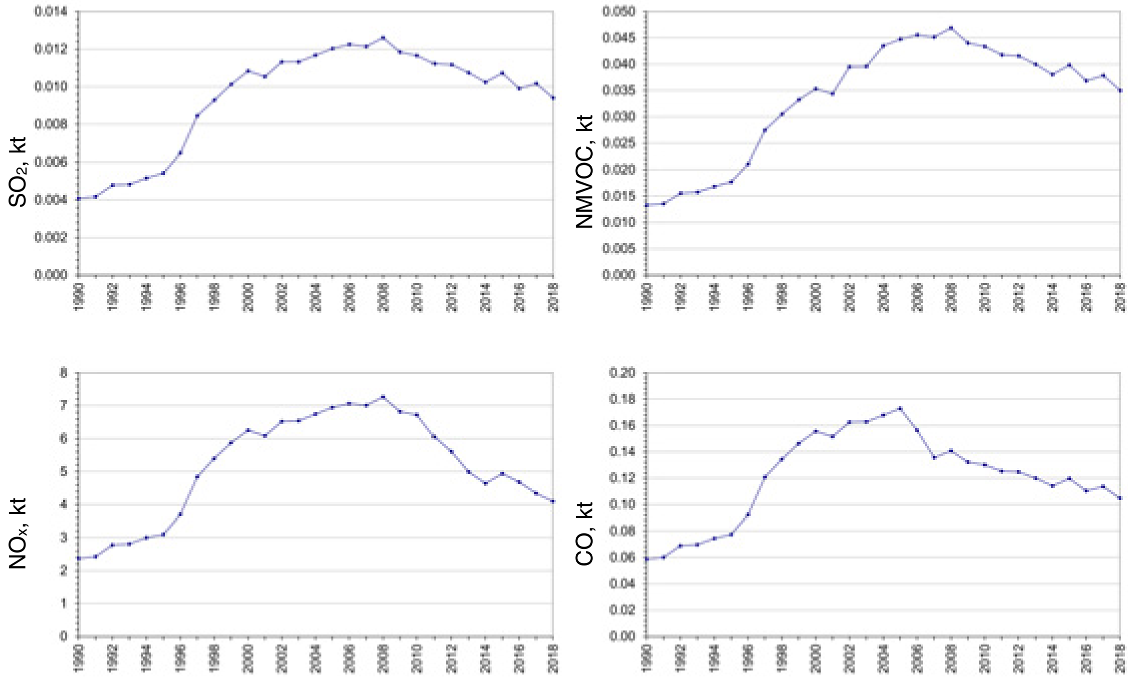



Figure 48 Time series for emission of $SO_2$, $NO_x$, NMVOCs and CO from 1A1c Oil and gas extraction.

## 5.2 1A2 Industry

Manufacturing industries and construction (Industry) consists of both stationary and mobile sources. In this report, only stationary sources are included. Emissions from industrial processes e.g. calcination are not included in the sector stationary combustion.

The emission source category 1A2 Industry consists of the subcategories:

- 1A2a Iron and steel
- 1A2b Non-ferrous metals
- 1A2c Chemicals
- 1A2d Pulp, paper and print
- 1A2e Food processing, beverages and tobacco
- 1A2f Non-metallic minerals
- 1A2 g viii Other manufacturing industry

The figures 49-54 show the time series for fuel consumption and emissions. The subsectors Non-metallic minerals, Other manufacturing industry and Food processing, beverages and tobacco are the main subsectors for fuel consumption and emissions.

The total fuel consumption in industrial combustion was 13 % lower in 2018 than in 1990. The consumption of natural gas has increased since 1990 whereas the consumption of coal has decreased. The consumption of residual oil has decreased, but the consumption of petroleum coke increased. The biomass consumption in 2018 was 2.2 times the consumption in 1990.

The greenhouse gas emission and the $CO_2$ emission are both rather stable until 2006 following the small fluctuations in fuel consumption. The emission decreased in 2006-2009. Due to change of applied fuels, the greenhouse gas and $CO_2$ emissions have decreased more than the fuel consumption since 1990; The GHG emission has decreased 30 % since 1990 and the $CO_2$ emission has decreased 31%.

The $CH_4$ emission has increased from 1994-2001 and decreased again from 2001 - 2007. In 2018, the emission was 3.2 times the emission level in 1990. The $CH_4$ emission follows the consumption of natural gas and biogas in gas engines (Figure 49). Most industrial CHP plants based on gas engines came in operation in the years 1995 to 1999. The decrease after 2004 is a result of the liberalisation of the electricity market. The increased emission after 2013 is related to new biogas fuelled gas engines in the food industry. The $CH_4$ emission factor for gas engines is higher than for other plant technologies, see Chapter 7.3.1. The $CH_4$ emission factor for natural gas fuelled engines is higher than for biogas-fuelled engines due to different engine technologies applied for the two fuels. A high share of natural gas is combusted in large prechamber engines whereas smaller open chamber lean-burn engines is the main technology for biogas-fuelled engines.

The $N_2O$ emission has increased 11 % since 1990. The emission from mineral wool production[11] is a large emission source, and the production of mineral

[11] Included in sector 1A2g viii Other manufacturing industry.

wool production has increased in later years. This cause the increase of the $N_2O$ emission in recent years.

The increase of $N_2O$ emission from 1994 to 1995 is related to combustion of coke oven coke in mineral wool production. Plant-specific fuel consumption data are only available from 1995 onwards for the mineral wool production plants.

The $SO_2$ emission has decreased 84 % since 1990. This is mainly a result of lower consumption of residual oil in the industrial sector (Figure 49). Further, the sulphur content of residual oil and several other fuels has decreased since 1990 due to legislation and tax laws.

The $NO_x$ emission has decreased 57 % since 1990 due to the reduced emission from industrial boilers in general. Cement production is the main emission source accounting for more than 30 % of the industrial emission in 1990-2018[12].

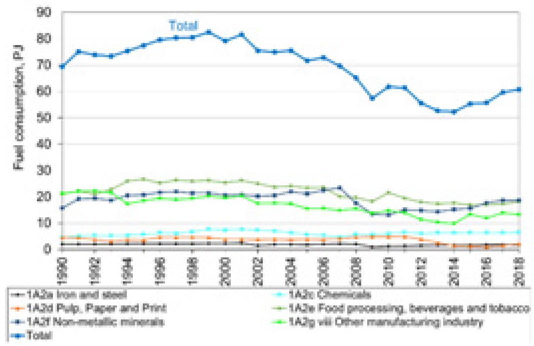
The $NO_x$ emission from cement production was reduced considerably in 2009-2013. The emission increased in 2013-2018. The $NO_x$ emission from cement industry was 42 % of the total emission from manufacturing industries and construction in 2018. The $NO_x$ emission from cement production was reduced 42 % since 1990. The reduced emission is a result of installation of SCR on all production units at the cement production plant in 2004-2007[13] and improved performance of the SCR units in recent years. A $NO_x$ tax was introduced in 2010 (DMT, 2008). The increase in 2015-2018 is related to a reduction of the $NO_x$ tax from 2015 (DMT, 2015).

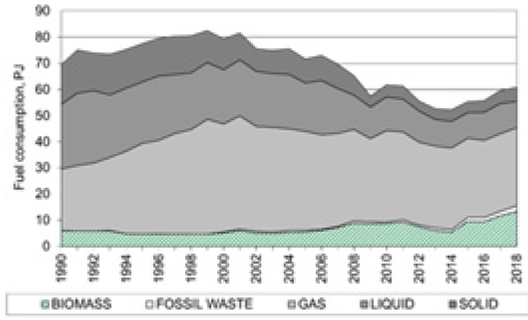
The NMVOC emissions has decreased 36 % since 1990. The decrease is mainly a result of decreased emission factor for combustion of wood in industrial boilers. The emission from gas engines has however increased considerably after 1995 due to the increased fuel consumption that is a result of the installation of a large number of industrial CHP plants (Figure 49). The NMVOC emission factor for gas engines is much higher than for boilers regardless of the fuel.

The CO emission in 2018 was 40 % higher than in 1990. The main sources of CO emission are combustion of wood and cement production. The CO emission from mineral wool production is included in the industry sector (2A6). The increased of emission in 1998 is related to the cement production plant in Denmark. The CO emission increased due to combustion of more paper pulp. In the following years, the combustion of this fuel was improved to decrease the CO emission (Annual environmental reports from Aalborg Portland, 1998-2002).

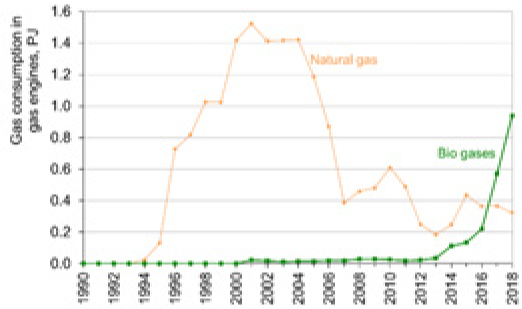
[12] More than 73 % of sector 1A2f i.

[13] To meet emission limit.




Fuel consumption in gas fuelled engines




Fuel consumption, residual oil and wood

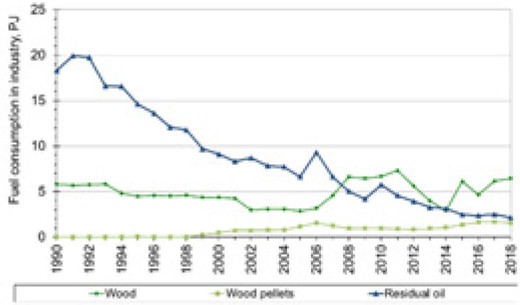



Figure 49 Time series for fuel consumption, 1A2 Industry.

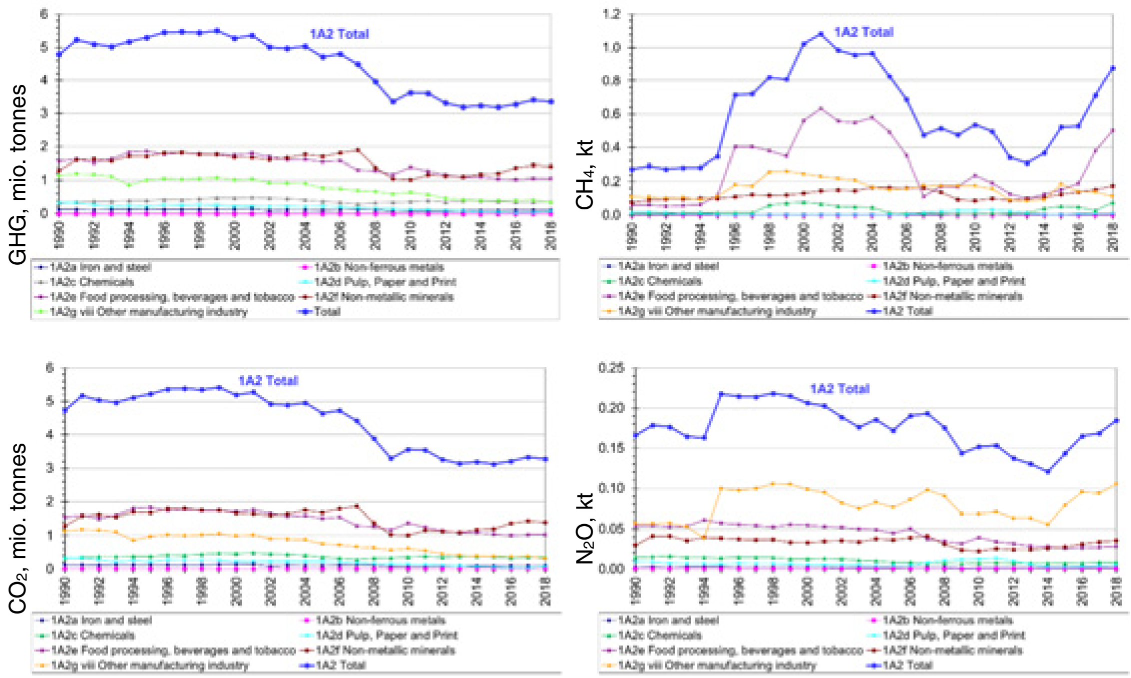



Figure 50 Time series for greenhouse gas emissions, 1A2 Industry.

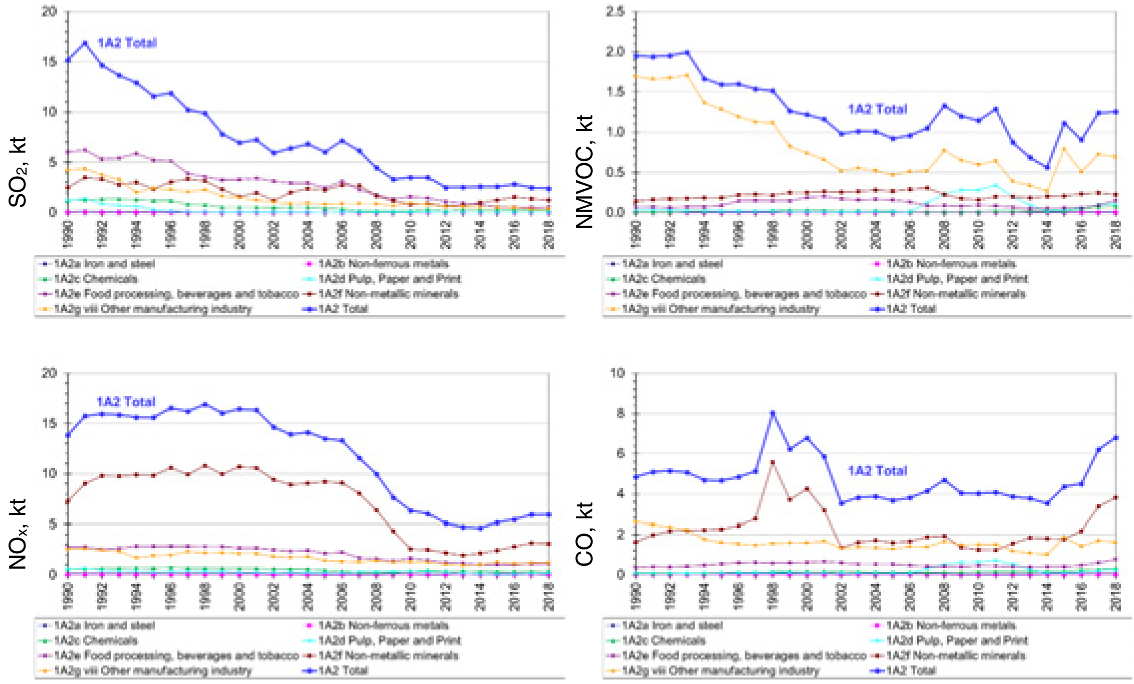



Figure 51   Time series for emission of $SO_2$, $NO_x$, NMVOC and CO, 1A2 Industry.

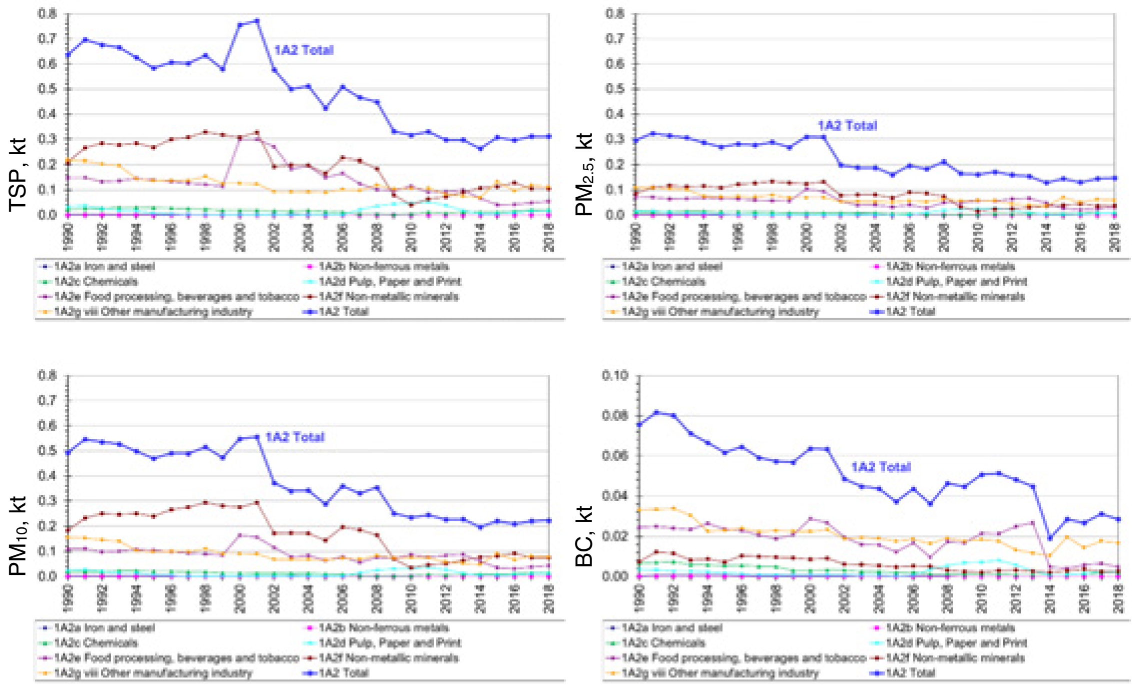



Figure 52   Time series for PM and BC emission, 1A2 Industry.

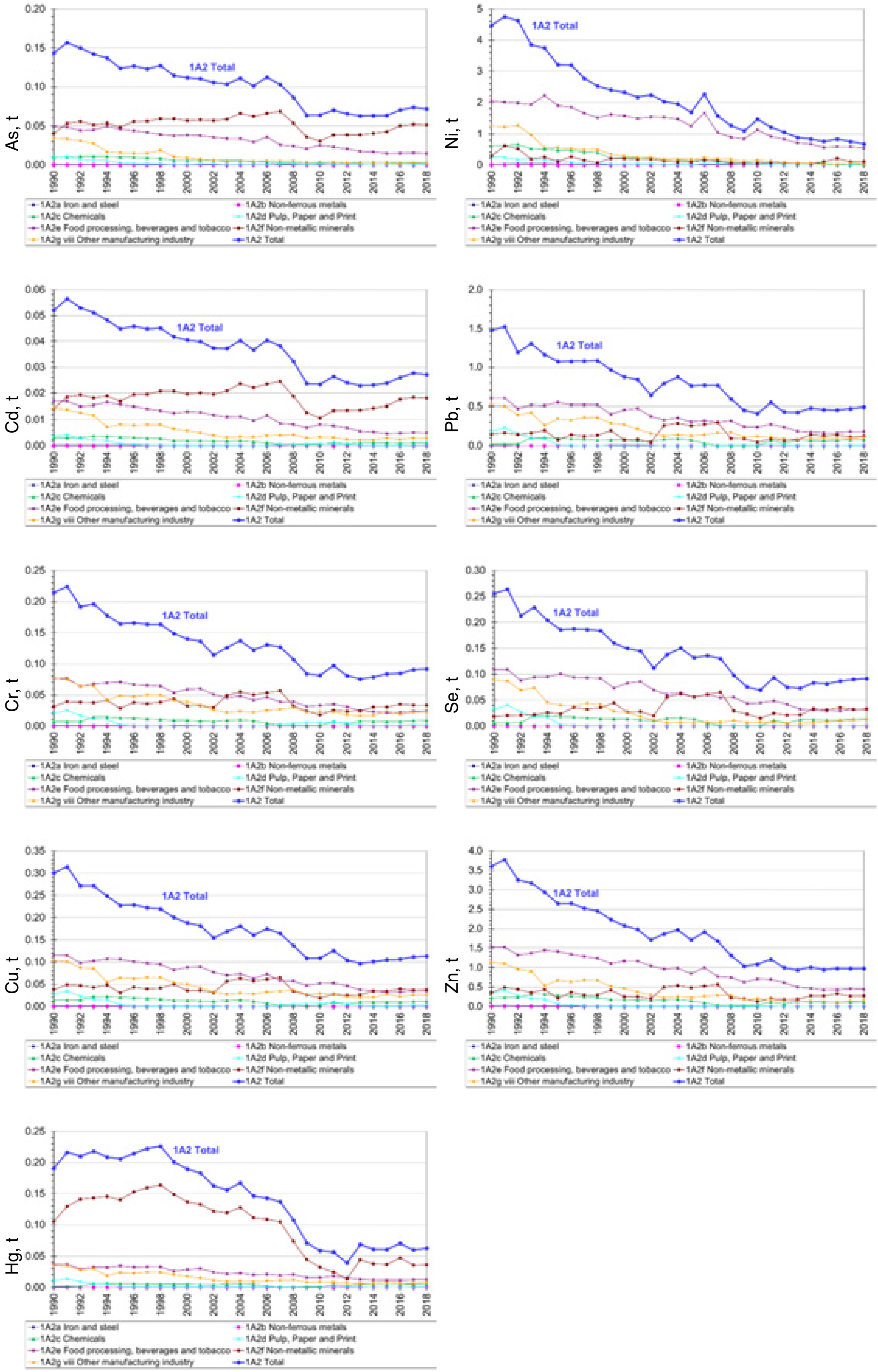



Figure 53 Time series for HM emissions, 1A2 Industry.

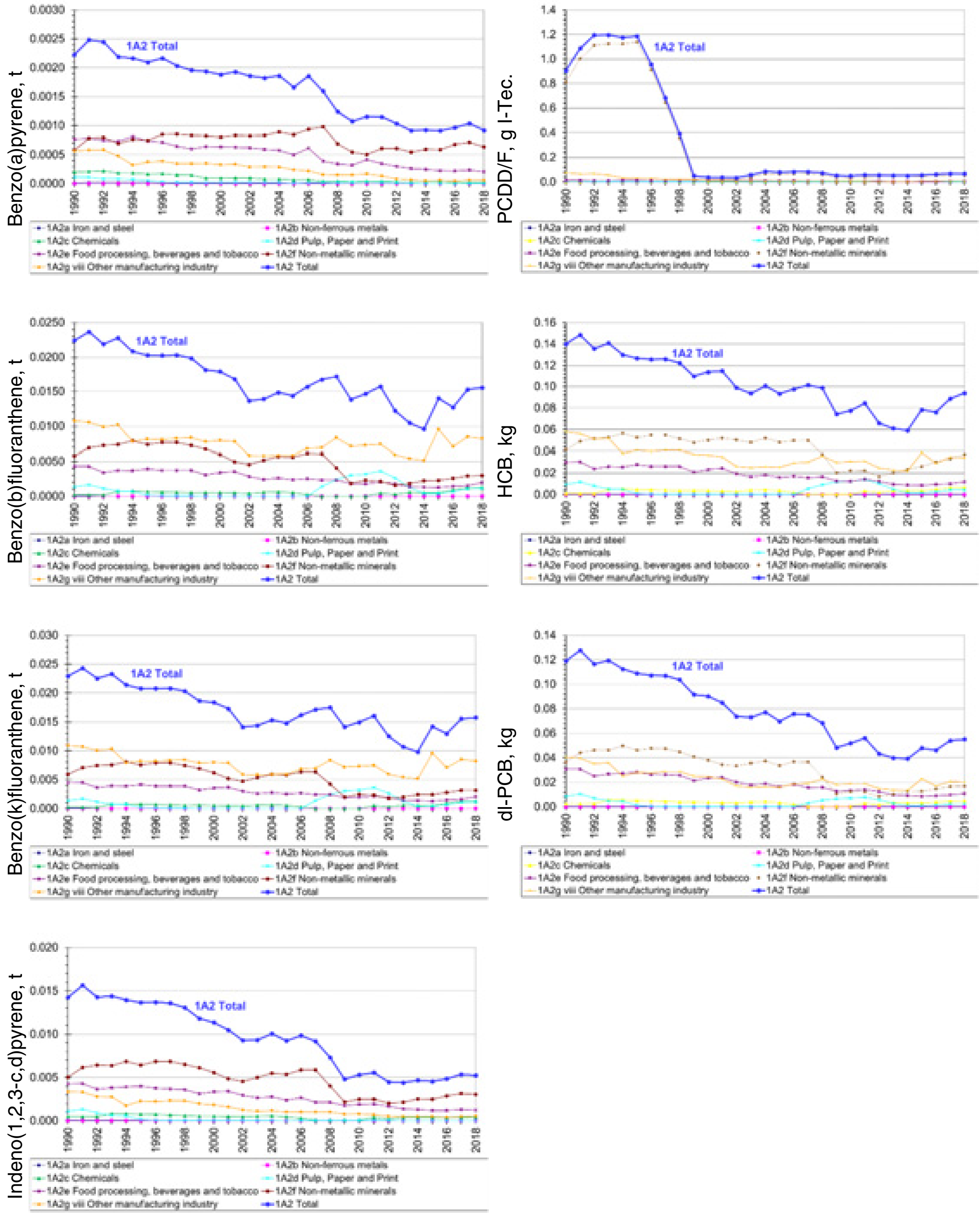



Figure 54 Time series for emission of PAHs, PCDD/Fs, HCB and dioxin-like PCBs, 1A2 Industry.

### 5.2.1 1A2a Iron and steel

Iron and steel is a very small emission source category. Figure 55 and Figure 56 show the time series for fuel consumption and emissions.

Natural gas is the main fuel in the subsector.

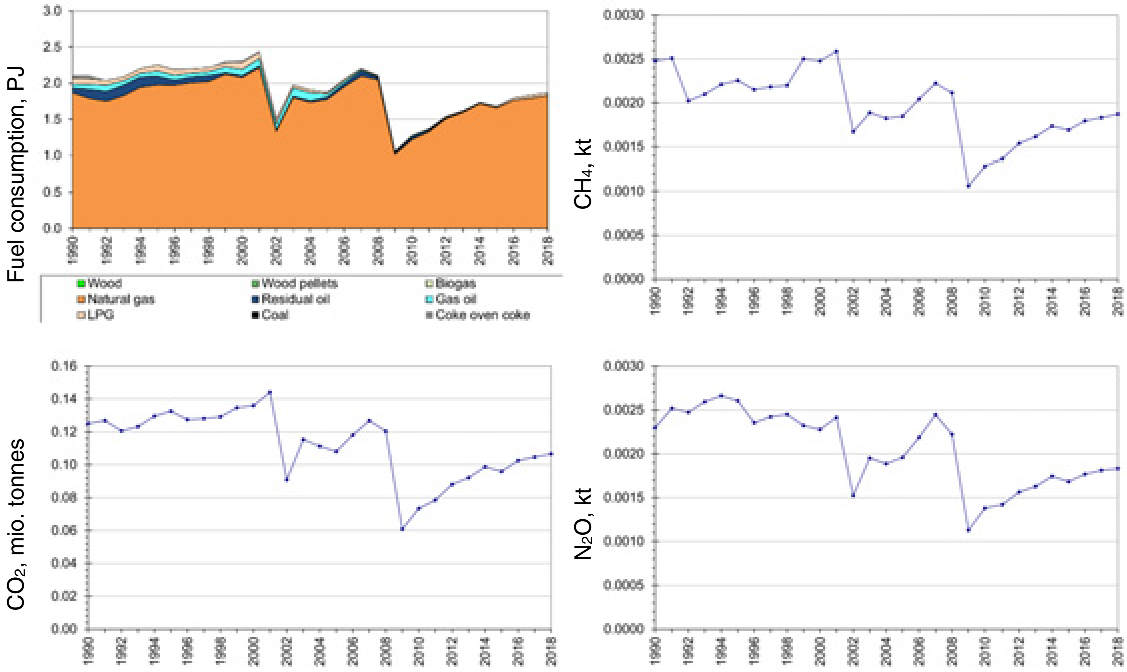



Figure 55 Time series for fuel consumption and GHG emissions from 1A2a Iron and steel.

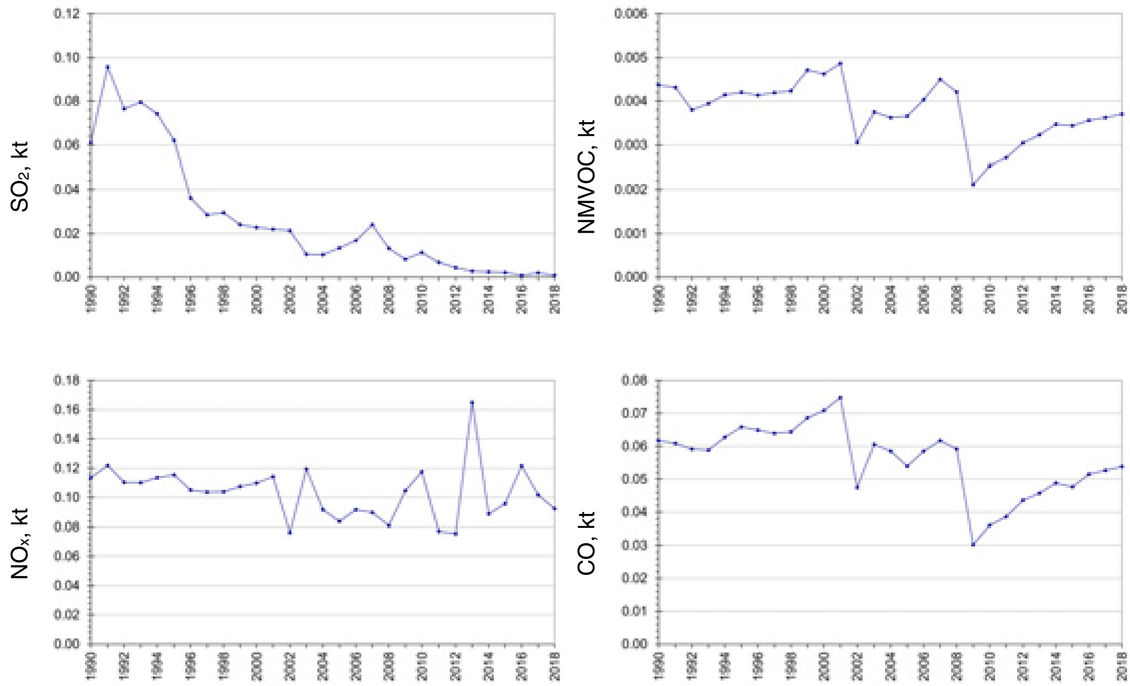



Figure 56 Time series for emission of $SO_2$, $NO_x$, NMVOCs and CO from 1A2a Iron and steel.

### 5.2.2 1A2b Non-ferrous metals

The energy statistics have been recalculated and now no fuel consumption is reported for non-ferrous metals.

### 5.2.3 1A2c Chemicals

Chemicals is a minor emission source category. Figure 57 and Figure 58 show the time series for fuel consumption and emissions.

Natural gas is the main fuel in this subsector. The $CO_2$ emission time series follow the time series for fuel consumption. The time series for $CH_4$ emission 1997-2006 is related to consumption of natural gas in gas engines. The increased $CH_4$ emission in 2014 to 2018 is related to one biogas fuelled engine. The decreasing time series for $N_2O$ emission is related to the decreasing consumption of residual oil.

Natural gas is the main fuel in this subsector. The consumption of residual oil has decreased and the $SO_2$ emission follows this fuel consumption. The increased emission of NMVOCs and CO in 2016-2018 is related to the consumption of wood.

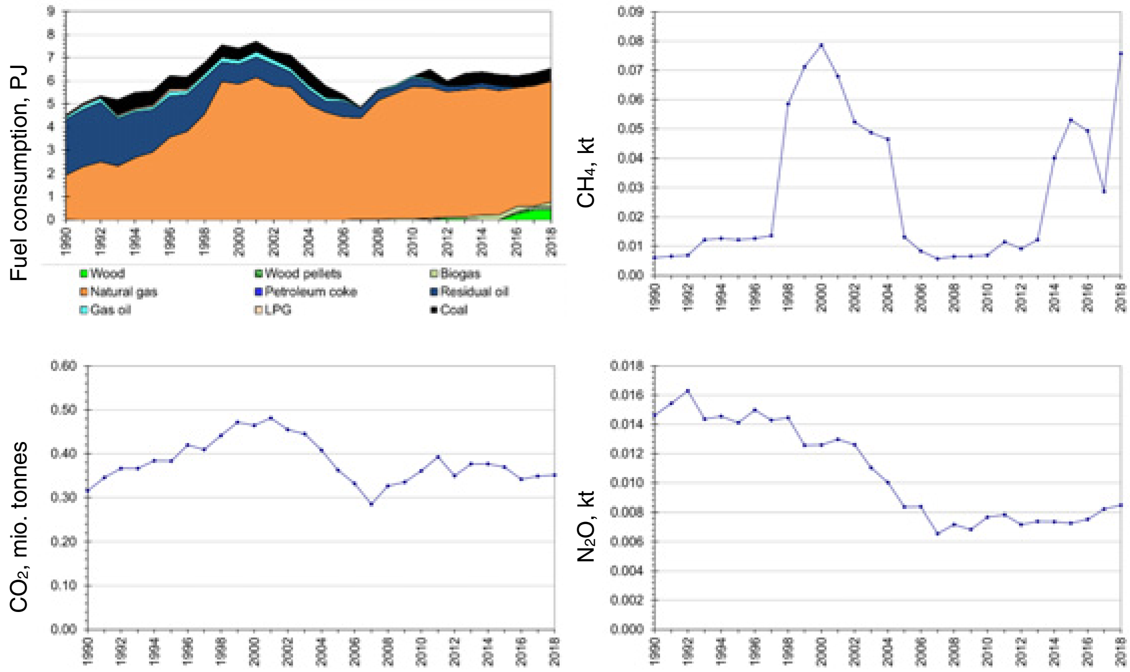



Figure 57 Time series for fuel consumption and GHG emissions from 1A2c Chemicals.

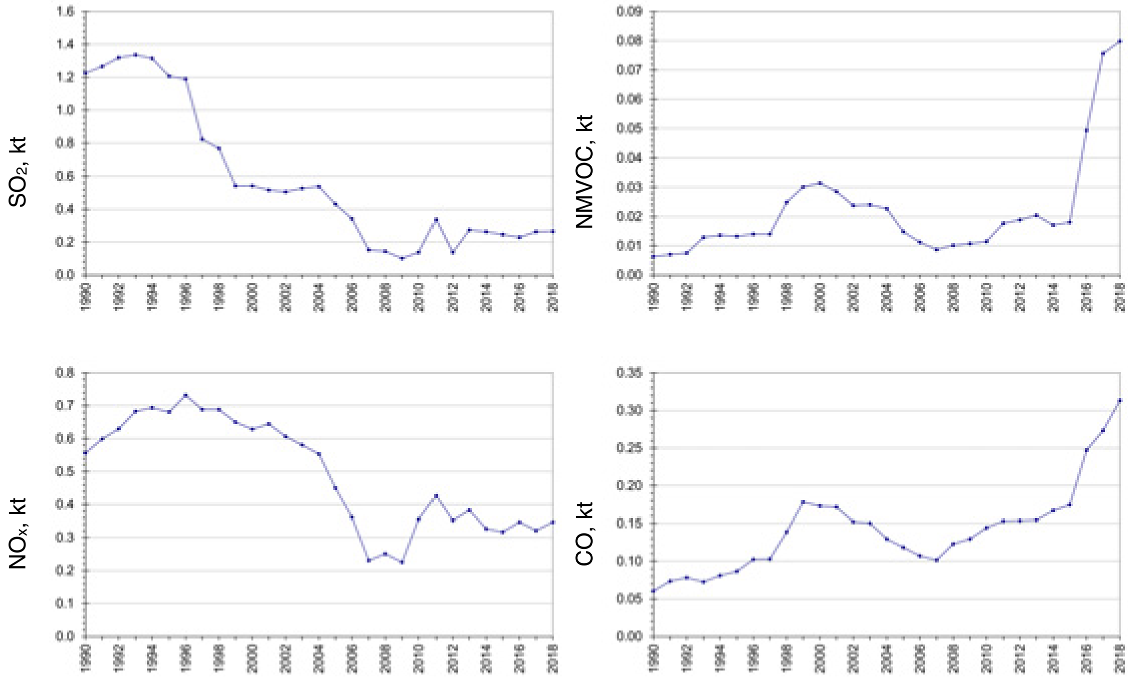



Figure 58 Time series for emission of $SO_2$, $NO_x$, NMVOCs and CO from 1A2c Chemicals.

### 5.2.4 1A2d Pulp, paper and print

Pulp, paper and print is a minor emission source category. Figure 59 and Figure 60 show the time series for fuel consumption and emissions.

The fuel consumption decreased 51 % from 1990. The time series is related to both closure of plants and new combustion units in exiting plants. In addition, the liberalisation of the electricity market caused less operational hours of a natural gas fuelled gas turbine. Natural gas, and in 2007-2013 also wood, are the main fuels in the subsector. The increased use of wood from 2007 is reflected in the $CO_2$ emission time series.

The increased consumption of wood in 2007-2013 is also reflected in the $CH_4$ and $N_2O$ emission time series.

The consumption of coal and residual oil has decreased and this is reflected in the $SO_2$ emission time series. The increased consumption of wood in 2007-2012 has resulted in a considerable increase and decrease in NMVOCs and CO emission in 2007-2012.

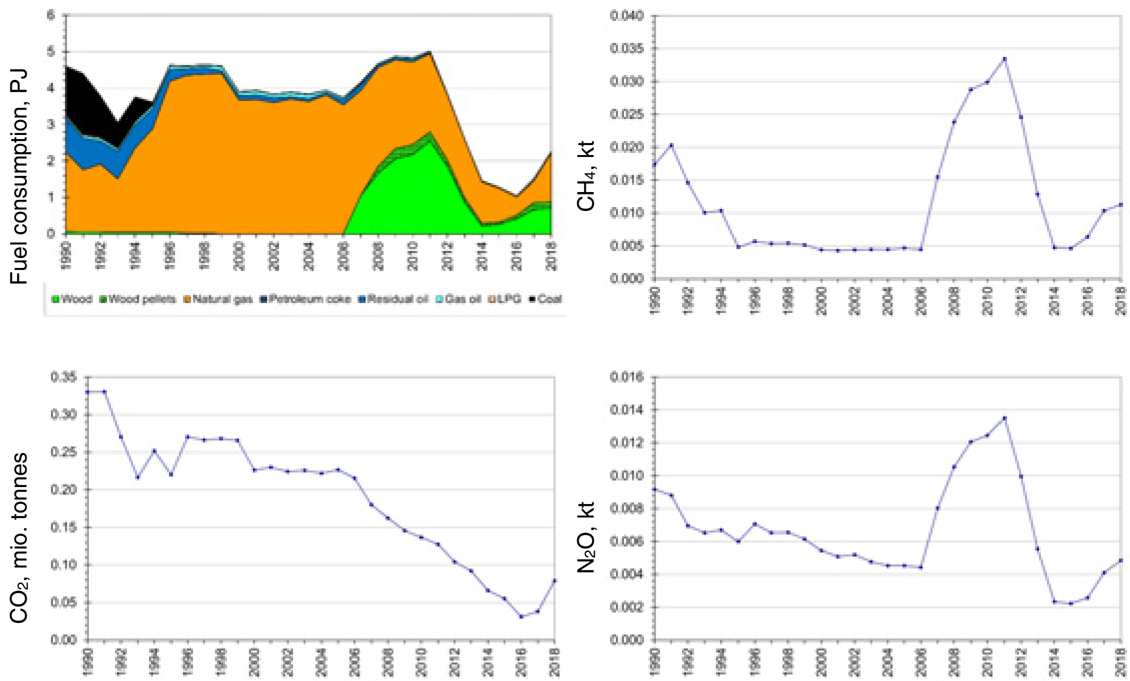



Figure 59 Time series for fuel consumption and GHG emissions from 1A2d Pulp, paper and print.

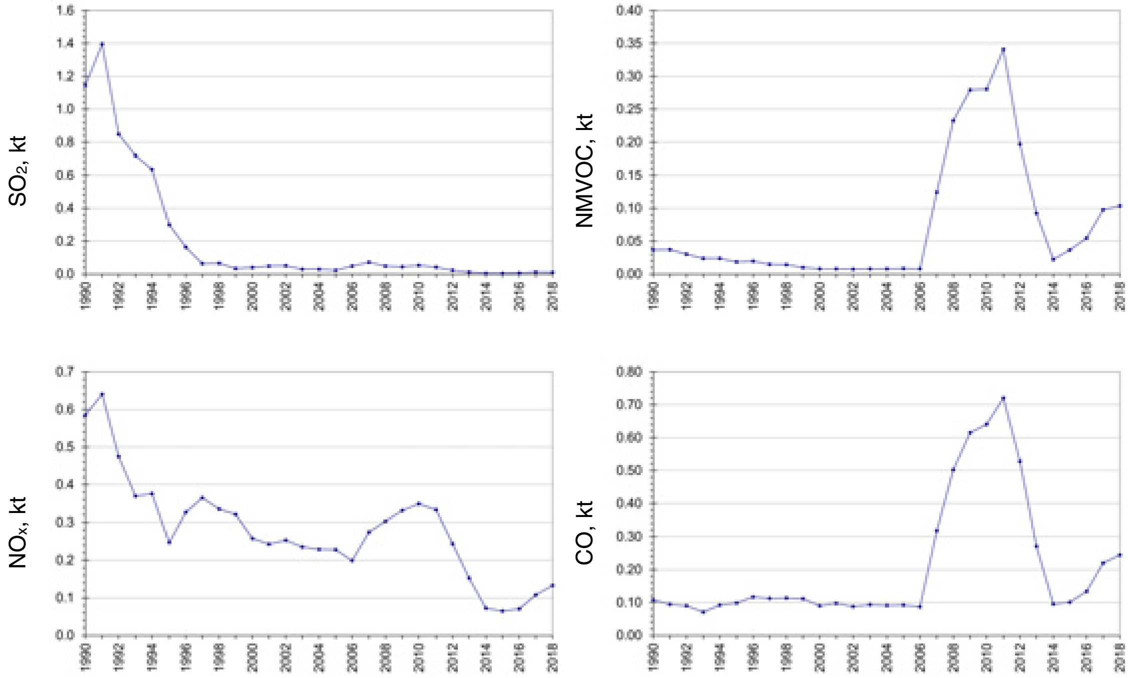



Figure 60 Time series for emission of $SO_2$, $NO_x$, NMVOCs and CO from 1A2d Pulp, paper and print.

### 5.2.5 1A2e Food processing, beverages and tobacco

Food processing, beverages and tobacco is a considerable industrial subsector. Figure 61 and Figure 62 show the time series for fuel consumption and emissions.

Natural gas, residual oil and coal are the main fuels in the subsector. The consumption of coal and residual oil has decreased whereas the consumption of natural gas has increased.

The time series for $CH_4$ emission follows the consumption of natural gas in gas engines.

The decreased consumption of residual oil and coal is reflected in the $SO_2$ emission time series.

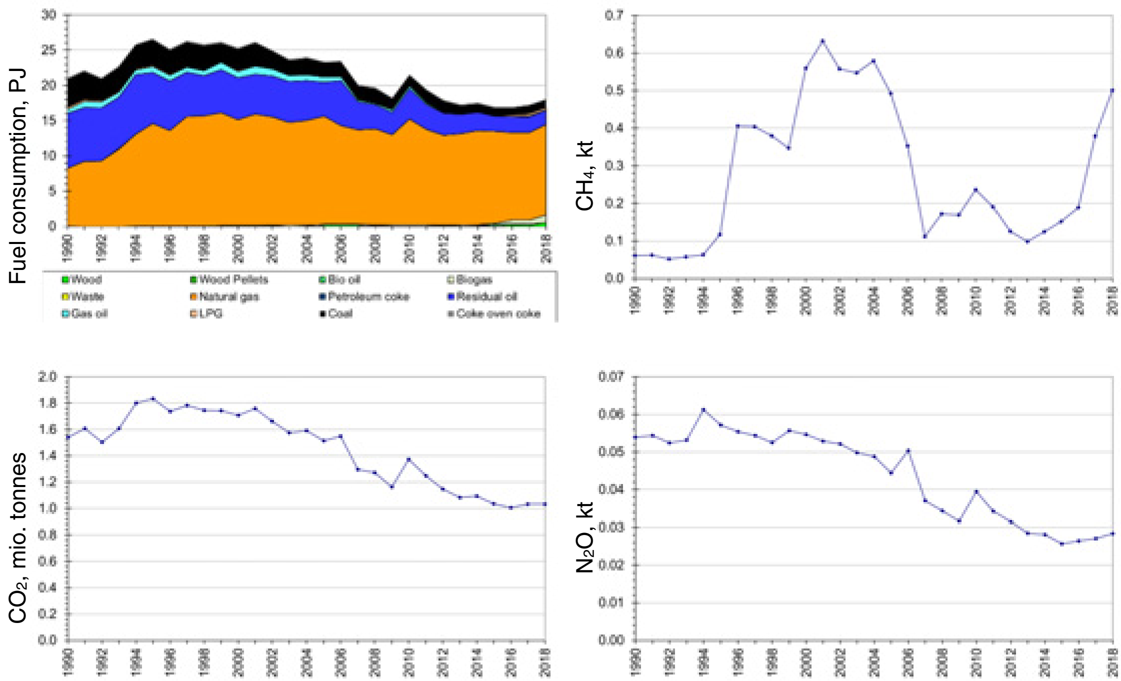



Figure 61 Time series for fuel consumption and GHG emissions from 1A2e Food processing, beverages and tobacco.

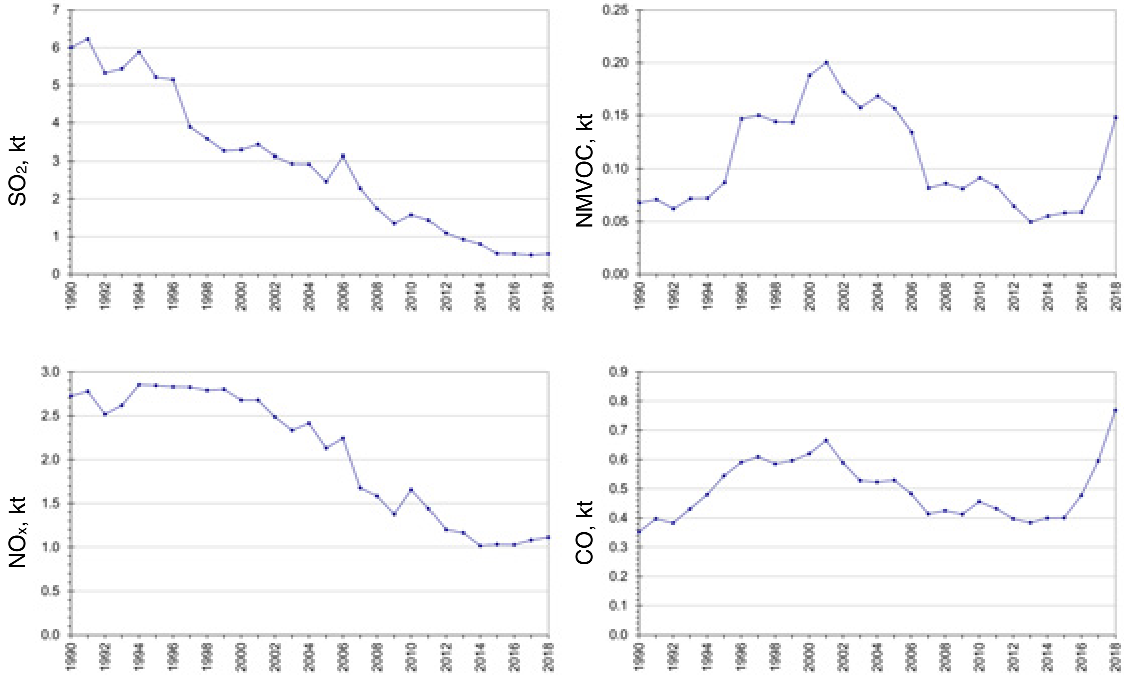



Figure 62 Time series for emission of $SO_2$, $NO_x$, NMVOCs and CO from 1A2e Food processing, beverages and tobacco.

### 5.2.6 1A2f Non-metallic minerals

Non-metallic minerals is a considerable industrial subsector. The subsector includes cement production that is a major industrial emission source in Denmark. Figure 63 and Figure 64 shows the time series for fuel consumption and emissions.

Petroleum coke, natural gas, industrial waste and coal are the main fuels in the subsector in recent years. The consumption of coal and residual oil has decreased.

Due to the global recession, cement production decreased in 2008 and 2009, but has slightly increased since then. This is reflected in the time series.

Emissions from industrial processes e.g. calcination are not included in the sector stationary combustion. Thus, the $CO_2$ time series for cement production shown in Figure 63 is only for combustion of fossil fuels in the cement industry. The calcination in cement industry is included in the emission inventory sector 2A Industrial processes and product use, Mineral industry.

The reduced $NO_x$ emission is a result of installation of SCR on all production units at the cement production plant in 2004-2007[14] and improved performance of the SCR units in the following years. A $NO_x$ tax was introduced in 2010 (DMT, 2008). The $NO_x$-tax was reduced after 2015 (DMT, 2015).

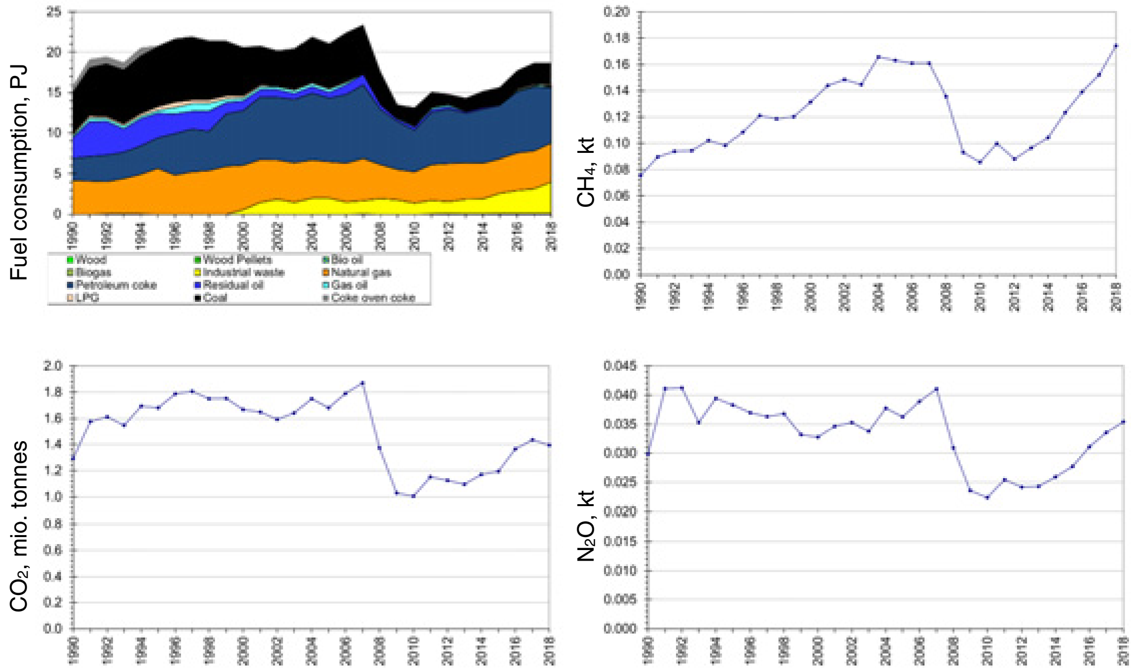



Figure 63 Time series for fuel consumption and GHG emissions from 1A2f Non-metallic minerals.

[14] To meet emission limit.

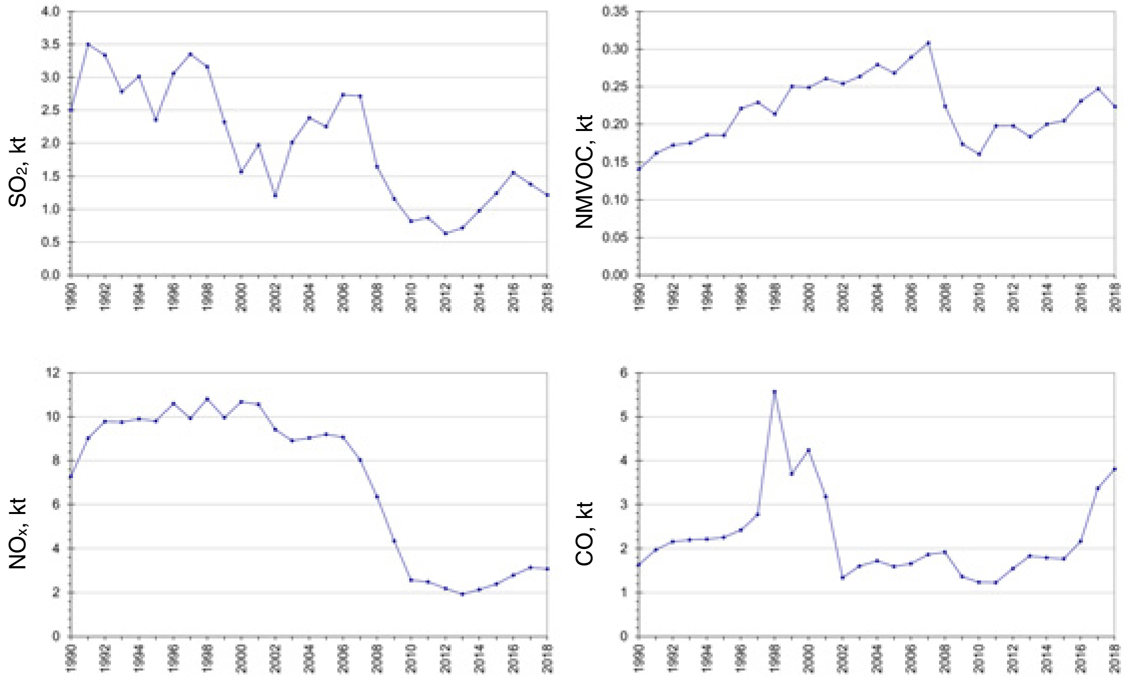



Figure 64 Time series for emission of $SO_2$, $NO_x$, NMVOCs and CO from 1A2f Non-metallic minerals.

## 5.2.7 1A2g Other manufacturing industry

Other manufacturing industry is a considerable industrial subsector including Process furnaces without contact, Food and tobacco industry, Textile and leather industry, Transport Equipment, Machinery, Wood and wood products, Construction and Non-specified industry. Figure 65 and Figure 66 show the time series for fuel consumption and emissions.

Natural gas and wood are the main fuels in the subsector in recent years. The consumption of coal and residual oil has decreased.

The time series for $CH_4$ is related to the consumption of natural gas in gas engines.

Combustion of coke oven coke in mineral wool production is a large emission source for $N_2O$. Plant-specific fuel consumption rates for the mineral wool production plants are available from 1995. This causes the increase in $N_2O$ emission between 1994 and 1995.

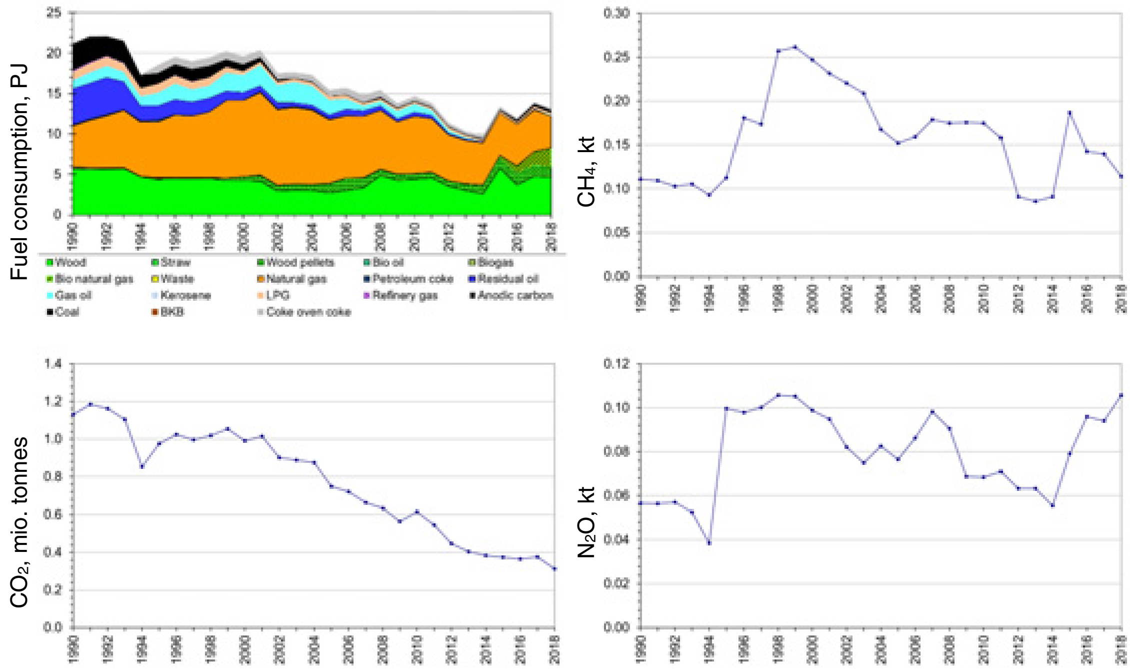



Figure 65 Time series for fuel consumption and GHG emissions from 1A2g Industry - other.

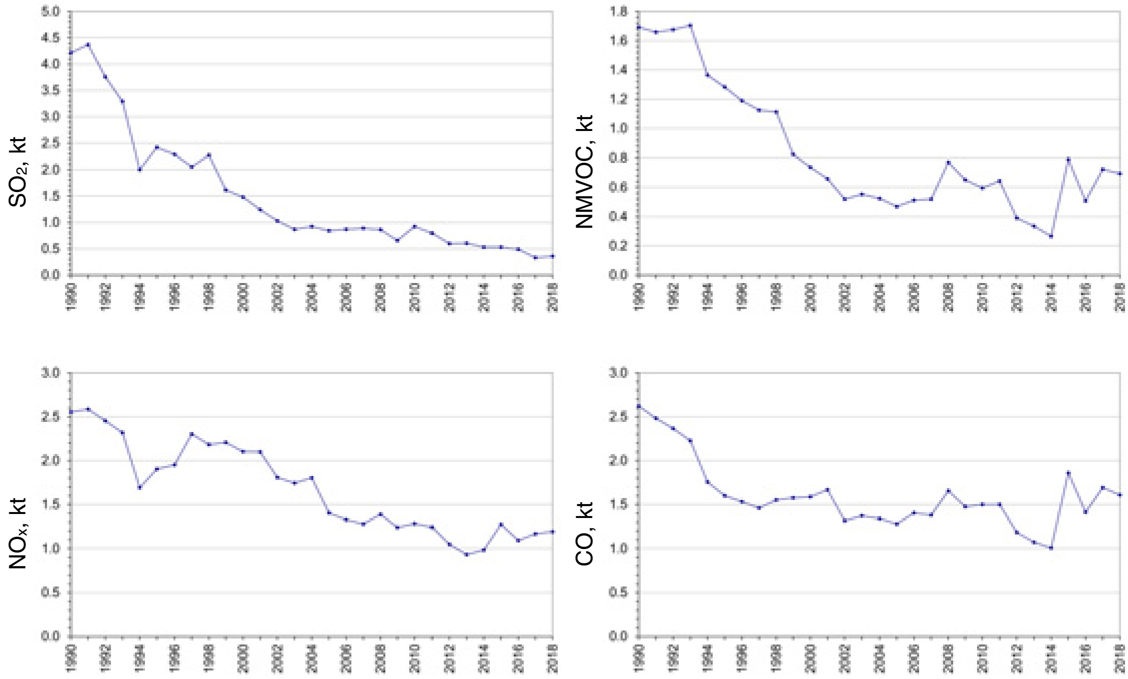



Figure 66 Time series for emission of $SO_2$, $NO_x$, NMVOCs and CO from 1A2g Other manufacturing industry.

## 5.3 1A4 Other sectors

The emission source category 1A4 Other sectors consists of the subcategories:

- 1A4a Commercial/institutional plants.
- 1A4b Residential plants.
- 1A1c Agriculture/forestry.

The Figures 67-72 present time series for this emission source category. Residential plants are the dominant subcategory accounting for the largest part of all emissions. Time series for GHGs, $SO_2$, $NO_x$, NMVOCs and CO are discussed below for each subcategory.

The PM emissions increased until 2007 and decreased after 2007. The increase until 2007 was caused by the increased wood combustion in residential plants. However, the PM emission factors have decreased for this emission source category due to installation of modern stoves and boilers (see Chapter 6.13). The stabilisation of wood consumption in residential plants in 2007-2014 has resulted in a decrease of PM emission from stationary combustion between 2007 and 2014. The PM emission data for residential wood combustion include condensable particles.

The emission of BC was 16 % higher in 2018 than in 1990. The largest emission sources for BC is combustion of wood and straw in residential plants and in agricultural/forestry plants. The combustion of wood in residential plants has increased since 1990, but the emission factor has decreased due to implementation of new improved stoves and boilers, see Chapter 6.13.

The emission of some HMs has increased since 1990, whereas the emission of other HMs has decreased. The decreased emissions are related to lower consumption of solid and liquid fossil fuels and waste. The emissions of Zn and Cd have increased due to a considerable emission from residential wood combustion even in 1990. The emission factors for HMs from residential wood combustion are not considered dependent of combustion technology (Chapter 6.13), and thus the increasing consumption of wood is reflected in the HM emissions.

Residential wood combustion is the predominant emission source for PAH emissions. The emission factors applied for residential wood combustion are technology dependent (Chapter 6.13) and thus the PAH emissions decrease in spite of the increasing consumption of wood.

The emission of PCDD/F has increased since 1990. The main emission source is residential wood combustion. The dioxin emission factors for residential wood combustion are dependent on the wood origin but independent of stove technology (Chapter 6.13). Thus, the dioxin emission from residential wood combustion has not decreased similar to e.g. the PM and PAH emissions due to replacements of old stoves and boilers.

The emission of dl-PCBs have decreased mainly due to decreased emission from Commercial/institutional plants. This is a result of decreased consumptions of solid and liquid fuels and waste in this sector.

The HCB emission time series follows the fuel consumption of coal in residential plants. The HCB emission factor for coal used in residential plants is high compared to other fuels.

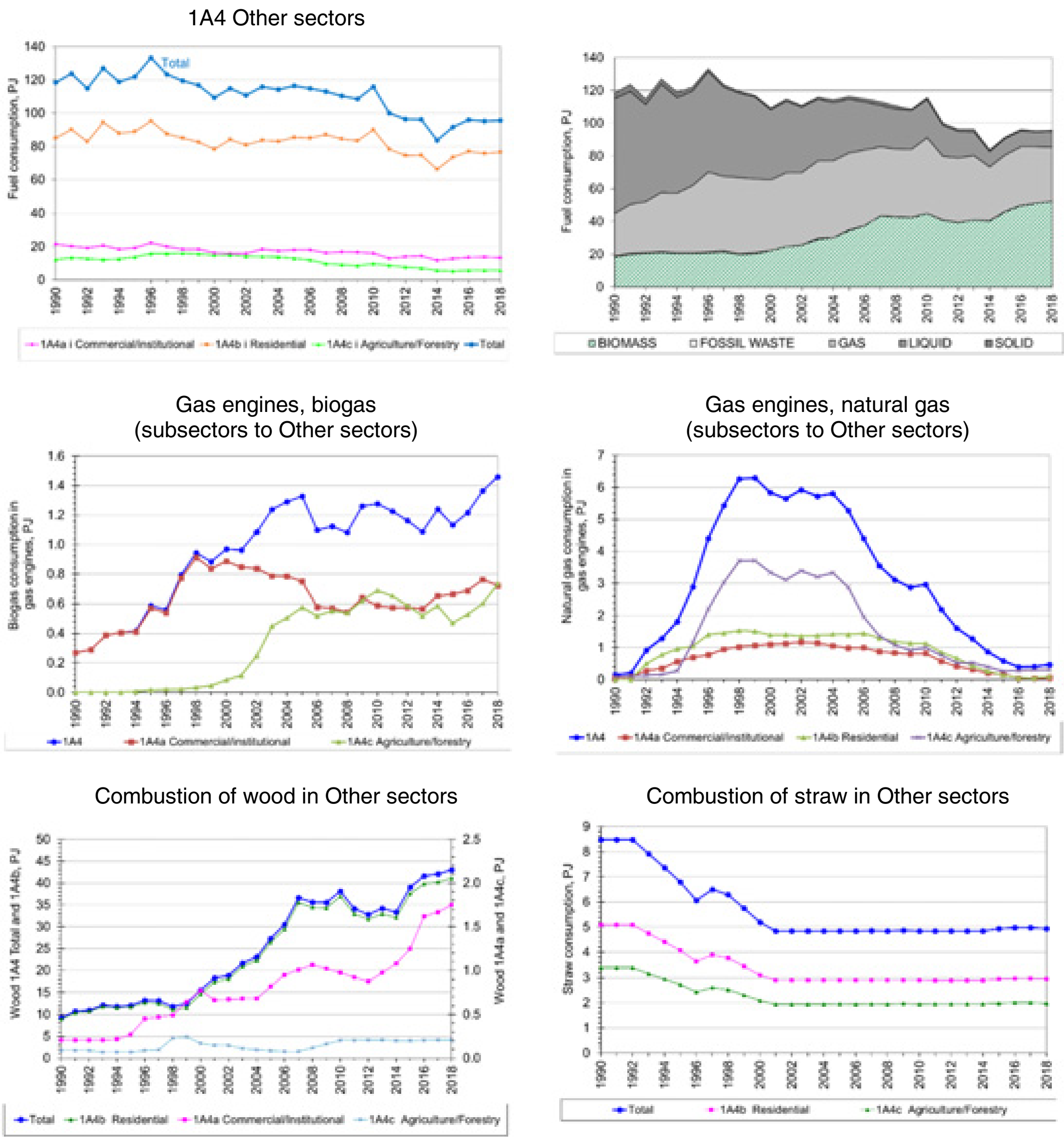



Figure 67 Time series for fuel consumption, 1A4 Other sectors.

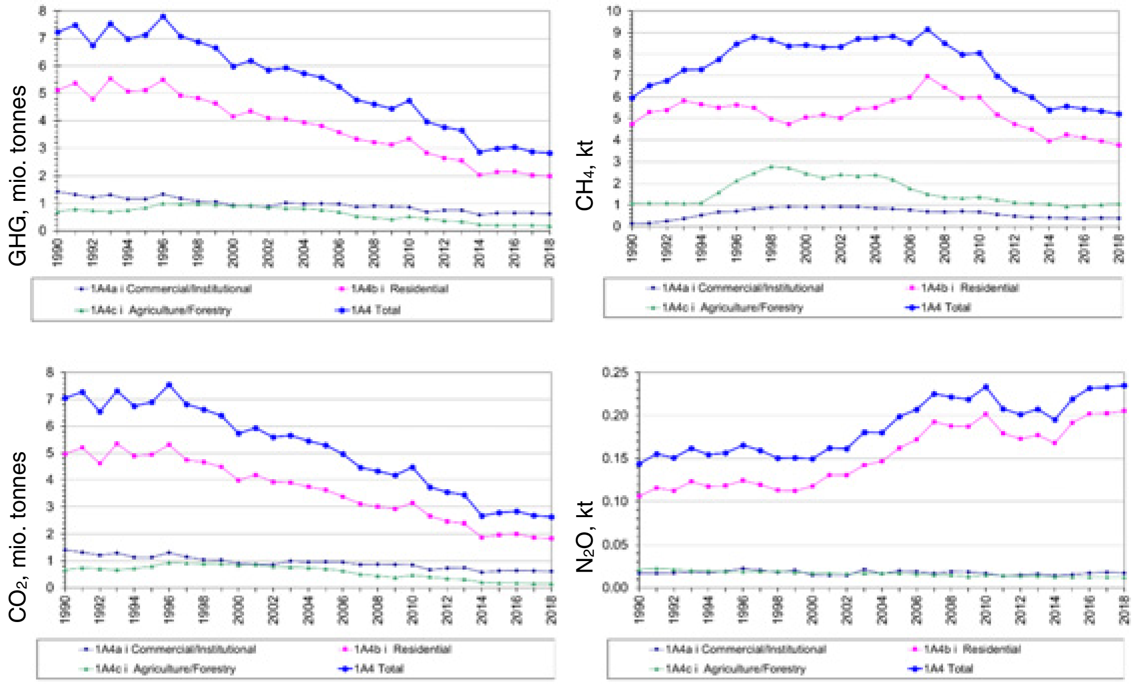



Figure 68 Time series for greenhouse gas emission, 1A4 Other sectors.

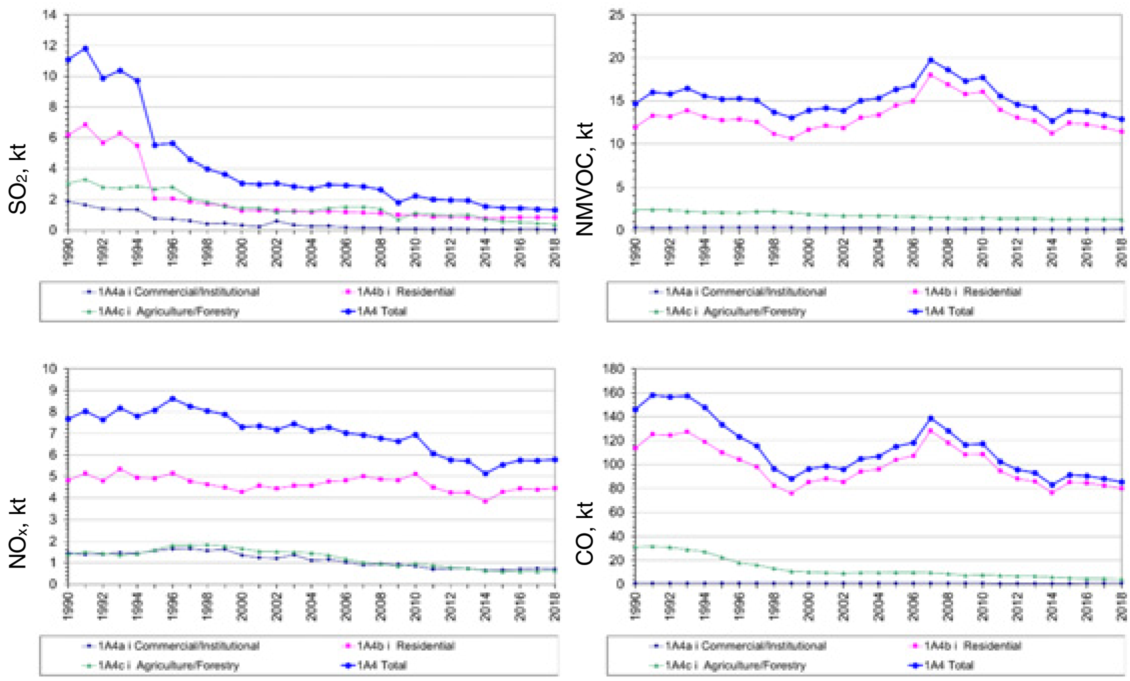



Figure 69 Time series for emission of $SO_2$, $NO_x$, NMVOCs and CO emission, 1A4 Other sectors.

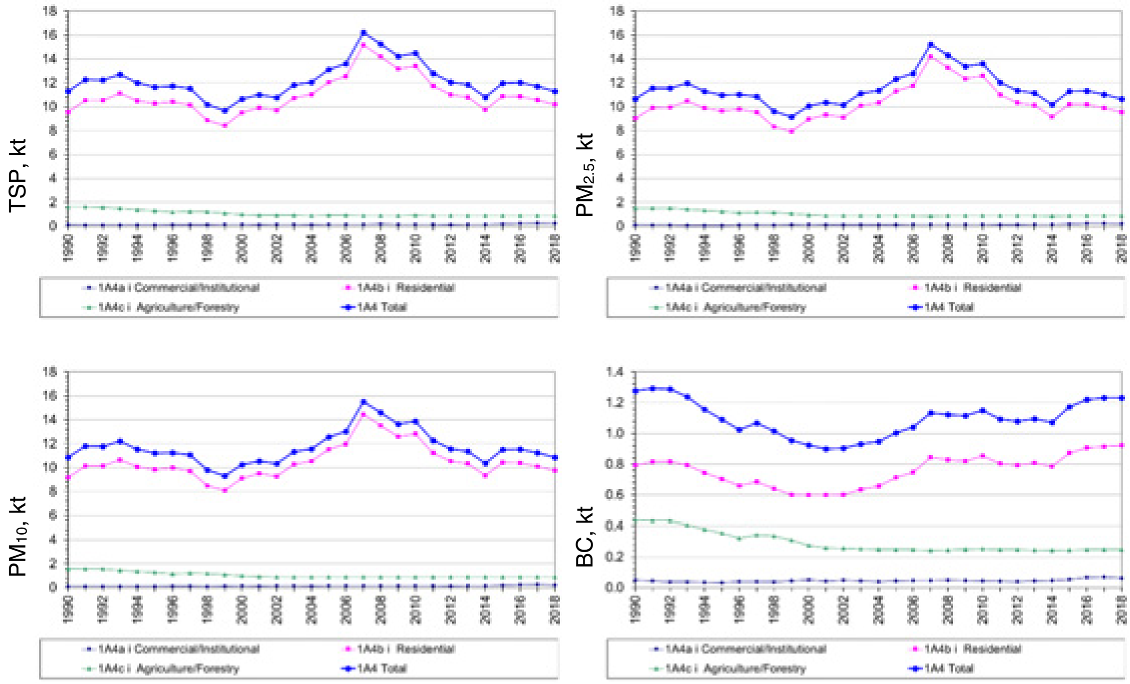



Figure 70 Time series for PM and BC emission, 1A4 Other sectors.

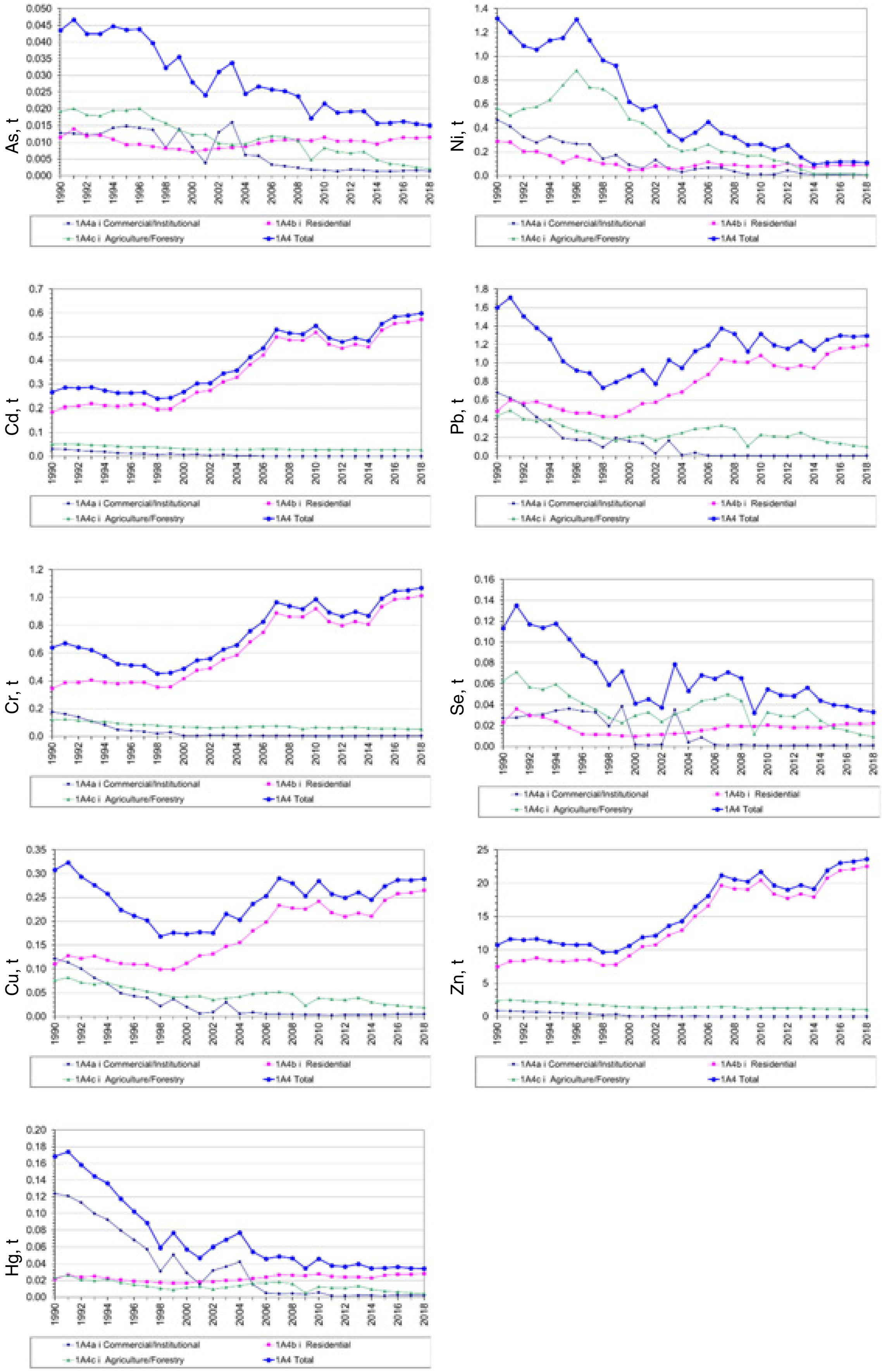



Figure 71 Time series for HM emissions, 1A4 Other sectors.

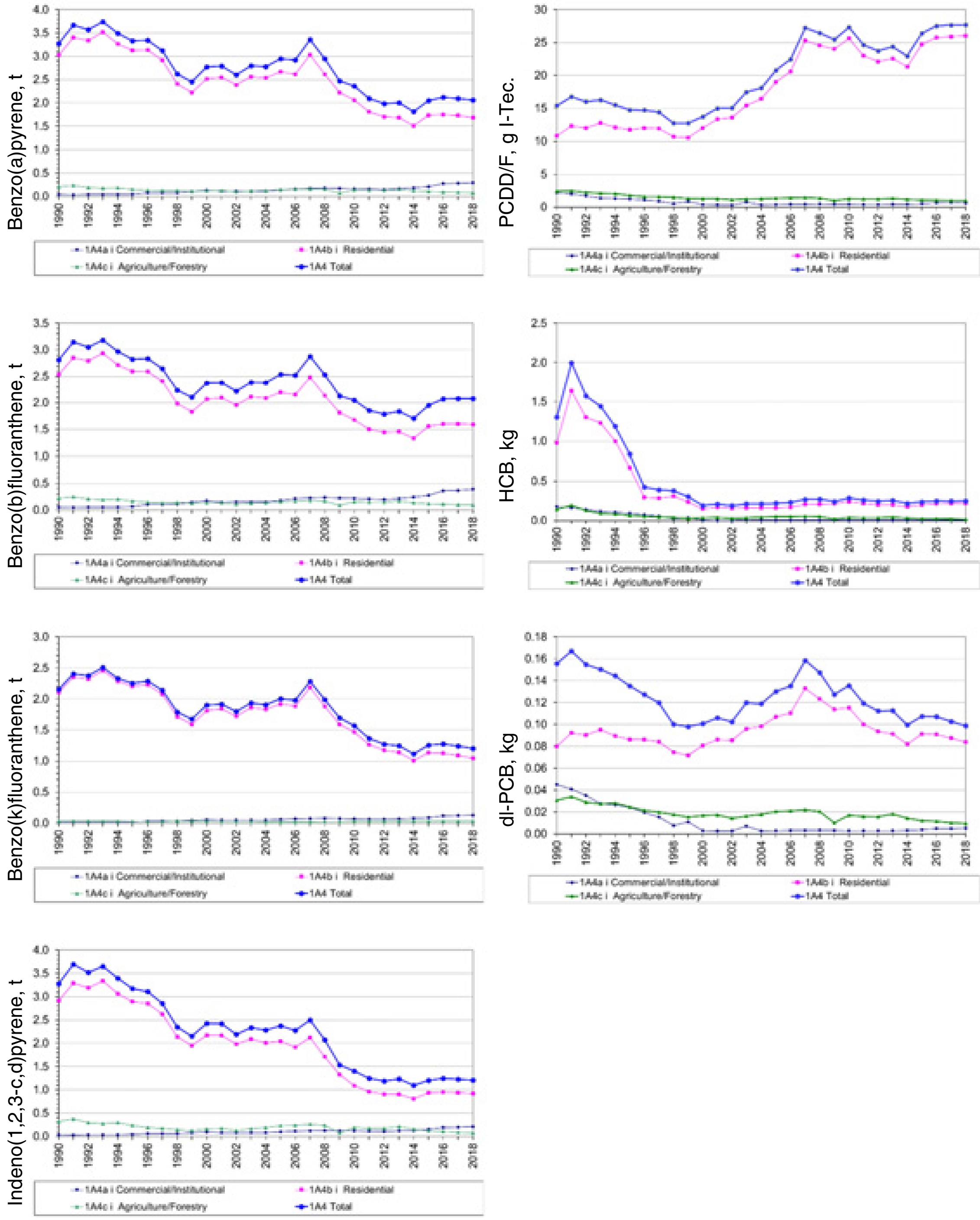



Figure 72 Time series for emission of PAHs, PCDD/F, HCB and dioxin-like PCBs, 1A4 Other sectors.

### 5.3.1 1A4a Commercial and institutional plants

The subcategory Commercial and institutional plants consists of both stationary and mobile sources. In this chapter, only stationary sources are included. Figure 73 and Figure 74 show the time series for fuel consumption and emissions.

The subcategory Commercial and institutional plants has low fuel consumption and emissions compared to the other stationary combustion emission source categories.

The fuel consumption in commercial/institutional plants has decreased 37 % since 1990 and the fuels applied have changed. The fuel consumption consists mainly of gas oil and natural gas. The consumption of gas oil has decreased since 1990. The consumption of wood and biogas has increased. The wood consumption in 2018 was 8.6 times the consumption in 1990.

The $CO_2$ emission has decreased 57 % since 1990. Both the decrease of fuel consumption and the change of fuels contribute to the decreased $CO_2$ emission.

The $CH_4$ emission in 2018 was 2.9 times the 1990 level. The increase is mainly a result of the increased emission from natural gas fuelled engines. The emissions from biogas fuelled engines and from combustion of wood also contribute to the increase. The time series for consumption of natural gas and biogas are shown in Figure 67.

The $N_2O$ emission in 2018 was 2 % higher than in 1990. The fluctuations of the $N_2O$ emission are mainly a result of fluctuations in consumption of natural gas and waste.

The $SO_2$ emission has decreased 97 % since 1990. The decrease is a result of both the change of fuel from gas oil to natural gas and of the lower sulphur content in gas oil and in residual oil. The lower sulphur content (0.05 % for gas oil since 1995 and 0.7 % for residual oil since 1997) is a result of Danish tax laws (DEPA, 1998).

The $NO_x$ emission was 51 % lower in 2018 than in 1990. The decrease is mainly a result of the lower fuel consumption but also the change from gas oil to natural gas has contributed to the decrease. The emission from wood combustion has increased.

The NMVOC emissions in 2018 was 52 % lower than the 1990 emission level. The combustion of wood has increased but the emission factor has decreased. The increase and decrease of natural gas consumption in gas engines (Figure 67) is also reflected in the time series for NMVOC emissions.

The CO emission has decreased 12 % since 1990. This is a result of the change of fuels used in the sector. The emission from wood has increased whereas the emission from gas oil has decreased.

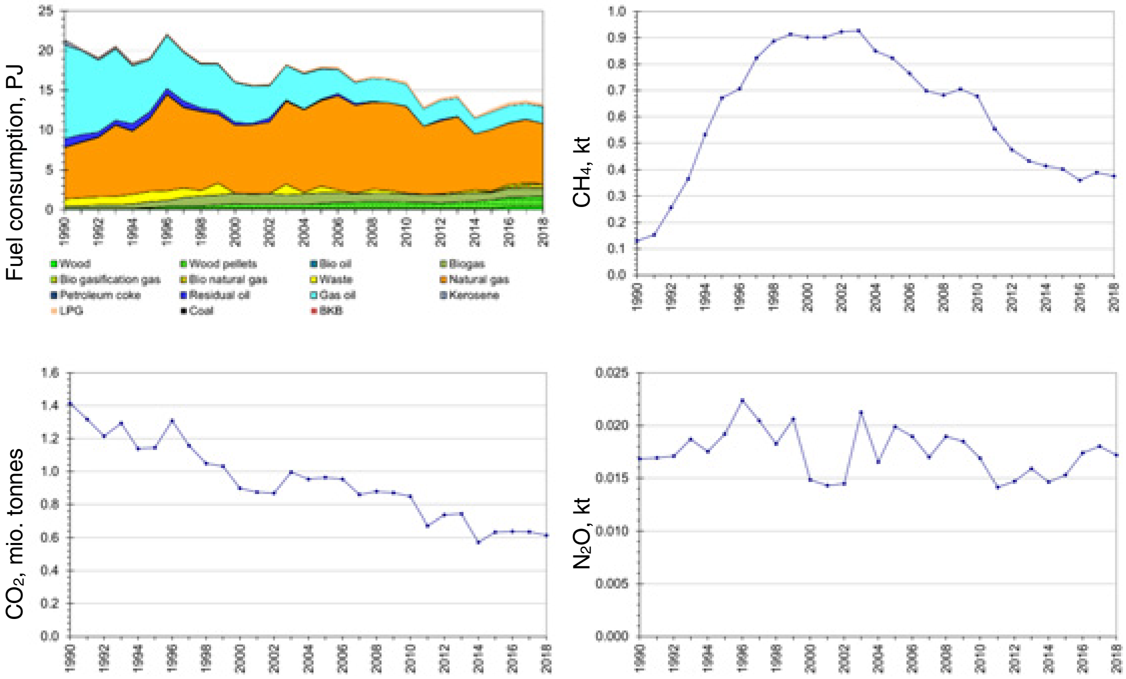



Figure 73 Time series for fuel consumption and GHG emissions from 1A4a Commercial /institutional.

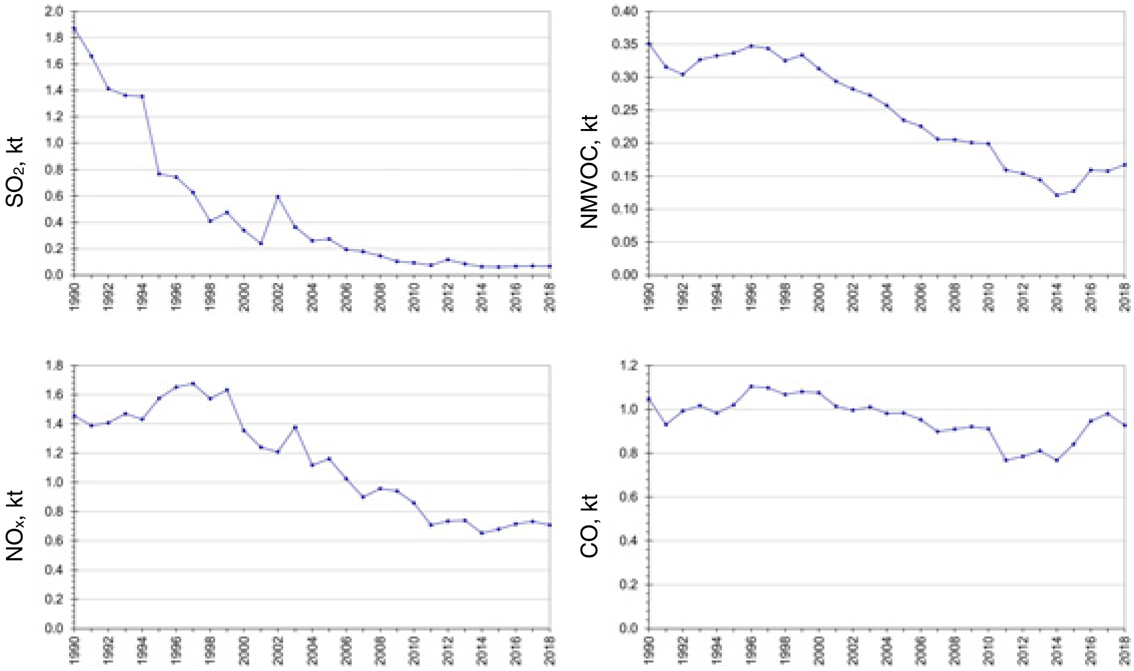



Figure 74 Time series for emission of $SO_2$, $NO_x$, NMVOCs and CO from 1A4a Commercial /institutional.

### 5.3.2 1A4b Residential plants

The emission source category Residential plants consists of both stationary and mobile sources. In this chapter, only stationary sources are included. Figure 75 and Figure 76 show the time series for fuel consumption and emissions.

For residential plants, the total fuel consumption was 10 % lower in 2018 than in 1990. The large decrease from 2010 to 2011 was caused by high temperature in the winter season of 2011 compared to the cold winter of 2010. The consumption of gas oil has decreased since 1990 whereas the consumption of wood has increased considerably (4.6 times the 1990 level). The consumption of natural gas has also increased since 1990.

Residential wood combustion is a large emission source for several pollutants. Replacement of older stoves and boilers with new improved stoves and boilers has been implemented in the emission inventory for residential wood combustion, see also Chapter 6.13.

The $CO_2$ emission has decreased by 63 % since 1990. This decrease is mainly a result of the considerable change in fuels used from gas oil to wood and natural gas.

The $CH_4$ emission from residential plants was 21 % lower in 2018 than in 1990. Residential wood combustion is a large source of $CH_4$ emission and the consumption of wood has increased whereas the emission factor has decreased since 1990.

The change of fuel from gas oil to wood has resulted in a 94 % increase of $N_2O$ emission since 1990 due to a higher emission factor for wood than for gas oil.

The large decrease (86 %) of $SO_2$ emission from residential plants is mainly a result of a change of sulphur content in gas oil since 1995. The lower sulphur content (less than 0.05 %) is a result of Danish tax laws (DEPA, 1998). In addition, the consumption of gas oil has decreased and the consumption of natural gas that results in very low $SO_2$ emissions has increased.

The $NO_x$ emission has decreased by 8 % since 1990. As mentioned above the fuel consumption has also decreased. The emission factor for wood is higher than for natural gas and gas oil and both consumption and the emission factor for wood have increased[15]. However, the $NO_x$ emission factor for natural gas has decreased.

The emission of NMVOCs has decreased 4 % since 1990. The consumption of wood has increased but the emission factor for wood has decreased since 1990. The emission factors for wood and straw are higher than for liquid or gaseous fuels.

The CO emission has decreased 30 % since 1990. The use of wood that is the main source of emission has increased whereas the emission factor has decreased. The emission from combustion of straw has decreased since 1990.

[15] The $NO_x$ emission factor for residential wood is technology dependent. The emission factor for new stoves is higher than for old stoves, see Chapter 6.13.2.

Time series for emission of PM, BC, HMs, PAHs, PCDD/F, PCBs, HCB are shown in Figure 70-72 in Chapter 5.3.

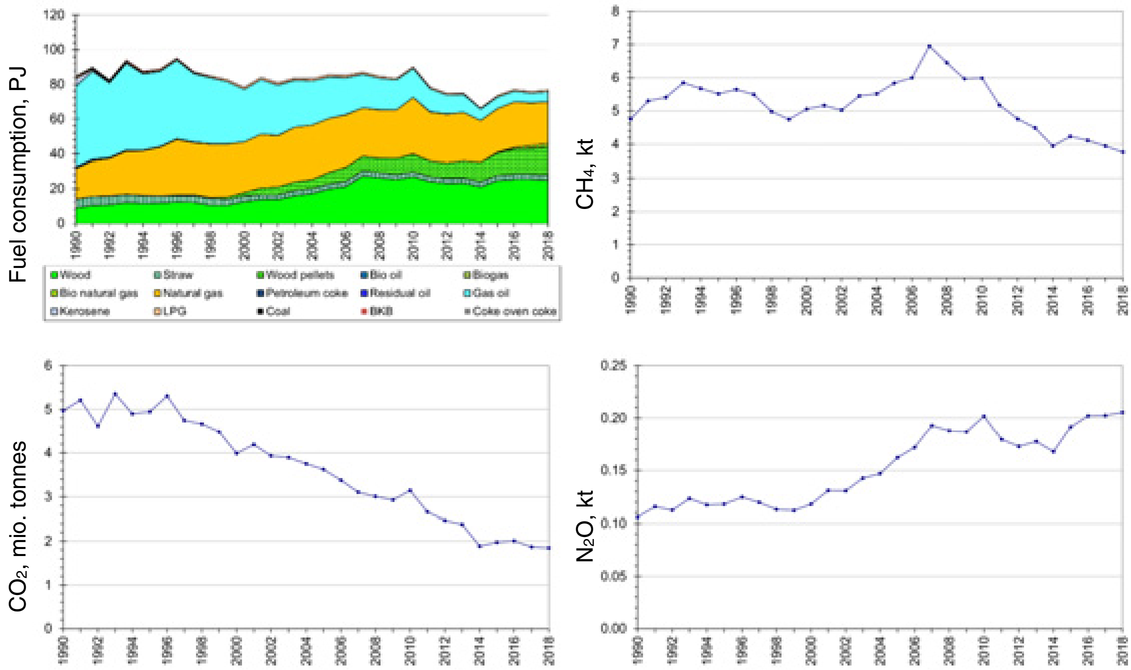



Figure 75 Time series for fuel consumption and GHG emissions from 1A4b Residential plants.

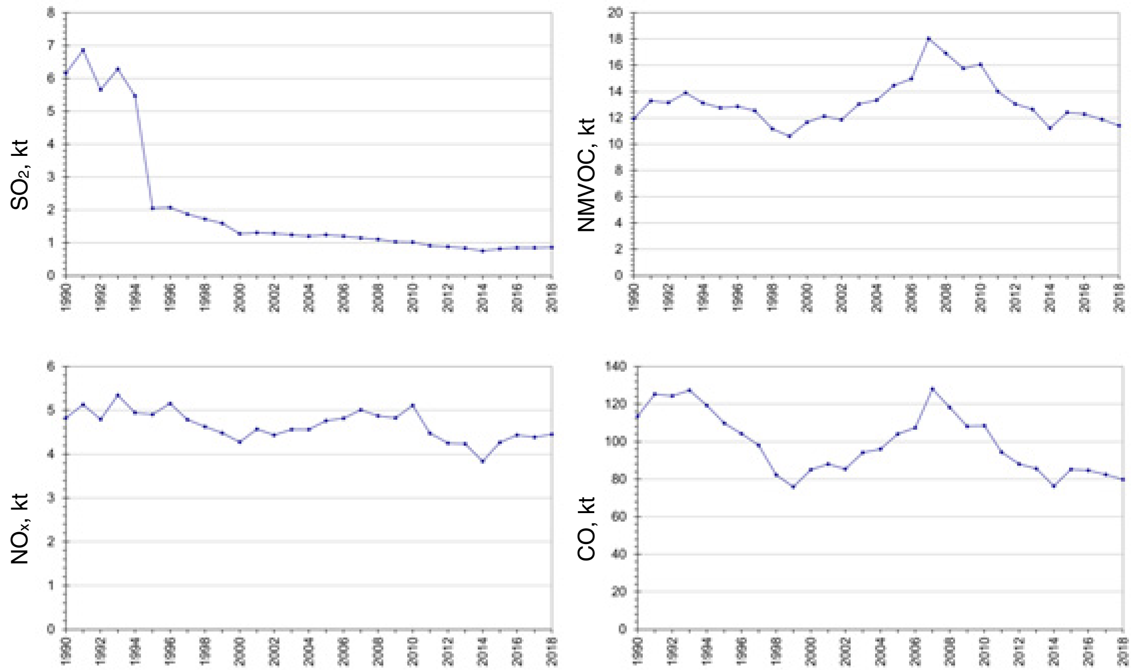



Figure 76 Time series for emission of $SO_2$, $NO_x$, NMVOCs and CO from 1A4b Residential plants.

### 5.3.3 1A4c Agriculture/forestry

The emission source category Agriculture / forestry consists of both stationary and mobile sources. In this chapter, only stationary sources are included. Figure 77 and Figure 78 show the time series for fuel consumption and emissions.

For plants in agriculture / forestry, the fuel consumption has decreased 54 % since 1990. A remarkable decrease of fuel consumption has taken place since year 2000.

The type of fuel that has been applied has changed since 1990. In the years 1994-2004, the consumption of natural gas was high, but after 2004, the consumption decreased again. A large part of the natural gas consumption has been applied in gas engines (Figure 67). Most CHP plants in agriculture / forestry based on gas engines came in operation in 1995-1999. The decrease after 2004 is a result of the liberalisation of the electricity market.

The consumption of coal, residual oil and straw has decreased since 1990. The consumption of biogas has increased.

The $CO_2$ emission in 2018 was 77 % lower than in 1990. The $CO_2$ emission increased from 1990 to 1996 due to increased fuel consumption. Since 1996, the $CO_2$ emission has decreased in line with the decrease in fuel consumption.

The $CH_4$ emission in 2018 was 1 % lower than in 1990. The emission follows the time series for natural gas combusted in gas engines (Figure 67). The emission from combustion of straw has decreased as a result of the decreasing consumption of straw in the sector.

The emission of $N_2O$ has decreased by 42 % since 1990. The decrease is a result of the lower fuel consumption as well as the change of fuel. The decreasing consumption of straw contributes considerably to the decrease of emission.

The $SO_2$ emission was 87 % lower in 2018 than in 1990. The emission decreased mainly in the years 1996-2002.

The emission of $NO_x$ was 55 % lower in 2018 than in 1990.

The emission of NMVOCs has decreased 46 % since 1990.

The CO emission has decreased 85 % since 1990. The major emission source is combustion of straw. In addition to the decrease of straw consumption, the emission factor for straw has also decreased since 1990.

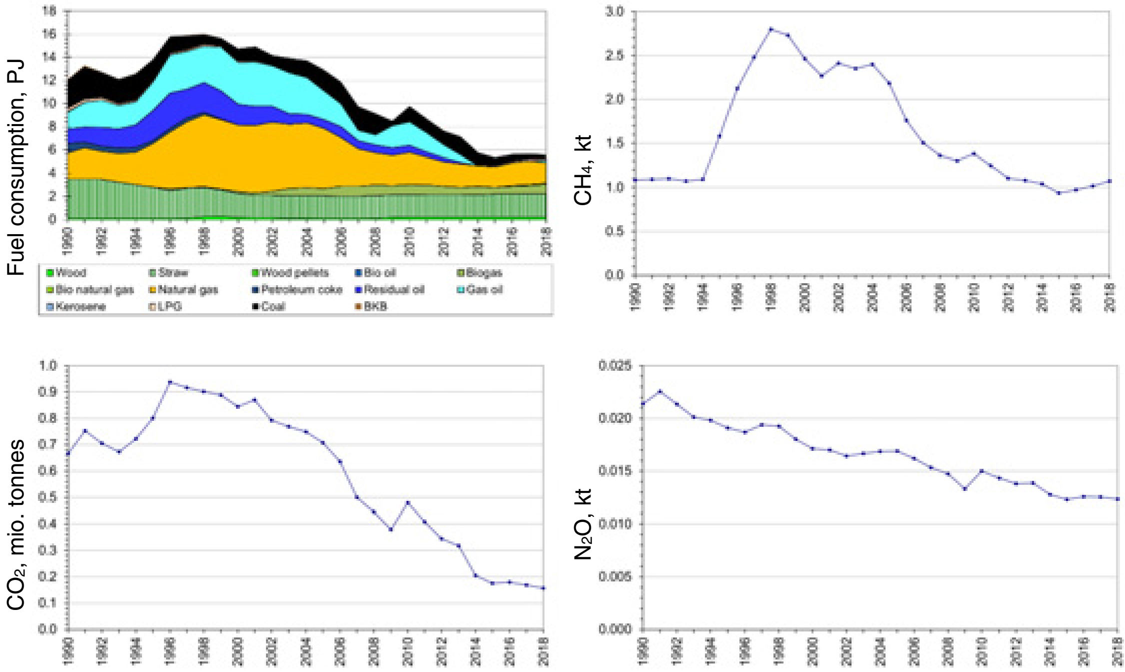



Figure 77 Time series for fuel consumption and GHG emissions from 1A4c Agriculture/forestry.

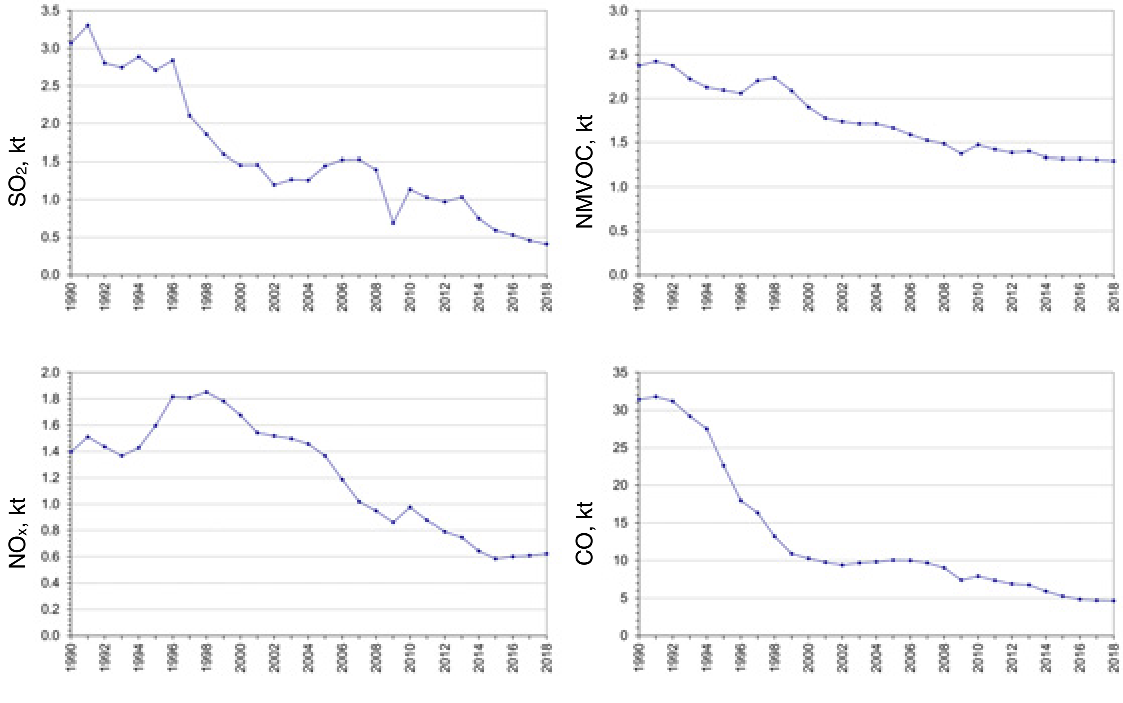



Figure 78 Time series for emission of $SO_2$, $NO_x$, NMVOC and CO from 1A4c Agriculture/forestry.

# 6 Methodological issues

The Danish emission inventory is based on the CORINAIR (CORe INventory on AIR emissions) system, which is a European program for air emission inventories. CORINAIR includes methodology structure and software for inventories. The methodology is described in the EEA Guidebook (EEA, 2016). Emission data are stored in MS Access databases, from which data are transferred to the reporting formats.

In the Danish emission database all activity rates and emissions are defined in SNAP sector categories (Selected Nomenclature for Air Pollution) according the CORINAIR system. The emission inventories are prepared from a complete emission database based on the SNAP source categories. Aggregation to the source category codes used in CRF is based on a correspondence list enclosed in Annex 1.

The emission inventory for stationary combustion is based on activity rates from the Danish energy statistics. General emission factors for various fuels, plants and sectors have been determined. Some large plants, such as power plants, are registered individually as large point sources and plant-specific emission data are used.

Recalculations and improvements are shown in Chapter 13.

## 6.1 Tiers

The type of GHG emission factor and the applied tier level for each emission source are shown in Table 21 below. The tier levels have been determined based on the IPCC Guidelines (IPCC, 2006). The fuel consumption data for transformation are technology specific. For end-use of fuels, the disaggregation to specific technologies is less detailed. However, for residential wood combustion technology specific fuel consumption rates have been estimated.

The tier level definitions have been interpreted as follows:

- Tier 1: The emission factor is an IPCC default tier 1 value.
- Tier 2: The emission factors are country-specific and based on a limited number of emission measurements or a technology specific IPCC tier 2 emission factor.
- Tier 3: Emission data are based on:
  - plant-specific emission measurements or
  - technology specific fuel consumption data and country-specific emission factors based on a considerable number of emission measurements from Danish plants.

Table 21 gives an overview of the calculation methods and type of emission factor. The table also shows which of the source categories are key in any of the key category analysis (including LULUCF, approach 1/approach 2, level/trend)[16].

[16] Key category according to the KCA approach 1 or approach 2 for Denmark (excluding Greenland and Faroe Islands), including LULUCF, level 1990/ level 2018/ trend.

Emissions from four emission source categories that have been identified as key sources have been based on a tier 1 approach. If possible, the emission estimate for all key categories should be based on a tier 2 or tier 3 approach. The total emission from the four emission sources adds up to 240 kton $CO_2$ equivalent or 0.4 % of the national total in 2018. In 1990, the emission from the four emission sources adds up to 630 kton or 0.8 % of national total. Data are shown in Table 22. If sufficient data are available, a tier 2 approach will be applied next year.

Table 21 Methodology and type of emission factor, 2018.

| | | Tier | EMF[1)] | Key category[2)] |
|---|---|---|---|---|
| 1A Stationary combustion, Coal, ETS data | $CO_2$ | Tier 3 | PS | Yes |
| 1A Stationary combustion, Coal, no ETS data | $CO_2$ | Tier 3 [3)] | CS | Yes |
| 1A Stationary combustion, BKB | $CO_2$ | Tier 1 | D | No |
| 1A Stationary combustion, Coke oven coke | $CO_2$ | Tier 1/Tier 3 | D/PS | No |
| 1A Stationary combustion, Fossil waste, ETS data | $CO_2$ | Tier 3 | PS | Yes |
| 1A Stationary combustion, Fossil waste, no ETS data | $CO_2$ | Tier 2 | CS | Yes |
| 1A Stationary combustion, Petroleum coke, ETS data | $CO_2$ | Tier 3 | PS | Yes |
| 1A Stationary combustion, Petroleum coke, no ETS data | $CO_2$ | Tier 2 | CS | Yes |
| 1A Stationary combustion, Residual oil, ETS data | $CO_2$ | Tier 3 | PS | Yes |
| 1A Stationary combustion, Residual oil, no ETS data | $CO_2$ | Tier 2 [4)] | CS | Yes |
| 1A Stationary combustion, Gas oil | $CO_2$ | Tier 2/Tier 3 [5)] | CS / PS | Yes |
| 1A Stationary combustion, Kerosene | $CO_2$ | Tier 1 | D | Yes |
| 1A Stationary combustion, LPG | $CO_2$ | Tier 1/Tier 3 [6)] | D / PS | Yes |
| 1A1b Stationary combustion, Petroleum refining, Refinery gas | $CO_2$ | Tier 3 | CS | Yes |
| 1A Stationary combustion, Natural gas, onshore | $CO_2$ | Tier 3 | CS | Yes |
| 1A1c_ii Stationary combustion, Oil and gas extraction, Offshore gas turbines, Natural gas | $CO_2$ | Tier 3 | CS | Yes |
| 1A1 Stationary combustion, solid fuels | $CH_4$ | Tier 2 | D(2) | No |
| 1A1 Stationary combustion, liquid fuels | $CH_4$ | Tier/Tier 2 | D / D(2) / CS | No |
| 1A1 Stationary combustion, not engines, gaseous fuels | $CH_4$ | Tier 2 | CS / D(2) | No |
| 1A1 Stationary combustion, waste | $CH_4$ | Tier 2 | CS | No |
| 1A1 Stationary combustion, not engines, biomass | $CH_4$ | Tier 3/Tier 2/Tier 1 | CS / D(2) / D | No |
| 1A2 Stationary combustion, solid fuels | $CH_4$ | Tier 1 | D | No |
| 1A2 Stationary combustion, liquid fuels | $CH_4$ | Tier 1/Tier 2 | D / D(2) / CS | No |
| 1A2 Stationary combustion, not engines, gaseous fuels | $CH_4$ | Tier 2 | CS / D(2) | No |
| 1A2 Stationary combustion, waste | $CH_4$ | Tier 1 | D | No |
| 1A2 Stationary combustion, not engines, biomass | $CH_4$ | Tier 2/Tier 1 | D(2) / D | No |
| 1A4 Stationary combustion, solid fuels | $CH_4$ | Tier 1 | D | No |
| 1A4 Stationary combustion, liquid fuels | $CH_4$ | Tier 1/Tier 2 | D / D(2) | No |
| 1A4 Stationary combustion, not engines, gaseous fuels | $CH_4$ | Tier 2 | D(2) | No |
| 1A4 Stationary combustion, waste | $CH_4$ | Tier 1 | D | No |
| 1A4 Stationary combustion, not engines, not residential wood and not residential/agricultural straw, biomass | $CH_4$ | Tier 1/Tier 2 | D / D(2) / CS | No |
| 1A4b_i Stationary combustion, Residential wood combustion | $CH_4$ | Tier 2 | CS | Yes |
| 1A4b_i/1A4c_i Stationary combustion, Residential and agricultural straw combustion | $CH_4$ | Tier 1 | D | Yes |
| 1A Stationary combustion, Natural gas fuelled engines, gaseous fuels | $CH_4$ | Tier 3 | CS | No |
| 1A Stationary combustion, Biogas fuelled engines, biomass | $CH_4$ | Tier 3 | CS | No |
| 1A1 Stationary combustion, solid fuels | $N_2O$ | Tier 2 | CS / D(2) | Yes |
| 1A1 Stationary combustion, liquid fuels | $N_2O$ | Tier 2/Tier 1 | D(2) / CS / D | No |
| 1A1 Stationary combustion, gaseous fuels | $N_2O$ | Tier 3/Tier 2 | CS / D(2) | Yes |
| 1A1 Stationary combustion, waste | $N_2O$ | Tier 2 | CS | Yes |
| 1A1 Stationary combustion, biomass | $N_2O$ | Tier 2/Tier 1 | CS / D(2) / D | Yes |
| 1A2 Stationary combustion, solid fuels | $N_2O$ | Tier 1/Tier 3 | D/PS | Yes |
| 1A2 Stationary combustion, liquid fuels | $N_2O$ | Tier 2/Tier 1 | D(2) / CS / D | Yes |
| 1A2 Stationary combustion, gaseous fuels | $N_2O$ | Tier 3/Tier 2 | CS / D(2) | Yes |
| 1A2 Stationary combustion, waste | $N_2O$ | Tier 1 | D | No |
| 1A2 Stationary combustion, biomass | $N_2O$ | Tier 1/Tier 2 | D / CS | No |
| 1A4 Stationary combustion, solid fuels | $N_2O$ | Tier 1 | D | No |
| 1A4 Stationary combustion, liquid fuels | $N_2O$ | Tier 2/Tier 1 | D(2) / CS / D | Yes |
| 1A4 Stationary combustion, gaseous fuels | $N_2O$ | Tier 3/Tier 2 | CS / D(2) | Yes |
| 1A4 Stationary combustion, waste | $N_2O$ | Tier 1 | D | No |
| 1A4 Stationary combustion, not residential wood and not residential/ agricultural straw, biomass | $N_2O$ | Tier 1/Tier 2 | D / CS | No |
| 1A4b_i Stationary combustion, Residential wood combustion | $N_2O$ | Tier 1 | D | Yes |
| 1A4b_i/1A4c_i Stationary combustion, Residential and agricultural straw combustion | $N_2O$ | Tier 1 | D | No |

1. D: IPCC (2006) default, tier 1. D(2): IPCC (2006) default, tier 2. CS: Country-specific. PS: Plant-specific.
2. KCA approach 1 or approach 2 for Denmark (excluding Greenland and Faroe Islands), including LULUCF, level 1990 or level 2018 or trend 1990-2018.
3. Only 3.4 % of the total coal consumption is included in the non-ETS category in 2018.
4. Only 8 % of the total residual oil consumption is included in the non-ETS category in 2018.
5. Tier 3 for 0.8 % of the gas oil consumption in 2018.
6. Tier 3 for 0.1 % of the LPG consumption in 2018.

Table 22 Emission data for key sources for which the estimated emissions are based on the tier 1 approach.

| Source category | $CO_2$ emission 1990, kton $CO_2$ equivalent | $CO_2$ emission 2018, kton $CO_2$ equivalent | Key source (KCA approach) |
|---|---|---|---|
| 1A Stationary combustion, Kerosene, $CO_2$ | 368 | 13 | Level 1990 (KCA 1), Trend (KCA 1) |
| 1A Stationary combustion, LPG, $CO_2$ | 188 | 141 | Level 2018 (KCA 1) |
| 1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion, $CH_4$ | 64 | 37 | Level 1990 (KCA 2) |
| 1A4b_i Stationary combustion, Residential wood combustion, $N_2O$ | 11 | 49 | Level 2018 (KCA 2), Trend (KCA 2) |
| Key sources for which the estimated emissions are based on the tier 1 approach, total | 630 | 240 | |

## 6.2 Large point sources

Large emission sources such as power plants, industrial plants and refineries are included as large point sources in the Danish emission database. Each point source may consist of more than one part, e.g. a power plant with several units. By registering the plants as point sources in the database, it is possible to use plant-specific emission factors.

In the inventory for the year 2018, 74 stationary combustion plants are specified as large point sources. Plant-specific emission data[17] are available from 62 of the plants. The point sources include:

- Power plants and decentralised CHP plants.
- Waste incineration plants.
- Large industrial combustion plants.
- Petroleum refining plants.

The criteria for selection of point sources are:

- All centralized power plants, including smaller units.
- All units with a capacity of above 25 $MW_e$.
- All district heating plants with an installed effect of 50 $MW_{th}$ or above and significant fuel consumption.
- All waste incineration plants obligated to report environmental data annually according to Danish law (DEPA, 2010b; DEPA, 2015).
- Industrial plants,
  - with an installed effect of 50 $MW_{th}$ or above and significant fuel consumption.
  - with a significant process related emission.

The fuel consumption of stationary combustion plants registered as large point sources in the 2018 inventory was 206 PJ. This corresponds to 51 % of the overall fuel consumption for stationary combustion.

A list of the large point sources for 2018 is provided in Annex 5. The number of large point sources registered in the databases increased from 1990 to 2018. Aggregated fuel consumption rates for the large point sources are also shown in Annex 5.

The emissions from a point source are based either on plant-specific emission data or, if plant-specific data are not available, on fuel consumption data and

[17] For $CO_2$ or other pollutants.

the general Danish emission factors. Which emission data are plant-specific is shown in Annex 5.

The plant-specific emission data from the EU ETS data represent 61 % of the total $CO_2$ emission from stationary combustion. $CO_2$ emission factors are plant-specific for the major power plants, refineries, offshore gas turbines, large municipal waste incineration plants and for cement production. Plant-specific emission data are obtained from $CO_2$ data reported under the EU Emission Trading Scheme (ETS). The EU ETS data are discussed below.

Emission measurement data for $CH_4$ and $N_2O$ are applied for estimating emission factors but not implemented as plant-specific data.

Annual environmental reports for the plants include a considerable number of emission data sets. In general, emission data from annual environmental reports are based on emission measurements, but some emissions have potentially been calculated from general emission factors.

If plant-specific emission factors are not available, emission factors for area sources are used.

## 6.3 Area sources

Fuels not combusted in large point sources are included as source category specific area sources in the emission database. Plants such as residential boilers, small district heating plants, small CHP plants and some industrial boilers are defined as area sources. Emissions from area sources are based on fuel consumption data and emission factors. Further information on emission factors is provided below in Chapter 7.

## 6.4 Fuels used for non-energy purposes

The Danish national energy statistics includes three fuels used for non-energy purposes; bitumen, white spirit and lubricants. The total consumption for non-energy purposes is relatively low, e.g. 10.3 PJ in 2018. The use of fuels for non-energy purposes is included in the inventory in sector 2D Non-energy products from fuels and solvent use.

The non-energy use of fuels is included in the reference approach for Climate Convention reporting and appropriately corrected in line with the IPCC Guidelines (IPCC, 2006). The reference approach is included in Chapter 10.

## 6.5 Activity rates, fuel consumption

The fuel consumption rates are based on the official Danish energy statistics prepared by the Danish Energy Agency (DEA). DCE aggregates fuel consumption rates to SNAP categories. Some fuel types in the official Danish energy statistics are added to obtain a less detailed fuel aggregation level cf. Annex 3. The calorific values on which the energy statistics are based are also enclosed in Annex 3. The correspondence list between the energy statistics and SNAP categories is enclosed in Annex 4.

The fuel consumption of the CRF category Manufacturing industries and construction (corresponding to SNAP category 03) is disaggregated into industrial subsectors based on the DEA data set aggregated for the Eurostat reporting (DEA, 2019c). The fuel consumption data flow is shown in Figure 79.

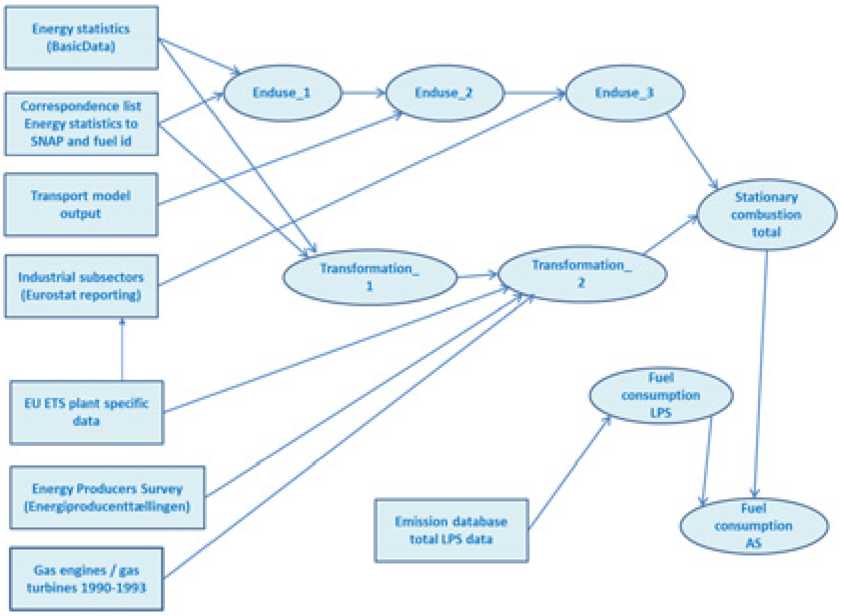


Figure 79 Fuel consumption data flow.

Both traded and non-traded fuels are included in the Danish energy statistics. Thus, for example, estimation of the annual consumption of non-traded wood is included.

Petroleum coke purchased abroad and combusted in Danish residential plants (border trade of 628 TJ in 2018) is not included in the Danish inventory. This is in agreement with the IPCC Guidelines (IPCC, 2006).

The fuel consumption data for large point sources refer to the EU Emission Trading Scheme (EU ETS) data for plants for which the $CO_2$ emission also refer to EU ETS.

For all other large point sources, the fuel consumption refers to an annually updated DEA database; the Energy Producers Survey (DEA, 2019b). The Energy Producers Survey includes the fuel consumption of each district heating and power-producing plant, based on data reported by plant operators. The consistency between EU ETS reporting and the Energy Producers Survey database (DEA, 2019b) is checked by the DEA and discrepancies are corrected prior to the use in the emission inventory.

The fuel consumption of area sources is calculated as total fuel consumption in the energy statistics minus fuel consumption included in the emission inventory database in large point sources.

In Denmark, all waste incineration are utilised for heat and power production. Thus, incineration of waste is included as stationary combustion in the source category Fuel combustion (subcategories *1A1*, *1A2* and *1A4)*.

Fuel consumption data are presented in Chapter 2.

## 6.6 Fuel consumption for 1A1c Oil and gas extraction

The consumption of natural gas reported in the EU ETS data are not in agreement with the energy statistics. This is because the energy statistics is based on the default net calorific value (NCV) for natural gas applied in Denmark whereas the EU ETS data are based on fuel analysis of the natural gas applied offshore at each individual platform. The total consumption of natural gas in 1A1c Oil and gas extraction applied in the emission inventories is based on the EU ETS data.

## 6.7 Fuel consumption for 1A1b Petroleum refining

The EU ETS data for fuel consumption reported by the two Danish refineries are not always in agreement with the energy statistics due to the use of default values for net calorific value (NCV) in the energy statistics. The EU ETS data are based on fuel analysis. Refinery gas is only applied in the two refineries. The total consumption of refinery gas applied in the emission inventories is based on the EU ETS data.

## 6.8 Upgraded biogas distributed in the natural gas grid

Biogas upgraded for distribution in the natural gas grid (bio natural gas or bio methane) has been included as a separate fuel in the energy statistics and in the emission inventory.

## 6.9 Biogas distributed in the town gas grid

The energy statistics includes a consumption of biogas for town gas production. This biogas is distributed in the town gas grid (119 TJ in 2018). This fuel consumption has been included in the fuel category town gas in the fuel consumption data of the energy statistics. In the emission inventory biogas distributed in the town gas grid have been included in the fuel category biogas.

## 6.10 Town gas

Town gas (the fossil part) has been included in the fuel category natural gas. The consumption of town gas in Denmark is very low, e.g. 0.6 PJ in 2018. In 1990, the town gas consumption was 1.6 PJ and the consumption has been steadily decreasing throughout the time series.

In Denmark, town gas is produced based on natural gas. The use of coal for town gas production ceased in the early 1980s.

An indicative composition of town gas in 2015 according to the largest supplier of town gas in Denmark is shown in Table 23 (KE, 2015).

Table 23 Composition of town gas currently used (KE, 2015).

| Component | Town gas, % (mol.) |
|---|---|
| Methane | 43.9 |
| Ethane | 2.9 |
| Propane | 1.1 |
| Butane | 0.5 |
| Carbon dioxide | 0.4 |
| Nitrogen | 40.5 |
| Oxygen | 10.7 |

The lower heating value of the town gas is 20.31 MJ per $Nm^3$ and the $CO_2$ emission factor 56.1 kg per GJ. This is very close to the emission factor used for natural gas in 2015 (57.06 kg per GJ). According to the supplier, both the composition and heating value will change during the year. It has not been possible to obtain a yearly average.

Biogas has been added to the town gas grid since 2014. This biogas distributed in the town gas grid is treated as a separate fuel in the emission inventories and thus not included in the data for town gas.

In earlier years, the composition of town gas was somewhat different. Table 24 shows data for town gas composition in 2000-2005. These data are constructed with the input from Københavns Energi (KE) (Copenhagen Energy) and Danish Gas Technology Centre (DGC), (Jeppesen, 2007; Kristensen, 2007). The data refer to three measurements performed several years apart, the first in 2000 and the latest in 2005.

Table 24 Composition of town gas, data from 2000-2005.

| Component | Town gas, % (mol.) |
|---|---|
| Methane | 22.3-27.8 |
| Ethane | 1.2-1.8 |
| Propane | 0.5-0.9 |
| Butane | 0.13-0.2 |
| Higher hydrocarbons | 0-0.6 |
| Carbon dioxide | 8-11.6 |
| Nitrogen | 15.6-20.9 |
| Oxygen | 2.3-3.2 |
| Hydrogen | 35.4-40.5 |
| Carbon monoxide | 2.6-2.8 |

The lower calorific value was been between 15.6 and 17.8 MJ per $Nm^3$. The $CO_2$ emission factors - derived from the few available measurements - are in the range of 52-57 kg per GJ.

The Danish sectoral approach includes town gas as part of the fuel category natural gas and thus indirectly assumes the same $CO_2$ emission factor. This is a conservative approach ensuring that the $CO_2$ emissions are not underestimated.

Due to the scarce data available and the very low consumption of town gas compared to consumption of natural gas (< 0.5 %), the methodology will be applied unchanged in future inventories.

## 6.11 Waste

All waste incineration in Denmark is utilised for heat and / or power production and thus included in the energy sector. The waste incinerated in Denmark for energy production consists of the waste fractions shown in Figure 80. In 2017[18], 3 % of the incinerated waste was hazardous waste.

[18]Data for 2018 have not yet been published, January 2020.

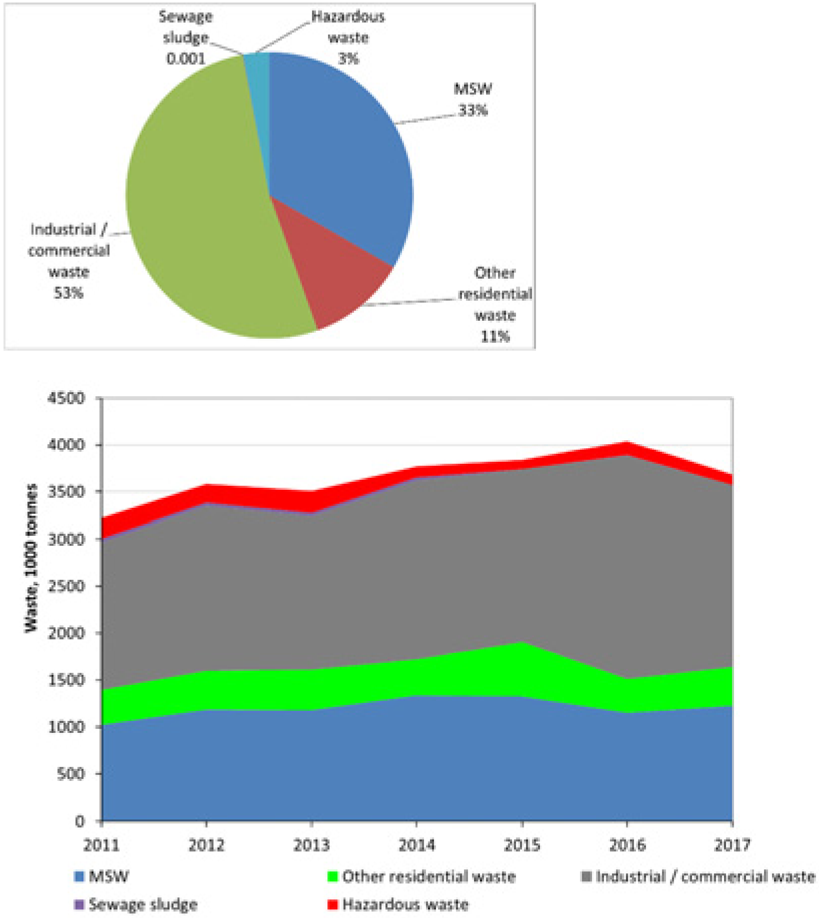



Figure 80 Waste fractions (weight) for incinerated waste in 2017 and the corresponding time series 2011-2017 (ADS, 2019)[19].

In connection to the project estimating an improved $CO_2$ emission factor for waste (Astrup et al., 2012), the fossil energy fraction was calculated. The fossil fraction was not measured or estimated as part of the project, but the flue gas measurements combined with data from Fellner & Rechberger (2010) indicated a fossil energy part of 45 %. The energy statistics also applies this fraction in the national statistics.

## 6.12 Biogas

Biogas includes landfill gas, sludge gas and manure / organic waste gas[20]. The Danish energy statistics specifies production and consumption of each of the biogas types. In 2018, 91 % of the applied biogas was based on manure / organic waste. An increasing part of the biogas based on manure / organic waste is upgraded to bio natural gas.

Biogas upgraded for distribution in the natural gas grid reported as bio natural gas and is not included in the fuel category “biogas” in the rest of this report. This is also the case for bio gasification gas.

[19] Data for 2018 have not yet been published, January 2020.
[20] Based on manure with addition of other organic waste. In the Danish energy statistics this biogas is called *Biogas, other*.

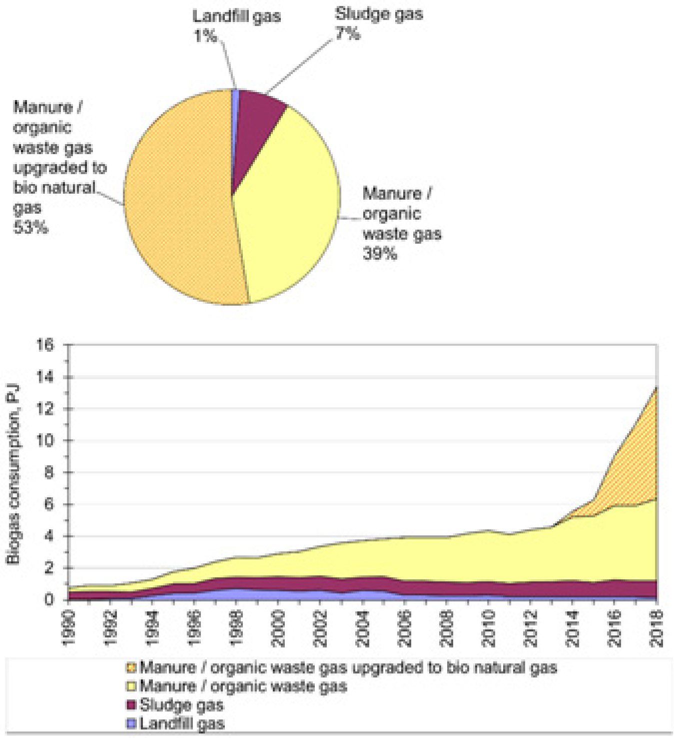



Figure 81 Biogas types (including bio natural gas) 2018 and the corresponding time series 1990-2018 (DEA, 2019a).

## 6.13 Residential wood combustion

Residential wood combustion is the main emission source for some pollutants. The model applied for estimating emissions from residential wood combustion takes into account the replacement of old units, the different fuel consumption rates and emission factors of the applied technologies. The model for residential wood combustion emissions was revised in 2019 and will be reported in detail in Nielsen et al. (2020c).

### 6.13.1 Residential wood combustion, fuel consumption

The total wood consumption is provided in the official energy statistics published by the DEA. However, for the purposes of calculating emissions from residential wood combustion, it is necessary to break down the wood consumption to different technologies, as different technologies have widely different emission factors.

In the Danish emission inventory, there is a differentiation between different types of stoves and boiler. In addition, there is a category for open fireplaces and similar and one for masonry stoves and similar. Wood pellets considered a separate fuel. The categories used in the inventory are provided in Table 25 below.

Table 25 Overview of the wood burning technologies.

| Technology |
|---|
| Stoves (-1989) |
| Stoves (1990-2007) |
| Stoves (2008-2014) |
| Stoves (2015-2016) |
| Stoves (2017-) |
| Eco labelled stoves / new advanced stoves (-2014) |
| Eco labelled stoves / new advanced stoves (2015-2016) |
| Eco labelled stoves / new advanced stoves (2017-) |
| Open fireplaces and similar |
| Masonry heat accumulating stoves and similar |
| Boilers with accumulation tank (-1979) |
| Boilers without accumulation tank (-1979) |
| Boilers with accumulation tank (1980-) |
| Boilers without accumulation tank (1980-) |
| Pellet boilers / pellet stoves |

The total number of wood burning appliances has been estimated based on data from the Danish Chimneysweepers Association (SFL) supplemented with data from the Danish Building and Dwelling Register and data for replacement of older units. For further information, please see Nielsen et al. (2020c). The estimated wood consumption rates for each category are shown in Table 26 and Figure 82 below.

Table 26 Time series for fuel consumption in residential wood combustion, TJ

| Technology | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2018 |
|---|---|---|---|---|---|---|---|---|
| Stoves (-1989) | 5555 | 5059 | 5505 | 4684 | 4829 | 4390 | 2069 | 1170 |
| Stoves (1990-2007) | 0 | 189 | 1456 | 3004 | 6476 | 8545 | 7389 | 6944 |
| Stoves (2008-2014) | 0 | 0 | 0 | 0 | 0 | 172 | 350 | 354 |
| Stoves (2015-2016) | 0 | 0 | 0 | 0 | 0 | 0 | 48 | 97 |
| Stoves (2017-) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 97 |
| Eco labelled stoves / new advanced stoves (-2014) | 0 | 0 | 0 | 0 | 1079 | 4003 | 5400 | 5466 |
| Eco labelled stoves / new advanced stoves (2015-2016) | 0 | 0 | 0 | 0 | 0 | 0 | 432 | 875 |
| Eco labelled stoves / new advanced stoves (2017-) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 875 |
| Open fireplaces and similar | 244 | 215 | 276 | 289 | 439 | 581 | 533 | 539 |
| Masonry heat accumulating stoves and similar | 58 | 51 | 65 | 69 | 104 | 138 | 126 | 128 |
| Boilers with accumulation tank (-1979) | 1571 | 1108 | 1064 | 745 | 566 | 1 | 0 | 0 |
| Boilers without accumulation tank (-1979) | 1571 | 1108 | 1064 | 745 | 566 | 1 | 0 | 0 |
| Boilers with accumulation tank (1980-) | 377 | 681 | 1355 | 1965 | 3866 | 6307 | 6195 | 6353 |
| Boilers without accumulation tank (1980-) | 251 | 426 | 773 | 1012 | 1786 | 2661 | 2029 | 1970 |
| Pellet boilers / pellet stoves | 0 | 117 | 201 | 2112 | 6690 | 10105 | 12999 | 16197 |

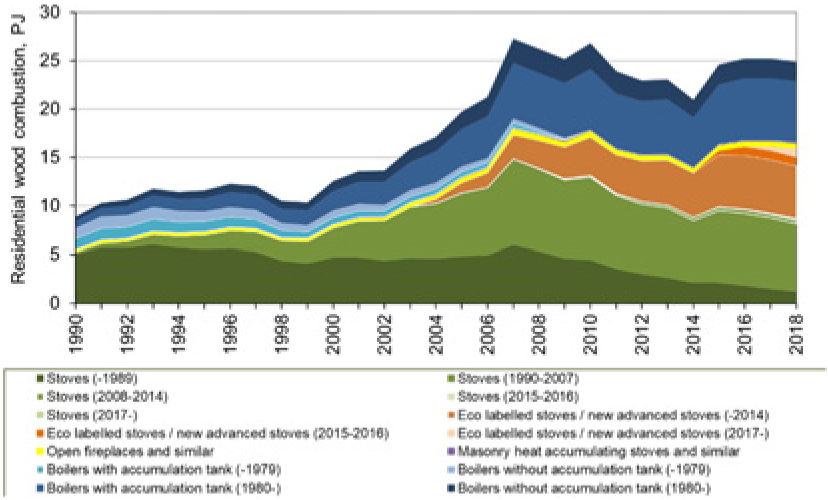


Figure 82 Technology specific wood consumption rates in residential plants.

### 6.13.2 Residential wood combustion, technology specific EMFs

For the pollutants $CH_4$, $NO_x$, NMVOC, CO, $NH_3$, TSP, $PM_{10}$, $PM_{2.5}$, BC, PCDD/F, PCB and PAH emission factors have been based on fuel consumption data and technology specific emission factors for 15 different technologies. Technology specific emission factors and implied emission factors for 2018 are shown in Table 27.

Emission measurements performed in Denmark applying dilution tunnel have been prioritised. Thus, condensable particles are included in the emission factors.

The emission factors for dioxins are dependent on the applied wood but independent of stove technology. Four different emission factors are applied for: stoves, open fireplaces, boilers and pellet stoves/boilers.

For pollutants not included in Table 27, technology specific emission factors and time series have not been estimated and the emission factors are included in Chapter 7.

Table 27 Technology specific emission factors for residential wood combustion and IEF for log wood/wood chips, 2018.

| Technology | $NO_x$, g/GJ | NMVOCs, g/GJ | $CH_4$, g/GJ | CO, g/GJ | $NH_3$, g/GJ | TSP, g/GJ | $PM_{10}$, g/GJ | $PM_{2.5}$, g/GJ | BC, g/GJ | PCDD/Fs, ng/GJ | dl-PCBs, ng/GJ | Benzo (a) pyrene, mg/GJ | Benzo (b) fluoranthene, mg/GJ | Benzo (k) fluoranthene, mg/GJ | Indeno (1.2.3-c,d) pyrene, mg/GJ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stoves (-1989) | 50 | 1200 | 430 | 8000 | 70 | 1000 | 950 | 930 | 18 | 1048 | 7049 | 116 | 55 | 119 | 62 |
| Stoves (1990-2007) | 50 | 600 | 215 | 4000 | 70 | 500 | 475 | 465 | 17 | 1048 | 7049 | 48 | 59 | 50 | 27 |
| Stoves (2008-2014) | 80 | 350 | 125 | 1900 | 37 | 389 | 370 | 362 | 23 | 1048 | 931 | 43 | 65 | 19 | 31 |
| Stoves (2015-2016) | 80 | 350 | 125 | 1900 | 37 | 317 | 301 | 295 | 44 | 1048 | 931 | 43 | 65 | 19 | 31 |
| Stoves (2017-) | 80 | 350 | 125 | 1900 | 37 | 253 | 240 | 235 | 44 | 1048 | 931 | 43 | 65 | 19 | 31 |
| Eco labelled stoves / new advanced stoves (-2014) | 75 | 175 | 2 | 1900 | 37 | 253 | 240 | 235 | 31 | 1048 | 466 | 43 | 65 | 19 | 31 |
| Eco labelled stoves / new advanced stoves (2015-2016) | 75 | 175 | 2 | 1900 | 37 | 190 | 181 | 177 | 31 | 1048 | 466 | 43 | 65 | 19 | 31 |
| Eco labelled stoves / new advanced stoves (2017-) | 75 | 175 | 2 | 1900 | 37 | 127 | 121 | 118 | 31 | 1048 | 466 | 43 | 65 | 19 | 31 |
| Open fireplaces and similar | 50 | 600 | 430 | 4000 | 74 | 882 | 838 | 820 | 34 | 55 | 60 | 35 | 25 | 29 | 21 |
| Masonry heat accumulating stoves and similar | 50 | 600 | 215 | 2402 | 70 | 63 | 60 | 59 | 18 | 282 | 7049 | 17 | 8 | 10 | 25 |
| Boilers with accumulation tank (-1979) | 80 | 350 | 211 | 9001 | 74 | 588 | 559 | 547 | 24 | 282 | 7049 | 991 | 926 | 632 | 1092 |
| Boilers without accumulation tank (-1979) | 80 | 350 | 256 | 10890 | 74 | 736 | 699 | 684 | 24 | 282 | 7049 | 991 | 926 | 632 | 1092 |
| Boilers with accumulation tank (1980-) | 95 | 175 | 50 | 1613 | 37 | 64 | 61 | 60 | 6 | 282 | 466 | 90 | 60 | 40 | 40 |
| Boilers without accumulation tank (1980-) | 95 | 350 | 50 | 1952 | 37 | 335 | 318 | 312 | 6 | 282 | 931 | 120 | 80 | 50 | 60 |
| **IEF residential log wood/wood chips, 2018** | **73** | **371** | **111** | **2752** | **49** | **324** | **307** | **301** | **18** | **766** | **2686** | **65.6** | **61.6** | **40.3** | **35.7** |
| Pellet boilers / pellet stoves | 80 | 10 | 3 | 300 | 12 | 51 | 48 | 47 | 7 | 333 | 466 | 0.9 | 1.3 | 1.3 | 1.2 |

References for the technology specific emission factors are shown in Table 28.

The emission factors for dioxins are dependent on the applied wood but independent of stove technology. Four different emission factors are applied for stoves, open fireplaces, boilers and pellet stoves/boilers.

Table 28 Emission factors for residential wood combustion.

| | Pollutant | Emission factor | Unit | Reference |
|---|---|---|---|---|
| Stoves (-1989) | $NO_x$ | 50 | g/GJ | EEA (2016), Small combustion, Table 3.40, conventional stoves |
| Stoves (1990-2007) | $NO_x$ | 50 | g/GJ | EEA (2016), Small combustion, Table 3.40, conventional stoves |
| Stoves (2008-2014) | $NO_x$ | 80 | g/GJ | EEA (2016), Small combustion, Table 3.41, energy efficient stoves |
| Stoves (2015-2016) | $NO_x$ | 80 | g/GJ | Same as Stoves (2008-2014) |
| Stoves (2017-) | $NO_x$ | 80 | g/GJ | Same as Stoves (2008-2014) |
| Eco labelled stoves / new advanced stoves (-2014) | $NO_x$ | 75 | g/GJ | Andersen & Hvidbjerg (2017) |
| Eco labelled stoves / new advanced stoves (2015-2016) | $NO_x$ | 75 | g/GJ | Andersen & Hvidbjerg (2017) |
| Eco labelled stoves / new advanced stoves (2017-) | $NO_x$ | 75 | g/GJ | Andersen & Hvidbjerg (2017) |
| Open fireplaces and similar | $NO_x$ | 50 | g/GJ | EEA (2019), Open fireplaces, Table 3.39 |
| Masonry heat accumulating stoves and similar | $NO_x$ | 50 | g/GJ | EEA (2016), Small combustion, table 3.40, conventional stoves |
| Boilers with accumulation tank (-1979) | $NO_x$ | 80 | g/GJ | EEA (2016), Small combustion, table 3.43, conventional boilers |
| Boilers without accumulation tank (-1979) | $NO_x$ | 80 | g/GJ | EEA (2016), Small combustion, table 3.43, conventional boilers |
| Boilers with accumulation tank (1980-) | $NO_x$ | 95 | g/GJ | EEA (2016), Small combustion, table 3.42, advanced / ecolabelled stoves and boilers |
| Boilers without accumulation tank (1980-) | $NO_x$ | 95 | g/GJ | EEA (2016), Small combustion, table 3.42, advanced / ecolabelled stoves and boilers |
| Pellet boilers / pellet stoves | $NO_x$ | 80 | g/GJ | EEA (2016), Small combustion, table 3.44, pellet stoves and boilers. |
| Stoves (-1989) | NMVOC | 1200 | g/GJ | Assumed two times Stoves (1990-2007). EEA (2016),Small combustion, table 3.40, conventional stoves; 600 g/GJ (20 g/GJ - 3000 g/GJ) |
| Stoves (1990-2007) | NMVOC | 600 | g/GJ | EEA (2016), Small combustion, table 3.40, conventional stoves |
| Stoves (2008-2014) | NMVOC | 350 | g/GJ | EEA (2016), Small combustion, table 3.41, energy efficient stoves |
| Stoves (2015-2016) | NMVOC | 350 | g/GJ | Same as Stoves (2008-2014) |
| Stoves (2017-) | NMVOC | 350 | g/GJ | Same as Stove (2008-2014) |
| Eco labelled stoves / new advanced stoves (-2014) | NMVOC | 175 | g/GJ | Assumed ½ stoves (2008-2014). The EEA (2016) emission factor for advanced / ecolabelled stoves and boilers is 250 g/GJ, but this emission factor has not been revised since the 2009 version of the Guidebook |
| Eco labelled stoves / new advanced stoves (2015-2016) | NMVOC | 175 | g/GJ | Same as ecolabelled stoves (-2014) |
| Eco labelled stoves / new advanced stoves (2017-) | NMVOC | 175 | g/GJ | Same as ecolabelled stoves (-2014) |
| Open fireplaces and similar | NMVOC | 600 | g/GJ | EEA (2019), Open fireplaces, Table 3.39 |
| Masonry heat accumulating stoves and similar | NMVOC | 600 | g/GJ | EEA (2016), Small combustion, table 3.40, conventional stoves |
| Boilers with accumulation tank (-1979) | NMVOC | 350 | g/GJ | EEA (2016), Small combustion, table 3.43, conventional boilers |
| Boilers without accumulation tank (-1979) | NMVOC | 350 | g/GJ | EEA (2016), Small combustion, table 3.43, conventional boilers |
| Boilers with accumulation tank (1980-) | NMVOC | 175 | g/GJ | Assumed equal to ecolabelled stoves (2014) |
| Boilers without accumulation tank (1980-) | NMVOC | 350 | g/GJ | Assumed 2 times the emission from boilers with accumulation tank (1980-) |
| Pellet boilers / pellet stoves | NMVOC | 10 | g/GJ | EEA (2016), Small combustion, table 3.44, pellet stoves and boilers |

| | Pollutant | Emission factor | Unit | Reference |
|---|---|---|---|---|
| Stoves (-1989) | $CH_4$ | 430 | g/GJ | Methane emissions from residential biomass combustion, Paulrud et al. (2005) (SMED report, Swe-den) |
| Stoves (1990-2007) | $CH_4$ | 215 | g/GJ | Assumed ½ the emission factor for stoves (-1989) |
| Stoves (2008-2014) | $CH_4$ | 125 | g/GJ | Estimated based on the emission factor for stoves (1990-2007) and the emission factors for NMVOCs |
| Stoves (2015-2016) | $CH_4$ | 125 | g/GJ | Same as stoves (2008-2014) |
| Stoves (2017-) | $CH_4$ | 125 | g/GJ | Same as stoves (2008-2014) |
| Eco labelled stoves / new advanced stoves (-2014) | $CH_4$ | 2 | g/GJ | Low emissions from wood burning in an ecolabelled residential boiler. Olsson & Kjällstrand (2005) |
| Eco labelled stoves / new advanced stoves (2015-2016) | $CH_4$ | 2 | g/GJ | Same as advanced / ecolabelled stoves |
| Eco labelled stoves / new advanced stoves (2017-) | $CH_4$ | 2 | g/GJ | Same as advanced / ecolabelled stoves |
| Open fireplaces and similar | $CH_4$ | 430 | g/GJ | Assumed equal to stoves (-1989) |
| Masonry heat accumulating stoves and similar | $CH_4$ | 215 | g/GJ | Assumed equal to stoves (-1989) |
| Boilers with accumulation tank (-1979) | $CH_4$ | 211 | g/GJ | Methane emissions from residential biomass combustion, Paulrud et al 2005 (SMED report, Swe-den) |
| Boilers without accumulation tank (-1979) | $CH_4$ | 256 | g/GJ | Methane emissions from residential biomass combustion, Paulrud et al 2005 (SMED report, Swe-den) |
| Boilers with accumulation tank (1980-) | $CH_4$ | 50 | g/GJ | Emission characteristics of modern and old-type residential boilers fired with wood logs and wood pellets. Johansson et al. (2004) |
| Boilers without accumulation tank (1980-) | $CH_4$ | 50 | g/GJ | Emission characteristics of modern and old-type residential boilers fired with wood logs and wood pellets. Johansson et al. (2004) |
| Pellet boilers / pellet stoves | $CH_4$ | 3 | g/GJ | Methane emissions from residential biomass combustion, Paulrud et al 2005 (SMED report, Swe-den) |
| Stoves (-1989) | CO | 8000 | g/GJ | Assumed two times stoves (1990-2007). EEA (2016),Small combustion, table 3.40, conventional stoves; 4000 g/GJ (1000 g/GJ - 10,000 g/GJ) |
| Stoves (1990-2007) | CO | 4000 | g/GJ | EEA (2016), Small combustion, table 3.40, conventional stoves. |
| Stoves (2008-2014) | CO | 1900 | g/GJ | Andersen & Hvidbjerg (2017) and Kindbom et al. (2017) |
| Stoves (2015-2016) | CO | 1900 | g/GJ | Andersen & Hvidbjerg (2017) and Kindbom et al. (2017) |
| Stoves (2017-) | CO | 1900 | g/GJ | Andersen & Hvidbjerg (2017) and Kindbom et al. (2017) |
| Eco labelled stoves / new advanced stoves (-2014) | CO | 1900 | g/GJ | Andersen & Hvidbjerg (2017) and Kindbom et al. (2017) |
| Eco labelled stoves / new advanced stoves (2015-2016) | CO | 1900 | g/GJ | Andersen & Hvidbjerg (2017) and Kindbom et al. (2017) |
| Eco labelled stoves / new advanced stoves (2017-) | CO | 1900 | g/GJ | Andersen & Hvidbjerg (2017) and Kindbom et al. (2017) |
| Open fireplaces and similar | CO | 4000 | g/GJ | EEA (2019), Small Combustion, Table 3.39 Open fireplaces |
| Masonry heat accumulating stoves and similar | CO | 2402 | g/GJ | Kindbom et al. (2017) |
| Boilers with accumulation tank (-1979) | CO | 9001 | g/GJ | Winther (2008) |
| Boilers without accumulation tank (-1979) | CO | 10890 | g/GJ | Winther (2008) |
| Boilers with accumulation tank (1980-) | CO | 1613 | g/GJ | Winther (2008) |
| Boilers without accumulation tank (1980-) | CO | 1952 | g/GJ | Winther (2008) |

| | Pollutant | Emission factor | Unit | Reference |
|---|---|---|---|---|
| Pellet boilers / pellet stoves | CO | 300 | g/GJ | EEA (2019), Small Combustion, Table 3.44 Pellet stoves and boilers |
| Stoves (-1989) | $NH_3$ | 70 | g/GJ | EEA (2016), Small combustion, table 3.40, conventional stoves |
| Stoves (1990-2007) | $NH_3$ | 70 | g/GJ | EEA (2016), Small combustion, table 3.40, conventional stoves |
| Stoves (2008-2014) | $NH_3$ | 37 | g/GJ | EEA (2016), Small combustion, table 3.41, energy efficient stoves |
| Stoves (2015-2016) | $NH_3$ | 37 | g/GJ | Same as stoves (2008-2014) |
| Stoves (2017-) | $NH_3$ | 37 | g/GJ | Same as stoves (2008-2014) |
| Eco labelled stoves / new advanced stoves (-2014) | $NH_3$ | 37 | g/GJ | EEA (2016), Small combustion, table 3.42, advanced / ecolabelled stoves and boilers |
| Eco labelled stoves / new advanced stoves (2015-2016) | $NH_3$ | 37 | g/GJ | EEA (2016), Small combustion, table 3.42, advanced / ecolabelled stoves and boilers |
| Eco labelled stoves / new advanced stoves (2017-) | $NH_3$ | 37 | g/GJ | EEA (2016), Small combustion, table 3.42, advanced / ecolabelled stoves and boilers |
| Open fireplaces and similar | $NH_3$ | 74 | g/GJ | EEA (2019), Open fireplaces, Table 3.39 |
| Masonry heat accumulating stoves and similar | $NH_3$ | 70 | g/GJ | EEA (2016), Small combustion, table 3.40, conventional stoves |
| Boilers with accumulation tank (-1979) | $NH_3$ | 74 | g/GJ | EEA (2016), Small combustion, table 3.43, conventional boilers |
| Boilers without accumulation tank (-1979) | $NH_3$ | 74 | g/GJ | EEA (2016), Small combustion, table 3.43, conventional boilers |
| Boilers with accumulation tank (1980-) | $NH_3$ | 37 | g/GJ | EEA (2016), Small combustion, table 3.42, advanced / ecolabelled stoves and boilers |
| Boilers without accumulation tank (1980-) | $NH_3$ | 37 | g/GJ | EEA (2016), Small combustion, table 3.42, advanced / ecolabelled stoves and boilers |
| Pellet boilers / pellet stoves | $NH_3$ | 12 | g/GJ | EEA (2016), Small combustion, table 3.44, pellet stoves and boilers |
| Stoves (-1989) | TSP | 1000 | g/GJ | Glasius et al. (2005) |
| Stoves (1990-2007) | TSP | 500 | g/GJ | Glasius et al. (2005), Glasius et al. (2007), Kindbom et al. (2017) and Schleicher (2018) |
| Stoves (2008-2014) | TSP | 389 | g/GJ | Kindbom et al. (2017) |
| Stoves (2015-2016) | TSP | 317 | g/GJ | MST (2015). Limit value 5 g/kg |
| Stoves (2017-) | TSP | 253 | g/GJ | MST (2015). Limit value 4 g/kg |
| Eco labelled stoves / new advanced stoves (-2014) | TSP | 253 | g/GJ | Nordic Ecolabelling limit 2012 update for hand fed stove for temporary firing or inset stove (4 g/kg) |
| Eco labelled stoves / new advanced stoves (2015-2016) | TSP | 190 | g/GJ | Nordic Ecolabelling limit update for hand fed stove for temporary firing or inset stove (3 g/kg) |
| Eco labelled stoves / new advanced stoves (2017-) | TSP | 127 | g/GJ | Nordic Ecolabelling limit update |
| Open fireplaces and similar | TSP | 882 | g/GJ | Alves et al. (2011) |
| Masonry heat accumulating stoves and similar | TSP | 63 | g/GJ | Tissari et al. (2009) |
| Boilers with accumulation tank (-1979) | TSP | 588 | g/GJ | Winther (2008) |
| Boilers without accumulation tank (-1979) | TSP | 736 | g/GJ | Winther (2008) |
| Boilers with accumulation tank (1980-) | TSP | 64 | g/GJ | Winther (2008) |
| Boilers without accumulation tank (1980-) | TSP | 335 | g/GJ | Winther (2008) |
| Pellet boilers / pellet stoves | TSP | 51 | g/GJ | Kindbom et al. (2017) |
| Stoves (-1989) | $PM_{10}$ | 950 | g/GJ | 95% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Stoves (1990-2007) | $PM_{10}$ | 475 | g/GJ | 95% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Stoves (2008-2014) | $PM_{10}$ | 370 | g/GJ | 95% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |

| | Pollutant | Emission factor | Unit | Reference |
|---|---|---|---|---|
| Stoves (2015-2016) | $PM_{10}$ | 301 | g/GJ | 95% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Stoves (2017-) | $PM_{10}$ | 240 | g/GJ | 95% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Eco labelled stoves / new advanced stoves (-2014) | $PM_{10}$ | 240 | g/GJ | 95% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Eco labelled stoves / new advanced stoves (2015-2016) | $PM_{10}$ | 181 | g/GJ | 95% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Eco labelled stoves / new advanced stoves (2017-) | $PM_{10}$ | 121 | g/GJ | 95% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Open fireplaces and similar | $PM_{10}$ | 838 | g/GJ | 95% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Masonry heat accumulating stoves and similar | $PM_{10}$ | 60 | g/GJ | 95% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Boilers with accumulation tank (-1979) | $PM_{10}$ | 559 | g/GJ | 95% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Boilers without accumulation tank (-1979) | $PM_{10}$ | 699 | g/GJ | 95% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Boilers with accumulation tank (1980-) | $PM_{10}$ | 61 | g/GJ | 95% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Boilers without accumulation tank (1980-) | $PM_{10}$ | 318 | g/GJ | 95% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Pellet boilers / pellet stoves | $PM_{10}$ | 48 | g/GJ | 95% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Stoves (-1989) | $PM_{2.5}$ | 930 | g/GJ | 93% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Stoves (1990-2007) | $PM_{2.5}$ | 465 | g/GJ | 93% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Stoves (2008-2014) | $PM_{2.5}$ | 362 | g/GJ | 93% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Stoves (2015-2016) | $PM_{2.5}$ | 295 | g/GJ | 93% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Stoves (2017-) | $PM_{2.5}$ | 235 | g/GJ | 93% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Eco labelled stoves / new advanced stoves (-2014) | $PM_{2.5}$ | 235 | g/GJ | 93% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Eco labelled stoves / new advanced stoves (2015-2016) | $PM_{2.5}$ | 177 | g/GJ | 93% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Eco labelled stoves / new advanced stoves (2017-) | $PM_{2.5}$ | 118 | g/GJ | 93% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Open fireplaces and similar | $PM_{2.5}$ | 820 | g/GJ | 93% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Masonry heat accumulating stoves and similar | $PM_{2.5}$ | 59 | g/GJ | 93% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Boilers with accumulation tank (-1979) | $PM_{2.5}$ | 547 | g/GJ | 93% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Boilers without accumulation tank (-1979) | $PM_{2.5}$ | 684 | g/GJ | 93% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Boilers with accumulation tank (1980-) | $PM_{2.5}$ | 60 | g/GJ | 93% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Boilers without accumulation tank (1980-) | $PM_{2.5}$ | 312 | g/GJ | 93% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Pellet boilers / pellet stoves | $PM_{2.5}$ | 47 | g/GJ | 93% of TSP. Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP |
| Stoves (-1989) | PCDD/F | 1048 | ng/GJ | Schleicher (2018), Glasius et al. (2005), Glasius et al. (2007) and Andersen & Hvidbjerg (2017) |
| Stoves (1990-2007) | PCDD/F | 1048 | ng/GJ | Schleicher (2018), Glasius et al. (2005), Glasius et al. (2007) and Andersen & Hvidbjerg (2017) |
| Stoves (2008-2014) | PCDD/F | 1048 | ng/GJ | Schleicher (2018), Glasius et al. (2005), Glasius et al. (2007) and Andersen & Hvidbjerg (2017) |
| Stoves (2015-2016) | PCDD/F | 1048 | ng/GJ | Schleicher (2018), Glasius et al. (2005), Glasius et al. (2007) and Andersen & Hvidbjerg (2017. |
| Stoves (2017-) | PCDD/F | 1048 | ng/GJ | Schleicher (2018), Glasius et al. (2005), Glasius et al. (2007) and Andersen & Hvidbjerg (2017) |
| Eco labelled stoves / new advanced stoves (-2014) | PCDD/F | 1048 | ng/GJ | Schleicher (2018), Glasius et al. (2005), Glasius et al. (2007) and Andersen & Hvidbjerg (2017) |
| Eco labelled stoves / new advanced stoves (2015-2016) | PCDD/F | 1048 | ng/GJ | Schleicher (2018), Glasius et al. (2005), Glasius et al. (2007) and Andersen & Hvidbjerg (2017) |

| | Pollutant | Emission factor | Unit | Reference |
|---|---|---|---|---|
| Eco labelled stoves / new advanced stoves (2017-) | PCDD/F | 1048 | ng/GJ | Schleicher (2018), Glasius et al. (2005), Glasius et al. (2007) and Andersen & Hvidbjerg (2017) |
| Open fireplaces and similar | PCDD/F | 55 | ng/GJ | Gullet et al. (2005) |
| Masonry heat accumulating stoves and similar | PCDD/F | 282 | ng/GJ | Assumed equal to boilers |
| Boilers with accumulation tank (-1979) | PCDD/F | 282 | ng/GJ | Glasius et al. (2005), Glasius et al. (2007), Hübner et al. (2005) and Hedman et al. (2006) |
| Boilers without accumulation tank (-1979) | PCDD/F | 282 | ng/GJ | Glasius et al. (2005), Glasius et al. (2007), Hübner et al. (2005) and Hedman et al. (2006) |
| Boilers with accumulation tank (1980-) | PCDD/F | 282 | ng/GJ | Glasius et al. (2005), Glasius et al. (2007), Hübner et al. (2005) and Hedman et al. (2006) |
| Boilers without accumulation tank (1980-) | PCDD/F | 282 | ng/GJ | Glasius et al. (2005), Glasius et al. (2007), Hübner et al. (2005) and Hedman et al. (2006) |
| Pellet boilers / pellet stoves | PCDD/F | 333 | ng/GJ | Hedman et al. (2006) |
| Stoves (-1989) | Benzo(a) | 116 | µg/GJ | Glasius et al. (2005) |
| Stoves (1990-2007) | Benzo(a) | 48 | µg/GJ | Glasius et al. (2005) except for Benzo(b)fluoranthene that refers to Schleicher (2018) |
| Stoves (2008-2014) | Benzo(a) | 43 | µg/GJ | Schleicher (2018) |
| Stoves (2015-2016) | Benzo(a) | 43 | µg/GJ | Schleicher (2018) |
| Stoves (2017-) | Benzo(a) | 43 | µg/GJ | Schleicher (2018) |
| Eco labelled stoves / new advanced stoves (-2014) | Benzo(a) | 43 | µg/GJ | Schleicher (2018) |
| Eco labelled stoves / new advanced stoves (2015-2016) | Benzo(a) | 43 | µg/GJ | Schleicher (2018) |
| Eco labelled stoves / new advanced stoves (2017-) | Benzo(a) | 43 | µg/GJ | Schleicher (2018) |
| Open fireplaces and similar | Benzo(a) | 35 | µg/GJ | Gullet et al. (2003) |
| Masonry heat accumulating stoves and similar | Benzo(a) | 17 | µg/GJ | Tissari et al. (2007) |
| Boilers with accumulation tank (-1979) | Benzo(a) | 991 | µg/GJ | Winther (2008) |
| Boilers without accumulation tank (-1979) | Benzo(a) | 991 | µg/GJ | Winther (2008) |
| Boilers with accumulation tank (1980-) | Benzo(a) | 90 | µg/GJ | Johansson et al. (2006) |
| Boilers without accumulation tank (1980-) | Benzo(a) | 120 | µg/GJ | Johansson et al. (2006) |
| Pellet boilers / pellet stoves | Benzo(a) | 0.9 | µg/GJ | Orasche et al. (2012), distribution between Benzo(b)fluoranthene and Benzo(k)fluoranthene according to Lamberg et al. (2011) |
| Stoves (-1989) | Benzo(b) | 55 | µg/GJ | Glasius et al. (2005) |
| Stoves (1990-2007) | Benzo(b) | 59 | µg/GJ | Glasius et al. (2005) except for Benzo(b)fluoranthene that refers to Schleicher (2018) |
| Stoves (2008-2014) | Benzo(b) | 65 | µg/GJ | Schleicher (2018) |
| Stoves (2015-2016) | Benzo(b) | 65 | µg/GJ | Schleicher (2018) |
| Stoves (2017-) | Benzo(b) | 65 | µg/GJ | Schleicher (2018) |
| Eco labelled stoves / new advanced stoves (-2014) | Benzo(b) | 65 | µg/GJ | Schleicher (2018) |
| Eco labelled stoves / new advanced stoves (2015-2016) | Benzo(b) | 65 | µg/GJ | Schleicher (2018) |
| Eco labelled stoves / new advanced stoves (2017-) | Benzo(b) | 65 | µg/GJ | Schleicher (2018) |
| Open fireplaces and similar | Benzo(b) | 25 | µg/GJ | Gullet et al. (2003) |
| Masonry heat accumulating stoves and similar | Benzo(b) | 7.6 | µg/GJ | Tissari et al. (2007) |
| Boilers with accumulation tank (-1979) | Benzo(b) | 926 | µg/GJ | Winther (2008) |

| | Pollutant | Emission factor | Unit | Reference |
|---|---|---|---|---|
| Boilers without accumulation tank (-1979) | Benzo(b) | 926 | µg/GJ | Winther (2008) |
| Boilers with accumulation tank (1980-) | Benzo(b) | 60 | µg/GJ | Johansson et al. (2006) |
| Boilers without accumulation tank (1980-) | Benzo(b) | 80 | µg/GJ | Johansson et al. (2006) |
| Pellet boilers / pellet stoves | Benzo(b) | 1.3 | µg/GJ | Orasche et al. (2012), distribution between Benzo(b)fluoranthene and Benzo(k)fluoranthene according to Lamberg et al. (2011) |
| Stoves (-1989) | Benzo(k) | 119 | µg/GJ | Glasius et al. (2005) |
| Stoves (1990-2007) | Benzo(k) | 50 | µg/GJ | Glasius et al. (2005) except for Benzo(b)fluoranthene that refers to Schleicher (2018) |
| Stoves (2008-2014) | Benzo(k) | 19 | µg/GJ | Schleicher (2018) |
| Stoves (2015-2016) | Benzo(k) | 19 | µg/GJ | Schleicher (2018) |
| Stoves (2017-) | Benzo(k) | 19 | µg/GJ | Schleicher (2018) |
| Eco labelled stoves / new advanced stoves (-2014) | Benzo(k) | 19 | µg/GJ | Schleicher (2018) |
| Eco labelled stoves / new advanced stoves (2015-2016) | Benzo(k) | 19 | µg/GJ | Schleicher (2018) |
| Eco labelled stoves / new advanced stoves (2017-) | Benzo(k) | 19 | µg/GJ | Schleicher (2018) |
| Open fireplaces and similar | Benzo(k) | 29 | µg/GJ | Gullet et al. (2003) |
| Masonry heat accumulating stoves and similar | Benzo(k) | 9.5 | µg/GJ | Tissari et al. (2007) |
| Boilers with accumulation tank (-1979) | Benzo(k) | 632 | µg/GJ | Winther (2008) |
| Boilers without accumulation tank (-1979) | Benzo(k) | 632 | µg/GJ | Winther (2008) |
| Boilers with accumulation tank (1980-) | Benzo(k) | 40 | µg/GJ | Johansson et al. (2006) |
| Boilers without accumulation tank (1980-) | Benzo(k) | 50 | µg/GJ | Johansson et al. (2006) |
| Pellet boilers / pellet stoves | Benzo(k) | 1.3 | µg/GJ | Orasche et al. (2012), distribution between Benzo(b)fluoranthene and Benzo(k)fluoranthene according to Lamberg et al. (2011) |
| Stoves (-1989) | Indeno | 62 | µg/GJ | Glasius et al. (2005) |
| Stoves (1990-2007) | Indeno | 27 | µg/GJ | Glasius et al. (2005) except for Benzo(b)fluoranthene that refers to Schleicher (2018) |
| Stoves (2008-2014) | Indeno | 31 | µg/GJ | Schleicher (2018) |
| Stoves (2015-2016) | Indeno | 31 | µg/GJ | Schleicher (2018) |
| Stoves (2017-) | Indeno | 31 | µg/GJ | Schleicher (2018) |
| Eco labelled stoves / new advanced stoves (-2014) | Indeno | 31 | µg/GJ | Schleicher (2018) |
| Eco labelled stoves / new advanced stoves (2015-2016) | Indeno | 31 | µg/GJ | Schleicher (2018) |
| Eco labelled stoves / new advanced stoves (2017-) | Indeno | 31 | µg/GJ | Schleicher (2018) |
| Open fireplaces and similar | Indeno | 21 | µg/GJ | Gullet et al. (2003) |
| Masonry heat accumulating stoves and similar | Indeno | 25 | µg/GJ | Tissari et al. (2007) |
| Boilers with accumulation tank (-1979) | Indeno | 1092 | µg/GJ | Winther (2008) |
| Boilers without accumulation tank (-1979) | Indeno | 1092 | µg/GJ | Winther (2008) |
| Boilers with accumulation tank (1980-) | Indeno | 40 | µg/GJ | Johansson et al. (2006) |
| Boilers without accumulation tank (1980-) | Indeno | 60 | µg/GJ | Johansson et al. (2006) |

| | Pollutant | Emission factor | Unit | Reference |
|---|---|---|---|---|
| Pellet boilers / pellet stoves | Indeno | 1.2 | µg/GJ | Orasche et al. (2012), distribution between Benzo(b)fluoranthene and Benzo(k)fluoranthene according to Lamberg et al. (2011) |
| Stoves (-1989) | dl-PCBs | 7049 | ng/GJ | Hedman (2006), old boiler. Recalculation from TEQ to sum of dioxin-like PCBs *133 (Thistlethwaite, 2001) |
| Stoves (1990-2007) | dl-PCBs | 7049 | ng/GJ | Hedman (2006), old boiler. Recalculation from TEQ to sum of dioxin-like PCBs *133 (Thistlethwaite, 2001) |
| Stoves (2008-2014) | dl-PCBs | 931 | ng/GJ | Hedman (2006), modern boiler. Recalculation from TEQ to sum of dioxin-like PCBs *133 (Thistlethwaite, 2001) |
| Stoves (2015-2016) | dl-PCBs | 931 | ng/GJ | Same as stoves (2008-2014) |
| Stoves (2017-) | dl-PCBs | 931 | ng/GJ | Same as stoves (2008-2014) |
| Eco labelled stoves / new advanced stoves (-2014) | dl-PCBs | 466 | ng/GJ | Hedman (2006), assumed ½ stoves (2017-) |
| Eco labelled stoves / new advanced stoves (2015-2016) | dl-PCBs | 466 | ng/GJ | Same as Eco labelled stoves / new advanced stoves (-2014) |
| Eco labelled stoves / new advanced stoves (2017-) | | 466 | ng/GJ | Same as Eco labelled stoves / new advanced stoves (-2014) |
| Open fireplaces and similar | dl-PCBs | 60 | ng/GJ | EEA (2019), Open fireplaces, Table 3.39 |
| Masonry heat accumulating stoves and similar | | 7049 | ng/GJ | Hedman (2006), old boiler. Recalculation from TEQ to sum of dioxin-like PCBs *133 (Thistlethwaite, 2001) |
| Boilers with accumulation tank (-1979) | dl-PCBs | 7049 | ng/GJ | Hedman (2006), old boiler. Recalculation from TEQ to sum of dioxin-like PCBs *133 (Thistlethwaite, 2001) |
| Boilers without accumulation tank (-1979) | dl-PCBs | 7049 | ng/GJ | Hedman (2006), old boiler. Recalculation from TEQ to sum of dioxin-like PCBs *133 (Thistlethwaite, 2001) |
| Boilers with accumulation tank (1980-) | dl-PCBs | 466 | ng/GJ | Assumed equal to Eco labelled stoves / new advanced stoves (-2014) |
| Boilers without accumulation tank (1980-) | dl-PCBs | 931 | ng/GJ | Hedman (2006), modern boiler. Recalculation from TEQ to sum of dioxin-like PCBs *133 (Thistlethwaite, 2001) |
| Pellet boilers / pellet stoves | dl-PCBs | 466 | ng/GJ | Hedman (2006), assumed ½ modern boiler |
| Stoves (-1989) | BC | 18 | g/GJ | Alves et al. (2011) |
| Stoves (1990-2007) | BC | 17 | g/GJ | Schleicher (2018) |
| Stoves (2008-2014) | BC | 23 | g/GJ | Schleicher (2018) |
| Stoves (2015-2016) | BC | 44 | g/GJ | Schleicher (2018) |
| Stoves (2017-) | BC | 44 | g/GJ | Schleicher (2018) |
| Eco labelled stoves / new advanced stoves (-2014) | BC | 31 | g/GJ | Andersen & Hvidbjerg (2017) |
| Eco labelled stoves / new advanced stoves (2015-2016) | BC | 31 | g/GJ | Andersen & Hvidbjerg (2017) |
| Eco labelled stoves / new advanced stoves (2017-) | | 31 | g/GJ | Andersen & Hvidbjerg (2017) |
| Open fireplaces and similar | BC | 34 | g/GJ | Alves et al. (2011) |
| Masonry heat accumulating stoves and similar | | 18 | g/GJ | Tissari et al. (2007) |
| Boilers with accumulation tank (-1979) | BC | 24 | g/GJ | Kindbom et al. (2017) |
| Boilers without accumulation tank (-1979) | BC | 24 | g/GJ | Kindbom et al. (2017) |
| Boilers with accumulation tank (1980-) | BC | 6 | g/GJ | Kindbom et al. (2017) |

| | Pollutant | Emission factor | Unit | Reference |
|---|---|---|---|---|
| Boilers without accumulation tank (1980-) | BC | 6 | g/GJ | Kindbom et al. (2017) |
| Pellet boilers / pellet stoves | BC | 7 | g/GJ | Kindbom et al. (2017) |

# 7 Emission factors

For each fuel and SNAP category (sector and e.g. type of plant), a set of general area source emission factors has been determined. The GHG emission factors are either nationally referenced or based on the IPCC Guidelines (2006). The emission factors for other pollutants are either nationally referenced or based on the EMEP/EEA Guidebook (EEA, 2016)[21].

An overview of the type of $CO_2$ emission factor is shown in Table 37. A complete list of emission factors including time series and references is provided in Chapter 7.2 – 7.16 and Annex 4.

## 7.1 EU ETS data for $CO_2$

The $CO_2$ emission factors for some large power plants and for combustion in the cement industry and refineries are plant-specific and based on the reporting to the EU Emission Trading Scheme (EU ETS). In addition, emission factors for offshore gas turbines and refinery gas are based on EU ETS data. The EU ETS data have been applied for the years 2006 - 2018.

The Danish emission inventory for stationary combustion only includes $CO_2$ emission data from plants using higher tier methods as defined in the EU decision (EU Commission, 2018), where the specific methods for determining carbon contents, oxidation factor and calorific value are specified. The EU decision includes rules for measuring, reporting and verification.

Fuel consumption data from EU ETS are included for some additional plants and fuels, e.g. biomass fuels.

For each of the plants included with plant and fuel specific $CO_2$ emission factors in the Danish inventory all applied methodologies are specified in individual monitoring plans that are approved by Danish authorities (DEA) prior to the reporting of the emissions. The plant and fuel specific $CO_2$ emission factors included in the Danish inventory are all based on fuel quality measurements[22], not default values from the Danish UNFCCC reporting. All fuel analyses are performed according to ISO 17025[23].

### 7.1.1 EU ETS data presentation

The EU ETS data include plant-specific emission factors for coal, residual oil, gas oil, natural gas, refinery gas, petroleum coke, coke oven coke and fossil waste. The EU ETS data accounted for 61 % of the $CO_2$ emission from stationary combustion in 2018.

[21] Or EEA (2019) or former updates of the Guidebook.
[22] Applying specific methods defined in the EU decision.
[23] General requirements for the competence of testing and calibration laboratories

### EU ETS data for coal

EU ETS data for 2018 were available from 18 coal fired plant (or units). The plant-specific information accounts for 97 % of the Danish coal consumption and 36 % of the total fossil $CO_2$ emission from stationary combustion plants.

Data from 17 of the 18 plants have been applied for estimating an average $CO_2$ emission factor for coal[24]. The average $CO_2$ emission factor for coal for these 17 units was 94.04 kg per GJ (Table 29). The plants all apply bituminous coal.

Table 29 EU ETS data for 17 coal fired plants, 2018.

| | Average | Min | Max |
|---|---|---|---|
| Heating value, GJ per tonne | 24.3 | 23.0 | 31.3 |
| $CO_2$ implied emission factor, kg per GJ[1)] | 94.04 | 89.46 | 95.89 |
| Oxidation factor | 0.997 | 0.989 | 1.000 |

1) Including oxidation factor.

Table 30 $CO_2$ implied emission factor time series for coal fired plants based on EU ETS data.

| Year | $CO_2$ implied emission factor, kg per GJ[1)] |
|---|---|
| 2006 | 94.4 |
| 2007 | 94.3 |
| 2008 | 94.0 |
| 2009 | 93.6 |
| 2010 | 93.6 |
| 2011 | 94.7 |
| 2012 | 94.25 |
| 2013 | 93.95 |
| 2014 | 94.17 |
| 2015 | 94.46 |
| 2016 | 94.95 |
| 2017 | 94.37 |
| 2018 | 94.04 |

1) Including oxidation factor.

### EU ETS data for residual oil

EU ETS data for 2018 based on higher tier methodologies were available from 10 plants (or units) combusting residual oil. The EU ETS data accounts for 92 % of the residual oil consumption in stationary combustion.

Data from 9 of the 10 plants have been applied for estimating an average $CO_2$ emission factor for residual oil[25]. Aggregated data and time series are shown in Table 31 and Table 32.

Table 31 EU ETS data for 10 plants combusting residual oil.

| | Average | Min | Max |
|---|---|---|---|
| Heating value, GJ per tonne | 40.7 | 40.5 | 40.9 |
| $CO_2$ implied emission factor, kg per GJ | 79.42 | 78.35 | 79.67 |
| Oxidation factor | 1.000 | 1.000 | 1.000 |

[24] Fuel consumption of the 17 plants adds up to more than 99.9% of the fuel consumption of the 18 plants. One plant is not considered representative for the coal consumption in Denmark.
[25] Fuel consumption of the 9 plants adds up to 74% of the fuel consumption of the 10 plants. The remaining plant is not considered representative for the residual oil consumption in Denmark.

Table 32 $CO_2$ implied emission factor time series for residual oil fired power plant units based on EU ETS data.

| Year | $CO_2$ implied emission factor, kg per GJ[1)] |
|---|---|
| 2006 | 78.2 |
| 2007 | 78.1 |
| 2008 | 78.5 |
| 2009 | 78.9 |
| 2010 | 79.2 |
| 2011 | 79.25 |
| 2012 | 79.21 |
| 2013 | 79.28 |
| 2014 | 79.49 |
| 2015 | 79.17 |
| 2016 | 79.29 |
| 2017 | 79.19 |
| 2018 | 79.42 |

1) Including oxidation factor.

### EU ETS data for gas oil

EU ETS data for 2018 based on higher tier methodologies were included from 2 plants combusting gas oil. Aggregated data and time series are shown in Table 33 and Table 34. The EU ETS data accounts for 0.8 % of the gas oil consumption in stationary combustion.

Table 33 EU ETS data for gas oil.

| | Average | Min | Max |
|---|---|---|---|
| Heating value, GJ per tonne | 36.7 | 35.9 | 40.6 |
| $CO_2$ implied emission factor, kg per GJ | 74.25 | 73.99 | 74.31 |
| Oxidation factor | 1.000 | 1.000 | 1.000 |

Table 34 $CO_2$ implied emission factor time series for gas oil based on EU ETS data.

| Year | $CO_2$ implied emission factor, kg per GJ[1)] |
|---|---|
| 2006 | 75.1 |
| 2007 | 74.9 |
| 2008 | 73.7 |
| 2009 | 75.1 |
| 2010 | 74.8 |
| 2011 | 74.7 |
| 2012 | 73.9 |
| 2013 | 72.7 |
| 2014 | 74.2 |
| 2015 | 73.8 |
| 2016 | 74.4 |
| 2017 | 74.7 |
| 2018 | 74.2 |

1) Including oxidation factor.

### EU ETS data for waste

EU ETS data for 2018 based on higher tier methodologies were included from 18 waste incineration plants (or units). The EU ETS data for waste incineration are based on emission measurements. The average emission factor value for the plants is 43.5 kg per GJ. The emission factors are in the interval 34.9 kg per GJ to 61.2 kg per GJ. The EU ETS data accounts for 74 % of the incinerated waste.

Table 35 EU ETS data for waste incineration.

| | Average | Min | Max |
|---|---|---|---|
| Heating value, GJ per tonne | 10.7 | 10.6 | 13.7 |
| $CO_2$ implied emission factor, kg per GJ | 43.5 | 34.9 | 61.2 |
| Oxidation factor | 1.000 | 1.000 | 1.000 |

Table 36 $CO_2$ implied emission factor time series for waste incineration.

| Year | $CO_2$ implied emission factor, kg per GJ[1)] |
|---|---|
| 2013 | 43.0 |
| 2014 | 40.8 |
| 2015 | 43.3 |
| 2016 | 43.0 |
| 2017 | 41.4 |
| 2018 | 43.5 |

#### EU ETS data for petroleum coke, coke oven coke, industrial waste and natural gas

The implemented EU ETS data set also includes $CO_2$ emission factors for industrial waste, petroleum coke and coke oven coke. The industrial plants with additional EU ETS data include cement industry, sugar production, glass wool production, lime production, and vegetable oil production.

#### EU ETS data for natural gas applied in offshore gas turbines

EU ETS data have been applied to estimate an average $CO_2$ emission factor for natural gas combusted in offshore gas turbines, see Chapter 7.2.13.

#### EU ETS data for refinery gas

EU ETS data are also applied for the two refineries in Denmark. The emission factor for refinery gas is based on EU ETS data, see Chapter 7.2.12.

## 7.2 $CO_2$ emission factors

The $CO_2$ emission factors that are not included in EU ETS data or that are included but based on lower tier methodologies are not plant-specific in the Danish inventory. The emission factors that are not plant-specific accounts for 39 % of the fossil $CO_2$ emission.

The $CO_2$ emission factors applied for 2018 are presented in Table 37. Time series have been estimated for:

- Coal
- Residual oil
- Refinery gas
- Natural gas applied in offshore gas turbines
- Natural gas, other
- Waste, fossil part
- Industrial waste, biomass part

For all other fuels, the same emission factor has been applied for 1990-2018.

In the reporting to the UNFCCC, the $CO_2$ emission is aggregated to six fuel types: solid fuels, liquid fuels, gaseous fuels, other fossil fuels, peat, and biomass. Peat is not combusted in Denmark. The correspondence list between the DCE fuel categories and the IPCC fuel categories is also provided in Table 37.

Only emissions from fossil fuels are included in the total national $CO_2$ emission. The biomass emission factors are also included in the table, because emissions from biomass are reported to the UNFCCC as a memo item[26].

[26] Data are reported, but not included in the national total.

The $CO_2$ emission from incineration of waste (42.5 + 63.3 kg per GJ) is divided into two parts: The emission from combustion of the fossil content of the waste, which is included in the national total, and the emission from combustion of the biomass part, which is reported as a memo item. In the CRF, the fuel consumption and emissions from the fossil content of the waste is reported in the fuel category Other fossil fuels.

Table 37 $CO_2$ emission factors, 2018.

| Fuel | Emission factor, kg per GJ | | Reference type | IPCC fuel category |
|---|---|---|---|---|
| | Biomass | Fossil fuel | | |
| Coal | | 94.04 1) | Country-specific | Solid |
| Brown coal briquettes | | 97.5 | IPCC (2006) | Solid |
| Coke oven coke | | 107 3) | IPCC (2006) | Solid |
| Other solid fossil fuels 6) | | 118 1) | Country-specific | Solid |
| Fly ash fossil (from coal) | | 94.04 | Country-specific | Solid |
| Petroleum coke | | 93 3) | Country-specific | Liquid |
| Residual oil | | 79.42 1) | Country-specific | Liquid |
| Gas oil | | 74.1 1) | Country-specific | Liquid |
| Kerosene | | 71.9 | IPCC (2006) | Liquid |
| Orimulsion | | 80 2) | Country-specific | Liquid |
| LPG | | 63.1 | IPCC (2006) | Liquid |
| Refinery gas | | 56.144 | Country-specific | Liquid |
| Natural gas, offshore gas turbines | | 57.639 | Country-specific | Gaseous |
| Natural gas, other | | 56.89 | Country-specific | Gaseous |
| Waste | 63.3 3)4) | + 42.5 1)3)4) | Country-specific | Biomass and Other fuels |
| Straw | 100 | | IPCC (2006) | Biomass |
| Wood | 112 | | IPCC (2006) | Biomass |
| Wood pellets | 112 | | IPCC (2006) | Biomass |
| Bio oil | 70.8 | | IPCC (2006) | Biomass |
| Biogas | 84.1 | | Country-specific | Biomass |
| Biomass gasification gas | 142.9 5) | | Country-specific | Biomass |
| Bio natural gas | 55.55 | | Country-specific | Biomass |

1) Plant-specific data from EU ETS incorporated for individual plants.
2) Not applied in 2018. Orimulsion was applied in Denmark in 1995 – 2004.
3) Plant-specific data from EU ETS incorporated for cement industry and sugar, lime and mineral wool production.
4) The emission factor for waste is (42.5+63.3) kg $CO_2$ per GJ waste. The fuel consumption and the $CO_2$ emission have been disaggregated to the two IPCC fuel categories Biomass and Other fossil fuels in CRF. The corresponding IEF for $CO_2$, Other fuels is 94.44 kg $CO_2$ per GJ fossil waste (not including plant-specific data).
5) Includes a high content of $CO_2$ in the gas.
6) Anodic carbon. Not applied in Denmark in 2018.

### 7.2.1 Coal

As mentioned above, EU ETS data have been utilised for the years 2006 - 2018 in the emission inventory. The emission factor for coal is the implied emission factor for plants that report EU ETS data that are based on fuel analysis. Data for industrial plants have been included. In 2018, the implied emission factor (including oxidation factor) was 94.04 kg per GJ. The implied emission factor values were between 89.46 and 95.89 kg per GJ.

The emission factors for coal in the years 2006-2018 refer to the implied emission factors of the EU ETS data estimated for each year. For the years 1990-2005, the emission factor for coal (94 kg / GJ) refers to the average IEF for 2006-2010.

Time series for net calorific value (NCV) of coal are available in the Danish energy statistics. NCV for Electricity plant coal fluctuates in the interval 24.1-25.8 GJ per tonne.

The correlation between NCV and $CO_2$ IEF (including the oxidation factor) in the EU ETS data (2006-2009) have been analysed and the results are shown in Annex 9. However, a significant correlation between NCV and IEF have not been found in the dataset and thus an emission factor time series based on the NCV time series was not relevant. In addition, the correlation of NCV and $CO_2$ emission factors has been analysed. This analysis is also shown in Annex 9. As expected, the correlation was better in this dataset, but still insufficient for estimating a time series for the $CO_2$ emission factor based on the NCV time series. All coal applied in Denmark is bituminous coal (DEA, 2019c) and within the range of coal qualities applied in the plants reporting data to EU ETS a correlation could not be documented.

In 2018, the $CO_2$ emission from coal consumption was based on the emission factor (94.04 kg per GJ) for 3.4% of the coal consumption. The remaining 96.6 % was covered by EU ETS data.

Time series for the $CO_2$ emission factor are shown in Table 38.

Table 38 $CO_2$ emission factor time series for coal.

| Year | $CO_2$ emission factor kg per GJ |
|---|---|
| 1990-2005 | 94.0 |
| 2006 | 94.4 |
| 2007 | 94.3 |
| 2008 | 94.0 |
| 2009 | 93.6 |
| 2010 | 93.6 |
| 2011 | 93.73 |
| 2012 | 94.25 |
| 2013 | 93.95 |
| 2014 | 94.17 |
| 2015 | 94.46 |
| 2016 | 94.95 |
| 2017 | 94.37 |
| 2018 | 94.04 |

### 7.2.2 Brown coal briquettes

The emission factor for brown coal briquettes, 97.5 kg per GJ refers to the IPCC Guidelines, 2006 (IPCC, 2006). The oxidation factor has been assumed equal to 1. The same emission factor has been applied for 1990-2018.

### 7.2.3 Coke oven coke

The emission factor for coke oven coke, 107 kg per GJ, refers to the IPCC Guidelines 2006 (IPCC, 2006). The oxidation factor has been assumed equal to 1. The same emission factor has been applied for 1990-2018.

### 7.2.4 Other solid fossil fuels (Anodic carbon)

Anodic carbon was not applied in 2018. Anodic carbon has been applied in Denmark in 2009-2013 in two mineral wool production units. The emission factor 118 kg per GJ refer to EU ETS data from one of the plants in 2012.

The emission factor is not applied because plant-specific data are available from the EU ETS dataset.

### 7.2.5 Fly ash fossil (from coal)

Fly ash from coal combustion is applied in some power plants. The emission factor has been assumed equal to the emission factor for coal. The emission factor is not applied because plant-specific data are available from the EU ETS dataset.

### 7.2.6 Petroleum coke

The emission factor 93 kg per GJ is based on EU ETS data for 2006-2010. The data includes one power plant and the cement production plant.

Plant-specific EU ETS data have been utilised for the cement production for the years 2006 - 2018.

### 7.2.7 Residual oil

The emission factor for residual oil is based on EU ETS data.

EU ETS data have been utilised for the 2006 - 2018 emission inventories. In 2018, the implied emission factor (including oxidation factor) for the plants combusting residual oil was 79.42 kg per GJ. The implied emission factor values were between 78.35 and 79.67 kg per GJ.

The emission factors for residual oil in the years 2006-2018 refer to the implied emission factors of the EU ETS data estimated for each year. For the years 1990-2005, the emission factor for residual oil refers to the average IEF for 2006-2010.

In 2018, 8 % of the $CO_2$ emission from residual oil consumption was based on the emission factor, whereas 92 % of the residual oil consumption was covered by EU ETS data.

Time series for the $CO_2$ emission factor are shown in Table 39.

Table 39 $CO_2$ emission factor time series for residual oil.

| Year | $CO_2$ emission factor kg per GJ |
|---|---|
| 1990-2005 | 78.7 |
| 2006 | 78.6 |
| 2007 | 78.5 |
| 2008 | 78.5 |
| 2009 | 78.9 |
| 2010 | 79.2 |
| 2011 | 79.25 |
| 2012 | 79.21 |
| 2013 | 79.28 |
| 2014 | 79.49 |
| 2015 | 79.17 |
| 2016 | 79.29 |
| 2017 | 79.19 |
| 2018 | 79.42 |

### 7.2.8 Gas oil

The emission factor for gas oil, 74.1 kg per GJ, is based on EU ETS data for the years 2008-2016. The emission factor is consistent with the IPCC default emission factor for gas oil (74.1 kg per GJ). The same emission factor has been applied for 1990-2018.

Plant-specific EU ETS data have been utilised for a few plants each year in the 2006 - 2018 emission inventories. In 2018, the implied emission factor for the power plants using gas oil was 74.25 kg per GJ. The EU ETS $CO_2$ emission factors were in the interval 73.99 – 74.31 kg per GJ. In 2018, only 0.8 % of the $CO_2$ emission from gas oil consumption was based on EU ETS data.

### 7.2.9 Kerosene

The emission factor for kerosene, 71.9 kg per GJ, refers to IPCC Guidelines (IPCC, 2006). The same emission factor has been applied for 1990-2018.

### 7.2.10 Orimulsion

The emission factor for orimulsion, 80 kg per GJ, refers to the Danish Energy Agency (DEA, 2019a). The IPCC default emission factor is almost the same: 80.7 kg per GJ assuming full oxidation. The $CO_2$ emission factor has been confirmed by the only major power plant operator using orimulsion (Andersen, 1996). The same emission factor has been applied for all years. Orimulsion was used in Denmark in 1995-2004.

### 7.2.11 LPG

The emission factor for LPG, 63.1 kg per GJ, refers to IPCC Guidelines (IPCC, 2006). The same emission factor has been applied for 1990-2018.

### 7.2.12 Refinery gas

The emission factor applied for refinery gas refers to EU ETS data for the two refineries in operation in Denmark. Since 2006, implied emission factors for Denmark have been estimated annually based on the EU ETS data. The average implied emission factor for 2006-2009 (57.6 kg per GJ) have been applied for the years 1990-2005. This emission factor is consistent with the emission factor stated in the IPCC Guidelines (IPCC, 2006). The time series is shown in Table 40.

Table 40 $CO_2$ emission factors for refinery gas, time series.

| Year | $CO_2$ emission factor, kg per GJ |
|---|---|
| 1990-2005 | 57.6 |
| 2006 | 57.812 |
| 2007 | 57.848 |
| 2008 | 57.948 |
| 2009 | 56.817 |
| 2010 | 57.134 |
| 2011 | 57.861 |
| 2012 | 58.108 |
| 2013 | 58.274 |
| 2014 | 57.620 |
| 2015 | 57.508 |
| 2016 | 57.335 |
| 2017 | 57.109 |
| 2018 | 56.144 |

### 7.2.13 Natural gas, offshore gas turbines

EU ETS data for the fuel consumption and $CO_2$ emission for offshore gas turbines are available for the years 2006-2018. Based on data for each oilfield, implied emission factors have been estimated for 2006-2018. The average value for 2006-2009 has been applied for the years 1990-2005. The time series is shown in Table 41.

Table 41 $CO_2$ emission factors for offshore gas turbines, time series.

| Year | $CO_2$ emission factor, kg per GJ |
|---|---|
| 1990-2005 | 57.469 |
| 2006 | 57.879 |
| 2007 | 57.784 |
| 2008 | 56.959 |
| 2009 | 57.254 |
| 2010 | 57.314 |
| 2011 | 57.379 |
| 2012 | 57.423 |
| 2013 | 57.295 |
| 2014 | 57.381 |
| 2015 | 57.615 |
| 2016 | 57.704 |
| 2017 | 57.628 |
| 2018 | 57.639 |

### 7.2.14 Natural gas, other source categories

The emission factor for natural gas is estimated by the Danish gas transmission company, Energinet.dk[27]. The calculation is based on gas analysis carried out daily by Energinet.dk at Egtved.

In 2018, the natural gas import was 15 PJ, the natural gas export 58 PJ and the consumption added up to 113 PJ. Before 2010, only natural gas from the Danish gas fields was utilised in Denmark. If the import of natural gas increases further, the methodology for estimating the $CO_2$ emission factor might have to be revised in future inventories. However, Energinet.dk have stated that the difference between the emission factor for 2011 based on measurements at Egtved and the average value at Froeslev very close to the border differed less than 0.3 % for 2011 (Bruun, 2012).

Energinet.dk and the Danish Gas Technology Centre have calculated emission factors for 2000-2018. The emission factor applied for 1990-1999 refers to Fenhann & Kilde (1994). This emission factor was confirmed by the two major power plant operators in 1996 (Christiansen, 1996 and Andersen, 1996). The time series for the $CO_2$ emission factor is provided in Table 42.

[27] Former Gastra and before that part of DONG. Historical data refer to these companies.

Table 42 $CO_2$ emission factor time series for natural gas.

| Year | $CO_2$ emission factor, kg per GJ |
|---|---|
| 1990-1999 | 56.9 |
| 2000 | 57.1 |
| 2001 | 57.25 |
| 2002 | 57.28 |
| 2003 | 57.19 |
| 2004 | 57.12 |
| 2005 | 56.96 |
| 2006 | 56.78 |
| 2007 | 56.78 |
| 2008 | 56.77 |
| 2009 | 56.69 |
| 2010 | 56.74 |
| 2011 | 56.97 |
| 2012 | 57.03 |
| 2013 | 56.79 |
| 2014 | 56.95 |
| 2015 | 57.06 |
| 2016 | 57.01 |
| 2017 | 57.00 |
| 2018 | 56.89 |

### 7.2.15 Waste

The $CO_2$ emission from incineration of waste is divided into two parts: The emission from combustion of the fossil content of the waste, which is included in the national total, and the emission from combustion of the rest of the waste – the biomass part, which is reported as a memo item.

The fossil $CO_2$ emission factor is based on EU ETS data for 2013-2016. The annual average emission factors for the plants that applied plant-specific data are shown in Table 43 below. The emission factor applied for 2013-2018 is the average value for 2013-2016 (42.5 kg per GJ). The emission factor corresponds to 94.44 kg per GJ fossil waste.

As mentioned, plant-specific EU ETS data have been reported by CHP plants incinerating waste for 2013-2018. In the inventory for 2018, plant-specific emission factors have been implemented for 18 plants or units. In 2018, the average emission factor for 17 plants (the cement production plant not included) was 43.48 kg fossil $CO_2$ per GJ total waste. The emission factors vary between plants – 34.9 kg per GJ to 61.2 kg per GJ. The 18 plants reporting data to EU ETS represent 74 % of the incinerated waste.

The emission factor for 1990-2010 is based on the project, *Biogenic carbon in Danish combustible waste* that included emission measurements from five Danish waste incineration plants (Astrup et al., 2012). The average of the fossil emission factors for waste was estimated to be 37 kg per GJ waste and the interval for the five plants was 25 – 51 kg per GJ. The five plants represented 44 % of the incinerated waste in 2010. The emission factor 37 kg per GJ waste corresponds to 82.22 kg per GJ fossil waste.

The emission factor for biogenic $CO_2$ from waste refers to Astrup et al. (2012). The average value for five plants is 63.3 kg biogenic $CO_2$ per GJ total waste. This emission factor has been applied all years. The emission factor corresponds to 115 kg biogenic $CO_2$ per GJ biogenic waste.

The time series for the fossil $CO_2$ emission factor is shown in Table 44.

Table 43 Average fossil $CO_2$ emission factors based on EU ETS data for waste.

| Year | Fossil $CO_2$ emission factor, kg fossil $CO_2$ per GJ waste (total) |
|---|---|
| 2013 | 43.0 |
| 2014 | 40.8 |
| 2015 | 43.3 |
| 2016 | 43.0 |
| 2017 | 41.4 |
| 2018 | 43.5 |
| Average 2013-2016 | 42.5 |

Table 44 Time series for the fossil $CO_2$ emission factor for waste.

| Year | $CO_2$ emission factor, kg per GJ |
|---|---|
| 1990-2010 | 37.0 |
| 2011 | 37.5 |
| 2012 | 40.0 |
| 2013-2018 | 42.5 |

Data from the waste statistics have been analysed with the purpose to improve the time series of the fossil waste emission factor. However, the data analysis has shown that is difficult to relate the available waste fraction data and the measured fossil $CO_2$ emission. Thus, currently it is not possible to estimate an improved time series for the emission factor for the years 1990-2012.

### 7.2.16 Wood

The emission factor for wood, 112 kg per GJ refers IPCC (2006). The same emission factor has been applied for 1990-2018.

### 7.2.17 Straw

The emission factor for wood, 100 kg per GJ refers IPCC (2006) for other primary solid biomass. The same emission factor has been applied for 1990-2018.

### 7.2.18 Bio oil

The emission factor, 70.8 kg per GJ refers to the IPCC (2006). The consumption of bio oil is below 1 PJ.

### 7.2.19 Biogas

In Denmark, three different types of biogas are applied: Manure/organic waste based biogas, landfill based biogas and wastewater treatment biogas (sludge gas). Manure / organic waste based biogas represent 91 % of the biogas production, see Chapter 6.12. Most of the biogas based on manure / organic waste is however upgraded to bio natural gas. The $CO_2$ emission factor for bio natural gas differs from the emission factor for biogas.

The emission factor for biogas, 84.1 kg per GJ refer to Kristensen (2015a) and the emission factor is based on a biogas with 65 % (vol.) $CH_4$ and 35 % (vol.) $CO_2$. Danish Gas Technology Centre has stated that this is a typical manure-based biogas as utilised in stationary combustion plants (Kristensen, 2015a). The same emission factor has been applied for 1990-2018.

### 7.2.20 Biomass gasification gas

Biomass gasification gas applied in Denmark is based on wood. The gas composition is known for three different plants and the applied emission factor have been estimated by Danish Gas Technology Centre (Kristensen, 2010) based on the gas composition measured on the plant with the highest consumption.

The consumption of biomass gasification gas is below 2 PJ for all years.

### 7.2.21 Bio natural gas

Biogas upgraded for distribution in the natural gas grid is referred to as bio natural gas in this report. Other references might refer to this fuel as bio-methane or upgraded biogas. Bio natural gas has been applied in Denmark since 2014. The emission factor is based on the gas composition of bio natural gas: 98.5 % $CH_4$ and 1.5 % $CO_2$. These data refer to Danish Gas Technology Centre (Kristensen, 2015b).

## 7.3 $CH_4$ emission factors

The $CH_4$ emission factors applied for 2018 are presented in Table 45. In general, the same emission factors have been applied for 1990-2018. However, time series have been estimated for both natural gas fuelled engines and biogas fuelled engines, residential wood combustion, natural gas fuelled gas turbines[28] and waste incineration plants.

Emission factors for CHP plants < 25 $MW_e$ refer to emission measurements carried out on Danish plants (Nielsen et al., 2010a; Nielsen & Illerup, 2003; Nielsen et al., 2008). The emission factors for residential wood combustion are based on technology dependent data.

Emission factors that are not nationally referenced all refer to the IPCC Guidelines (IPCC, 2006).

Gas engines combusting natural gas or biogas accounted for 49% of the $CH_4$ emission from stationary combustion plants in 2018. The relatively high emission factor for gas engines is well documented and further discussed below.

[28] A minor emission source.

Table 45 $CH_4$ emission factors, 2018.

| Fuel group | Fuel | CRF source category | CRF source category | SNAP | Emission factor, g per GJ | Reference |
|---|---|---|---|---|---|---|
| SOLID | Coal | 1A1a | Public electricity and heat production | 0101<br>0102 | 0.9 | IPCC (2006), Tier 3, Table 2-6, Utility Boiler, Pulverised bituminous coal combustion, Wet bottom |
| | | 1A2 a-g | Industry | 03 | 10 | IPCC (2006), Tier 1, Table 2-3, Manufacturing industries |
| | | 1A4b i | Residential | 0202 | 300 | IPCC (2006), Tier 1, Table 2.5, Residential, Bituminous coal |
| | | 1A4c i | Agriculture/forestry | 0203 | 10 | IPCC (2006), Tier 1, Table 2-4, Commercial, coal[1)] |
| | BKB | 1A4b i | Residential | 0202 | 300 | IPCC (2006), Tier 1, Table 2-5, Residential, brown coal briquettes |
| | Coke oven coke | 1A2 a-g | Industry | 03 | 10 | IPCC (2006), Tier 1, Table 2-4, Commercial, coke oven coke |
| | | 1A4b i | Residential | 0202 | 300 | IPCC (2006), Tier 1, Table 2-5, Residential, coke oven coke |
| | Anodic carbon | 1A2 a-g | Industry | 03 | 10 | IPCC (2006), Tier 1, Table 2-3, Manufacturing industries |
| | Fossil fly ash | 1A1a | Public electricity and heat production | 0101 | 0.9 | IPCC (2006), Tier 3, Table 2-6, Utility Boiler, Pulverised bituminous coal combustion, Wet bottom |
| LIQUID | Petroleum coke | 1A2 a-g | Industry | 03 | 3 | IPCC (2006), Tier 1, Table 2-3, Industry, petroleum coke |
| | | 1A4a | Commercial/ Institutional | 0201 | 10 | IPCC (2006), Tier 1, Table 2-4, Commercial, Petroleum coke |
| | | 1A4b | Residential | 0202 | 10 | IPCC (2006), Tier 1, Table 2-5, Residential / agricultural, Petroleum coke |
| | | 1A4c | Agriculture/forestry | 0203 | 10 | IPCC (2006), Tier 1, Table 2-5, Residential / agricultural, Petroleum coke |
| | Residual oil | 1A1a | Public electricity and heat production | 010101 | 0.8 | IPCC (2006), Tier 3, Table 2-6, Utility Boiler, Residual fuel oil |
| | | | | 010102<br>010103 | 1.3 | Nielsen et al. (2010a) |
| | | | | 010104 | 3 | IPCC (2006), Tier 1, Table 2-2, Energy industries, residual oil |
| | | | | 010105 | 4 | IPCC (2006), Tier 3, Table 2-6, Utility, Large diesel engines |
| | | | | 010203 | 0.8 | IPCC (2006), Tier 3, Table 2-6, Utility Boiler, Residual fuel oil |
| | | 1A1b | Petroleum refining | 010306 | 3 | IPCC (2006), Tier 1, Table 2-2, Energy industries, residual fuel oil |
| | | 1A2 a-g | Industry | 03 | 1.3 | Nielsen et al. (2010a) |
| | | | | Engines | 4 | IPCC (2006), Tier 3, Table 2-6, Utility, Large diesel engines |
| | | 1A4a | Commercial/ Institutional | 0201 | 1.4 | IPCC (2006), Tier 3, Table 2-10, Commercial, residual fuel oil boilers |
| | | 1A4b | Residential | 0202 | 1.4 | IPCC (2006), Tier 3, Table 2-9, Residential, residual fuel oil |
| | | 1A4c | Agriculture/forestry | 0203 | 1.4 | IPCC (2006), Tier 3, Table 2-10, Commercial, residual fuel oil boilers[1)]. |
| | Gas oil | 1A1a | Public electricity and heat production | 010101<br>010102<br>010103 | 0.9 | IPCC (2006), Tier 3, Table 2-6, Utility, gas oil, boilers |
| | | | | 010104 | 3 | IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil |
| | | | | 010105 | 24 | Nielsen et al. (2010a) |
| | | | | 010202<br>010203 | 0.9 | IPCC (2006), Tier 3, Table 2-6, Utility, gas oil, boilers |
| | | 1A1b | Petroleum refining | 010306 | 3 | IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil |
| | | 1A1c | Oil and gas extraction | 010504 | 3 | IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil |
| | | 1A2 a-g | Industry | 03 | 0.2 | IPCC (2006), Tier 3, Table 2-7, Industry, gas oil, boilers |
| | | | | Turbines | 3 | IPCC (2006), Tier 1, Table 2-3, Industry, gas oil |
| | | | | Engines | 24 | Nielsen et al. (2010a) |

| Fuel group | Fuel | CRF source category | CRF source category | SNAP | Emission factor, g per GJ | Reference |
|---|---|---|---|---|---|---|
| | | 1A4a | Commercial/ Institutional | 0201 | 0.7 | IPCC (2006), Tier 3, Table 2-10, Commercial, gas oil |
| | | | | 020105 | 24 | Nielsen et al. (2010a) |
| | | 1A4b i | Residential | 0202 | 0.7 | IPCC (2006), Tier 3, Table 2.9, Residential, gas oil |
| | | | | 020204 | 24 | Nielsen et al. (2010a) |
| | | 1A4c | Agriculture/forestry | 0203 | 0.7 | IPCC (2006), Tier 3, Table 2-10, Commercial, gas oil[1)] |
| | | | | 020304 | 24 | Nielsen et al. (2010a) |
| | Kerosene | 1A2 a-g | Industry | 03 | 3 | IPCC (2006), Tier 1, Table 2-3, Industry, other kerosene |
| | | 1A4a | Commercial/ Institutional | 0201 | 10 | IPCC (2006), Tier 1, Table 2-4, Commercial, other kerosene |
| | | 1A4b i | Residential | 0202 | 10 | IPCC (2006), Tier 1, Table 2-5, Residential/agricultural, other kerosene |
| | | 1A4c i | Agriculture/forestry | 0203 | 10 | IPCC (2006), Tier 1, Table 2-5, Residential/agricultural, other kerosene |
| | LPG | 1A1a | Public electricity and heat production | 0101<br>0102 | 1 | IPCC (2006), Tier 1, Table 2-2, Energy industries, LPG |
| | | 1A1b | Petroleum refining | 0103 | 1 | IPCC (2006), Tier 1, Table 2-2, Energy industries, LPG |
| | | 1A2 a-g | Industry | 03 | 1 | IPCC (2006), Tier 1, Table 2-3, Industry, LPG |
| | | 1A4a | Commercial/ Institutional | 0201 | 5 | IPCC (2006), Tier 1, Table 2-4, Commercial, LPG |
| | | 1A4b i | Residential | 0202 | 5 | IPCC (2006), Tier 1, Table 2-5, Residential / agricultural, LPG |
| | | 1A4c i | Agriculture/forestry | 0203 | 5 | IPCC (2006), Tier 1, Table 2-5, Residential / agricultural, LPG |
| | Refinery gas | 1A1b | Petroleum refining | 010304 | 1.7 | Assumed equal to natural gas fuelled gas turbines. Nielsen et al. (2010a) |
| | | | | 010306 | 1 | IPCC (2006), Tier 1, Table 2-2, refinery gas |
| GAS | Natural gas | 1A1a | Public electricity and heat production | 010101<br>010102<br>010103 | 1 | IPCC (2006), Tier 3, Table 2-6, Utility, natural gas, boilers |
| | | | | 010104 | 1.7 | Nielsen et al. (2010a) |
| | | | | 010105 | 481 | Nielsen et al. (2010a) |
| | | | | 010202<br>010203 | 1 | IPCC (2006), Tier 3, Table 2-6, Utility, natural gas, boilers |
| | | 1A1b | Petroleum refining | 010306 | 1 | Assumed equal to industrial boilers |
| | | 1A1c | Oil and gas extraction | 010503 | 1 | Assumed equal to industrial boilers |
| | | | | 010504 | 1.7 | Nielsen et al. (2010a) |
| | | 1A2 a-g | Industry | Other | 1 | IPCC (2006), Tier 3, Table 2-7, Industry, natural gas boilers |
| | | | | Gas turbines | 1.7 | Nielsen et al. (2010a) |
| | | | | Engines | 481 | Nielsen et al. (2010a) |
| | | 1A4a | Commercial/ Institutional | 0201<br>020105 | 1<br>481 | IPCC (2006), Tier 3, Table 2-10, Commercial, natural gas boilers<br>Nielsen et al. (2010a) |
| | | 1A4b i | Residential | 0202 | 1 | IPCC (2006), Tier 3, Table 2-9. Residential, natural gas boilers |
| | | | | 020204 | 481 | Nielsen et al. (2010a) |
| | | 1A4c i | Agriculture/forestry | 0203 | 1 | IPCC (2006), Tier 3, Table 2-10, Commercial, natural gas boilers[1)] |
| | | | | 020304 | 481 | Nielsen et al. (2010a) |
| WASTE | Waste | 1A1a | Public electricity and heat production | 0101<br>0102 | 0.34 | Nielsen et al. (2010a) |
| | | 1A2 a-g | Industry | 03 | 30 | IPCC (2006), Tier 1, Table 2-3, Industry, municipal wastes |
| | | 1A4a | Commercial/ Institutional | 0201 | 30 | IPCC (2006), Tier 1, Table 2-3, Industry, municipal wastes [2)] |
| | Industrial waste | 1A2f | Industry | 0316 | 30 | IPCC (2006), Tier 1, Table 2-3, Industry, industrial wastes |
| BIOMASS | Wood | 1A1a | Public electricity and heat production | 0101 | 3.1 | Nielsen et al. (2010a) |

| Fuel group | Fuel | CRF source category | CRF source category | SNAP | Emission factor, g per GJ | Reference |
|---|---|---|---|---|---|---|
| | | | | 0102 | 11 | IPCC (2006), Tier 3, Table 2-6, Utility boilers, wood |
| | | 1A2 a-g | Industry | 03 | 11 | IPCC (2006), Tier 3, Table 2-7, Industry, wood, boilers |
| | | 1A4a | Commercial/ Institutional | 0201 | 11 | IPCC (2006), Tier 3, Table 2-10, Commercial, wood |
| | | 1A4b i | Residential | 0202 | 110.77 | DCE estimate based on technology distribution, Nielsen et al. (2020) [3)] |
| | | 1A4c i | Agriculture/forestry | 0203 | 11 | IPCC (2006), Tier 3, Table 2-10, Commercial, wood.[1)] |
| | Straw | 1A1a | Public electricity and heat production | 0101 | 0.47 | Nielsen et al. (2010a) |
| | | | | 0102 | 30 | IPCC (2006), Tier 1, Table 2-2, Energy industries, other primary solid biomass |
| | | 1A4b i | Residential | 0202 | 300 | IPCC (2006), Tier 1, Table 2-5, Residential, other primary solid biomass |
| | | 1A4c i | Agriculture/forestry | 020300 | 300 | IPCC (2006), Tier 1, Table 2-5, Agriculture, other primary solid biomass |
| | | | | 020302 | 30 | IPCC (2006), Tier 1, Table 2-2, Energy industries, other primary solid biomass (large agricultural plants considered equal to this plant category) |
| | Wood pellets | 1A1a | Public electricity and heat production | 0101 | 3.1 | Nielsen et al. (2010a) |
| | | | | 0102 | 11 | IPCC (2006), Tier 3, Table 2-6, Utility boilers, wood |
| | | 1A2 a-g | Industry | 03 | 11 | IPCC (2006), Tier 3, Table 2-7, Industry, wood, boilers |
| | | 1A4a | Commercial/ Institutional | 0201 | 11 | IPCC (2006), Tier 3, Table 2-10, Commercial, wood |
| | | 1A4b i | Residential | 0202 | 3 | Paulrud et al. (2005) |
| | | 1A4c i | Agriculture/forestry | 0203 | 11 | IPCC (2006), Tier 3, Table 2-10, Commercial, wood.[1)] |
| | Bio oil | 1A1a | Public electricity and heat production | 010102 | 3 | IPCC (2006), Tier 1, Table 2-2, Energy industries, biodiesels |
| | | | | 010105 | 24 | Nielsen et al. (2010a) assumed same emission factor as for gas oil fuelled engines |
| | | | | 0102 | 3 | IPCC (2006), Tier 1, Table 2-2, Energy industries, biodiesels |
| | | 1A2 a-g | Industry | 03 | 3 | IPCC (2006), Tier 1, Table 2-3, Industry, biodiesels |
| | | | | 030902 | 0.2 | - |
| | | 1A4b i | Residential | 0202 | 10 | IPCC (2006), Tier 1, Table 2-5, Residential, biodiesels |
| | Biogas | 1A1a | Public electricity and heat production | 0101 | 1 | IPCC (2006), Tier 1, Table 2-2, Energy ndustries, other biogas |
| | | | | 010105 | 434 | Nielsen et al. (2010a) |
| | | | | 0102 | 1 | IPCC (2006), Tier 1, Table 2-2, Energy industries, other biogas |
| | | 1A2 a-g | Industry | 03 | 1 | IPCC (2006), Tier 1, Table 2-3, Industry, other biogas |
| | | | | Engines | 434 | Nielsen et al. (2010a) |
| | | 1A4a | Commercial/ Institutional | 0201 | 5 | IPCC (2006), Tier 1, Table 2-4, Commercial, other biogas |
| | | | | 020105 | 434 | Nielsen et al. (2010a) |
| | | 1A4b | Residential | 0202 | 1 | Assumed equal to natural gas |
| | | 1A4c i | Agriculture/forestry | 0203 | 5 | IPCC (2006), Tier 1, Table 2-5, Agriculture, other biogas |
| | | | | 020304 | 434 | Nielsen et al. (2010a) |
| | Bio gasification gas | 1A1a | Public electricity and heat production | 010101 | 1 | Assumed equal to biogas |
| | | | | 010105 | 13 | Nielsen et al. (2010a) |
| | | 1A4a | Commercial/institutional | 020105 | 13 | Nielsen et al. (2010a) |
| | Bio natural gas | 1A1a | Public electricity and heat production | 0101 0102 | 1 | Assumed equal to natural gas |

| Fuel group | Fuel | CRF source category | CRF source category | SNAP | Emission factor, g per GJ | Reference |
|---|---|---|---|---|---|---|
| | | 1A2 a-g | Industry | 03 | 1 | Assumed equal to natural gas |
| | | 1A4a | Commercial/ Institutional | 0201 | 1 | Assumed equal to natural gas |
| | | 1A4b | Residential | 0202 | 1 | Assumed equal to natural gas |
| | | 1A4c | Agriculture/forestry | 0203 | 1 | Assumed equal to natural gas |

1) Assumed same emission factors as for commercial plants. Plant capacity and technology are similar for Danish plants.

2) Assumed same emission factor as for industrial plants. Plant capacity and technology is similar to industrial plants rather than to residential plants.

3) Aggregated emission factor based on the technology distribution in the sector (Nielsen et al., 2020) and technology specific emission factors that refer to Paulrud et al. (2005), Johansson et al. (2004) and Olsson & Kjällstrand (2005). The emission factor is within the IPCC (2006) interval for residential wood combustion (100-900 g per GJ).

### 7.3.1 CHP plants

A considerable part of the electricity production in Denmark is based on decentralised CHP plants, and well-documented emission factors for these plants are, therefore, of importance. In a project carried out for the electricity transmission company, Energinet.dk, emission factors for CHP plants <25MW$_e$ have been estimated. The work was reported in 2010 (Nielsen et al., 2010a).

The work included waste incineration plants, CHP plants combusting wood and straw, natural gas and biogas-fuelled (reciprocating) engines, natural gas fuelled gas turbines, gas oil fuelled engines, gas oil fuelled gas turbines, steam turbines fuelled by residual oil and engines fuelled by biomass gasification gas. $CH_4$ emission factors for these plants all refer to Nielsen et al. (2010a). The estimated emission factors were based on existing emission measurements as well as on emission measurements carried out within the project. The number of emission data sets was comprehensive. Emission factors for subgroups of each plant type were estimated, e.g. the $CH_4$ emission factors for different gas engine types were determined.

Time series for the $CH_4$ emission factors are based on a similar project estimating emission factors for year 2000 (Nielsen & Illerup, 2003).

#### Natural gas, gas engines

The emission factor for natural gas engines refers to the Nielsen et al. (2010a). The emission factor includes the increased emission during start/stop of the engines estimated by Nielsen et al. (2008). Emission factor time series for the years 1990-2007 have been estimated based on Nielsen & Illerup (2003). These three references are discussed below.

Nielsen et al. (2010a):

> *$CH_4$ emission factors for gas engines were estimated for 2003-2006 and for 2007-2010. The dataset was split in two, due to new emission limits for engines from October 2006. The emission factors were based on emission measurements from 366 (2003-2006) and 157 (2007-2010) engines respectively. The engines from which emission measurements were available for 2007-2010 represented 38 % of the gas consumption. The emission factors were estimated based on fuel consumption for each gas engine type and the emission factor for each engine type. The majority of emission measurements that were not performed within the project related solely to the emis-*

*sion of total unburned hydrocarbon ($CH_4$ + NMVOC). A constant disaggregation factor was estimated based on 9 emission measurements including both $CH_4$ and NMVOC.*

Nielsen & Illerup (2003):

*The emission factor for natural gas engines was based on 291 emission measurements in 114 different plants. The plants from which emission measurements were available represented 44 % of the total gas consumption in gas engines in year 2000.*

Nielsen et al. (2008):

*This study calculated a start/stop correction factor. This factor was applied to the time series estimated in Nielsen & Illerup (2003). Further, the correction factors were applied in Nielsen et al. (2010a).*

The emission factor for lean-burn gas engines is relatively high, especially for pre-chamber engines, which account for more than half the gas consumption in Danish gas engines. However, the emission factors for different pre-chamber engine types differ considerably.

The installation of natural gas engines in decentralised CHP plants in Denmark has taken place since 1990. The first engines installed were relatively small open-chamber engines but later mainly pre-chamber engines were installed. As mentioned above, pre-chamber engines have a higher emission factor than open-chamber engines; therefore, the emission factor has increased during the period 1990-1995. After that, technical improvements of the engines have been implemented as a result of upcoming emission limits that most installed gas engines had to meet in late 2006 (DEPA, 2005).

The time series were based on:

- Full load emission factors for different engine types in year 2000 (Nielsen & Illerup, 2003), 2003-2006 and 2007-2010 (Nielsen et al., 2010a).
- Data for year of installation for each engine and fuel consumption of each engine 1994-2002 from the Danish Energy Agency (DEA, 2003).
- Research concerning the $CH_4$ emission from gas engines carried out in 1997 (Nielsen & Wit, 1997).
- Correction factors including increased emission during start/stop of the engines (Nielsen et al., 2008).

Table 46 Time series for the $CH_4$ emission factor for natural gas fuelled engines.

| Year | Emission factor, g per GJ |
|---|---|
| 1990 | 266 |
| 1991 | 309 |
| 1992 | 359 |
| 1993 | 562 |
| 1994 | 623 |
| 1995 | 632 |
| 1996 | 616 |
| 1997 | 551 |
| 1998 | 542 |
| 1999 | 541 |
| 2000 | 537 |
| 2001 | 522 |
| 2002 | 508 |
| 2003 | 494 |
| 2004 | 479 |
| 2005 | 465 |
| 2006 | 473 |
| 2007-2018 | 481 |

#### Gas engines, biogas

The emission factor for biogas engines was estimated to 434 g per GJ in 2007-2018. The emission factor is lower than the factor for natural gas mainly because most biogas-fuelled engines are lean-burn open-chamber engines - not pre-chamber engines.

Time series for the emission factor have been estimated. The emission factors for biogas engines were based on Nielsen et al. (2010a) and Nielsen & Illerup (2003). The two references are discussed below. The time series are shown in Table 47.

Nielsen et al. (2010a):

> *$CH_4$ emission factors for gas engines were estimated for 2006 based on emission measurements performed in 2003-2010. The emission factor was based on emission measurements from 10 engines. The engines from which emission measurements were available represented 8 % of the gas consumption. The emission factor was estimated based on fuel consumption for each gas engine type and the emission factor for each engine type. The majority of emission measurements that were not performed within the project related solely to the emission of total unburned hydrocarbon ($CH_4$ + NMVOC). A constant disaggregation factor was estimated based on 3 emission measurements including both $CH_4$ and NMVOC.*

Nielsen & Illerup (2003):

> *The emission factor for natural gas engines was based on 18 emission measurements from 13 different engines. The engines from which emission measurements were available represented 18 % of the total biogas consumption in gas engines in year 2000.*

Table 47 Time series for the $CH_4$ emission factor for biogas-fuelled engines.

| Year | Emission factor, g per GJ |
|---|---|
| 1990 | 239 |
| 1991 | 251 |
| 1992 | 264 |
| 1993 | 276 |
| 1994 | 289 |
| 1995 | 301 |
| 1996 | 305 |
| 1997 | 310 |
| 1998 | 314 |
| 1999 | 318 |
| 2000 | 323 |
| 2001 | 342 |
| 2002 | 360 |
| 2003 | 379 |
| 2004 | 397 |
| 2005 | 416 |
| 2006 | 434 |
| 2007-2018 | 434 |

#### Gas turbines, natural gas

The emission factor for gas turbines was estimated to be below 1.7 g per GJ in 2005 (Nielsen et al., 2010a). The emission factor was based on emission measurements on five plants. The emission factor in year 2000 was 1.5 g per GJ (Nielsen & Illerup, 2003). A time series have been estimated.

#### CHP, wood

The emission factor for CHP plants combusting wood was estimated to be below 3.1 g per GJ (Nielsen et al., 2010a) and the emission factor 3.1 g per GJ has been applied for all years. The emission factor was based on emission measurements on two plants.

#### CHP, straw

The emission factor for CHP plants combusting straw was estimated to be below 0.47 g per GJ (Nielsen et al., 2010a) and the emission factor 0.47 g per GJ has been applied for all years. The emission factor was based on emission measurements on four plants.

#### CHP, waste

The emission factor for CHP plants combusting waste was estimated to be below 0.34 g per GJ in 2006 (Nielsen et al., 2010a) and 0.59 g per GJ in year 2000 (Nielsen & Illerup, 2003). A time series have been estimated. The emission factor was based on emission measurements on nine plants.

The emission factor has also been applied for district heating plants.

### 7.3.2 Residential wood combustion

The emission factor for residential wood refers to Nielsen et al. (2020c), see Chapter 6.13. The emission factor for residential wood combustion (not including wood pellets) is based on technology specific data. The emission factor time series is shown in Table 48.

Table 48 $CH_4$ emission factor time series for residential wood combustion[1)].

| Year | Emission factor, g per GJ |
|---|---|
| 1990 | 327 |
| 1991 | 321 |
| 1992 | 314 |
| 1993 | 308 |
| 1994 | 302 |
| 1995 | 296 |
| 1996 | 289 |
| 1997 | 283 |
| 1998 | 276 |
| 1999 | 270 |
| 2000 | 263 |
| 2001 | 256 |
| 2002 | 248 |
| 2003 | 240 |
| 2004 | 227 |
| 2005 | 215 |
| 2006 | 206 |
| 2007 | 197 |
| 2008 | 188 |
| 2009 | 178 |
| 2010 | 167 |
| 2011 | 160 |
| 2012 | 152 |
| 2013 | 145 |
| 2014 | 138 |
| 2015 | 131 |
| 2016 | 124 |
| 2017 | 117 |
| 2018 | 111 |

1) Wood pellets not included.

### 7.3.3 Other stationary combustion plants

Emission factors for other plants refer to the IPCC Guidelines (IPCC, 2006).

## 7.4 $N_2O$ emission factors

The $N_2O$ emission factors applied for the 2018 inventory are listed in Table 49. Time series have been estimated for natural gas fuelled gas turbines and refinery gas fuelled turbines. All other emission factors have been applied unchanged for 1990-2018.

Emission factors for natural gas fuelled reciprocating engines, natural gas fuelled gas turbines, CHP plants < 300 MW combusting wood, straw or residual oil, waste incineration plants, engines fuelled by gas oil and gas engines fuelled by biomass gasification gas all refer to emission measurements carried out on Danish plants, Nielsen et al. (2010a).

The emission factor for coal-powered plants in public power plants refers to research conducted by Elsam (now part of Ørsted).

Plant-specific emission factors have been included for two industrial plants.

The emission factor for offshore gas turbines has been assumed to follow the time series for natural gas fuelled gas turbines in Danish CHP plants. There is no evidence to suggest that offshore gas turbines have different emission characteristics for $N_2O$ compared to on-shore natural gas turbines and the emission factor is considered applicable.

The emission factor for natural gas fuelled gas turbines has been applied for refinery gas fuelled gas turbines. Refinery gas has similar properties as natural gas, i.e. similar nitrogen content in the fuel, which means that $N_2O$ formation will be similar under similar combustion conditions.

All emission factors that are not nationally referenced refer to the IPCC Guidelines (IPCC, 2006).

Table 49 $N_2O$ emission factors 2018.

| Fuel group | Fuel | CRF source category | CRF source category | SNAP | Emission factor, g per GJ | Reference |
|---|---|---|---|---|---|---|
| SOLID | Coal | 1A1a | Public electricity and heat production | 0101 | 0.8 | Henriksen (2005) |
| | | | | 0102 | 1.4 | IPCC (2006), Tier 3, Table 2.6, Utility source, pulverised bituminous coal, wet bottom boiler |
| | | 1A2 a-g | Industry | 03 | 1.5 | IPCC (2006), Tier 1, Table 2-3, Manufacturing industries, coal |
| | | 1A4b i | Residential | 0202 | 1.5 | IPCC (2006), Tier 1, Table 2-5, Residential, coal |
| | | 1A4c i | Agriculture/forestry | 0203 | 1.5 | IPCC (2006), Tier 1, Table 2-4, Commercial, coal[1)] |
| | BKB | 1A4b i | Residential | 0202 | 1.5 | IPCC (2006), Tier 1, Table 2-5, Residential, brown coal briquettes |
| | Coke oven coke | 1A2 a-g | Industry | 03 | 1.5 | IPCC (2006), Tier 1, Table 2-3, Industry, coke oven coke |
| | | 1A4b i | Residential | 020200 | 1.5 | IPCC (2006), Tier 1, Table 2-5, Residential, coke oven coke |
| | Anodic carbon | 1A2 a-g | Industry | 03 | 1.5 | IPCC (2006), Tier 1, Table 2-3, manufacturing industries, other bituminous coal |
| | Fossil fly ash | 1A1a | Public electricity and heat production | 0101 | 0.8 | Assumed equal to coal |
| LIQUID | Petroleum coke | 1A2 a-g | Industry – other | 03 | 0.6 | IPCC (2006), Tier 1, Table 2-3, Industry, petroleum coke |
| | | | | 031600 | 1.5 | - |
| | | 1A4a | Commercial/ Institutional | 0201 | 0.6 | IPCC (2006), Tier 1, Table 2-4, Commercial, petroleum coke |
| | | 1A4b i | Residential | 0202 | 0.6 | IPCC (2006), Tier 1, Table 2-5, Residential, petroleum coke |
| | | 1A4c i | Agriculture/forestry | 0203 | 0.6 | IPCC (2006), Tier 1, Table 2-5, Residential/Agricultural, petroleum coke |
| | Residual oil | 1A1a | Public electricity and heat production | 010101 | 0.3 | IPCC (2006), Tier 3, Table 2-6, Utility, residual fuel oil |
| | | | | 010102<br>010103 | 5 | Nielsen et al. (2010a) |
| | | | | 010104<br>010105 | 0.6 | IPCC (2006), Tier 1, Table 2-2, Energy industries, residual fuel oil |
| | | | | 010203 | 0.3 | IPCC (2006), Tier 3, Table 2-6, Utility, residual fuel oil |
| | | 1A1b | Petroleum refining | 010306 | 0.6 | IPCC (2006), Tier 1, Table 2-2, Energy industries, residual fuel oil |
| | | 1A2 a-g | Industry | 03 | 5 | Nielsen et al. (2010a) |
| | | | | Engines | 0.6 | IPCC (2006), Tier 1, Table 2-3, Manufacturing industries and construction, residual fuel oil. |
| | | 1A4a | Commercial/ Institutional | 0201 | 0.3 | IPCC (2006), Tier 3, Table 2-10, Commercial, fuel oil boilers |
| | | 1A4b i | Residential | 0202 | 0.6 | IPCC (2006), Tier 1, Table 2-5, Residential, residual fuel oil |
| | | 1A4c i | Agriculture/forestry | 0203 | 0.3 | IPCC (2006), Tier 3, Table 2-10, Commercial, fuel oil boilers[1)] |
| | Gas oil | 1A1a | Public electricity and heat production | 010101<br>010102<br>010103 | 0.4 | IPCC (2006), Tier 3, Table 2-6, Utility, gas oil boilers |
| | | | | 010104 | 0.6 | IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil |
| | | | | 010105 | 2.1 | Nielsen et al. (2010a) |
| | | | | 0102 | 0.4 | IPCC (2006), Tier 3, Table 2-6, Utility, gas oil boilers |

| Fuel group | Fuel | CRF source category | CRF source category | SNAP | Emission factor, g per GJ | Reference |
|---|---|---|---|---|---|---|
| | | 1A1b | Petroleum refining | 010306 | 0.6 | IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil |
| | | 1A1c | Oil and gas extraction | 010504 | 0.6 | IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil |
| | | 1A2 a-g | Industry | 03 | 0.4 | IPCC (2006), Tier 3, Table 2-7, Industry, gas oil boilers |
| | | | | Turbi-nes | 0.6 | IPCC (2006), Tier 1, Table 2-3, Industry, gas oil |
| | | | | Engines | 2.1 | Nielsen et al. (2010a) |
| | | 1A4a | Commercial/ Institutional | 0201 | 0.4 | IPCC (2006), Tier 3, Table 2-10, Commercial, gas oil boilers |
| | | | | Engines | 2.1 | Nielsen et al. (2010a) |
| | | 1A4b i | Residential | 0202 | 0.6 | IPCC (2006), Tier 1, Table 2-5, Residen-tial, gas oil |
| | | | | Engines | 2.1 | Nielsen et al. (2010a) |
| | | 1A4c | Agriculture/forestry | 0203 | 0.4 | IPCC (2006), Tier 3, Table 2-10, Commercial, gas oil boilers[1)] |
| | | | | Engines | 2.1 | Nielsen et al. (2010a) |
| | Kerosene | 1A2 a-g | Industry | 03 | 0.6 | IPCC (2006), Tier 1, Table 2-3, Industry, other kerosene |
| | | 1A4a | Commercial/ Institutional | 0201 | 0.6 | IPCC (2006), Tier 1, Table 2-4, Commercial, other kerosene |
| | | 1A4b i | Residential | 0202 | 0.6 | IPCC (2006), Tier 1, Table 2-5, Residential, other kerosene |
| | | 1A4c i | Agriculture/forestry | 0203 | 0.6 | IPCC (2006), Tier 1, Table 2-4, Commercial, other kerosene [1)] |
| | LPG | 1A1a | Public electricity and heat production | 0101<br>0102 | 0.1 | IPCC (2006), Tier 1, Table 2-2, Energy industries, LPG |
| | | 1A1b | Petroleum refining | 010306 | 0.1 | IPCC (2006), Tier 1, Table 2-2, Energy industries, LPG |
| | | 1A2 a-g | Industry | 03 | 0.1 | IPCC (2006), Tier 1, Table 2-3, Industry, LPG |
| | | 1A4a | Commercial/ Institutional | 0201 | 0.1 | IPCC (2006), Tier 1, Table 2-4, Commercial, LPG |
| | | 1A4b i | Residential | 0202 | 0.1 | IPCC (2006), Tier 1, Table 2-5, Residential, LPG |
| | | 1A4c i | Agriculture/forestry | 0203 | 0.1 | IPCC (2006), Tier 1, Table 2-5, Residential/Agricultural, LPG |
| | Refinery gas | 1A1b | Petroleum refining | 010304 | 1 | Assumed equal to natural gas fuelled tur-bines. Based on Nielsen et al. (2010a). |
| | | | | 010306 | 0.1 | IPCC (2006), Tier 1, Table 2-2, Energy industries, refinery gas |
| GAS | Natural gas | 1A1a | Public electricity and heat production | 010101<br>010102<br>010103 | 1 | IPCC (2006), Tier 3, Table 2-6, Natural gas, Utility, boiler |
| | | | | 010104 | 1 | Nielsen et al. (2010a) |
| | | | | 010105 | 0.58 | Nielsen et al. (2010a) |
| | | | | 0102 | 1 | IPCC (2006), Tier 3, Table 2-6, Natural gas, Utility, boiler |
| | | 1A1b | Petroleum refining | 010306 | 1 | IPCC (2006), Tier 3, Table 2-6, Natural gas, Utility, boiler |
| | | 1A1c | Oil and gas extraction | 010504 | 1 | Nielsen et al. (2010a) |
| | | 1A2 a-g | Industry | 03 | 1 | IPCC (2006), Tier 3, Table 2-7, Industry, natural gas boilers |
| | | | | Gas tur-bines | 1 | Nielsen et al. (2010a) |
| | | | | Engines | 0.58 | Nielsen et al. (2010a) |
| | | 1A4a | Commercial/ Institutional | 020100<br>020103 | 1 | IPCC (2006), Tier 3, Table 2-10, Commercial, natural gas boilers |

| Fuel group | Fuel | CRF source category | CRF source category | SNAP | Emission factor, g per GJ | Reference |
|---|---|---|---|---|---|---|
| | | | | Engines | 0.58 | Nielsen et al. (2010a) |
| | | 1A4b i | Residential | 0202 | 1 | IPCC (2006), Tier 3, Table 2-9, Residential, natural gas boilers |
| | | | | Engines | 0.58 | Nielsen et al. (2010a) |
| | | 1A4c i | Agriculture/forestry | 0203 | 1 | IPCC (2006), Tier 3, Table 2-10, Commercial, natural gas boilers 1) |
| | | | | Engines | 0.58 | Nielsen et al. (2010a) |
| WA-STE | Waste | 1A1a | Public electricity and heat production | 0101 0102 | 1.2 | Nielsen et al. (2010a) |
| | | 1A2 a-g | Industry | 03 | 4 | IPCC (2006), Tier 1, Table 2-3, Industry, wastes |
| | | 1A4a | Commercial/ Institutional | 0201 | 4 | IPCC (2006), Tier 1, Table 2-4, Commercial, municipal wastes |
| | Industrial waste | 1A2 a-g | Industry | 03 | 4 | IPCC (2006), Tier 1, Table 2-3, Industry, industrial wastes |
| BIO-MASS | Wood | 1A1a | Public electricity and heat production | 0101 | 0.8 | Nielsen et al. (2010a) |
| | | | | 0102 | 4 | IPCC (2006), Tier 1, Table 2-2, Energy industries, wood |
| | | 1A2 a-g | Industry | 03 | 4 | IPCC (2006), Tier 1, Table 2-3, Industry, wood |
| | | 1A4a | Commercial/ Institutional | 0201 | 4 | IPCC (2006), Tier 1, Table 2-4, Commercial, wood |
| | | 1A4b i | Residential | 0202 | 4 | IPCC (2006), Tier 1, Table 2-5, Residential, wood |
| | | 1A4c i | Agriculture/forestry | 0203 | 4 | IPCC (2006), Tier 1, Table 2-5, Agriculture, wood |
| | Straw | 1A1a | Public electricity and heat production | 0101 | 1.1 | Nielsen et al. (2010a) |
| | | | | 0102 | 4 | IPCC (2006), Tier 1, Table 2-2, Energy industries, other primary solid bio-mass |
| | | 1A4b i | Residential | 0202 | 4 | IPCC (2006), Tier 1, Table 2-5, Residential, other primary solid biomass |
| | | 1A4c i | Agriculture/forestry | 0203 | 4 | IPCC (2006), Tier 1, Table 2-5, Agriculture, other primary solid biomass |
| | Wood pellets | 1A1a | Public electricity and heat production | 0101 | 0.8 | Nielsen et al. (2010a) |
| | | | | 0102 | 4 | IPCC (2006), Tier 1, Table 2-2, Energy industries, wood |
| | | 1A2 a-g | Industry | 03 | 4 | IPCC (2006), Tier 1, Table 2-3, Industry, wood |
| | | 1A4a | Commercial/ Institutional | 0201 | 4 | IPCC (2006), Tier 1, Table 2-4, Commercial, wood |
| | | 1A4b i | Residential | 0202 | 4 | IPCC (2006), Tier 1, Table 2-5, Residential, wood |
| | Bio oil | 1A1a | Public electricity and heat production | 0101 0102 | 0.6 | IPCC (2006), Tier 3, Table 2-2, Utility, biodiesels |
| | | | | Engines | 2.1 | Assumed equal to gas oil. Based on Nielsen et al. (2010a) |
| | | 1A2 a-g | Industry | 03 | 0.4 | Assumed equal to gas oil. |
| | | 1A4b i | Residential | 0202 | 0.6 | IPCC (2006), Tier 1, Table 2-5, Residential, biodiesels |
| | Biogas | 1A1a | Public electricity and heat production | 0101 0102 | 0.1 | IPCC (2006), Tier 1, Table 2-2, Energy industries, other biogas |
| | | | | Engines | 1.6 | Nielsen et al. (2010a) |
| | | 1A2 a-g | Industry | 03 | 0.1 | IPCC (2006), Tier 1, Table 2-3, Industry, other biogas |
| | | | | Engines | 1.6 | Nielsen et al. (2010a) |

| Fuel group | Fuel | CRF source category | CRF source category | SNAP | Emission factor, g per GJ | Reference |
|---|---|---|---|---|---|---|
| | | 1A4a | Commercial/ Institutional | 0201 | 0.1 | IPCC (2006), Tier 1, Table 2,4, Commercial, other biogas |
| | | | | Engines | 1.6 | Nielsen et al. (2010a) |
| | | 1A4b | Residential | 0202 | 1 | Assumed equal to natural gas. |
| | | 1A4c i | Agriculture/forestry | 0203 | 0.1 | IPCC (2006), Tier 1, Table 2-5, Agriculture, other biogas |
| | | | | Engines | 1.6 | Nielsen et al. (2010a) |
| | Bio gasification gas | 1A1a | Public electricity and heat production | 010101 | 0.1 | Assumed equal to biogas |
| | | | | 010105 | 2.7 | Nielsen et al. (2010a) |
| | | 1A4a | Commercial/ Institutional | 020105 | 2.7 | Nielsen et al. (2010a) |
| | Bio natural gas | 1A1a | Public electricity and heat production | 0101 or 0102 | 1 | Assumed equal to natural gas |
| | | 1A2 a-g | Industry | 03 | 1 | Assumed equal to natural gas |
| | | 1A4a | Commercial/ Institutional | 0201 | 1 | Assumed equal to natural gas |
| | | 1A4b | Residential | 0202 | 1 | Assumed equal to natural gas |
| | | 1A4c | Agriculture/forestry | 0203 | 1 | Assumed equal to natural gas |

1) In Denmark, plants in Agriculture/forestry are similar to Commercial plants.

## 7.5 $SO_2$ emission factors

The $SO_2$ emission factors and references are shown in Table 50. Further details are included in Nielsen et al. (2018).

Time series are shown in Annex 4. Time series have been estimated for:

- Combustion of coal in power plants.
- Combustion of coal in other plants (including district heating).
- Combustion of coal in food industry.
- Combustion of coal, petroleum coke and industrial waste in cement industry.
- Combustion of BKB in residential and industrial plants.
- Combustion of coke oven coke in power plants.
- Combustion of coke oven coke in residential and industrial plants.
- Combustion of petroleum coke in other sectors than cement industry.
- Combustion of residual oil in power plants.
- Combustion of residual oil in refineries.
- Combustion of residual oil in other plants.
- Combustion of gas oil.
- Combustion of orimulsion.
- Waste incineration in CHP plants.
- Waste incineration in district heating and other plants.

Table 50 $SO_2$ emission factors and references, 2018.

| Fuel type | Fuel | NFR | NFR_name | SNAP | $SO_2$ emission factor, g/GJ | Reference |
|---|---|---|---|---|---|---|
| Solid | Anodic carbon | 1A2g | Industry - other | 032002 | 855 | DCE estimate based on plant-specific data |
| | Coal | 1A1a | Public electricity and heat production | 0101 | 10 | DCE estimate based on emission data reported by plant owners and fuel consumption data from EU ETS (2019) |
| | | | | 0102 | 438 | DCE estimate based on country-specific coal data from Dong Energy (Jensen, 2017) and coal import data from DEA (2019c) |
| | | 1A2a-g | Industry | 03 except 0309 and 0316 | 438 | DCE estimate based on country-specific coal data from Dong Energy (Jensen, 2017) and coal import data from DEA (2019c) |
| | | 1A2e | Industry, food, beverages and tobacco | 0309 | 231 | DCE estimate based on plant-specific data for 2010. |
| | | 1A2f | Cement industry | 0316 | 67 | DCE estimate based on plant-specific data for 2011-2015 |
| | | 1A2g | Mineral wool production | Mineral wool 032002 | 861 | DCE estimate based on plant-specific data for 2010-2015 |
| | | 1A4b i | Residential | 020200 | 438 | DCE estimate based on country-specific coal data from Dong Energy (Jensen, 2017) and coal import data from DEA (2019c) |
| | | 1A4c i | Agriculture/forestry | 0203 | 438 | DCE estimate based on country-specific coal data from Dong Energy (Jensen, 2017) and coal import data from DEA (2019c) |
| | Fly ash fossil | 1A1a | Public electricity and heat production | 010101 | 10 | Assumed equal to coal |
| | BKB | 1A4b | Residential | 0202 | 438 | Assumed equal to coal. DCE assumption |
| | Coke oven coke | 1A2a-g | Industry | 03 | 438 | Assumed equal to coal. DCE assumption |
| | | 1A2e | Industry, food, beverages and tobacco | 0309 | 231 | DCE estimate based on plant-specific data for 2010 |
| | | 1A2g | Mineral wool production | Mineral wool 032002 | 861 | DCE estimate based on plant-specific data for 2010-2015 |
| | | 1A4b | Residential | 0202 | 438 | Assumed equal to coal. DCE assumption |
| Liquid | Petroleum coke | 1A2a-g | Industry | 03 | 605 | DCE calculation based on DEPA (2001b), DEPA (2014), DEA (2016a) and EMEP (2006) |
| | | 1A2g | Cement industry | 0316 | 67 | DCE estimate based on plant-specific data for 2011-2015 |
| | | 1A4a | Commercial/ Institutional | 0201 | 605 | DCE calculation based on DEPA (2001b), DEPA (2014), DEA (2016a) and EMEP (2006) |
| | | 1A4b | Residential | 0202 | 605 | DCE calculation based on DEPA (2001b), DEPA (2014), DEA (2016a) and EMEP (2006) |
| | | 1A4c | Agriculture/forestry | 0203 | 605 | DCE calculation based on DEPA (2001b), DEPA (2014), DEA (2016a) and EMEP (2006) |
| | Residual oil | 1A1a | Public electricity and heat production | 0101 | 100 | DCE estimate based on plant-specific data for 2008 and 2009 |
| | | | | 0102 | 344 | DCE estimate based on EOF (2017) and DEA (2016a) |
| | | 1A1b | Petroleum refining | 010306 | 339 | DCE estimate based on plant-specific data for year 2019 |

| Fuel type | Fuel | NFR | NFR_name | SNAP | $SO_2$ emission factor, g/GJ | Reference |
|---|---|---|---|---|---|---|
| | | 1A2a-g | Industry | 03 | 344 | DCE estimate based on EOF (2017) and DEA (2016a) |
| | | 1A4a | Commercial/ Institutional | 0201 | 344 | DCE estimate based on EOF (2017) and DEA (2016a) |
| | | 1A4b | Residential | 0202 | 344 | DCE estimate based on EOF (2017) and DEA (2016a) |
| | | 1A4c i | Agriculture/forestry | 0203 | 344 | DCE estimate based on EOF (2017) and DEA (2016a) |
| | Gas oil | 1A1a | Public electricity and heat production | 0101 0102 | 6.7 | DCE estimate based on DEA (2018e) |
| | | 1A1b | Petroleum refining | 010306 | 6.7 | DCE estimate based on DEA (2018e) |
| | | 1A1c | Oil and gas extraction | 0105 | 6.7 | DCE estimate based on DEA (2018e) |
| | | 1A2a-g | Industry | 03 | 6.7 | DCE estimate based on DEA (2018e) |
| | | 1A4a | Commercial/ Institutional | 0201 | 6.7 | DCE estimate based on DEA (2018e) |
| | | 1A4b i | Residential | 0202 | 6.7 | DCE estimate based on DEA (2018e) |
| | | 1A4c | Agriculture/forestry | 0203 | 6.7 | DCE estimate based on DEA (2018e) |
| | Kerosene | 1A2g | Industry - other | 03 | 5 | DCE estimate based on Tønder (2004) and Shell (2013) |
| | | 1A4a | Commercial/ Institutional | 0201 | 5 | DCE estimate based on Tønder (2004) and Shell (2013) |
| | | 1A4b i | Residential | 0202 | 5 | DCE estimate based on Tønder (2004) and Shell (2013. |
| | | 1A4c i | Agriculture/forestry | 0203 | 5 | DCE estimate based on Tønder (2004) and Shell (2013) |
| | LPG | 1A1a | Public electricity and heat production | All | 0.13 | DCE estimate based on Augustesen (2003), Krebs (2003) and DEA (2016a) |
| | | 1A2a-g | Industry | 03 | 0.13 | DCE estimate based on Augustesen (2003), Krebs (2003) and DEA (2016a) |
| | | 1A4a | Commercial/ Institutional | 0201 | 0.13 | DCE estimate based on Augustesen (2003), Krebs (2003) and DEA (2016a) |
| | | 1A4b i | Residential | 0202 | 0.13 | DCE estimate based on Augustesen (2003), Krebs (2003) and DEA (2016a) |
| | | 1A4c i | Agriculture/forestry | 0203 | 0.13 | DCE estimate based on Augustesen (2003), Krebs (2003) and DEA (2016a) |
| | Refinery gas | 1A1b | Petroleum refining | 0103 | 1 | DCE estimate based on plant-specific data for one plant, average value for 1995-2002 |
| Gas | Natural gas | 1A1a | Public electricity and heat production | 0101, 0102, except engines | 0.43 | DCE estimate based on data from Energinet.dk (2017) and Energinet.dk (2013) |
| | | | | 010105, engines | 0.5 | Kristensen (2003) |
| | | 1A1b | Petroleum refining | 0103 | 0.43 | DCE estimate based on data from Energinet.dk (2017) and Energinet.dk (2013) |
| | | 1A1c | Oil and gas extraction | 0105 | 0.43 | DCE estimate based on data from Energinet.dk (2017) and Energinet.dk (2013) |
| | | 1A2a-g | Industry | 03 except engines | 0.43 | DCE estimate based on data from Energinet.dk (2017) and Energinet.dk (2013) |
| | | | | Engines | 0.5 | Kristensen (2003) |

| Fuel type | Fuel | NFR | NFR_name | SNAP | $SO_2$ emission factor, g/GJ | Reference |
|---|---|---|---|---|---|---|
| | | 1A4a | Commercial/ Institutional | 0201 except engines | 0.43 | DCE estimate based on data from Energinet.dk (2017) and Energinet.dk (2013) |
| | | | | Engines | 0.5 | Kristensen (2003) |
| | | 1A4b i | Residential | 0202 except engines | 0.43 | DCE estimate based on data from Energinet.dk (2017) and Energinet.dk (2013) |
| | | | | Engines | 0.5 | Kristensen (2003) |
| | | 1A4c i | Agriculture/forestry | 0203 except engines | 0.43 | DCE estimate based on data from Energinet.dk (2017) and Energinet.dk (2013) |
| | | | | Engines | 0.5 | Kristensen (2003) |
| Waste | Waste | 1A1a | Public electricity and heat production | 0101 | 8.3 | Nielsen et al. (2010a) |
| | | | | 0102 | 14 | DCE estimate based on plant-specific data for four plants, 2009 data |
| | | 1A2a-g | Industry | 03 | 14 | Assumed equal to district heating plants DCE assumption |
| | | 1A4a | Commercial/ Institutional | 0201 | 14 | Assumed equal to district heating plants DCE assumption |
| | Industrial waste | 1A2f | Industry – non-metallic minerals | 031600 | 67 | DCE estimate based on plant-specific data for 2011-2015 |
| Biomass | Wood | 1A1a | Public electricity and heat production | 0101 | 1.9 | Nielsen et al. (2010a) |
| | | | | 0102 | 11 | EEA (2019), Energy industries Table 3.13 Wood |
| | | 1A2a-g | Industry | 03 | 11 | EEA (2019), Manufacturing industries and construction (combustion) |
| | | 1A4a | Commercial/ Institutional | 0201 | 11 | EEA (2019), Small combustion Table 3.10 and Table 3.45 – Table 3.48 |
| | | 1A4b i | Residential | 0202 | 11 | EEA (2019), Small combustion Table 3.6 Residential wood |
| | | 1A4c i | Agriculture/forestry | 0203 | 11 | EEA (2019), Small combustion Table 3.10 and Table 3.45 – Table 3.48 |
| | Straw | 1A1a | Public electricity and heat production | 0101 | 49 | Nielsen et al. (2010a) |
| | | | | 0102 | 115 | Assumed equal to farmhouse boilers. |
| | | 1A4b i | Residential | 0202 | 115 | Jensen et al. (2017) |
| | | 1A4c i | Agriculture/forestry | 0203 | 115 | Jensen et al. (2017) |
| | Wood pellets | 1A1a | Public electricity and heat production | 0101 | 1.9 | Nielsen et al. (2010a) |
| | | 1A2a-g | Industry | 03 | 11 | EEA (2019), Manufacturing industries and construction (combustion) |
| | | 1A4a | Commercial/ Institutional | 0201 | 11 | EEA (2019), Small combustion Table 3.10 and Table 3.45 – Table 3.48 |
| | | 1A4b i | Residential | 0202 | 11 | EEA (2019), Small combustion Table 3.6 Residential wood |
| | | 1A4c i | Agriculture/forestry | 0203 | 11 | EEA (2019), Small combustion Table 3.10 and Table 3.45 – Table 3.48 |
| | Bio oil | 1A1a | Public electricity and heat production | 0101 | 0.3 | DCE estimate based on Folkecenter for Vedvarende Energi (2000) and DEA (2016a). |
| | | | | 0102 | 0.3 | DCE estimate based on Folkecenter for Vedvarende Energi (2000) and DEA (2016a) |

| Fuel type | Fuel | NFR | NFR_name | SNAP | $SO_2$ emission factor, g/GJ | Reference |
|---|---|---|---|---|---|---|
| | | 1A2a-g | Industry | 03 | 0.3 | DCE estimate based on Folkecenter for Vedvarende Energi (2000) and DEA (2016a) |
| | | 1A4b i | Residential | 0202 | 0.3 | DCE estimate based on Folkecenter for Vedvarende Energi (2000) and DEA (2016a) |
| | Biogas | 1A1a | Public electricity and heat production | 0101, except engines | 25 | DCE estimate based on Christiansen (2003), Hjort-Gregersen (1999) and DEA (2016a) |
| | | | | Engines | 19.2 | Nielsen & Illerup (2003) |
| | | | | 0102 | 25 | DCE estimate based on Christiansen (2003), Hjort-Gregersen (1999) and DEA (2016a) |
| | | 1A2a-g | Industry | 03, except engines | 25 | DCE estimate based on Christiansen (2003), Hjort-Gregersen (1999) and DEA (2016a) |
| | | | | 03, engines | 19.2 | Nielsen & Illerup (2003) |
| | | 1A4a | Commercial/ Institutional | 0201, except engines | 25 | DCE estimate based on Christiansen (2003), Hjort-Gregersen (1999) and DEA (2016a) |
| | | | | 020105 | 19.2 | Nielsen & Illerup (2003) |
| | | 1A4b | Residential | 0202 | 25 | DCE estimate based on Christiansen (2003), Hjort-Gregersen (1999) and DEA (2016a) |
| | | 1A4c i | Agriculture/forestry | 0203, except engines | 25 | DCE estimate based on Christiansen (2003), Hjort-Gregersen (1999) and DEA (2016a) |
| | | | | 020304 | 19.2 | Nielsen & Illerup (2003) |
| | Bio gasification gas | 1A1a | Public electricity and heat production | 010105 | 7 | Kristensen (2016a) and Kristensen (2017b) |
| | Bio natural gas | 1A1a | Public electricity and heat production | 0101 | 0.43 | Assumed equal to natural gas |
| | | 1A2a-g | Industry | 03 | 0.43 | Assumed equal to natural gas |
| | | 1A4a | Commercial/ Institutional | 0201 | 0.43 | Assumed equal to natural gas |
| | | 1A4b | Residential | 0202 | 0.43 | Assumed equal to natural gas |
| | | 1A4c | Agriculture/forestry | 0203 | 0.43 | Assumed equal to natural gas |

## 7.6 $NO_x$ emission factors

The $NO_x$ emission factors and references are shown in Table 51. Further details are included in Nielsen et al. (2018).

Time series are included in Annex 4. Time series have been estimated for:

- Combustion of coal in power plants.
- Combustion of coal in district heating and non-industrial plants.
- Combustion of coal in industrial plants.
- Combustion of coal, petroleum coke, residual oil and industrial waste in cement industry.
- Combustion of BKB in industrial and residential plants.
- Combustion of coke oven coke in industrial and residential plants.
- Combustion of fossil fly ash.
- Combustion of petroleum coke in public electricity and heat production.
- Combustion of petroleum coke in industrial plants.
- Combustion of residual oil in power plants.
- Combustion of residual oil in industrial plants.
- Combustion of gas oil in power plants.
- Combustion of gas oil in offshore gas turbines.
- Combustion of orimulsion in power plants.
- Combustion of refinery gas.
- Combustion of natural gas in power plants.
- Combustion of natural gas in gas turbines.
- Combustion of natural gas in gas engines.
- Combustion of natural gas in district heating plants, large industrial boilers, large boilers in commercial/institutional plants and large boilers in agriculture/forestry.
- Combustion of natural gas in offshore gas turbines.
- Combustion of natural gas in residential boilers.
- Combustion of natural gas in non-metallic minerals (bricks and tiles).
- Waste incineration in CHP plants.
- Combustion of wood in residential plants.
- Combustion of bio oil in power plants.
- Combustion of biogas in gas engines.
- Combustion of biogas in power plants.
- Combustion of biogas in large boilers.
- Combustion of biogas in residential boilers.
- Combustion of bio natural gas in power plants, district heating plants, large boilers and residential boilers.

Table 51 $NO_x$ emission factors and references, 2018.

| Fuel type | Fuel | NFR | NFR_name | SNAP | $NO_x$ emission factor, g/GJ | Reference |
|---|---|---|---|---|---|---|
| Solid | Anodic carbon | 1A2g | Industry - other | 032000 | 183 | Assumed equal to coal. DCE assumption. |
| | Coal | 1A1a | Public electricity and heat production | 0101 | 25 | DCE estimate based on plant-specific emission data and EU ETS (2019) |
| | | | | 0102 | 95 | DEPA (2001a) |
| | | 1A2a-g | Industry | 03 except cement production | 183 | DCE estimate based on plant-specific data for four plants in 2015 |
| | | 1A2f | Industry, cement production | 0316 | 195 | DCE estimate based on plant-specific data for 2018 |
| | | 1A4b i | Residential | 020200 | 95 | DEPA (2001a) |
| | | 1A4c i | Agriculture/forestry | 0203 | 95 | DEPA (2001a) |
| | Fly ash fossil | 1A1a | Public electricity and heat production | 0101 | 25 | Assumed equal to the emission factor for coal |
| | BKB | 1A4b | Residential | 0202 | 95 | Assumed equal to coal. DCE assumption |
| | Coke oven coke | 1A2a-g | Industry | 03 | 183 | Assumed equal to coal. DCE assumption |
| | | 1A4b | Residential | 0202 | 95 | Assumed equal to coal. DCE assumption |
| Liquid | Petroleum coke | 1A2a-g | Industry | 03 | 129 | Assumed equal to residual oil. DCE assumption |
| | | | Industry, non-metallic minerals, cement | 0316 | 195 | DCE estimate based on plant-specific data for 2018 |
| | | 1A4a | Commercial/ Institutional | 0201 | 51 | EEA (2016). Tier 1, Small combustion, liquid fuels applied in residential plants |
| | | 1A4b | Residential | 0202 | 51 | EEA (2016). Tier 1, Small combustion, liquid fuels applied in residential plants |
| | | 1A4c | Agriculture/forestry | 0203 | 51 | EEA (2016). Tier 1, Small combustion, liquid fuels applied in residential plants |
| | Residual oil | 1A1a | Public electricity and heat production | 0101 | 138 | DCE estimate based on plant-specific data for 2008, 2009 and 2010. Plant-specific data refer to: Energinet.dk (2009); Energinet.dk (2010); Energinet.dk (2011): EU ETS (2009-2011) |
| | | | | 0102 | 142 | DEPA (2001a) |
| | | 1A1b | Petroleum refining | 010306 | 142 | EEA (2019), Energy industries, Table 4-4 Tier 2 emission factors for source category 1.A.1.b, process furnaces using residual oil |
| | | 1A2a-g | Industry | 03 | 129 | DCE estimate based on plant-specific data for 2015 |
| | | 1A2f | Industry, non-metallic minerals, cement | 0316 | 195 | DCE estimate based on plant-specific data for 2018 |
| | | 1A4a | Commercial/ Institutional | 0201 | 142 | DEPA (2001a) |
| | | 1A4b | Residential | 0202 | 142 | DEPA (2001a) |
| | | 1A4c i | Agriculture/forestry | 0203 | 142 | DEPA (2001a) |
| | Gas oil | 1A1a | Public electricity and heat production | 010101, 010102, 010103 | 114 | DCE estimate based on plant-specific data for 2011 |
| | | | | 010104 | 230 | DCE estimate based on plant-specific data year 2015 |
| | | | | 010105 | 942 | Nielsen et al. (2010a) |

| Fuel type | Fuel | NFR | NFR_name | SNAP | $NO_x$ emission factor, g/GJ | Reference |
|---|---|---|---|---|---|---|
| | | | | 0102 | 130 | DEPA (2016b), DEPA (2012b), DEPA (2003b) and DEPA (1990) |
| | | 1A1b | Petroleum refining | 010306 | 65 | EEA (2019), Energy industries, Table 4-5 Tier 2 emission factors for source category 1.A.1.b, process furnaces, using gas oil |
| | | 1A1c | Oil and gas extraction | 010504 | 188 | Assumed equal to natural gas combustion applied in offshore gas turbines. DCE assumption. |
| | | 1A2a-g | Industry | 03 except engines and turbines | 130 | DEPA (2016b), DEPA (2012b), DEPA (2003b) and DEPA (1990) |
| | | | | Turbines | 230 | DCE estimate based on plant-specific data year 2015 |
| | | | | Engines | 942 | Nielsen et al. (2010a) |
| | | 1A4a | Commercial/ Institutional | 0201 | 52 | DEPA (2001a) |
| | | | | Engines | 942 | Nielsen et al. (2010a) |
| | | 1A4b i | Residential | 0202 | 52 | DEPA (2001a) |
| | | | | Engines | 942 | Nielsen et al. (2010a) |
| | | 1A4c | Agriculture/forestry | 0203 | 52 | DEPA (2001a) |
| | | | | Engines | 942 | Nielsen et al. (2010a) |
| | Kerosene | 1A2g | Industry - other | 03 | 51 | EEA (2016). The emission factor is for liquid fuels combusted in residential plants |
| | | 1A4a | Commercial/ Institutional | 0201 | 51 | EEA (2016). The emission factor is for liquid fuels combusted in residential plants |
| | | 1A4b i | Residential | 0202 | 51 | EEA (2016). The emission factor is for liquid fuels combusted in residential plants |
| | | 1A4c i | Agriculture/forestry | 0203 | 51 | EEA (2016). The emission factor is for liquid fuels combusted in residential plants |
| | LPG | 1A1a | Public electricity and heat production | All | 96 | IPCC (1996). |
| | | 1A2a-g | Industry | 03 | 96 | IPCC (1996). |
| | | 1A4a | Commercial/ Institutional | 0201 | 71 | IPCC (1996). |
| | | 1A4b i | Residential | 0202 | 47 | IPCC (1996) |
| | | 1A4c i | Agriculture/forestry | 0203 | 71 | IPCC (1996) |
| | Refinery gas | 1A1b | Petroleum refining | 010304 | 170 | DCE estimate based on plant-specific data for a gas turbine in year 2000 |
| | | | | 010306 | 56 | DCE estimate based on plant-specific data for year 2015. |
| Gas | Natural gas | 1A1a | Public electricity and heat production | 010101, 010102 | 28 | DEPA (2012b); DEPA (2015); DEPA (2016b) |
| | | | | 010103 | 32.02 | Schweitzer & Kristensen (2015) |
| | | | | 010104 | 48 | Nielsen et al. (2010a) |
| | | | | 010105 | 135 | Nielsen et al. (2010a) |
| | | | | 0102 | 32.02 | Schweitzer & Kristensen (2015) |
| | | 1A1b | Petroleum refining | 0103 | 32.02 | Schweitzer & Kristensen (2015) |
| | | 1A1c | Oil and gas extraction | 010504 | 188 | Estimate based on plant-specific data. Madsen (2019) |

| Fuel type | Fuel | NFR | NFR_name | SNAP | $NO_x$ emission factor, g/GJ | Reference |
|---|---|---|---|---|---|---|
| | | 1A2a-g | Industry | 03 | 32.02 | Schweitzer & Kristensen (2015) |
| | | | | Engines | 135 | Nielsen et al. (2010a) |
| | | | | Turbines | 48 | Nielsen et al. (2010a) |
| | | 1A2f | | 030700 | 87 | DCE estimate based on plant-specific data for 11 clay production plants, EU ETS (2011-2012); DEPA (2012b) |
| | | 1A4a | Commercial/ Institutional | 0201 | 32.02 | Schweitzer & Kristensen (2015) |
| | | | | Engines | 135 | Nielsen et al. (2010a) |
| | | 1A4b i | Residential | 0202 | 20.4 | Schweitzer & Kristensen (2014) |
| | | | | Engines | 135 | Nielsen et al. (2010a) |
| | | 1A4c i | Agriculture/forestry | 0203 | 32.02 | Schweitzer & Kristensen (2015) |
| | | | | Engines | 135 | Nielsen et al. (2010a) |
| Waste | Waste | 1A1a | Public electricity and heat production | 0101 | 75 | DCE estimate based on plant-specific data for year 2018 |
| | | | | 0102 | 164 | DCE estimate based on plant-specific data for year 2000 |
| | | 1A2a-g | Industry | 03 | 164 | DCE estimate based on plant-specific data for district heating plants in year 2000 |
| | | 1A4a | Commercial/ Institutional | 0201 | 164 | DCE estimate based on plant-specific data for district heating plants in year 2000 |
| | Industrial waste | 1A2f | Industry – non-metallic minerals, cement | 031600 | 195 | DCE estimate based on plant-specific data for 2018 |
| Biomass | Wood | 1A1a | Public electricity and heat production | 0101 | 81 | Nielsen et al. (2010a) |
| | | | | 0102 | 90 | Serup et al. (1999) |
| | | 1A2a-g | Industry | 03 | 90 | Serup et al. (1999) |
| | | 1A4a | Commercial/ Institutional | 0201 | 90 | Serup et al. (1999) |
| | | 1A4b i | Residential | 0202 | 73.0 | Nielsen et al. (2020). The methodology for estimating this emission factor is included in Chapter 6.13 |
| | | 1A4c i | Agriculture/forestry | 0203 | 90 | Serup et al. (1999) |
| | Straw | 1A1a | Public electricity and heat production | 0101 | 125 | Nielsen et al. (2010a) |
| | | | | 0102 | 90 | Nikolaisen et al. (1998) |
| | | 1A4b i | Residential | 0202 | 154 | Jensen et al. (2017) |
| | | 1A4c i | Agriculture/forestry | 0203 | 154 | Jensen et al. (2017) |
| | Wood pellets | 1A1a | Public electricity and heat production | 0101 | 81 | Nielsen et al. (2010a) |
| | | | | 0102 | 90 | Serup et al. (1999) |
| | | 1A2a-g | Industry | 03 | 90 | Serup et al. (1999) |
| | | 1A4a | Commercial/ Institutional | 0201 | 90 | Serup et al. (1999) |
| | | 1A4b i | Residential | 0202 | 80 | Nielsen et al. (2020). |
| | | 1A4c i | Agriculture/forestry | 0203 | 90 | Serup et al. (1999) |
| | Bio oil | 1A1a | Public electricity and heat production | 0101 | 114 | Assumed equal to gas oil. DCE assumption |
| | | | | 0102 | 130 | Assumed equal to gas oil. DCE assumption |
| | | 1A2a-g | Industry | 03 | 130 | Assumed equal to gas oil. DCE assumption |
| | | | | Engines | 942 | Assumed equal to gas oil. DCE assumption |
| | | 1A4b i | Residential | 0202 | 52 | Assumed equal to gas oil. DCE assumption |
| | Biogas | 1A1a | Public electricity and heat production | 0101, not engines | 28 | Assumed equal to large natural gas fuelled boilers |

| Fuel type | Fuel | NFR | NFR_name | SNAP | $NO_x$ emission factor, g/GJ | Reference |
|---|---|---|---|---|---|---|
| | | | | Engines | 202 | Nielsen et al. (2010a) |
| | | | | 0102 | 28 | DEPA (2001a) |
| | | 1A2a-g | Industry | 03, not engines | 28 | Assumed equal to large natural gas fuelled boilers |
| | | | | 03, engines | 202 | Nielsen et al. (2010a) |
| | | | | 030902 | 32.02 | Assumed equal to large natural gas fuelled boilers |
| | | 1A4a | Commercial/ Institutional | 0201, not engines | 28 | DEPA (2001a) |
| | | | | 020105 | 202 | Nielsen et al. (2010a) |
| | | 1A4b | Residential | 0202 | 20.4 | Assumed equal to natural gas (upgraded biogas) |
| | | 1A4c i | Agriculture/forestry | 0203, not engines | 28 | DEPA (2001a) |
| | | | | 020304 | 202 | Nielsen et al. (2010a) |
| | Bio gasification gas | 1A1a | Public electricity and heat production | 010105 | 173 | Nielsen et al. (2010a) |
| | Bio natural gas | 1A1a | Public electricity and heat production | 0101 | 28 | Assumed equal to natural gas. DCE assumption |
| | | | | 0102 | 32.02 | Assumed equal to natural gas. DCE assumption |
| | | 1A2a-g | Industry | 03 | 32.02 | Assumed equal to natural gas. DCE assumption |
| | | 1A4a | Commercial/ Institutional | 0201 | 32.02 | Assumed equal to natural gas. DCE assumption |
| | | 1A4b | Residential | 0202 | 20.4 | Assumed equal to natural gas. DCE assumption |
| | | 1A4c | Agriculture/forestry | 0203 | 32.02 | Assumed equal to natural gas. DCE assumption |

## 7.7 NMVOC emission factors

The NMVOC emission factors and references are shown in Table 52.

The emission factors for NMVOC refer to:

- An emission measurement program for decentralised CHP plants (Nielsen et al., 2010a).
- The EEA Guidebook (EEA, 2016) and former editions.
- Aggregated emission factor based on the technology distribution for residential wood combustion (Nielsen et al., 2020).
- DGC - Danish Gas Technology Centre 2001, Naturgas – Energi og miljø (DGC, 2001).
- Gruijthuijsen & Jensen (2000). Energi- og miljøoversigt, Danish Gas Technology Centre, 2000 (In Danish).

The time series are included in Annex 4. Time series have been estimated for:

- Natural gas applied in gas engines.
- Natural gas applied in gas turbines.
- Natural gas applied in gas turbines offshore.
- Waste incineration plants.
- Industrial waste incineration.
- Wood applied in the industrial sector.
- Wood applied in residential plants.
- Wood applied in institutional/commercial plants.
- Wood applied in agricultural plants.
- Biogas applied in gas engines.

Table 52 NMVOC emission factors and references, 2018.

| Fuel type | Fuel | NFR | NFR_name | SNAP | NMVOC, g/GJ | Reference |
|---|---|---|---|---|---|---|
| Solid | Anodic carbon | 1A2g | Industry - other | 0320 | 10 | Assumed equal to coal. DCE assumption |
| | Coal | 1A1a | Public electricity and heat production | 0101<br>0102 | 1.0 | EEA (2016), Tier 1, Energy industries Table 3-2 |
| | | 1A2a-g | Industry | 03 | 10 | EEA (2016), Tier 1, Industry Table 3-2, assumed lower interva. |
| | | 1A4c i | Agriculture/forestry | 0203 | 88.8 | EEA (2016), Tier 1, Small combustion Table 3-7 |
| | Fly ash fossil | 1A1a | Public electricity and heat production | 0101 | 1.0 | Assumed equal to coal. DCE assumption |
| | BKB | 1A4b i | Residential | 0202 | 484 | EEA (2016), Tier 1, Small combustion Table 3-3 |
| | Coke oven coke | 1A2a-g | Industry | 03 | 10 | EEA (2016), Tier 1, Industry Table 3-2, assumed lower interval |
| | | 1A4b | Residential | 0202 | 484 | EEA (2016), Tier 1, Small combustion Table 3-3 (and Table 3-2) |
| Liquid | Petroleum coke | 1A2a-g | Industry | 03 | 25 | EEA (2016) Tier 1, Industry Table 3-4 |
| | | 1A4a | Commercial/ Institutional | 0201 | 20 | EEA (2016), Tier 1, Small combustion Table 3-9 |
| | | 1A4b | Residential | 0202 | 20 | EEA (2016), Tier 1 for 1A4a/1A4c have been applied (DCE assumption). Small combustion Table 3-9 |
| | | 1A4c | Agriculture/forestry | 0203 | 20 | EEA (2016), Tier 1, Small combustion Table 3-9 |
| | Residual oil | 1A1a | Public electricity and heat production | 010101<br>010102<br>010103 | 0.8 | Nielsen et al. (2010a) |
| | | | | 010104 | 2.3 | EEA (2016), Tier 1, Energy industries Table 3-5 |
| | | | | 010105 | 2.3 | EEA (2016), Tier 1, Energy industries Table 3-5 |
| | | | | 010203 | 2.3 | EEA (2016), Tier 1, Energy industries Table 3-5 |
| | | 1A1b | Petroleum refining | 010306 | 2.3 | EEA (2016), Tier 2, Energy industries Table 4-4 |
| | | 1A2a-g | Industry | 03 except engines | 0.8 | Nielsen et al. (2010a) |
| | | | | Engines | 25 | EEA (2016), Tier 1, Industry Table 3-4 |
| | | 1A4a | Commercial/ Institutional | 0201 | 20 | EEA (2016), Tier 1, Small combustion Table 3-9 |
| | | 1A4b | Residential | 0202 | 20 | EEA (2016), Tier 1, Small combustion Table 3-9, as-sumed equal to 1A4a/1A4c |
| | | 1A4c i | Agriculture/forestry | 0203 | 20 | EEA (2016), Small combustion Tier 1, Table 3-9 |
| | Gas oil | 1A1a | Public electricity and heat production | 010101<br>010102<br>010103 | 0.8 | EEA (2016), Tier 1, Energy industries Table 3-6 |
| | | | | 010104 | 0.19 | EEA (2016), Tier 2, Energy industries Table 3-18 |
| | | | | 010105 | 37.1 | EEA (2016), Tier 2, Energy industries Table 3-19 |
| | | | | 0102 | 0.8 | EEA (2016), Tier 1, Energy industries Table 3-6 |
| | | 1A1b | Petroleum refining | 010306 | 0.8 | EEA (2016), Tier 1, Energy industries Table 3-6 (and Table 4.1) |

| Fuel type | Fuel | NFR | NFR_name | SNAP | NMVOC, g/GJ | Reference |
|---|---|---|---|---|---|---|
| | | 1A1c | Oil and gas extraction | 010504 | 0.19 | EEA (2016), Tier 2, Energy industries Table 3-18 |
| | | 1A2a-g | Industry | 03 boilers | 0.8 | EEA (2016), Tier 1, Energy Industries Table 3-6 |
| | | | | Gas turbines | 0.19 | EEA (2016), Tier 2, Energy industries Table 3-18 |
| | | | | Engines | 37.1 | EEA (2016), Tier 2, Energy industries Table 3-19 |
| | | 1A4a | Commercial/ Institutional | 0201 except engines | 20 | EEA (2016), Tier 1, Small Combustion Table 3-9 |
| | | | | Engines | 37.1 | EEA (2016), Tier 2, Energy Industries Table 3-19 |
| | | 1A4b i | Residential | 0202 | 20 | EEA (2016), Tier 1, Small Combustion Table 3-9 |
| | | | | Engines | 37.1 | EEA (2016), Tier 2, Energy industries Table 3-19 |
| | | 1A4c | Agriculture/forestry | 0203 | 20 | EEA (2016), Tier 1, Small Combustion Table 3-9 |
| | Kerosene | 1A2a-g | Industry | 03 | 0.8 | EEA (2016), Tier 1, Energy industries Table 3-6 |
| | | 1A4a | Commercial/ Institutional | 0201 | 20 | EEA (2016), Tier 1, Small Combustion Table 3-9 |
| | | 1A4b i | Residential | 0202 | 20 | EEA (2016), Tier 1, Small Combustion Table 3-9 |
| | | 1A4c i | Agriculture/forestry | 0203 | 20 | EEA (2016), Tier 1, Small Combustion Table 3-9 |
| | LPG | 1A1a | Public electricity and heat production | 0101<br>0102 | 0.8 | EEA (2016), Tier 1, Energy industries Table 3-6 |
| | | 1A2a-g | Iron and steel | 03 | 0.8 | EEA (2016), Tier 1, Energy industries Table 3-6 |
| | | 1A4a | Commercial/ Institutional | 0201 | 20 | EEA (2016), Tier 1, Small Combustion Table 3-9 |
| | | 1A4b i | Residential | 0202 | 20 | EEA (2016), Tier 1, Small Combustion Table 3-9 |
| | | 1A4c i | Agriculture/forestry | 0203 | 20 | EEA (2016), Tier 1, Small Combustion Table 3-9 |
| | Refinery gas | 1A1b | Petroleum refining | 0103 | 1.4 | Assumed equal to natural gas fuelled gas turbines. DCE assumption |
| Gas | Natural gas | 1A1a | Public electricity and heat production | 010101<br>010102<br>010103 | 2 | Danish Gas Technology Centre (2001) |
| | | | | 010104 | 1.6 | Nielsen et al. (2010a) |
| | | | | 010105 | 92 | Nielsen et al. (2010a) |
| | | | | 0102 | 2 | Danish Gas Technology Centre (2001) |
| | | 1A1b | Petroleum refining | 0103 | 2 | Danish Gas Technology Centre (2001) |
| | | 1A1c | Oil and gas extraction | 0105 | 1.6 | Nielsen et al. (2010a) |
| | | 1A2a-g | Industry | 03 except engines and turbines | 2 | Danish Gas Technology Centre (2001) |
| | | | | Turbines | 1.6 | Nielsen et al. (2010a) |
| | | | | Engines | 92 | Nielsen et al. (2010a) |
| | | 1A4a | Commercial/ Institutional | 0201 except engines | 2 | Danish Gas Technology Centre (2001) |
| | | | | Engines | 92 | Nielsen et al. (2010a) |
| | | 1A4b i | Residential | 0202 except engines | 4 | Gruijthuijsen & Jensen (2000) |
| | | | | Engines | 92 | Nielsen et al. (2010a) |
| | | 1A4c i | Agriculture/forestry | 0203 except engines | 2 | Danish Gas Technology Centre (2001) |
| | | | | Engines | 92 | Nielsen et al. (2010a) |

| Fuel type | Fuel | NFR | NFR_name | SNAP | NMVOC, g/GJ | Reference |
|---|---|---|---|---|---|---|
| Waste | Waste | 1A1a | Public electricity and heat production | 0101 | 0.56 | Nielsen et al. (2010a) |
| | | | | 0102 | 0.56 | Nielsen et al. (2010a). The CHP emission factor has been applied for other plant categories |
| | | 1A2a-g | Industry | 03 | 0.56 | Nielsen et al. (2010a). The CHP emission factor has been applied for other plant categories |
| | | 1A4a | Commercial/ Institutional | 0201 | 0.56 | Nielsen et al. (2010a). The CHP emission factor has been applied for other plant categories |
| | Industrial waste | 1A2f | Industry | 0316 | 0.56 | Nielsen et al. (2010a). The CHP emission factor has been applied for other plant categories |
| Bio-mass | Wood | 1A1a | Public electricity and heat production | 0101 | 5.1 | Nielsen et al. (2010a) |
| | | | | 0102 | 7.3 | EEA (2016), Tier 1, Energy industries Table 3-7 |
| | | 1A2a-g | Industry | 03 | 141 | Estimate based on country-specific data, see (1) |
| | | 1A4a | Commercial/ Institutional | 0201 | 175 | Estimate based on country-specific data, see (1) |
| | | 1A4b i | Residential | 0202 | 371 | Nielsen et al. (2020) The methodology for estimating this emission factor is included in Chapter 6.13 |
| | | 1A4c i | Agriculture/forestry | 0203 | 175 | Estimate based on country-specific data, see (1) |
| | Straw | 1A1a | Public electricity and heat production | 0101 | 0.78 | Nielsen et al. (2010a) |
| | | | | 0102 | 7.3 | EEA (2016), Tier 1, Energy industries Table 3-7 |
| | | 1A4b i | Residential | 0202 | 600 | EEA (2016), Tier 1, Small Combustion Table 3-6 |
| | | 1A4c i | Agriculture/forestry | 0203 | 600 | EEA (2016). Plants are assumed equal to residential plants |
| | | | | 020302 | 12 | EEA (2016), Tier 2, Small Combustion Table 3-45 |
| | Wood pellets | 1A1a | Public electricity and heat production | 0101 | 5.1 | Nielsen et al. (2010a) |
| | | | | 0102 | 7.3 | EEA (2016), Tier 1, Energy industries Table 3-7 |
| | | 1A2a-g | Industry | 03 | 10 | Nielsen et al. (2020) |
| | | 1A4a | Commercial/ Institutional | 0201 | 10 | Nielsen et al. (2020) |
| | | 1A4b i | Residential | 0202 | 10 | Nielsen et al. (2020) |
| | | 1A4c i | Agriculture/forestry | 0203 | 10 | Nielsen et al. (2020) |
| | Bio oil | 1A1a | Public electricity and heat production | 010102 | 0.8 | EEA (2016), Tier 1, Energy industries Table 3-6 (gas oil) |
| | | | | 010105 | 37 | EEA (2016), Tier 2, Energy industries Table 3-19 (gas oil, large stationary CI reciprocating engines ) |
| | | | | 0102 | 0.8 | EEA (2016), Tier 1, Energy industries Table 3-6 (gas oil) |
| | | 1A2a-g | Industry | 03, not engines | 0.8 | EEA (2016), Tier 1, Energy industries Table 3-6 (gas oil) |
| | | | | 010105 | 37 | EEA (2016), Tier 2, Energy industries Table 3-19 (gas oil, large stationary CI reciprocating engines ) |

| Fuel type | Fuel | NFR | NFR_name | SNAP | NMVOC, g/GJ | Reference |
|---|---|---|---|---|---|---|
| | | 1A4b i | Residential | 0202 | 20 | EEA (2016), Tier 1, Small combustion Table 3-9 (liquid fuels) |
| | Biogas | 1A1a | Public electricity and heat production | 0101 | 2 | Assumed equal to natural gas. DCE assumption |
| | | | | 010105 | 10 | Nielsen et al. (2010a) |
| | | | | 0102 | 2 | Assumed equal to natural gas. DCE assumption |
| | | 1A2a-g | Industry | 03 except engines | 2 | Assumed equal to natural gas. DCE assumption |
| | | | | Engines | 10 | Nielsen et al. (2010a) |
| | | 1A4a | Commercial/ Institutional | 0201 except engines | 2 | Assumed equal to natural gas. DCE assumption |
| | | | | Engines | 10 | Nielsen et al. (2010a) |
| | | 1A4b | Residential | 0202 | 4 | Assumed equal to natural gas. DCE assumption |
| | | 1A4c i | Agriculture/forestry | 0203 except engines | 2 | Assumed equal to natural gas. DCE assumption |
| | | | | Engines | 10 | Nielsen et al. (2010a) |
| | Bio gasification gas | 1A1a | Public electricity and heat production | 010105 | 2 | Nielsen et al. (2010a) |
| | | | | 0101 except engines | 2 | Assumed equal to natural gas. DCE assumption |
| | Bio natural gas | 1A1a | Public electricity and heat production | 0101 and 0102 | 2 | Assumed equal to natural gas. DCE assumption |
| | | 1A2a-g | Industry | 03 | 2 | Assumed equal to natural gas. DCE assumption |
| | | 1A4a | Commercial/ Institutional | 0201 | 2 | Assumed equal to natural gas. DCE assumption |
| | | 1A4b | Residential | 0202 | 4 | Assumed equal to natural gas. DCE assumption |
| | | 1A4c | Agriculture/forestry | 0203 | 2 | Assumed equal to natural gas. DCE assumption |

1) The emission factor for combustion of wood in commercial/institutional plants, agricultural plants and industrial plants have been aggregated based on technology specific emission factors: industrial plants with production of electricity or district heating: 12 g/GJ (EEA, 2016) and other plants 350 g/GJ (EEA, 2016) in 1990-1995 and 175 g/GJ (EEA, 2016) since 2002. The aggregated emission factors for 2018 are 141 g/GJ for industrial plants and 175 g/GJ for commercial/institutional/agricultural plants. A time series have been applied in the inventory.

## 7.8 CO emission factors

The CO emission factors 2018 and references are shown in Table 53.

The emission factors for CO refer to:

- The EEA Guidebook (EEA, 2016)[29].
- An emission measurement program for decentralised CHP plants (Nielsen et al., 2010a).
- Danish legislation (DEPA, 2001a)
- Nielsen et al. (2020). Aggregated emission factor based on the technology distribution for residential wood combustion and technology specific emission factors. See Chapter 6.13.
- DCE estimate based on annual environmental reports for Danish waste incineration plants without power production, year 2000.
- Nikolaisen et al. (1998).
- Jensen & Nielsen (1990).
- Bjerrum (2002).
- Sander (2002).
- Gruijthuijsen & Jensen (2000).
- Kristensen & Kristensen (2004).

The time series are included in Annex 4. Time series have been estimated for:

- Natural gas fuelled engines.
- Natural gas fuelled gas turbines.
- Waste incineration, CHP plants.
- Waste incineration, other plants.
- Wood and wood pellet combustion in district heating plants.
- Wood and wood pellet combustion in industrial plants.
- Wood and wood pellet combustion in commercial/institutional plants.
- Wood combustion in agricultural plants.
- Wood combustion in residential plants.
- Straw combustion in district heating plants.
- Straw combustion in residential / agricultural plants.

[29] And EEA (2007) for one emission factor.

Table 53 CO emission factors and references 2018.

| Fuel type | Fuel | NFR | NFR_name | SNAP | CO emission factor, g/GJ | Reference |
|---|---|---|---|---|---|---|
| Solid | Anodic carbon | 1A2a-g | Industry | 03 | 10 | Assumed the same emission factor as for coal. DCE assumption |
| | Coal | 1A1a | Public electricity and heat production | 0101 and 0102 | 10 | Sander (2002) |
| | | 1A2a-g | Industry | 03 | 10 | Assumed equal to boilers in public electricity and heat production. DCE assumption |
| | | 1A4b i | Residential | 0202 | 4787 | EEA (2016), Tier 2, Small Combustion Table 3.15, residential boilers, solid fuels |
| | | 1A4c i | Agriculture/forestry | 0203 | 931 | EEA (2016), Tier 1, Small Combustion Table 3.7 |
| | Fly ash fossil | 1A1a | Public electricity and heat production | 0101 | 10 | Assumed equal to coal. DCE assumption |
| | BKB | 1A4b i | Residential | 0202 | 4787 | EEA (2016), Tier 2, Small Combustion Table 3.15, residential boilers, solid fuels |
| | Coke oven coke | 1A2a-g | Industry | 03 | 10 | Assumed the same emission factor as for coal. DCE assumption |
| | | 1A4b | Residential | 0202 | 4787 | EEA (2016), Tier 2, Small Combustion Table 3.15, residential boilers, solid fuels |
| Liquid | Petroleum coke | 1A1a | Public electricity and heat production | 0101 | 66 | EEA (2016), Tier 1, Manufacturing industries and construction Table 3.4 for liquid fuels |
| | | 1A2a-g | Industry | 03 | 66 | EEA (2016), Tier 1, Manufacturing industries and construction Table 3.4 for liquid fuels |
| | | 1A4a | Commercial/institutional | 0201 | 93 | EEA (2016), Tier 1, Small Combustion Table 3.9 |
| | | 1A4b | Residential | 0202 | 93 | EEA (2016), Tier 1, Small Combustion Table 3.9 (assumed equal to the emission factor for 1A4a/1A4c). |
| | | 1A4c | Agriculture/ forestry | 0203 | 93 | EEA (2016), Tier 1, Small Combustion Table 3.9 |
| | Residual oil | 1A1a | Electricity and heat production | 010101<br>010104<br>010105 | 15 | Sander (2002) |
| | | | | 010102<br>010103 | 2.8 | Nielsen et al. (2010a) |
| | | | | 0102 | 15.1 | EEA (2016), Tier 1, Energy industries Table 3.5. |
| | | 1A1b | Petroleum refining | 010306 | 6 | EEA (2016), Tier 2, Energy industries Table 4.4. |
| | | 1A2a-g | Industry | 03 except engines | 2.8 | Nielsen et al. (2010a) |
| | | | | Engines | 130 | EEA (2016). Tier 2 emission factor for gas oil fuelled engines in Energy industries. Refers to Nielsen et al. (2010a) |
| | | 1A4a | Commercial/institutional | 0201 | 40 | EEA (2016). Tier 2, Small Combustion Table 3.25 |
| | | 1A4b | Residential | 0202 | 57 | EEA (2016), Tier 1, Small Combustion Table 3.5 |
| | | 1A4c i | Agriculture/ forestry | 0203 | 40 | EEA (2016). Tier 2, Small Combustion Table 3.25 |

| Fuel type | Fuel | NFR | NFR_name | SNAP | CO emission factor, g/GJ | Reference |
|---|---|---|---|---|---|---|
| | Gas oil | 1A1a | Public electricity and heat production | 0101 except engines | 15 | Sander (2002) |
| | | | | Engines | 130 | Nielsen et al. (2010a) |
| | | | | 0102 | 16.2 | EEA (2016), Tier 1, Energy industries Table 3.6 |
| | | 1A1b | Petroleum refining | 010306 | 16.2 | EEA (2016), Tier 1, Energy industries Table 4.5 |
| | | 1A1c | Oil and gas extraction | 0105 | 15 | Sander (2002) |
| | | 1A2a-g | Industry | 03 except gas turbines and engines | 66 | EEA (2016), Tier 1, Manufacturing industries and construction Table 3.4 for liquid fuels |
| | | | | Gas turbines | 15 | Sander (2002) |
| | | | | Engines | 130 | Nielsen et al. (2010a) |
| | | 1A4a | Commercial/ Institutional | 0201 except engines | 40 | EEA (2016). Tier 2, Small Combustion Table 3.24 |
| | | | | Engines | 130 | Nielsen et al. (2010a) |
| | | 1A4b i | Residential | 0202 except engines | 3.7 | EEA (2016). Tier 2, Small Combustion Table 3.18. Gas oil applied in small residential boilers |
| | | | | Engines | 130 | Nielsen et al. (2010a) |
| | | 1A4c | Agriculture/forestry | 0203 | 40 | EEA (2016). Tier 2, Small Combustion Table 3.24 |
| | Kerosene | 1A2a-g | Industry | 03 | 66 | EEA (2016), Tier 1, Manufacturing industries and construction Table 3.4 for liquid fuels |
| | | 1A4a | Commercial/ Institutional | 0201 | 40 | EEA (2016). Tier 2, Small Combustion Table 3.24 |
| | | 1A4b i | Residential | 0202 | 3.7 | EEA (2016). Tier 2, Small Combustion Table 3.18 Gas oil applied in small residential boilers |
| | | 1A4c i | Agriculture/forestry | 0203 | 40 | EEA (2016). Tier 2, Small Combustion Table 3.24 |
| | LPG | 1A1a | Public electricity and heat production | 0101 and 0102 | 16.2 | EEA (2016), Tier 1, Energy industries Table 3.6 |
| | | 1A2a-g | Industry | 03 | 66 | EEA (2016), Tier 1, Manufacturing industries and construction Table 3.4 for liquid fuels |
| | | 1A4a | Commercial/ Institutional | 0201 | 40 | EEA (2016). Tier 2, Small Combustion Table 3.24 |
| | | 1A4b i | Residential | 0202 | 3.7 | EEA (2016). Tier 2, Small Combustion Table 3.18 Gas oil applied in small residential boilers |
| | | 1A4c i | Agriculture/forestry | 0203 | 40 | EEA (2016). Tier 2, Small Combustion Table 3.24 |
| | Refinery gas | 1A1b | Petroleum refining | 0103 | 12.1 | EEA (2016). Tier 1, Energy industries Table 4.2 for refinery gas applied in petroleum refining |
| Gas | Natural gas | 1A1a | Public electricity and heat production | 010101 and 010102 | 15 | Sander (2002) |
| | | | | 010103 | 28 | DEPA (2001a) |
| | | | | 010104 | 4.8 | Nielsen et al. (2010a) |
| | | | | 010105 | 58 | Nielsen et al. (2010a) |
| | | | | 0102 | 28 | DEPA (2001a) |
| | | 1A1b | Petroleum refining | 0103 | 28 | Assumed equal to district heating plants |
| | | 1A1c | Oil and gas extraction | 0105 | 4.8 | Nielsen et al. (2010a) |

| Fuel type | Fuel | NFR | NFR_name | SNAP | CO emission factor, g/GJ | Reference |
|---|---|---|---|---|---|---|
| | | 1A2a-g | Industry | 03 except gas turbines and engines | 28 | DEPA (2001a) |
| | | | | Gas turbines | 4.8 | Nielsen et al. (2010a) |
| | | | | Engines | 58 | Nielsen et al. (2010a) |
| | | 1A4a | Commercial/ Institutional | 0201 except engines | 28 | DEPA (2001a) |
| | | | | Engines | 58 | Nielsen et al. (2010a) |
| | | 1A4b i | Residential | 0202 except engines | 20 | Gruijthuijsen & Jensen (2000) |
| | | | | Engines | 58 | Nielsen et al. (2010a) |
| | | 1A4c i | Agriculture/forestry | 0203 except engines | 28 | DEPA (2001a) |
| | | | | Engines | 58 | Nielsen et al. (2010a) |
| Waste | Waste | 1A1a | Public electricity and heat production | 0101 | 3.9 | Nielsen et al. (2010a) |
| | | | | 0102 | 10 | DCE calculation based on annual environmental reports for Danish plants year 2000. |
| | | 1A2a-g | Industry | 03 | 10 | DCE calculation based on annual environmental reports for Danish plants year 2000 |
| | | 1A4a | Commercial/ Institutional | 0201 | 10 | DCE calculation based on annual environmental reports for Danish plants year 2000 |
| | Industrial waste | 1A2f | Industry | 0316 | 10 | Assumed equal to waste, district heating plants. DCE assumption |
| Biomass | Wood | 1A1a | Public electricity and heat production | 0101 | 90 | Nielsen et al. (2010a) |
| | | | | 010203 | 240 | DEPA (2001a) |
| | | 1A2a-g | Industry | 03 | 240 | DEPA (2001a) |
| | | 1A4a | Commercial/ Institutional | 020100 | 240 | DEPA (2001a) |
| | | 1A4b i | Residential | 0202 | 2752 | Nielsen et al. (2020). The methodology for estimating this emission factor is included in Chapter 6.13 |
| | | 1A4c i | Agriculture/forestry | 020300 | 240 | DEPA (2001a) |
| | Straw | 1A1a | Public electricity and heat production | 0101 | 67 | Nielsen et al. (2010a) |
| | | | | 0102 | 325 | DEPA (2001a); Nikolaisen et al (1998) |
| | | 1A4b i | Residential | 0202 | 2000 | EEA (2007); Jensen & Nielsen (1990) and Bjerrum (2002), Kristensen & Kristensen (2004). Time series |
| | | 1A4c i | Agriculture/forestry | 0203 | 2000 | EEA (2007); Jensen & Nielsen (1990) and Bjerrum (2002), Kristensen & Kristensen (2004). Time series |
| | | | | 020302 | 325 | DEPA (2001a); Nikolaisen et al (1998) |
| | Wood pellets | 1A1a | Public electricity and heat production | 0101 | 90 | Nielsen et al. (2010a) |
| | | | | 010203 | 240 | DEPA (2001a) |
| | | 1A2a-g | Industry | 03 | 240 | DEPA (2001a) |
| | | 1A4a | Commercial/ Institutional | 020100 | 240 | DEPA (2001a) |
| | | 1A4b i | Residential | 0202 | 300 | Nielsen et al. (2020) |

| Fuel type | Fuel | NFR | NFR_name | SNAP | CO emission factor, g/GJ | Reference |
|---|---|---|---|---|---|---|
| | | 1A4c i | Agriculture/forestry | 020300 | 240 | DEPA (2001a) |
| | Bio oil | 1A1a | Public electricity and heat production | 0101 | 15 | Assumed same emission factor as for gas oil. DCE assumption |
| | | | | 0102 | 16.2 | Assumed same emission factor as for gas oil. DCE assumption |
| | | 1A2a-g | Industry | 03 | 66 | Assumed same emission factor as for gas oil. DCE assumption |
| | | 1A4b i | Residential | 0202 | 3.7 | Assumed same emission factor as for gas oil. DCE assumption |
| | Biogas | 1A1a | Public electricity and heat production | 0101 except engines | 36 | DEPA (2001a) |
| | | | | Engines | 310 | Nielsen et al. (2010a) |
| | | | | 0102 | 36 | DEPA (2001a) |
| | | 1A2a-g | Industry | 03 except engines | 36 | DEPA (2001a) |
| | | | | Engines | 310 | Nielsen et al. (2010a) |
| | | 1A4a | Commercial/ Institutional | 0201 except engines | 36 | DEPA (2001a) |
| | | | | Engines | 310 | Nielsen et al. (2010a) |
| | | 1A4b | Residential | 0202 | 20 | Assumed equal to natural gas. DCE assumption |
| | | 1A4c i | Agriculture/forestry | 0203 except engines | 36 | DEPA (2001a) |
| | | | | Engines | 310 | Nielsen et al. (2010a) |
| | Bio gasification gas | 1A1a | Public electricity and heat production | 010105 | 586 | Nielsen et al. (2010a) |
| | | | | 010101 | 36 | DEPA (2001a) |
| | Bio natural gas | 1A1a | Public electricity and heat production | 0101 | 15 | Assumed equal to natural gas. DCE assumption |
| | | | | 0102 | 28 | Assumed equal to natural gas. DCE assumption |
| | | 1A2a-g | Industry | 03 | 28 | Assumed equal to natural gas. DCE assumption |
| | | 1A4a | Commercial/ Institutional | 0201 | 28 | Assumed equal to natural gas. DCE assumption |
| | | 1A4b i | Residential | 0202 | 20 | Assumed equal to natural gas. DCE assumption |
| | | 1A4c i | Agriculture/forestry | 0203 | 28 | Assumed equal to natural gas. DCE assumption |

## 7.9 $NH_3$ emission factors

$NH_3$ emissions have been estimated for:

- Combustion of wood and wood pellets in residential plants.
- Combustion of wood and wood pellets in commercial/institutional, agricultural and industrial plants.
- Straw combustion in residential and agricultural plants.
- Straw combustion in commercial/institutional and industrial plants.
- Waste incineration in public power and heat production.
- Residential combustion of coal.
- Residential combustion of BKB.
- Residential combustion of coke oven coke.

The $NH_3$ emission factors 2018 and references are shown in Table 54.

The emission factor for waste incineration plants refers to a Danish emission measurement programme (Nielsen et al., 2010a). The emission factor for residential wood combustion is based on Nielsen et al. (2020). All other emission factors refer to the EEA (2016).

Time series have been estimated for residential wood combustion, see Chapter 6.13 and Annex 4.

Table 54 $NH_3$ emission factors and references, 2018.

| Fuel | NFR (SNAP) | Emission factor, g/GJ | Reference |
|---|---|---|---|
| Coal | 1A4b | 0.3 | EEA (2016), Tier 1, Small combustion Table 3-3 |
| BKB | 1A4b | 0.3 | EEA (2016), Tier 1, Small combustion Table 3-3 |
| Coke oven coke | 1A4b | 0.3 | EEA (2016), Tier 1, Small combustion Table 3-3 |
| Wood | 1A4b | 48.7 | Nielsen et al. (2020). The methodology for estimating this emission factor is included in Chapter 6.13 |
| Wood | 1A4a, 1A4c, 1A2 | 37 | EEA (2016), Tier 1, Small combustion Table 3-10 |
| Wood pellets | 1A4b | 12 | Nielsen et al. (2020).. |
| Wood pellets | 1A4a, 1A4c, 1A2 | 37 | EEA (2016), Tier 1, Small combustion Table 3-10 |
| Waste | 1A1a | 0.29 | Nielsen et al. (2010a) |
| Straw | 1A4b, 1A4c | 70 | EEA (2016), Tier 1, Small combustion Table 3-6 |
| Straw | 1A4a, 1A2 | 37 | EEA (2016), Tier 1, Small combustion Table 3-10 |

## 7.10 Particulate matter (PM) emission factors

The PM emission factors and references are shown in Table 55. The emission factors for PM refer to

- The TNO/CEPMEIP emission factor database (TNO, 2001).
- Danish legislation:
    - DEPA (2001a), The Danish Environmental Protection Agency, Luftvejledningen (legislation from Danish Environmental Protection Agency).

    - DEPA (1990), The Danish Environmental Protection Agency, Bekendtgørelse 698 (legislation from Danish Environmental Protection Agency).
- Calculations based on plant-specific emission data from a considerable number of waste incineration plants.
- Nielsen et al. (2020). See Chapter 6.13.
- Two emission measurement programs for decentralised CHP plants (Nielsen et al., 2010a; Nielsen & Illerup, 2003).
- An emission measurement program for large power plants (Livbjerg et al., 2001).
- Additional personal communication concerning straw combustion in residential plants (Kristensen, 2017c).

Emission factor time series have been estimated for residential wood combustion and waste incineration. All other emission factors have been considered constant in 1990-2018. The time series are included in Annex 4.

Table 55 PM emission factors and references, 2018.

| fuel_type | fuel | fuel | nfr | snap_id | TSP, g/GJ | Reference for TSP | $PM_{10}$, g/GJ | $PM_{2.5}$, g/GJ | Reference for $PM_{10}$ and $PM_{2.5}$ emission factors or for the $PM_{10}$ and the $PM_{2.5}$ fraction |
|---|---|---|---|---|---|---|---|---|---|
| Solid | 101A | Anodic carbon | 1A2g iii | 0320 | 17 | DEPA (1990), DEPA (1995) | 12 | 7 | TNO (2001) |
| | 102A | Coal | 1A1a | 0101 | 3 | Livbjerg et al. (2001) | 2.6 | 2.1 | Livbjerg et al. (2001) |
| | | | | 0102 | 6 | TNO (2001) | 6 | 5 | TNO (2001) |
| | | | 1A2 a-g | 03 | 17 | DEPA (1990), DEPA (1995) | 12 | 7 | TNO (2001) |
| | | | 1A4c i | 0203 | 17 | DEPA (1990), DEPA (1995) | 12 | 7 | TNO (2001) |
| | 103A | Fly ash fossil | 1A1a | 0101 | 3 | Livbjerg et al. (2001) | 2.6 | 2.1 | Livbjerg et al. (2001) |
| | 106A | BKB | 1A4b i | 0202 | 17 | Same emission factor as for coal is assumed (DCE assumption) | 12 | 7 | Same emission factor as for coal is assumed. DCE assumption |
| | 107A | Coke oven coke | 1A2 a-g | 03 | 17 | Same emission factor as for coal is assumed (DCE assumption) | 12 | 7 | Same emission factor as for coal is assumed. DCE assumption |
| | | | 1A4b | 0202 | 17 | Same emission factor as for coal is assumed (DCE assumption) | 12 | 7 | Same emission factor as for coal is assumed. DCE assumption |
| Liquid | 110A | Petroleum coke | 1A2 a-g | 03 | 10 | TNO (2001) | 7 | 3 | TNO (2001) |
| | | | 1A4a | 0201 | 100 | TNO (2001) | 60 | 30 | TNO (2001) |
| | | | 1A4b | 0202 | 100 | TNO (2001) | 60 | 30 | TNO (2001) |
| | | | 1A4c | 0203 | 100 | TNO (2001) | 60 | 30 | TNO (2001) |
| | 203A | Residual oil | 1A1a | 010101 | 3 | Nielsen & Illerup (2003) | 3 | 2.5 | Nielsen & Illerup (2003) |
| | | | | 010102 | 9.5 | Nielsen et al. (2010a) | 9.5 | 7.9 | TNO (2001) |
| | | | | 010103 | 9.5 | Nielsen et al. (2010a) | 9.5 | 7.9 | TNO (2001) |
| | | | | 010104 | 3 | TNO (2001) | 3 | 2.5 | TNO (2001) |
| | | | | 010105 | 3 | TNO (2001) | 3 | 2.5 | TNO (2001) |
| | | | | 0102 | 3 | TNO (2001) | 3 | 2.5 | TNO (2001) |
| | | | 1A1b | 010306 | 50 | TNO (2001) | 40 | 35 | TNO (2001) |
| | | | 1A2 a-g | 03 | 9.5 | Nielsen et al. (2010a) | 7.1 | 4.8 | TNO (2001) |
| | | | 1A4a | 0201 | 14 | DEPA (1990), DEPA (1995) | 10.5 | 7 | TNO (2001) |
| | | | 1A4b | 0202 | 14 | DEPA (1990), DEPA (1995) | 10.5 | 7 | TNO (2001) |
| | | | 1A4c i | 0203 | 14 | DEPA (1990), DEPA (1995) | 10.5 | 7 | TNO (2001) |
| | 204A | Gas oil | 1A1a | 0101 | 5 | TNO (2001) | 5 | 5 | TNO (2001) |
| | | | | 0102 | 5 | TNO (2001) | 5 | 5 | TNO (2001) |
| | | | 1A1b | 010306 | 5 | TNO (2001) | 5 | 5 | TNO (2001) |
| | | | 1A1c | 0105 | 5 | TNO (2001) | 5 | 5 | TNO (2001) |
| | | | 1A2a-g | 03 | 5 | TNO (2001) | 5 | 5 | TNO (2001) |
| | | | 1A4a i | 0201 | 5 | TNO (2001) | 5 | 5 | TNO (2001) |
| | | | 1A4b i | 0202 | 5 | TNO (2001) | 5 | 5 | TNO (2001) |
| | | | 1A4c i | 0203 | 5 | TNO (2001) | 5 | 5 | TNO (2001) |
| | 206A | Kerosene | 1A2 a-g | all | 5 | TNO (2001) | 5 | 5 | TNO (2001) |
| | | | 1A4a i | 0201 | 5 | TNO (2001) | 5 | 5 | TNO (2001) |

| fuel_type | fuel | fuel | nfr | snap_id | TSP, g/GJ | Reference for TSP | $PM_{10}$, g/GJ | $PM_{2.5}$, g/GJ | Reference for $PM_{10}$ and $PM_{2.5}$ emission factors or for the $PM_{10}$ and the $PM_{2.5}$ fraction |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1A4b i | 0202 | 5 | TNO (2001) | 5 | 5 | TNO (2001) |
| | | | 1A4c i | 0203 | 5 | TNO (2001) | 5 | 5 | TNO (2001) |
| | 303A | LPG | 1A1a | 0101, 0102 | 0.2 | TNO (2001) | 0.2 | 0.2 | TNO (2001) |
| | | | 1A2 a-g | 03 | 0.2 | TNO (2001) | 0.2 | 0.2 | TNO (2001) |
| | | | 1A4a i | 0201 | 0.2 | TNO (2001) | 0.2 | 0.2 | TNO (2001) |
| | | | 1A4b i | 0202 | 0.2 | TNO (2001) | 0.2 | 0.2 | TNO (2001) |
| | | | 1A4c i | 0203 | 0.2 | TNO (2001) | 0.2 | 0.2 | TNO (2001) |
| | 308A | Refinery gas | 1A1b | 0103 | 5 | TNO (2001) | 5 | 5 | TNO (2001) |
| Gas | 301A | Natural gas | 1A1a | 0101 | 0.1 | TNO (2001) | 0.1 | 0.1 | TNO (2001) |
| | | | | Gas turbi-nes | 0.1 | Nielsen & Illerup (2003) | 0.061 | 0.051 | Nielsen & Illerup (2003) |
| | | | | Engines | 0.76 | Nielsen & Illerup (2003) | 0.189 | 0.161 | Nielsen & Illerup (2003) |
| | | | | 0102 | 0.1 | TNO (2001) | 0.1 | 0.1 | TNO (2001) |
| | | | 1A1b | 0103 | 0.1 | TNO (2001) | 0.1 | 0.1 | TNO (2001) |
| | | | 1A1c | 0105 | 0.1 | Nielsen & Illerup (2003) | 0.061 | 0.051 | Nielsen & Illerup (2003) |
| | | | 1A2a-g | Engines | 0.76 | Nielsen & Illerup (2003) | 0.189 | 0.161 | Nielsen & Illerup (2003) |
| | | | | Turbines | 0.1 | Nielsen & Illerup (2003) | 0.061 | 0.051 | Nielsen & Illerup (2003) |
| | | | | Other | 0.1 | TNO (2001) | 0.1 | 0.1 | TNO (2001) |
| | | | 1A4a i | 0201 | 0.1 | TNO (2001) | 0.1 | 0.1 | TNO (2001) |
| | | | | Engines | 0.76 | Nielsen & Illerup (2003) | 0.189 | 0.161 | Nielsen & Illerup (2003) |
| | | | 1A4b i | 0202 | 0.1 | TNO (2001) | 0.1 | 0.1 | TNO (2001) |
| | | | | Engines | 0.76 | Nielsen & Illerup (2003) | 0.189 | 0.161 | Nielsen & Illerup (2003) |
| | | | 1A4c i | 0203 | 0.1 | TNO (2001) | 0.1 | 0.1 | TNO (2001) |
| | | | | Engines | 0.76 | Nielsen & Illerup (2003) | 0.189 | 0.161 | Nielsen & Illerup (2003) |
| Waste | 114A | Waste | 1A1a | 0101 | 0.29 | Nielsen et al. (2010a) | 0.29 | 0.29 | Nielsen & Illerup (2003) |
| | | | | 0102 | 4.2 | The emission factor have been estimated by DCE based on plant-specific data from MSW incineration plants, district heating, 2008 | 3.2 | 2.1 | The emission factor have been estimated by DCE based on plant-specific data from MSW incineration plants, district heating, 2008 |
| | | | 1A2 a-g | 03 | 4.2 | The emission factor have been estimated by DCE based on plant-specific data from MSW incineration plants, district heating, 2008 | 3.2 | 2.1 | The emission factor have been estimated by DCE based on plant-specific data from MSW incineration plants, district heating, 2008 |
| | | | 1A4a i | 0201 | 4.2 | The emission factor have been estimated by DCE based on plant-specific data from MSW incineration plants, district heating, 2008 | 3.2 | 2.1 | The emission factor have been estimated by DCE based on plant-specific data from MSW incineration plants, district heating, 2008 |

| fuel_type | fuel | fuel | nfr | snap_id | TSP, g/GJ | Reference for TSP | $PM_{10}$, g/GJ | $PM_{2.5}$, g/GJ | Reference for $PM_{10}$ and $PM_{2.5}$ emission factors or for the $PM_{10}$ and the $PM_{2.5}$ fraction |
|---|---|---|---|---|---|---|---|---|---|
| | 115A | Industrial waste | 1A2f | 0316 | 4.2 | The emission factor have been estimated by DCE based on plant-specific data from MSW incineration plants, district heating, 2008 | 3.2 | 2.1 | The emission factor have been estimated by DCE based on plant-specific data from MSW incineration plants, district heating, 2008 |
| Biomass | 111A | Wood | 1A1a | 0101 | 10 | Nielsen et al. (2010a) | 7.45 | 4.82 | Estimated based on the TSP emission factor |
| | | | | 0102 | 19 | DEPA (2001a) | 13 | 10 | DEPA (2001a), TNO (2001) |
| | | | 1A2 a-g | 03 | 19 | DEPA (2001a) | 13 | 10 | DEPA (2001a), TNO (2001) |
| | | | 1A4a i | 0201 | 143 | DEPA (2001a) | 143 | 135 | TNO (2001) |
| | | | 1A4b i | 0202 | 323 | Nielsen et al. (2020). See Chapter 6.13. | 307 | 301 | Nielsen et al. (2020). See Chapter 6.13 |
| | | | 1A4c i | 0203 | 143 | DEPA (2001a) | 143 | 135 | TNO (2001) |
| | 117A | Straw | 1A1a i | 0101 | 2.3 | Nielsen et al. (2010a) | 1.71 | 1.11 | Nielsen & Illerup (2003) |
| | | | | 0102 | 21 | DEPA (2001a) | 15 | 12 | TNO (2001) |
| | | | 1A4b i | 0202 | 433 | Kristensen (2017c) | 433 | 433 | Zefeng (2011) |
| | | | 1A4c i | 0203 | 433 | Kristensen (2017c) | 433 | 433 | Zefeng (2011) |
| | | | | 020302 | 21 | DEPA (2001a) | 15 | 12 | TNO (2001) |
| | | Wood pellets | 1A1a | 0101 | 10 | Nielsen et al. (2010a) | 7.45 | 4.82 | Estimated based on the TSP emission factor |
| | | | | 0102 | 19 | DEPA (2001a) | 13 | 10 | DEPA (2001a), TNO (2001) |
| | | | 1A2 a-g | 03 | 19 | DEPA (2001a) | 13 | 10 | DEPA (2001a), TNO (2001) |
| | | | 1A4a i | 0201 | 143 | DEPA (2001a) | 143 | 135 | TNO (2001) |
| | | | 1A4b i | 0202 | 51 | Nielsen et al. (2020). See Chapter 6.13. | 48 | 47 | Nielsen et al. (2020). See Chapter 6.13 |
| | | | 1A4c i | 0203 | 143 | DEPA (2001a) | 143 | 135 | TNO (2001) |
| | 215A | Bio oil | 1A1a | 0101 | 5 | Assuming same emission factors as for gas oil (DCE assumption) | 5 | 5 | Assuming same emission factors as for gas oil. DCE assumption |
| | | | | 0102 | 5 | Assuming same emission factors as for gas oil (DCE assumption) | 5 | 5 | Assuming same emission factors as for gas oil. DCE assumption |
| | | | 1A2a-g | 03 | 5 | Assuming same emission factors as for gas oil (DCE assumption) | 5 | 5 | Assuming same emission factors as for gas oil. DCE assumption |
| | | | 1A4b i | 0202 | 5 | Assuming same emission factors as for gas oil (DCE assumption) | 5 | 5 | Assuming same emission factors as for gas oil. DCE assumption |
| | 309A | Biogas | 1A1a | 0101, not engines | 1.5 | DEPA (1990), DEPA (1995) | 1.5 | 1.5 | All TSP emission is assumed to be <2,5µm. DCE assumption |
| | | | | 010105 | 2.63 | Nielsen & Illerup (2003) | 0.451 | 0.206 | Nielsen & Illerup (2003) |
| | | | | 0102 | 1.5 | DEPA (1990), DEPA (1995) | 1.5 | 1.5 | All TSP emission is assumed to be <2,5µm. DCE assumption |

| fuel_type | fuel | fuel | nfr | snap_id | TSP, g/GJ | Reference for TSP | $PM_{10}$, g/GJ | $PM_{2.5}$, g/GJ | Reference for $PM_{10}$ and $PM_{2.5}$ emission factors or for the $PM_{10}$ and the $PM_{2.5}$ fraction |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1A2a-g | Engines | 2.63 | Nielsen & Illerup (2003) | 0.451 | 0.206 | Nielsen & Illerup (2003) |
| | | | | Other | 1.5 | DEPA (1990), DEPA (1995) | 1.5 | 1.5 | All TSP emission is assumed to be <2,5µm. DCE assumption |
| | | | 1A4a i | 0201 | 1.5 | DEPA (1990), DEPA (1995) | 1.5 | 1.5 | All TSP emission is assumed to be <2,5µm. DCE assumption |
| | | | | Engines | 2.63 | Nielsen & Illerup (2003) | 0.451 | 0.206 | Nielsen & Illerup (2003) |
| | | | 1A4b | 0202 | 0.1 | Biogas upgraded for the town gas grid. Assumed equal to natural gas | 0.1 | 0.1 | Biogas upgraded for the town gas grid. Assumed equal to natural gas |
| | | | 1A4c i | 0203 | 1.5 | DEPA (1990), DEPA (1995) | 1.5 | 1.5 | All TSP emission is assumed to be <2,5µm. DCE assumption |
| | | | | Engines | 2.63 | Nielsen & Illerup (2003) | 0.451 | 0.206 | Nielsen & Illerup (2003) |
| | 310A | Bio gasification gas | 1A1a | 010105 | 2.63 | Same emission factor as for biogas assumed (DCE assumption) | 0.451 | 0.206 | Same emission factor as for biogas assumed. DCE assumption |
| | | | | 010101 | 0.2 | Assumed equal to LPG | 0.2 | 0.2 | Assumed equal to LPG |
| | 315A | Bio natural gas | 1A1a | 0101 and 0102 | 0.1 | Assumed equal to natural gas | 0.1 | 0.1 | Assumed equal to natural gas |
| | | | 1A2a-g | 03 | 0.1 | Assumed equal to natural gas | 0.1 | 0.1 | Assumed equal to natural gas |
| | | | 1A4a | 0201 | 0.1 | Assumed equal to natural gas | 0.1 | 0.1 | Assumed equal to natural gas |
| | | | 1A4b | 0202 | 0.1 | Assumed equal to natural gas | 0.1 | 0.1 | Assumed equal to natural gas |
| | | | 1A4c | 0203 | 0.1 | Assumed equal to natural gas | 0.1 | 0.1 | Assumed equal to natural gas |

## 7.11 Black carbon (BC) emission factors

The BC fractions of $PM_{2.5}$ and the references for the fractions are shown in Table 56. The BC fractions depend on fuel and sector.

Emission factor fractions for BC all refer to EEA (2013). All emission factors are shown as percentage of $PM_{2.5}$ and in g per GJ.

The time series are included in Annex 4. Time series have been estimated for residential wood combustion and for waste incineration. The BC fraction of $PM_{2.5}$ is considered constant for each fuel / technology.

Table 56 BC fraction of $PM_{2.5}$, 2018.

| Fuel | Fuel | NFR | SNAP | BC share of $PM_{2.5}$ | BC emission factor, g/GJ | Reference: EEA (2013) |
|---|---|---|---|---|---|---|
| 101A | Anodic carbon | 1A2 | 03 | 2.2% | 0.154 | Energy industries, Table 3-2 |
| 102A | Coal | 1A1a | 0101 | 2.2% | 0.0462 | Energy industries, Table 3-2 |
| 102A | Coal | 1A1a | 0102 | 2.2% | 0.11 | Energy industries, Table 3-2 |
| 102A | Coal | 1A4a | 0201 | 6.4% | 0.448 | Small combustion, Table 3-7 |
| 102A | Coal | 1A4b | 0202 | 6.4% | 0.448 | Small combustion, Table 3-3 |
| 102A | Coal | 1A4c | 0203 | 6.4% | 0.448 | Small combustion, Table 3-7 |
| 102A | Coal | 1A2 | 03 | 6.4% | 0.448 | Manufacturing industries, Table 3-2 |
| 103A | Fly ash fossil | 1A1a | 010104 | 2.2% | 0.0462 | Assumed equal to coal. DCE assumption. |
| 106A | BKB | 1A4a | 0201 | 6.4% | 0.448 | Small combustion, Table 3-7 |
| 106A | BKB | 1A4b | 0202 | 6.4% | 0.448 | Small combustion, Table 3-3 |
| 106A | BKB | 1A4c | 0203 | 6.4% | 0.448 | Small combustion, Table 3-7 |
| 106A | BKB | 1A2 | 03 | 6.4% | 0.448 | Manufacturing industries, Table 3-2 |
| 107A | Coke oven coke | 1A4b | 0202 | 6.4% | 0.448 | Small combustion, Table 3-3 |
| 107A | Coke oven coke | 1A2 | 0301 | 6.4% | 0.448 | Manufacturing industries, Table 3-2 |
| 110A | Petroleum coke | 1A1a | 0101 | 5.6% | 0.168 | Energy industries, table 3-5 |
| 110A | Petroleum coke | 1A4a | 0201 | 56.0% | 16.8 | Small combustion, Table 3-5 |
| 110A | Petroleum coke | 1A4b | 0202 | 8.5% | 2.55 | Small combustion, Table 3-5 |
| 110A | Petroleum coke | 1A4c | 0203 | 56.0% | 16.8 | Small combustion, Table 3-5 |
| 110A | Petroleum coke | 1A2 | 03 | 56.0% | 1.68 | Manufacturing industries, Table 3-4 |
| 111A | Wood | 1A1a | 0101 | 3.3% | 0.15906 | Energy industries, Table 3-7 |
| 111A | Wood | 1A1a | 0102 | 3.3% | 0.33 | Energy industries, Table 3-7 |
| 111A | Wood | 1A4a | 0201 | 28.0% | 37.8 | Small combustion, Table 3-10 |
| 111A | Wood | 1A4b | 0202 | - | 18.098 | See residential wood combustion, Chapter 6.13 |
| 111A | Wood | 1A4c | 0203 | 28.0% | 37.8 | Small combustion, Table 3-10 |
| 111A | Wood | 1A2 | 0301 | 28.0% | 2.8 | Manufacturing industries, Table 3-5 |
| 114A | Waste | 1A1a | 0101 | 3.5% | 0.01015 | Municipal waste Incineration, Table 3-1 |
| 114A | Waste | 1A1a | 0102 | 3.5% | 0.0735 | Municipal waste Incineration, Table 3-1 |
| 114A | Waste | 1A4a | 0201 | 3.5% | 0.0735 | Municipal waste Incineration, Table 3-1 |
| 114A | Waste | 1A2 | 03 | 3.5% | 0.0735 | Municipal waste Incineration, Table 3-1 |
| 115A | Industrial waste | 1A2 | 03 | 3.5% | 0.0735 | Municipal waste Incineration, Table 3-1 |
| 117A | Straw | 1A1a | 0101 | 3.3% | 0.03663 | Energy industries, Table 3-7 |
| 117A | Straw | 1A1a | 0102 | 3.3% | 0.396 | Energy industries, Table 3-7 |
| 117A | Straw | 1A4a | 020103 | 28.0% | 121 | Small combustion, Table 3-10 |
| 117A | Straw | 1A4b | 0202 | 28.0% | 121 | Small combustion, Table 3-10 (Assumed equal to agricultural plants) |
| 117A | Straw | 1A4c | 020300 | 28.0% | 3.36 | Small combustion, Table 3-10 |
| 117A | Straw | 1A2 | 03 | 28.0% | 3.36 | Manufacturing industries, Table 3-5 |
| 122A | Wood pellets | 1A1a | 0101 | 3.3% | 0.15906 | Energy industries, Table 3-7 |
| 122A | Wood pellets | 1A1a | 0102 | 3.3% | 0.33 | Energy industries, Table 3-7 |
| 122A | Wood pellets | 1A4a | 0201 | 28.0% | 37.8 | Small combustion, Table 3-10 |
| 122A | Wood pellets | 1A4b | 0202 | - | 7 | See residential wood combustion, Chapter 6.13 |
| 122A | Wood pellets | 1A4c | 0203 | 28.0% | 37.8 | Small combustion, Table 3-10 |
| 122A | Wood pellets | 1A2 | 0301 | 28.0% | 2.8 | Manufacturing industries, Table 3-5 |
| 203A | Residual oil | 1A1a | 010101 | 5.6% | 0.14 | Energy industries, Table 3-5 |
| 203A | Residual oil | 1A1a | 010102, 010103 | 5.6% | 0.4424 | Energy industries, Table 3-5 |
| 203A | Residual oil | 1A1a | 0102 | 5.6% | 0.14 | Energy industries, Table 3-5 |
| 203A | Residual oil | 1A1b | 010306 | 5.6% | 1.96 | Energy industries, Table 4-4 |
| 203A | Residual oil | 1A4a | 0201 | 56.0% | 3.92 | Small combustion, Table 3-9 |
| 203A | Residual oil | 1A4b | 0202 | 8.5% | 0.595 | Small combustion, Table 3-5 |
| 203A | Residual oil | 1A4c | 0203 | 56.0% | 3.92 | Small combustion, Table 3-9 |
| 203A | Residual oil | 1A2 | 03 | 56.0% | 2.688 | Manufacturing industries, Table 3-4 |
| 204A | Gas oil | 1A1a | 0101, 0102 | 33.5% | 1.675 | Energy industries, Table 3-6 |
| 204A | Gas oil | 1A1a | 010104 | 33.5% | 1.675 | Energy industries, Table 3-18 |
| 204A | Gas oil | 1A1a | 010105 | 78.0% | 3.9 | Energy industries, Table 3-19 |

| Fuel | Fuel | NFR | SNAP | BC share of $PM_{2.5}$ | BC emission factor, g/GJ | Reference: EEA (2013) |
|---|---|---|---|---|---|---|
| 204A | Gas oil | 1A1a | 010205 | 78.0% | 3.9 | Energy industries, Table 3-19 |
| 204A | Gas oil | 1A1b | 010306 | 33.5% | 1.675 | Energy industries, Table 4-5 |
| 204A | Gas oil | 1A1c | 010504 | 33.5% | 1.675 | Energy industries, Table 3-18 |
| 204A | Gas oil | 1A1c | 010505 | 78.0% | 3.9 | Energy industries, Table 3-19 |
| 204A | Gas oil | 1A4a | 0201 | 56.0% | 2.8 | Small combustion, Table 3-9 |
| 204A | Gas oil | 1A4a | 020105 | 78.0% | 3.9 | Energy industries, Table 3-37 |
| 204A | Gas oil | 1A4b | 0202 | 3.9% | 0.295 | Small combustion, Table 3-21 |
| 204A | Gas oil | 1A4b | 020204 | 78.0% | 3.9 | Energy industries, Table 3-19 |
| 204A | Gas oil | 1A4c | 0203 | 56.0% | 2.8 | Small combustion, Table 3-9 |
| 204A | Gas oil | 1A4c | 020304 | 78.0% | 3.9 | Energy industries, Table 3-37 |
| 204A | Gas oil | 1A2 | 03 | 56.0% | 2.8 | Manufacturing industries, Table 3-4 |
| 204A | Gas oil | 1A2 | 03 turbines | 33.5% | 1.675 | Energy industries, Table 3-18 |
| 204A | Gas oil | 1A2 | 03 engines | 78.0% | 3.9 | Energy industries, Table 3-19 |
| 206A | Kerosene | 1A4a | 0201 | 56.0% | 2.8 | Small combustion, Table 3-9 |
| 206A | Kerosene | 1A4b | 0202 | 8.5% | 0.425 | Small combustion, Table 3-5 |
| 206A | Kerosene | 1A4c | 0203 | 56.0% | 2.8 | Small combustion, Table 3-9 |
| 206A | Kerosene | 1A2 | 03 | 56.0% | 2.8 | Manufacturing industries, Table 3-4 |
| 215A | Bio oil | 1A1a | 0101 | 33.5% | 1.675 | Assumed equal to gas oil. DCE assumption. |
| 215A | Bio oil | 1A1a | 010105 | 78.0% | 3.9 | Assumed equal to gas oil. DCE assumption. |
| 215A | Bio oil | 1A1a | 0102 | 33.5% | 1.675 | Assumed equal to gas oil. DCE assumption. |
| 215A | Bio oil | 1A1a | 020105 | 78.0% | 3.9 | Assumed equal to gas oil. DCE assumption. |
| 215A | Bio oil | 1A4b | 020200 | 3.9% | 0.295 | Assumed equal to gas oil. DCE assumption. |
| 215A | Bio oil | 1A4b | 020304 | 78.0% | 3.9 | Assumed equal to gas oil. DCE assumption. |
| 215A | Bio oil | 1A2 | 03 | 56.0% | 2.8 | Manufacturing industries, Table 3-4 |
| 215A | Bio oil | 1A2 | 03 engines | 78.0% | 3.9 | Assumed equal to gas oil. DCE assumption. |
| 225A | Orimulsion | 1A1a | 010101 | 2.2% | 0.0352 | Assumed equal to coal. DCE assumption. |
| 301A | Natural gas | 1A1a | 0101 | 2.5% | 0.0025 | Energy industries, Table 3-4 |
| 301A | Natural gas | 1A1a | 010104 | 2.5% | 0.001275 | Energy industries, Table 3-17 |
| 301A | Natural gas | 1A1a | 010105 | 2.5% | 0.004025 | Energy industries, Table 3-20 |
| 301A | Natural gas | 1A1a | 010200 | 2.5% | 0.0025 | Energy industries, Table 3-4 |
| 301A | Natural gas | 1A1c | 0105 | 2.5% | 0.001275 | Energy industries, Table 3-4 |
| 301A | Natural gas | 1A1c | 010504 | 2.5% | 0.001275 | Energy industries, Table 3-17 |
| 301A | Natural gas | 1A1c | 010505 | 2.5% | 0.004025 | Energy industries, Table 3-20 |
| 301A | Natural gas | A14a | 0201 | 4.0% | 0.004 | Small combustion, Table 3-8 |
| 301A | Natural gas | 1A4a | 020104 | 2.5% | 0.001275 | Small combustion, Table 3-34 |
| 301A | Natural gas | 1A4a | 020105 | 2.5% | 0.004025 | Energy industries, Table 3-36 |
| 301A | Natural gas | 1A4b | 0202 | 5.4% | 0.0054 | Small combustion, Table 3-19 |
| 301A | Natural gas | 1A4b | 020204 | 2.5% | 0.004025 | Energy industries, Table 3-20 |
| 301A | Natural gas | 1A4c | 020300 | 4.0% | 0.004 | Small combustion, Table 3-8 |
| 301A | Natural gas | 1A4c | 020303 | 2.5% | 0.001275 | Energy industries, Table 3-17 |
| 301A | Natural gas | 1A4c | 020304 | 2.5% | 0.004025 | Energy industries, Table 3-36 |
| 301A | Natural gas | 1A2 | 03 | 4.0% | 0.004 | Manufacturing industries, Table 3-3 |
| 301A | Natural gas | 1A2 | 03 turbines | 2.5% | 0.001275 | Energy industries, Table 3-17 |
| 301A | Natural gas | 1A2 | 03 engines | 2.5% | 0.004025 | Energy industries, Table 3-20 |
| 303A | LPG | 1A1a | 0101 | 2.5% | 0.005 | Assumed equal to natural gas. DCE assumption. |
| 303A | LPG | 1A1a | 010104 | 2.5% | 0.005 | Assumed equal to natural gas. DCE assumption. |
| 303A | LPG | 1A1a | 0102 | 2.5% | 0.005 | Assumed equal to natural gas. DCE assumption. |
| 303A | LPG | 1A2b | 010306 | 2.5% | 0.005 | Assumed equal to natural gas. DCE assumption. |
| 303A | LPG | 1A4a | 020100 | 4.0% | 0.008 | Assumed equal to natural gas. DCE assumption. |
| 303A | LPG | 1A4a | 020105 | 4.0% | 0.008 | Assumed equal to natural gas. DCE assumption. |
| 303A | LPG | 1A4b | 0202 | 5.4% | 0.0108 | Assumed equal to natural gas. DCE assumption. |

| Fuel | Fuel | NFR | SNAP | BC share of $PM_{2.5}$ | BC emission factor, g/GJ | Reference: EEA (2013) |
|---|---|---|---|---|---|---|
| 303A | LPG | 1A4c | 0203 | 4.0% | 0.008 | Assumed equal to natural gas. DCE assumption. |
| 303A | LPG | 1A2 | 03 | 4.0% | 0.008 | Assumed equal to natural gas. DCE assumption. |
| 308A | Refinery gas | 1A1a | 010101 | 18.4% | 0.92 | Energy industries, Table 4-2 |
| 308A | Refinery gas | 1A1a | 010203 | 18.4% | 0.92 | Energy industries, Table 4-2 |
| 308A | Refinery gas | 1A1b | 0103 | 18.4% | 0.92 | Energy industries, Table 4-2 |
| 308A | Refinery gas | 1A2 | 03 | 18.4% | 0.92 | Energy industries, Table 4-2 |
| 309A | Biogas | 1A1a | 0101 | 3.3% | 0.0495 | Assumed % equal to wood. DCE assumption |
| 309A | Biogas | 1A1a | 010105 | 3.3% | 0.006798 | |
| 309A | Biogas | 1A1a | 0102 | 3.3% | 0.0495 | Assumed % equal to wood. DCE assumption |
| 309A | Biogas | 1A1c | 010505 | 3.3% | 0.006798 | Assumed % equal to wood. DCE assumption |
| 309A | Biogas | 1A4a | 0201 | 28.0% | 0.42 | Assumed % equal to wood. DCE assumption |
| 309A | Biogas | 1A4c | 0203 | 28.0% | 0.0054 | Assumed % equal to wood. DCE assumption |
| 309A | Biogas | 1A2 | 03 | 28.0% | 0.42 | Assumed % equal to wood. DCE assumption |
| 310A | Bio gasification gas | 1A1a | 010105 | 3.3% | 0.006798 | Assumed % equal to wood. DCE assumption |
| 310A | Bio gasification gas | 1A4a | 020105 | 3.3% | 0.006798 | Assumed % equal to wood. DCE assumption |
| 310A | Bio gasification gas | 1A4c | 020304 | 28.0% | 0.05768 | Assumed % equal to wood. DCE assumption |
| 310A | Bio gasification gas | 1A2 | 03 engines | 28.0% | 0.05768 | Assumed % equal to wood. DCE assumption |
| 315A | Bio natural gas | 1A1a | 0101 | 2.5% | 0.0025 | Assumed equal to natural gas. DCE assumption. |
| 315A | Bio natural gas | 1A1a | 0102 | 2.5% | 0.0025 | Assumed equal to natural gas. DCE assumption. |
| 315A | Bio natural gas | 1A4a | 0201 | 4.0% | 0.004 | Assumed equal to natural gas. DCE assumption. |
| 315A | Bio natural gas | 1A4b | 0202 | 5.4% | 0.0054 | Assumed equal to natural gas. DCE assumption. |
| 315A | Bio natural gas | 1A4c | 0203 | 4.0% | 0.004 | Assumed equal to natural gas. DCE assumption. |
| 315A | Bio natural gas | 1A2 | 03 | 4.0% | 0.004 | Assumed equal to natural gas. DCE assumption. |

## 7.12 Heavy metals emission factors

The heavy metal emission inventory has been documented in detail in Nielsen et al. (2013c).

The HM emission factors 2018 and references are shown in Table 57.

The emission factors for HM refer to:

- Two emission measurement programmes carried out on Danish decentralised CHP plants (Nielsen et al., 2010a; Nielsen & Illerup, 2003).
- Implied Emission Factors for power plants based on plant-specific data reported by the power plant owners.
- A CONCAWE study (Gon & Kuenen, 2009).
- Data for Danish natural gas (Gruijthuijsen, 2001; Energinet.dk, 2010).

- The EEA Guidebook (EEA, 2016).
- Struschka et al. (2008).
- Hedberg et al. (2002).

The time series are included in Annex 4. Time series have been estimated for:

- Coal combustion in electricity and district heat production plants.
- Waste incineration plants in public electricity and heat production.
- Waste incineration in other combustion plants.

Table 57 HM emission factors and references, 2018.

| fuel_type | fuel_gr_abbr | nfr | nfr_name | snap | As mg/GJ | Cd mg/GJ | Cr mg/GJ | Cu mg/GJ | Hg mg/GJ | Ni mg/GJ | Pb mg/GJ | Se mg/GJ | Zn mg/GJ | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Solid | Anodic carbon | 1A2g | Industry | All | 4 | 1.8 | 13.5 | 17.5 | 7.9 | 13 | 134 | 1.8 | 200 | EEA (2016), Tier 1, Industry Table 3-2 |
| | Coal | 1A1a | Public electricity and heat production | All | 0.51 | 0.07 | 0.86 | 0.48 | 1.3 | 0.97 | 0.62 | 5.9 | 1.9 | Implied emission factor 2008 estimated by DCE based on plant-specific emission data for power plants |
| | | All other | All other | All | 4 | 1.8 | 13.5 | 17.5 | 7.9 | 13 | 134 | 23 | 200 | EEA (2016), Tier 1, Industry Table 3-2. For Se: Tier 1, Energy industries Table 3-2. See also Nielsen et al. (2013c) |
| | Fly ash fossil | 1A1a | Public electricity and heat production | 0101 | 0.51 | 0.07 | 0.86 | 0.48 | 1.3 | 0.97 | 0.62 | 5.9 | 1.9 | Implied emission factor 2008 estimated by DCE based on plant-specific emission data for power plants |
| | BKB | 1A4b i | Residential | 0202 | 2.5 | 1.5 | 11.2 | 22.3 | 5.1 | 12.7 | 130 | 1.8 | 220 | EEA (2016), Tier 1, Small Combustion Table 3-3. For Se Tier 1, Small Combustion Table 3-7 (for 1A4a/c) |
| | Coke oven coke | 1A2 a-g | Industry | All | 4 | 1.8 | 13.5 | 17.5 | 7.9 | 13 | 134 | 1.8 | 200 | EEA (2016), Tier 1, Industry Table 3-2 |
| | | 1A4b | Residential | 0202 | 2.5 | 1.5 | 11.2 | 22.3 | 5.1 | 12.7 | 130 | 1.8 | 220 | EEA (2016), Tier 1, Small Combustion Table 3-3. For Se Tier 1, Small Combustion Table 3-7 (for 1A4a/c) |
| Liquid | Petroleum coke | all | All | All | 3.98 | 1.2 | 2.55 | 5.31 | 0.341 | 255 | 4.56 | 2.06 | 87.8 | EEA (2016), Tier 1, Energy industries Table 3-5 (for heavy fuel oil) |
| | Residual oil | 1A1a | Public electricity and heat production | All | 2.1 | 0.53 | 2.6 | 2.4 | 0.21 | 362 | 2.6 | 1.2 | 7.4 | Implied emission factor 2008 estimated by DCE based on plant-specific emission data for power plants |
| | | All other | All other | All | 3.98 | 1.2 | 2.55 | 5.31 | 0.341 | 255 | 4.56 | 2.06 | 87.8 | EEA (2016), Tier 1, Energy industries Table 3-5 (for heavy fuel oil) |
| | Gas oil | - | Engines | all | 0.055 | 0.011 | 0.2 | 0.3 | 0.11 | 0.013 | 0.15 | 0.22 | 58 | Nielsen et al. (2010a) |
| | | - | All other | All | 0.002 | 0.001 | 0.2 | 0.13 | 0.12 | 0.005 | 0.012 | 0.002 | 0.42 | Gon & Kuenen (2009) |
| | Kerosene | All | All | All | 0.002 | 0.001 | 0.2 | 0.13 | 0.12 | 0.005 | 0.012 | 0.002 | 0.42 | Assumed equal to gas oil. DCE assumption |

| fuel_type | fuel_gr_abbr | nfr | nfr_name | snap | As mg/GJ | Cd mg/GJ | Cr mg/GJ | Cu mg/GJ | Hg mg/GJ | Ni mg/GJ | Pb mg/GJ | Se mg/GJ | Zn mg/GJ | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LPG | All | All | All | 0.002 | 0.001 | 0.2 | 0.13 | 0.12 | 0.005 | 0.012 | 0.002 | 0.42 | EEA (2016), Tier 1, Small Combustion Table 3-5 (for 1A4b, other liquid fuels) |
| | Refinery gas | 1A1b | Petroleum refining | All | 0.343 | 0.712 | 2.74 | 2.22 | 0.086 | 3.6 | 1.79 | 0.42 | 25.5 | EEA (2016), Tier 1, Energy industries Table 4-2 (for refinery gas, 1A1b) |
| Gas | Natural gas | - | Engines | All | 0.05 | 0.003 | 0.05 | 0.01 | 0.1 | 0.05 | 0.04 | 0.01 | 2.9 | Nielsen et al. (2010a) |
| | | - | All other | All | 0.119 | 0.00025 | 0.00076 | 0.000076 | 0.1 | 0.00051 | 0.0015 | 0.0112 | 0.0015 | Gruijthuijsen (2001). For Hg: Nielsen et al. (2010a), also applied in EEA (2016), Tier 1, Energy industries Table 3-4. For Se: EEA (2016), Tier 1, Energy industries Table 3-4 |
| Waste | Waste | - | All | All | 0.59 | 0.44 | 1.56 | 1.3 | 1.79 | 2.06 | 5.52 | 1.11 | 2.33 | Nielsen et al. (2010a). |
| | Industrial waste | 1A2f | Industry - Other | All | 0.59 | 0.44 | 1.56 | 1.3 | 1.79 | 2.06 | 5.52 | 1.11 | 2.33 | Nielsen et al. (2010a). |
| Biomass | Wood and wood pellets | - | All non-residential | All | 0.19 | 0.27 | 2.34 | 2.6 | 0.4 | 2.34 | 3.62 | 0.5 | 2.3 | For Cd, Hg and Zn: Nielsen et al. (2010a) For Cr, Cu, Ni and Pb: Nielsen & Illerup (2003) For As and Se: EEA (2016), Tier 1, Small Combustion Table 3-10 (for solid biomass applied in 1A4a/c) Reference for As: Struschka et al. (2008). Reference for Se: Hedberg et al. (2002) |
| | | 1A4b i | Residential | All | 0.19 | 13 | 23 | 6 | 0.56 | 2 | 27 | 0.5 | 512 | EEA (2016) |
| | Straw | 1A1a | Public electricity and heat production | All | 0.19 | 0.32 | 1.6 | 1.7 | 0.31 | 1.7 | 6.2 | 0.5 | 0.41 | For Cd, Hg and Zn: Nielsen et al. (2010a) For Cr, Cu, Ni and Pb: Nielsen & Illerup (2003) For As and Se: EEA (2016), Tier 1, Small Combustion Table 3-10 |
| | | 1A4b i | Residential | 0202 | 0.19 | 13 | 23 | 6 | 0.56 | 2 | 27 | 0.5 | 512 | EEA (2016), Tier 1, Small Combustion Table 3-6 |
| | | 1A4c i | Agriculture/forestry | 0203 | 0.19 | 13 | 23 | 6 | 0.56 | 2 | 27 | 0.5 | 512 | EEA (2016), Tier 1, Small Combustion Table 3-6 (for 1A4b) |

| fuel_type | fuel_gr_abbr | nfr | nfr_name | snap | As mg/GJ | Cd mg/GJ | Cr mg/GJ | Cu mg/GJ | Hg mg/GJ | Ni mg/GJ | Pb mg/GJ | Se mg/GJ | Zn mg/GJ | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bio oil | - | Engines | engi-nes | 0.055 | 0.011 | 0.2 | 0.3 | 0.11 | 0.013 | 0.15 | 0.22 | 58 | Assumed equal to gas oil. DCE assumption |
| | | - | All other | - | 0.002 | 0.001 | 0.2 | 0.13 | 0.12 | 0.005 | 0.012 | 0.002 | 0.42 | Assumed equal to gas oil. DCE assumption |
| | Biogas | - | All non-residential | All | 0.04 | 0.002 | 0.18 | 0.31 | 0.12 | 0.23 | 0.005 | 0.21 | 3.95 | Nielsen et al. (2010a) |
| | | 1A4b | Residential | All | 0.119 | 0.00025 | 0.00076 | 0.000076 | 0.1 | 0.00051 | 0.0015 | 0.0112 | 0.0015 | Assumed equal to natural gas (biogas upgraded for distribution in the town gas grid) |
| | Bio gasification gas | 1A1a | Public electricity and heat production | 010105 | 0.12 | 0.009 | 0.029 | 0.045 | 0.54 | 0.014 | 0.022 | 0.18 | 0.058 | Nielsen et al. (2010a) |
| | | | | 010101 | 0.002 | 0.001 | 0.2 | 0.13 | 0.12 | 0.005 | 0.012 | 0.002 | 0.42 | Assumed equal to gas oil. DCE assumption |
| | Bio natural gas | - | All | All | 0.119 | 0.00025 | 0.00076 | 0.000076 | 0.1 | 0.00051 | 0.0015 | 0.0112 | 0.0015 | Assumed equal to natural gas |

## 7.13 PAH emission factors

The PAH emission factors 2018 and references are shown in Table 58.

The emission factors for PAH refer to:

- Research carried out by TNO (Berdowski et al., 1995).
- Research carried out by Statistics Norway (Finstad et al., 2001).
- An emission measurement program performed on biomass-fuelled plants. The project was carried out for the Danish Environmental Protection Agency (Jensen & Nielsen, 1996).
- Finstad et al. (2001).
- Two emission measurement programs carried out on Danish decentralised CHP plants (Nielsen et al., 2010a; Nielsen & Illerup, 2003).
- Additional information from the gas sector (Jensen, 2001).
- EEA (2016).
- Nielsen et al. (2020).

In general, emission factors for PAH are uncertain.

The time series are included in Annex 4. Time series have been estimated for:

- Residential wood combustion.
- Natural gas fuelled engines.
- Biogas-fuelled engines.

Table 58 PAH emission factors and references, 2018.

| fuel_type | fuel_id | fuel_gr_abbr | nfr_id | snap_id | Benzo(a)-pyrene µg per GJ | Benzo(b)-fluoranthene µg per GJ | Benzo(k)-fluoranthene µg per GJ | Indeno-(1,2,3-c,d)-pyrene µg per GJ | Reference |
|---|---|---|---|---|---|---|---|---|---|
| Solid | 102A | Anodic carbon | 1A2g | 0320 | 23 | 929 | 929 | 698 | Finstad et al. (2001) |
| | | Coal | 1A1a | All | 0.7 | 37 | 29 | 1.1 | EEA (2016). Tier 1, Energy industries Table 3-2 |
| | | | 1A2 a-g | All | 23 | 929 | 929 | 698 | Finstad et al. (2001) |
| | | | 1A4c i | 0203 | 59524 | 63492 | 1984 | 119048 | Finstad et al. (2001) |
| | 103A | Fly ash fossil | 1A1a | 0101 | 0.7 | 37 | 29 | 1.1 | EEA (2016). Tier 1, Energy industries Table 3-2 |
| | 106A | BKB | 1A4b i | 0202 | 59524 | 63492 | 1984 | 119048 | Finstad et al. (2001) (Same emission factor as for coal is assumed. DCE assumption) |
| | 107A | Coke oven coke | 1A2 a-g | All | 23 | 929 | 929 | 698 | Finstad et al. (2001) |
| | | | 1A4b | 0202 | 59524 | 63492 | 1984 | 119048 | Finstad et al. (2001) |
| Liquid | 110A | Petroleum coke | 1A2 a-g | All | 80 | 42 | 66 | 160 | Finstad et al. (2001). Assumed equal to residual oil |
| | | | 1A4a i | All | 80 | 42 | 66 | 160 | Finstad et al. (2001). Assumed equal to residual oil |
| | | | 1A4b i | All | 80 | 42 | 66 | 160 | Finstad et al. (2001). Assumed equal to residual oil |
| | | | 1A4c i | All | 80 | 42 | 66 | 160 | Finstad et al. (2001). Assumed equal to residual oil |
| | 203A | Residual oil | 1A1a | All | 109.6 | 475.41 | 93.21 | 177.28 | Finstad et al. (2001) |
| | | | 1A1b | 010306 | 109.6 | 475.41 | 93.21 | 177.28 | Finstad et al. (2001) |
| | | | 1A2 a-g | All | 80 | 42 | 66 | 160 | Finstad et al. (2001) |
| | | | 1A4a i | All | 80 | 42 | 66 | 160 | Finstad et al. (2001) |
| | | | 1A4b i | All | 80 | 42 | 66 | 160 | Finstad et al. (2001) |
| | | | 1A4c i | All | 80 | 42 | 66 | 160 | Finstad et al. (2001) |
| | 204A | Gas oil | 1A1a | Not engines | 109.6 | 475.41 | 93.21 | 177.28 | Finstad et al. (2001) |
| | | | | Engines | 1.9 | 15 | 1.7 | 1.5 | Nielsen et al. (2010a) |
| | | | 1A1b | 010306 | 109.6 | 475.41 | 93.21 | 177.28 | Finstad et al. (2001) |
| | | | 1A1c | 010504 | 109.6 | 475.41 | 93.21 | 177.28 | Finstad et al. (2001) |
| | | | 1A2 a-g | Not engines | 80 | 42 | 66 | 160 | Finstad et al. (2001) |
| | | | | Engines | 1.9 | 15 | 1.7 | 1.5 | Nielsen et al. (2010a) |
| | | | 1A4a i | Not engines | 80 | 42 | 66 | 160 | Finstad et al. (2001) |
| | | | | Engines | 1.9 | 15 | 1.7 | 1.5 | Nielsen et al. (2010a) |
| | | | 1A4b i | 0202 | 80 | 42 | 66 | 160 | Finstad et al. (2001) |
| | | | 1A4c i | 0203 | 80 | 42 | 66 | 160 | Finstad et al. (2001) |
| Gas | 301A | Natural gas | 1A1a | 010104 | 1 | 1 | 2 | 3 | Nielsen & Illerup (2003) |
| | | | | 010105 | 1.2 | 9 | 1.7 | 1.8 | Nielsen et al. (2010a) |
| | | | 1A1c | 010504 | 1 | 1 | 2 | 3 | Nielsen & Illerup (2003) |
| | | | 1A2 a-g | Turbines | 1 | 1 | 2 | 3 | Nielsen & Illerup (2003) |
| | | | | Engines | 1.2 | 9 | 1.7 | 1.8 | Nielsen et al. (2010a) |
| | | | 1A4a i | 020105 | 1.2 | 9 | 1.7 | 1.8 | Nielsen et al. (2010a) |
| | | | 1A4b i | 020202 | 0.133 | 0.663 | 0.265 | 2.653 | Jensen (2001) |

| fuel_type | fuel_id | fuel_gr_abbr | nfr_id | snap_id | Benzo(a)-pyrene | Benzo(b)-fluoranthene | Benzo(k)-fluoranthene | Indeno-(1,2,3-c,d)-pyrene | Reference |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 020204 | 1.2 | 9 | 1.7 | 1.8 | Nielsen et al. (2010a) |
| | | | 1A4c i | 020304 | 1.2 | 9 | 1.7 | 1.8 | Nielsen et al. (2010a) |
| Waste | 114A | Waste | 1A1a | All | 0.8 | 1.7 | 0.9 | 1.1 | Nielsen et al. (2010a) |
| | | | 1A4a i | 0201 | 0.8 | 1.7 | 0.9 | 1.1 | Nielsen et al. (2010a) |
| | 115A | Industrial waste | 1A2f | 0316 | 0.8 | 1.7 | 0.9 | 1.1 | Nielsen et al. (2010a) |
| Biomass | 111A | Wood | 1A1a | 0101 | 11 | 15 | 5 | 10 | Nielsen et al. (2010a) |
| | | | | 0102 | 6.46 | 1292.52 | 1292.52 | 11.56 | Finstad et al. (2001) |
| | | | 1A2 a-g | all | 6.46 | 1292.52 | 1292.52 | 11.56 | Finstad et al. (2001) |
| | | | 1A4a i | 0201 | 168707 | 221769 | 73469 | 119728 | Finstad et al. (2001) |
| | | | 1A4b i | All | 65630 | 61603 | 40349 | 35691 | Nielsen et al. (2020) |
| | | | 1A4c i | all | 168707 | 221769 | 73469 | 119728 | Finstad et al. (2001) |
| | 117A | Straw | 1A1a | 0101 | 0.5 | 0.5 | 0.5 | 0.5 | Nielsen et al. (2010a) |
| | | | | 0102 | 1529 | 3452 | 1400 | 1029 | Berdowski et al. (1995) |
| | | | 1A4b i | 0202 | 12956 | 12828 | 6912 | 4222 | Berdowski et al. (1995) |
| | | | 1A4c i | 0203 | 12956 | 12828 | 6912 | 4222 | Berdowski et al. (1995) |
| | 122A | Wood pellets | 1A1a | 0101 | 11 | 15 | 5 | 10 | Nielsen et al. (2010a) |
| | | | | 0102 | 6.46 | 1292.52 | 1292.52 | 11.56 | Finstad et al. (2001) |
| | | | 1A2 a-g | 03 | 6.46 | 1292.52 | 1292.52 | 11.56 | Finstad et al. (2001) |
| | | | 1A4a i | 0201 | 168707 | 221769 | 73469 | 119728 | Finstad et al. (2001) |
| | | | 1A4b i | 0202 | 900 | 1300 | 1300 | 1200 | Nielsen et al. (2020) |
| | 215A | Bio oil | 1A1a | All | 109.6 | 475.41 | 93.21 | 177.28 | Same emission factors as for gas oil is assumed. DCE assumption |
| | | | 1A2 a-g | All | 80 | 42 | 66 | 160 | Same emission factors as for gas oil is assumed. DCE assumption). |
| | | | 1A4b i | 0202 | 80 | 42 | 66 | 160 | Same emission factors as for gas oil is assumed (DCE assumption |
| | 309A | Biogas | Engines | All | 1.3 | 1.2 | 1.2 | 0.6 | Nielsen et al. (2010a) |
| | 310A | Bio gasification gas | Engines | 010105 | 2 | 2 | 2 | 2 | Nielsen et al. (2010a) |
| | 315A | Bio natural gas | 1A4b i | 0202 | 0.133 | 0.663 | 0.265 | 2.653 | Jensen (2001) |

## 7.14 PCDD/F emission factors

The PCDD/F emission factors 2018 and references are shown in Table 59.

The emission factor for residential wood combustion refers to Nielsen et al. (2020). The emission factor is based on technology specific emission factors, see Chapter 6.13.

The emission factors for decentralised CHP plants[30] refer to an emission measurement program for these plants (Nielsen et al. 2010a).

All other emission factors refer to research regarding PCDD/F emissions carried out by NERI (now DCE) to prepare a new PCDD/F emission inventory (Henriksen et al., 2006).

In general, emission factors for PCDD/F are uncertain.

The time series are included in Annex 4. Time series have been estimated for:

- Residential wood combustion.
- Waste incineration plants.

[30] Natural gas fueled engines, biogas fueled engines, gas oil fueled engines, engines fueled by biomass gasification gas, CHP plants combusting straw or wood and waste incineration plants.

Table 59 Emission factors for PCDD/F, 2018.

| fuel_type | fuel_id | fuel_gr_abbr | nfr_id | snap_id | PCDD/F, ng per GJ | Reference |
|---|---|---|---|---|---|---|
| Solid | 102A | Anodic carbon | 1A2g | 0320 | 1.32 | Henriksen et al., 2006 |
| | | Coal | 1A1a | 0101 and 0102 | 1.32 | Henriksen et al., 2006 |
| | | | 1A2 a-g | 03 | 1.32 | Henriksen et al., 2006 |
| | | | 1A4c i | 0203 | 300 | Henriksen et al., 2006 |
| | 103A | Fly ash fossil | 1A1a | 0101 | 1.32 | Henriksen et al., 2006 |
| | 106A | BKB | 1A4b i | 0202 | 800 | Henriksen et al., 2006 |
| | 107A | Coke oven coke | 1A2 a-g | 03 | 1.32 | Henriksen et al., 2006 |
| | | | 1A4c | 0203 | 800 | Henriksen et al., 2006 |
| Liquid | 110A | Petroleum coke | 1A2 a-g | 03 | 1.32 | Henriksen et al., 2006 |
| | | | 1A4a i | 0201 | 300 | Henriksen et al., 2006 |
| | | | 1A4b i | 0202 | 800 | Henriksen et al., 2006 |
| | | | 1A4c i | 0203 | 300 | Henriksen et al., 2006 |
| | 203A | Residual oil | 1A1a | All | 0.882 | Henriksen et al., 2006 |
| | | | 1A1b | 010306 | 0.882 | Henriksen et al., 2006 |
| | | | 1A2 a-g | 03 | 0.882 | Henriksen et al., 2006 |
| | | | 1A4a i | 0201 | 10 | Henriksen et al., 2006 |
| | | | 1A4b i | 0202 | 10 | Henriksen et al., 2006 |
| | | | 1A4c i | 0203 | 10 | Henriksen et al., 2006 |
| | 204A | Gas oil | 1A1a | Not engines | 0.882 | Henriksen et al., 2006 |
| | | | | Engines | 0.99 | Nielsen et al., 2010a |
| | | | 1A1b | 010306 | 0.882 | Henriksen et al., 2006 |
| | | | 1A1c | 010504 | 0.882 | Henriksen et al., 2006 |
| | | | 1A2 a-g | Not engines | 0.882 | Henriksen et al., 2006 |
| | | | | Engines | 0.99 | Nielsen et al., 2010a |
| | | | 1A4a i | Not engines | 10 | Henriksen et al., 2006 |
| | | | | Engines | 0.99 | Nielsen et al., 2010a |
| | | | 1A4b i | Not engines | 10 | Henriksen et al., 2006 |
| | | | | Engines | 0.99 | Nielsen et al., 2010a |
| | | | 1A4c i | 0203 | 10 | Henriksen et al., 2006 |
| | 206A | Kerosene | 1A2a-g | 03 | 0.882 | Henriksen et al., 2006 |
| | | | 1A4a i | 0201 | 10 | Henriksen et al., 2006 |
| | | | 1A4b i | 0202 | 10 | Henriksen et al., 2006 |
| | | | 1A4c i | 0203 | 10 | Henriksen et al., 2006 |
| | 303A | LPG | 1A1a | 0101 and 0102 | 0.025 | Henriksen et al., 2006 |
| | | | 1A2a-g | 03 | 0.025 | Henriksen et al., 2006 |
| | | | 1A4a i | 0201 | 2 | Henriksen et al., 2006 |
| | | | 1A4b i | 0202 | 2 | Henriksen et al., 2006 |
| | | | 1A4c i | 0203 | 2 | Henriksen et al., 2006 |
| | 308A | Refinery gas | 1A1b | 0103 | 0.025 | Henriksen et al., 2006 |
| Gas | 301A | Natural gas | 1A1a | Not engines | 0.025 | Henriksen et al., 2006 |
| | | | | Engines | 0.57 | Nielsen et al., 2010a |
| | | | 1A1b | 0103 | 0.025 | Henriksen et al., 2006 |
| | | | 1A1c | 010504 | 0.025 | Henriksen et al., 2006 |
| | | | 1A2 a-g | 03, Not engines | 0.025 | Henriksen et al., 2006 |
| | | | | Engines | 0.57 | Nielsen et al., 2010a |
| | | | 1A4a i | 0201 | 2 | Henriksen et al., 2006 |
| | | | | 020105 | 0.57 | Nielsen et al., 2010a |
| | | | 1A4b i | 0202 | 2 | Henriksen et al., 2006 |
| | | | | 020204 | 0.57 | Nielsen et al., 2010a |
| | | | 1A4c i | 0203 | 2 | Henriksen et al., 2006 |
| | | | | 020304 | 0.57 | Nielsen et al., 2010a |
| Waste | 114A | Waste | 1A1a | 0101 and 0102 | 5 | Nielsen et al., 2010a |
| | | | 1A4a i | 0201 | 5 | Nielsen et al., 2010a |
| | 115A | Industrial waste | 1A2f | 0316 | 5 | Nielsen et al., 2010a |

| fuel_type | fuel_id | fuel_gr_abbr | nfr_id | snap_id | PCDD/F, ng per GJ | Reference |
|---|---|---|---|---|---|---|
| Biomass | 111A | Wood | 1A1a | 0101 | 14 | Nielsen et al., 2010a |
| | | | | 0102 | 1 | Henriksen et al., 2006 |
| | | | 1A2 a-g | 03 | 1 | Henriksen et al., 2006 |
| | | | 1A4a i | 0201 | 400 | Henriksen et al., 2006 |
| | | | 1A4b i | 0202 | 766 | Nielsen et al. (2020) |
| | | | 1A4c i | 0203 | 400 | Henriksen et al., 2006 |
| | 117A | Straw | 1A1a | 0101 | 19 | Nielsen et al., 2010a |
| | | | | 0102 | 22 | Henriksen et al., 2006 |
| | | | 1A4b i | 0202 | 500 | Henriksen et al., 2006 |
| | | | 1A4c i | 0203 | 400 | Henriksen et al., 2006 |
| | 122A | Wood pellets | 1A1a | 0101 | 14 | Nielsen et al., 2010a |
| | | | | 0102 | 1 | Henriksen et al., 2006 |
| | | | 1A2 a-g | 03 | 1 | Henriksen et al., 2006 |
| | | | 1A4a i | 0201 | 400 | Henriksen et al., 2006 |
| | | | 1A4b i | 0202 | 333 | Nielsen et al. (2020) |
| | | | 1A4c i | 0203 | 400 | Henriksen et al., 2006 |
| | 215A | Bio oil | 1A1a | 0101 and 0102 | 0.882 | Henriksen et al., 2006 |
| | | | 1A2 a-g | 03 | 0.882 | Henriksen et al., 2006 |
| | | | 1A4b i | 0202 | 10 | Henriksen et al., 2006 |
| | 309A | Biogas | 1A1a | Engines | 0.96 | Nielsen et al., 2010a |
| | | | | Not engines | 0.025 | Henriksen et al., 2006 |
| | | | 1A2a-g | Not engines | 0.025 | Henriksen et al., 2006 |
| | | | | Engines | 0.96 | Nielsen et al., 2010a |
| | | | 1A4a i | Not engines | 2 | Henriksen et al., 2006 |
| | | | | Engines | 0.96 | Nielsen et al., 2010a |
| | | | 1A4b | Not engines | 2 | Henriksen et al., 2006 |
| | | | 1A4c i | Not engines | 2 | Henriksen et al., 2006 |
| | | | | Engines | 0.96 | Nielsen et al., 2010a |
| | 310A | Bio gasification gas | 1A1a | 010105 | 1.7 | Nielsen et al., 2010a |
| | 315A | Bio natural gas | 1A1a | 0101 and 0102 | 0.025 | Assumed equal to natural gas |
| | | | 1A2a-g | 03 | 0.025 | Assumed equal to natural gas |
| | | | 1A4a | 0201 | 2 | Assumed equal to natural gas |
| | | | 1A4b | 0202 | 2 | Assumed equal to natural gas |
| | | | 1A4c | 0203 | 2 | Assumed equal to natural gas |

## 7.15 HCB emission factors

The HCB emission inventory has been documented in Nielsen et al. (2014b).

Table 60 shows the emission factors and references for the Danish emission factors.

Table 60 Emission factors for HCB, 2018.

| Fuel | NFR (SNAP) | Emission factor, ng/GJ | Reference |
|---|---|---|---|
| Coal | 1A1, 1A2 | 6,700 | Grochowalski & Konieczyński (2008); EEA (2013) |
| Coal | 1A4b | 1,200,000 | Syc et al. (2011) |
| Coal | 1A4a and 1A4c | 23,000 | Syc et al. (2011) |
| Other solid fuels | 1A1, 1A2 | 6,700 | Assumed equal to coal |
| Other solid fuels | 1A4 | 1,200,000 | Assumed equal to coal |
| Liquid fuels[1)] | 1A1, 1A2, 1A4 | 220 | Nielsen et al. (2010a) |
| Gaseous fuels | 1A1, 1A2, 1A4 | - | Negligible |
| Waste | 1A1, 1A2, 1A4 | 4300 | Nielsen et al. (2010a). A time series have been estimated. The emission factor for 1990 (190,000 ng/GJ) refer to Pacyna et al. (2003) |
| Wood and wood pellets | 1A1, 1A2 | 5,000 | EEA (2013) |
| Wood and wood pellets | 1A4 | 5,000 | EEA (2013) |
| Straw | 1A1, 1A2 | 113 | Nielsen et al. (2010a) |
| Straw | 1A4 | 5,000 | EEA (2013) |
| Biogas | 1A1, 1A2, 1A4 | 190 | Nielsen et al. (2010a) |
| Producer gas | 1A1, 1A2, 1A4 | 800 | Nielsen et al. (2010a) |

1) The emission factor for LPG and refinery gas is negligible.

For coal, the emission factor from Grochowalski & Konieczyński (2008) is applied for Energy industries and for industrial plants. This emission factor is also applied in the EEA Guidebook (EEA, 2013).

For residential plants, the emission factor 1,200,000 ng / GJ is applied referring to Syc et al. (2011). For commercial / institutional plants and for plants in agriculture / forestry the lower end of the value in Syc et al. (2011) (23,000 ng / GJ) is applied.

The emission factor for gas oil fuelled CHP engines (220 ng / GJ) referring to Nielsen et al. (2010a) is applied for all liquid fuels except for LPG and refinery gas.

For gaseous fuels, LPG and refinery gas no data are available and the emission is negligible.

For waste combustion, emission data from Danish plants are available and these data are applied (Nielsen et al., 2010a). The emission factor 4,300 ng / GJ is applied for 2005 onwards. The HCB emission factor for 1990 refers to Pacyna et al. (2003). The emission of HCB is related to emission of PCDD / Fs and the decline rate between 1990 and 2005 is based on the decline rate for PCDD / Fs.

Recent emission measurements from Polish industrial waste incineration plants confirms the emission factor level for waste incineration considering that the PCDD / F emission level is 15 times the PCDD / F emission level for Danish plants.

For wood combustion, the emission factors from EEA (2013) are applied for both Energy industries, industrial plants and for non-industrial plants. For residential wood combustion, it would be relevant to estimate a time series. However, the currently available data are considered insufficient for this estimate.

The chlorine (Cl) content in straw is higher than in wood (Villeneuve et al., 2013) and thus the emission from straw combustion might potentially be higher. However, the emission factor for CHP plants combusting straw reported in Nielsen et al. (2010a) is lower than the emission factor applied for wood.

The emission factor for Energy industries and industrial combustion refer to Nielsen et al. (2010a). For non-industrial plants, the EEA (2013) emission factor is applied.

The emission factors for biogas and biomass gasification gas both refer to Nielsen et al. (2010a).

## 7.16 PCB emission factors

The PCB emission inventory has been documented in Nielsen et al. (2014b).

The PCB emissions are strongly related to the chlorine (Cl) content of the fuel (Syc et al., 2011) and to the emission level for PCDD/Fs (Hedman et al., 2006; Syc et al., 2011; Pandelova et al., 2009).

The Cl content of straw, bark and manure is higher than for wood (Villeneuve et al., 2012). Villeneuve et al. (2012) states the Cl contents 50-60 mg/kg wood, 100-370 mg/kg bark, 1000-7000 mg/kg straw.

Different references for PCB emissions are not directly comparable because some PCB emission data are reported for individual PCB congeners, some as a sum of a specified list of PCB congeners and some PCB emission data are reported as toxic equivalence (teq) based on toxicity equivalence factors (TEF) for 12 dioxin-like PCB congeners. The emission measurements reported by Thistlethwaite (2001a and 2001b) show that the emission of non-dioxin-like PCBs are high compared to the emission of dioxin-like PCBs.

Furthermore, teq values based on TEF are reported as $WHO_{2005}$-teq or $WHO_{1998}$-teq. This difference is however typically less than 50%[31].

Table 61 shows the emission factors that have been selected for the Danish PCB emission inventory and reference for each emission factor. All emission factors are dioxin-like PCBs (but not teq values). PCB emission factors have been added for all fuels except LPG, refinery gas and natural gas. The emission from these three fuels is considered negligible.

[31] Data have been compared for a few datasets in which each dioxin-like PCB congeners were specified.

Table 61 Emission factors for ∑dl-PCBs, stationary combustion, 2018.

| Fuel | NFR (SNAP) | Emission factor, ∑ dl-PCBs, ng/GJ | Emission factor, PCB, ng $WHO_{1998}$-teq/GJ | Reference |
|---|---|---|---|---|
| Coal | 1A1 | 839 | 3.16 | Grochowalski & Konieczyński (2008) |
| Coal | 1A2 | 5,700 | 53 | Thistlethwaite (2001a) |
| Coal | 1A4 | 7,403 | 66 | Syc et al. (2011) |
| Other solid fuels | 1A1 | 839 | 3.16 | Assumed equal to coal |
| Other solid fuels | 1A2 | 5,700 | 53 | Assumed equal to coal |
| Other solid fuels | 1A4 | 7,403 | 66 | Assumed equal to coal |
| Residual oil and orimulsion | 1A1, 1A2, 1A4 | 839 | 3.2 | The teq value refers to Dyke et al. (2003)<br><br>The TEQ value is equal to the emission factor for coal combustion in power plants and the sum of dioxin-like PCB congeners has been assumed equal to the corresponding factor for coal |
| Gas oil | 1A1, 1A2, 1A4 | 93 | 0.11 | Nielsen et al. (2010a) |
| Other liquid fuels[1)] | 1A1, 1A2, 1A4 | 93 | 0.11 | Assumed equal to gas oil |
| Gaseous fuels | 1A1, 1A2, 1A4 | - | - | Negligible |
| Waste | 1A1, 1A2, 1A4 | 109 (time series) | 0.28 (time series) | Nielsen et al. (2010a). A time series have been estimated. The emission factor for 1990 (46,000 ng/GJ or 117 ng WHO1998teq/GJ) have been estimated based on the assumption that the PCB emission factor time series follow the PCDD/F time series |
| Wood | 1A1, 1A2, 1A4a/c | 2,800 | 21 | Thistlethwaite (2001a) |
| Wood | 1A4b | 2,686 (time series) | - | Hedman et al. (2006). A time series have been estimated based on time series for technologies applied in Denmark |
| Straw | 1A1, 1A2 | 3,110 | 31.2 | Assumed equal to residential plants |
| Straw | 1A4 | 3,110 | 31.2 | Syc et al. (2011) |
| Wood pellets | 1A1, 1A2, 1A4a/c | 2,800 | 21 | Thistlethwaite (2001a) |
| Wood pellets | 1A4b | 465.5 | - | Hedman et al. (2006). |
| Biogas | 1A1, 1A2, 1A4 | 90 | 0.13 | Nielsen et al. (2010a) |
| Producer gas | 1A1, 1A2, 1A4 | 144 | 0.17 | Nielsen et al. (2010a) |

1) Except LPG and refinery gas.

The emission factor for waste incineration refers to recent Danish field measurements. Historical data are not available, but a time series have been estimated based on the assumption that the dl-PCB emission factor follows the PCDD/-F emission factor. The estimated emission factor for 1990 is 45,671 ng/GJ or 117 ng WHO-teq/GJ. This emission level is confirmed by other references (Kakareka & Kukharchyk, 2005; Andrijewski et al., 2004). The emission factor time series is shown in Table 62.

For residential wood combustion, technology specific emission factors in toxicological equivalence are available from Hedman et al. (2006). However, sums of dioxin-like PCBs are not included in the reference. The emission factors for dioxin-like PCBs have been estimated based on the data for toxicological equivalence and the sum of dioxin-like PCBs in Thistlethwaite (2001a). Thus, the teq factors referring to Hedman (2006) have been multiplied by 2800/21. This assumption is highly uncertain, but the resulting emission factors seem to be in agreement with other references for residential wood combustion. A technology distribution time series for residential wood combustion in Denmark is available and have been applied for estimating the time series for the aggregated emission factor shown in Table 62.

Emission factor time series for waste incineration and for residential wood combustion are shown in Table 62.

Table 62 Emission factor time series for waste incineration and for residential wood combustion.

| Year | Waste incineration ∑dl-PCBs, ng/GJ | Residential wood combustion ∑dl-PCBs, ng/GJ |
|---|---|---|
| 1990 | 45671 | 6076 |
| 1991 | 38063 | 6000 |
| 1992 | 30433 | 5924 |
| 1993 | 22825 | 5849 |
| 1994 | 19773 | 5774 |
| 1995 | 16721 | 5701 |
| 1996 | 13690 | 5629 |
| 1997 | 10638 | 5560 |
| 1998 | 7586 | 5492 |
| 1999 | 5515 | 5425 |
| 2000 | 3423 | 5359 |
| 2001 | 3423 | 5293 |
| 2002 | 3423 | 5226 |
| 2003 | 3423 | 5162 |
| 2004 | 1766 | 4921 |
| 2005 | 109 | 4687 |
| 2006 | 109 | 4509 |
| 2007 | 109 | 4333 |
| 2008 | 109 | 4142 |
| 2009 | 109 | 3930 |
| 2010 | 109 | 3718 |
| 2011 | 109 | 3588 |
| 2012 | 109 | 3459 |
| 2013 | 109 | 3330 |
| 2014 | 109 | 3200 |
| 2015 | 109 | 3071 |
| 2016 | 109 | 2941 |
| 2017 | 109 | 2814 |
| 2018 | 109 | 2686 |

## 7.17 Implied emission factors

A considerable part of the emission data for waste incineration plants and large power plants are plant-specific. Thus, the area source emission factors do not necessarily represent average values for these plant categories. To attain a set of emission factors that expresses the average emission for power plants combusting coal and for waste incineration plants, implied emission factors have been calculated for these two plant categories. The implied emission factors are presented in Annex 5. The implied emission factors are calculated as total emission divided by total fuel consumption.

# 8 Uncertainty

## 8.1 Uncertainty for greenhouse gases

Uncertainty estimates include uncertainty with regard to the total emission inventory as well as uncertainty with regard to trends.

### 8.1.1 Methodology

The uncertainty for greenhouse gas emissions have been estimated according to the IPCC Guidelines (IPCC, 2006). This year the uncertainty has been estimated only by approach 1.

Approach 1 is based on a normal distribution and a confidence interval of 95 %.

The input data for the approach 1 are:

- Emission data for the base year and the latest year.
- Uncertainties for emission factors.
- Uncertainty for fuel consumption rates.

The emission source categories applied are listed in Table 63.

#### Source categories

Due to large differences in data uncertainty, some emission source categories have been further disaggregated than suggested in the IPCC Guidelines (2006):

- For five different fuels, $CO_2$ emissions based on ETS data and on non-ETS data have been considered two different emission sources.
- $CH_4$ emission from natural gas fuelled engines.
- $CH_4$ emission from biogas fuelled engines.
- $CH_4$ emission from residential wood combustion.
- $CH_4$ emission from residential and agricultural combustion of straw
- $N_2O$ emission from residential wood combustion.
- $N_2O$ emission from residential and agricultural combustion of straw.

The separate uncertainty estimation for gas engine $CH_4$ emission and $CH_4$ emission from other plants is applied, because in Denmark, the $CH_4$ emission from gas engines is much larger than the emission from other stationary combustion plants, and the $CH_4$ emission factor for gas engines is estimated with a much smaller uncertainty level than for other stationary combustion plants.

The 2018 uncertainty levels have been applied in uncertainty calculation.

#### Fuel consumption

The applied uncertainty rates for fuel consumption are shown below.

Table 63 Uncertainties for fuel consumption 2018.

| IPCC Source category | 2018 | Reference |
|---|---|---|
| 1A1, 1A2, 1A4 St. comb., Coal, ETS data, $CO_2$ | 0.5% | ETS data |
| 1A1, 1A2, 1A4 St. comb., Coal, no ETS data, $CO_2$ | 1.5% | Estimated based on IPCC (2006) values |
| 1A1, 1A2, 1A4 St. comb., BKB, $CO_2$ | 2.9% | Estimated based on IPCC (2006) values |
| 1A1, 1A2, 1A4 St. comb., Coke oven coke, $CO_2$ | 1.5% | Estimated based on IPCC (2006) values |
| 1A1, 1A2, 1A4 St. comb., Fossil waste, ETS data, $CO_2$ | 2% | DCE assumption |
| 1A1, 1A2, 1A4 St. comb., Fossil waste, no ETS data, $CO_2$ | 5% | DCE assumption |
| 1A1, 1A2, 1A4 St. comb., Petroleum coke, ETS data, $CO_2$ | 0.5% | ETS data |
| 1A1, 1A2, 1A4 St. comb., Petroleum coke, no ETS data, $CO_2$ | 1.9% | Estimated based on IPCC (2006) values |
| 1A1, 1A2, 1A4 St. comb., Residual oil, ETS data, $CO_2$ | 0.5% | ETS data |
| 1A1, 1A2, 1A4 St. comb., Residual oil, no ETS data, $CO_2$ | 1.0% | Estimated based on IPCC (2006) values |
| 1A1, 1A2, 1A4 St. comb., Gas oil, $CO_2$ | 2.6% | Estimated based on IPCC (2006) values |
| 1A1, 1A2, 1A4 St. comb., Kerosene, $CO_2$ | 2.0% | Estimated based on IPCC (2006) values |
| 1A1, 1A2, 1A4 St. comb., LPG, $CO_2$ | 2.0% | Estimated based on IPCC (2006) values |
| 1A1b,St. comb., Refinery gas, $CO_2$ | 1.0% | Estimated based on IPCC (2006) values |
| 1A1, 1A2, 1A4, Stationary combustion, Natural gas, onshore, $CO_2$ | 1.3% | Estimated based on IPCC (2006) values. Offshore gas turbines not included in this category |
| 1A1c Off shore gas turbines, Natural gas, $CO_2$ | 0.5% | ETS data for 2018, IPCC (2006) for 1990 |
| 1A1, Stationary combustion, Solid, $CH_4$ | 1.0% | IPCC (2006), less than 1% |
| 1A1, Stationary combustion, Liquid, $CH_4$ | 1.0% | IPCC (2006), less than 1% |
| 1A1, Stationarycombustion, not engines, GAS, $CH_4$ | 1.0% | IPCC (2006), less than 1% |
| 1A1, Stationary combustion, Waste, $CH_4$ | 3.0% | DCE assumption. The uncertainty for the total consumption of waste is lower than the uncertainty for the fossil part |
| 1A1, Stationary combustion, not engines, Biomass, $CH_4$ | 3.0% | DCE assumption |
| 1A2, Stationary combustion, Solid, $CH_4$ | 2.0% | IPCC (2006) |
| 1A2, Stationary combustion, Liquid, $CH_4$ | 2.0% | IPCC (2006) |
| 1A2, Stationary combustion, not engines, GAS, $CH_4$ | 2.0% | IPCC (2006) |
| 1A2, Stationary combustion, Waste, $CH_4$ | 3.0% | DCE assumption. The uncertainty for the total consumption of waste is lower than the uncertainty for the fossil part |
| 1A2, Stationary combustion, not engines, BIOMASS, $CH_4$ | 3.0% | IPCC (2006) |
| 1A4, Stationary combustion, Solid, $CH_4$ | 3.0% | IPCC (2006) |
| 1A4, Stationary combustion, Liquid, $CH_4$ | 3.0% | IPCC (2006) |
| 1A4, Stationary combustion, not engines, GAS, $CH_4$ | 3.0% | IPCC (2006) |
| 1A4, Stationary combustion, Waste, $CH_4$ | 3.0% | DCE assumption. The uncertainty for the total consumption of waste is lower than the uncertainty for the fossil part |
| 1A4, Stationary combustion, not engines, not residential wood and not residential/agricultural straw, Biomass, $CH_4$ | 3.0% | IPCC (2006) |
| 1A4, Stationary combustion, Residential wood combustion, $CH_4$ | 10.0% | DCE assumption |
| 1A4, Stationary combustion, Residential and agricultural straw combustion, $CH_4$ | 10.0% | DCE assumption |
| 1A1, 1A2, 1A4 Natural gas fuelled engines, Gas, $CH_4$ | 1.0% | Lindgren (2010) |
| 1A1, 1A2, 1A4 Biogas fuelled engines, Gas, $CH_4$ | 3.0% | DCE assumption |
| 1A1, Stationary combustion, Solid, $N_2O$ | 1.0% | IPCC (2006), less than 1% |
| 1A1, Stationary combustion, Liquid, $N_2O$ | 1.0% | IPCC (2006), less than 1% |
| 1A1, Stationary combustion, Gas, $N_2O$ | 1.0% | IPCC (2006), less than 1% |
| 1A1, Stationary combustion, Waste, $N_2O$ | 3.0% | DCE assumption |
| 1A1, Stationary combustion, Biomass, $N_2O$ | 3.0% | DCE assumption |
| 1A2, Stationary combustion, Solid, $N_2O$ | 2.0% | IPCC (2006) |
| 1A2, Stationary combustion, Liquid, $N_2O$ | 2.0% | IPCC (2006) |
| 1A2, Stationary combustion, Gas, $N_2O$ | 2.0% | IPCC (2006) |
| 1A2, Stationary combustion, Waste, $N_2O$ | 3.0% | DCE assumption |
| 1A2, Stationary combustion, Biomass, $N_2O$ | 3.0% | DCE assumption |
| 1A4, Stationary combustion, Solid, $N_2O$ | 3.0% | IPCC (2006) |
| 1A4, Stationary combustion, Liquid, $N_2O$ | 3.0% | IPCC (2006) |
| 1A4, Stationary combustion, Gas, $N_2O$ | 3.0% | IPCC (2006) |
| 1A4, Stationary combustion, Waste, $N_2O$ | 3.0% | DCE assumption |

| IPCC Source category | 2018 | Reference |
|---|---|---|
| 1A4, Stationary combustion, not residential wood and not residential/agricultural straw, Biomass, $N_2O$ | 3.0% | DCE assumption |
| 1A4b, Stationary combustion, Residential wood combustion, $N_2O$ | 10.0% | DCE assumption |
| 1A4b/c, Stationary combustion, Residential and agricultural straw combustion, $N_2O$ | 10.0% | DCE assumption |

### Emission factors

Uncertainties for emission factors are shown in Table 64.

Table 64 Uncertainties for emission factors, 2018.

| IPCC Source category | 2018 | Reference |
|---|---|---|
| 1A1, 1A2, 1A4 St. comb., Coal, ETS data, $CO_2$ | 0.3% | ETS data, 2018 estimate |
| 1A1, 1A2, 1A4 St. comb., Coal, no ETS data, $CO_2$ | 1.0% | DCE assumption |
| 1A1, 1A2, 1A4 St. comb., BKB, $CO_2$ | 5.0% | IPCC (2000), chapter 2.1.1.6 |
| 1A1, 1A2, 1A4 St. comb., Coke oven coke, $CO_2$ | 5.0% | IPCC (2000), chapter 2.1.1.6 |
| 1A1, 1A2, 1A4 St. comb., Fossil waste, ETS data, $CO_2$ | 3.0% | ETS data, DCE estimate based on Astrup et al. (2012. |
| 1A1, 1A2, 1A4 St. comb., Fossil waste, no ETS data, $CO_2$ | 10.0% | Non-ETS data, DCE estimate based on Astrup et al. (2012) |
| 1A1, 1A2, 1A4 St. comb., Petroleum coke, ETS data, $CO_2$ | 0.5% | ETS data, 2018 estimate |
| 1A1, 1A2, 1A4 St. comb., Petroleum coke, no ETS data, $CO_2$ | 5.0% | IPCC (2000), chapter 2.1.1.6 |
| 1A1, 1A2, 1A4 St. comb., Residual oil, ETS data, $CO_2$ | 0.5% | ETS data, 2015 estimate |
| 1A1, 1A2, 1A4 St. comb., Residual oil, no ETS data, $CO_2$ | 2.0% | Jensen & Lindroth (2002) |
| 1A1, 1A2, 1A4 St. comb., Gas oil, $CO_2$ | 1.3% | DCE estimate |
| 1A1, 1A2, 1A4 St. comb., Kerosene, $CO_2$ | 3.0% | Based on interval in IPCC (2006) |
| 1A1, 1A2, 1A4 St. comb., LPG, $CO_2$ | 4.0% | Based on interval in IPCC (2006) |
| 1A1b,St. comb., Refinery gas, $CO_2$ | 0.5% | 1990: IPCC (2000), chapter 2.1.1.6<br>2018: DCE assumption, EU ETS data |
| 1A1, 1A2, 1A4, Stationary combustion, Natural gas, onshore, $CO_2$ | 0.4% | Lindgren (2010). Personal communication |
| 1A1c Offshore gas turbines, Natural gas, $CO_2$ | 0.5% | ETS data for 2018, but not for 1990 |
| 1A1, Stationary combustion, Solid, $CH_4$ | 100% | Based on interval in IPCC (2006), table 2.12 |
| 1A1, Stationary combustion, Liquid, $CH_4$ | 100% | Based on interval in IPCC (2006), table 2.12 |
| 1A1, Stationary combustion, not engines, Gas, $CH_4$ | 100% | Based on interval in IPCC (2006), table 2.12 |
| 1A1, Stationary combustion, Waste, $CH_4$ | 100% | Based on interval in IPCC (2006), table 2.12 |
| 1A1, Stationary combustion, not engines, Biomass, $CH_4$ | 100% | Based on interval in IPCC (2006), table 2.12 |
| 1A2, Stationary combustion, Solid, $CH_4$ | 100% | Based on interval in IPCC (2006), table 2.12 |
| 1A2, Stationary combustion, Liquid, $CH_4$ | 100% | Based on interval in IPCC (2006), table 2.12 |
| 1A2, Stationary combustion, not engines, G, $CH_4$ | 100% | Based on interval in IPCC (2006), table 2.12 |
| 1A2, Stationary combustion, Waste, $CH_4$ | 100% | Based on interval in IPCC (2006), table 2.12 |
| 1A2, Stationary combustion, not engines, Biomass, $CH_4$ | 100% | Based on interval in IPCC (2006), table 2.12 |
| 1A4, Stationary combustion, Solid, $CH_4$ | 100% | Based on interval in IPCC (2006), table 2.12 |
| 1A4, Stationary combustion, Liquid, $CH_4$ | 100% | Based on interval in IPCC (2006), table 2.12 |
| 1A4, Stationary combustion, not engines, Gas, $CH_4$ | 100% | Based on interval in IPCC (2006), table 2.12 |
| 1A4, Stationary combustion, Waste, $CH_4$ | 100% | Based on interval in IPCC (2006), table 2.12 |
| 1A4, Stationary combustion, not engines, not residential wood and not residential/agricultural straw, Biomass, $CH_4$ | 100% | Based on interval in IPCC (2006), table 2.12 |
| 1A4, Stationary combustion, Residential wood combustion, $CH_4$ | 150% | Upper value in IPCC (2006), table 2.12 |
| 1A4, Stationary combustion, Residential and agricultural straw combustion, $CH_4$ | 150% | Upper value in IPCC (2006), table 2.12 |
| 1A1, 1A2, 1A4 Natural gas fuelled engines, Gas, $CH_4$ | 2% | 1990: DCE estimate based on Nielsen et al. (2010a). 2018: Jørgensen et al. (2010). Uncertainty data for NMVOCs + $CH_4$ |
| 1A1, 1A2, 1A4 Biogas fuelled engines, Gas, $CH_4$ | 10% | DCE estimate based on Nielsen et al. (2010a) |
| 1A1, Stationary combustion, Solid, $N_2O$ | 400% | DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark |
| *Continued* | | |

| IPCC Source category | 2018 | Reference |
|---|---|---|
| 1A1, Stationary combustion, Liquid, $N_2O$ | 1000% | IPCC (2000) |
| 1A1, Stationarycombustion, Gas, $N_2O$ | 750% | DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark and 1000 % if not |
| 1A1, Stationary combustion, Waste, $N_2O$ | 400% | DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark |
| 1A1, Stationary combustion, Biomass, $N_2O$ | 400% | DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark |
| 1A2, Stationary combustion, Solid, $N_2O$ | 400% | DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark |
| 1A2, Stationary combustion, Liquid, $N_2O$ | 1000% | IPCC (2006) |
| 1A2, Stationary combustion, Gas, $N_2O$ | 750% | DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark and 1000 % if not |
| 1A2, Stationary combustion, Waste, $N_2O$ | 400% | DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark |
| 1A2, Stationary combustion, Biomass, $N_2O$ | 400% | DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark |
| 1A4, Stationary combustion, Solid, $N_2O$ | 400% | DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark |
| 1A4, Stationary combustion, Liquid, $N_2O$ | 1000% | IPCC (2000) |
| 1A4, Stationary combustion, Gas, $N_2O$ | 750% | DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark and 1000 % if not |
| 1A4, Stationary combustion, Waste, $N_2O$ | 400% | DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark |
| 1A4, Stationary combustion, not residential wood and not residential/agricultural straw, Biomass, $N_2O$ | 400% | DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark |
| 1A4b, Stationary combustion, Residential wood combustion, $N_2O$ | 500% | DCE estimate |
| 1A4b/c, Stationary combustion, Residential and agricultural straw combustion, $N_2O$ | 500% | DCE estimate |

### 8.1.2 Results

Approach 1 uncertainty estimates for stationary combustion emission inventories are shown in Table 65. Detailed calculation sheets are provided in Annex 7.

The uncertainty interval for the total greenhouse gas emission is estimated to be ±2.3 % and the trend in greenhouse gas emissions is -53.9 % ± 1.0 %-age points. The main sources of uncertainty for greenhouse gas emissions in 2018 are $N_2O$ and $CH_4$ emission from residential wood combustion, $N_2O$ emission from biomass combusted in Energy industries (1A1) and $N_2O$ emission from gaseous fuels combusted in Energy industries (1A1). The main sources of uncertainty in the trend in greenhouse gas emission are the $CO_2$ emission from coal and natural gas combustion, $N_2O$ emission from residential wood combustion and $N_2O$ emissions from biomass combusted in Energy industries (1A1).

Table 65 Danish uncertainty estimates, Approach 1, 2018.

| Pollutant | Uncertainty Total emission, % | Trend 1990-2018, % | Uncertainty trend, %-age points |
|---|---|---|---|
| GHG | ±2.3 | -53.9 | ±1.0 |
| $CO_2$ | ±0.6 | -54.8 | ±0.4 |
| $CH_4$ | ±45 | +54 | ±65 |
| $N_2O$ | ±173 | +18.5 | ±247 |

## 8.2 Uncertainty for other pollutants

According to the EEA Guidelines (EEA, 2016), uncertainty estimates should be estimated. Uncertainty estimates include uncertainty with regard to the total emission inventory as well as uncertainty with regard to trends.

### 8.2.1 Methodology

The Danish uncertainty estimates are based on the Tier 1 approach.

The uncertainty estimates are based on emission data for the base year and year 2018 as well as on uncertainties for fuel consumption and emission factors for each of the NFR source categories. Residential plants have however been split in two parts: Residential wood combustion and other residential plants.

For the purpose of the uncertainty estimation, the base year for all pollutants is considered to be 1990.

The uncertainty for fuel consumption in stationary combustion plants is based on EEA (2013). The uncertainties are shown in Table 66.

The applied uncertainties for emission factors are based on EEA (2013). The uncertainty for emission factors that are based on recent Danish emission measurements are however estimated lower than suggested in the Guidebook. The applied uncertainties for emission factors are listed in Table 67.

Table 66 Uncertainty rates for fuel consumption, %.

| Sector | % |
|---|---|
| 1A1a Public electricity and heat production | 1 |
| 1A1b Petroleum refining | 1 |
| 1A1c_ii Oil and gas extraction | 1 |
| 1A2 Manufacturing industries and construction | 2 |
| 1A4a_i Commercial / institutional | 3 |
| 1A4b_i Residential (excluding wood) | 3 |
| 1A4b_i Residential wood | 10 |
| 1A4c_i Agriculture / forestry / fishing | 3 |

Table 67 Uncertainty rates for emission factors, %.

| Sector | $SO_2$ | $NO_x$ | NMVOC | CO | PM | HM | PAH | HCB | Dioxin | $NH_3$ | PCB | BC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A1a Public electricity and heat production | 10 | 15 | 50 | 20 | 20 | 50 | 100 | 1000 | 200 | 1000 | 1000 | 1000 |
| 1A1b Petroleum refining | 10 | 20 | 50 | 20 | 50 | 100 | 100 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 1A1c_ii Oil and gas extraction | 10 | 20 | 50 | 20 | 50 | 100 | 100 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 1A2 Manufacturing industries and construction | 10 | 20 | 50 | 20 | 30 | 100 | 100 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 1A4a_i Commercial/institutional | 20 | 50 | 50 | 50 | 50 | 300 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 1A4b_i Residential (excluding wood) | 20 | 30 | 50 | 50 | 50 | 300 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 1A4b_i Residential wood | 20 | 50 | 100 | 100 | 200 | 1000 | 1000 | 500 | 600 | 100 | 1000 | 1000 |
| 1A4c_i Agriculture / forestry/fishing | 20 | 50 | 50 | 50 | 50 | 300 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |

### 8.2.2 Results

The uncertainty estimates for stationary combustion emission inventories are shown in Table 68. Detailed calculation sheets are provided in Annex 7.

The total emission uncertainty is 6.0 % for $SO_2$ and 10 % for $NO_x$.

Table 68 Uncertainty estimates, tier 1 approach, 2018.

| Pollutant | Uncertainty Total emission, % | Trend 1990-2018, % | Uncertainty Trend, %-age points |
|---|---|---|---|
| $SO_2$ | ±6.0 | -96 | ±0.2 |
| $NO_x$ | ±10 | -76 | ±2 |
| NMVOC | ±63 | -10 | ±19 |
| CO | ±70 | -33 | ±22 |
| $NH_3$ | ±212 | +56 | ±300 |
| TSP | ±143 | -5 | ±35 |
| $PM_{10}$ | ±145 | -5 | ±36 |
| $PM_{2.5}$ | ±147 | -4 | ±35 |
| BC | ±555 | +10 | ±358 |
| As | ±79 | -88 | ±9 |
| Cd | ±485 | -37 | ±264 |
| Cr | ±283 | -76 | ±65 |
| Cu | ±431 | -84 | ±68 |
| Hg | ±46 | -92 | ±3 |
| Ni | ±79 | -92 | ±5 |
| Pb | ±210 | -86 | ±29 |
| Se | ±43 | -90 | ±2 |
| Zn | ±167 | -18 | ±114 |
| HCB | ±733 | -79 | ±38 |
| PCDD/F | ±511 | -39 | ±272 |
| Benzo(b)fluoranthene | ±752 | -26 | ±153 |
| Benzo(k)fluoranthene | ±827 | -43 | ±87 |
| Benzo(a)pyrene | ±808 | -37 | ±102 |
| Indeno(1,2,3-c,d)pyrene | ±766 | -63 | ±73 |
| PCBs | ±681 | -63 | ±65 |

# 9 QA/AC and verification

An updated quality manual for the Danish emission inventories has been published in 2013 (Nielsen et al., 2013a). The quality manual describes the concepts of quality work and definitions of sufficient quality, critical control points and a list of Point for Measuring.

Documentation concerning verification of the Danish GHG emission inventories has been published by (Fauser et al., 2013). In addition, the IPCC reference approach for $CO_2$ emission is an important verification of the $CO_2$ emission from the energy sector. The reference approach for the energy sector is shown in Chapter 10.

Source specific QA / QC and Point for Measuring are shown below.

## 9.1 National external review

The 2004, 2006, 2009, 2014 and 2018 updates of the sector report for stationary combustion has been reviewed by external experts (Nielsen & Illerup, 2004; Nielsen & Illerup, 2006; Nielsen et al., 2009, Nielsen et al., 2014; Nielsen et al., 2018). The national external review forms a vital part of the QA activities for stationary combustion.

The 2004, 2006, 2009, 2014 and 2018 updates of this report were reviewed by Jan Erik Johnsson from the Technical University of Denmark, Bo Sander from Elsam Engineering, Annemette Geertinger from FORCE Technology, Vibeke Vestergaard Nielsen, AU DCE and energy statistics experts from the Danish Energy Agency.

## 9.2 Data storage, level 1

Table 69 lists the sector specific Point for Measuring for data storage level 1.

Table 69 List of Point for Measuring, data storage level 1.

| Level | CCP | Id | Description | Sectoral/ general | Stationary combustion |
|---|---|---|---|---|---|
| Data Storage level 1 | 1. Accuracy | DS.1.1.1 | General level of uncertainty for every data set including the reasoning for the specific values | Sectoral | Uncertainties are estimated and references given in chapter 8 |
| | 2. Comparability | DS1.2.1 | Comparability of the emission factors / calculation parameters with data from international guidelines, and evaluation of major discrepancies | Sectoral | In general, if national referenced emission factors differ considerably from IPCC Guideline/EEA Guidebook values this is discussed in NIR chapter 7. This documentation is improved annually based on reviews.<br>At CRF level, a project has been carried out comparing the Danish inventories with those of other countries (Fauser et al., 2013) |
| | 3.Completeness | DS.1.3.1 | Ensuring that the best possible national data for all sources are included, by setting down the reasoning behind the selection of datasets | Sectoral | A list of external data are shown and discussed below |
| | 4.Consistency | DS.1.4.1 | The original external data has to be archived with proper reference | Sectoral | It is ensured that all original external data are archived. Subsequent data processing takes place in other spreadsheets or databases. The datasets are archived annually in order to ensure that the basic data for a given report are always available in their original form |
| | 6.Robustness | DS.1.6.1 | Explicit agreements between the external institution holding the data and DCE about the conditions of delivery | Sectoral | For stationary combustion, a data delivery agreement is made with the DEA. DCE and DEA have renewed the data delivery agreement in 2014.<br>Most of the other external data sources are available due to legislation. See Table below |
| | 7.Transparency | DS.1.7.1 | Listing of all archived datasets and external contacts | Sectoral | A list of external datasets and external contacts is shown in the table below |

Table 70 List of external data sources.

| Dataset | Description | Activity data or emission factor | Reference | Contact(s) | Data agreement/ Comment |
|---|---|---|---|---|---|
| Energy Producers Survey (Energiproducenttællingen) | Energy Producers Survey. Data set for all electricity and heat producing plants | Activity data | The Danish Energy Agency (DEA) | Kaj Stærkind | Data agreement 2014 |
| Gas consumption for gas engines and gas turbines 1990-1994 | Historical data set for gas engines and gas turbines | Activity data | The Danish Energy Agency (DEA) | Kaj Stærkind | No data agreement. Historical data |
| Basic data (Grunddata.xls) | The Danish energy statistics. Data set applied for both the reference approach and the national approach | Activity data | The Danish Energy Agency (DEA) | Jane Rusbjerg | Data agreement 2014. However, the data set is also published as part of national energy statistics |
| Energy statistics for industrial subsectors | Disaggregation of the industrial fuel consumption | Activity data | The Danish Energy Agency (DEA) | Jane Rusbjerg | Included in data delivery agreement 2014 |
| Emission factors | Emission factors refer to a large number of sources | Emission factors | See chapter regarding emission factors | | Some of the annually updated $CO_2$ emission factors are based on EU ETS data, see below. For other emission factors no formal data delivery agreement |
| Annual environmental reports / environmental data | Emissions from plants defined as large point sources | Emissions | Various plants | | No data agreement. Some plants are obligated by law to report data (DEPA, 2010b; DEPA, 2015) and data are published on the Danish EPA homepage |
| EU ETS data | Plant-specific $CO_2$ emission factors | Emission factors and fuel consumption | The Danish Energy Agency (DEA) | Dorte Maimann/Rikke Brynaa Lintrup | Plants are obligated by law. The availability of detailed information is part of the data agreement with DEA (2014 update) |

### 9.2.1 Energy Producers Survey (Energiproducenttællingen). Statistic on fuel consumption from district heating and power plants (DEA)

The data set includes all plants producing power or district heating. The spreadsheet from DEA is listing fuel consumption of all plants included as large point sources in the emission inventory. The statistic on fuel consumption from district heating and power plants is regarded as complete and with no significant uncertainty since the plants are bound by law to report their fuel consumption and other information.

### 9.2.2 Gas consumption for gas engines and gas turbines 1990-1994 (DEA)

For the years 1990-1994, DEA has estimated consumption of natural gas and biogas in gas engines and gas turbines (DEA, 2003). Estimated fuel consumption data for 1990-1993 was based on engine specific data for year of installation and for fuel consumption in 1994. DCE assesses that the DEA estimate is the best available data.

### 9.2.3 Basic data (DEA)

The spreadsheet from the Danish energy statistics (DEA) is used for the $CO_2$ emission calculation in accordance with the IPCC reference approach and is also the first data set applied in the national approach. The data set is included in the data delivery agreement with DEA, but it is also published annually on DEA's homepage.

### 9.2.4 Energy statistics for industrial subsectors (DEA)

The data includes disaggregation of the fuel consumption for industrial plants. The data set is estimated for the reporting to Eurostat. The data are included in the 2014 update of the agreement with DEA.

### 9.2.5 Emission factors

For specific references, see the Chapter 7 regarding emission factors. Some of the annually updated $CO_2$ emission factors are based on EU ETS data, see below.

### 9.2.6 Annual environmental reports (DEPA)

A large number of plants are obligated by law to report annual environmental data including emission data. DCE compares the data with those from previous years and large discrepancies are checked.

### 9.2.7 EU ETS data (DEA)

EU ETS data includes information on fuel consumption, heating values, carbon content of fuel, oxidation factor and $CO_2$ emissions. DCE receives the verified reports for all plants, which utilises a detailed estimation methodology. DCE's QC of the received data consists of comparing to calculation using standard emission factors as well as comparing reported values with those for previous years. The data set is included in the 2014 update of the agreement with DEA.

## 9.3 Data processing, level 1

Table 71 lists the sector specific Point for Measuring for data processing level 1.

Table 71 List of Point for Measuring, data processing level 1.

| Level | CCP | Id | Description | Sectoral / general | Stationary combustion |
|---|---|---|---|---|---|
| Data Processing level 1 | 1. Accuracy | DP.1.1.1 | Uncertainty assessment for every data source not part of DS.1.1.1 as input to Data Storage level 2 in relation to type and scale of variability | Sectoral | Uncertainties are estimated and references given in chapter 8 |
| | 2.Comparability | DP.1.2.1 | The methodologies have to follow the international guidelines suggested by UNFCCC and IPCC | Sectoral | The methodological approach is consistent with international guidelines. An overview of tiers is given in Chapter 6 |
| | 3.Completeness | DP.1.3.1 | Identification of data gaps with regard to data sources that could improve quantitative knowledge | Sectoral | The energy statistics is considered complete |
| | 4.Consistency | DP.1.4.1 | Documentation and reasoning of methodological changes during the time series and the qualitative assessment of the impact on time series consistency | Sectoral | The two main methodological changes in the time series; implementation of Energy Producers Survey (plant-specific fuel consumption data) from 1994 onwards and implementation of EU ETS data from 2006 onwards is discussed in chapter 6.1 |
| | 5.Correctness | DP.1.5.2 | Verification of calculation results using time series | Sectoral | Time series for activity data on SNAP and CRF source category level are used to identify possible errors. Time series for emission factors and the emission from CRF subcategories are also examined |
| | | DP.1.5.3 | Verification of calculation results using other measures | Sectoral | The IPCC reference approach validates the fuel consumption rates and $CO_2$ emission. Except for 2016, both differ less than 2.0 % in 1990-2018. The reference approach is further discussed in Chapter 10 |
| | 7.Transparency | DP.1.7.1 | The calculation principle, the equations used and the assumptions made must be described | Sectoral | This is included in chapter 6 |
| | | DP.1.7.2 | Clear reference to dataset at Data Storage level 1 | Sectoral | This is included in chapter 6 |
| | | DP.1.7.3 | A manual log to collect information about recalculations | Sectoral | - |

## 9.4 Data storage, level 2

Table 72 lists the sector specific Point for Measuring for data storage level 2.

Table 72 List of Point for Measuring, data storage level 2.

| Level | CCP | Id | Description | Sectoral / general | Stationary combustion |
|---|---|---|---|---|---|
| Data Storage level 2 | 5.Correctness | DS.2.5.1 | Check if a correct data import to level 2 has been made | Sectoral | To ensure a correct connection between data on level 2 and level 1, different controls are in place, e.g. control of sums and random tests |

## 9.5 Data storage level 4

Table 73 lists the sector specific Point for Measuring for data storage level 4.

Table 73 List of Point for Measuring, data storage level 4.

| Level | CCP | Id | Description | Sectoral / general | Stationary combustion |
|---|---|---|---|---|---|
| Data Storage level 4 | 4. Consistency | DS.4.4.3 | The IEFs from the CRF are checked regarding both level and trend. The level is compared to relevant emission factors to ensure correctness. Large dips/jumps in the time series are explained | Sectoral | Large dips/jumps in time series are discussed and explained in chapter 3, 4, 5 and 7 |

## 9.6 Other QC procedures

Some automated checks have been prepared for the emission databases:

- Check of units for fuel rate, emission factors and plant-specific emissions.
- Check of emission factors for large point sources. Emission factors for pollutants that are not plant-specific should be the same as those defined for area sources.
- Additional checks on database consistency.
- Emission factor references are included in this report (Chapter 7).
- Annual environmental reports are kept for subsequent control of plant-specific emission data.
- QC checks of the country-specific emission factors have not been performed, but most factors are based on input from companies that have implemented some QA / QC work. The major power plant owner / operator in Denmark, Ørsted (former DONG Energy) has obtained the ISO 14001 certification for an environmental management system. The Danish Gas Technology Centre and Force Technology both run accredited laboratories for emission measurements.
- The emission from each large point source is compared with the emission reported the previous year.

# 10 Reference approach

In addition to the sector specific $CO_2$ emission inventories (the sectoral approach - SA), the $CO_2$ emission from the energy sector[32] is also estimated using the reference approach (RA) described in the IPCC Guidelines (IPCC, 2006). The reference approach is based on data for fuel production, import, export and stock change. The $CO_2$ emission inventory based on the reference approach is reported to the Climate Convention and used for verification of the sectoral approach.

Data for import, export and stock change used in the reference approach originate from the annual "basic data" table prepared by the Danish Energy Agency (DEA) and published on their home page (DEA, 2019a). The fraction of carbon oxidised has been assumed 1.00.

The applied carbon emission factors are equal to the emission factors also applied in the sectoral approach and thus include nationally referenced emission factors. This is in agreement with the 2006 IPCC Guidelines.

The Climate Convention reporting tables include a comparison of the sectoral approach and the reference approach estimates.

## 10.1 Non-energy use of fuels

The consumption for non-energy purposes is subtracted in the reference approach, because non-energy use of fuels is included in other sectors (Industrial processes and Solvent use) in the Danish sectoral approach. Three fuels are used for non-energy purposes: lubricants, bitumen and white spirit. The total consumption for non-energy purposes is relatively low – 10.3 PJ in 2018.

The $CO_2$ emission from oxidation of lube oil during use was 31.7 Gg in 2018 and this emission is reported in the sector Industrial processes and product use (sector 2.D). The reported emission corresponds to 20 % of the $CO_2$ emission from lube oil consumption assuming full oxidation. This is in agreement with the methodology for lube oil emissions in the 2006 IPCC Guidelines (IPCC, 2006). Methodology and emission data for lube oil are shown in the National Inventory Report (Nielsen et al., 2020a), Chapter 4.5.3.

For white spirit, the $CO_2$ emission is indirect as the emissions occur as NMVOC emissions from the use of white spirit as a solvent. The indirect $CO_2$ emission from solvent use was 60.7 Gg in 2018. The methodology and emission data for white spirit are included in the National Inventory Report (Nielsen et al., 2020a), Chapter 4.5.4.

The $CO_2$ emission from bitumen is included in sector 2.D.3, Road paving with asphalt and Asphalt roofing. The total $CO_2$ emissions for these sectors are 0.96 Gg in 2018. Methodology and emission data for non-energy use of bitumen are shown in the National Inventory Report (Nielsen et al., 2020a), Chapter 4.5.6.

[32] Including energy consumption in mobile sources.

## 10.2 Reference approach results and comparison to the national approach

The sectoral approach and the reference approach have been compared and the differences between the two approaches are shown in Table 74 below.

Table 74 Difference between sectoral approach and reference approach.

| Year | Reference approach, fossil fuel consumption, PJ | Reference approach, fossil $CO_2$ emission, kt | Difference Energy consumption [%] | Difference $CO_2$ emission [%] |
|---|---|---|---|---|
| 1990 | 644 | 51,129 | 0.28 | -0.32 |
| 1991 | 753 | 60,927 | -0.55 | -0.96 |
| 1992 | 695 | 55,302 | -0.02 | -0.63 |
| 1993 | 724 | 57,459 | -0.40 | -1.01 |
| 1994 | 773 | 61,455 | -0.31 | -0.89 |
| 1995 | 749 | 58,369 | -0.56 | -0.94 |
| 1996 | 903 | 71,581 | -0.49 | -0.76 |
| 1997 | 803 | 62,332 | -0.03 | -0.12 |
| 1998 | 777 | 59,307 | 1.50 | 1.33 |
| 1999 | 731 | 54,884 | -0.58 | -0.88 |
| 2000 | 692 | 51,431 | 0.27 | 0.06 |
| 2001 | 715 | 53,345 | 0.75 | 0.62 |
| 2002 | 706 | 52,651 | 0.05 | -0.15 |
| 2003 | 763 | 57,917 | 0.10 | -0.07 |
| 2004 | 700 | 52,188 | 0.00 | -0.18 |
| 2005 | 655 | 48,450 | -0.88 | -0.93 |
| 2006 | 743 | 56,357 | -0.64 | -0.87 |
| 2007 | 682 | 51,529 | -0.91 | -1.02 |
| 2008 | 655 | 48,890 | -0.22 | -0.35 |
| 2009 | 622 | 46,460 | -1.69 | -1.75 |
| 2010 | 644 | 47,519 | 0.12 | -0.21 |
| 2011 | 567 | 42,115 | -0.99 | -1.08 |
| 2012 | 511 | 37,499 | -1.54 | -1.88 |
| 2013 | 530 | 39,603 | -0.79 | -1.08 |
| 2014 | 473 | 35,251 | -1.39 | -1.58 |
| 2015 | 449 | 32,940 | -1.51 | -1.73 |
| 2016 | 460 | 33,935 | -2.79 | -3.28 |
| 2017 | 445 | 32,457 | -0.75 | -0.87 |
| 2018 | 441 | 32,181 | -1.44 | -1.58 |

The comparison of the sectoral approach and the reference approach is illustrated in Figure 83. In 2018, the fuel consumption rates in the two approaches differ by 1.4 % and the $CO_2$ emission differs by 1.6 %. Both the fuel consumption and the $CO_2$ emission differ by less than 2 % for all years except 2016.

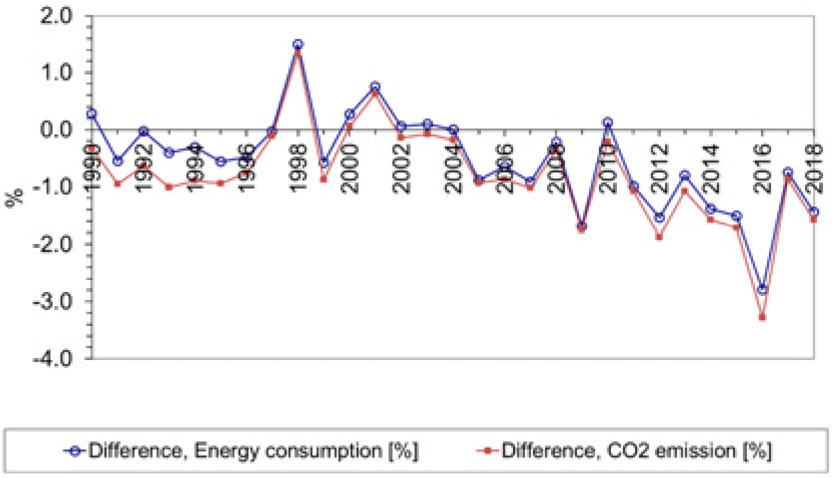



Figure 83 Comparison of the reference approach and the sectoral approach.

The fluctuations in Figure 83 follow the fluctuations of the statistical difference in the Danish energy statistics shown in Figure 84. The large differences in certain years, e.g. in 1998, 2009, 2012 and 2016 are due to high statistical differences in the Danish energy statistics in these years.

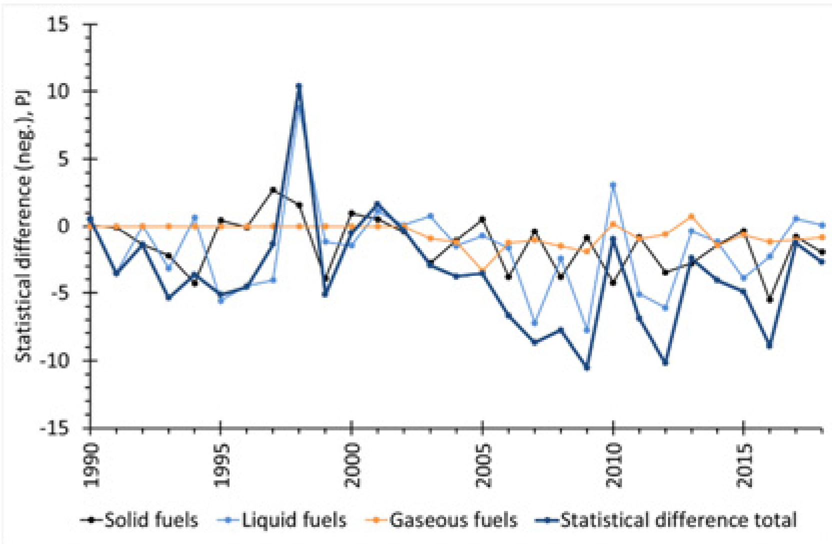



Figure 84 Statistical difference in the Danish energy statistics (DEA, 2019a).

The difference between SA and RA is above 2 % in 2016 and the reason for this difference have been further analysed.

The large difference between RA and SA in 2016 is mainly related to fuel consumption data. The fuel consumption applied in the SA was higher than in the RA for all fuel categories for 2016.

## 10.3 Analysis of the differences between the sectoral approach and the reference approach for each of the fuel categories

The difference between the sectoral approach and the reference approach is above 2 % in 2016 and thus the sources causing this difference have been analysed for each of the fossil fuel categories.

### 10.3.1 Solid fuels

The difference for solid fuels is 6.2 % or 5.5 PJ. The statistical difference for solid fuels in the Danish energy statistics is 5.5 PJ for 2016. This difference mainly relates to coal (5.5 PJ). Thus, the difference between approaches is a result of the statistical difference. A time series for the difference of solid fuel consumption is shown in Figure 85.

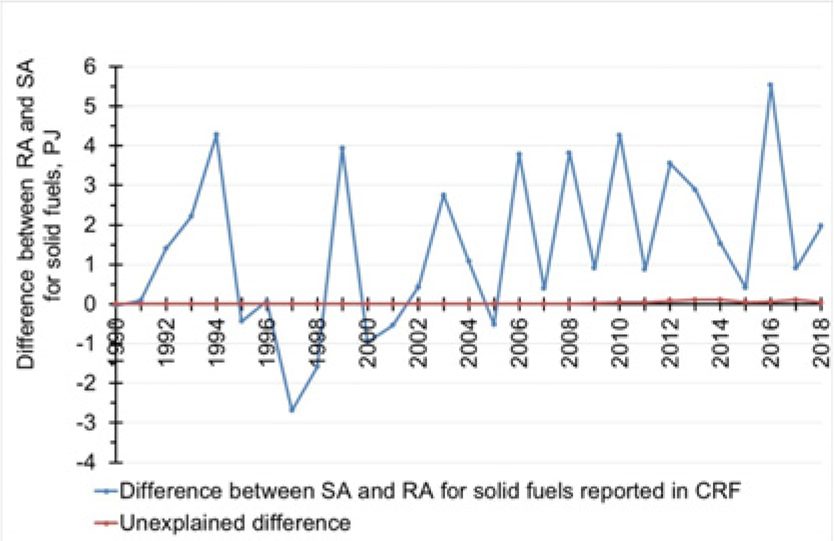



Figure 85 Difference between RA and SA for solid fuels reported in CRF and the difference not explained by statistical difference of the Danish energy statistics.

### 10.3.2 Liquid fuels

The difference for liquid fuels in 2016 is 1.7 % or 4.1 PJ. This difference have been further analysed and several sources identified.

- The statistical difference for liquid fuels in the Danish energy statistics is 2.3 PJ for 2016. This difference mainly relates to crude oil (3.7 PJ).
- The Danish energy statistics includes data for net input of blends. In 2016, the net input was 0.2 PJ.
- In the Danish energy statistics, the fuel input to refineries is not equal to the fuel output added to fuel consumption. In 2016, the difference was 2.7 PJ.
- For refinery gas, the fuel consumption applied in the SA is based on EU ETS data rather than the energy statistics (see Chapter 6.7). For 2016, the fuel consumption in EU ETS that are applied in SA is 0.5 TJ *lower* than the data from the energy statistics.

The explained differences for liquid fuels in 2016 add up to 5.2 PJ. Thus, only the remaining 1.1 PJ is not explained. The time series for reported difference for liquid fuels between SA and RA for 1990-2018 is shown in Figure 86 below. In the figure, the estimated difference taking into account the four known sources explained above is also shown.

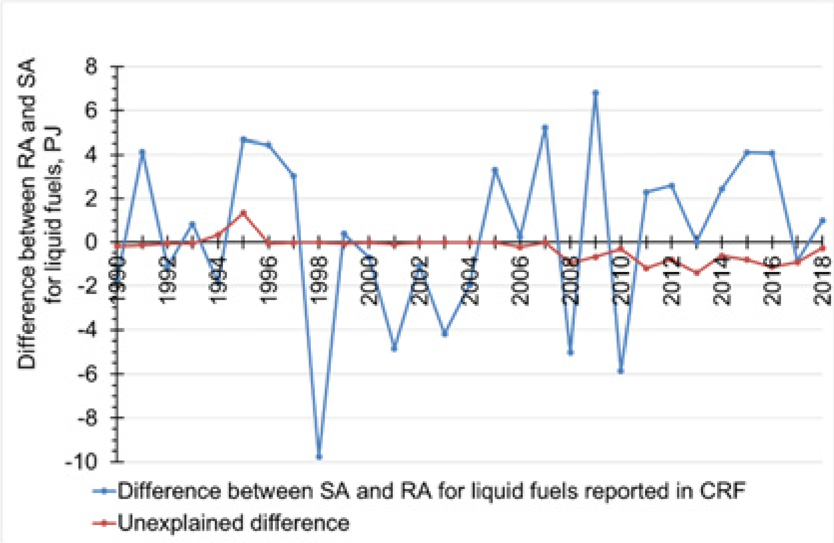



Figure 86 Difference between RA and SA for liquid fuels reported in CRF and the difference not explained by four known sources.

### 10.3.3 Gaseous fuels

For 2016, the difference for gaseous fuels is 1.8 % or 2.2 PJ. The statistical difference for gaseous fuels in the Danish energy statistics is 1.2 PJ for 2016. For off shore gas turbines the fuel consumption applied in the sectoral approach is based on EU ETS data rather than the energy statistics (see Chapter 6.6). For 2016, the consumption in EU ETS that are applied in SA was 1.0 PJ higher than the data from the energy statistics. Thus, the statistical difference and the different data sets applied for off shore gas turbines cause the difference between the two approaches for gaseous fuels.

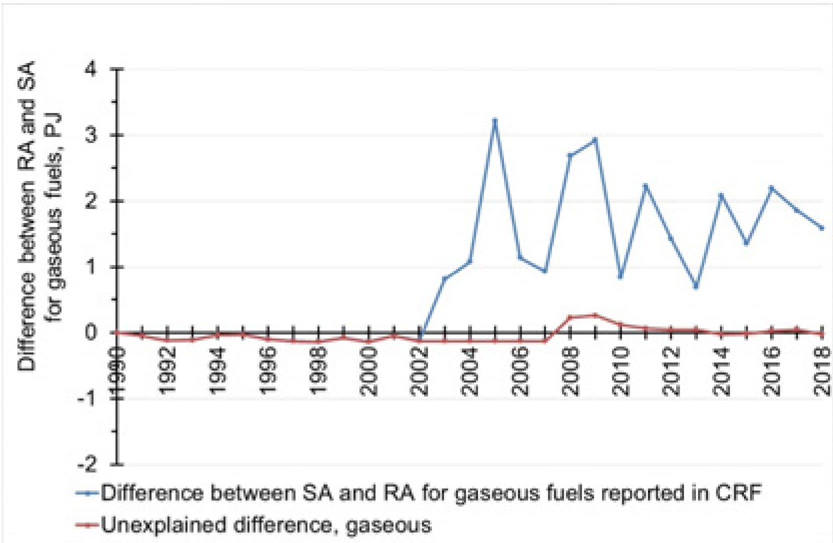



Figure 87 Difference between RA and SA for gaseous fuels reported in CRF and the difference not explained by two known sources.

### 10.3.4 Other fossil fuels

For 2016, the difference for other fossil fuels (fossil waste) is 7.2 % or 1.4 PJ.

The statistical difference for fossil waste in the Danish energy statistics is 0.0 PJ for 2016. The fossil part of waste applied in the Danish cement production plant is higher than for other waste applied in Danish incineration plants. The higher fossil part of waste applied in the cement production plant have been implemented in the SA but not in the RA. For 2016, this corresponds to a 0.5 PJ difference. In addition, the combustion of waste in individual plants implemented in the SA for 2016 added up to a higher total than included in the energy statistics. This difference corresponds to a difference of 0.5 PJ fossil waste. Finally, the fossil part of biodiesel reported in SA sector 1A3 is included in the fuel category other fossil fuels. This fuel consumption is included in biomass in RA. In 2016, the fossil part of biodiesel added up to 0.5 PJ.

The reason for the higher total waste consumption based on the plant-specific data than in the energy statistics will be further analysed. The recent implementation of EU ETS data as a data source for the industrial subsectors has improved transparency.

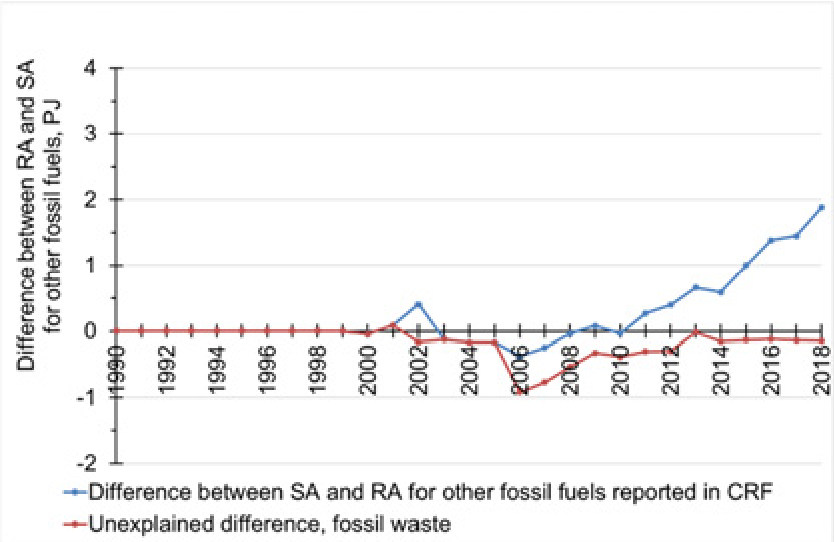



Figure 88 Difference between RA and SA for other fossil fuels reported in CRF and the difference not explained by four known sources.

### 10.3.5 Recalculations and improvements for the reference approach

Data for both reference approach and national approach have been updated according to the latest energy statistics.

### 10.3.6 Planned improvements for the reference approach

The differences mentioned above are part of the ongoing dialogue with the Danish Energy Agency.

# 11 Verification based on data from Eurostat

As part of the EU review of the reported GHG emission data, EU performs for each member state a comparison of Eurostat energy data in terms of TJ with energy data provided in the CRF. The comparison has been performed in accordance with the Commission implementing reulation (EU) No 749/2014 of 30 June 2014 and with the IPCC Guidelines (2006). The comparison includes comparisons of the reference approach (RA) and the sectoral approach (SA) for the years 2005 and 2008-2018.

In Denmark, the emission inventory is based on the energy statistics published by the Danish Energy Agency (DEA). DEA is also responsible for the reporting to Eurostat.

## 11.1 Reference approach, comparison of CRF and Eurostat data

### 11.1.1 Methodology

The correspondence lists for activity and fuel applied in CRF and Eurostat are shown in Table 75 and Table 76 below.

Table 75 Correspondence list for activity, Reference Approach (EU, 2020).

| Eurostat code | Eurostat nomenclature | CRF_RA |
|---|---|---|
| PPRD | Primary production | Production in CRF table 1A(b) |
| IMP | Imports | Imports in CRF table 1A(b) |
| STK_CHG | Change in stock | Stock changes in CRF table 1A(b) |
| EXP | Exports | Exports in CRF table 1A(b) |
| INTMARB | International maritime bunkers | International bunkers in CRF table 1A(b) |
| FC_NE | Final consumption - non-energy use | Non-energy use of fuels |
| INTAVI | International aviation | International bunkers in CRF table 1A(b) |

Table 76 Correspondence list for fuel, Reference Approach (EU, 2020).

| Eurostat Product Code | Eurostat Product Name | CRF Reference Approach fuel name |
|---|---|---|
| C0000X0350-0370 | Solid fossil fuels | |
| C0110 | Anthracite | Anthracite |
| C0121 | Coking coal | Coking Coal |
| C0129 | Other bituminous coal | Other Bituminous Coal |
| C0210 | Sub-bituminous coal | Sub-bituminous Coal |
| C0220 | Lignite | Lignite |
| C0311 | Coke oven coke | Coke oven/gas coke |
| C0312 | Gas coke | Coke oven/gas coke |
| C0320 | Patent fuel | BKB and patent fuel |
| C0330 | Brown coal briquettes | BKB and patent fuel |
| C0340 | Coal tar | Coal tar |
| C0350 | Coke oven gas | Other solid |
| C0350-0370 | Manufactured gases | |
| C0360 | Gas works gas | Other solid |
| C0371 | Blast furnace gas | Other solid |
| C0379 | Other recovered gases | Other solid |
| E7000 | Electricity | |
| G3000 | Natural gas | Natural gas |
| H8000 | Heat | |
| N900H | Nuclear heat | |
| O4000XBIO | Oil and petroleum products (excluding biofuel portion) | |
| O4100_TOT | Crude oil | Crude Oil |
| O4200 | Natural gas liquids | Natural Gas Liquids |
| O4300 | Refinery feedstocks | Refinery Feedstocks |
| O4400X4410 | Additives and oxygenates (excluding biofuel portion) | Refinery Feedstocks |
| O4500 | Other hydrocarbons | Refinery Feedstocks |
| O4610 | Refinery gas | Other Oil |
| O4620 | Ethane | Ethane |
| O4630 | Liquefied petroleum gases | Liquefied Petroleum Gas (LPG) |
| O4640 | Naphtha | Naphta |
| O4651 | Aviation gasoline | Gasoline |
| O4652XR5210B | Motor gasoline (excluding biofuel portion) | Gasoline |
| O4653 | Gasoline-type jet fuel | Gasoline |
| O4661XR5230B | Kerosene-type jet fuel (excluding biofuel portion) | Jet Kerosene |
| O4669 | Other kerosene | Other Kerosene |
| O4671XR5220B | Gas oil and diesel oil (excluding biofuel portion) | Gas/diesel oil |
| O4680 | Fuel oil | Residual Fuel Oil |
| O4691 | White spirit and special boiling point industrial spirits | Other Oil |
| O4692 | Lubricants | Lubricants |
| O4693 | Paraffin waxes | Other Oil |
| O4694 | Petroleum coke | Petroleum Coke |
| O4695 | Bitumen | Bitumen |
| O4699 | Other oil products n.e.c. | Other Oil |
| P1000 | Peat and peat products | |
| P1100 | Peat | Peat |
| P1200 | Peat products | Peat |
| R5110-5150_W6000RI | Primary solid biofuels | Solid biomass |
| R5160 | Charcoal | Solid biomass |
| R5210B | Blended biogasoline | Liquid biomass |
| R5210P | Pure biogasoline | Lliquid biomass |

| Eurostat Product Code | Eurostat Product Name | CRF Reference Approach fuel name |
|---|---|---|
| R5220B | Blended biodiesels | Liquid biomass |
| R5220P | Pure biodiesels | Liquid biomass |
| R5230B | Blended bio jet kerosene | Liquid biomass |
| R5230P | Pure bio jet kerosene | Liquid biomass |
| R5290 | Other liquid biofuels | Liquid biomass |
| R5300 | Biogases | Gas biomass |
| RA000 | Renewables and biofuels | |
| RA100 | Hydro | |
| RA200 | Geothermal | |
| RA300 | Wind | |
| RA410 | Solar thermal | |
| RA420 | Solar photovoltaic | |
| RA500 | Tide | |
| RA600 | Ambient heat (heat pumps) | |
| S2000 | Oil shale and oil sands | Oil shale and tar sand |
| TOTAL | Total | |
| W6100 | Industrial waste (non-renewable) | Waste |
| W6100_6220 | Non-renewable waste | |
| W6210 | Renewable municipal waste | Other biomass |
| W6220 | Non-renewable municipal waste | waste |

In addition to the comparison of the fuel consumption data aggregated by the EU review team DCE have aggregated data[33] for production, import, export, international bunkers and stock change to improve transparency and explain the origin of the found differences.

### 11.1.2 Results

The apparent fuel consumption reported in the reference approach has been comparted as part of the EU review and results are shown in Table 77. The additional comparison of data for production, import, export, international bunkers and stock change is shown in Table 78.

The apparent fossil fuel consumption based on the Eurostat data differs 2 % (or 11642 TJ) from the apparent fossil fuel consumption stated in CRF. The differences are 9 % for solid fuels (6258 TJ), 0.2 % for liquid fuels (603 TJ), 0 % for gaseous fuels (0 TJ) and 0 % for fossil waste (0 TJ).

The Danish energy statistics include two different types of coal in the fuel category Other bituminous coal. The LCV of the two coal types differ but only one of the LCVs have been reported to Eurostat. The Danish Energy Agency that are responsible for the reporting to Eurostat have indicated that they will consider to report an average LCV to Eurostat next year (Zarnaghi, 2020a).

Fuel consumption for transport between mainland Denmark and Greenland and the Faroe Islands is not included in the reporting to the IEA and Eurostat. In the Danish emission inventory, the transport between Denmark, Greenland and the Faroe Islands is considered domestic. This causes a difference for liquid fuels used for aviation and navigation.

[33] Based on the same fuel correspondence list.

For jet kerosene, the fuel consumption to/from Greenland or Faroe Islands was 647 TJ in 2018. This is equal to the difference for international bunkers for jet kerosene.

For diesel oil, the fuel consumption to/from Greenland or Faroe Islands was 431 TJ in 2018. This is equal to the difference for international bunkers for gas-/diesel oil. The export of fossil gas-/diesel oil reported by the DEA in the Danish energy statistics (Grunddatatabellen) and in the international reporting to Eurostat does not agree. The difference is 1896 TJ. This value corresponds to the difference in export. It seems that the biodiesel have been subtracted from the fossil gas-/diesel oil in the international reporting. DEA has confirmed an inaccuracy in the international reporting and that this will be corrected next year (Zarnaghi, 2020c).

For residual oil, the fuel consumption to/from Greenland or Faroe Islands was 1360 TJ in 2018. This is close to the difference for international bunkers for residual oil (1453 TJ). The export of residual oil reported by the DEA in the Danish energy statistics (Grunddatatabellen) and in the international reporting to Eurostat is in agreement. However, Eurostat apply a LCV of 40.4 GJ/tonnes whereas Denmark reports the LCV 40.65 GJ/tonnes. This cause the difference 711 TJ in export, 449 TJ in import, 55 TJ in international bunkers and 43 TJ in stock change.

DCE reports white spirit in the CRF fuel category Other liquid fossil, whereas the aggregation based on data from Eurostat includes white spirit in the fuel category Other oil.

Data for production of solid biomass in the international reporting seems to include bio oil (234 TJ). DEA will correct this next year (Zarnaghi, 2020b).

Data for gaseous biomass differ for production. The production is 13414 TJ according to the Danish energy statistics of which 7060 TJ is upgraded to distribution in the natural gas grid (bio natural gas or bio methane). The Danish reporting to Eurostat are in agreement with the Danish energy statistics. The Eurostat data however, include a double counting of the upgraded biogas.

Table 77 Comparison apparent consumption in 2018, EU (2020). Source of difference have been added by DCE.

| CRF Fuel Group | CRF Fuel Name | Eurostat TJ | Crf TJ | Difference TJ | Difference % | Source of difference (Comments added by DCE) | Eurostat NEU, TJ | CRF NEU, TJ | Difference NEU, TJ | Difference NEU, % |
|---|---|---|---|---|---|---|---|---|---|---|
| Solid | Anthracite | - - | - - | 0 | 0% | | - - | - - | 0 | 0% |
| | BKB and patent fuel | - - | 0 | 0 | 0% | | - - | - - | 0 | 0% |
| | Coal tar | - - | - - | 0 | 0% | | - - | - - | 0 | 0% |
| | Coke oven/gas coke | 370 | 370 | 0 | 0% | | - - | - - | 0 | 0% |
| | Coking coal | - - | - - | 0 | 0% | | - - | - - | 0 | 0% |
| | Lignite | - - | - - | 0 | 0% | | - - | - - | 0 | 0% |
| | Oil shale and tar sand | - - | - - | 0 | 0% | | - - | - - | 0 | 0% |
| | Other bituminous coal | 71,530 | 65,272 | -6,258 | -9% | The Danish energy statistics include two different types of coal in this fuel category. The LCV of the two coal types differ but only one of the LCVs have been reported to Eurostat. The Danish Energy Agency that are responsible for the reporting to Eurostat have indicated that they will consider to report an average LCV to Eurostat next year (Zarnaghi, 2020). | - - | - - | 0 | 0% |
| | Other solid | - - | - - | 0 | 0% | | - - | - - | 0 | 0% |
| | Sub-bituminous coal | - - | - - | 0 | 0% | | - - | - - | 0 | 0% |
| Liquid | Bitumen | 7,847 | 7,847 | 0 | 0% | | 7,857 | 7,857 | 0 | 0% |
| | Crude oil | 324,487 | 324,490 | 3 | 0% | Waste oil has been included in the fuel category crude oil in the reference approach in CRF. | - - | - - | 0 | 0% |
| | Ethane | - - | - - | 0 | 0% | | - - | - - | 0 | 0% |
| | Gas/diesel oil | 22,896 | 21,402 | -1,493 | -7% | Fuel consumption for transport between mainland Denmark and Greenland and the Faroe Islands is not included in the reporting to the IEA and Eurostat. In the Danish emission inventory, the transport between Denmark, Greenland and the Faroe Islands is considered domestic. This causes a difference for liquid fuels used for aviation and navigation. For diesel oil, the fuel consumption to/from Greenland or Faroe Islands was 431 TJ in 2018. This is equal to the difference for international bunkers for gas-/diesel oil. The export of fossil gas-/diesel oil reported by the DEA in the Danish energy statistics (Grunddatatabellen) and in the international reporting to Eurostat does not agree. The difference | - - | - - | 0 | 0% |

| CRF Fuel Group | CRF Fuel Name | Eurostat TJ | Crf TJ | Difference TJ | Difference % | Source of difference (Comments added by DCE) | Euro-stat NEU, TJ | CRF NEU, TJ | Diffe-rence NEU, TJ | Diffe-rence NEU, % |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | is 1896 TJ. This value corresponds to the difference in export. It seems that the biodiesel have been subtracted from the fossil gas-/diesel oil in the international reporting. DEA has confirmed an inaccuracy in the international reporting (Zarnaghi, 24-03-2020). | | | | |
| | Gasoline | -31,678 | -31,727 | -50 | 0% | The stock change data differs 50 TJ. The international reporting seems to be inaccurate. This is part of the ongoing dialogue with DEA. | - - | - - | 0 | 0% |
| | Jet kerosene | -2,949 | -2,302 | 647 | -22% | Fuel consumption for transport between mainland Denmark and Greenland and the Faroe Islands is not included in the reporting to the IEA and Eurostat. In the Danish emission inventory, the transport between Denmark, Greenland and the Faroe Islands is considered domestic. This causes a difference for liquid fuels used for aviation and navigation. For jet kerosene, the fuel consumption to/from Greenland or Faroe Islands was 647 TJ in 2018. This is equal to the difference for international bunkers for jet kerosene. | - - | - - | 0 | 0% |
| | Liquefied petroleum gas (LPG) | -3,076 | -3,076 | 0 | 0% | | - - | - - | 0 | 0% |
| | Lubricants | 2,150 | 2,150 | 0 | 0% | | 2,150 | 2,150 | 0 | 0% |
| | Naphta | - - | - - | 0 | 0% | | - - | - - | 0 | 0% |
| | Natural gas liquids | - - | - - | 0 | 0% | | - - | - - | 0 | 0% |
| | Orimulsion | - - | - - | 0 | 0% | | - - | - - | 0 | 0% |
| | Other kerosene | - - | - - | 0 | 0% | | - - | - - | 0 | 0% |
| | Other liquid | - - | 262 | 262 | 0% | DCE reports white spirit in the CRF fuel category Other liquid fossil, whereas the aggregation based on data from Eurostat includes white spirit in the fuel category Other oil. | - - | 262 | 262 | 0% |
| | Other oil | 262 | - - | -262 | -100% | DCE reports white spirit in the CRF fuel category Other liquid fossil, whereas the aggregation based on data from Eurostat includes white spirit in the fuel category Other oil. | 218 | - - | -218 | -100% |
| | Petroleum coke | 6,916 | 6,916 | 0 | 0% | | - - | - - | 0 | 0% |
| | Refinery feedstocks | -26,861 | -26,861 | 0 | 0% | | - - | - - | 0 | 0% |
| | Residual fuel oil | -44,322 | -43,088 | 1,234 | -3% | Fuel consumption for transport between mainland Denmark and Greenland and the Faroe Islands is not included in the reporting to the IEA and Eurostat. In the Danish emission inventory the transport between Denmark, Greenland and the Faroe Islands is considered domestic. This causes a difference for liquid fuels used for aviation and navigation. | - - | - - | 0 | 0% |

| CRF Fuel Group | CRF Fuel Name | Eurostat TJ | Crf TJ | Difference TJ | Difference % | Source of difference (Comments added by DCE) | Euro-stat NEU, TJ | CRF NEU, TJ | Diffe-rence NEU, TJ | Diffe-rence NEU, % |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | For residual oil, the fuel consumption to/from Greenland or Faroe Islands was 1360 TJ in 2018. This is close to the difference for international bunkers for residual oil (1453 TJ). The export of residual oil reported by the DEA in the Danish energy statistics (Grunddatatabellen) and in the international reporting to Eurostat is in agreement. However, Eurostat apply a LCV of 40.4 GJ/tonnes whereas Denmark reports the LCV 40.65 GJ/tonnes. This cause the difference 711 TJ in export, 449 TJ in import, 55 TJ in international bunkers and 43 TJ in stock change. | | | | |
| | Shale oil | - - | - - | 0 | 0% | | - - | - - | 0 | 0% |
| Gaseous | Natural gas | 111,932 | 111,932 | 0 | 0% | | - - | - - | 0 | 0% |
| | Other gaseous | - - | - - | 0 | 0% | | - - | - - | 0 | 0% |
| Waste | Waste | 17,297 | 17,297 | 0 | 0% | | - - | - - | 0 | 0% |
| Other | Other fossil fuels | - - | - - | 0 | 0% | | - - | - - | 0 | 0% |
| Peat | Peat | - - | - - | 0 | 0% | | - - | - - | 0 | 0% |
| Biomass | Solid biomass | 136,096 | 135,862 | -234 | 0% | Data for production of solid biomass in the international reporting seems to include bio oil (234 TJ). DEA will correct this next year (Zarnaghi, 2020). | - - | - - | 0 | 0% |
| | Liquid biomass | 9,314 | 9,315 | 1 | 0% | A 1 TJ error in the production data in CRF. Will be corrected in the next inventory. | - - | - - | 0 | 0% |
| | Gas biomass | 20,474 | 13,414 | -7,060 | -34% | Data for gaseous biomass differ for production. The production is 13414 TJ according to the Danish energy statistics. 7060 TJ of the biogas is upgraded to distribution in the natural gas grid (bio natural gas or bio methane). The Danish reporting to Eurostat are in agreement with the Danish energy statistics. The Eurostat data however, include a double counting of the upgraded biogas. | - - | - - | 0 | 0% |
| | Other biomass | 21,141 | 21,141 | 0 | 0% | | - - | - - | 0 | 0% |

Table 78 Difference between fuel data for the reference approach from CRF and Eurostat, 2018.

| FUEL TYPES | | | Unit | Production | Imports | Exports | International bunkers | Stock change | Apparent consumption |
|---|---|---|---|---|---|---|---|---|---|
| Liquid fossil | Primary fuels | Crude oil | TJ | -2.6 | 0.0 | 0.0 | 0.0 | 0.0 | -2.6 |
| | | Orimulsion | TJ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Natural gas liquids | TJ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Secondary fuels | Gasoline | TJ | 0.0 | 0.0 | 0.0 | 0.0 | -49.5 | 49.5 |
| | | Jet kerosene | TJ | 0.0 | 0.0 | 0.0 | 647.3 | 0.0 | -647.3 |
| | | Other kerosene | TJ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Shale oil | TJ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Gas/diesel oil | TJ | 0.0 | 0.0 | -1895.7 | 430.9 | -28.7 | 1493.5 |
| | | Residual fuel oil | TJ | 0.0 | -449.0 | -710.7 | 1453.5 | 42.5 | -1234.3 |
| | | Liquefied petroleum gases (LPG) | TJ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Ethane | TJ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Naphtha | TJ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Bitumen | TJ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Lubricants | TJ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Petroleum coke | TJ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Refinery feedstocks | TJ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Other oil | TJ | 0.0 | 299.7 | 38.2 | 0.0 | 0.0 | 0.0 |
| Other liquid fossil | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | White Spirit | | 0.0 | -299.7 | 0.0 | 0.0 | 0.0 | 0.0 |
| Liquid fossil totals | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Solid fossil | Primary fuels | Anthracite(3) | TJ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Coking coal | TJ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Other bituminous coal | TJ | 0.0 | 6490.6 | 29.8 | 0.0 | 202.6 | 6258.3 |
| | | Sub-bituminous coal | TJ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Lignite | TJ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Oil shale and tar sand | TJ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Secondary fuels | BKB(4) and patent fuel | TJ | 0.0 | 0.0 | -0.2 | 0.0 | 0.0 | 0.2 |
| | | Coke oven/gas coke | TJ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Coal tar | TJ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Other solid fossil | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Solid fossil totals | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Gaseous fossil | | Natural gas (dry) | TJ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Other gaseous fossil | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Gaseous fossil totals | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Waste (non-biomass fraction) | | | TJ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Other fossil fuels | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Peat(5,6) | | | TJ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| FUEL TYPES | | | Unit | Production | Imports | Exports | International bunkers | Stock change | Apparent consumption |
|---|---|---|---|---|---|---|---|---|---|
| **Total** | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Biomass total | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Solid biomass | TJ | 234.1 | 0.0 | 0.0 | 0.0 | 0.0 | 234.1 |
| | | Liquid biomass | TJ | -1.0 | 0.0 | 0.0 | 0.0 | 0.0 | -1.0 |
| | | Gas biomass | TJ | 7060.1 | 0.0 | 0.0 | 0.0 | 0.0 | 7060.1 |
| | | Other non-fossil fuels (biogenic waste) | TJ | 0.3 | -0.2 | 0.0 | 0.0 | 0.0 | 0.1 |

## 11.2 Sectoral approach, comparison of CRF and Eurostat data

Table 79 shows the total fuel consumption in the sectoral approach based on CRF and Eurostat respectively. The fossil fuel consumption is 4 % higher in the Eurostat data than reported in the CRF. The largest differences are for solid and gaseous fuels.

The fuel consumption for solid fuels is 9 % higher in the Eurostat data than reported in CRF. This difference is related to the LCV for coal applied in Denmark. The Danish energy statistics include two different types of coal in the fuel category Other bituminous coal. The LCV of the two coal types differ but only one of the LCVs have been reported to Eurostat. The Danish Energy Agency that are responsible for the reporting to Eurostat have indicated that they will consider to report an average LCV to Eurostat next year (Zarnaghi, 2020a).

The fuel consumption for liquid fuels is 1 % lower in the Eurostat data than reported in CRF.

For liquid fuels, the domestic consumption jet kerosene, gas / diesel oil and residual oil reported to Eurostat is lower than in CRF. The fuel consumption for transport between mainland Denmark and Greenland and the Faroe Islands is included in international bunkers in the reporting to Eurostat. In the Danish emission inventory, the transport between Denmark, Greenland and the Faroe Islands is considered domestic. This causes a difference for liquid fuels used for aviation and navigation. For jet kerosene, the consumption reported to Eurostat is 647 TJ lower. For diesel oil, the consumption in sector 1A3 is 8500 TJ lower in the Eurostat data than in CRF. However, the consumption of gas / diesel oil is reallocated in CRF, and thus a comparison of the consumption in sector 1A3 does not give an accurate picture of the difference for the total gas / diesel oil consumption reported in CRF and by Eurostat respectively. The difference related to the transport between mainland Denmark and Greenland and the Faroe Islands is 431 TJ. For residual oil, the difference related to Greenland and the Faroe Islands is 1360 TJ.

For gaseous fuels, the consumption in Eurostat is 5 % higher (6238 TJ) than the CRF data. The Eurostat data for gaseous fuels includes biogas upgraded for distribution in the natural gas grid (bio natural gas or bio methane). The consumption of this fuel adds up to 7052 TJ. In CRF, this fuel consumption is included in the fuel category biomass. In addition, the gaseous fuel consumption for offshore gas turbines is higher in CRF than in the Eurostat data. CRF data for offshore gas turbines is based on EU ETS data that are not in agreement with the energy statistics due to application of an inaccurate NCV in the energy statistics. Thus the fuel consumption in the energy statistics and in the Eurostat data are 761 TJ lower for Oil and gas extraction than reported in CRF. This adds up to a 6291 TJ difference.

For fossil waste, the consumption in the Eurostat data are 10 % lower (1882 TJ) than in CRF. The bottom up approach applied in the Danish emission inventory adds up to higher consumption of waste than stated in the energy statistics for 2018. Thus, the waste consumption in CRF is 1889 TJ higher than the consumption in the energy statistics and the Eurostat data. In addition, the fossil part of waste is plant-specific for some plants in the CRF data whereas a fixed fossil energy part is applied in the energy statistics.

For biomass, the consumption in the Eurostat data is 1 % lower (2456 TJ) than in the CRF data.

Bio natural gas has been reported in this fuel category in CRF whereas it has been included in gaseous fuels in the Eurostat data. This cause a 7052 TJ lower fuel consumption in the Eurostat data.

In addition, the bottom up approach applied in the Danish emission inventory adds up to higher consumption of waste than stated in the energy statistics for 2018. Thus, the waste consumption in CRF is 1889 TJ higher than the consumption in the energy statistics and the Eurostat data. This corresponds to a biogenic difference of 1039 TJ. Finally, the biogenic part of waste is plant-specific for some plants in the CRF data whereas a fixed fossil energy part is applied in the energy statistics.

Table 79 Total fuel consumption, sectoral approach, 2018 (EU, 2020).

| | Fuel Eurostat, TJ | Fuel CRF, TJ | Fuel Eurostat / Fuel CRF, % | Difference, TJ |
|---|---|---|---|---|
| Solid | 74021 | 67616 | 109% | 6405 |
| Liquid | 69358 | 70382 | 99% | -1024 |
| Gaseous | 119749 | 113518 | 105% | 6231 |
| Other fossil | 17297 | 19179 | 90% | -1882 |
| Biomass | 177183 | 179639 | 99 % | -2456 |
| Fossil fuels | 280425 | 270695 | 104% | 9730 |

# 12 Sum of EU ETS data compared to CRF data

The annual reporting of GHGs to EU includes a comparison of the CRF data and the total ETS data. The comparison has been made regarding the verified emissions reported under the (EU ETS Directive 2003/87/EC) and the emissions reported in the CRF tables.

## 12.1 The allocation of the verified emissions reported under EU ETS to CRF categories

The verification is based on the database for all EU ETS data from the Danish Energy Agency. CRF emission categories have been added to all EU ETS data.

For fuel combustion, all plants in the EU ETS database have a plant id that can be linked to another plant-specific database from DEA that includes all plants that supply power or district heating to the public grid (Energy Producers Survey). This database includes SNAP sector codes and thus CRF sector codes can be linked based on the correspondence list between SNAP and CRF sector codes. The emissions from combustion from the remaining plants (offshore gas turbines, refineries and a large number of different industrial plants) have been allocated to the relevant CRF sector manually. In addition, CRF sector codes were included in the EU ETS data set for 2016 from DEA.

For process emissions, the CRF categories have been added manually for each emission source included in the EU ETS database.

## 12.2 Consistency of data reported under EU ETS with the CRF inventory

In the Danish inventory the data reported under the EU ETS (Directive 2003/87/EC) are used directly in the inventory for plants using higher tier methods. For plants reporting using a lower tier method, the data are not used in the inventory. However, the data reported is checked in terms of overall sum checks of individual categories to ensure that the emissions reported under EU ETS for a source category do not exceed the emissions in the inventory.

The comparison of CRF data and EU ETS data is shown in Table 80. The following main points have been identified:

- The sum of ETS data for sector 1A1b Residential plants exceeds the emission reported in CRF for this source category. Regeneration of catalysts is included in this source category in ETS data but not in the CRF reporting.
- The sum of ETS data for sector 1A1c Manufacture of solid fuels and other Energy Iindustries exceeds the emissions reported in CRF. The consumption of gas oil reported for 1A1c in the energy statistics is not in agreement with the consumption in the ETS reports. This problem is however related to disaggregation of the gas oil consumption and do not affect the total $CO_2$ emission reported in CRF.
- The fuel consumption in CRF is based on the Danish energy statistics. The EU ETS data are implemented as a data source for the disaggregation to industrial subsectors in the Danish energy statistics. However, for 1A2f Non-metallic minerals there is a minor difference between the two data sets.

Table 80 Sum of EU ETS data compared to the CRF reporting, 2018.

## Implementing Regulation Article 10: Reporting on consistency of reported emissions with data from the emissions trading system

1.Member States shall report the information referred to in Article 7(1)(k) of Regulation (EU) No 525/2013 in accordance with the tabular format set out in Annex V to this Regulation.
2.Member States shall report textual information on the results of the checks performed pursuant to Article 7(1)(l) of Regulation (EU) No 525/2013.

| Allocation of verified emissions reported by installations and operators under Directive 2003/87/EC to source categories of the national greenhouse gas inventory | |
|---|---|
| Member State: | Denmark |
| Reporting year: | 2018 |
| Basis for data: verified ETS emissions and greenhouse gas emissions as reported in inventory submission for the year X-2 | |

| Total emissions (CO2 -eq) | | | | | |
|---|---|---|---|---|---|
| Category[1] | Gas | Greenhouse gas inventory emissions [kt $CO_2$eq][3] | Verified emissions under Directive 2003/87/EC [kt $CO_2$eq][3] | Ratio in % (Verified emissions/ inventory emissions)[3] | Comment[2] |
| Greenhouse gas emissions (total emissions without LULUCF for GHG inventory and without emissions from 1A3a Civil aviation, total emissions from installations under Article 3h of Directive 2003/87/EC) | Total GHG | 54323.91 | 14948.4 | 27.5% | |
| $CO_2$ emissions (total $CO_2$ emissions without LULUCF for GHG inventory and without emissions from 1A3a Civil aviation, total emissions from installations under Article 3h of Directive 2003/87/EC) | Total GHG | 34518.23 | 14948.4 | 43.3% | |

| CO2 emissions | | | | | |
|---|---|---|---|---|---|
| Category[1] | | Greenhouse gas inventory emissions [kt $CO_2$eq][3] | Verified emissions under Directive 2003/87/EC [kt $CO_2$eq][3] | Ratio in % (Verified emissions/ inventory emissions)[3] | Comment[2] |
| **1.A Fuel combustion activities, total** | $CO_2$ | 32696.2 | 13451.3 | 41.1% | |
| **1.A Fuel combustion activities, stationary combustion [4]** | $CO_2$ | 17159.0 | 13451.3 | 78.4% | |
| 1.A.1 Energy industries | $CO_2$ | 11263.9 | 10957.0 | 97.3% | |
| 1.A.1.a Public electricity and heat production | $CO_2$ | 9112.7 | 8761.4 | 96.1% | |
| 1.A.1.b Petroleum refining | $CO_2$ | 891.4 | 902.6 | 101.3% | Regeneration of catalysts is included in this source category in EU ETS data but not in the CRF reporting |
| 1.A.1.c Manufacture of solid fuels and other Energy industries | $CO_2$ | 1259.7 | 1293.1 | 102.6% | The energy statistics do not include consumption of gas oil in oil and gas extraction. The gas oil consumption is however included in other sectors. |
| Iron and steel total (1.A.2, 1.B, 2.C.1) [5] | $CO_2$ | 106.6 | 94.3 | 88.4% | |
| 1.A.2. Manufacturing industries and construction | $CO_2$ | 3880.0 | 2456.4 | 63.3% | |
| 1.A.2.a Iron and steel | $CO_2$ | 106.6 | 94.3 | 88.4% | |
| 1.A.2.b Non-ferrous metals | $CO_2$ | NO | 0.0 | NO | |
| 1.A.2.c Chemicals | $CO_2$ | 350.8 | 85.2 | 24.3% | |
| 1.A.2.d Pulp, paper and print | $CO_2$ | 79.3 | 49.1 | 61.9% | |
| 1.A.2.e Food processing, beverages and tobacco | $CO_2$ | 1030.9 | 755.3 | 73.3% | |
| 1.A.2.f Non-metallic minerals | $CO_2$ | 1394.5 | 1396.3 | 100.1% | The fuel consumption in CRF is based on the Danish energy statistics. The EU ETS data are implemented as a data source for the disaggregation to industrial subsectors in the Danish energy statistics. However, for 1A2f there is a minor difference between the two data sets. |

| | | | | | |
|---|---|---|---|---|---|
| 1.A.2.g Other | $CO_2$ | 917.8 | 76.3 | 8.3% | |
| 1.A.3. Transport | $CO_2$ | 13285.0 | 0.0 | 0.0% | |
| 1.A.3.e Other transportation (pipeline transport) | $CO_2$ | NO | 0.0 | NO | |
| 1.A.4 Other sectors | $CO_2$ | 4052.3 | 37.9 | 0.9% | |
| 1.A.4.a Commercial / Institutional | $CO_2$ | 698.2 | 5.0 | 0.7% | |
| 1.A.4.c Agriculture/forestry / Fisheries | $CO_2$ | 1482.4 | 32.9 | 2.2% | |
| **1.B Fugitive emissions from Fuels** | $CO_2$ | 232.4 | 232.0 | 99.8% | |
| **1.C CO2 Transport and storage** | $CO_2$ | NO | NO | NO | |
| 1.C.1 Transport of CO2 | $CO_2$ | NO | NO | NO | |
| 1.C.2 Injection and storage | $CO_2$ | NO | NO | NO | |
| 1.C:3 Other 2.A Mineral products | $CO_2$ | NO | NO | NO | |
| **2.A Mineral products** | $CO_2$ | 1298.0 | 1265.1 | 97.5% | |
| 2.A.1 Cement Production | $CO_2$ | 1159.7 | 1159.7 | 100.0% | |
| 2.A.2. Lime production | $CO_2$ | 36.8 | 24.3 | 66.1% | |
| 2.A.3. Glass production | $CO_2$ | 10.4 | 10.4 | 100.0% | |
| 2.A.4. Other process uses of carbonates | $CO_2$ | 91.1 | 70.7 | 77.6% | |
| **2.B Chemical industry** | $CO_2$ | 1.4 | 0.0 | 0.0% | |
| 2.B.1. Ammonia production | $CO_2$ | NO | NO | NO | |
| 2.B.3. Adipic acid production (CO2) | $CO_2$ | NO | NO | NO | |
| 2.B.4. Caprolactam, glyoxal and glyoxylic acid production | $CO_2$ | NO | NO | NO | |
| 2.B.5. Carbide production | $CO_2$ | NO | NO | NO | |
| 2.B.6 Titanium dioxide production | $CO_2$ | NO | NO | NO | |
| 2.B.7 Soda ash production | $CO_2$ | NO | NO | NO | |
| 2.B.8 Petrochemical and carbon black production | $CO_2$ | NO | NO | NO | |
| **2.C Metal production** | $CO_2$ | 0.1 | 0.0 | 0.0% | |
| 2.C.1. Iron and steel production | $CO_2$ | NO | NO | NO | |
| 2.C.2 Ferroalloys production | $CO_2$ | NO | NO | NO | |
| 2.C.3 Aluminium production | $CO_2$ | NO | NO | NO | |
| 2.C.4 Magnesium production | $CO_2$ | NO | NO | NO | |
| 2.C.5 Lead production | $CO_2$ | 0.1 | 0.0 | 0.0% | |
| 2.C.6 Zinc production | $CO_2$ | NO | NO | NO | |
| 2.C.7 Other metal production | $CO_2$ | NO | NO | NO | |

| N2O emissions | | | | | |
|---|---|---|---|---|---|
| Category[1] | Gas | Greenhouse gas inventory emissions [kt $CO_2$eq][3] | Verified emissions under Directive 2003/87/EC [kt $CO_2$eq][3] | Ratio in % (Verified emissions/ inventory emissions)[3] | Comment[2] |
| 2.B.2. Nitric acid production | $N_2O$ | NO | NO | NO | |
| 2.B.3. Adipic acid production | $N_2O$ | NO | NO | NO | |
| 2.B.4. Caprolactam, glyoxal and glyoxylic acid production | $N_2O$ | NO | NO | NO | |

| PFC emissions | | | | | |
|---|---|---|---|---|---|
| Category[1] | Gas | Greenhouse gas inventory emissions [kt $CO_2$eq][3] | Verified emissions under Directive 2003/87/EC [kt $CO_2$eq][3] | Ratio in % (Verified emissions/ inventory emissions)[3] | Comment[2] |
| 2.C.3 Aluminium production | PFC | NO | NO | NO | |

[1] The allocation of verified emissions to disaggregated inventory categories at four digit level must be reported where such allocation of verified emissions is possible and emissions occur. The following notation keys should be used: NO = not occurring IE = included elsewhere C = confidential negligible = small amount of verified emissions may occur in respective CRF category, but amount is < 5% of the category
[2] The column comment should be used to give a brief summary of the checks performed and if a Member State wants to provide additional explanations with regard to the allocation reported. Member States should add a short explanation when using IE or other notation keys to ensure transparency.

[3] Data to be reported up to one decimal point for kt and % values

[4] 1.A Fuel combustion, stationary combustion should include the sum total of the relevant rows below for 1.A (without double counting) plus the addition of other stationary combustion emissions not explicitly included in any of the rows below.
[5] To be filled on the basis of combined CRF categories pertaining to 'Iron and Steel' , to be determined individually by each Member State; e.g. (1.A.2.a+ 2.C.1 + 1.A.1.c and other relevant CRF categories that include emissions from iron and steel (e.g. 1A1a, 1B1))

Notation: x = reporting year

# 13 Source specific recalculations and improvements in the 2020 reporting

## 13.1 Greenhouse gases

Table 81 shows recalculations of the $CO_2$, $CH_4$ and $N_2O$ emissions. Emissions reported this year have been compared to emissions reported last year. Sector specific recalculations for 2017 are shown in Table 82. The main recalculations are discussed below.

Table 81 Recalculations. Emissions reported in 2020 compared to emissions reported in 2019.

| GHG | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | % | % | % | % | % |
| $CO_2$ | 99.99 | 99.99 | 99.99 | 99.99 | 99.99 | 99.99 | 100.00 | 100.00 | 100.00 | 100.00 |
| $CH_4$ | 98.40 | 98.43 | 98.59 | 98.82 | 99.18 | 99.47 | 99.59 | 99.62 | 99.75 | 99.75 |
| $N_2O$ | 100.00 | 100.00 | 100.00 | 100.00 | 100.04 | 100.04 | 100.03 | 100.05 | 100.05 | 100.04 |

| GHG | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | % | % | % | % | % |
| $CO_2$ | 100.00 | 100.00 | 100.00 | 100.00 | 99.99 | 99.99 | 100.00 | 99.99 | 99.99 | 100.00 |
| $CH_4$ | 99.72 | 99.66 | 99.60 | 99.48 | 99.08 | 98.66 | 98.45 | 98.47 | 99.04 | 99.07 |
| $N_2O$ | 100.05 | 100.03 | 100.00 | 100.00 | 100.00 | 100.17 | 99.99 | 100.48 | 99.77 | 100.19 |

| GHG | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | % | % | % |
| $CO_2$ | 100.00 | 100.01 | 100.00 | 100.00 | 99.97 | 99.90 | 99.94 | 99.79 |
| $CH_4$ | 99.10 | 98.96 | 98.61 | 98.36 | 98.09 | 97.63 | 97.63 | 97.91 |
| $N_2O$ | 100.02 | 100.81 | 101.66 | 102.14 | 100.81 | 103.40 | 109.07 | 108.26 |

Table 82 Recalculations for stationary combustion, 2017.

| | $CO_2$ , kt $CO_2$ | $CH_4$, kt $CO_2$ eqv. | $N_2O$ kt $CO_2$ eqv. | $CO_2$ % | $CH_4$, % | $N_2O$ % |
|---|---|---|---|---|---|---|
| 1A1 Energy industries | -11.4 | 0.3 | 0.0 | -0.1% | 0.3% | 0.1% |
| 1A1a Public electricity and heat production | -11.4 | 0.3 | 0.0 | -0.1% | 0.3% | 0.1% |
| 1A1b Petroleum refining | 0.0 | 0.0 | 0.0 | 0.0% | 0.0% | 0.0% |
| 1A1c Oil and gas extraction | 0.0 | 0.0 | 0.0 | 0.0% | 0.0% | 0.0% |
| 1A2 Industry | -36.0 | 0.3 | 15.0 | -1.1% | 2.0% | 42.6% |
| 1A2a Iron and steel | -7.8 | 0.0 | 0.0 | -6.9% | -6.9% | -6.8% |
| 1A2b Non-ferrous metals | 0.0 | 0.0 | 0.0 | - | - | - |
| 1A2c Chemicals | -11.4 | 0.0 | 0.1 | -3.2% | 6.4% | 3.9% |
| 1A2d Pulp, paper and print | -7.1 | 0.1 | 0.5 | -15.6% | 97.0% | 77.3% |
| 1A2e Food processing, beverages and tobacco | -34.3 | 0.1 | -0.2 | -3.2% | 0.7% | -2.1% |
| 1A2f Non-metallic minerals | 3.0 | 0.1 | 0.0 | 0.2% | 1.5% | 0.2% |
| 1A2gviii Other manufacturing industry | 21.6 | 0.1 | 14.6 | 6.1% | 1.7% | 108.6% |
| 1A4 Other sectors | 10.7 | -6.1 | 0.6 | 0.4% | -4.3% | 0.9% |
| 1A4ai Commercial/institutional: Stationary | 0.5 | 0.1 | 0.1 | 0.1% | 0.8% | 1.2% |
| 1A4bi Residential: Stationary | 6.3 | -6.4 | 0.5 | 0.3% | -6.1% | 0.9% |
| 1A4ci Agriculture/forestry/fishing: Stationary | 3.9 | 0.2 | 0.0 | 2.4% | 0.9% | 1.0% |
| Stationary combustion | -36.6 | -5.4 | 15.7 | -0.2% | -2.1% | 8.3% |

For stationary combustion plants, the emission estimates for the years 1990-2017 have been updated according to the latest energy statistics published by the Danish Energy Agency. The update included both end use and transformation and also a source category update. The changes in the energy statistics are largest for the years 2015, 2016 and 2017.

The disaggregation to industrial subsectors has been updated to the latest data set. The largest changes are for 2017 and for waste incineration in 2011.

The $CO_2$ emission factor for coal applied in other plants than public power and district heating plants have been revised. The emission factor applied for these plants was a default emission factor from the IPCC Guidelines (2006). However, based on an analysis of EU ETS data from 2006-2018 it was concluded that a common emission factor for coal should be applied. Plant-specific emission factors have been applied for large industrial plants, and thus the recalculation is small. The recalculation of $CO_2$ the emission for 1990 is -1.9 kt or -0.005 % of the $CO_2$ emission from stationary combustion. The recalculation of $CO_2$ the emission for 2017 is -0.09 kt or -0.001 % of the $CO_2$ emission from stationary combustion.

The $CO_2$ emission factor for residual oil applied in other plants than public power and district heating plants have been revised. The emission factor applied for these plants was based on ET ETS data for 2006-2009. However, based on an analysis of EU ETS data from 2006-2018 it was concluded that a common emission factor for residual oil should be applied. Plant-specific emission factors have been applied for large industrial plants, and thus the recalculation is small. The recalculation of $CO_2$ emission for 1990 is +1.4 kt or 0.004 % of the $CO_2$ emission from stationary combustion. The recalculation of $CO_2$ emission for 2017 is +0.03 kt or less than 0.001 % of the $CO_2$ emission from stationary combustion.

The disaggregation between different residential wood combustion technologies have been recalculated, and this cause minor changes in the estimated $CH_4$ emission from residential plants. The recalculation of $CH_4$ emission from residential wood combustion in 1990 is 0.11 kt or -1.6 % of the $CH_4$ emission from stationary combustion. The recalculation of $CH_4$ emission from residential wood combustion in 2017 is 0.26 kt or -2.5 % of the $CH_4$ emission from stationary combustion.

The $N_2O$ emission for 2017 has been recalculated due to improved plant-specific data from two mineral wool production plants.

## 13.2 Other pollutants

For stationary combustion plants, the emission estimates for the years 1990-2017 have been updated according to the latest energy statistics published by the Danish Energy Agency. The update included both end use and transformation sectors as well as a source category update. The changes in the energy statistics are largest for the years 2015, 2016 and 2017.

The emission inventory for residential wood combustion has been improved based on recent emission measurements. This cause the considerable recalculations for pollutants for which residential wood combustion is the largest emission source.

The $SO_2$ emission factor for gas oil has been improved based on improved data for sulphur content of the applied gas oil.

Recalculations for stationary combustion as a whole are shown in Table 83.

Table 83 Recalculations for stationary combustion. Emissions reported in 2020 compared to emissions reported in 2019.

| | 1990 | 1995 | 2000 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Percent | | | | | | | | | | | | | | | |
| $SO_2$ | 100.0 | 100.0 | 100.0 | 100.0 | 99.8 | 99.5 | 99.1 | 98.4 | 97.9 | 97.8 | 97.0 | 97.7 | 98.0 | 97.8 | 99.9 | 100.8 |
| $NO_x$ | 100.0 | 100.0 | 100.0 | 100.1 | 100.0 | 100.0 | 100.0 | 100.0 | 99.9 | 99.9 | 99.8 | 99.8 | 99.7 | 99.6 | 100.0 | 100.1 |
| NMVOC | 98.2 | 98.7 | 99.4 | 97.5 | 97.9 | 98.8 | 100.0 | 100.0 | 100.1 | 99.9 | 99.5 | 99.3 | 99.0 | 98.9 | 98.9 | 99.3 |
| CO | 107.9 | 108.6 | 108.5 | 103.9 | 103.1 | 103.8 | 104.1 | 103.2 | 102.3 | 102.3 | 102.3 | 102.5 | 102.6 | 103.0 | 103.4 | 103.6 |
| TSP | 86.6 | 84.3 | 83.0 | 78.0 | 77.8 | 77.5 | 78.7 | 79.2 | 79.3 | 79.2 | 79.0 | 79.0 | 79.2 | 78.2 | 78.3 | 78.1 |
| $PM_{10}$ | 86.5 | 84.2 | 82.7 | 77.4 | 77.6 | 77.3 | 78.5 | 79.0 | 79.2 | 79.1 | 78.8 | 78.9 | 79.1 | 78.0 | 78.1 | 77.9 |
| $PM_{2.5}$ | 86.7 | 84.4 | 82.8 | 77.5 | 77.6 | 77.4 | 78.6 | 79.1 | 79.2 | 79.1 | 78.8 | 78.8 | 79.0 | 78.0 | 78.1 | 77.8 |
| BC | 61.4 | 53.4 | 50.4 | 43.6 | 43.5 | 40.1 | 41.9 | 43.8 | 43.9 | 45.9 | 47.0 | 47.7 | 49.5 | 48.5 | 49.5 | 50.4 |
| $NH_3$ | 99.8 | 99.6 | 99.6 | 98.5 | 98.6 | 99.0 | 99.4 | 99.5 | 99.5 | 99.5 | 99.5 | 99.4 | 99.4 | 99.8 | 100.2 | 101.0 |
| As | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 99.9 | 100.0 | 100.0 | 100.0 | 99.8 | 100.0 | 100.0 | 99.9 | 100.7 | 101.5 |
| Cd | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.4 | 100.9 | 101.0 |
| Cr | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 99.9 | 100.0 | 100.0 | 100.3 | 101.1 | 101.4 |
| Cu | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 99.7 | 100.0 | 100.0 | 100.0 | 101.6 | 102.4 |
| Hg | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 99.7 | 100.0 | 100.0 | 99.9 | 101.1 | 101.9 |
| Ni | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.3 | 100.0 | 100.0 | 99.8 | 99.9 | 100.0 | 100.0 | 99.9 | 100.4 | 99.7 |
| Pb | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 99.4 | 100.0 | 100.0 | 100.2 | 102.7 | 103.9 |
| Se | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 99.8 | 100.0 | 100.0 | 100.0 | 101.6 | 102.7 |
| Zn | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 99.9 | 100.0 | 100.0 | 100.4 | 101.1 | 101.3 |
| HCB | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 99.9 | 100.0 | 100.0 | 100.2 | 100.5 | 100.9 |
| PCDD/F | 101.2 | 103.3 | 109.1 | 127.5 | 133.0 | 137.7 | 142.0 | 149.0 | 153.0 | 155.2 | 156.7 | 161.4 | 164.4 | 173.1 | 177.9 | 180.9 |
| Benzo(a)pyrene | 245.3 | 223.2 | 179.8 | 135.9 | 127.5 | 123.1 | 116.3 | 108.3 | 99.7 | 100.4 | 100.9 | 101.5 | 101.4 | 102.9 | 104.0 | 105.1 |
| Benzo(b)fluoranthene | 213.8 | 193.1 | 153.3 | 117.0 | 109.4 | 105.3 | 99.1 | 91.6 | 84.6 | 86.4 | 88.0 | 89.6 | 90.2 | 92.4 | 94.3 | 96.0 |
| Benzo(k)fluoranthene | 468.8 | 423.8 | 330.0 | 254.8 | 237.0 | 231.1 | 214.7 | 196.0 | 178.0 | 174.7 | 172.8 | 169.4 | 163.8 | 163.9 | 160.4 | 158.5 |
| Indeno(123cd)pyrene | 309.6 | 295.8 | 240.9 | 168.3 | 153.2 | 142.7 | 128.5 | 113.8 | 95.2 | 96.2 | 96.6 | 98.4 | 99.1 | 100.9 | 103.0 | 104.7 |
| PCB | 99.8 | 99.6 | 99.3 | 97.9 | 98.2 | 98.1 | 98.3 | 98.4 | 98.5 | 98.5 | 98.3 | 98.5 | 98.5 | 98.3 | 99.0 | 99.5 |

# 14 Planned improvements

For GHGs, four emission source categories based on tier 1 approach have been identified as key sources this year. If sufficient data are available, a tier 2 approach will be applied next year.

The emission factors that refer to EEA (2016) will be updated according to EEA (2019).

BC emission factors will be updated according to EEA (2019).

PM and BC emission factors for wood pellets applied in non-residential plants will be revised.

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# Annexes

# Annex 1 Correspondence list between SNAP and CRF/NFR source categories

Table 1.1 Correspondence list between SNAP and CRF / NFR source categories for stationary combustion.

| | snap_name | CRF id | CRF name |
|---|---|---|---|
| 010100 | Public power | 1A1a | Public electricity and heat production |
| 010101 | Combustion plants >= 300 MW (boilers) | 1A1a | Public electricity and heat production |
| 010102 | Combustion plants >= 50 and < 300 MW (boilers) | 1A1a | Public electricity and heat production |
| 010103 | Combustion plants < 50 MW (boilers) | 1A1a | Public electricity and heat production |
| 010104 | Gas turbines | 1A1a | Public electricity and heat production |
| 010105 | Stationary engines | 1A1a | Public electricity and heat production |
| 010200 | District heating plants | 1A1a | Public electricity and heat production |
| 010201 | Combustion plants >= 300 MW (boilers) | 1A1a | Public electricity and heat production |
| 010202 | Combustion plants >= 50 and < 300 MW (boilers) | 1A1a | Public electricity and heat production |
| 010203 | Combustion plants < 50 MW (boilers) | 1A1a | Public electricity and heat production |
| 010204 | Gas turbines | 1A1a | Public electricity and heat production |
| 010205 | Stationary engines | 1A1a | Public electricity and heat production |
| 010300 | Petroleum refining plants | 1A1b | Petroleum refining |
| 010301 | Combustion plants >= 300 MW (boilers) | 1A1b | Petroleum refining |
| 010302 | Combustion plants >= 50 and < 300 MW (boilers) | 1A1b | Petroleum refining |
| 010303 | Combustion plants < 50 MW (boilers) | 1A1b | Petroleum refining |
| 010304 | Gas turbines | 1A1b | Petroleum refining |
| 010305 | Stationary engines | 1A1b | Petroleum refining |
| 010306 | Process furnaces | 1A1b | Petroleum refining |
| 010400 | Solid fuel transformation plants | 1A1c | Oil and gas extraction |
| 010401 | Combustion plants >= 300 MW (boilers) | 1A1c | Oil and gas extraction |
| 010402 | Combustion plants >= 50 and < 300 MW (boilers) | 1A1c | Oil and gas extraction |
| 010403 | Combustion plants < 50 MW (boilers) | 1A1c | Oil and gas extraction |
| 010404 | Gas turbines | 1A1c | Oil and gas extraction |
| 010405 | Stationary engines | 1A1c | Oil and gas extraction |
| 010406 | Coke oven furnaces | 1A1c | Oil and gas extraction |
| 010407 | Other (coal gasification, liquefaction) | 1A1c | Oil and gas extraction |
| 010500 | Coal mining, oil / gas extraction, pipeline compressors | 1A1c | Oil and gas extraction |
| 010501 | Combustion plants >= 300 MW (boilers) | 1A1c | Oil and gas extraction |
| 010502 | Combustion plants >= 50 and < 300 MW (boilers) | 1A1c | Oil and gas extraction |
| 010503 | Combustion plants < 50 MW (boilers) | 1A1c | Oil and gas extraction |
| 010504 | Gas turbines | 1A1c | Oil and gas extraction |
| 010505 | Stationary engines | 1A1c | Oil and gas extraction |
| 010506 | Pipeline compressors | 1A3e i | Pipeline transport |
| 020100 | Commercial and institutional plants | 1A4a i | Commercial/institutional: Stationary |
| 020101 | Combustion plants >= 300 MW (boilers) | 1A4a i | Commercial/institutional: Stationary |
| 020102 | Combustion plants >= 50 and < 300 MW (boilers) | 1A4a i | Commercial/institutional: Stationary |
| 020103 | Combustion plants < 50 MW (boilers) | 1A4a i | Commercial/institutional: Stationary |
| 020104 | Stationary gas turbines | 1A4a i | Commercial/institutional: Stationary |
| 020105 | Stationary engines | 1A4a i | Commercial/institutional: Stationary |
| 020106 | Other stationary equipments | 1A4a i | Commercial/institutional: Stationary |
| 020200 | Residential plants | 1A4b i | Residential: Stationary |
| 020201 | Combustion plants >= 50 MW (boilers) | 1A4b i | Residential: Stationary |
| 020202 | Combustion plants < 50 MW (boilers) | 1A4b i | Residential: Stationary |
| 020203 | Gas turbines | 1A4b i | Residential: Stationary |
| 020204 | Stationary engines | 1A4b i | Residential: Stationary |
| 020205 | Other equipments (stoves, fireplaces, cooking) | 1A4b i | Residential: Stationary |
| 020300 | Plants in agriculture, forestry and aquaculture | 1A4c i | Agriculture/Forestry/Fishing: Stationary |
| 020301 | Combustion plants >= 50 MW (boilers) | 1A4c i | Agriculture/Forestry/Fishing: Stationary |
| 020302 | Combustion plants < 50 MW (boilers) | 1A4c i | Agriculture/Forestry/Fishing: Stationary |
| 020303 | Stationary gas turbines | 1A4c i | Agriculture/Forestry/Fishing: Stationary |
| 020304 | Stationary engines | 1A4c i | Agriculture/Forestry/Fishing: Stationary |
| 020305 | Other stationary equipments | 1A4c i | Agriculture/Forestry/Fishing: Stationary |
| 030100 | Comb. in boilers, gas turbines and stationary | 1A2g viii | Other manufacturing industry |
| 030101 | Combustion plants >= 300 MW (boilers) | 1A2g viii | Other manufacturing industry |

| | snap_name | CRF id | CRF name |
|---|---|---|---|
| 030102 | Combustion plants >= 50 and < 300 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 030103 | Combustion plants < 50 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 030104 | Gas turbines | 1A2g viii | Other manufacturing industry |
| 030105 | Stationary engines | 1A2g viii | Other manufacturing industry |
| 030106 | Other stationary equipments | 1A2g viii | Other manufacturing industry |
| 030200 | Process furnaces without contact (a) | 1A2g viii | Other manufacturing industry |
| 030203 | Blast furnace cowpers | 1A2a | Iron and steel |
| 030204 | Plaster furnaces | 1A2g viii | Other manufacturing industry |
| 030205 | Other furnaces | 1A2g viii | Other manufacturing industry |
| 030400 | Iron and Steel | 1A2a | Iron and steel |
| 030401 | Combustion plants >= 300 MW (boilers) | 1A2a | Iron and steel |
| 030402 | Combustion plants >= 50 and < 300 MW (boilers) | 1A2a | Iron and steel |
| 030403 | Combustion plants < 50 MW (boilers) | 1A2a | Iron and steel |
| 030404 | Gas turbines | 1A2a | Iron and steel |
| 030405 | Stationary engines | 1A2a | Iron and steel |
| 030406 | Other stationary equipments | 1A2a | Iron and steel |
| 030500 | Non-Ferrous Metals | 1A2b | Non-ferrous metals |
| 030501 | Combustion plants >= 300 MW (boilers) | 1A2b | Non-ferrous metals |
| 030502 | Combustion plants >= 50 and < 300 MW (boilers) | 1A2b | Non-ferrous metals |
| 030503 | Combustion plants < 50 MW (boilers) | 1A2b | Non-ferrous metals |
| 030504 | Gas turbines | 1A2b | Non-ferrous metals |
| 030505 | Stationary engines | 1A2b | Non-ferrous metals |
| 030506 | Other stationary equipments | 1A2b | Non-ferrous metals |
| 030600 | Chemical and Petrochemical | 1A2c | Chemicals |
| 030601 | Combustion plants >= 300 MW (boilers) | 1A2c | Chemicals |
| 030602 | Combustion plants >= 50 and < 300 MW (boilers) | 1A2c | Chemicals |
| 030603 | Combustion plants < 50 MW (boilers) | 1A2c | Chemicals |
| 030604 | Gas turbines | 1A2c | Chemicals |
| 030605 | Stationary engines | 1A2c | Chemicals |
| 030606 | Other stationary equipments | 1A2c | Chemicals |
| 030700 | Non-Metallic Minerals | 1A2f | Non-metallic minerals |
| 030701 | Combustion plants >= 300 MW (boilers) | 1A2f | Non-metallic minerals |
| 030702 | Combustion plants >= 50 and < 300 MW (boilers) | 1A2f | Non-metallic minerals |
| 030703 | Combustion plants < 50 MW (boilers) | 1A2f | Non-metallic minerals |
| 030704 | Gas turbines | 1A2f | Non-metallic minerals |
| 030705 | Stationary engines | 1A2f | Non-metallic minerals |
| 030706 | Other stationary equipments | 1A2f | Non-metallic minerals |
| 030800 | Mining and Quarrying | 1A2g viii | Other manufacturing industry |
| 030801 | Combustion plants >= 300 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 030802 | Combustion plants >= 50 and < 300 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 030803 | Combustion plants < 50 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 030804 | Gas turbines | 1A2g viii | Other manufacturing industry |
| 030805 | Stationary engines | 1A2g viii | Other manufacturing industry |
| 030806 | Other stationary equipments | 1A2g viii | Other manufacturing industry |
| 030900 | Food and Tobacco | 1A2e | Food processing, beverages and tobacco |
| 030901 | Combustion plants >= 300 MW (boilers) | 1A2e | Food processing, beverages and tobacco |
| 030902 | Combustion plants >= 50 and < 300 MW (boilers) | 1A2e | Food processing, beverages and tobacco |
| 030903 | Combustion plants < 50 MW (boilers) | 1A2e | Food processing, beverages and tobacco |
| 030904 | Gas turbines | 1A2e | Food processing, beverages and tobacco |
| 030905 | Stationary engines | 1A2e | Food processing, beverages and tobacco |
| 030906 | Other stationary equipments | 1A2e | Food processing, beverages and tobacco |
| 031000 | Textile and Leather | 1A2g viii | Other manufacturing industry |
| 031001 | Combustion plants >= 300 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 031002 | Combustion plants >= 50 and < 300 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 031003 | Combustion plants < 50 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 031004 | Gas turbines | 1A2g viii | Other manufacturing industry |
| 031005 | Stationary engines | 1A2g viii | Other manufacturing industry |
| 031006 | Other stationary equipments | 1A2g viii | Other manufacturing industry |
| 031100 | Paper, Pulp and Print | 1A2d | Pulp, Paper and Print |

| | snap_name | CRF id | CRF name |
|---|---|---|---|
| 031101 | Combustion plants >= 300 MW (boilers) | 1A2d | Pulp, Paper and Print |
| 031102 | Combustion plants >= 50 and < 300 MW (boilers) | 1A2d | Pulp, Paper and Print |
| 031103 | Combustion plants < 50 MW (boilers) | 1A2d | Pulp, Paper and Print |
| 031104 | Gas turbines | 1A2d | Pulp, Paper and Print |
| 031105 | Stationary engines | 1A2d | Pulp, Paper and Print |
| 031106 | Other stationary equipments | 1A2d | Pulp, Paper and Print |
| 031200 | Transport Equipment | 1A2g viii | Other manufacturing industry |
| 031201 | Combustion plants >= 300 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 031202 | Combustion plants >= 50 and < 300 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 031203 | Combustion plants < 50 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 031204 | Gas turbines | 1A2g viii | Other manufacturing industry |
| 031205 | Stationary engines | 1A2g viii | Other manufacturing industry |
| 031206 | Other stationary equipments | 1A2g viii | Other manufacturing industry |
| 031300 | Machinery | 1A2g viii | Other manufacturing industry |
| 031301 | Combustion plants >= 300 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 031302 | Combustion plants >= 50 and < 300 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 031303 | Combustion plants < 50 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 031304 | Gas turbines | 1A2g viii | Other manufacturing industry |
| 031305 | Stationary engines | 1A2g viii | Other manufacturing industry |
| 031306 | Other stationary equipments | 1A2g viii | Other manufacturing industry |
| 031400 | Wood and Wood Products | 1A2g viii | Other manufacturing industry |
| 031401 | Combustion plants >= 300 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 031402 | Combustion plants >= 50 and < 300 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 031403 | Combustion plants < 50 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 031404 | Gas turbines | 1A2g viii | Other manufacturing industry |
| 031405 | Stationary engines | 1A2g viii | Other manufacturing industry |
| 031406 | Other stationary equipments | 1A2g viii | Other manufacturing industry |
| 031500 | Construction | 1A2g viii | Other manufacturing industry |
| 031501 | Combustion plants >= 300 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 031502 | Combustion plants >= 50 and < 300 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 031503 | Combustion plants < 50 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 031504 | Gas turbines | 1A2g viii | Other manufacturing industry |
| 031505 | Stationary engines | 1A2g viii | Other manufacturing industry |
| 031506 | Other stationary equipments | 1A2g viii | Other manufacturing industry |
| 031600 | Cement production | 1A2f | Non-metallic minerals |
| 031601 | Combustion plants >= 300 MW (boilers) | 1A2f | Non-metallic minerals |
| 031602 | Combustion plants >= 50 and < 300 MW (boilers) | 1A2f | Non-metallic minerals |
| 031603 | Combustion plants < 50 MW (boilers) | 1A2f | Non-metallic minerals |
| 031604 | Gas turbines | 1A2f | Non-metallic minerals |
| 031605 | Stationary engines | 1A2f | Non-metallic minerals |
| 031606 | Other stationary equipments | 1A2f | Non-metallic minerals |
| 032000 | Non-specified (Industry) | 1A2g viii | Other manufacturing industry |
| 032001 | Combustion plants >= 300 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 032002 | Combustion plants >= 50 and < 300 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 032003 | Combustion plants < 50 MW (boilers) | 1A2g viii | Other manufacturing industry |
| 032004 | Gas turbines | 1A2g viii | Other manufacturing industry |
| 032005 | Stationary engines | 1A2g viii | Other manufacturing industry |
| 032006 | Other stationary equipment | 1A2g viii | Other manufacturing industry |

# Annex 2 Fuel rate

Table 2.1 Fuel consumption rate for stationary combustion plants 1990-2018, PJ.

| Sum of Fuel_rate_PJ | | | Year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **fuel_type** | **fuel_id** | **fuel_gr_abbr** | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** |
| SOLID | 101A | Other solid fossil | | | | | | | | | | |
| | 102A | Coal | 253.4 | 344.3 | 286.8 | 300.8 | 323.4 | 270.3 | 371.9 | 276.3 | 234.3 | 196.5 |
| | 103A | Fly ash (fossil) | | | | | | | | | | |
| | 106A | BKB | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 |
| | 107A | Coke oven coke | 1.3 | 1.4 | 1.2 | 1.2 | 1.2 | 1.3 | 1.2 | 1.3 | 1.3 | 1.4 |
| LIQUID | 110A | Petroleum coke | 4.5 | 4.4 | 4.3 | 5.7 | 7.5 | 5.3 | 5.9 | 6.0 | 5.3 | 6.8 |
| | 203A | Residual oil | 32.1 | 37.0 | 37.3 | 32.5 | 46.6 | 33.3 | 38.1 | 26.7 | 29.5 | 23.0 |
| | 204A | Gas oil | 63.9 | 67.6 | 58.7 | 64.7 | 56.7 | 56.5 | 60.9 | 54.1 | 51.5 | 50.6 |
| | 206A | Kerosene | 5.1 | 1.0 | 0.8 | 0.8 | 0.7 | 0.6 | 0.5 | 0.4 | 0.4 | 0.3 |
| | 225A | Orimulsion | | | | | | 19.9 | 36.8 | 40.5 | 32.6 | 34.2 |
| | 303A | LPG | 3.0 | 2.8 | 2.5 | 2.6 | 2.6 | 2.8 | 3.1 | 2.6 | 2.8 | 2.5 |
| | 308A | Refinery gas | 14.2 | 14.5 | 14.9 | 15.4 | 16.4 | 20.8 | 21.4 | 16.9 | 15.2 | 15.7 |
| GAS | 301A | Natural gas | 76.1 | 86.1 | 90.5 | 102.5 | 114.6 | 132.7 | 156.3 | 164.5 | 178.7 | 187.9 |
| WASTE | 114A | Waste | 15.5 | 16.7 | 17.8 | 19.4 | 20.3 | 22.9 | 25.0 | 26.8 | 26.6 | 29.1 |
| | 115A | Industrial waste | | | | | | | | | | |
| BIOMASS | 111A | Wood | 16.7 | 17.9 | 18.6 | 20.1 | 19.7 | 19.5 | 20.7 | 20.5 | 19.7 | 20.3 |
| | 117A | Straw | 12.5 | 13.3 | 13.9 | 13.4 | 12.7 | 13.1 | 13.5 | 13.9 | 13.9 | 13.7 |
| | | Wood pellets | 1.6 | 2.1 | 2.5 | 2.1 | 2.1 | 2.3 | 2.7 | 2.9 | 3.2 | 4.0 |
| | 215A | Bio oil | 0.7 | 0.7 | 0.7 | 0.8 | 0.2 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 |
| | 309A | Biogas | 0.8 | 0.9 | 0.9 | 1.1 | 1.3 | 1.8 | 2.0 | 2.4 | 2.7 | 2.7 |
| | 310A | Bio gasification gas | | | | | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 315A | Bio natural gas | | | | | | | | | | |
| **Total** | | | **501.4** | **611.0** | **551.5** | **583.1** | **626.2** | **603.5** | **760.1** | **655.9** | **617.8** | **588.8** |
| *Continued* | | | | | | | | | | | | |
| Sum of Fuel_rate_PJ | | | Year | | | | | | | | | |
| fuel_type | fuel_id | fuel_gr_abbr | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
| SOLID | 101A | Other solid fossil | | | | | | | | | | 0.0 |
| | 102A | Coal | 164.7 | 174.3 | 174.7 | 239.0 | 182.5 | 154.0 | 232.0 | 194.1 | 170.5 | 167.7 |
| | 103A | Fly ash (fossil) | | | | | | | | | | |
| | 106A | BKB | 0.0 | 0.0 | 0.0 | 0.0 | | | | | 0.0 | 0.0 |
| | 107A | Coke oven coke | 1.2 | 1.1 | 1.1 | 1.0 | 1.1 | 1.0 | 1.0 | 1.1 | 1.0 | 0.8 |
| LIQUID | 110A | Petroleum coke | 6.8 | 7.8 | 7.8 | 8.0 | 8.4 | 8.1 | 8.5 | 9.2 | 6.9 | 5.9 |
| | 203A | Residual oil | 18.0 | 20.2 | 24.8 | 27.3 | 23.5 | 21.1 | 25.4 | 19.3 | 15.3 | 14.2 |
| | 204A | Gas oil | 44.2 | 46.5 | 41.4 | 41.6 | 38.4 | 34.4 | 29.8 | 25.5 | 25.2 | 27.6 |
| | 206A | Kerosene | 0.2 | 0.3 | 0.3 | 0.3 | 0.2 | 0.3 | 0.2 | 0.1 | 0.1 | 0.1 |
| | 225A | Orimulsion | 34.1 | 30.2 | 23.8 | 1.9 | 0.0 | | | | | |
| | 303A | LPG | 2.4 | 2.1 | 2.0 | 2.0 | 2.1 | 2.1 | 2.2 | 1.8 | 1.6 | 1.5 |
| | 308A | Refinery gas | 15.6 | 15.8 | 15.2 | 16.6 | 15.9 | 15.3 | 16.1 | 15.9 | 14.1 | 15.0 |
| GAS | 301A | Natural gas | 186.1 | 193.8 | 193.6 | 195.9 | 195.1 | 187.4 | 191.1 | 171.0 | 173.3 | 166.1 |
| WASTE | 114A | Waste | 29.8 | 31.3 | 33.3 | 35.1 | 35.3 | 35.8 | 36.9 | 38.1 | 39.6 | 37.6 |
| | 115A | Industrial waste | 0.5 | 1.4 | 1.9 | 1.5 | 2.0 | 2.0 | 1.5 | 1.6 | 2.0 | 1.7 |
| BIOMASS | 111A | Wood | 22.3 | 23.7 | 23.7 | 29.1 | 31.1 | 33.7 | 36.5 | 43.8 | 45.1 | 45.9 |
| | 117A | Straw | 12.2 | 13.7 | 15.7 | 16.9 | 17.9 | 18.5 | 18.5 | 18.8 | 15.9 | 17.4 |
| | | Wood pellets | 5.1 | 7.1 | 7.9 | 9.8 | 12.8 | 16.1 | 15.6 | 16.5 | 18.5 | 20.1 |
| | 215A | Bio oil | 0.0 | 0.2 | 0.1 | 0.4 | 0.6 | 0.8 | 1.1 | 1.2 | 1.8 | 1.7 |
| | 309A | Biogas | 2.9 | 3.0 | 3.4 | 3.6 | 3.7 | 3.8 | 3.9 | 3.9 | 3.9 | 4.2 |
| | 310A | Bio gasification gas | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.3 |
| | 315A | Bio natural gas | | | | | | | | | | |
| **Total** | | | **546.5** | **572.7** | **570.5** | **630.1** | **570.7** | **534.4** | **620.4** | **562.1** | **535.0** | **527.8** |

| *Continued* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sum of Fuel_rate_PJ | | | Year | | | | | | | | |
| **fuel_type** | **fuel_id** | **fuel_gr_abbr** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** |
| SOLID | 101A | Other solid fossil | 0.0 | 0.0 | 0.0 | 0.0 | | | | | |
| | 102A | Coal | 163.0 | 135.5 | 106.2 | 135.0 | 107.0 | 76.0 | 88.2 | 65.8 | 67.2 |
| | 103A | Fly ash (fossil) | | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 |
| | 106A | BKB | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | | |
| | 107A | Coke oven coke | 0.7 | 0.7 | 0.6 | 0.6 | 0.6 | 0.5 | 0.3 | 0.3 | 0.4 |
| LIQUID | 110A | Petroleum coke | 5.1 | 6.5 | 6.7 | 6.1 | 6.6 | 6.6 | 7.6 | 7.9 | 6.9 |
| | 203A | Residual oil | 12.8 | 7.8 | 7.2 | 5.5 | 4.5 | 4.2 | 4.1 | 4.1 | 3.2 |
| | 204A | Gas oil | 27.2 | 21.2 | 17.7 | 15.8 | 9.5 | 9.8 | 9.5 | 8.7 | 9.3 |
| | 206A | Kerosene | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 |
| | 225A | Orimulsion | | | | | | | | | |
| | 303A | LPG | 1.5 | 1.5 | 1.7 | 1.5 | 1.2 | 1.8 | 2.0 | 2.2 | 2.2 |
| | 308A | Refinery gas | 14.3 | 13.7 | 14.8 | 14.8 | 15.4 | 16.2 | 14.4 | 15.6 | 15.0 |
| GAS | 301A | Natural gas | 186.0 | 157.5 | 147.3 | 139.5 | 119.4 | 120.7 | 122.5 | 116.5 | 113.0 |
| WASTE | 114A | Waste | 36.8 | 36.7 | 35.9 | 35.7 | 36.9 | 37.7 | 37.8 | 37.8 | 36.4 |
| | 115A | Industrial waste | 1.4 | 1.7 | 1.5 | 1.8 | 1.8 | 2.5 | 2.9 | 3.0 | 3.9 |
| BIOMASS | 111A | Wood | 51.3 | 48.8 | 48.6 | 46.4 | 45.0 | 53.1 | 53.9 | 57.2 | 61.6 |
| | 117A | Straw | 23.3 | 20.2 | 18.3 | 20.3 | 18.6 | 19.8 | 19.7 | 20.2 | 17.6 |
| | 122A | Wood pellets | 29.9 | 30.0 | 33.2 | 34.6 | 36.3 | 36.5 | 44.3 | 57.4 | 55.2 |
| | 215A | Bio oil | 2.0 | 0.8 | 1.1 | 0.9 | 0.7 | 0.6 | 0.3 | 0.2 | 0.2 |
| | 309A | Biogas | 4.3 | 4.1 | 4.4 | 4.6 | 5.2 | 5.3 | 5.9 | 5.9 | 6.4 |
| | 310A | Bio gasification gas | 0.2 | 0.3 | 0.4 | 0.4 | 0.4 | 0.5 | 0.5 | 1.0 | 1.4 |
| | 315A | Bio natural gas | | | | | 0.3 | 1.0 | 3.1 | 5.1 | 7.1 |
| **Total** | | | **559.9** | **487.2** | **445.7** | **463.6** | **409.7** | **392.8** | **417.0** | **409.1** | **407.3** |

Table 2.2 Detailed fuel consumption data for stationary combustion plants, 1990-2018, PJ. This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/greenhouse-gases/supporting-documentation/

# Annex 3 Default Lower Calorific Value (LCV) of fuels and fuel correspondence list

Table 3.1 Time series for calorific values of fuels (DEA, 2019a).

| | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Crude Oil, Average | GJ per tonne | 42.40 | 42.40 | 42.40 | 42.70 | 42.70 | 42.70 | 42.70 | 43.00 | 43.00 | 43.00 |
| Crude Oil, Golf | GJ per tonne | 41.80 | 41.80 | 41.80 | 41.80 | 41.80 | 41.80 | 41.80 | 41.80 | 41.80 | 41.80 |
| Crude Oil, North Sea | GJ per tonne | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 43.00 | 43.00 | 43.00 |
| Refinery Feedstocks | GJ per tonne | 41.60 | 41.60 | 41.60 | 41.60 | 41.60 | 41.60 | 41.60 | 42.70 | 42.70 | 42.70 |
| Refinery Gas | GJ per tonne | 52.00 | 52.00 | 52.00 | 52.00 | 52.00 | 52.00 | 52.00 | 52.00 | 52.00 | 52.00 |
| LPG | GJ per tonne | 46.00 | 46.00 | 46.00 | 46.00 | 46.00 | 46.00 | 46.00 | 46.00 | 46.00 | 46.00 |
| Naphtha (LVN) | GJ per tonne | 44.50 | 44.50 | 44.50 | 44.50 | 44.50 | 44.50 | 44.50 | 44.50 | 44.50 | 44.50 |
| Motor Gasoline | GJ per tonne | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 |
| Aviation Gasoline | GJ per tonne | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 |
| JP4 | GJ per tonne | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 |
| Other Kerosene | GJ per tonne | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 |
| JP1 | GJ per tonne | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 |
| Gas/Diesel Oil | GJ per tonne | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 |
| Fuel Oil | GJ per tonne | 40.40 | 40.40 | 40.40 | 40.40 | 40.40 | 40.40 | 40.70 | 40.65 | 40.65 | 40.65 |
| Orimulsion | GJ per tonne | 27.60 | 27.60 | 27.60 | 27.60 | 27.60 | 28.13 | 28.02 | 27.72 | 27.84 | 27.58 |
| Petroleum Coke | GJ per tonne | 31.40 | 31.40 | 31.40 | 31.40 | 31.40 | 31.40 | 31.40 | 31.40 | 31.40 | 31.40 |
| Waste Oil | GJ per tonne | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 |
| White Spirit | GJ per tonne | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 |
| Bitumen | GJ per tonne | 39.80 | 39.80 | 39.80 | 39.80 | 39.80 | 39.80 | 39.80 | 39.80 | 39.80 | 39.80 |
| Lubricants | GJ per tonne | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 |
| Natural Gas | GJ per 1000 Nm$^3$ | 39.00 | 39.00 | 39.00 | 39.30 | 39.30 | 39.30 | 39.30 | 39.60 | 39.90 | 40.00 |
| Town Gas | GJ per 1000 m$^3$ | | | | | | | 17.00 | 17.00 | 17.00 | 17.00 |
| Electricity Plant Coal | GJ per tonne | 25.30 | 25.40 | 25.80 | 25.20 | 24.50 | 24.50 | 24.70 | 24.96 | 25.00 | 25.00 |
| Other Hard Coal | GJ per tonne | 26.10 | 26.50 | 26.50 | 26.50 | 26.50 | 26.50 | 26.50 | 26.50 | 26.50 | 26.50 |
| Coke | GJ per tonne | 31.80 | 29.30 | 29.30 | 29.30 | 29.30 | 29.30 | 29.30 | 29.30 | 29.30 | 29.30 |
| Brown Coal Briquettes | GJ per tonne | 18.30 | 18.30 | 18.30 | 18.30 | 18.30 | 18.30 | 18.30 | 18.30 | 18.30 | 18.30 |
| Straw | GJ per tonne | 14.50 | 14.50 | 14.50 | 14.50 | 14.50 | 14.50 | 14.50 | 14.50 | 14.50 | 14.50 |
| Wood Chips | GJ per Cubic metre | 2.80 | 2.80 | 2.80 | 2.80 | 2.80 | 2.80 | 2.80 | 2.80 | 2.80 | 2.80 |
| Wood Chips | GJ per m$^3$ | 9.30 | 9.30 | 9.30 | 9.30 | 9.30 | 9.30 | 9.30 | 9.30 | 9.30 | 9.30 |
| Firewood, Hardwood | GJ per m$^3$ | 10.40 | 10.40 | 10.40 | 10.40 | 10.40 | 10.40 | 10.40 | 10.40 | 10.40 | 10.40 |
| Firewood, Conifer | GJ per tonne | 7.60 | 7.60 | 7.60 | 7.60 | 7.60 | 7.60 | 7.60 | 7.60 | 7.60 | 7.60 |
| Wood Pellets | GJ per tonne | 17.50 | 17.50 | 17.50 | 17.50 | 17.50 | 17.50 | 17.50 | 17.50 | 17.50 | 17.50 |
| Wood Waste | GJ per Cubic metre | 14.70 | 14.70 | 14.70 | 14.70 | 14.70 | 14.70 | 14.70 | 14.70 | 14.70 | 14.70 |
| Wood Waste | GJ per 1000 m$^3$ | 3.20 | 3.20 | 3.20 | 3.20 | 3.20 | 3.20 | 3.20 | 3.20 | 3.20 | 3.20 |
| Biogas | GJ per tonne | | | | | | | | 23.00 | 23.00 | 23.00 |
| Wastes | GJ per tonne | 8.20 | 8.20 | 9.00 | 9.40 | 9.40 | 10.00 | 10.50 | 10.50 | 10.50 | 10.50 |
| Bioethanol | GJ per tonne | 26.70 | 26.70 | 26.70 | 26.70 | 26.70 | 26.70 | 26.70 | 26.70 | 26.70 | 26.70 |
| Liquid Biofuels | GJ per tonne | 37.60 | 37.60 | 37.60 | 37.60 | 37.60 | 37.60 | 37.60 | 37.60 | 37.60 | 37.60 |
| Bio Oil | GJ per tonne | 37.20 | 37.20 | 37.20 | 37.20 | 37.20 | 37.20 | 37.20 | 37.20 | 37.20 | 37.20 |
| *Continued* | | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
| Crude Oil, Average | GJ per tonne | 43.00 | 43.00 | 43.00 | 43.00 | 43.00 | 43.00 | 43.00 | 43.00 | 43.00 | 43.00 |
| Crude Oil, Golf | GJ per tonne | 41.80 | 41.80 | 41.80 | 41.80 | 41.80 | 41.80 | 41.80 | 41.80 | 41.80 | 41.80 |
| Crude Oil, North Sea | GJ per tonne | 43.00 | 43.00 | 43.00 | 43.00 | 43.00 | 43.00 | 43.00 | 43.00 | 43.00 | 43.00 |
| Refinery Feedstocks | GJ per tonne | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 |
| Refinery Gas | GJ per tonne | 52.00 | 52.00 | 52.00 | 52.00 | 52.00 | 52.00 | 52.00 | 52.00 | 52.00 | 52.00 |
| LPG | GJ per tonne | 46.00 | 46.00 | 46.00 | 46.00 | 46.00 | 46.00 | 46.00 | 46.00 | 46.00 | 46.00 |
| Naphtha (LVN) | GJ per tonne | 44.50 | 44.50 | 44.50 | 44.50 | 44.50 | 44.50 | 44.50 | 44.50 | 44.50 | 44.50 |
| Motor Gasoline | GJ per tonne | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 |
| Aviation Gasoline | GJ per tonne | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 |
| JP4 | GJ per tonne | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 |
| Other Kerosene | GJ per tonne | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 |
| JP1 | GJ per tonne | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 |
| Gas/Diesel Oil | GJ per tonne | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 |
| Fuel Oil | GJ per tonne | 40.65 | 40.65 | 40.65 | 40.65 | 40.65 | 40.65 | 40.65 | 40.65 | 40.65 | 40.65 |
| Orimulsion | GJ per tonne | 27.62 | 27.64 | 27.71 | 27.65 | 27.65 | 27.65 | 27.65 | 27.65 | 27.65 | 27.65 |
| Petroleum Coke | GJ per tonne | 31.40 | 31.40 | 31.40 | 31.40 | 31.40 | 31.40 | 31.40 | 31.40 | 31.40 | 31.40 |
| Waste Oil | GJ per tonne | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 |
| White Spirit | GJ per tonne | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 |
| Bitumen | GJ per tonne | 39.80 | 39.80 | 39.80 | 39.80 | 39.80 | 39.80 | 39.80 | 39.80 | 39.80 | 39.80 |

| *Continued* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lubricants | GJ per tonne | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 |
| Natural Gas | GJ per 1000 $Nm^3$ | 40.15 | 39.99 | 40.06 | 39.94 | 39.77 | 39.67 | 39.54 | 39.59 | 39.48 | 39.46 |
| Town Gas | GJ per 1000 $m^3$ | 17.01 | 16.88 | 17.39 | 16.88 | 17.58 | 17.51 | 17.20 | 17.14 | 15.50 | 21.29 |
| Electricity Plant Coal | GJ per tonne | 24.80 | 24.90 | 25.15 | 24.73 | 24.60 | 24.40 | 24.80 | 24.40 | 24.30 | 24.60 |
| Other Hard Coal | GJ per tonne | 26.50 | 26.50 | 26.50 | 26.50 | 26.50 | 26.50 | 26.50 | 26.50 | 25.81 | 25.13 |
| Coke | GJ per tonne | 29.30 | 29.30 | 29.30 | 29.30 | 29.30 | 29.30 | 29.30 | 29.30 | 29.30 | 29.30 |
| Brown Coal Briquettes | GJ per tonne | 18.30 | 18.30 | 18.30 | 18.30 | 18.30 | 18.30 | 18.30 | 18.30 | 18.30 | 18.30 |
| Straw | GJ per tonne | 14.50 | 14.50 | 14.50 | 14.50 | 14.50 | 14.50 | 14.50 | 14.50 | 14.50 | 14.50 |
| Wood Chips | GJ per Cubic metre | 2.80 | 2.80 | 2.80 | 2.80 | 2.80 | 2.80 | 2.80 | 2.80 | 2.80 | 2.80 |
| Wood Chips | GJ per $m^3$ | 9.30 | 9.30 | 9.30 | 9.30 | 9.30 | 9.30 | 9.30 | 9.30 | 9.30 | 9.30 |
| Firewood, Hardwood | GJ per $m^3$ | 10.40 | 10.40 | 10.40 | 10.40 | 10.40 | 10.40 | 10.40 | 10.40 | 10.40 | 10.40 |
| Firewood, Conifer | GJ per tonne | 7.60 | 7.60 | 7.60 | 7.60 | 7.60 | 7.60 | 7.60 | 7.60 | 7.60 | 7.60 |
| Wood Pellets | GJ per tonne | 17.50 | 17.50 | 17.50 | 17.50 | 17.50 | 17.50 | 17.50 | 17.50 | 17.50 | 17.50 |
| Wood Waste | GJ per Cubic metre | 14.70 | 14.70 | 14.70 | 14.70 | 14.70 | 14.70 | 14.70 | 14.70 | 14.70 | 14.70 |
| Wood Waste | GJ per 1000 $m^3$ | 3.20 | 3.20 | 3.20 | 3.20 | 3.20 | 3.20 | 3.20 | 3.20 | 3.20 | 3.20 |
| Biogas | GJ per tonne | 23.00 | 23.00 | 23.00 | 23.00 | 23.00 | 23.00 | 23.00 | 23.00 | 23.00 | 23.00 |
| Wastes | GJ per tonne | 10.50 | 10.50 | 10.50 | 10.50 | 10.50 | 10.50 | 10.50 | 10.50 | 10.50 | 10.50 |
| Bioethanol | GJ per tonne | 26.70 | 26.70 | 26.70 | 26.70 | 26.70 | 26.70 | 26.70 | 26.70 | 26.70 | 26.70 |
| Liquid Biofuels | GJ per tonne | 37.60 | 37.60 | 37.60 | 37.60 | 37.60 | 37.60 | 37.60 | 37.60 | 37.50 | 37.50 |
| Bio Oil | GJ per tonne | 37.20 | 37.20 | 37.20 | 37.20 | 37.20 | 37.20 | 37.20 | 37.20 | 37.20 | 37.20 |

| *Continued* | | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|
| Crude Oil, Average | GJ per tonne | 43.00 | 43.00 | 43.00 | 43.00 | 43.00 | 43.00 | 43.00 | 43.00 | 43.00 |
| Crude Oil, Golf | GJ per tonne | 41.80 | 41.80 | 41.80 | 41.80 | 41.80 | 41.80 | 41.80 | 41.80 | 41.80 |
| Crude Oil, North Sea | GJ per tonne | 43.00 | 43.00 | 43.00 | 43.00 | 43.00 | 43.00 | 43.00 | 43.00 | 43.00 |
| Refinery Feedstocks | GJ per tonne | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 |
| Refinery Gas | GJ per tonne | 52.00 | 52.00 | 52.00 | 52.00 | 52.00 | 52.00 | 52.00 | 52.00 | 52.00 |
| LPG | GJ per tonne | 46.00 | 46.00 | 46.00 | 46.00 | 46.00 | 46.00 | 46.00 | 46.00 | 46.00 |
| Naphtha (LVN) | GJ per tonne | 44.50 | 44.50 | 44.50 | 44.50 | 44.50 | 44.50 | 44.50 | 44.50 | 44.50 |
| Motor Gasoline | GJ per tonne | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 |
| Aviation Gasoline | GJ per tonne | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 |
| JP4 | GJ per tonne | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 | 43.80 |
| Other Kerosene | GJ per tonne | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 |
| JP1 | GJ per tonne | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 |
| Gas/Diesel Oil | GJ per tonne | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 | 42.70 |
| Fuel Oil | GJ per tonne | 40.65 | 40.65 | 40.65 | 40.65 | 40.65 | 40.65 | 40.65 | 40.65 | 40.65 |
| Orimulsion | GJ per tonne | 27.65 | 27.65 | 27.65 | 27.65 | 27.65 | 27.65 | 27.65 | 27.65 | 27.65 |
| Petroleum Coke | GJ per tonne | 31.40 | 31.40 | 31.40 | 31.40 | 31.40 | 31.40 | 31.40 | 31.40 | 31.40 |
| Waste Oil | GJ per tonne | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 |
| White Spirit | GJ per tonne | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 | 43.50 |
| Bitumen | GJ per tonne | 39.80 | 39.80 | 39.80 | 39.80 | 39.80 | 39.80 | 39.80 | 39.80 | 39.80 |
| Lubricants | GJ per tonne | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 | 41.90 |
| Natural Gas | GJ per 1000 $Nm^3$ | 39.46 | 39.51 | 39.55 | 38.99 | 39.53 | 39.64 | 39.63 | 39.66 | 39.59 |
| Town Gas | GJ per 1000 $m^3$ | 21.35 | 21.37 | 19.30 | 19.31 | 20.20 | 19.80 | 20.28 | 20.80 | 20.82 |
| Electricity Plant Coal | GJ per tonne | 24.44 | 24.38 | 24.23 | 24.49 | 24.70 | 24.10 | 24.29 | 24.33 | 24.13 |
| Other Hard Coal | GJ per tonne | 24.44 | 24.38 | 24.23 | 24.49 | 24.70 | 24.10 | 26.10 | 26.88 | 26.64 |
| Coke | GJ per tonne | 29.30 | 29.30 | 29.30 | 29.30 | 29.30 | 29.30 | 29.30 | 29.30 | 29.30 |
| Brown Coal Briquettes | GJ per tonne | 18.30 | 18.30 | 18.30 | 18.30 | 18.30 | 18.30 | 18.30 | 18.30 | 18.30 |
| Straw | GJ per tonne | 14.50 | 14.50 | 14.50 | 14.50 | 14.50 | 14.50 | 14.50 | 14.50 | 14.50 |
| Wood Chips | GJ per Cubic metre | 2.80 | 2.80 | 2.80 | 2.80 | 2.80 | 2.80 | 2.80 | 2.80 | 2.80 |
| Wood Chips | GJ per $m^3$ | 9.30 | 9.30 | 9.30 | 9.30 | 9.30 | 9.30 | 9.30 | 9.30 | 9.30 |
| Firewood, Hardwood | GJ per $m^3$ | 10.40 | 10.40 | 10.40 | 10.40 | 10.40 | 10.40 | 10.40 | 10.40 | 10.40 |
| Firewood, Conifer | GJ per tonne | 7.60 | 7.60 | 7.60 | 7.60 | 7.60 | 7.60 | 7.60 | 7.60 | 7.60 |
| Wood Pellets | GJ per tonne | 17.50 | 17.50 | 17.50 | 17.50 | 17.50 | 17.50 | 17.50 | 17.50 | 17.50 |
| Wood Waste | GJ per Cubic metre | 14.70 | 14.70 | 14.70 | 14.70 | 14.70 | 14.70 | 14.70 | 14.70 | 14.70 |
| Wood Waste | GJ per 1000 $m^3$ | 3.20 | 3.20 | 3.20 | 3.20 | 3.20 | 3.20 | 3.20 | 3.20 | 3.20 |
| Biogas | GJ per tonne | 23.00 | 23.00 | 23.00 | 23.00 | 23.00 | 23.00 | 23.00 | 23.00 | 23.00 |
| Wastes | GJ per tonne | 10.50 | 10.50 | 10.50 | 10.60 | 10.60 | 10.60 | 10.60 | 10.60 | 10.60 |
| Bioethanol | GJ per tonne | 26.70 | 26.70 | 26.70 | 26.70 | 26.70 | 26.70 | 26.70 | 26.70 | 26.70 |
| Liquid Biofuels | GJ per tonne | 37.50 | 37.50 | 37.50 | 37.50 | 37.50 | 37.50 | 37.50 | 37.50 | 37.50 |
| Bio Oil | GJ per tonne | 37.20 | 37.20 | 37.20 | 37.20 | 37.20 | 37.20 | 37.20 | 37.20 | 37.20 |

Table 3.2 Fuel category correspondence list, DEA, DCE and Climate Convention reporting (CRF).

| Danish Energy Agency | DCE Emission database | IPCC fuel category |
|---|---|---|
| Other Hard Coal | Coal | Solid |
| Coke | Coke oven coke | Solid |
| Electricity Plant Coal | Coal | Solid |
| Brown Coal Briquettes | BKB | Solid |
| - | Other solid fossil | Solid |
| - | Fly ash fossil | Solid |
| Orimulsion | Orimulsion | Liquid |
| Petroleum Coke | Petroleum coke | Liquid |
| Fuel Oil | Residual oil | Liquid |
| Waste Oil | Residual oil | Liquid |
| Gas/Diesel Oil | Gas oil | Liquid |
| Other Kerosene | Kerosene | Liquid |
| LPG | LPG | Liquid |
| Refinery Gas | Refinery gas | Liquid |
| Town Gas | Natural gas | Gas |
| Natural Gas | Natural gas | Gas |
| Straw | Straw | Biomass |
| Wood Waste | Wood | Biomass |
| Wood Pellets | Wood pellets | Biomass |
| Wood Chips | Wood | Biomass |
| Firewood, Hardwood & Conifer | Wood | Biomass |
| Waste Combustion (biomass) | Municipal wastes | Biomass |
| Bio fuels | Liquid biofuels | Biomass |
| Biogas | Biogas | Biomass |
| Biogas, other | Biogas | Biomass |
| Biogas, landfill | Biogas | Biomass |
| Biogas, sewage sludge | Biogas | Biomass |
| (Wood applied in gas engines) | Biomass gasification gas | Biomass |
| Biogas upgraded for distribution in the natural gas grid | Bio natural gas | Biomass |
| Biogas distributed in the town gas grid | Biogas | Biomass |
| Waste Combustion (fossil) | Fossil waste | Other fuel |

# Annex 4 Emission factors

Table 4.1 $CO_2$ emission factors, 2018.

| Fuel | Emission factor, kg per GJ | | Reference type | IPCC fuel category |
|---|---|---|---|---|
| | Biomass | Fossil fuel | | |
| Coal | | 94.04 [1)] | Country specific | Solid |
| Brown coal briquettes | | 97.5 | IPCC (2006) | Solid |
| Coke oven coke | | 107 [3)] | IPCC (2006) | Solid |
| Other solid fossil fuels [6)] | | 118 [1)] | Country specific | Solid |
| Fly ash fossil (from coal) | | 94.04 | Country specific | Solid |
| Petroleum coke | | 93 [3)] | Country-specific | Liquid |
| Residual oil | | 79.42 [1)] | Country-specific | Liquid |
| Gas oil | | 74.1 [1)] | Country-specific | Liquid |
| Kerosene | | 71.9 | IPCC (2006) | Liquid |
| Orimulsion | | 80 [2)] | Country-specific | Liquid |
| LPG | | 63.1 | IPCC (2006) | Liquid |
| Refinery gas | | 56.144 | Country-specific | Liquid |
| Natural gas, offshore gas turbines | | 57.639 | Country-specific | Gas |
| Natural gas, other | | 56.89 | Country-specific | Gas |
| Waste | 63.3 [3)4)] | + 42.5[1)3)4)] | Country-specific | Biomass and Other fuels |
| Straw | 100 | | IPCC (2006) | Biomass |
| Wood | 112 | | IPCC (2006) | Biomass |
| Wood pellets | 112 | | IPCC (2006) | Biomass |
| Bio oil | 70.8 | | IPCC (2006) | Biomass |
| Biogas | 84.1 | | Country-specific | Biomass |
| Biomass gasification gas | 142.9[5)] | | Country-specific | Biomass |
| Bio natural gas | 55.55 | | Country-specific | Biomass |

1) Plant specific data from EU ETS incorporated for individual plants.

2) Not applied in 2018. Orimulsion was applied in Denmark in 1995 – 2004.

3) Plant specific data from EU ETS incorporated for cement industry and sugar, lime and mineral wool production.

4) The emission factor for waste is (42.5+63.3) kg $CO_2$ per GJ waste. The fuel consumption and the $CO_2$ emission have been disaggregated to the two IPCC fuel categories Biomass and Other fossil fuels in CRF. The corresponding IEF for $CO_2$, Other fuels is 94.44 kg $CO_2$ per GJ fossil waste (not including plant specific data).

5) Includes a high content of $CO_2$ in the gas.

6) Anodic carbon. Not applied in Denmark in 2018.

Time series have been estimated for:

- Coal
- Residual oil
- Refinery gas
- Natural gas applied in offshore gas turbines
- Natural gas, other
- Waste, fossil part
- Industrial waste, biomass part

For all other fuels the same emission factor has been applied for 1990-2018.

Table 4.2 $CO_2$ emission factors, time series.

| Year | Coal, kg per GJ | Residual oil, kg per GJ | Refinery gas, kg per GJ | Natural gas, offshore gas turbines, kg per GJ | Natural gas, other, kg per GJ | Waste, fossil part | Industrial waste, biomass part |
|---|---|---|---|---|---|---|---|
| 1990 | 94 | 78.7 | 57.6 | 57.469 | 56.9 | 37 | 86.7 |
| 1991 | 94 | 78.7 | 57.6 | 57.469 | 56.9 | 37 | 86.7 |
| 1992 | 94 | 78.7 | 57.6 | 57.469 | 56.9 | 37 | 84.2 |
| 1993 | 94 | 78.7 | 57.6 | 57.469 | 56.9 | 37 | 83.0 |
| 1994 | 94 | 78.7 | 57.6 | 57.469 | 56.9 | 37 | 83.0 |
| 1995 | 94 | 78.7 | 57.6 | 57.469 | 56.9 | 37 | 81.1 |
| 1996 | 94 | 78.7 | 57.6 | 57.469 | 56.9 | 37 | 79.6 |
| 1997 | 94 | 78.7 | 57.6 | 57.469 | 56.9 | 37 | 79.6 |
| 1998 | 94 | 78.7 | 57.6 | 57.469 | 56.9 | 37 | 79.6 |
| 1999 | 94 | 78.7 | 57.6 | 57.469 | 56.9 | 37 | 79.6 |
| 2000 | 94 | 78.7 | 57.6 | 57.469 | 57.1 | 37 | 79.6 |
| 2001 | 94 | 78.7 | 57.6 | 57.469 | 57.25 | 37 | 79.6 |
| 2002 | 94 | 78.7 | 57.6 | 57.469 | 57.28 | 37 | 79.6 |
| 2003 | 94 | 78.7 | 57.6 | 57.469 | 57.19 | 37 | 79.6 |
| 2004 | 94 | 78.7 | 57.6 | 57.469 | 57.12 | 37 | 79.6 |
| 2005 | 94 | 78.7 | 57.6 | 57.469 | 56.96 | 37 | 79.6 |
| 2006 | 94.4 | 78.6 | 57.812 | 57.879 | 56.78 | 37 | 79.6 |
| 2007 | 94.3 | 78.5 | 57.848 | 57.784 | 56.78 | 37 | 79.6 |
| 2008 | 94.0 | 78.5 | 57.948 | 56.959 | 56.77 | 37 | 79.6 |
| 2009 | 93.6 | 78.9 | 56.817 | 57.254 | 56.69 | 37 | 79.6 |
| 2010 | 93.6 | 79.2 | 57.134 | 57.314 | 56.74 | 37 | 79.6 |
| 2011 | 94.73 | 79.25 | 57.861 | 57.379 | 56.97 | 37.5 | 79.6 |
| 2012 | 94.25 | 79.21 | 58.108 | 57.423 | 57.03 | 40.0 | 79.6 |
| 2013 | 93.95 | 79.28 | 58.274 | 57.295 | 56.79 | 42.5 | 79.6 |
| 2014 | 94.17 | 79.49 | 57.620 | 57.381 | 56.95 | 42.5 | 79.6 |
| 2015 | 94.46 | 79.17 | 57.508 | 57.615 | 57.06 | 42.5 | 79.6 |
| 2016 | 94.95 | 79.29 | 57.335 | 57.704 | 57.01 | 42.5 | 79.6 |
| 2017 | 94.37 | 79.19 | 57.109 | 57.628 | 57.00 | 42.5 | 79.6 |
| 2018 | 94.04 | 79.42 | 56.144 | 57.639 | 56.89 | 42.5 | 79.6 |

Table 4.3 $CH_4$ emission factors and references, 2018.

| Fuel group | Fuel | CRF source category | CRF source category | SNAP | Emission factor, g per GJ | Reference |
|---|---|---|---|---|---|---|
| SOLID | Coal | 1A1a | Public electricity and heat production | 0101<br>0102 | 0.9 | IPCC (2006), Tier 3, Table 2-6, Utility Boiler, Pulverised bituminous coal combustion, Wet bottom. |
| | | 1A2 a-g | Industry | 03 | 10 | IPCC (2006), Tier 1, Table 2-3, Manufacturing industries. |
| | | 1A4b i | Residential | 0202 | 300 | IPCC (2006), Tier 1, Table 2.5, Residential, Bituminous coal. |
| | | 1A4c i | Agriculture/Forestry | 0203 | 10 | IPCC (2006), Tier 1, Table 2-4, Commercial, coal.[1)] |
| | BKB | 1A4b i | Residential | 0202 | 300 | IPCC (2006), Tier 1, Table 2-5, Residential, brown coal briquettes |
| | Coke oven coke | 1A2 a-g | Industry | 03 | 10 | IPCC (2006), Tier 1, Table 2-4, Commercial, coke oven coke. |
| | | 1A4b i | Residential | 0202 | 300 | IPCC (2006), Tier 1, Table 2-5, Residential, coke oven coke. |
| | Anodic carbon | 1A2 a-g | Industry | 03 | 10 | IPCC (2006), Tier 1, Table 2-3, Manufacturing industries. |
| | Fossil fly ash | 1A1a | Public electricity and heat production | 0101 | 0.9 | IPCC (2006), Tier 3, Table 2-6, Utility Boiler, Pulverised bituminous coal combustion, Wet bottom. |
| LIQUID | Petroleum coke | 1A2 a-g | Industry | 03 | 3 | IPCC (2006), Tier 1, Table 2-3, Industry, petroleum coke. |
| | | 1A4a | Commercial/ Institutional | 0201 | 10 | IPCC (2006), Tier 1, Table 2-4, Commercial, Petroleum coke. |
| | | 1A4b | Residential | 0202 | 10 | IPCC (2006), Tier 1, Table 2-5, Residential / agricultural, Petroleum coke. |
| | | 1A4c | Agriculture/Forestry | 0203 | 10 | IPCC (2006), Tier 1, Table 2-5, Residential / agricultural, Petroleum coke. |
| | Residual oil | 1A1a | Public electricity and heat production | 010101 | 0.8 | IPCC (2006), Tier 3, Table 2-6, Utility Boiler, Residual fuel oil. |
| | | | | 010102<br>010103 | 1.3 | Nielsen et al. (2010a) |
| | | | | 010104 | 3 | IPCC (2006), Tier 1, Table 2-2, Energy industries, residual oil. |
| | | | | 010105 | 4 | IPCC (2006), Tier 3, Table 2-6, Utility, Large diesel engines |
| | | | | 010203 | 0.8 | IPCC (2006), Tier 3, Table 2-6, Utility Boiler, Residual fuel oil. |
| | | 1A1b | Petroleum refining | 010306 | 3 | IPCC (2006), Tier 1, Table 2-2, Energy industries, residual fuel oil. |
| | | 1A2 a-g | Industry | 03 | 1.3 | Nielsen et al. (2010a) |
| | | | | Engines | 4 | IPCC (2006), Tier 3, Table 2-6, Utility, Large diesel engines |
| | | 1A4a | Commercial/ Institutional | 0201 | 1.4 | IPCC (2006), Tier 3, Table 2-10, Commercial, residual fuel oil boilers. |
| | | 1A4b | Residential | 0202 | 1.4 | IPCC (2006), Tier 3, Table 2-9, Residential, residual fuel oil. |
| | | 1A4c | Agriculture/Forestry | 0203 | 1.4 | IPCC (2006), Tier 3, Table 2-10, Commercial, residual fuel oil boilers.[1)]. |
| | Gas oil | 1A1a | Public electricity and heat production | 010101<br>010102<br>010103 | 0.9 | IPCC (2006), Tier 3, Table 2-6, Utility, gas oil, boilers. |
| | | | | 010104 | 3 | IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil. |
| | | | | 010105 | 24 | Nielsen et al. (2010a) |
| | | | | 010202<br>010203 | 0.9 | IPCC (2006), Tier 3, Table 2-6, Utility, gas oil, boilers. |
| | | 1A1b | Petroleum refining | 010306 | 3 | IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil. |
| | | 1A1c | Oil and gas extraction | 010504 | 3 | IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil. |
| | | 1A2 a-g | Industry | 03 | 0.2 | IPCC (2006), Tier 3, Table 2-7, Industry, gas oil, boilers. |
| | | | | Turbines | 3 | IPCC (2006), Tier 1, Table 2-3, Industry, gas oil. |
| | | | | Engines | 24 | Nielsen et al. (2010a) |

| Fuel group | Fuel | CRF source category | CRF source category | SNAP | Emission factor, g per GJ | Reference |
|---|---|---|---|---|---|---|
| | | 1A4a | Commercial/ Institutional | 0201 | 0.7 | IPCC (2006), Tier 3, Table 2-10, Commercial, gas oil. |
| | | | | 020105 | 24 | Nielsen et al. (2010a) |
| | | 1A4b i | Residential | 0202 | 0.7 | IPCC (2006), Tier 3, Table 2.9, Residential, gas oil. |
| | | | | 020204 | 24 | Nielsen et al. (2010a) |
| | | 1A4c | Agriculture/Forestry | 0203 | 0.7 | IPCC (2006), Tier 3, Table 2-10, Commercial, gas oil[1]. |
| | | | | 020304 | 24 | Nielsen et al. (2010a) |
| | Kerosene | 1A2 a-g | Industry | 03 | 3 | IPCC (2006), Tier 1, Table 2-3, Industry, other kerosene. |
| | | 1A4a | Commercial/ Institutional | 0201 | 10 | IPCC (2006), Tier 1, Table 2-4, Commercial, other kerosene. |
| | | 1A4b i | Residential | 0202 | 10 | IPCC (2006), Tier 1, Table 2-5, Residential/agricultural, other kerosene. |
| | | 1A4c i | Agriculture/Forestry | 0203 | 10 | IPCC (2006), Tier 1, Table 2-5, Residential/agricultural, other kerosene. |
| | LPG | 1A1a | Public electricity and heat production | 0101<br>0102 | 1 | IPCC (2006), Tier 1, Table 2-2, Energy Industries, LPG. |
| | | 1A1b | Petroleum refining | 0103 | 1 | IPCC (2006), Tier 1, Table 2-2, Energy Industries, LPG. |
| | | 1A2 a-g | Industry | 03 | 1 | IPCC (2006), Tier 1, Table 2-3, Industry, LPG |
| | | 1A4a | Commercial/ Institutional | 0201 | 5 | IPCC (2006), Tier 1, Table 2-4, Commercial, LPG. |
| | | 1A4b i | Residential | 0202 | 5 | IPCC (2006), Tier 1, Table 2-5, Residential / agricultural, LPG. |
| | | 1A4c i | Agriculture/ Forestry | 0203 | 5 | IPCC (2006), Tier 1, Table 2-5, Residential / agricultural, LPG. |
| | Refinery gas | 1A1b | Petroleum refining | 010304 | 1.7 | Assumed equal to natural gas fuelled gas turbines. Nielsen et al. (2010a) |
| | | | | 010306 | 1 | IPCC (2006), Tier 1, Table 2-2, refinery gas. |
| GAS | Natural gas | 1A1a | Public electricity and heat production | 010101<br>010102<br>010103 | 1 | IPCC (2006), Tier 3, Table 2-6, Utility, natural gas, boilers. |
| | | | | 010104 | 1.7 | Nielsen et al. (2010a) |
| | | | | 010105 | 481 | Nielsen et al. (2010a) |
| | | | | 010202<br>010203 | 1 | IPCC (2006), Tier 3, Table 2-6, Utility, natural gas, boilers. |
| | | 1A1b | Petroleum refining | 010306 | 1 | Assumed equal to industrial boilers. |
| | | 1A1c | Oil and gas extraction | 010503 | 1 | Assumed equal to industrial boilers. |
| | | | | 010504 | 1.7 | Nielsen et al. (2010a) |
| | | 1A2 a-g | Industry | Other | 1 | IPCC (2006), Tier 3, Table 2-7, Industry, natural gas boilers. |
| | | | | Gas tur-bines | 1.7 | Nielsen et al. (2010a) |
| | | | | Engines | 481 | Nielsen et al. (2010a) |
| | | 1A4a | Commercial/ Institu-tional | 0201 | 1 | IPCC (2006), Tier 3, Table 2-10, Commer-cial, natural gas boilers. |
| | | | | 020105 | 481 | Nielsen et al. (2010a) |
| | | 1A4b i | Residential | 0202 | 1 | IPCC (2006), Tier 3, Table 2-9. Residen-tial, natural gas boilers. |
| | | | | 020204 | 481 | Nielsen et al. (2010a) |
| | | 1A4c i | Agriculture/ Forestry | 0203 | 1 | IPCC (2006), Tier 3, Table 2-10, Commercial, natural gas boilers[1]. |
| | | | | 020304 | 481 | Nielsen et al. (2010a) |
| WAST E | Waste | 1A1a | Public electricity and heat production | 0101<br>0102 | 0.34 | Nielsen et al. (2010a) |
| | | 1A2 a-g | Industry | 03 | 30 | IPCC (2006), Tier 1, Table 2-3, Industry, municipal wastes. |
| | | 1A4a | Commercial/ Institutional | 0201 | 30 | IPCC (2006), Tier 1, Table 2-3, Industry, municipal wastes [2]. |
| | Industrial waste | 1A2f | Industry | 0316 | 30 | IPCC (2006), Tier 1, Table 2-3, Industry, industrial wastes. |
| BIO-MASS | Wood | 1A1a | Public electricity and heat production | 0101 | 3.1 | Nielsen et al. (2010a) |

| Fuel group | Fuel | CRF source category | CRF source category | SNAP | Emission factor, g per GJ | Reference |
|---|---|---|---|---|---|---|
| | | | | 0102 | 11 | IPCC (2006), Tier 3, Table 2-6, Utility boilers, wood |
| | | 1A2 a-g | Industry | 03 | 11 | IPCC (2006), Tier 3, Table 2-7, Industry, wood, boilers. |
| | | 1A4a | Commercial/ Institutional | 0201 | 11 | IPCC (2006), Tier 3, Table 2-10, Commercial, wood. |
| | | 1A4b i | Residential | 0202 | 110.77 | DCE estimate based on technology distribution, Nielsen et al. (2020) 3) |
| | | 1A4c i | Agriculture/ Forestry | 0203 | 11 | IPCC (2006), Tier 3, Table 2-10, Commercial, wood.1). |
| | Straw | 1A1a | Public electricity and heat production | 0101 | 0.47 | Nielsen et al. (2010a) |
| | | | | 0102 | 30 | IPCC (2006), Tier 1, Table 2-2, Energy industries, other primary solid biomass |
| | | 1A4b i | Residential | 0202 | 300 | IPCC (2006), Tier 1, Table 2-5, Residential, other primary solid biomass. |
| | | 1A4c i | Agriculture/ Forestry | 020300 | 300 | IPCC (2006), Tier 1, Table 2-5, Agriculture, other primary solid biomass. |
| | | | | 020302 | 30 | IPCC (2006), Tier 1, Table 2-2, Energy industries, other primary solid biomass (large agricultural plants considered equal to this plant category) |
| | Wood pellets | 1A1a | Public electricity and heat production | 0101 | 3.1 | Nielsen et al. (2010a) |
| | | | | 0102 | 11 | IPCC (2006), Tier 3, Table 2-6, Utility boilers, wood |
| | | 1A2 a-g | Industry | 03 | 11 | IPCC (2006), Tier 3, Table 2-7, Industry, wood, boilers. |
| | | 1A4a | Commercial/ Institutional | 0201 | 11 | IPCC (2006), Tier 3, Table 2-10, Commercial, wood. |
| | | 1A4b i | Residential | 0202 | 3 | Paulrud et al. (2005) |
| | | 1A4c i | Agriculture/ Forestry | 0203 | 11 | IPCC (2006), Tier 3, Table 2-10, Commercial, wood.1). |
| | Bio oil | 1A1a | Public electricity and heat production | 010102 | 3 | IPCC (2006), Tier 1, Table 2-2, Energy industries, biodiesels. |
| | | | | 010105 | 24 | Nielsen et al. (2010a) assumed same emission factor as for gas oil fuelled engines. |
| | | | | 0102 | 3 | IPCC (2006), Tier 1, Table 2-2, Energy industries, biodiesels. |
| | | 1A2 a-g | Industry | 03 | 3 | IPCC (2006), Tier 1, Table 2-3, Industry, biodiesels. |
| | | | | 030902 | 0.2 | - |
| | | 1A4b i | Residential | 0202 | 10 | IPCC (2006), Tier 1, Table 2-5, Residential, biodiesels. |
| | Biogas | 1A1a | Public electricity and heat production | 0101 | 1 | IPCC (2006), Tier 1, Table 2-2, Energy industries, other biogas. |
| | | | | 010105 | 434 | Nielsen et al. (2010a) |
| | | | | 0102 | 1 | IPCC (2006), Tier 1, Table 2-2, Energy industries, other biogas. |
| | | 1A2 a-g | Industry | 03 | 1 | IPCC (2006), Tier 1, Table 2-3, Industry, other biogas. |
| | | | | Engines | 434 | Nielsen et al. (2010a) |
| | | 1A4a | Commercial/ Institutional | 0201 | 5 | IPCC (2006), Tier 1, Table 2-4, Commercial, other biogas. |
| | | | | 020105 | 434 | Nielsen et al. (2010a) |
| | | 1A4b | Residential | 0202 | 1 | Assumed equal to natural gas. |
| | | 1A4c i | Agriculture/ Forestry | 0203 | 5 | IPCC (2006), Tier 1, Table 2-5, Agriculture, other biogas. |
| | | | | 020304 | 434 | Nielsen et al. (2010a) |
| | Bio gasification gas | 1A1a | Public electricity and heat production | 010101 | 1 | Assumed equal to biogas. |
| | | | | 010105 | 13 | Nielsen et al. (2010a) |
| | | 1A4a | Commercial/ Institutional | 020105 | 13 | Nielsen et al. (2010a) |

| Fuel group | Fuel | CRF source category | CRF source category | SNAP | Emission factor, g per GJ | Reference |
|---|---|---|---|---|---|---|
| | Bio natural gas | 1A1a | Public electricity and heat production | 0101 0102 | 1 | Assumed equal to natural gas. |
| | | 1A2 a-g | Industry | 03 | 1 | Assumed equal to natural gas. |
| | | 1A4a | Commercial/ Institutional | 0201 | 1 | Assumed equal to natural gas. |
| | | 1A4b | Residential | 0202 | 1 | Assumed equal to natural gas. |
| | | 1A4c | Agriculture/ Forestry | 0203 | 1 | Assumed equal to natural gas. |

1. Assumed same emission factors as for commercial plants. Plant capacity and technology are similar for Danish plants.
2. Assumed same emission factor as for industrial plants. Plant capacity and technology is similar to industrial plants rather than to residential plants.
3. Aggregated emission factor based on the technology distribution in the sector (Nielsen et al., 2020) and technology specific emission factors that refer to Paulrud et al. (2005), Johansson et al. (2004) and Olsson & Kjällstrand (2005). The emission factor is within the IPCC (2006) interval for residential wood combustion (100-900 g per GJ).

In general, the same $CH_4$ emission factors have been applied for 1990-2018. However, time series have been estimated for both natural gas fuelled engines and biogas fuelled engines, residential wood combustion, natural gas fuelled gas turbines[34] and waste incineration plants**Error! Bookmark not defined.**.

Table 4.4 $CH_4$ emission factors, time series.

| Year | Natural gas fuelled engines Emission factor, g per GJ | Biogas fuelled engines Emission factor, g per GJ | Residential wood combustion, g per GJ | Waste incineration g per GJ | Natural gas fuelled gas turbines, g per GJ |
|---|---|---|---|---|---|
| 1990 | 266 | 239 | 327 | 0.59 | 1.5 |
| 1991 | 309 | 251 | 321 | 0.59 | 1.5 |
| 1992 | 359 | 264 | 314 | 0.59 | 1.5 |
| 1993 | 562 | 276 | 308 | 0.59 | 1.5 |
| 1994 | 623 | 289 | 302 | 0.59 | 1.5 |
| 1995 | 632 | 301 | 296 | 0.59 | 1.5 |
| 1996 | 616 | 305 | 289 | 0.59 | 1.5 |
| 1997 | 551 | 310 | 283 | 0.59 | 1.5 |
| 1998 | 542 | 314 | 276 | 0.59 | 1.5 |
| 1999 | 541 | 318 | 270 | 0.59 | 1.5 |
| 2000 | 537 | 323 | 263 | 0.59 | 1.5 |
| 2001 | 522 | 342 | 256 | 0.59 | 1.5 |
| 2002 | 508 | 360 | 248 | 0.59 | 1.6 |
| 2003 | 494 | 379 | 240 | 0.59 | 1.6 |
| 2004 | 479 | 397 | 227 | 0.51 | 1.7 |
| 2005 | 465 | 416 | 215 | 0.42 | 1.7 |
| 2006 | 473 | 434 | 206 | 0.34 | 1.7 |
| 2007 | 481 | 434 | 197 | 0.34 | 1.7 |
| 2008 | 481 | 434 | 188 | 0.34 | 1.7 |
| 2009 | 481 | 434 | 178 | 0.34 | 1.7 |
| 2010 | 481 | 434 | 167 | 0.34 | 1.7 |
| 2011 | 481 | 434 | 160 | 0.34 | 1.7 |
| 2012 | 481 | 434 | 152 | 0.34 | 1.7 |
| 2013 | 481 | 434 | 145 | 0.34 | 1.7 |
| 2014 | 481 | 434 | 138 | 0.34 | 1.7 |
| 2015 | 481 | 434 | 131 | 0.34 | 1.7 |
| 2016 | 481 | 434 | 124 | 0.34 | 1.7 |
| 2017 | 481 | 434 | 117 | 0.34 | 1.7 |
| 2018 | 481 | 434 | 111 | 0.34 | 1.7 |

[34] A minor emission source.

Table 4.5 $N_2O$ emission factors and references, 2018.

| Fuel group | Fuel | CRF source category | CRF source category | SNAP | Emission factor, g per GJ | Reference |
|---|---|---|---|---|---|---|
| SOLID | Coal | 1A1a | Public electricity and heat production | 0101 | 0.8 | Henriksen (2005) |
| | | | | 0102 | 1.4 | IPCC (2006), Tier 3, Table 2.6, Utility source, pulverised bituminous coal, wet bottom boiler. |
| | | 1A2 a-g | Industry | 03 | 1.5 | IPCC (2006), Tier 1, Table 2-3, Manufacturing industries, coal |
| | | 1A4b i | Residential | 0202 | 1.5 | IPCC (2006), Tier 1, Table 2-5, Residential, coal |
| | | 1A4c i | Agriculture/ Forestry | 0203 | 1.5 | IPCC (2006), Tier 1, Table 2-4, Commercial, coal[1)] |
| | BKB | 1A4b i | Residential | 0202 | 1.5 | IPCC (2006), Tier 1, Table 2-5, Residential, brown coal briquettes |
| | Coke oven coke | 1A2 a-g | Industry | 03 | 1.5 | IPCC (2006), Tier 1, Table 2-3, Industry, coke oven coke |
| | | 1A4b i | Residential | 020200 | 1.5 | IPCC (2006), Tier 1, Table 2-5, Residential, coke oven coke |
| | Anodic carbon | 1A2 a-g | Industry | 03 | 1.5 | IPCC (2006), Tier 1, Table 2-3, manufacturing industries, other bituminous coal |
| | Fossil fly ash | 1A1a | Public electricity and heat production | 0101 | 0.8 | Assumed equal to coal. |
| LIQUID | Petroleum coke | 1A2 a-g | Industry – other | 03 | 0.6 | IPCC (2006), Tier 1, Table 2-3, Industry, petroleum coke |
| | | | | 031600 | 1.5 | - |
| | | 1A4a | Commercial/ Institutional | 0201 | 0.6 | IPCC (2006), Tier 1, Table 2-4, Commercial, petroleum coke |
| | | 1A4b i | Residential | 0202 | 0.6 | IPCC (2006), Tier 1, Table 2-5, Residential, petroleum coke |
| | | 1A4c i | Agriculture/ Forestry | 0203 | 0.6 | IPCC (2006), Tier 1, Table 2-5, Residential/Agricultural, petroleum coke |
| | Residual oil | 1A1a | Public electricity and heat production | 010101 | 0.3 | IPCC (2006), Tier 3, Table 2-6, Utility, residual fuel oil |
| | | | | 010102<br>010103 | 5 | Nielsen et al. (2010a) |
| | | | | 010104<br>010105 | 0.6 | IPCC (2006), Tier 1, Table 2-2, Energy industries, residual fuel oil |
| | | | | 010203 | 0.3 | IPCC (2006), Tier 3, Table 2-6, Utility, residual fuel oil |
| | | 1A1b | Petroleum refining | 010306 | 0.6 | IPCC (2006), Tier 1, Table 2-2, Energy industries, residual fuel oil |
| | | 1A2 a-g | Industry | 03 | 5 | Nielsen et al. (2010a) |
| | | | | Engines | 0.6 | IPCC (2006), Tier 1, Table 2-3, manufacturing industries and construction, residual fuel oil. |
| | | 1A4a | Commercial/ Institutional | 0201 | 0.3 | IPCC (2006), Tier 3, Table 2-10, Commercial, fuel oil boilers |
| | | 1A4b i | Residential | 0202 | 0.6 | IPCC (2006), Tier 1, Table 2-5, Residential, residual fuel oil |
| | | 1A4c i | Agriculture/ Forestry | 0203 | 0.3 | IPCC (2006), Tier 3, Table 2-10, Commercial, fuel oil boilers[1)] |
| | Gas oil | 1A1a | Public electricity and heat production | 010101<br>010102<br>010103 | 0.4 | IPCC (2006), Tier 3, Table 2-6, Utility, gas oil boilers |
| | | | | 010104 | 0.6 | IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil |
| | | | | 010105 | 2.1 | Nielsen et al. (2010a) |
| | | | | 0102 | 0.4 | IPCC (2006), Tier 3, Table 2-6, Utility, gas oil boilers |
| | | 1A1b | Petroleum refining | 010306 | 0.6 | IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil |

| Fuel group | Fuel | CRF source category | CRF source category | SNAP | Emission factor, g per GJ | Reference |
|---|---|---|---|---|---|---|
| | | 1A1c | Oil and gas extraction | 010504 | 0.6 | IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil |
| | | 1A2 a-g | Industry | 03 | 0.4 | IPCC (2006), Tier 3, Table 2-7, Industry, gas oil boilers |
| | | | | Tur-bines | 0.6 | IPCC (2006), Tier 1, Table 2-3, Industry, gas oil |
| | | | | Engines | 2.1 | Nielsen et al. (2010a) |
| | | 1A4a | Commercial/ Institutional | 0201 | 0.4 | IPCC (2006), Tier 3, Table 2-10, Commercial, gas oil boilers |
| | | | | Engines | 2.1 | Nielsen et al. (2010a) |
| | | 1A4b i | Residential | 0202 | 0.6 | IPCC (2006), Tier 1, Table 2-5, Residen-tial, gas oil |
| | | | | Engines | 2.1 | Nielsen et al. (2010a) |
| | | 1A4c | Agriculture/ Forestry | 0203 | 0.4 | IPCC (2006), Tier 3, Table 2-10, Commercial, gas oil boilers[1)] |
| | | | | Engines | 2.1 | Nielsen et al. (2010a) |
| | Kerosene | 1A2 a-g | Industry | 03 | 0.6 | IPCC (2006), Tier 1, Table 2-3, Industry, other kerosene |
| | | 1A4a | Commercial/ Institutional | 0201 | 0.6 | IPCC (2006), Tier 1, Table 2-4, Commercial, other kerosene |
| | | 1A4b i | Residential | 0202 | 0.6 | IPCC (2006), Tier 1, Table 2-5, Residential, other kerosene |
| | | 1A4c i | Agriculture/ Forestry | 0203 | 0.6 | IPCC (2006), Tier 1, Table 2-4, Commercial, other kerosene [1)] |
| | LPG | 1A1a | Public electricity and heat production | 0101<br>0102 | 0.1 | IPCC (2006), Tier 1, Table 2-2, Energy industries, LPG |
| | | 1A1b | Petroleum refining | 010306 | 0.1 | IPCC (2006), Tier 1, Table 2-2, Energy industries, LPG |
| | | 1A2 a-g | Industry | 03 | 0.1 | IPCC (2006), Tier 1, Table 2-3, Industry, LPG |
| | | 1A4a | Commercial/ Institutional | 0201 | 0.1 | IPCC (2006), Tier 1, Table 2-4, Commercial, LPG |
| | | 1A4b i | Residential | 0202 | 0.1 | IPCC (2006), Tier 1, Table 2-5, Residential, LPG |
| | | 1A4c i | Agriculture/ Forestry | 0203 | 0.1 | IPCC (2006), Tier 1, Table 2-5, Residential/Agricultural, LPG |
| | Refinery gas | 1A1b | Petroleum refining | 010304 | 1 | Assumed equal to natural gas fuelled tur-bines. Based on Nielsen et al. (2010a). |
| | | | | 010306 | 0.1 | IPCC (2006), Tier 1, Table 2-2, Energy industries, refinery gas |
| GAS | Natural gas | 1A1a | Public electricity and heat production | 010101<br>010102<br>010103 | 1 | IPCC (2006), Tier 3, Table 2-6, Natural gas, Utility, boiler |
| | | | | 010104 | 1 | Nielsen et al. (2010a) |
| | | | | 010105 | 0.58 | Nielsen et al. (2010a) |
| | | | | 0102 | 1 | IPCC (2006), Tier 3, Table 2-6, Natural gas, Utility, boiler |
| | | 1A1b | Petroleum refining | 010306 | 1 | IPCC (2006), Tier 3, Table 2-6, Natural gas, Utility, boiler |
| | | 1A1c | Oil and gas extraction | 010504 | 1 | Nielsen et al. (2010a) |
| | | 1A2 a-g | Industry | 03 | 1 | IPCC (2006), Tier 3, Table 2-7, Industry, natural gas boilers |
| | | | | Gas tur-bines | 1 | Nielsen et al. (2010a) |
| | | | | Engines | 0.58 | Nielsen et al. (2010a) |
| | | 1A4a | Commercial/ Institutional | 020100<br>020103 | 1 | IPCC (2006), Tier 3, Table 2-10, Commercial, natural gas boilers |
| | | | | Engines | 0.58 | Nielsen et al. (2010a) |
| | | 1A4b i | Residential | 0202 | 1 | IPCC (2006), Tier 3, Table 2-9, Residential, natural gas boilers |
| | | | | Engines | 0.58 | Nielsen et al. (2010a) |

| Fuel group | Fuel | CRF source category | CRF source category | SNAP | Emission factor, g per GJ | Reference |
|---|---|---|---|---|---|---|
| | | 1A4c i | Agriculture/ Forestry | 0203 | 1 | IPCC (2006), Tier 3, Table 2-10, Commercial, natural gas boilers [1)] |
| | | | | Engines | 0.58 | Nielsen et al. (2010a) |
| WASTE | Waste | 1A1a | Public electricity and heat production | 0101 0102 | 1.2 | Nielsen et al. (2010a) |
| | | 1A2 a-g | Industry | 03 | 4 | IPCC (2006), Tier 1, Table 2-3, Industry, wastes |
| | | 1A4a | Commercial/ Institutional | 0201 | 4 | IPCC (2006), Tier 1, Table 2-4, Commercial, municipal wastes |
| | Industrial waste | 1A2 a-g | Industry | 03 | 4 | IPCC (2006), Tier 1, Table 2-3, Industry, industrial wastes |
| BIO-MASS | Wood | 1A1a | Public electricity and heat production | 0101 | 0.8 | Nielsen et al. (2010a) |
| | | | | 0102 | 4 | IPCC (2006), Tier 1, Table 2-2, Energy industries, wood |
| | | 1A2 a-g | Industry | 03 | 4 | IPCC (2006), Tier 1, Table 2-3, Industry, wood |
| | | 1A4a | Commercial/ Institutional | 0201 | 4 | IPCC (2006), Tier 1, Table 2-4, Commercial, wood |
| | | 1A4b i | Residential | 0202 | 4 | IPCC (2006), Tier 1, Table 2-5, Residential, wood |
| | | 1A4c i | Agriculture/ Forestry | 0203 | 4 | IPCC (2006), Tier 1, Table 2-5, Agriculture, wood |
| | Straw | 1A1a | Public electricity and heat production | 0101 | 1.1 | Nielsen et al. (2010a) |
| | | | | 0102 | 4 | IPCC (2006), Tier 1, Table 2-2, Energy industries, other primary solid bio-mass |
| | | 1A4b i | Residential | 0202 | 4 | IPCC (2006), Tier 1, Table 2-5, Residential, other primary solid biomass |
| | | 1A4c i | Agriculture/ Forestry | 0203 | 4 | IPCC (2006), Tier 1, Table 2-5, Agriculture, other primary solid biomass |
| | Wood pellets | 1A1a | Public electricity and heat production | 0101 | 0.8 | Nielsen et al. (2010a) |
| | | | | 0102 | 4 | IPCC (2006), Tier 1, Table 2-2, Energy industries, wood |
| | | 1A2 a-g | Industry | 03 | 4 | IPCC (2006), Tier 1, Table 2-3, Industry, wood |
| | | 1A4a | Commercial/ Institutional | 0201 | 4 | IPCC (2006), Tier 1, Table 2-4, Commercial, wood |
| | | 1A4b i | Residential | 0202 | 4 | IPCC (2006), Tier 1, Table 2-5, Residential, wood |
| | Bio oil | 1A1a | Public electricity and heat production | 0101 0102 | 0.6 | IPCC (2006), Tier 3, Table 2-2, Utility, biodiesels |
| | | | | Engines | 2.1 | Assumed equal to gas oil. Based on Nielsen et al. (2010a) |
| | | 1A2 a-g | Industry | 03 | 0.4 | Assumed equal to gas oil. |
| | | 1A4b i | Residential | 0202 | 0.6 | IPCC (2006), Tier 1, Table 2-5, Residential, biodiesels |
| | Biogas | 1A1a | Public electricity and heat production | 0101 0102 | 0.1 | IPCC (2006), Tier 1, Table 2-2, Energy industries, other biogas |
| | | | | Engines | 1.6 | Nielsen et al. (2010a) |
| | | 1A2 a-g | Industry | 03 | 0.1 | IPCC (2006), Tier 1, Table 2-3, Industry, other biogas |
| | | | | Engines | 1.6 | Nielsen et al. (2010a) |
| | | 1A4a | Commercial/ Institutional | 0201 | 0.1 | IPCC (2006), Tier 1, Table 2,4, Commercial, other biogas |
| | | | | Engines | 1.6 | Nielsen et al. (2010a) |
| | | 1A4b | Residential | 0202 | 1 | Assumed equal to natural gas. |
| | | 1A4c i | Agriculture/ Forestry | 0203 | 0.1 | IPCC (2006), Tier 1, Table 2-5, Agriculture, other biogas |

| Fuel group | Fuel | CRF source category | CRF source category | SNAP | Emission factor, g per GJ | Reference |
|---|---|---|---|---|---|---|
| | | | | Engines | 1.6 | Nielsen et al. (2010a) |
| | Bio gasification gas | 1A1a | Public electricity and heat production | 010101 | 0.1 | Assumed equal to biogas. |
| | | | | 010105 | 2.7 | Nielsen et al. (2010a) |
| | | 1A4a | Commercial/ Institutional | 020105 | 2.7 | Nielsen et al. (2010a) |
| | Bio natural gas | 1A1a | Public electricity and heat production | 0101 or 0102 | 1 | Assumed equal to natural gas. |
| | | 1A2 a-g | Industry | 03 | 1 | Assumed equal to natural gas. |
| | | 1A4a | Commercial/ Institutional | 0201 | 1 | Assumed equal to natural gas. |
| | | 1A4b | Residential | 0202 | 1 | Assumed equal to natural gas. |
| | | 1A4c | Agriculture/ Forestry | 0203 | 1 | Assumed equal to natural gas. |

1) In Denmark, plants in Agriculture/Forestry are similar to Commercial plants.

Time series have been estimated for natural gas fuelled gas turbines and refinery gas fuelled turbines. All other emission factors have been applied unchanged for 1990-2018.

Table 4.6 $N_2O$ emission factors, time series.

| Year | Natural gas fuelled gas turbines. Emission factor, g per GJ | Refinery gas fuelled gas turbines. Emission factor, g per GJ |
|---|---|---|
| 1990 | 2.2 | 2.2 |
| 1991 | 2.2 | 2.2 |
| 1992 | 2.2 | 2.2 |
| 1993 | 2.2 | 2.2 |
| 1994 | 2.2 | 2.2 |
| 1995 | 2.2 | 2.2 |
| 1996 | 2.2 | 2.2 |
| 1997 | 2.2 | 2.2 |
| 1998 | 2.2 | 2.2 |
| 1999 | 2.2 | 2.2 |
| 2000 | 2.2 | 2.2 |
| 2001 | 2.0 | 2.0 |
| 2002 | 1.9 | 1.9 |
| 2003 | 1.7 | 1.7 |
| 2004 | 1.5 | 1.5 |
| 2005 | 1.4 | 1.4 |
| 2006 | 1.2 | 1.2 |
| 2007 | 1.0 | 1.0 |
| 2008 | 1.0 | 1.0 |
| 2009 | 1.0 | 1.0 |
| 2010 | 1.0 | 1.0 |
| 2011 | 1.0 | 1.0 |
| 2012 | 1.0 | 1.0 |
| 2013 | 1.0 | 1.0 |
| 2014 | 1.0 | 1.0 |
| 2015 | 1.0 | 1.0 |
| 2016 | 1.0 | 1.0 |
| 2017 | 1.0 | 1.0 |
| 2018 | 1.0 | 1.0 |

Table 4.7 Technology specific $CH_4$ emission factors for residential wood combustion.

| Technology | Emission factor, g per GJ | Reference |
|---|---|---|
| Stoves (-1989) | 430 | Methane emissions from residential biomass combustion, Paulrud et al. (2005) (SMED report, Sweden) |
| Stoves (1990-2007) | 215 | Assumed ½ the emission factor for old stoves. |
| Stoves (2008-2014) | 125 | Estimated based on the emission factor for new stoves and the emission factors for NMVOC. |
| Stoves (2015-2016) | 125 | Same as modern stove (2008-2015) |
| Stoves (2017-) | 125 | Same as modern stove (2008-2015) |
| Eco labelled stoves / new advanced stoves (-2014) | 2 | Low emissions from wood burning in an ecolabelled residential boiler. Olsson & Kjällstrand (2005). |
| Eco labelled stoves / new advanced stoves (2015-2016) | 2 | Same as advanced/ecolabelled stoves |
| Eco labelled stoves / new advanced stoves (2017-) | 2 | Same as advanced/ecolabelled stoves |
| Open fireplaces and similar | 430 | Assumed equal to old stove. |
| Masonry heat accumulating stoves and similar | 215 | Assumed equal to old stove. |
| Boilers with accumulation tank (-1979) | 211 | Methane emissions from residential biomass combustion, Paulrud et al. 2005 (SMED report, Sweden) |
| Boilers without accumulation tank (-1979) | 256 | Methane emissions from residential biomass combustion, Paulrud et al. 2005 (SMED report, Sweden) |
| Boilers with accumulation tank (1980-) | 50 | Emission characteristics of modern and old-type residential boilers fired with wood logs and wood pellets. Johansson et al. (2004) |
| Boilers without accumulation tank (1980-) | 50 | Emission characteristics of modern and old-type residential boilers fired with wood logs and wood pellets. Johansson et al. (2004) |

Table 4.8 $SO_2$ emission factors time series, g per GJ for the years 1990 to 2018.
This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

Table 4.9 $NO_x$ emission factors time series, g per GJ for the years 1990 to 2018.
This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

Table 4.10 NMVOC emission factors time series, g per GJ for the years 1990 to 2018.
This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

Table 4.11 CO emission factors time series, g per GJ for the years 1990 to 2018.
This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

Table 4.12 $NH_3$ emission factors time series, g per GJ for the years 1990 to 2018.
This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

Table 4.13 TSP emission factors, time series, g per GJ for the years 1990 to 2018. This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

Table 4.14 $PM_{10}$ emission factors, time series, g per GJ for the years 1990 to 2018. This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

Table 4.15 $PM_{2.5}$ emission factors, time series, g per GJ for the years 1990 to 2018. This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

Table 4.16 BC emission factors, time series, g per GJ for the years 1990 to 2018. This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

Table 4.17 As emission factors time series, mg per GJ, for the years 1990 to 2018. This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

Table 4.18 Cd emission factors time series, mg per GJ, for the years 1990 to 2018. This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

Table 4.19 Cr emission factors time series, mg per GJ, for the years 1990 to 2018. This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

Table 4.20 Cu emission factors time series, mg per GJ, for the years 1990 to 2018. This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

Table 4.21 Hg emission factors time series, mg per GJ, for the years 1990 to 2018. This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

Table 4.22 Ni emission factors time series, mg per GJ, for the years 1990 to 2018. This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

Table 4.23 Pb emission factors time series, mg per GJ, for the years 1990 to 2018. This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

Table 4.24 Se emission factors time series, mg per GJ, for the years 1990 to 2018. This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

Table 4.25 Zn emission factors time series, mg per GJ, for the years 1990 to 2018. This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation//

Table 4.26 PAH emission factors time series, µg pr GJ for the years 1990 to 2018.

This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

Table 4.27 HCB emission factors time series, ng per GJ for the years 1990 to 2018.
This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

Table 4.28 PCDD/F emission factors time series, ng per GJ for the years 1990 to 2018.
This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

Table 4.29 PCB emission factors time series, ng per GJ for the years 1990 to 2018.
This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

# Annex 5 Large point sources

Table 5.1 Large point sources, 2018 (stationary combustion).

| Large point sources |
|---|
| AffaldPlus+, Naestved Forbraendingsanlaeg |
| Affaldplus+, Slagelse Forbr. and DONG Slagelse KVV |
| Affaldscenter aarhus - Forbraendsanlaegget |
| Amagerforbraending |
| Amagervaerket |
| Ardagh Glass Holmegaard A/S |
| Asnaesvaerket |
| Avedoerevaerket |
| AVV Forbraendingsanlaeg |
| Bofa I/S |
| Centralkommunernes Transmissionsselskab F_berg |
| Cheminova |
| Dalum Kraftvarmevaerk |
| Danisco Grindsted Dupont |
| DanSteel |
| Enstedvaerket |
| Esbjergvaerket |
| Faxe Kalk |
| Fjernvarme Fyn, Centrum Varmecentral |
| Frederikshavn Affaldskraftvarmevaerk |
| Fynsvaerket |
| H.C.Oerstedsvaerket |
| Haldor Topsoee |
| Hammel Fjernvarmeselskab |
| Helsingoer Kraftvarmevaerk |
| Herningvaerket |
| Hilleroed Kraftvarmevaerk |
| I/S Faelles Forbraending |
| I/S Kara Affaldsforbraendingsanlaeg |
| I/S Kraftvarmevaerk Thisted |
| I/S Reno Nord |
| I/S Reno Syd |
| I/S Vestforbraending |
| Koege Kraftvarmevaerk |
| Kolding Forbraendingsanlaeg TAS |
| Kommunekemi |
| Kyndbyvaerket |
| L90 Affaldsforbraending |
| Maricogen |
| Nordic Sugar Nakskov |
| Nordic Sugar Nykoebing |
| Nordjyllandsvaerket |
| Nybro Gasbehandlingsanlaeg |
| Odense Kraftvarmevaerk |
| Oestkraft |
| Randersvaerket Verdo |
| Rensningsanlaegget Lynetten |
| Rockwool A/S Doense |
| Rockwool A/S Vamdrup |
| Saint-Gobain Isover A/S |
| Shell Raffinaderi |
| Silkeborg Kraftvarmevaerk |

| Large point sources |
|---|
| Skaerbaekvaerket |
| Soenderborg Kraftvarmevaerk |
| Statoil Raffinaderi |
| Studstrupvaerket |
| Svanemoellevaerket |
| Svendborg Kraftvarmevaerk |
| Viborg Kraftvarme |
| Vordingborg Kraftvarme |
| Aalborg Portland |
| AarhusKarlshamn Denmark A/S |

Table 5.2 Large point sources, aggregated fuel consumption in 2018.

| nfr_id_EA | fuel_id | fuel_gr_abbr | Sum of Fuel_TJ |
|---|---|---|---|
| 1A1a | 102A | COAL | 61849 |
| | 103A | SUB-BITUMINOUS | 31 |
| | 111A | WOOD | 16250 |
| | 114A | WASTE | 36436 |
| | 117A | STRAW | 4792 |
| | 122A | Wood Pellets | 33888 |
| | 203A | RESIDUAL OIL | 707 |
| | 204A | GAS OIL | 502 |
| | 215A | BIO OIL | 23 |
| | 301A | NATURAL GAS | 14084 |
| | 303A | LPG | 1 |
| | 309A | BIOGAS | 113 |
| 1A1a Total | | | 168677 |
| 1A1b | 203A | RESIDUAL OIL | 376 |
| | 204A | GAS OIL | 4 |
| | 301A | NATURAL GAS | 513 |
| | 303A | LPG | 0 |
| | 308A | REFINERY GAS | 14981 |
| 1A1b Total | | | 15875 |
| 1A1c | 204A | GAS OIL | 0 |
| | 301A | NATURAL GAS | 108 |
| 1A1c Total | | | 108 |
| 1A2a | 204A | GAS OIL | 0 |
| | 301A | NATURAL GAS | 1654 |
| | 303A | LPG | 2 |
| 1A2a Total | | | 1656 |
| 1A2c | 204A | GAS OIL | 0 |
| | 301A | NATURAL GAS | 1208 |
| | 303A | LPG | 1 |
| 1A2c Total | | | 1209 |
| 1A2e | 102A | COAL | 452 |
| | 107A | COKE OVEN COKE | 100 |
| | 111A | WOOD | 538 |
| | 203A | RESIDUAL OIL | 2043 |
| | 204A | GAS OIL | 25 |
| | 215A | BIO OIL | 2 |
| | 301A | NATURAL GAS | 387 |
| | 303A | LPG | 11 |
| | 309A | BIOGAS | 95 |
| 1A2e Total | | | 3654 |
| 1A2f | 102A | COAL | 2257 |
| | 110A | PETROLEUM COKE | 6695 |
| | 115A | INDUSTR. WASTES | 3891 |

| | | | |
|---|---|---|---|
| | 203A | RESIDUAL OIL | 83 |
| | 204A | GAS OIL | 117 |
| | 215A | BIO OIL | 0 |
| | 301A | NATURAL GAS | 7 |
| 1A2f Total | | | 13050 |
| 1A2g viii | 102A | COAL | 388 |
| | 107A | COKE OVEN COKE | 266 |
| | 204A | GAS OIL | 0 |
| | 301A | NATURAL GAS | 1334 |
| | 303A | LPG | 1 |
| 1A2g viii Total | | | 1989 |
| 1A4a i | 111A | WOOD | 245 |
| | 114A | WASTE | 0 |
| | 309A | BIOGAS | 0 |
| 1A4a i Total | | | 245 |
| Grand Total | | | 206463 |

Table 5.3 Large point sources, plant specific emissions[1].

| Year | 2018 | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **nfr_id** | **lps_name** | **$SO_2$** | **$NO_x$** | **NMVOC** | **CO** | **$NH_3$** | **TSP** | **$PM_{10}$** | **$PM_{2.5}$** | **BC [2]** | **As** | **Cd** | **Cr** | **Cu** | **Hg** | **Ni** | **Pb** | **Se** | **Zn** | **PCDD /F** |
| 1A1a | AffaldPlus+, Naestved Forbraendingsan-laeg | x | x | x | x | x | x | x | x | x | | x | | | x | | | | | x |
| 1A1a | Affaldplus+, Slagelse Forbr. and DONG Slagelse KVV | x | x | x | x | x | x | x | x | x | | x | | | x | | | | | x |
| 1A1a | Affaldscenter aarhus - Forbraendsan-laegget | x | x | x | | | x | x | x | x | | x | | | x | | | | | x |
| 1A1a | Amagerforbraending | x | x | | x | x | x | x | x | x | x | x | x | x | x | x | x | | | x |
| 1A1a | Amagervaerket | x | x | | x | | x | x | x | x | x | x | x | x | x | x | x | x | x | |
| 1A1a | Asnaesvaerket | x | x | | | | x | x | x | x | x | x | x | x | x | x | x | x | x | |
| 1A1a | Avedoerevaerket | x | x | | x | | x | x | x | x | x | x | x | x | x | x | x | x | x | |
| 1A1a | AVV Forbraendingsanlaeg | x | x | | x | | | | | | | x | | | x | | | | | x |
| 1A1a | Bofa I/S | x | x | | x | | | | | | x | x | x | x | x | x | x | | | x |
| 1A1a | Centralkommunernes Transmis-sionsselskab F_berg | x | x | | | | | | | | | | | | | | | | | |
| 1A1a | Esbjergvaerket | x | x | | | | x | x | x | x | x | x | x | x | x | x | x | x | x | |
| 1A1a | Fjernvarme Fyn, Centrum Varmecentral | | x | | | | | | | | | | | | | | | | | |
| 1A1a | Frederikshavn Affaldskraftvarmevaerk | x | x | x | x | | x | x | x | x | x | x | x | x | x | x | x | | | x |
| 1A1a | Fynsvaerket | x | x | | | | x | x | x | x | x | x | x | x | x | x | x | x | x | |
| 1A1a | H.C.Oerstedsvaerket | | x | | x | | | | | | | | | | | | | | | |
| 1A1a | Helsingoer Kraftvarmevaerk | | x | | | | | | | | | | | | | | | | | |
| 1A1a | Herningvaerket | x | x | | | | x | x | x | x | x | x | x | x | x | x | x | x | x | |
| 1A1a | Hilleroed Kraftvarmevaerk | | x | | | | | | | | | | | | | | | | | |
| 1A1a | I/S Kara Affaldsforbraendingsanlaeg | x | x | | x | | x | x | x | x | | | | | x | | | | | x |
| 1A1a | I/S Reno Nord | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | |
| 1A1a | I/S Reno Syd | x | x | x | x | | x | x | x | x | | | | | x | | | | | x |
| 1A1a | I/S Vestforbraending | x | x | x | x | | x | x | x | x | x | x | x | x | x | x | x | | | x |
| 1A1a | Koege Kraftvarmevaerk | | x | | | | | | | | | | | | | | | | | |
| 1A1a | Kolding Forbraendingsanlaeg TAS | x | x | x | x | x | x | x | x | x | | | | | x | | | | | x |
| 1A1a | Kommunekemi | x | x | x | x | | x | x | x | x | | | | | | | | | | |
| 1A1a | Kyndbyvaerket | x | x | | x | | | | | | x | x | x | x | x | x | x | x | x | |
| 1A1a | L90 Affaldsforbraending | x | x | x | x | | x | x | x | x | x | x | x | x | x | x | x | | | x |
| 1A1a | Nordjyllandsvaerket | x | x | x | x | | x | x | x | x | x | x | x | x | x | x | x | x | x | |
| 1A1a | Odense Kraftvarmevaerk | x | x | | | | x | x | x | x | | | | | | | | | | |
| 1A1a | Oestkraft | x | x | | | | x | x | x | x | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A1a | Silkeborg Kraftvarmevaerk | | x | | | | | | | | | | | | | | | | | |
| 1A1a | Skaerbaekvaerket | x | x | x | x | | x | x | x | x | x | x | x | x | x | x | x | x | x | |
| 1A1a | Soenderborg Kraftvarmevaerk | x | x | | x | | x | x | x | x | x | x | | | x | | | | | x |
| 1A1a | Studstrupvaerket | x | x | | | | x | x | x | x | x | x | x | x | x | x | x | x | x | |
| 1A1a | Svanemoellevaerket | | x | | x | | | | | | | | | | | | | | | |
| 1A1a | Svendborg Kraftvarmevaerk | x | x | | x | | x | x | x | x | x | x | x | x | x | x | x | | | x |
| 1A1a | Viborg Kraftvarme | | x | | | | | | | | | | | | | | | | | |
| 1A1a | Vordingborg Kraftvarme | x | x | | | | | | | | | | | | | | | | | |
| 1A1a | Dalum Kraftvarmevaerk | x | x | | | | x | x | x | x | | | | | | | | | | |
| 1A1a | Randersvaerket Verdo | x | x | | | | x | x | x | x | | | | | | | | | | |
| 1A1a | I/S Kraftvarmevaerk Thisted | x | x | | x | | x | x | x | x | | | | | | | | | | x |
| 1A1a | Hammel Fjernvarmeselskab | x | x | x | x | | x | x | x | x | | x | | | x | | | | | x |
| 1A1b | Shell Raffinaderi | x | x | | | | | | | | | | | | | | | | | |
| 1A1b | Statoil Raffinaderi | x | x | | | | | | | | | | | | | | | | | |
| 1A1c | Nybro Gasbehandlingsanlaeg | | x | | | | | | | | | | | | | | | | | |
| 1A2a | DanSteel | | x | | | | | | | | | | | | | | | | | |
| 1A2c | Haldor Topsoee | | x | | | | | | | | | | | | | | | | | |
| 1A2e | Maricogen | | x | | x | | | | | | | | | | | | | | | |
| 1A2e | Nordic Sugar Nakskov | x | x | | | | | | | | | | | | | | | | | |
| 1A2e | Nordic Sugar Nykoebing | x | x | | | | x | x | x | x | | | | | | | | | | |
| 1A2e | AarhusKarlshamn Denmark A/S | x | x | | | | x | x | x | x | | | | | | | | | | |
| 1A2e | Danisco Grindsted Dupont | | x | | | | | | | | | | | | | | | | | |
| 1A2f | Faxe Kalk | x | x | | | | | | | | | | | | | | | | | |
| 1A2f | Aalborg Portland | x | x | | x | x | x | x | x | x | | | | | x | | | | | |
| 1A2g viii | Ardagh Glass Holmegaard A/S | | x | | | | | | | | | | | | | | | | | |
| 1A2g viii | Rockwool A/S Doense | x | x | | | | | | | | | | | | | | | | | |
| 1A2g viii | Rockwool A/S Vamdrup | x | x | | | | | | | | | | | | | | | | | |
| 1A2g viii | Saint-Gobain Isover A/S | | x | | | | | | | | | | | | | | | | | |
| 1A4a i | Rensningsanlaegget Lynetten | x | x | | x | | x | x | x | x | | x | | | x | | x | | | x |
| Total | | 2895 | 10789 | 57 | 6645 | 93 | 319 | 257 | 179 | 6 | 20 | 7 | 31 | 27 | 111 | 38 | 53 | 206 | 194 | 119 |
| Total emission from stationary combustion | | 6256 | 28009 | 15251 | 106135 | 2200 | 12411 | 11672 | 11284 | 1288 | 138 | 661 | 1341 | 573 | 220 | 1151 | 2139 | 399 | 25414 | 28997 |
| Share of total emission from stationary combustion based on plant specific data, % | | 46% | 39% | 0.4% | 6% | 4.2% | 3% | 2% | 2% | 0.5% | 14% | 1.1% | 2% | 5% | 51% | 3% | 2% | 52% | 0.8% | 0.4% |

1) Emissions of the pollutants marked with “x” are plant specific. Emission of other pollutants is estimated based on emission factors. The total shown *in this table* only includes plant specific data.

2) Based on particle size distribution and BC fractions.

# Annex 6 Adjustment of $CO_2$ emission

Table 6.1 Adjustment of $CO_2$ emission (DEA, 2019a).

| | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual Degree Days | Degree days | 2857 | 3284 | 3022 | 3434 | 3148 | 3297 | 3837 | 3236 | 3217 | 3056 |
| Normal Degree Days | Degree days | 0 | 0 | 0 | 6603 | 3285 | 394 | -1117 | -2135 | -427 | 427 |
| Net electricity import | PJ | 25.4 | -7.1 | 13.5 | 4.3 | -17.4 | -2.9 | -55.4 | -26.1 | -15.6 | -8.3 |
| Actual $CO_2$ emission | 1 000 000 tonnes | 0.0 | 0.0 | Total | 38.3 | 47.9 | 42.1 | 44.4 | 48.1 | 45.0 | 58.3 |
| Adjusted $CO_2$ emission | 1 000 000 tonnes | 0.0 | 0.0 | 0.0 | 44.5 | 46.3 | 45.0 | 45.5 | 44.3 | 44.3 | 45.2 |
| ***Continued*** | | **2000** | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** |
| Actual Degree Days | Degree days | 2902 | 3279 | 3011 | 3150 | 3113 | 3068 | 2908 | 2807 | 2853 | 3061 |
| Normal Degree Days | Degree days | 886.95 | 391.572 | 3360.99 | 4401.9 | 3055.05 | 2463.75 | 1642.5 | 1642.5 | 1642.5 | 821.25 |
| Net electricity import | PJ | 2.4 | -2.1 | -7.5 | -30.8 | -10.3 | 4.9 | -25.0 | -3.4 | 5.2 | 1.2 |
| Actual $CO_2$ emission | 1 000 000 tonnes | 48.4 | 44.5 | 41.3 | 37.3 | 38.9 | 38.4 | 43.2 | 37.2 | 33.4 | 41.1 |
| Adjusted $CO_2$ emission | 1 000 000 tonnes | 42.4 | 40.8 | 39.4 | 38.0 | 38.6 | 36.8 | 36.4 | 34.9 | 34.6 | 35.5 |
| ***Continued*** | | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** | |
| Actual Degree Days | Degree days | 3742 | 2970 | 3234 | 3207 | 2664 | 2921 | 2998 | 2970 | 2900 | |
| Normal Degree Days | Degree days | 0 | 0 | 0 | 1807 | 1807 | 2070 | 1511 | 2595 | 2300 | |
| Net electricity import | PJ | -4.1 | 4.7 | 18.8 | 3.9 | 10.3 | 21.3 | 18.2 | 16.4 | 18.8 | |
| Actual CO2 emission | 1 000 000 tonnes | 35.6 | 32.9 | 32.0 | 32.5 | 27.7 | 24.0 | 25.9 | 21.6 | 19.1 | |
| Adjusted CO2 emission | 1 000 000 tonnes | 34.9 | 34.0 | 32.3 | 31.6 | 28.7 | 28.2 | 26.6 | 23.4 | 22.6 | |

# Annex 7 Uncertainty estimates

Table 7.1 Uncertainty estimation, approach 1, GHG. This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/greenhouse-gases/supporting-documentation/

Table 7.2 Uncertainty estimation, approach 1, $CO_2$. This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/greenhouse-gases/supporting-documentation/

Table 7.3 Uncertainty estimation, approach 1, $CH_4$ This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/greenhouse-gases/supporting-documentation/

Table 7.4 Uncertainty estimation, approach 1, $N_2O$. This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/greenhouse-gases/supporting-documentation/

Table 7.5 Uncertainty estimates for non-GHGs. This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

# Annex 8 Emission inventory 2018 based on SNAP sectors

Table 8.1 Emission inventory for GHGs 2018 based on SNAP sectors.

| CRF | SNAP | $CO_2$, kt | $CH_4$, t | $N_2O$, t |
|---|---|---|---|---|
| 1A1a | 010100 | 0.000 | 1.161 | 1.161 |
| | 010101 | 6215.530 | 116.580 | 69.783 |
| | 010102 | 918.511 | 47.011 | 39.022 |
| | 010103 | 496.130 | 8.877 | 15.641 |
| | 010104 | 570.047 | 76.077 | 29.994 |
| | 010105 | 298.546 | 3805.547 | 11.516 |
| | 010200 | 0.000 | 0.975 | 0.975 |
| | 010201 | 0.000 | 0.000 | 0.000 |
| | 010202 | 79.901 | 1.467 | 1.382 |
| | 010203 | 534.063 | 348.002 | 93.044 |
| | 010205 | 0.000 | 0.000 | 0.000 |
| 1A1b | 010304 | 111.027 | 3.334 | 1.961 |
| | 010306 | 780.396 | 14.673 | 2.043 |
| 1A1c | 010503 | 6.119 | 0.108 | 0.108 |
| | 010504 | 1253.580 | 36.973 | 21.749 |
| | 010505 | 0.000 | 0.000 | 0.000 |
| 1A2a | 030400 | 12.353 | 0.214 | 0.179 |
| | 030402 | 94.259 | 1.656 | 1.654 |
| 1A2b | 030500 | 0.000 | 0.000 | 0.000 |
| 1A2c | 030600 | 282.062 | 15.823 | 7.048 |
| | 030602 | 34.819 | 0.612 | 0.611 |
| | 030603 | 0.000 | 0.000 | 0.000 |
| | 030604 | 33.943 | 1.014 | 0.597 |
| | 030605 | 0.000 | 58.298 | 0.215 |
| 1A2d | 031100 | 60.342 | 10.733 | 4.524 |
| | 031102 | 0.000 | 0.000 | 0.000 |
| | 031103 | 0.000 | 0.000 | 0.000 |
| | 031104 | 18.968 | 0.567 | 0.333 |
| 1A2e | 030900 | 719.852 | 18.904 | 12.289 |
| | 030902 | 143.468 | 11.170 | 9.602 |
| | 030903 | 97.468 | 3.547 | 4.087 |
| | 030904 | 55.252 | 1.651 | 0.971 |
| | 030905 | 14.897 | 465.489 | 1.404 |
| 1A2f | 030700 | 341.058 | 11.219 | 5.972 |
| | 030703 | 22.070 | 2.361 | 0.360 |
| | 030705 | 0.424 | 3.587 | 0.004 |
| | 031600 | 1030.964 | 157.169 | 29.101 |
| | 031604 | 0.000 | 0.000 | 0.000 |
| | 031605 | 0.000 | 0.000 | 0.000 |
| 1A2gviii | 030104 | 0.000 | 0.000 | 0.000 |
| | 030105 | 0.000 | 0.000 | 0.000 |
| | 030106 | 3.991 | 0.070 | 0.070 |
| | 030800 | 51.502 | 10.602 | 4.396 |
| | 031000 | 12.313 | 0.555 | 0.337 |
| | 031005 | 0.000 | 0.000 | 0.000 |
| | 031200 | 9.938 | 0.300 | 0.217 |
| | 031205 | 0.000 | 0.000 | 0.000 |
| | 031300 | 60.471 | 7.799 | 3.377 |
| | 031305 | 1.691 | 14.301 | 0.017 |
| | 031400 | 5.511 | 4.386 | 1.652 |
| | 031403 | 0.000 | 2.494 | 0.907 |

| *Continued* | | | | |
|---|---|---|---|---|
| | 031405 | 0.594 | 5.023 | 0.006 |
| | 031500 | 23.598 | 0.423 | 0.313 |
| | 032000 | 56.515 | 44.429 | 18.238 |
| | 032002 | 86.031 | 6.907 | 76.162 |
| | 032004 | 0.017 | 0.001 | 0.000 |
| | 032005 | 0.801 | 16.790 | 0.047 |
| 1A4ai | 020100 | 607.108 | 29.835 | 14.941 |
| | 020103 | 3.885 | 2.869 | 1.037 |
| | 020105 | 4.234 | 343.307 | 1.213 |
| 1A4bi | 020200 | 1837.898 | 3723.228 | 205.314 |
| | 020202 | 5.253 | 0.106 | 0.111 |
| | 020204 | 5.391 | 45.250 | 0.056 |
| 1A4ci | 020300 | 137.934 | 598.278 | 10.878 |
| | 020302 | 0.007 | 0.630 | 0.084 |
| | 020303 | 0.001 | 0.000 | 0.000 |
| | 020304 | 18.262 | 473.493 | 1.363 |
| | 020305 | 0.000 | 0.000 | 0.000 |
| Grand Total | | 17158.999 | 10555.877 | 708.070 |

Table 8.2 Emission inventory 2018 for non-GHGs based on SNAP sectors. This table is available at: https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/air-emissions/air-pollutants/supporting-documentation/

## Annex 9 EU ETS data for coal

EU ETS data are available for the years 2006-2018. Corresponding values for lower calorific value (LCV) and implied emission factor (IEF) for $CO_2$ for 2006-2009 are shown in Figure 9.1. The IEF factors include the oxidation factors.

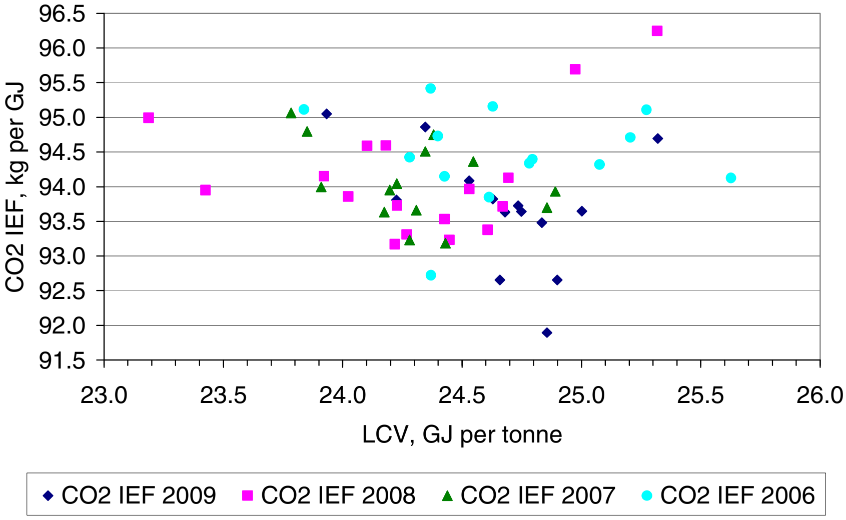



Figure 9.1 EU ETS data for LCV and $CO_2$ IEF (including oxidation factor) for coal. Data for the years 2006-2009.

# Annex 10 Implied emission factors for power plants and municipal waste incineration plants

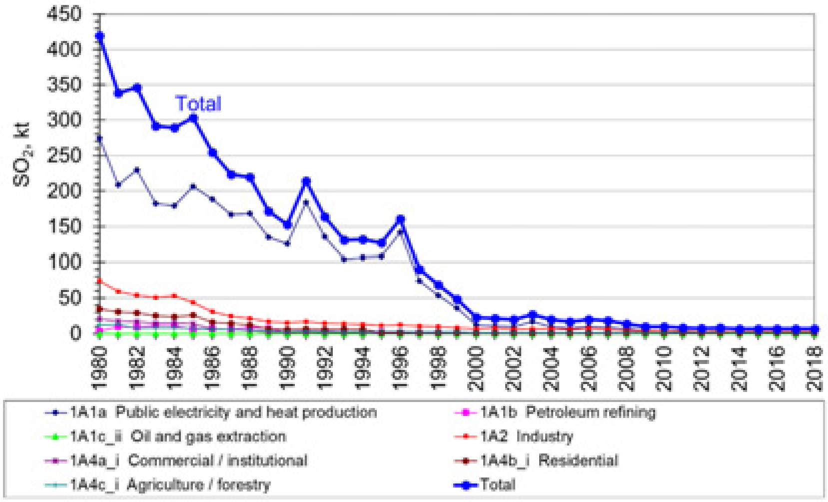
Table 10.1 Implied emission factors for municipal waste incineration plants, 2018.

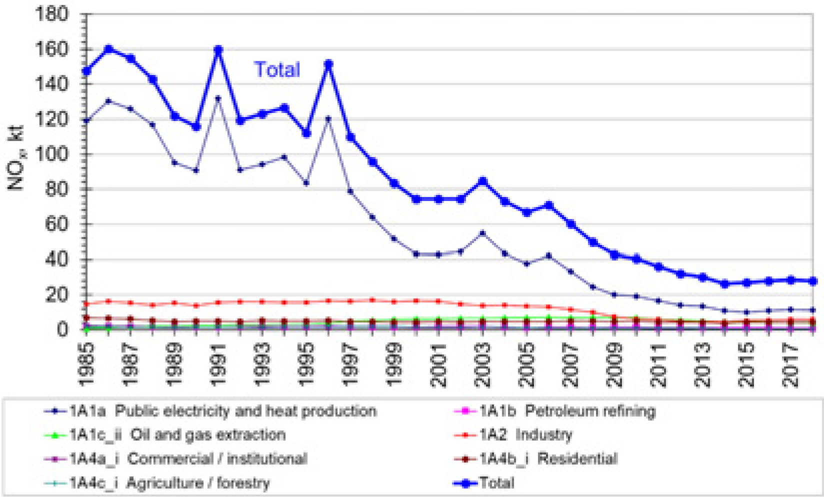
| Pollutant | Implied emission factor | Unit |
|---|---|---|
| $SO_2$ | 6.2 | g /GJ |
| $NO_x$ | 75 | g / GJ |
| TSP | 0.51 | g / GJ |
| $PM_{10}$ | 0.44 | g / GJ |
| $PM_{2.5}$ | 0.36 | g / GJ |
| As | 0.39 | mg / GJ |
| Cd | 0.29 | mg / GJ |
| Cr | 1.21 | mg / GJ |
| Cu | 1.22 | mg / GJ |
| Hg | 1.15 | mg / GJ |
| Ni | 2.20 | mg / GJ |
| Pb | 4.49 | mg / GJ |
| Se | 1.15 | mg / GJ |
| Zn | 2.48 | mg / GJ |

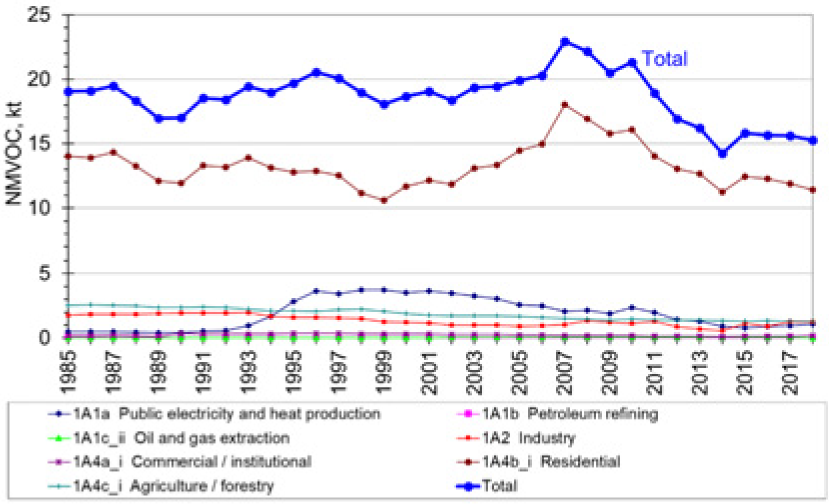
Table 10.2 Implied emission factors for power plants combusting coal, 2018.

| Pollutant | Implied emission factor | Unit |
|---|---|---|
| $SO_2$ | 10.3 | g / GJ |
| $NO_x$ | 25 | g / GJ |
| TSP | 2.32 | g / GJ |
| $PM_{10}$ | 2.01 | g / GJ |
| $PM_{2.5}$ | 1.62 | g / GJ |
| As | 0.34 | mg / GJ |
| Cd | 0.02 | mg / GJ |
| Cr | 0.25 | mg / GJ |
| Cu | 0.21 | mg / GJ |
| Hg | 0.89 | mg / GJ |
| Ni | 0.46 | mg / GJ |
| Pb | 0.23 | mg / GJ |
| Se | 3.74 | mg / GJ |
| Zn | 0.78 | mg / GJ |

# Annex 11 Time-series 1980/1985 – 2018



*Continued*

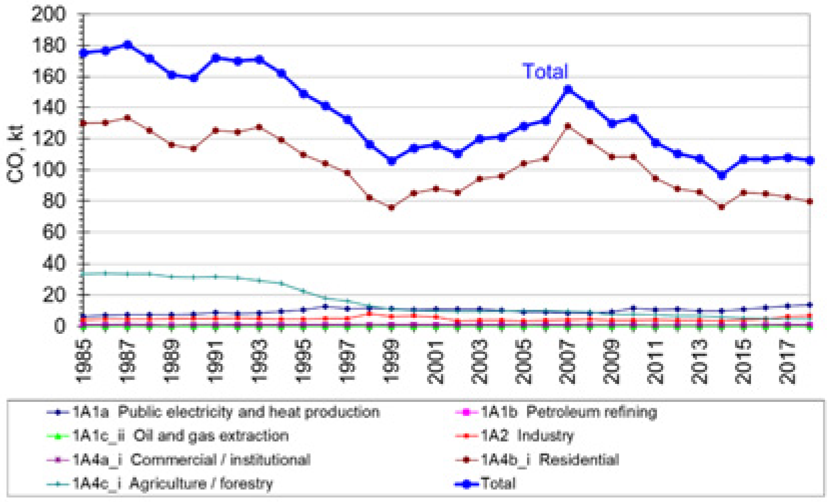



Figure 11.1 Time-series for fuel consumption and emissions, 1980/1985 - 2018.

## Annex 12 Description of the Danish energy statistics

This description of the Danish energy statistics has been prepared by Denmark's National Environmental Research Institute, NERI (now DCE) in cooperation with the Danish Energy Agency (DEA) as background information to the Danish National Inventory Report (NIR).

### The Danish energy statistics system

DEA is responsible for the Danish energy balance. Main contributors to the energy statistics outside DEA are Statistics Denmark and Danish Energy Association (before Association of Danish Energy Companies). The statistics is performed using an integrated statistical system building on an Access database and Excel spreadsheets.

The DEA follows the recommendations of the International Energy Agency as well as Eurostat.

The national energy statistics is updated annually and all revisions are immediately included in the published statistics, which can be found on the DEA homepage. It is an easy task to check for breaks in a series because the statistics is 100 % time-series oriented.

The national energy statistics does not include Greenland and Faroe Islands.

For historical reasons, DEA receive monthly information from the Danish oil companies regarding Danish deliveries of oil products to Greenland and Faroe Islands. However, the monthly (MOS) and annual (AOS) reporting of oil statistics to Eurostat and IEA exclude Greenland and Faroe Islands. For all other energy products, the Danish figures are also excluding Greenland and Faroe Islands.

### Reporting to the Danish Energy Agency

The Danish Energy Agency receives monthly statistics for the following fuel groups:

- Crude oil and oil products.
    - Monthly data from 46 oil companies, the main purpose is monitoring oil stocks according to the oil preparedness system.
- Natural gas.
    - Fuel/flare from platforms in the North Sea.
    - Natural gas balance from the regulator Energinet.dk (National monopoly).
- Coal and coke.
    - Power plants (94 %).
    - Industry companies (4 %).
    - Coal and coke traders (2 %).
- Electricity.
    - Monthly reporting by e-mail from the regulator Energinet.dk (National monopoly).
    - The statistics covers:
        - Production by type of producer.
        - Own use of electricity.
        - Import and export by country.
        - Domestic supply (consumption + distribution loss).

- Town gas (quarterly) from two town gas producers.
- The large central power plants also report monthly consumption of biomass.

Annual data includes renewable energy including waste. The DEA conducts a biannual survey on wood pellets and wood fuel. Statistics Denmark conducts biannual surveys on the energy consumption in the service and industrial sectors. Statistics Denmark prepares annual surveys on forest (wood fuel) & straw.

Other annual data sources include:

- DEA:
  - Survey on production of electricity and heat and fuels used.
  - Survey on end use of oil.
  - Survey on end use of natural gas.
  - Survey on end use of coal and coke.
- DCE (former NERI), Aarhus University.
  - Energy consumption for domestic air transport.
- Danish Energy Association (Association of Danish Energy companies).
  - Survey on electricity consumption.
- Ministry of Taxation.
  - Border trade.
- Centre for Biomass Technology.
  - Annual estimates of final consumption of straw and wood chips.

### Annual revisions

In general, DEA follows the same procedures as in the Danish national account. This means that normally only figures for the last two years are revised.

### Aggregating the energy statistics on SNAP level

The sectors used in the official energy statistics have been mapped to SNAP categories, used in the Danish emission database. DCE aggregates the official energy statistics to SNAP level based on a source correspondence table.

In cooperation between DEA and DCE, a fuel correspondence table has been developed mapping the fuels used by the DEA in the official energy statistics with the fuel codes used in the Danish national emission database. The fuel correspondence table between fuel categories used by the DEA, DCE and NFR is presented in Annex 3A-3.

The mapping between the energy statistics and the SNAP and fuel codes used by DCE can be seen in the table below.

Table 12.1 Correspondence between the Danish national energy statistics and the SNAP nomenclature (only stationary combustion part shown).

| Unit: TJ | End-use | | | Transformation 1980-1993 | |
|---|---|---|---|---|---|
| | SNAP | Fuel (in Danish) | Fuel-code | SNAP | Fuel-code |
| Foreign Trade | | | | | |
| - Border Trade | | | | | |
| - - Motor Gasoline | | | | | |
| - - Gas-/Diesel Oil | | | | | |
| - - Petroleum Coke | 0202 | Petrokoks | 110A | | |
| Vessels in Foreign Trade | | | | | |
| - International Marine Bunkers | | | | | |
| - - Gas-/Diesel Oil | | | | | |
| - - Fuel Oil | | | | | |
| - - Lubricants | | | | | |
| Energy Sector | | | | | |
| Extraction and Gasification | | | | | |
| - Extraction | | | | | |
| - - Natural Gas | 010504 | Naturgas | 301A | | |
| - Gasification | | | | | |
| - - Biogas, Landfill | 091006 | Biogas | 309A | | |
| - - Biogas, Other | 091006 | Biogas | 309A | | |
| Refineries | | | | | |
| - Own Use | | | | | |
| - - Refinery Gas | 010306 | Raffinaderigas | 308A | | |
| - - LPG | 010306 | LPG | 303A | | |
| - - Gas-/Diesel Oil | 010306 | Gas & Dieselolie | 204A | | |
| - - Fuel Oil | 010306 | Fuelolie & Spildolie | 203A | | |
| Transformation Sector | | | | | |
| Large-scale Power Units | | | | | |
| - Fuels Used for Power Production | | | | | |
| - - Gas-/Diesel Oil | | | | 0101 | 204A |
| - - Fuel Oil | | | | 0101 | 203A |
| - - Electricity Plant Coal | | | | 0101 | 102A |
| - - Straw | | | | 0101 | 117A |
| Large-Scale CHP Units | | | | | |
| - Fuels Used for Power Production | | | | | |
| - - Refinery Gas | | | | 0103 | 308A |
| - - LPG | | | | 0101 | 303A |
| - - Naphtha (LVN) | | | | 0101 | 210A |
| - - Gas-/Diesel Oil | | | | 0101 | 204A |
| - - Fuel Oil | | | | 0101 | 203A |
| - - Petroleum Coke | | | | 0101 | 110A |
| - - Orimulsion | | | | 0101 | 225A |
| - - Natural Gas | | | | 0101 | 301A |
| - - Electricity Plant Coal | | | | 0101 | 102A |
| - - Straw | | | | 0101 | 117A |
| - - Wood Chips | | | | 0101 | 111A |
| - - Wood Pellets | | | | 0101 | 111A |
| - - Wood Waste | | | | 0101 | 111A |
| - - Biogas, Landfill | | | | 0101 | 309A |
| - - Biogas, Others | | | | 0101 | 309A |
| - - Waste, Non-renewable | | | | 0101 | 114A |
| - - Wastes, Renewable | | | | 0101 | 114A |
| - Fuels Used for Heat Production | | | | | |
| - - Refinery Gas | | | | 0103 | 308A |
| - - LPG | | | | 0101 | 303A |
| - - Naphtha (LVN) | | | | 0101 | 210A |
| - - Gas-/Diesel Oil | | | | 0101 | 204A |
| - - Fuel Oil | | | | 0101 | 203A |
| - - Petroleum Coke | | | | 0101 | 110A |
| - - Orimulsion | | | | 0101 | 225A |
| - - Natural Gas | | | | 0101 | 301A |

| Unit: TJ | End-use | | | Transformation 1980-1993 | |
|---|---|---|---|---|---|
| | SNAP | Fuel (in Danish) | Fuel-code | SNAP | Fuel-code |
| - - Electricity Plant Coal | | | | 0101 | 102A |
| - - Straw | | | | 0101 | 117A |
| - - Wood Chips | | | | 0101 | 111A |
| - - Wood Pellets | | | | 0101 | 111A |
| - - Wood Waste | | | | 0101 | 111A |
| - - Biogas, Landfill | | | | 0101 | 309A |
| - - Biogas, Other | | | | 0101 | 309A |
| - - Waste, Non-renewable | | | | 0101 | 114A |
| - - Wastes, Renewable | | | | 0101 | 114A |
| Small-Scale CHP Units | | | | | |
| - Fuels Used for Power Production | | | | | |
| - - Gas-/Diesel Oil | | | | 0101 | 204A |
| - - Fuel Oil | | | | 0101 | 203A |
| - - Natural Gas | | | | 0101 | 301A |
| - - Hard Coal | | | | 0101 | 102A |
| - - Straw | | | | 0101 | 117A |
| - - Wood Chips | | | | 0101 | 111A |
| - - Wood Pellets | | | | 0101 | 111A |
| - - Wood Waste | | | | 0101 | 111A |
| - - Biogas, Landfill | | | | 0101 | 309A |
| - - Biogas, Other | | | | 0101 | 309A |
| - - Waste, Non-renewable | | | | 0101 | 114A |
| - - Wastes, Renewable | | | | 0101 | 114A |
| - Fuels Used for Heat Production | | | | | |
| - - Gas-/Diesel Oil | | | | 0101 | 204A |
| - - Fuel Oil | | | | 0101 | 203A |
| - - Natural Gas | | | | 0101 | 301A |
| - - Coal | | | | 0101 | 102A |
| - - Straw | | | | 0101 | 117A |
| - - Wood Chips | | | | 0101 | 111A |
| - - Wood Pellets | | | | 0101 | 111A |
| - - Wood Waste | | | | 0101 | 111A |
| - - Biogas, Landfill | | | | 0101 | 309A |
| - - Biogas, Other | | | | 0101 | 309A |
| - - Waste, Non-renewable | | | | 0101 | 114A |
| - - Wastes, Renewable | | | | 0101 | 114A |
| District Heating Units | | | | | |
| - Fuels Used for Heat Production | | | | | |
| - - Refinery Gas | | | | 0103 | 308A |
| - - LPG | | | | 0102 | 303A |
| - - Gas-/Diesel Oil | | | | 0102 | 204A |
| - - Fuel Oil | | | | 0102 | 203A |
| - - Waste Oil | | | | 0102 | 203A |
| - - Petroleum Coke | | | | 0102 | 110A |
| - - Natural Gas | | | | 0102 | 301A |
| - - Electricity Plant Coal | | | | 0102 | 102A |
| - - Coal | | | | 0102 | 102A |
| - - Straw | | | | 0102 | 117A |
| - - Wood Chips | | | | 0102 | 111A |
| - - Wood Pellets | | | | 0102 | 111A |
| - - Wood Waste | | | | 0102 | 111A |
| - - Biogas, Landfill | | | | 0102 | 309A |
| - - Biogas, Sludge | | | | 0102 | 309A |
| - - Biogas, Other | | | | 0102 | 309A |
| - - Waste, Non-renewable | | | | 0102 | 114A |
| - - Wastes, Renewable | | | | 0102 | 114A |
| - - Fish Oil | | | | 0102 | 215A |
| Autoproducers, Electricity Only | | | | | |
| - Fuels Used for Power Production | | | | | |
| - - Natural Gas | | | | 0320 | 301A |
| - - Biogas, Landfill | | | | 0320 | 309A |
| - - Biogas, Sewage Sludge | | | | 0320 | 309A |

| Unit: TJ | End-use | | | Transformation 1980-1993 | |
|---|---|---|---|---|---|
| | SNAP | Fuel (in Danish) | Fuel-code | SNAP | Fuel-code |
| - - Biogas, Other | | | | 0320 | 309A |
| Autoproducers, CHP Units | | | | | |
| - Fuels Used for Power Production | | | | | |
| - - Refinery Gas | | | | 0103 | 308A |
| - - Gas-/Diesel Oil | | | | 0320 | 204A |
| - - Fuel Oil | | | | 0320 | 203A |
| - - Waste Oil | | | | 0320 | 203A |
| - - Natural Gas | | | | 0320 | 301A |
| - - Coal | | | | 0320 | 102A |
| - - Straw | | | | 0320 | 117A |
| - - Wood Chips | | | | 0320 | 111A |
| - - Wood Pellets | | | | 0320 | 111A |
| - - Wood Waste | | | | 0320 | 111A |
| - - Biogas, Landfill | | | | 0320 | 309A |
| - - Biogas, Sludge | | | | 0320 | 309A |
| - - Biogas, Other | | | | 0320 | 309A |
| - - Fish Oil | | | | 0320 | 215A |
| - - Waste, Non-renewable | | | | 0320 | 114A |
| - - Wastes, Renewable | | | | 0320 | 114A |
| - Fuels Used for Heat Production | | | | | |
| - - Refinery Gas | | | | 0103 | 308A |
| - - Gas-/Diesel Oil | | | | 0320 | 204A |
| - - Fuel Oil | | | | 0320 | 203A |
| - - Waste Oil | | | | 0320 | 203A |
| - - Natural Gas | | | | 0320 | 301A |
| - - Coal | | | | 0320 | 102A |
| - - Wood Chips | | | | 0320 | 111A |
| - - Wood Waste | | | | 0320 | 111A |
| - - Biogas, Landfill | | | | 0320 | 309A |
| - - Biogas, Sludge | | | | 0320 | 309A |
| - - Biogas, Other | | | | 0320 | 309A |
| - - Waste, Non-renewable | | | | 0320 | 114A |
| - - Wastes, Renewable | | | | 0320 | 114A |
| Autoproducers, Heat Only | | | | | |
| - Fuels Used for Heat Production | | | | | |
| - - Gas-/Diesel Oil | | | | 0320 | 204A |
| - - Fuel Oil | | | | 0320 | 203A |
| - - Waste Oil | | | | 0320 | 203A |
| - - Natural Gas | | | | 0320 | 301A |
| - - Straw | | | | 0320 | 117A |
| - - Wood Chips | | | | 0320 | 111A |
| - - Wood Chips | | | | 0320 | 111A |
| - - Wood Waste | | | | 0320 | 111A |
| - - Biogas, Landfill | | | | 0320 | 309A |
| - - Biogas, Sludge | | | | 0320 | 309A |
| - - Biogas, Other | | | | 0320 | 309A |
| - - Waste, Non-renewable | | | | 0102 | 114A |
| - - Wastes, Renewable | | | | 0102 | 114A |
| Town Gas Units | 030106 | Naturgas | 301A | | |
| - Fuels Used for Production of District Heating | 030106 | Kul (-83) / Gasolie (84-) | 102A / 204A | | |
| Transport sector | | | | | |
| Military Transport | | | | | |
| - Aviation Gasoline | | | | | |
| - Motor Gasoline | | | | | |
| - JP4 | | | | | |
| - JP1 | | | | | |
| - Gas-/Diesel Oil | | | | | |
| Road | | | | | |
| - LPG | | | | | |
| - Motor Gasoline | | | | | |

| Unit: TJ | End-use | | | Transformation 1980-1993 | |
|---|---|---|---|---|---|
| | SNAP | Fuel (in Danish) | Fuel-code | SNAP | Fuel-code |
| - Other Kerosene | 0202 | Petroleum | 206A | | |
| - Gas-/Diesel Oil | | | | | |
| - Fuel Oil | | | | | |
| Rail | | | | | |
| - Motor Gasoline | | | | | |
| - Other Kerosene | | | | | |
| - Gas-/Diesel Oil | | | | | |
| - Electricity | | | | | |
| Domestic Sea Transport | | | | | |
| - LPG | | | | | |
| - Other Kerosene | | | | | |
| - Gas-/Diesel Oil | | | | | |
| - Fuel Oil | | | | | |
| Air Transport, Domestic | | | | | |
| - LPG | | | | | |
| - Aviation Gasoline | | | | | |
| - Motor Gasoline | | | | | |
| - Other Kerosene | 0201 | Petroleum | 206A | | |
| - JP1 | | | | | |
| Air Transport, International | | | | | |
| - Aviation Gasoline | | | | | |
| - JP1 | | | | | |
| Agriculture and Forestry | | | | | |
| - LPG | | | | | |
| - Motor Gasoline | | | | | |
| - Other Kerosene | 0203 | Petroleum | 206A | | |
| - Gas-/Diesel Oil | | | | | |
| - Fuel Oil | 0203 | Fuelolie & Spildolie | 203A | | |
| - Petroleum Coke | 0203 | Petrokoks | 110A | | |
| - Natural Gas | 0203 | Naturgas | 301A | | |
| - Coal | 0203 | Kul | 102A | | |
| - Brown Coal Briquettes | 0203 | Brunkul | 106A | | |
| - Straw | 0203 | Halm | 117A | | |
| - Wood Chips | 0203 | Træ | 111A | | |
| - Wood Waste | 0203 | Træ | 111A | | |
| - Biogas, Other | 0203 | Biogas | 309A | | |
| Horticulture | | | | | |
| - LPG | | | | | |
| - Motor Gasoline | | | | | |
| - Gas-/Diesel Oil | | | | | |
| - Fuel Oil | 0203 | Fuelolie & Spildolie | 203A | | |
| - Petroleum Coke | 0203 | Petrokoks | 110A | | |
| - Natural Gas | 0203 | Naturgas | 301A | | |
| - Coal | 0203 | Kul | 102A | | |
| - Wood Waste | 0203 | Træ | 111A | | |
| Fishing | | | | | |
| - LPG | | | | | |
| - Motor Gasoline | | | | | |
| - Other Kerosene | | | | | |
| - Gas-/Diesel Oil | | | | | |
| - Fuel Oil | | | | | |
| Manufacturing Industry | | | | | |
| - Refinery Gas | 0320 | Raffinaderigas | 308A | | |
| - LPG | | | | | |
| - Naphtha (LVN) | | | | | |
| - Motor Gasoline | | | | | |
| - Other Kerosene | 0320 | Petroleum | 206A | | |
| - Gas-/Diesel Oil | | | | | |

| Unit: TJ | End-use | | | Transformation 1980-1993 | |
|---|---|---|---|---|---|
| | SNAP | Fuel (in Danish) | Fuel-code | SNAP | Fuel-code |
| - Fuel Oil | 0320 | Fuelolie & Spildolie | 203A | | |
| - Waste Oil | 0320 | Fuelolie & Spildolie | 203A | | |
| - Petroleum Coke | 0320 | Petrokoks | 110A | | |
| - Natural Gas | 0320 | Naturgas | 301A | | |
| - Coal | 0320 | Kul | 102A | | |
| - Coke | 0320 | Koks | 107A | | |
| - Brown Coal Briquettes | 0320 | Brunkul | 106A | | |
| - Wood Pellets | 0320 | Træ | 111A | | |
| - Wood Waste | 0320 | Træ | 111A | | |
| - Biogas, Landfill | 0320 | Biogas | 309A | | |
| - Biogas, Other | 0320 | Biogas | 309A | | |
| - Wastes, Non-renewable | 0320 | Affald | 114A | | |
| - Wastes, Renewable | 0320 | Affald | 114A | | |
| - Town Gas | 0320 | Naturgas | 301A | | |
| Construction | | | | | |
| - LPG | 0320 | LPG | 303A | | |
| - Motor Gasoline | | | | | |
| - Other Kerosene | 0320 | Petroleum | 206A | | |
| - Gas-/Diesel Oil | | | | | |
| - Fuel Oil | 0320 | Fuelolie & Spildolie | 203A | | |
| - Natural Gas | 0320 | Naturgas | 301A | | |
| Wholesale | | | | | |
| - LPG | 0201 | LPG | 303A | | |
| - Motor Gasoline | 0201 | Petroleum | 206A | | |
| - Other Kerosene | 0201 | Gas & Dieselolie | 204A | | |
| - Gas-/Diesel Oil | 0201 | Fuelolie & Spildolie | 203A | | |
| - Petroleum Coke | 0201 | Petrokoks | 110A | | |
| - Natural Gas | 0201 | Naturgas | 301A | | |
| - Wood Waste | 0201 | Træ | 111A | | |
| Retail Trade | | | | | |
| - LPG | 0201 | LPG | 303A | | |
| - Other Kerosene | 0201 | Petroleum | 206A | | |
| - Gas-/Diesel Oil | 0201 | Gas & Dieselolie | 204A | | |
| - Fuel Oil | 0201 | Fuelolie & Spildolie | 203A | | |
| - Petroleum Coke | 0201 | Petrokoks | 110A | | |
| - Natural Gas | 0201 | Naturgas | 301A | | |
| Private Service | | | | | |
| - LPG | 0201 | LPG | 303A | | |
| - Other Kerosene | 0201 | Petroleum | 206A | | |
| - Gas-/Diesel Oil | 0201 | Gas & Dieselolie | 204A | | |
| - Fuel Oil | 0201 | Fuelolie & Spildolie | 203A | | |
| - Waste Oil | 0201 | Fuelolie & Spildolie | 203A | | |
| - Petroleum Coke | 0201 | Petrokoks | 110A | | |
| - Natural Gas | 0201 | Naturgas | 301A | | |
| - Wood Chips | 0201 | Træ | 111A | | |
| - Wood Waste | 0201 | Træ | 111A | | |
| - Biogas, Landfill | 0201 | Biogas | 309A | | |
| - Biogas, Sludge | 0201 | Biogas | 309A | | |
| - Biogas, Other | 0201 | Biogas | 309A | | |
| - Wastes, Non-renewable | 0201 | Affald | 114A | | |
| - Wastes, Renewable | 0201 | Affald | 114A | | |
| - Town Gas | 0201 | Naturgas | 301A | | |
| Public Service | | | | | |
| - LPG | 0201 | LPG | 303A | | |

| Unit: TJ | End-use | | | Transformation 1980-1993 | |
|---|---|---|---|---|---|
| | SNAP | Fuel (in Danish) | Fuel-code | SNAP | Fuel-code |
| - Other Kerosene | 0201 | Petroleum | 206A | | |
| - Gas-/Diesel Oil | 0201 | Gas & Dieselolie | 204A | | |
| - Fuel Oil | 0201 | Fuelolie & Spildolie | 203A | | |
| - Petroleum Coke | 0201 | Petrokoks | 110A | | |
| - Natural Gas | 0201 | Naturgas | 301A | | |
| - Coal | 0201 | Kul | 102A | | |
| - Brown Coal Briquettes | 0201 | Brunkul | 106A | | |
| - Wood Chips | 0201 | Træ | 111A | | |
| - Wood Pellets | 0201 | Træ | 111A | | |
| - Town Gas | 0201 | Naturgas | 301A | | |
| Single Family Houses | | | | | |
| - LPG | 0202 | LPG | 303A | | |
| - Motor Gasoline | | | | | |
| - Other Kerosene | 0202 | Petroleum | 206A | | |
| - Gas-/Diesel Oil | 0202 | Gas & Dieselolie | 204A | | |
| - Fuel Oil | 0202 | Fuelolie & Spildolie | 203A | | |
| - Petroleum Coke | 0202 | Petrokoks | 110A | | |
| - Natural Gas | 0202 | Naturgas | 301A | | |
| - Coal | 0202 | Kul | 102A | | |
| - Coke | 0202 | koks | 107A | | |
| - Brown Coal Briquettes | 0202 | Brunkul | 106A | | |
| - Straw | 0202 | Halm | 117A | | |
| - Firewood | 0202 | Træ | 111A | | |
| - Wood Chips | 0202 | Træ | 111A | | |
| - Wood Pellets | 0202 | Træ | 111A | | |
| - Town Gas | 0202 | Naturgas | 301A | | |
| Multi-family Houses | | | | | |
| - LPG | 0202 | LPG | 303A | | |
| - Other Kerosene | 0202 | Petroleum | 206A | | |
| - Gas-/Diesel Oil | 0202 | Gas & Dieselolie | 204A | | |
| - Fuel Oil | 0202 | Fuelolie & Spildolie | 203A | | |
| - Petroleum Coke | 0202 | Petrokoks | 110A | | |
| - Natural Gas | 0202 | Naturgas | 301A | | |
| - Coal | 0202 | Kul | 102A | | |
| - Coke | 0202 | Koks | 107A | | |
| - Brown Coal Briquettes | 0202 | Brunkul | 106A | | |
| - Town Gas | 0202 | Naturgas | 301A | | |

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# DANISH EMISSION INVENTORIES FOR STATIONARY COMBUSTION PLANTS

Inventories until 2018

Emission inventories for stationary combustion plants are presented and the methodologies and assumptions used for the inventories are described. The pollutants considered are $SO_2$, $NO_x$, NMVOCs, $CH_4$, CO, $CO_2$, $N_2O$, $NH_3$, particulate matter, black carbon, heavy metals, PCDD/Fs, HCB, PCBs and PAHs. The $CO_2$ emission from stationary combustion was 54.8 % lower in 2018 than in 1990 and the total greenhouse gas emission was 53.9 % lower than in 1990. However, fluctuations in the emission level for $CO_2$ are large as a result of electricity import/export. A considerable decrease of the $SO_2$, $NO_x$ and heavy metal emissions is mainly a result of decreased emissions from large power plants and waste incineration plants. The PM emissions increased until 2007 and decreased after 2007. The increase until 2007 was caused by the increased wood combustion in residential plants. However, the PM emission factors have decreased for this emission source category due to installation of modern stoves and boilers. The stabilisation of wood consumption in residential plants in 2007-2014 has resulted in a decrease of PM emission from stationary combustion between 2007 and 2014. The PCDD/F emission decreased until 1999 due to improved flue gas cleaning on waste incineration plants. In recent years, residential wood combustion is the largest emission source.

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