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# Updating the Emission Factors for Large Combustion Plants

For People & the Environment

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# Updating the Emission Factors for Large Combustion Plants

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**Short summary: Updating the Emission Factors for Large Combustion Plants**

Large combustion plants are still a major source of emissions of various air pollutants. By the mid-1990s, emissions of particulate matter, sulphur dioxide, nitrogen dioxide and carbon monoxide had declined significantly. Thereafter, the specific emissions remained largely stable over many years. In the course of regulatory changes, a changing composition of the plant park as well as changes in fuel usage, there has been a significant reduction for sulphur dioxide ($SO_2$) in recent years, but also changes for $NO_X$ and particulate matter. It was therefore essential to update the existing factors.

Due to the regulatory requirements and the associated monitoring obligations, extensive data are available for these pollutants. The available emission values were evaluated for various years. As a result, the specific emission factors are presented in the following document and, if necessary, qualitatively evaluated.

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## List of abbreviations

| | |
|---|---|
| **060** | Survey of energy use of manufacturing, mining and quarrying companies |
| **064** | Survey of generation, use, purchase and transmission of heat |
| **066** | Monthly report on the electricity supply |
| **11th BImSchV** | 11th Ordinance on the Implementation of the Federal Immission Control Act (Ordinance on emission declarations) |
| **13th BImSchV** | 13th Ordinance on the Implementation of the Federal Immission Control Act (Ordinance on large combustion plants, gas turbine plants and combustion engine systems) |
| **17th BImSchV** | 17th Ordinance on the Implementation of the Federal Immission Control Act (Ordinance on the incineration and co-incineration of waste) |
| **BAT** | Best available technology |
| **CO** | Carbon monoxide |
| **$CO_2$** | Carbon dioxide |
| **DEBRIV** | Federal German association of lignite producing companies and their affiliated organisations (Deutscher Braunkohlen-Industrie-Verein e.V.) |
| **Destatis** | Federal Statistical Office |
| **DFIU** | Franco-German Institute for Environmental Research |
| **DT-Anlage** | Steam turbine plant |
| **ED** | Emission declaration (Emissionserklärung) |
| **EF** | Emission factor |
| **EIFER** | European Institute for Energy Research |
| **EMEP EEA Guidebook** | European Monitoring and Evaluation Programme / European Environment Agency air pollutant emission inventory guidebook |
| **EPER** | European Pollutant Emission Register |
| **ETS** | Emissions Trading System |
| **GT-Anlage** | Gas turbine plant |
| **GuD-Anlage** | Gas and steam turbine plant |
| **Hg** | Mercury |
| **KIT** | Karlsruhe Institute of Technology |
| **LCP** | Large combustion plant |
| **NACE code** | Code within the Nomenclature générale des activités économiques dans les Communautés Européennes |
| **NFR** | Nomenclature for Reporting |
| **$NH_3$** | Ammonia |
| **$NO_X$** | Nitrogen dioxide |
| **PM 10** | Particulate matter ≤ 10 µm |
| **PM 2.5** | Particulate matter ≤ 2.5 µm |
| **POSO** | Point source (large combustion plant database) |
| **PRTR** | Pollutant Release and Transfer Register |

| | |
|---|---|
| **SCR** | Selective catalytic reduction |
| **SNCR** | Selective non-catalytic reduction |
| **$SO_2$** | Sulphur dioxide ($SO_X$ given as $SO_2$) |
| **TA Luft** | First General Administrative Regulation Pertaining to the Federal Immission Control Act (Technical Instructions on Air Quality Control) |
| **WZ** | Classification of Economic Activities |
| **WZ 06** | Economic Activity: Extraction of crude petroleum and natural gas |
| **WZ 20** | Economic Activity: Manufacture of chemicals and chemical products |
| **ZSE** | Central System of Emissions (CSE) |
| | |

## Overview of the Nomenclature for Reporting (NFR) structure – Energy (NFR 1)

| NFR code | German designation | English designation |
|---|---|---|
| **1.A** | **Verbrennung fossiler Brennstoffe** | **Fuel Combustion** |
| **1.A.1** | **Energiewirtschaft** | **Energy Industries** |
| **1.A.1.a** | Öffentliche Strom- und Wärmeerzeugung | Public electricity and heat production |
| **1.A.1.b** | Erdölraffination | Petroleum refining |
| **1.A.1.c** | Herstellung von festen Brennstoffen… | Manufacture of solid fuels, and other energy industries |
| **1.A.2** | **Verarbeitendes Gewerbe** | **Manufacturing Industries and Construction** |
| **1.A.2.a** | Eisen & Stahl | Stationary combustion in manufacturing industries and construction: Iron and steel |
| **1.A.2.b** | Nichteisenmetalle | Stationary combustion in manufacturing industries and construction: Non-ferrous metals |
| **1.A.2.c** | | Stationary combustion in manufacturing industries and construction: Chemicals |
| **1.A.2.d** | Papier & Zellstoff | Stationary combustion in manufacturing industries and construction: Pulp, paper and print |
| **1.A.2.e** | Food | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco |
| **1.A.2.f** | | Stationary combustion in manufacturing industries and construction: Non-metallic minerals |
| **1.A.2.g.vii** | | Mobile combustion in manufacturing industries and construction: (please specify in the IIR) |
| **1.A.2.g.viii** | | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) |
| **1.A.3** | **Verkehr** | **Transport** |
| **1.A.3.a** | **Luftverkehr** | **Aviation** |
| **1.A.3.a.i(i)** | | International aviation LTO (civil) |

| NFR code | German designation | English designation |
|---|---|---|
| 1.A.3.a.ii(i) | | Domestic aviation LTO (civil) |
| **1.A.3.b** | **Straßenverkehr** | **Road Transport** |
| **1.A.3.b.i** | PKW | Road transport: Passenger cars |
| **1.A.3.b.ii** | Leichte Nutzfahrzeuge | Road transport: Light duty vehicles |
| **1.A.3.b.iii** | Schwere Nutzfahrzeuge | Road transport: Heavy duty vehicles and buses |
| **1.A.3.b.iv** | Mopeds & Motorräder | Road transport: Mopeds & motorcycles |
| **1.A.3.b.v** | Verdunstung von Kraftstoffen | Road transport: Gasoline evaporation |
| **1.A.3.b.vi** | Reifen- und Bremsabrieb | Road transport: Automobile tyre and brake wear |
| **1.A.3.b.vii** | Straßenabrieb | Road transport: Automobile road abrasion |
| **1.A.3.c** | **Schienenverkehr** | **Railways** |
| **1.A.3.d** | **Seeverkehr** | **Navigation** |
| **1.A.3.d.i(ii)** | | International inland waterways |
| **1.A.3.dii** | | National navigation (shipping) |
| **1.A.3.e** | | **Other Transportation** |
| **1.A.3.e.i** | Pipelines | Pipeline transport |
| **1.A.3.e.ii** | | Other (please specify in the IIR) |
| **1.A.4** | **Übrige Feuerungsanlagen** | **Other sectors** |
| **1.A.4.a** | **Gewerbe, Handel, Dienstleistung** | **Commercial/institutional** |
| **1.A.4.a.i** | | Commercial/institutional: Stationary |
| **1.A.4.a.ii** | | Commercial/institutional: Mobile |
| **1.A.4.b** | **Haushalte** | **Residential** |
| **1.A.4.b.i** | | Residential: Stationary |
| **1.A.4.b.ii** | | Residential: Household and gardening (mobile) |
| **1.A.4.c.i** | | Agriculture/Forestry/Fishing: Stationary |
| **1.A.4.c.ii** | | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery |
| **1.A.4.c.iii** | | Agriculture/Forestry/Fishing: National fishing |
| **1.A.5** | **Sonstige Feuerungsanlagen: Military** | **Other: Military** |
| **1.A.5.a** | | Other stationary (including military) |
| **1.A.5.b** | | Other, mobile (including military, land based and recreational boats) |
| **1.B** | **Diffuse Emissionen aus Brennstoffen** | **Fugitive Emissions from Solid Fuels** |
| **1.B.1** | **Feste Brennstoffe** | **Fugitive Emissions from Solid Fuels – Solid Fuels** |
| **1.B.1.a.** | | Fugitive emissions from solid fuels: Coal mining and handling |
| **1.B.1.b.** | | Fugitive emissions from solid fuels: Solid fuel transformation |
| **1.B.1.c** | | Other fugitive emissions from solid fuels |
| 1.B.2 | Öl und Erdgas | Fugitive emissions from solid fuels – Oil & natural gas |
| 1.B.2.a | Öl | Fugitive emissions from solid fuels: Oil |
| **1.B.2.a.i** | | Fugitive emissions oil: Exploration, production, transport |
| **1.B.2.a.iv** | | Fugitive emissions oil: Refining / storage |
| **1.B.2.a.v** | | Distribution of oil products |

| NFR code | German designation | English designation |
|---|---|---|
| **1.B.2.b** | Erdgas | Fugitive emissions from natural gas (exploration, production, processing, transmission, storage, distribution and other) |
| **1.B.2.c** | | Venting and flaring (oil, gas, combined oil and gas) |
| **1.B.2.d** | | Other fugitive emissions from energy production |

## Summary

The Federal Republic of Germany is obligated, on the basis of various international regimes, to report annually on emissions of about 20 air pollutants. The present report has revised reporting on (solely) the main air pollutants nitrogen dioxide ($NO_X$), sulphur dioxide ($SO_2$), particulate matter, carbon monoxide (CO), mercury (Hg) and ammonia ($NH_3$), on the basis of an evaluation of the data reported pursuant to Section 25 of the 13th Ordinance for the Implementation of the Federal Immission Control Act (BImschV).

The annual reporting obligations under the 13th BImschV cover the air pollutants nitrogen dioxide, sulphur dioxide and particulate matter. With regard to CO and $NH_3$, the emission declarations for the year 2016 were evaluated.

Pursuant to Section 27 of the Federal Immission Control Act, operators of installations subject to licensing are required to update their emission declarations at four-year intervals. The content, scope and form of emission declarations are set forth by the 11th BImschV. Reporting in such declarations must include the air pollutants CO and $NH_3$. For mercury, the evaluation was carried out on the basis of the emissions data annually reported in the PRTR.

For all pollutants, calculations are based only on measured values. Unfortunately, the data sources do not make a distinction between continuous measurements and single measurements. It may be assumed, however, that the main pollutants $SO_2$, $NO_X$ and particulate matter are, for the most part, continuously measured. CO and Hg are continuously measured in part and, to some extent, tracked via single measurements. On the other hand, $NH_3$, as a rule, is recorded only via single measurements.

Specific emission factors are generated from the reported emissions data and the pertinent fuel inputs. This provides a basis for annual reporting in the national emissions inventory.

# 1 Methodological issues

Emission factors have been determined in the framework of the following past projects: "Ermittlung und Evaluierung von Emissionsfaktoren für Feuerungsanlagen in Deutschland für die Jahre 1995, 2000 und 2010" ("Determination and evaluation of emission factors for combustion plants in Germany for the years 1995, 2000 and 2010") by O. Rentz, U. Karl and H. Peter of the University of Karlsruhe's French-German Institute for Environmental Research (DFIU) (study from 2002) and "Fortschreibung der Emissionsfaktoren für Feuerungs- und Gasturbinenanlagen nach 13./17. BImSchV und TA Luft" (Updating of emission factors for combustion and gas turbine plants pursuant to the 13th/17th Ordinance for the Implementation of the Federal Immission Control Act (BImSchV) and the Technical Instructions on Air Quality Control (TA Luft)") by W. Fichtner, U. Karl and R. Hartel and D. Balussou of the DFIU, the Karlsruhe Institute of Technology (KIT) and the European Institute for Energy Research (EIFER) (study from 2011).

In general, emission factors serve as tools for calculating total emissions on the basis of fuel quantities. The applicable fuel quantities are available in the national Energy Balance, which is generated with data of the Federal Statistical Office.

While plant-specific annual emissions data and fuel inputs are available for large combustion plants, it would be unfeasible to carry out annual evaluations of some 600 plants and 1,000 plant components. For this reason, at regular intervals, and on the basis of data on large combustion plants, pollutant- and fuel-specific emission factors are determined that can be carried forward for several years at a time. The emission factors have to be updated whenever significant changes in the plant sector occur, or whenever the applicable legal requirements are tightened, however. To date, the required revisions of the factors in such cases have been carried out via projects. For the present updating of the emission factors, no call for projects was issued. Instead, the data on large combustion plants were revised by the German Environment Agency (Umweltbundesamt).

It may be assumed that the data on large combustion plants, pursuant to Section 25 of the 13th BImSchV and to Section 22 of the 17th BImSchV, have been completely available to the German Environment Agency since 2016. This is relevant for $NO_X$, $SO_2$ and particulate matter. Prior to that year, some data are missing, since the 17th BImSchV did not mandate reporting obligations for power plants that were licensed pursuant to the 17th BImSchV due to their co-incineration of waste. As of report year 2016, such plants report their emissions with and without co-incineration. Due to the completeness of the plant data, the authors of the present report were able to carry out evaluations of their own. In addition to focussing on updating emission factors, this work was aimed at comparing the fuel-input data with relevant statistical data, and at updating the fuel fractions, including co-incineration, used in plants subject to the TA Luft and the 13th BImSchV. In the case of obvious discrepancies, fuel-input data from emissions trading were used as an additional data source. In addition, for the years 2005 – 2015, fuel-input data from emissions trading were included for those plants that, due to their co-incineration of waste, had not submitted reports pursuant to the 13th BImSchV. In addition, the pertinent emissions data from the PRTR were included. Since some pollutants fall below the PRTR's cut-off threshold, it was not possible to complete the emissions data in all areas. Some gaps remained especially in the area of particulate matter. Due to the large number of plants involved, it was not possible to carry out a complete-coverage comparison with the fuel data from emissions trading.

For purposes of generating emission factors, plants are assigned to the regime of the 13th BImSchV. This approach is in keeping with the approach used to date in the inventory. In reality, however, plants that co-incinerate waste, along with their regular fuels – such as hard coal – fall under the regime of the 17th BImSchV and have to comply with tighter standards. For plants operating in the co-incineration mode, reporting covers not only the proportional emissions loads corresponding to the pertinent waste inputs; it also covers the total emissions loads, i.e. the loads including the fractions tied to use of regular fuels. To date, the available data have not supported any differentiation between co-incineration modes and regular operation. For this reason, use of regular fuels – even when plants were operating in the co-incineration mode – was assigned to the 13th BImSchV. For reasons of consistency, this approach was also used in the present project. Therefore, the emission factors listed in the relevant tables, for coal, are somewhat lower than they would be for plants in their regular operating mode, since the emission factors are mixed factors that take account of both the co-incineration mode and regular operation. As of 2016, the data provided by the German Länder make a distinction in this regard, with the result that it is possible to differentiate between regular operation and co-incineration. It will be necessary to consider how such data should best be handled. The data cannot be presented as a consistent time series, however, since the available data are inadequate for any recalculation for the years prior to 2015.

The calculation method was changed in the course of the revision. In the future, emission factors weighted by fuel inputs will be calculated. To date, the national emission factors have been calculated from the averages or medians of the factors for individual plants. In the process, factors were differentiated in terms of the various combustion technologies they represented, and they were weighted in accordance with their technology fractions in the various combustion sectors. Furthermore, commissioned research contractors were required to purchase a plant database that contained the relevant technical data. The so-purchased databases did not contain any information on annual fuel inputs, however. The weighting had to be carried out on the basis of the performance figures given.

It must also be noted that it was not possible to calculate emission factors directly for the years 2005 to 2012. For that period, as a rule, the measurement uncertainties were deducted from the total emissions. That is customary in measurement-based monitoring of emission limit values prescribed under immission-protection law. It is useful to use such monitoring-related measurement data also for purposes of emissions reporting. (The primary purpose of the measuring equipment installed in plants is to monitor compliance with prescribed emission limit values. The data such equipment collects, a sort of by-product of the monitoring process, can also be used for reporting purposes.) This approach is less useful for calculation of actually emitted annual loads, however, since it leads to a systematic underestimation of actual emissions. By the year 2013, the evaluation computers installed in systems for measurement-based monitoring were adapted in a manner that made it possible to also use their emissions measurements for emissions reporting, without any deductions to account for measurement uncertainties.

The emission factors for the year 2004 are used for the year 2005, due to a lack of realistic emission factors for the year 2005. This is consistent with the approach used in the project "Determination and evaluation of emission factors for combustion plants in Germany for the years 1995, 2000 and 2010." The approach was used to determine emission factors for the year 2004, and to calculate forecast values for the years 2010, 2015 and 2020. The emission factors for the years 2006 to 2012 have been determined via interpolation between the factors for the year 2005 (2004) and the year 2013.

That said, it must be noted that reliable information about termination of the procedure for deducting measurement uncertainties, by 2013, is available only for plants in the public sector. No reliable information on handling of measurement uncertainties is available with regard to industry data. The available factors were used nonetheless, due to a lack of alternative data. For this reason, the emission factors for industrial plants are subject to higher uncertainties.

In the project Fichtner et al 2011, and in predecessor projects, retrospective emission factors and forecast values were always calculated. The calculations are based on the data in the emission declarations for the years 2004 and 1996. The forecast values were determined on the basis of the applicable requirements under immission-protection law. Since emission declarations are produced only every 4 years, and since the projects have durations in keeping with their considerable scopes, it has not always been possible for the inventory to take prompt account of current developments. In the interest of achieving a certain timeliness nonetheless, the emissions for recent report years were determined via interpolation between the most recently reported data and forecast values.

The German Environment Agency now has complete access to $NO_X$, $SO_2$ and particulate matter emissions and fuel-inputs data for large combustion plants, however. As a result, emission factors can now be promptly determined, and there is no longer a need for forecast values. In the future, forecast values will be used only for projections and scenarios, and not for emissions reporting. The large quantity of data involved makes it unfeasible to carry out annual updates. Where updates cannot be carried out, the currently used factors have to be carried forward.

The emission data for carbon monoxide (CO) and ammonia (NH3) for the year 2016 were supplied to UBA once by the federal states. They originate from the emission declarations submitted by the operators every 4 years. Updates can therefore only be made at this interval.

The calculation of mercury emissions is based on the annual PRTR reporting. For the year 2016, an additional data query was sent to the federal states as part of a project. Therefore it was possible to include data on hard coal fired plants which are below the PRTR threshold.

# 2 Emission factors

## 2.1 Lignite-fired power plants in the public sector and the lignite mining sector

German lignite-fired power plants are fired primarily with coal dust. Only a few use grate firing and fluidised bed combustion. The plants are fitted with electrostatic filters and wet-desulphurisation systems. All lignite-fired power plants reduce nitrogen oxide emissions solely by means of primary measures. For the emission calculation, power plants with a total thermal output of about 63 GW were evaluated. As of report year 2016, complete emission reports for lignite-fired power plants are again available. The emissions data for raw lignite were evaluated on a mining-district-specific basis, to take account of the differences between coal from different districts. Mining-district-specific fuel data are also available in the coal statistics collected by the DEBRIV Federal German association of lignite-producing companies and their affiliated organisations. Currently, three mining districts are still in operation in Germany: the Rhineland (Rheinland), Lusatia (Lausitz) and Central German (Mitteldeutschland) districts. Coal mining in the Helmstedt lignite-mining district was terminated in the summer of 2016. Since the emission factors have been revised retroactively, the Helmstedt district was included in the evaluation.

Lignite differs, from district to district, primarily with regard to its net calorific value and sulphur content. Lignite from the Rhineland district has a low sulphur content, while lignite from the Lusatian and Central German mining districts has higher sulphur content levels. Some power plants claim exemptions pursuant to Section 4 (11) of the 13th Ordinance for the Implementation of the Federal Immission Control Act (BImSchV), to take account of the fact that lignite in some eastern German mining districts has a particularly high sulphur content. For this reason, in the framework of reporting for large combustion plants for the year 2016, operators also reported to the German Environment Agency on the sulphur content of their lignite and on the pertinent separation efficiency of their plants. For affected Lusatian-district plants, sulphur content levels of 0.8 – 1.8% were reported. Affected plants in the Central German district reported sulphur content levels between 2.9 and 3.4%.

Lignite also varies with respect to its net calorific value. In 2016, the Central German raw lignite used in power plants had an average net calorific value of 10.56 MJ/kg, while lignite from the Rhineland district had an average net calorific value of 8.86 MJ/kg. Such differences lead to differences in specific $CO_2$ emissions. Power plants in the Rhineland mining district had an average $CO_2$ emission factor of about 113 t $CO_2$/TJ, while the factor calculated for power plants in the Central German district amounted to 103.9 t $CO_2$/TJ (ETS 2017).

Significant differences are also seen in heavy metal emissions. The factors responsible for them, apart from the characteristics of the coal itself in the various mining districts – which can vary considerably even within individual open-pit mines – include the firing and waste-gas-scrubbing systems used. With respect to heavy metal emissions, the present evaluation considered only mercury emissions. Other heavy metal emissions need to be verified via additional measurements.

Along with emission factors, the applicable minimum and maximum 95% percentile values were determined. The following table compares the results with the emission factors obtained in the project Fichtner et al 2011. The table values in boldface type are the newly calculated factors that are being used for emissions reporting.

Table 1: Emission factors for public-sector raw-lignite-fired power plants (1.A.1.a) – Helmstedt mining district

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **$NO_X$** | CSE | kg/TJ | 68.50 | 68.50 | 68.50 | 68.50 | 68.50 |
| **$NO_X$** | **POSO** | **kg/TJ** | **68.54** | **63.81** | **61.77** | **58.35** | **55.21** |
| **$SO_2$** | CSE | kg/TJ | 134.10 | 72.64 | 73.82 | 75.00 | 75.00 |
| **$SO_2$** | **POSO** | **kg/TJ** | **134.02** | **95.12** | **101.66** | **115.12** | **107.13** |
| **Particulate matter** | CSE | kg/TJ | 20.00 | 8.30 | 8.30 | 8.30 | 8.30 |
| **Particulate matter** | **POSO** | **kg/TJ** | **3.60** | **-** | **-** | **-** | **1.21** |
| **PM10** | CSE | kg/TJ | 18.00 | 7.47 | 7.47 | 7.47 | 7.47 |
| **PM10** | **POSO** | **kg/TJ** | **3.25** | **-** | **-** | **-** | **1.095** |
| **PM2.5** | CSE | kg/TJ | 16.00 | 6.64 | 6.64 | 6.64 | 6.64 |
| **PM2.5** | **POSO** | **kg/TJ** | **2.89** | **-** | **-** | **-** | **0.97** |
| **CO** | CSE | kg/TJ | 22.60 | 22.60 | 22.60 | 22.60 | 22.60 |
| CO | ED | kg/TJ | - | - | - | - | 5.85 |

Table 2: Emission factors for public-sector raw-lignite-fired power plants (1.A.1.a) – Lusatian mining district

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **$NO_X$** | CSE | kg/TJ | 69.60 | 69.60 | 69.60 | 69.60 | 69.60 |
| **$NO_X$** | **POSO** | **kg/TJ** | **69.65** | **78.66** | **71.31** | **76.65** | **78.77** |
| **$NO_X$ min** | POSO | kg/TJ | 53.44 | 54.06 | 52.56 | 55.41 | 57.17 |
| **$NO_X$ max** | POSO | kg/TJ | 77.81 | 87.61 | 87.36 | 86.65 | 88.02 |
| **$SO_2$** | CSE | kg/TJ | 92.00 | 92.00 | 92.00 | 92.00 | 92.00 |
| **$SO_2$** | **POSO** | **kg/TJ** | **82.37** | **91.39** | **85.91** | **83.20** | **74.49** |
| **$SO_2$ min** | POSO | kg/TJ | 70.94 | 77.27 | 72.09 | 75.78 | 65.79 |
| **$SO_2$ max** | POSO | kg/TJ | 89.02 | 97.51 | 93.35 | 86.58 | 80.45 |

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **Particulate matter** | CSE | kg/TJ | 3.64 | 2.50 | 2.50 | 2.50 | 2.50 |
| **Particulate matter** | **POSO** | **kg/TJ** | **2.50** | **2.75** | **2.47** | **2.43** | **2.32** |
| **Particulate matter min** | POSO | kg/TJ | 1.07 | 0.84 | 0.46 | 0.62 | 0.81 |
| **Particulate matter max** | POSO | kg/TJ | 3.20 | 3.83 | 3.22 | 3.38 | 3.16 |
| **PM10** | CSE | kg/TJ | 3.28 | 2.25 | 2.25 | 2.25 | 2.25 |
| **PM10** | **POSO** | **kg/TJ** | **2.24** | **2.48** | **2.22** | **2.18** | **2.09** |
| **PM2.5** | CSE | kg/TJ | 2.91 | 2.00 | 2.00 | 2.00 | 2.00 |
| **PM2.5** | **POSO** | **kg/TJ** | **1.99** | **2.20** | **1.97** | **1.94** | **1.86** |
| **CO** | CSE | kg/TJ | 56.50 | 56.50 | 56.50 | 56.50 | 56.50 |
| **CO** | ED | kg/TJ | - | - | - | - | **39.21** |
| **CO min** | ED | kg/TJ | - | - | - | - | 8.15 |
| **CO max** | ED | kg/TJ | - | - | - | - | 72.45 |

**Table 3: Emission factors for public-sector raw-lignite-fired power plants (1.A.1.a) – Central German mining district**

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **$NO_X$** | CSE | kg/TJ | 76.30 | 76.30 | 76.30 | 76.30 | 76.30 |
| **$NO_X$** | **POSO** | **kg/TJ** | **78.55** | **69.54** | **72.77** | **75.04** | **76.53** |
| **$NO_X$ min** | POSO | kg/TJ | 48.76 | 51.08 | 49.11 | 50.67 | 56.63 |
| **$NO_X$ max** | POSO | kg/TJ | 235.73 | 126.63 | 152.35 | 101.74 | 121.24 |
| **$SO_2$** | CSE | kg/TJ | 131.30 | 108.80 | 108.80 | 108.80 | 108.80 |
| **$SO_2$** | **POSO** | **kg/TJ** | **136.09** | **121.58** | **118.57** | **96.90** | **92.01** |
| **$SO_2$ min** | POSO | kg/TJ | 87.92 | 98.10 | 98.19 | 85.75 | 65.58 |
| **$SO_2$ max** | POSO | kg/TJ | 701.47 | 597.71 | 611.55 | 408.62 | 668.04 |
| **Particulate matter** | CSE | kg/TJ | 3.64 | 2.50 | 2.50 | 2.50 | 2.50 |
| **Particulate matter** | **POSO** | **kg/TJ** | **4.72** | **2.42** | **2.02** | **1.80** | **1.37** |
| **Particulate matter min** | POSO | kg/TJ | 2.82 | 1.47 | 1.00 | 0.80 | 0.88 |
| **Particulate matter max** | POSO | kg/TJ | 6.62 | 9.36 | 6.61 | 4.50 | 6.30 |
| **PM10** | CSE | kg/TJ | 3.28 | 2.25 | 2.25 | 2.25 | 2.25 |
| **PM10** | **POSO** | **kg/TJ** | **4.25** | **2.18** | **1.82** | **1.62** | **1.23** |
| **PM2.5** | CSE | kg/TJ | 2.91 | 2.00 | 2.00 | 2.00 | 2.00 |
| **PM2.5** | **POSO** | **kg/TJ** | **3.78** | **1.94** | **1.62** | **1.44** | **1.10** |
| **CO** | CSE | kg/TJ | 15.90 | 15.90 | 15.90 | 15.90 | 15.90 |
| **CO** | **ED** | **kg/TJ** | **-** | **-** | **-** | **-** | **12.30** |
| **CO min** | ED | kg/TJ | - | - | - | - | 4.13 |
| **CO max** | ED | kg/TJ | - | - | - | - | 82.91 |

**Table 4: Emission factors for public-sector raw-lignite-fired power plants (1.A.1.a) – Rhineland mining district**

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **$NO_X$** | CSE | kg/TJ | 74.60 | 74.60 | 74.60 | 74.60 | 74.60 |
| **$NO_X$** | **POSO** | **kg/TJ** | **74.63** | **76.13** | **77.01** | **76.74** | **77.00** |
| **$NO_X$ min** | POSO | kg/TJ | 64.29 | 65.52 | 57.22 | 52.84 | 63.31 |
| **$NO_X$ max** | POSO | kg/TJ | 81.14 | 78.63 | 79.21 | 79.69 | 78.62 |

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **$SO_2$** | CSE | kg/TJ | 35.30 | 35.30 | 35.30 | 35.30 | 35.30 |
| **$SO_2$** | **POSO** | **kg/TJ** | **35.37** | **31.00** | **30.59** | **29.24** | **26.18** |
| **$SO_2$ min** | POSO | kg/TJ | 21.19 | 23.37 | 22.12 | 23.25 | 19.49 |
| **$SO_2$ max** | POSO | kg/TJ | 67.19 | 53.04 | 42.27 | 39.84 | 38.91 |
| **Particulate matter** | CSE | kg/TJ | 3.18 | 3.18 | 3.18 | 3.18 | 3.18 |
| **Particulate matter** | **POSO** | **kg/TJ** | **3.58** | **1.70** | **1.79** | **1.83** | **1.90** |
| **Particulate matter min** | POSO | kg/TJ | 2.36 | 1.56 | 1.24 | 0.73 | 1.72 |
| **Particulate matter max** | POSO | kg/TJ | 5.70 | 2.37 | 1.98 | 2.09 | 2.31 |
| **PM10** | CSE | kg/TJ | 2.86 | 2.86 | 2.86 | 2.86 | 2.86 |
| **PM10** | **POSO** | **kg/TJ** | **3.22** | **1.53** | **1.61** | **1.65** | **1.71** |
| **PM2.5** | CSE | kg/TJ | 2.54 | 2.54 | 2.54 | 2.54 | 2.54 |
| **PM2.5** | **POSO** | **kg/TJ** | **2.86** | **1.36** | **1.43** | **1.47** | **1.52** |
| **CO** | CSE | kg/TJ | 43.30 | 43.30 | 43.30 | 43.30 | 43.30 |
| **CO** | **ED** | **kg/TJ** | **-** | **-** | **-** | **-** | **32.36** |
| **CO min** | ED | kg/TJ | - | - | - | - | 8.06 |
| **CO max** | ED | kg/TJ | - | - | - | - | 59.50 |

The source for the data from the Central System of Emissions (CSE) is Fichtner et al 2011. The abbreviation "POSO" used in this table refers to the "Point Source" database, into which / in which all data reported pursuant to Section 25 of the 13th Ordinance for the Implementation of the Federal Immission Control Act (BImSchV) are imported / evaluated. The study Fichtner et al 2011 evaluated emission declarations from the year 2004 and used the results to derive emission factors. For the years 2010, 2015 and 2020, forecast values were determined, on the basis of the expected development of the power plant sector and the mandated limits. The comparison with the real emission factors calculated for 2013-2016 shows that the $NO_X$ EF tended to be underestimated. They thus need to be upwardly corrected. The factors for $SO_2$ and particulate matter, on the other hand, were overestimated and can now be significantly reduced. The split factors for particulate matter continue to be 90% for PM10 and 80% for PM2.5. In general, review is needed to determine whether these factors are still accurate or whether measures to reduce particulate matter emissions have led to changes in PM fractions. The data for CO come from emission declarations (ED). While many plants continuously measure CO, this pollutant is not covered by reporting obligations pursuant to Section 25 of the 13th BImSchV. In reporting pursuant to PRTR, many plants' CO emissions are below the cut-off threshold. As a result, no pertinent annual data are available to the German Environment Agency. Emission declarations are the only extensive data source. They are submitted only every 4 years, however. As a result of data-availability limitations, and of the fact that CO values can vary widely from year to year, even within one and the same plant, it is difficult to calculate realistic emission factors. A comparison with the data collected for the best-available-technology (BAT) process suggests that, for some plants, the measurement uncertainty was deducted in calculation of the CO load. The pertinent results need to be reviewed, in a further step.

### 2.1.1 Co-incineration in public-sector lignite-fired power plants

Along with their standard fuels, Germany's coal-fired power plants often co-incinerate certain types of waste. The waste types involved include sewage sludges, residual substances from the paper industry and processed settlement waste. While plants that operate solely with standard fuels are subject to the emissions-control provisions of the 13th Ordinance for the Implementation of the Federal Immission Control Act (13. BImSchV), plants that co-incinerate waste are subject to the provisions of the 17th BImSchV (Ordinance on the incineration and co-incineration of waste), which tend to be more stringent.

For report year 2016, the German Environment Agency received, for the first time, a separate set of emissions and fuel data on co-incineration in large combustion plants. This made it possible to carry out a plant-specific evaluation. The following table shows the results for co-incineration, in a comparison with the weighted average values listed in Table 1 through Table 4, which are overall results, including co-incineration, for the various mining districts.

**Table 5: Additional evaluation applying to co-incineration in public-sector lignite-fired power plants**

| Mining district (Revier) | Combustion mode | Pollutant | Units | 2016 |
|---|---|---|---|---|
| **Helmstedt** | All plants | $NO_X$ | kg/TJ | 55.21 |
| | Only co-incineration | $NO_X$ | kg/TJ | 56.27 |
| | All plants | $SO_2$ | kg/TJ | 107.13 |
| | Only co-incineration | $SO_2$ | kg/TJ | 110.71 |
| | All plants | Particulate matter | kg/TJ | 1.21 |
| | Only co-incineration | Particulate matter | kg/TJ | 1.18 |
| **Lusatia (Lausitz)** | All plants | $NO_X$ | kg/TJ | 78.77 |
| | Only co-incineration | $NO_X$ | kg/TJ | 75.04 |
| | All plants | $SO_2$ | kg/TJ | 74.49 |
| | Only co-incineration | $SO_2$ | kg/TJ | 74.72 |
| | All plants | Particulate matter | kg/TJ | 2.32 |
| | Only co-incineration | Particulate matter | kg/TJ | 2.14 |

| Mining district (Revier) | Combustion mode | Pollutant | Units | 2016 |
|---|---|---|---|---|
| **Central German district (Mitteldeutschland)** | All plants | $NO_X$ | kg/TJ | 76.53 |
| | Only co-incineration | $NO_X$ | kg/TJ | 82.46 |
| | All plants | $SO_2$ | kg/TJ | 92.01 |
| | Only co-incineration | $SO_2$ | kg/TJ | 100.82 |
| | All plants | Particulate matter | kg/TJ | 1.37 |
| | Only co-incineration | Particulate matter | kg/TJ | 1.05 |
| **Rhineland (Rheinland)** | All plants | $NO_X$ | kg/TJ | 77.00 |
| | Only co-incineration | $NO_X$ | kg/TJ | 75.86 |
| | All plants | $SO_2$ | kg/TJ | 26.18 |
| | Only co-incineration | $SO_2$ | kg/TJ | 21.68 |
| | All plants | Particulate matter | kg/TJ | 1.90 |
| | Only co-incineration | Particulate matter | kg/TJ | 1.84 |

As a result of differences between the various types of lignite used, and between the plants within the sector, only a few conclusions can be drawn from the comparison within the table. One is that particulate-matter emission factors for co-incineration are slightly lower than the overall factors, which is consistent with the 17th BImSchV's more-stringent limits on particulate matter in comparison with the 13th BImSchV. No clear trend is apparent for $NO_X$ and $SO_2$.

### 2.1.2 Mercury emissions of lignite-fired power stations

For the most part, mercury emission factors are calculated on the basis of PRTR 2018 data. Those data were compared with the data in the large combustion plant (LCP) reports pursuant to Section 25, 13th BImSchV. The applicable fuel-input data were obtained from the LCP reports. For the year 2016, the data from all emission declarations were available. The data in the emission declarations are identical with the PRTR data for public-sector lignite-fired power plants, however. The evaluation was carried out only on the basis of measurements. Both the emission declarations and the PRTR make distinctions between measured, calculated and estimated emissions. Unfortunately, measured values are not broken down into the categories "continuous measurements" and "single measurements." It proved possible to calculate weighted average values for the Lusatian and Central German mining districts. Since nearly all plants in those two mining districts are subject to measurement requirements, the coverage rate is nearly 100%. In the Rhineland mining district, measurements are carried out in only a small number of plants. The measurements cover only about 1/3 of the total fuel inputs involved. For this reason, it was not possible to calculate any weighted factors for that district's plants. Instead, average values were obtained from the individual factors.

Table 6: Mercury emission factors of lignite-fired power plants

| Mining district (Revier) | Pollutant | Units | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|
| **Helmstedt** | **Hg, weighted average** | **g/TJ** | **3.56** | **5.23** | **2.79** | **1.87** | **2.13** | **4.81** | **8.24** |
| **Lausitz (Lusatia)** | **Hg, weighted average** | **g/TJ** | **2.70** | **2.16** | **2.02** | **1.77** | **2.44** | **3.06** | **2.62** |
| | Hg, average | g/TJ | 2.68 | 2.43 | 1.98 | 1.83 | 2.52 | 3.42 | 2.67 |
| | Hg, median | g/TJ | 2.76 | 2.53 | 2.04 | 1.90 | 2.33 | 3.14 | 2.73 |
| | Hg min | g/TJ | 2.48 | 1.68 | 1.70 | 1.48 | 2.30 | 2.20 | 2.22 |
| | Hg max | g/TJ | 2.82 | 3.10 | 2.23 | 2.13 | 2.86 | 4.83 | 3.07 |
| **Central German district (Mittel-deutschland)** | **Hg, weighted average** | **g/TJ** | **7.71** | **6.06** | **5.56** | **4.89** | **5.26** | **5.01** | **5.54** |
| | Hg, average | g/TJ | 5.04 | 5.12 | 4.79 | 4.75 | 5.26 | 4.93 | 6.02 |
| | Hg, median | g/TJ | 3.98 | 5.18 | 4.35 | 4.65 | 5.31 | 5.11 | 6.01 |
| | Hg min | g/TJ | 2.77 | 3.54 | 2.47 | 2.76 | 2.86 | 3.93 | 4.59 |
| | Hg max | g/TJ | 8.82 | 6.61 | 7.73 | 7.43 | 7.60 | 5.67 | 7.87 |
| **Rhineland** | **Hg, average** | **g/TJ** | **-** | **-** | **-** | **-** | **-** | **-** | **1.98** |
| | Hg, median | g/TJ | - | - | - | - | - | - | 1.74 |
| | Hg min | g/TJ | - | - | - | - | - | - | 1.69 |
| | Hg max | g/TJ | - | - | - | - | - | - | 2.62 |

### 2.1.3 Emission factors for lignite-dust and fluidised-bed coal

In addition to raw lignite, lignite products are also used in public power plants. Some of these products are used together with raw lignite. In these cases it is not possible to generate own emission factors because the amount of raw lignite used is very dominant. However, there are also some smaller plants that exclusively use lignite dust or fluidised bed coal. Specific factors can be derived from these. These are shown in the following table.

Table 7: Emission factors for lignite-dust and fluidised-bed coal of public power plants

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **$NO_X$** | CSE | kg/TJ | 100.00 | 99.28 | 99.24 | 99.20 | 99.16 |
| **$NO_X$** | **POSO** | **kg/TJ** | **75.42** | **79.99** | **78.26** | **76.53** | **72.16** |

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| $SO_2$ | CSE | kg/TJ | 110.00 | 107.44 | 107.22 | 107.00 | 106.88 |
| **$SO_2$** | **POSO** | **kg/TJ** | **-** | **98.34** | **99.93** | **109.25** | **91.20** |
| **Partic-ulate matter** | CSE | kg/TJ | 6.35 | 6.20 | 6.20 | 6.20 | 6.20 |
| **Partic-ulate matter** | **POSO** | **kg/TJ** | **3.03** | **0.70** | **0.38** | **0.13** | **0.26** |
| **PM10** | CSE | kg/TJ | 5.72 | 5.58 | 5.58 | 5.58 | 5.58 |
| **PM10** | **POSO** | **kg/TJ** | **3.03** | **0.70** | **0.38** | **0.13** | **0.26** |
| **PM2.5** | CSE | kg/TJ | 5.08 | 4.96 | 4.96 | 4.96 | 4.96 |
| **PM2.5** | **POSO** | **kg/TJ** | **3.03** | **0.70** | **0.38** | **0.13** | **0.26** |
| **CO** | CSE | kg/TJ | 32.00 | 32.00 | 32.00 | 32.00 | 32.00 |
| **CO** | ED | kg/TJ | - | - | - | - | 5.20 |

For the evaluated combustion plants listed in Table 7, which operate either with lignite dust or fluidised bed coal, it was not possible to generate emission factors for all pollutants. In the case of some plants, individual emission factors exhibited considerable jumps for which no technical explanation could be found. The questionably high and very low values were seen as indications that the underlying emissions and/or fuel data were of poor quality, and they were not included in determination of the new EF values for the CSE. Since only a few plants use lignite dust or fluidised bed coal, large discrepancies on the part of individual plants lead to anomalous overall values and emissions trends. Such anomalies have to be validated by licensing authorities, with the help of additional information. With regard to the particulate-matter emission factors, PM2.5 is assumed to account for a 100 % fraction of total particulate matter, since the affected plants are equipped with fabric hose filters. This is a conservative assumption, and it is based on information provided by a measuring institute. In further work, this assumption will need to be validated by further measurements. As a result of the small number of plants concerned, the group of factors was not broken down by mining districts.

**Table 8: Emission factors for raw lignite and lignite briquettes in power plants of the lignite mining sector and in other plants in the transformation sector (1.A.1.c)**

| Mining district (Revier) | Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **Central German (Mittel-deutschland) mining district** | $NO_X$ | CSE | kg/TJ | - | 76.30 | 76.30 | 76.30 | 66.11 |
| | **$NO_X$** | **POSO** | **kg/TJ** | **-** | **87.35** | **92.97** | **86.62** | **74.52** |
| | $SO_2$ | CSE | kg/TJ | - | 108.80 | 108.80 | 108.80 | 94.27 |
| | **$SO_2$** | **POSO** | **kg/TJ** | **-** | **166.99** | **162.62** | **166.05** | **125.01** |
| | Particulate matter | CSE | kg/TJ | - | 2.50 | 2.50 | 2.50 | 2.17 |
| | Particulate matter | POSO | kg/TJ | - | - | - | - | - |
| | CO | CSE | kg/TJ | 65.60 | 65.60 | 65.60 | 65.60 | 65.60 |
| | **CO** | **EE** | **kg/TJ** | **-** | **-** | **-** | **-** | **41.95** |
| **Rhineland** | $NO_X$ | CSE | kg/TJ | 79.60 | 79.60 | 79.60 | 79.60 | 79.28 |
| | **$NO_X$** | **POSO** | **kg/TJ** | **79.57** | **58.41** | **56.22** | **59.75** | **62.54** |
| | $SO_2$ | CSE | kg/TJ | 67.60 | 67.60 | 67.60 | 67.60 | 67.33 |
| | **$SO_2$** | **POSO** | **kg/TJ** | **73.43** | **39.43** | **37.19** | **39.59** | **36.42** |
| | Partic-ulate matter | CSE | kg/TJ | 4.82 | 4.40 | 4.40 | 4.40 | 4.38 |
| | **Partic-ulate matter** | **POSO** | **kg/TJ** | **2.63** | **3.11** | **2.47** | **2.30** | **1.90** |
| | PM10 | CSE | kg/TJ | 4.34 | 3.96 | 3.96 | 3.96 | 3.96 |
| | **PM10** | **POSO** | **kg/TJ** | **2.37** | **2.80** | **2.22** | **2.07** | **1.71** |
| | PM2.5 | CSE | kg/TJ | 3.86 | 3.52 | 3.52 | 3.52 | 3.52 |
| | **PM2.5** | **POSO** | **kg/TJ** | **2.10** | **2.50** | **1.98** | **1.84** | **1.52** |
| | CO | CSE | kg/TJ | 12.20 | 12.20 | 12.20 | 12.20 | 12.20 |
| | **CO** | **ED** | **kg/TJ** | **-** | **-** | **-** | **-** | **11.17** |

A comparison of the emission factors used to date in the CSE and the factors newly calculated from the POSO LCP database turns up larger differences than are seen in the case of public-sector power plants. These differences can be explained as the result of regular sector changes that are not necessarily predictable. In work for the new emission factors, all previous statistical plant reclassifications were taken into account in the calculations.

The evaluation of all large combustion plants has shown that all lignite used in this sector is used in large combustion plants.

### 2.1.4 Emission factors for lignite dust in power plants of the lignite mining sector and other plants of the conversion sector

Similar to public utilities, lignite dust is also used as fuel in lignite mining and other coal processing plants. The following table shows the specific emission factors for $NO_X$, $SO_2$, dust and CO.

**Table 9: Emission factors for lignite dust in power plants of the lignite mining sector and in other plants in the transformation sector (1.A.1.c)**

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **$NO_X$** | **POSO** | **kg/TJ** | **123.52** | **83.17** | **100.36** | **95.78** | **70.38** |
| **$SO_2$** | **POSO** | **kg/TJ** | **438.17** | **291.74** | **284.55** | **312.10** | **240.30** |
| **Partic-ulate matter** | **POSO** | **kg/TJ** | **5.57** | **1.00** | **1.51** | **2.02** | **0.98** |
| **PM10** | **POSO** | **kg/TJ** | **5.01** | **0.90** | **1.36** | **1.82** | **0.88** |
| **PM2.5** | **POSO** | **kg/TJ** | **4.45** | **0.80** | **1.21** | **1.62** | **0.78** |
| **CO** | **ED** | **kg/TJ** | **-** | **-** | **-** | **-** | **58.14** |

Due to the small number of plants involved, the data were not evaluated on a mining-district-specific basis. To date, the CSE has no structural element for use of lignite dust in large combustion plants of the other transformation sector. Nor can such an element be created, since the Energy Balance does not list fuel inputs for heat generation in plants of the "other" transformation sector. The Energy Balance lists only fuel inputs for power generation. To date, this fuel fraction, and the pertinent emissions, have been reported in the "other" industrial sector (1.A.2.gviii).

## 2.2 Lignite-fired power plants in industry (1.A.2.gviii)

**Table 10: Emission factors for use of raw lignite in industrial power plants (1.A.2.gviii)**

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **$NO_X$** | CSE | kg/TJ | 76.80 | 76.80 | 76.80 | 76.80 | 76.80 |
| **$NO_X$** | **POSO** | **kg/TJ** | **134.19** | **95.07** | **97.48** | **93.52** | **50.76** |
| **$SO_2$** | CSE | kg/TJ | 171.10 | 165.52 | 164.86 | 164.20 | 163.54 |
| **$SO_2$** | **POSO** | **kg/TJ** | **76.49** | **76.14** | **76.45** | **73.20** | **57.78** |

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **Partic-ulate matter** | CSE | kg/TJ | 9.48 | 8.70 | 8.70 | 8.70 | 8.70 |
| **Partic-ulate matter** | **POSO** | **kg/TJ** | **6.12** | **1.27** | **1.31** | **0.97** | **0.94** |
| **PM10** | CSE | kg/TJ | 8.53 | 7.83 | 7.83 | 7.83 | 7.83 |
| **PM10** | **POSO** | **kg/TJ** | **5.51** | **1.14** | **1.17** | **0.87** | **0.85** |
| **PM2.5** | CSE | kg/TJ | 7.58 | 6.96 | 6.96 | 6.96 | 6.96 |
| **PM2.5** | **POSO** | **kg/TJ** | **4.90** | **1.01** | **1.04** | **0.78** | **0.75** |
| **CO** | CSE | kg/TJ | 42.90 | 42.90 | 42.90 | 42.90 | 42.90 |

The newly calculated, POSO-database emission factors shown here diverge – considerably, in part – from the values used to date in the CSE. They need to be corrected, throughout the period back to 2004. The reason for the discrepancies is that in 2011, when KIT calculated the emission factors for the CSE, there was still some ambiguity in assignments of power plants to the public sector and to industry. As a result of quality problems, it was not possible to generate any new factors for the year 2016. For that year, the 2015 emission factor has been carried forward.

**Table 11: Emission factors for use of lignite briquettes in industrial power plants (1.A.2.gviii)**

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **$NO_X$** | **POSO** | **kg/TJ** | **113.66** | **70.24** | **80.71** | **84.85** | **70.80** |
| **$SO_2$** | **POSO** | **kg/TJ** | **139.57** | **83.17** | **91.57** | **92.49** | **61.93** |
| **Partic-ulate matter** | **POSO** | **kg/TJ** | **1.75** | **0.52** | **0.61** | **0.98** | **0.27** |
| **PM10** | **POSO** | **kg/TJ** | **1.57** | **0.47** | **0.55** | **0.89** | **0.25** |
| **PM2.5** | **POSO** | **kg/TJ** | **1.26** | **0.38** | **0.44** | **0.71** | **0.20** |
| **CO** | **ED** | **kg/TJ** | **-** | **-** | **-** | **-** | **22.18** |

To date, the CSE has had no structural element for industrial-sector large combustion plants that use lignite briquettes. As a result, no emission factors were available that could be used for comparisons in this area. It proved possible to calculate a large combustion plant (LCP) fraction from the data pursuant to Section 25 of the 13th BImSchV. The calculation showed that large combustion plants account for about 60% of industrial power plants' lignite briquette use. Briquettes are used almost exclusively in grate firing systems.

**Table 12: Emission factors for use of lignite-dust and fluidised-bed coal in industrial power plants and boilers (1.A.2.g.viii)**

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| $NO_X$ | CSE | kg/TJ | 100.00 | 99.28 | 99.24 | 99.20 | 99.16 |
| **$NO_X$** | **POSO** | **kg/TJ** | **72.39** | **106.47** | **104.79** | **68.72** | **66.49** |
| $SO_2$ | CSE | kg/TJ | 336.95 | 311.45 | 303.44 | 302.26 | 276.52 |
| **$SO_2$** | **POSO** | **kg/TJ** | **43.68** | **62.65** | **57.13** | **20.75** | **22.88** |
| Partic-ulate matter | CSE | kg/TJ | 14.60 | 8.00 | 8.00 | 8.00 | 8.00 |
| **Partic-ulate matter** | **POSO** | **kg/TJ** | **15.08** | **1.14** | **0.77** | **1.03** | **0.62** |
| PM10 | CSE | kg/TJ | 13.14 | 7.20 | 7.20 | 7.20 | 7.20 |
| **PM10** | **POSO** | **kg/TJ** | **13.57** | **1.03** | **0.69** | **0.93** | **0.56** |
| PM2.5 | CSE | kg/TJ | 11.68 | 6.40 | 6.40 | 6.40 | 6.40 |
| **PM2.5** | **POSO** | **kg/TJ** | **12.07** | **0.92** | **0.61** | **0.83** | **0.49** |
| CO | CSE | kg/TJ | 32.00 | 32.00 | 32.00 | 32.00 | 32.00 |

Table 12 also shows considerable discrepancies between the emission factors used to date in the CSE and the newly calculated emission factors. This is also due to ambiguities in sectoral assignments. In the past, lignite-dust inputs of source category 1.A.1.c were taken into account in this area.

In 2008, one plant was decommissioned, and this had a pronounced effect on the development of the overall emission factors. This explains why the $NO_X$ and $SO_2$ emission factors are lower for 2005 than they are for 2013. Since the plant in question had particularly high particulate-matter emissions, the PM-emission factors for 2005 are considerably higher than the factors for 2013.

**Table 13: LCP fractions for use of raw lignite in industrial power plants and boilers (1.A.2.gviii)**

| 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|
| 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | |
| 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | |

**Table 14: LCP fractions for use of lignite briquettes in industrial power plants and boilers (1.A.2.gviii)**

| 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|
| 61.6% | 65.8% | 60.4% | 65.8% | 52.9% | 66.5% | 67.2% |
| **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | |
| 67.0% | 62.8% | 63.2% | 67.3% | 58.5% | 61.4% | |

**Table 15: LCP fractions for use of lignite dust and fluidised bed coal in industrial power plants and boilers (1.A.2.gviii)**

| 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|
| 49.7% | 54.2% | 52.9% | 40.5% | 33.4% | 30.5% | 26.7% |
| **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | |
| 28.8% | 30.8% | 30.9% | 20.2% | 33.9% | 21.7% | |

The percentage values listed in Table 13 through Table 15 represent the relevant large combustion plants' shares of total fuel inputs in this sector. The differences with respect to 100% represent the plants licensed pursuant to the Technical Instructions on Air Quality Control (TA Luft). The fuel inputs for process emissions of the non-metallic minerals industry and the metal-producing industry are not considered here, since they are reported separately. Asphalt mixing plants, on the other hand, are included in the pertinent TA Luft fraction for use of lignite dust and fluidised-bed coal.

## 2.3 Hard-coal-fired power plants in the public sector

A total of about 70 plants and plant components were evaluated. Due to the large number of individual data items available, more-detailed evaluations were possible in this area. In addition to the weighted averages that are calculated as a matter of course, simple averages ("averages") were calculated from the individual factors, and the median was determined. In addition, 95% percentile minimum and maximum values were determined. Weighted averages are to be used in future reporting.

**Table 16: Emission factors for public-sector hard-coal-fired power plants (1.A.1.a)**

| Pollutant | Origin | | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **$NO_X$** | CSE | | kg/TJ | 61.20 | 57.14 | 56.42 | 55.70 | 55.00 |
| **$NO_X$** | **POSO** | **weighted average** | **kg/TJ** | **63.76** | **61.16** | **60.14** | **59.58** | **55.63** |
| **$NO_X$** | POSO | average | kg/TJ | 69.38 | 63.11 | 62.79 | 62.27 | 59.35 |
| **$NO_X$** | POSO | median | kg/TJ | 63.54 | 63.53 | 63.00 | 63.06 | 62.61 |
| **$NO_X$** | POSO | min | kg/TJ | 34.86 | 29.90 | 29.87 | 28.45 | 23.18 |
| **$NO_X$** | POSO | max | kg/TJ | 129.83 | 97.88 | 98.07 | 98.19 | 91.67 |

| Pollutant | Origin | | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **$SO_2$** | CSE | | kg/TJ | 51.40 | 48.74 | 48.42 | 48.10 | 47.90 |
| **$SO_2$** | **POSO** | **weighted average** | **kg/TJ** | **55.80** | **46.95** | **43.56** | **42.88** | **36.87** |
| **$SO_2$** | POSO | average | kg/TJ | 64.65 | 51.53 | 50.13 | 50.09 | 41.99 |
| **$SO_2$** | POSO | median | kg/TJ | 55.27 | 45.30 | 42.76 | 43.38 | 42.38 |
| **$SO_2$** | POSO | min | kg/TJ | 17.02 | 10.91 | 11.62 | 10.78 | 8.38 |
| **$SO_2$** | POSO | max | kg/TJ | 122.61 | 103.56 | 91.74 | 91.90 | 73.80 |
| **Particulate matter** | CSE | | kg/TJ | 3.48 | 3.30 | 3.30 | 3.30 | 3.30 |
| **Particulate matter** | **POSO** | **weighted average** | **kg/TJ** | **4.33** | **1.65** | **1.63** | **1.58** | **1.43** |
| **Particulate matter** | POSO | Average | kg/TJ | 3.80 | 1.38 | 1.47 | 1.47 | 1.36 |
| **Particulate matter** | POSO | median | kg/TJ | 3.07 | 1.18 | 1.15 | 1.12 | 1.08 |
| **Particulate matter** | POSO | min | kg/TJ | 0.40 | 0.10 | 0.21 | 0.27 | 0.20 |
| **Particulate matter** | POSO | max | kg/TJ | 8.54 | 3.47 | 3.16 | 3.00 | 3.44 |
| **PM10** | CSE | | kg/TJ | 3.13 | 2.97 | 2.97 | 2.97 | 2.97 |
| **PM10** | **POSO** | **weighted average** | **kg/TJ** | **3.89** | **1.48** | **1.47** | **1.42** | **1.29** |
| **PM2.5** | CSE | | kg/TJ | 2.78 | 2.64 | 2.64 | 2.64 | 2.64 |
| **PM2.5** | **POSO** | **weighted average** | **kg/TJ** | **3.46** | **1.32** | **1.31** | **1.26** | **1.15** |
| **CO** | CSE | | kg/TJ | 7.77 | 6.98 | 6.94 | 6.90 | 6.86 |
| **CO** | ED | weighted average | kg/TJ | - | - | - | - | 6.16 |
| **CO** | ED | average | kg/TJ | - | - | - | - | 9.01 |
| **CO** | ED | median | kg/TJ | - | - | - | - | 5.17 |
| **CO** | ED | min | kg/TJ | - | - | - | - | 1.09 |
| **CO** | ED | max | kg/TJ | - | - | - | - | 30.01 |

Overall, the emission factors determined by Fichtner et al 2011 (CSE) in for 2004 are very close to the newly calculated values. The values for $SO_2$ and particulate matter emissions, at the periphery of the current value range, have decreased more markedly than was originally expected. These changes seem plausible in light of the facts that exemptions for PM limit values expired on 1 January 2011 and that stricter $SO_2$ limit values came into force on 1 January 2016. The $NO_X$ emissions are slightly higher than was expected.

As a result of erroneous fuel information for one large power plant, the hard-coal inputs for large combustion plants between 2010 and 2012 considerably exceeded the total hard-coal-input quantities reported in statistics. Via a review of the individual factors for all power plants, it proved possible to identify the plant in question. The time series shows noticeable jumps for all pollutants. The erroneous fuel data were replaced with emissions trading data.

Pursuant to energy statistics, public-sector power plants use only hard coal. Transformation products, such as hard-coal coke and hard-coal briquettes, do not play a role.

### 2.3.1 Co-incineration in public-sector hard-coal-fired power plants

Some hard-coal-fired power plants also co-incinerate waste, of various types. The explanations given in Chapter 3.1.1 with regard to the applicable legal provisions also apply to hard-coal-fired power plants that co-incinerate waste. Specific data on co-incineration are also available for such plants as of 2016. The following table shows the relevant evaluation results.

**Table 17: Additional evaluation: Co-incineration in public-sector hard-coal-fired power plants**

| Pollutant | Combustion mode | Units | 2016 |
|---|---|---|---|
| **$NO_X$** | All plants | kg/TJ | 55.36 |
| **$NO_X$** | Only co-incineration | kg/TJ | 60.04 |
| **$SO_2$** | All plants | kg/TJ | 37.10 |
| **$SO_2$** | Only co-incineration | kg/TJ | 35.74 |
| **Particulate matter** | All plants | kg/TJ | 1.45 |
| **Particulate matter** | Only co-incineration | kg/TJ | 1.29 |

The emission factors shown in the table, for the entire power plant fleet, lend themselves only partly to comparison with the values for co-incineration, since the two power plant fleets are not identical. For hard-coal-fired power plants – as for lignite-fired power plants – the specific particulate matter emissions for co-incineration are somewhat lower than the emissions determined for the power plant fleet as a whole. This is a result of the stricter PM limit values introduced by the 17th Ordinance for the Implementation of the Federal Immission Control Act (BImSchV) for waste incineration plants. The lower $SO_2$ emission factors for co-incineration, by contrast, cannot be explained as the result of differences in limit values. Presumably, the differences are due to changes in the composition of the power plant fleet, and to the use of different qualities of coal that such changes entail. On average, the sulphur content levels of the substitute fuels involved are lower than those of hard coal.

### 2.3.2 Firing-technology-specific evaluation

In previous research projects, emission factors for the different firing technologies used were determined first. Then, the factors were weighted via the different technologies' shares of the thermal output. Since complete emissions data can now be assumed to be available for large combustion plants, weighted factors can be calculated from the entire mix. For comparison with the previous method, technology-specific emission factors were also evaluated. The relevant factors are listed in the following tables.

**Table 18: Additional evaluation: Public-sector hard-coal-fired power plants with fluidised bed combustion**

| Pollutant | Origin | Units | Technology | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **$NO_X$** | POSO | kg/TJ | Fluidised-bed combustion | 33.78 | 34.20 | 32.77 | 36.09 | 37.67 |
| **$SO_2$** | POSO | kg/TJ | Fluidised-bed combustion | 62.17 | 36.41 | 39.54 | 41.46 | 53.24 |
| **Particulate matter** | POSO | kg/TJ | Fluidised-bed combustion | 3.55 | 1.31 | 0.94 | 0.71 | 1.20 |

**Table 19: Additional evaluation: Public-sector hard-coal-fired power plants with slag tap firing**

| Pollutant | Origin | Units | Equipment and techniques | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **$NO_X$** | POSO | kg/TJ | Wet bottom | 68.37 | 72.52 | 72.54 | 70.34 | 67.86 |
| **$SO_2$** | POSO | kg/TJ | Wet bottom | 73.08 | 47.50 | 46.80 | 50.93 | 44.80 |
| **Particulate matter** | POSO | kg/TJ | Wet bottom | 2.67 | 1.72 | 1.74 | 1.47 | 1.60 |

**Table 20: Additional evaluation: Public-sector hard-coal-fired power plants with grate firing**

| Pollutant | Origin | Units | Equipment and techniques | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **$NO_X$** | POSO | kg/TJ | Grate firing | 67.09 | 68.03 | 63.20 | 60.40 | 53.71 |
| **$SO_2$** | POSO | kg/TJ | Grate firing | 70.83 | 48.64 | 50.37 | 48.04 | 40.62 |
| **Particulate matter** | POSO | kg/TJ | Grate firing | 0.92 | 1.05 | 1.12 | 0.99 | 0.81 |

**Table 21: Additional evaluation: Public-sector hard-coal-fired power plants with dust firing**

| Pollutant | Origin | Units | Equipment and techniques | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **$NO_X$** | POSO | kg/TJ | Dust firing | 64.47 | 61.53 | 62.31 | 60.19 | 58.20 |
| **$SO_2$** | POSO | kg/TJ | Dust firing | 52.98 | 46.26 | 42.07 | 40.84 | 37.47 |
| **Particulate matter** | POSO | kg/TJ | Dust firing | 4.27 | 1.40 | 1.41 | 1.42 | 1.39 |

Some 85% of fuel inputs take place in power plants that use "dust firing," i.e. that grind the hard coal first and then burn it in dust form in their boilers.

The comparison shows that the specific $NO_X$ emissions of fluidised bed combustion are lower than those of all other combustion technologies listed here, due to the lower combustion temperatures involved in the fluidised bed combustion process. That process tends to produce higher $N_2O$ emissions, however. Slag tap firing systems have somewhat higher $NO_X$ emission factors, in keeping with the nature of their combustion technology. The temperatures reached in the melting chambers of slag tap systems are considerably higher than the average temperatures occurring in dust-firing systems.

Particulate matter emissions tend to depend more on the effectiveness of dust-removal systems and less on combustion technologies. For example, plants with fabric filters have considerably lower particulate matter emissions than do plants with electrostatic filters. Plants in urban areas, where stricter limit values usually apply, are often equipped with fabric filters. Younger, more-modern plants usually are also subject to stricter limit values.

Fluidised bed combustion systems, by comparison, have slightly higher specific $SO_2$ emissions, since they usually operate only with dry flue-gas desulphurisation. On the other hand, $SO_2$ emissions depend much more strongly on the type of coal that is being burned.

In general, specific emissions depend very strongly on plant size, because stricter limit values apply at thermal output thresholds of 100 MW and 300 MW.

### 2.3.3 Mercury emissions of public-sector hard-coal-fired power plants

In an approach similar to that used for lignite-fired power plants, mercury emission factors for hard-coal-fired power plants were obtained by evaluating PRTR data. The PRTR data were compared with data from reports pursuant to Section 25 of the 13th Ordinance for the Implementation of the Federal Immission Control Act (BImSchV), for the "classical" group of pollutants. This made it possible to add the relevant fuel-input data. The emission declarations of the German Länder yielded a complete set of data for the year 2016. Only those data were evaluated that were designated as measurements. The data have a smaller degree of coverage than do the data for lignite-fired power plants. In terms of the fuel quantities used in all public-sector hard-coal-fired power plants, it proved possible to evaluate only about 60% of the plants concerned. Due to the lower degree of coverage involved, no weighted average value was calculated for this area; instead, the simple average of the individual factors was used. As a result of the cut-off threshold in the PRTR, the emissions quantities listed in the PRTR, for hard-coal-fired power plants, continue to differ somewhat from those reported in the emission declarations. The emission declarations, for example, also include additionally measured mercury emissions from a group of plants with a total annual fuel input of about 140 PJ. This has a noticeable impact on the emission factor. Evaluation of the mercury emissions data published in the PRTR, for 2016, yields a factor of 1.42 g/TJ, while the emission factor calculated from the emission declarations amounts to 0.95 g/TJ. For the years prior to 2016, the evaluation was carried out solely on the basis of the PRTR. The values for 2005 were carried forward from the EPER 2004. The following table lists the emission factors, along with the pertinent minimum and maximum values:

**Table 22: Mercury emission factors for public-sector hard-coal-fired power plants**

| Pollutant | | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **Hg** | **average** | **g/TJ** | **2.09** | **1.52** | **1.38** | **1.19** | **1.06** |
| **Hg** | median | g/TJ | 1.73 | 1.54 | 1.31 | 1.17 | 0.94 |
| **Hg** | min | g/TJ | 0.34 | 0.43 | 0.69 | 0.49 | 0.27 |
| **Hg** | max | g/TJ | 5.07 | 2.80 | 2.01 | 2.25 | 2.19 |

### 2.3.4 Ammonia emissions of hard-coal-fired power plants

To date, large combustion plants have not been required to monitor their ammonia emissions. As a result, emissions of this pollutant are measured only sporadically. No continuous measurements take place. With a view to calculating an emission factor, and on a one-time basis, the German Länder were requested to provide those data, for the year 2016, that operators had provided to the competent authorities in their emission declarations. With respect to fuel inputs, the measurements' coverage of the entire fleet of plants amounts to 36%. For ammonia, it makes little sense to group the power plants into the categories "industry" and "public sector," since the available data does not support such differentiation. Any attempt to so group the plants would only increase the uncertainties.

In general, ammonia emissions are expected to occur only in plants that reduce their nitrogen oxide emissions with the help of SCR or SNCR systems. Any ammonia emissions that remain in clean gas are the result of the "ammonia slip" that can occur in SCR and SNCR systems.

The levels of ammonia emissions in clean gas are affected by changes in the locations, within the exhaust-gas pathway, at which ammonia injection takes place and ammonia slip occurs. With regard to hard-coal-fired power plants, various constellations are differentiated:

1. Tail end: The SCR system is located downstream from the flue-gas desulphurisation system – and, thus, at the end of the flue-gas cleaning track.
2. High dust: The SCR system is located between the feed-water preheating system and the air preheating system, but upstream from the electrostatic filter and the flue-gas desulphurisation system located after it.
3. SNCR: Because of the high temperatures, this process is always sited near the boiler(s) – and, thus, upstream from the electrostatic filter and the flue-gas desulphurisation system.

According to the available measurement data, and the fuel-input data for 2016, nearly 2/3 of denitrification takes place in high-dust circuits, and somewhat less than 1/3 takes place in tail-end circuits. No secondary measures are carried out in the plants with fluidised bed combustion, which account for about 3% of the plants concerned. Consequently, no measurable ammonia emissions are to be expected. Only 1% of all plants use SNCR systems.

**Table 23: Ammonia emission factors for hard-coal-fired power plants**

| Pollutant | | Units | Tail end | High dust | SNCR | Entire fleet of plants |
|---|---|---|---|---|---|---|
| **$NH_3$** | weighted average | kg/TJ | 0.43 | 0.14 | | **0.23** |
| **$NH_3$** | average | kg/TJ | 0.46 | 0.15 | 0.74 | |
| **$NH_3$** | min | kg/TJ | 0.06 | 0.02 | | |
| **$NH_3$** | max | kg/TJ | 1.62 | 0.50 | | |

Ammonia emissions in clean gas are very low in plants with high-dust circuits, since in such plants a large part of any "slip"-related ammonia is separated out via the electrostatic filter and the flue-gas desulphurisation system. Higher values are seen in connection with tail-end systems, since such systems lack sinks for ammonia separation prior to clean-gas discharge.

The same emission factor is assumed for the heating oil used in hard coal-fired power plants as for hard coal, so that emissions are not underestimated.

Digression: Ammonia emissions in large combustion plants other than hard-coal-fired power plants

Logically enough, lignite-fired power plants that comply with $NO_X$ limit values without using SCR or SNCR systems, and that apply only primary measures, exhibit no ammonia slip. Under the assumption that no other ammonia-formation mechanisms are active in such plants, no ammonia emission factors were generated for such plants. The emission declarations for 2016 contained only one pertinent measurement, for a fluidised bed combustion system using lignite dust, and that measurement was at the limit of determination. Presumably, in that case, the limit of determination was treated as a concentration value, for the emission calculation.

Currently, very few SCR and SNCR systems are in service in gas turbine plants, steam power plants and other large boiler systems fired with natural gas, heating oil or biomass fuels. Due to the low level of utilisation of SCR and SNCR systems, and under the assumption that no other ammonia-formation mechanisms are active in such plants, no ammonia emission factors were generated for such plants.

Quantifiable ammonia emissions are seen only in connection with combustion of biogas. The $NH_3$ emission factor for biogas is the same as that for hard coal: 0.23 kg/TJ. In the case of biogas systems, the ammonia is released from the biogas fuel itself, however. To date, biogas engines have not been equipped with SCR or SNCR systems. Since biogas plants are too small to fall into the large combustion plant category, they have not been given further attention in the framework of this project.

### 2.3.5 Emission factors for former power plants in the hard-coal mining sector

In 2012, the power plants in the hard-coal-mining sector reclassified themselves into the public sector, since hard coal mining is being phased out in Germany by 2019. The power-plant reclassifications were taken into account in calculation of emission factors for the public sector. The following table shows the originally used emission factors.

Table 24: Emission factors for power plants in the hard-coal mining sector (1.A.1.c)

| Pollutant | Origin | Units | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 1011 |
|---|---|---|---|---|---|---|---|---|---|---|
| **$NO_X$** | CSE | kg/TJ | 72.02 | 72.02 | 72.02 | 72.02 | 72.02 | 72.02 | 72.02 | 72.02 |
| **$SO_2$** | CSE | kg/TJ | 85.35 | 85.31 | 85.36 | 85.40 | 85.21 | 85.08 | 85.08 | 85.08 |
| **Partic-ulate matter** | CSE | kg/TJ | 2.40 | 2.40 | 2.40 | 2.40 | 2.40 | 2.40 | 2.40 | 2.40 |
| **PM10** | CSE | kg/TJ | 2.16 | 2.16 | 2.16 | 2.16 | 2.16 | 2.16 | 2.16 | 2.16 |
| **PM2.5** | CSE | kg/TJ | 1.92 | 1.92 | 1.92 | 1.92 | 1.92 | 1.92 | 1.92 | 1.92 |

Starting in 2012, the emissions from these plants will be reported in the public sector. The corresponding power plant data are included in the calculation.

A data comparison showed that the fuel inputs listed in the CSE are considerably lower, for all years in question, than those listed in the POSO database of large combustion plants. The error in this case was not in the data for the large combustion plants; a direct comparison with energy statistics data for this sector showed good agreement. For reporting purposes, the fuel-input data are taken directly from the Energy Balance or are set as equal to the Energy Balance values. Clearly enough, the Energy Balance was prepared with a data source other than the energy statistics. This has led to underestimation – considerably, in part – of the fuel inputs. The difference is as high as 40 PJ (in that case, for the year 2010). That figure is equivalent to about 36% of the total hard-coal inputs in this source category.

## 2.4 Hard-coal-fired power plants in industry

Sectoral changes occasionally also occur in the hard-coal sector; they are related to the operator structures involved. Some industrial sites have outsourced their energy supply, by commissioning energy companies to operate their industrial power plants. In such cases, the affected power plants report as part of the public sector. Industrial power plants that are operated by the relevant industrial companies themselves usually report as part of the industrial sector concerned. Power plants in industrial parks also often report as part of the public sector, since industrial park sites usually include a range of different companies that produce different products and thus are assigned to different NACE codes. Sectoral classifications and sectoral changes can also be tied to other reasons. Changes of plant operators often lead to changes in sectoral classifications. A plant-operator change, for example, was the reason why, in 2016, one large plant switched from the public sector to the industrial sector.

Table 25: Emission factors for industry hard-coal-fired power plants and boiler systems

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **$NO_X$** | CSE | kg/TJ | 105.80 | 92.23 | 92.30 | 93.70 | 93.21 |
| **$NO_X$** | **POSO** | **kg/TJ** | **178.29** | **117.46** | **117.75** | **119.46** | **83.94** |
| **$SO_2$** | CSE | kg/TJ | 201.04 | 158.51 | 156.56 | 157.23 | 156.14 |
| **$SO_2$** | **POSO** | **kg/TJ** | **166.33** | **98.08** | **95.48** | **104.25** | **55.66** |

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **Particulate matter** | CSE | kg/TJ | 10.58 | 7.33 | 7.72 | 8.37 | 8.36 |
| **Particulate matter** | **POSO** | **kg/TJ** | **7.24** | **2.51** | **2.24** | **3.16** | **1.94** |
| **PM10** | CSE | kg/TJ | 9.52 | 6.57 | 6.57 | 6.57 | 6.57 |
| **PM10** | **POSO** | **kg/TJ** | **6.52** | **2.26** | **2.02** | **2.84** | **1.75** |
| **PM2.5** | CSE | kg/TJ | 8.46 | 5.84 | 5.84 | 5.84 | 5.84 |
| **PM2.5** | **POSO** | **kg/TJ** | **5.80** | **2.01** | **1.79** | **2.52** | **1.56** |
| **CO** | CSE | kg/TJ | 15.60 | 15.60 | 15.60 | 15.60 | 15.60 |
| **CO** | ED | kg/TJ | - | - | - | - | 16.23 |

Since the industry sector has only a few plants fired with hard coal, the relevant emission factors do not always develop in a continuous manner. Again and again, fluctuations occur. Overall, considerable reductions occurred during the period from 2005 to 2016. The development of the overall emission factors is driven primarily by the development of emissions of plants < 300 MW. As of 2016, existing plants in this performance class are subject to more-stringent legal provisions aimed at limiting NOx and $SO_2$ emissions. The development of emissions in 2016 was strongly influenced by the reclassification of one large power plant – from the public sector into the industry sector.

The factors obtained from the CSE are, actually, implied emission factors calculated on the basis of the entire fuel quantities used in large combustion plants and of the pertinent emissions. Those quantities also include boilers used for heat generation only and to which, so far, other emission factors have been assigned in the CSE. The new evaluation of large combustion plants, along with a comparison with the POSO database of large combustion plants, has found that no industry-sector hard-coal-fired boilers can be identified in POSO that are used solely for heat generation. All large combustion plants subject to reporting obligations are listed in the LCP database. The LCP database contains only plants for electricity generation. While it is certainly conceivable that a few licensed boiler systems are indeed used solely for heat generation, such systems are not visible at this aggregation level. Large combustion plant (LCP) data are reported in different ways, depending on the Land (state) involved. Reporting for some plants is block-specific, while reporting for others is based on combinations of plants.

For the years 2004 – 2016, an LCP fraction was calculated from the total hard-coal inputs in industry and the fuel inputs in large combustion plants. In all likelihood, the fuel inputs that result as the difference between the inputs of large combustion plants and those of all plants together are inputs in plants licensed pursuant to the Technical Instructions on Air Quality Control (TA Luft). The following table shows the results:

**Table 26: Hard-coal-fired power plants in industry: Percentages of plants that are large combustion plants**

| 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|
| 63.1% | 81.3% | 86.8% | 86.3% | 71.7% | 79.9% | 67.8% |
| **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | |
| 84.3% | 100.0% | 100.0% | 83.9% | 63.7% | 77.9 | |

### 2.4.1 Hard-coal-fired power plants in industry: Technology-specific evaluation

An additional evaluation of technology-specific emission factors was carried out for industry plants, as was done for the public-sector power plants. In the process, it was not possible to identify any plants with fluidised bed combustion, however. The following tables provide an overview:

**Table 27: Additional evaluation: Industrial hard-coal-fired power plants with slag tap firing**

| Pollutant | Origin | Equipment and techniques | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **$NO_X$** | POSO | Melting chamber | kg/TJ | 72.02 | 72.02 | 72.02 | 72.02 | 72.02 |
| **$SO_2$** | POSO | Melting chamber | kg/TJ | 85.31 | 85.36 | 85.40 | 85.21 | 85.08 |
| **Partic-ulate matter** | POSO | Melting chamber | kg/TJ | 2.40 | 2.40 | 2.40 | 2.40 | 2.40 |

**Table 28: Additional evaluation: Industrial hard-coal-fired power plants with grate firing**

| Pollutant | Origin | Equipment and techniques | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **$NO_X$** | POSO | Grate firing | kg/TJ | 116.32 | 111.86 | 107.90 | 111.70 | 85.22 |
| **$SO_2$** | POSO | Grate firing | kg/TJ | 309.95 | 269.29 | 263.91 | 246.68 | 140.56 |
| **Partic-ulate matter** | POSO | Grate firing | kg/TJ | 6.31 | 1.60 | 2.30 | 1.34 | 1.56 |

**Table 29: Additional evaluation: Industrial hard-coal-fired power plants with dust firing**

| Pollutant | Origin | Equipment and techniques | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **$NO_X$** | POSO | Dust firing | kg/TJ | 95.13 | 75.49 | 78.62 | 72.06 | 63.62 |
| **$SO_2$** | POSO | Dust firing | kg/TJ | 142.52 | 97.43 | 88.72 | 160.76 | 63.45 |

| Pollutant | Origin | Equipment and techniques | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **Partic-ulate matter** | POSO | Dust firing | kg/TJ | 7.82 | 3.94 | 3.49 | 6.44 | 2.23 |

In industry, dust firing accounts for about 50% of fuel inputs. That percentage is considerably lower than the corresponding figure for the public sector.

The differences apparent in the tables cannot be explained as solely the result of differences in combustion technology. The primary reason why grate firing systems have considerably higher emissions, for example, is that most grate firing systems are found in the lower performance range of large combustion plants with thermal outputs between 50 and 100 MW. In addition, the legal $NO_X$ and $SO_2$ emission limit values (ELVs) for such plants are considerably less stringent than those for larger plants, most of which have dust firing systems with dry ash removal (older large plants have dust firing systems with liquid ash removal (slag tap firing)).

## 2.5 Combustion of solid biomass

Only very few wood-fired plants > 50 MW thermal output are fired solely with fresh wood. Most plants, also in the range < 50 MW, are licensed pursuant to the 17th BImSchV and thus authorised to use category III and category IV waste wood. As a result of the stricter requirements applying to waste incineration plants, the particulate matter emissions from plants in this group are relatively low. Only large combustion plants were evaluated in this group. Some of the plants concerned also co-incinerate waste wood.

**Table 30: Emission factors for biomass-fired plants**

| Pollutant | | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **$NO_X$** | **weighted average** | **kg/TJ** | **135.22** | **66.99** | **65.85** | **60.40** | **76.42** |
| **$NO_X$** | average | kg/TJ | 153.01 | 63.38 | 63.37 | 59.67 | 83.67 |
| **$NO_X$** | median | kg/TJ | 126.72 | 55.09 | 52.85 | 54.02 | 60.74 |
| **$NO_X$** | min | kg/TJ | 124.14 | 42.93 | 42.11 | 38.76 | 51.14 |
| **$NO_X$** | max | kg/TJ | 200.29 | 90.56 | 101.70 | 93.01 | 192.79 |
| **$SO_2$** | **weighted average** | **kg/TJ** | **4.24** | **4.93** | **5.58** | **8.45** | **6.89** |
| **$SO_2$** | average | kg/TJ | - | 5.65 | 4.23 | 7.79 | 6.61 |
| **$SO_2$** | median | kg/TJ | - | 1.05 | 1.60 | 5.06 | 3.83 |
| **$SO_2$** | min | kg/TJ | - | 0.92 | 0.24 | 0.57 | 0.34 |
| **$SO_2$** | max | kg/TJ | - | 13.60 | 11.90 | 19.98 | 17.86 |

| Pollutant | | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **Particulate matter** | **weighted average** | **kg/TJ** | **5.60** | **0.28** | **0.54** | **0.86** | **0.83** |
| **Particulate matter** | average | kg/TJ | - | 0.30 | 0.67 | 0.84 | 1.16 |
| **Particulate matter** | median | kg/TJ | - | 0.26 | 0.26 | 0.44 | 0.56 |
| **Particulate matter** | min | kg/TJ | - | 0.07 | 0.04 | 0.12 | 0.03 |
| **Particulate matter** | max | kg/TJ | - | 0.56 | 1.57 | 2.48 | 4.23 |
| **CO** | **weighted average** | **kg/TJ** | **-** | **-** | **-** | **-** | **14.91** |
| **CO** | average | kg/TJ | - | - | - | - | 14.05 |
| **CO** | median | kg/TJ | - | - | - | - | 11.99 |
| **CO** | min | kg/TJ | - | - | - | - | 3.16 |
| **CO** | max | kg/TJ | - | - | - | - | 28.77 |
| **$NH_3$** | **weighted average** | **kg/TJ** | **-** | **-** | **-** | **-** | **1.28** |
| **$NH_3$** | average | kg/TJ | - | - | - | - | 1.44 |
| **$NH_3$** | median | kg/TJ | - | - | - | - | 1.66 |
| **$NH_3$** | min | kg/TJ | - | - | - | - | 0.14 |
| **$NH_3$** | max | kg/TJ | - | - | - | - | 2.65 |

Data source of table 30 is POSO (annual LCP data provision) relating $NO_X$, $SO_2$ and particulate matter. The German Länder made data on CO and $NH_3$ available (emission declaration). Since considerably fewer measurements were available for ammonia than were available for other pollutants, it was not possible to use the weighted average value in this case. The values tend to be higher than the $NH_3$ EF for hard-coal-fired power plants. As a rule, the deNOx systems used in biomass-fired plants are SNCR systems. Presumably, the somewhat higher ammonia emissions in the clean gas of such plants, in comparison to the clean gas of hard-coal-fired power plants, are due to a lack of wet $SO_2$-flue-gas scrubbing systems.

## 2.6 Blast-furnace gas power plants

There are no longer any public-sector power plants that use blast-furnace gas. In 2014, all of the remaining systems reclassified themselves into the industry sector. Emission factors for the public sector and for the industry sector were calculated in light of the current sectoral allocations.

**Table 31: Emission factors for public-sector power plants fired with blast-furnace gas (1.A.1.a)**

| Pollutant | Origin | Units | 2005 | 2013 | 2014 |
|---|---|---|---|---|---|
| **$NO_X$** | CSE | kg/TJ | 36.50 | 36.50 | 36.50 |
| **$NO_X$** | **POSO** | **kg/TJ** | **27.35** | **19.85** | **21.82** |
| **$SO_2$** | CSE | kg/TJ | 34.00 | 34.00 | 34.00 |
| **$SO_2$** | **POSO** | **kg/TJ** | **44.17** | **35.74** | **41.83** |
| **Particulate matter** | CSE | kg/TJ | 0.30 | 0.30 | 0.30 |
| **Particulate matter** | **POSO** | **kg/TJ** | **1.61** | **0.88** | **1.00** |

In the public sector, all fuel inputs were combusted in large combustion plants. There were no plants with thermal output < 50 MW.

In general, for gaseous fuels, the PM fraction is assumed to be 100%. Consequently, the PM10 and PM2.5 emission factors are considered to be equivalent to the particulate matter factors.

**Table 32: Emission factors for steel-industry power plants fired with blast-furnace gas (1.A.1.a)**

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **$NO_X$** | CSE | kg/TJ | 44.55 | 42.96 | 42.83 | 43.18 | 43.32 |
| **$NO_X$** | **POSO** | **kg/TJ** | **42.07** | **36.03** | **34.84** | **29.78** | **32.66** |
| **$NO_X$ min** | POSO | kg/TJ | 14.07 | 6.56 | 5.49 | 4.24 | 7.41 |
| **$NO_X$ max** | POSO | kg/TJ | 131.03 | 55.43 | 47.61 | 53.28 | 51.59 |
| **$SO_2$** | CSE | kg/TJ | 28.63 | 29.69 | 29.78 | 29.55 | 29.45 |
| **$SO_2$** | **POSO** | **kg/TJ** | **37.61** | **39.97** | **42.70** | **44.41** | **47.36** |
| **$SO_2$ min** | POSO | kg/TJ | 26.49 | 11.72 | 14.17 | 15.19 | 14.01 |
| **$SO_2$ max** | POSO | kg/TJ | 59.24 | 106.16 | 88.01 | 83.23 | 77.22 |
| **Particulate matter** | CSE | kg/TJ | 0.200 | 0.200 | 0.200 | 0.200 | 0.200 |
| **Particulate matter** | **POSO** | **kg/TJ** | **0.851** | **0.876** | **0.882** | **0.805** | **0.810** |
| **Particulate matter min** | POSO | kg/TJ | 0.36 | 0.20 | 0.17 | 0.21 | 0.16 |
| **Particulate matter max** | POSO | kg/TJ | 3.23 | 1.58 | 1.64 | 1.97 | 2.06 |

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **CO** | CSE | kg/TJ | 2.20 | 2.20 | 2.20 | 2.20 | 2.20 |
| **CO** | **ED** | **kg/TJ** | **-** | **-** | **-** | **-** | **4.53** |
| **CO min** | ED | kg/TJ | - | - | - | - | 0.78 |
| **CO max** | ED | kg/TJ | - | - | - | - | 9.33 |

In plants fired with blast furnace gas, mixtures consisting of blast furnace gas and basic oxygen furnace gas, coke oven gas and natural gas are usually used. No fuel-specific individual factors can be generated for such multifuel systems. As a result, the emission factors shown in the table referred to above refer to mixtures of blast furnace gas, basic oxygen furnace gas and coke oven gas. Consequently, the factors calculated for plants fired with blast furnace gas are applied to blast furnace gas and basic oxygen furnace gas and to coke oven gas. The same $NO_X$ factors are also used for natural gas. Since natural gas contains almost no sulphur, and very little particulate matter, the relevant $SO_2$ and particulate matter emissions were assigned completely to the gases of the steel industry. While the natural gas fraction used in plants fired with blast furnace gas is low, it should still be reported along with the other fractions in source category 1.A.2.a. For that natural gas fraction, the same $SO_2$ and particulate matter emission factors are used that are used for all other industrial power plants.

**Table 33: Percentages of steel-industry power plants that are large combustion plants**

| 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|
| 86.9% | 68.8% | 67.1% | 56.5% | 57.2% | 55.2% | 57.9% |
| **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | |
| 53.2% | 57.5% | 58.5% | 54.3% | 82.5% | 82.0% | |

## 2.7 District heating plants

Most district heating plants use natural gas. Light heating oil is also used, to a considerable extent. Very few plants in this group are fired with coal. In an approach similar to that taken for other areas, a large combustion plant (LCP) fraction was also calculated for district heating plants. This was done by dividing the fuel inputs of all large combustion plants identified as district heating plants by the total fuel inputs listed in Energy Balance line 16 (district heating plants). This approach yields unrealistically low LCP fractions, however. Presumably, the reason for this is that Energy Balance line 16 also includes the uncoupled heat generation of public-sector power plants. It could also originate with peak-load boilers installed next to large steam power plants. To date, it has not been possible to identify the real factors behind these values. Licensing law and energy statistics can be expected to differ in their references in this regard. The next amendment of the Act on Energy Statistics (Energiestatistikgesetz) is expected to make surveys more precise in this area. In all likelihood, the data will change as a result. Once data from the first report years following the change are available, the data will need to be evaluated again. Possibly, the applicable fractions will then have to be corrected.

No use of raw lignite in district heating plants was identified, although such use is listed in the Energy Balance, in line 16. The Federal Statistical Office's Statistik 064 statistics, by contrast, currently list 14 operators that report use of lignite dust. Since the POSO database of large combustion plants does not include any district heating plants that use lignite dust, it may be assumed that all use of lignite dust occurs in plants licensed under the Technical Instructions on Air Quality Control (TA Luft).

**Table 34: Emission factors for use of hard coal in district heating plants (LCP)**

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **$NO_X$** | CSE | kg/TJ | 123.10 | 109.60 | 106.70 | 103.80 | 103.40 |
| **$NO_X$** | **POSO** | **kg/TJ** | **120.94** | **111.65** | **113.90** | **115.76** | **95.43** |
| **$SO_2$** | CSE | kg/TJ | 250.10 | 198.18 | 188.64 | 179.10 | 177.88 |
| **$SO_2$** | **POSO** | **kg/TJ** | **240.39** | **197.53** | **158.73** | **149.30** | **119.44** |
| **Particulate matter** | CSE | kg/TJ | 13.68 | 7.30 | 7.30 | 7.30 | 7.30 |
| **Particulate matter** | **POSO** | **kg/TJ** | **-** | **2.20** | **2.81** | **-** | **2.28** |
| **PM10** | CSE | kg/TJ | 12.31 | 6.57 | 6.57 | 6.57 | 6.57 |
| **PM10** | **POSO** | **kg/TJ** | **-** | **1.98** | **2.53** | **-** | **2.06** |
| **PM2.5** | CSE | kg/TJ | 10.94 | 5.84 | 5.84 | 5.84 | 5.84 |
| **PM2.5** | **POSO** | **kg/TJ** | **-** | **1.76** | **2.25** | **-** | **1.83** |
| **CO** | CSE | kg/TJ | 21.30 | 21.30 | 21.30 | 21.30 | 21.30 |
| **CO** | ED | kg/TJ | - | - | - | - | 4.37 |

Due to quality problems, the particulate matter emission factors for some years were unsuitable for use.

**Table 35: Large combustion plant (LCP) fraction of district heating plants that use hard coal**

| 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|
| 9.2% | 15.1% | 7.8% | 5.0% | 4.8% | 4.5% | 3.6% |
| **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | |
| 2.4% | 2.2% | 3.8% | 3.1% | 2.7% | 3.3% | |

The percentage shares seem quite low. When the fuel inputs given in the POSO database of large combustion plants are set in relationship solely to the "Survey of generation, use, purchase and transmission of heat" ("Erhebung über Erzeugung, Bezug, Verwendung und Abgabe von Wärme (064)", Table 2: "Net heat production and fuel inputs of heating plants, by fuels" ("Nettowärmeerzeugung und Brennstoffeinsatz der Heizwerke nach Energieträgern"), considerably higher percentages result:

**Table 36: Large combustion plant (LCP) fraction of district heating plants that use hard coal, seen in relationship to the Federal Statistical Office's Statistik 064**

| 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|
| 19.5% | 31.1% | 28.5% | 15.7% | 25.8% | 14.0% | 15.8% |
| **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | |
| 12.9% | 31.8% | 48.9% | 55.5% | 64.9% | 65.0% | |

In Statistik 064, which is designed to accommodate heat-only producers, a case number of 13 is given for the year 2016. In the POSO database of large combustion plants, two large combustion plants were identified that use hard coal.

**Table 37: Emission factors for use of natural gas in district heating plants (LCP)**

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **$NO_X$** | CSE | kg/TJ | 37.00 | 32.20 | 31.60 | 31.00 | 30.40 |
| **$NO_X$** | **POSO** | **kg/TJ** | **37.71** | **38.77** | **44.43** | **40.81** | **37.31** |
| **$SO_2$** | **CSE** | **kg/TJ** | **0.14** | **0.14** | **0.14** | **0.14** | **0.14** |
| **$SO_2$** | POSO | kg/TJ | - | - | - | - | - |
| **Particulate matter** | **CSE** | **kg/TJ** | **0.16** | **0.10** | **0.10** | **0.10** | **0.10** |
| **Particulate matter** | POSO | kg/TJ | - | - | - | - | - |
| **CO** | CSE | kg/TJ | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 |
| **CO** | ED | kg/TJ | - | - | - | - | 5.16 |

No new emission factors can be determined for sulphur dioxide and particulate matter, since emissions of these substances, essentially, are listed in multifuel systems using heating oil. For these pollutants, the factors used to date in reporting remain in force and will continue to be used. The $SO_2$ emission factors used in the CSE were calculated from the sulphur content of the natural-gas types used in Germany, with odorization included. They are used for all natural gas inputs, in all sectors. This is a somewhat conservative approach, since large gas-fired plants also use natural gas without odorization. It would be unfeasible to determine and deduct the relevant quantities, however, especially since the total quantity emitted from natural gas is very small.

**Table 38: Large combustion plant (LCP) fraction of district heating plants that use natural gas**

| 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|
| 17.7% | 15.9% | 15.5% | 10.0% | 14.4% | 16.3% | 14.9% |
| **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | |
| 14.9% | 15.1% | 13.5% | 12.4% | 12.1% | 13.5% | |

With regard to the natural gas quantity identified, in the POSO database of large combustion plants, as natural gas used in district heating plants: If one sets this quantity in relationship only to the fuel quantity given in the Federal Statistical Office's Statistik 064 statistics – and not to the total quantity listed in Energy Balance line 16 – the following fractions result:

**Table 39: Large combustion plant (LCP) fraction of district heating plants that use natural gas, seen in relationship to the Federal Statistical Office's Statistik 064 statistics**

| 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|
| 21.4% | 18.9% | 18.9% | 11.6% | 18.2% | 22.1% | 21.5% |
| **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | |
| 22.5% | 22.8% | 23.0% | 20.1% | 20.0% | 20.2% | |

The fractions are all within a range around 20%. Only once, in 2007, does a markedly different value occur. The LCP data reported for that year are lower than the figures for 2016. They then decreased to a degree seen in 2006, and they are now at the same level seen in 2008. For this reason, the time series does not seem truly anomalous. Presumably, in that year (2007) considerably larger quantities of fuel were used in small plants licensed pursuant to the TA Luft. For the year 2016, the Federal Statistical Office's Statistik 064 statistics yield a case number of 697. In the POSO database of large combustion plants, a total of 61 district heating plants were identified that use natural gas.

**Table 40: Emission factors for use of heavy heating oil in district heating plants (LCP)**

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **$NO_X$** | CSE | kg/TJ | 128.70 | 107.52 | 105.36 | 103.20 | 102.40 |
| **$NO_X$** | **POSO** | **kg/TJ** | **145.44** | **161.54** | **-** | **163.88** | **147.20** |
| **$SO_2$** | CSE | kg/TJ | 210.10 | 151.00 | 151.00 | 151.00 | 151.00 |
| **$SO_2$** | **POSO** | **kg/TJ** | **284.57** | **130.77** | **-** | **133.47** | **134.02** |
| **Particulate matter** | CSE | kg/TJ | 8.46 | 7.50 | 7.50 | 7.50 | 7.50 |
| **Particulate matter** | **POSO** | **kg/TJ** | **12.02** | **11.54** | **-** | **10.00** | **13.41** |
| **PM10** | CSE | kg/TJ | 7.47 | 6.75 | 6.75 | 6.75 | 6.75 |
| **PM10** | **POSO** | **kg/TJ** | **8.54** | **8.19** | **-** | **7.10** | **9.52** |
| **PM2.5** | CSE | kg/TJ | 6.64 | 6.00 | 6.00 | 6.00 | 6.00 |
| **PM2.5** | **POSO** | **kg/TJ** | **6.61** | **6.35** | **-** | **5.50** | **7.38** |
| **CO** | CSE | kg/TJ | 6.80 | 6.80 | 6.80 | 6.80 | 6.80 |
| **CO** | ED | kg/TJ | - | - | - | - | 0.47 |

Only a few district heating plants use heavy heating oil. To data, the POSO database of large combustion plants has listed only "liquid fuels." For this reason, it has not been possible to break the data down by different qualities of heating oil. Since report year 2016, the relevant fuels are listed more specifically, and specific allocations are possible. In the evaluation, it was assumed that those plants that reported use of heavy heating oil in 2016 had always used the same fuel.

Since district heating plants do not measure particulate matter emissions, the calculation was based on other particulate matter measurements. The PM-fraction values given in the EMEP EEA Guidebook 2016 were used (71% PM10 and 55% PM2.5).

The CO emission factor derived from emission declarations seems very low, especially in comparison to the values calculated for light heating oil. These values need to be reviewed further.

**Table 41: Large combustion plant (LCP) fraction of district heating plants that use heavy heating oil**

| 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|
| 27.3% | 33.8% | 38.0% | 8.5% | 3.8% | 9.1% | 26.6% |
| **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | |
| 2.3% | 10.2% | 2.6% | 3.3% | 4.5% | 9.3% | |

For heavy heating oil, the Federal Statistical Office's Statistik 064 statistics give a case number of 1 for the year 2016. The case number for each of the previous years was 2. Two relevant plants were identified in the POSO database of large combustion plants. The fuel inputs for those plants do not agree. Review needs to be carried out, in cooperation with the Federal Statistical Office, to determine whether the plants are identical. It should be noted that, until the year 2014, only "liquid fuels" were reported in the context of reporting by large combustion plants. Clear differentiation between light and heavy heating oil has been possible only since 2015; that is the first report year for which operators have provided detailed figures. For purpose of allocations in previous years, it was assumed that those plants that have used heavy heating oil since 2015, as a fuel, have always used that fuel. It may be assumed that only a few conversions from light heating oil to heavy heating oil have occurred. Very likely, conversions in the other direction (heavy to light) have occurred much more frequently.

**Table 42: Emission factors for use of light heating oil in district heating plants**

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **$NO_X$** | CSE | kg/TJ | 57.60 | 57.60 | 57.60 | 57.60 | 57.60 |
| **$NO_X$** | **POSO** | **kg/TJ** | **56.05** | **38.96** | **40.65** | **-** | **46.78** |
| **$SO_2$** | CSE | kg/TJ | 56.17 | 46.70 | 46.70 | 26.50 | 36.97 |
| **$SO_2$** | **POSO** | **kg/TJ** | **41.92** | **13.27** | **8.82** | **10.35** | **13.90** |
| **Particulate matter** | CSE | kg/TJ | 2.20 | 1.60 | 1.60 | 1.60 | 1.60 |
| **Particulate matter** | **POSO** | **kg/TJ** | **0.22** | **0.45** | **0.68** | **0.50** | **0.85** |

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **CO** | CSE | kg/TJ | 1.40 | 1.40 | 1.40 | 1.40 | 1.40 |
| **CO** | ED | kg/TJ | - | - | - | - | 8.49 |

In the inventory, the emission factor for $SO_2$ is calculated on the basis of the maximum permitted sulphur content in light heating oil and of sales of low-sulphur heating oil. This is done for purposes of the overall balance. In individual sectors, inputs of low-sulphur heating oil can diverge markedly from the corresponding figures in the overall balance. It is not possible to determine whether this is indeed happening in any given individual case, however. Only in the case of small combustion plants can it safely be assumed that only low-sulphur heating oil is being used. The remaining fractions are assigned to the other source categories that also use light heating oil. For $SO_2$, the most useful approach is to continue using the CSE emission factors – rather than determining new ones – and to update them annually, using the described method. This makes sense even though, obviously enough, considerably more low-sulphur heating oil is used in district heating plants than in other types of large combustion plants.

With regard to particulate matter, we assume, conservatively, that total particulate matter emissions are equivalent to PM2.5 emissions. One aspect to note in this regard is that the EMEP EEA Guidebook 2016 lists other fractions for use of "gas oil" in the energy sector; it has PM10 accounting for 50% of total particulate matter and PM2.5 accounting for 12% of total particulate matter. Those percentages contradict the approach taken in the EMEP EEA 2016 Guidebook's transport chapter, which is of relevance in the present context. For diesel fuel, that source assumes that PM2.5 accounts for 100% of total particulate matter, even in cases in which no fine particulate air filters are being used. Diesel fuel and light heating oil differ only marginally in terms of their characteristics.

**Table 43: Large combustion plant (LCP) fraction of district heating plants that use light heating oil**

| 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|
| 15.2% | 16.7% | 15.8% | 16.4% | 17.6% | 25.9% | 24.9% |
| **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | |
| 14.1% | 18.1% | 13.6% | 7.2% | 4.1% | 7.0% | |

With regard to the quantity of light heating oil identified, in the POSO database of large combustion plants, as light heating oil used in district heating plants: If one sets this quantity in relationship only to the fuel quantity given in the Federal Statistical Office's Statistik 064 statistics – and not to the total quantity listed in Energy Balance line 16 – the following fractions result:

**Table 44: Large combustion plant (LCP) fraction of district heating plants that use light heating oil, seen in relationship to the Federal Statistical Office's Statistik 064 statistics**

| 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|
| 15.4% | 16.9% | 16.0% | 16.7% | 18.0% | 26.3% | 25.3% |
| **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | |
| 14.4% | 18.4% | 13.7% | 7.3% | 5.1% | 10.6% | |

For light heating oil, the two calculation methods hardly disagree, since the Federal Statistical Office's Statistik 066 statistics show virtually no fuel inputs for uncoupled heat generation, and thus the main reports in this area are made via the Federal Statistical Office's Statistik 064 statistics. For 2016, in the large combustion plants database, a total of 66 district heating plants can be identified that use light heating oil. The Federal Statistical Office's Statistik 064 statistics give a case number of 357 for the same year.

## 2.8 Public-sector power plants fired with natural gas

Germany has a great many gas-fired power plants. For the present purposes, the plants are grouped by basic types, each of which has its own emissions behaviour. Emission factors were calculated for gas-and-steam (combined cycle) systems, gas turbine plants, steam turbine plants and boiler systems. Emission factors for plants with combustion engines were determined in another project.

For $SO_2$, in the CSE database, cross-technology- and cross-sectoral emission factors are currently being used that were calculated on the basis of the sulphur content levels of the grades of natural gas used in Germany, with odorization included. For particulate matter, cross-technology emission factors were calculated, since only a few plants use only natural gas. In multifuel plants that use only small fractions of heating oil, $SO_2$ and particulate matter emissions are still determined primarily by the behaviour of the liquid fuel. As a result, it would not be possible to correctly assign such emissions to natural gas. For this reason, only plants that use only natural gas were evaluated. Due to this restriction, the number of evaluable plants is comparatively low. In addition, high uncertainties result in that the emissions values are highly rounded and, as a rule, given in tonnes. As a result of these constraints on quality, the newly calculated emission factors for particulate matter and $SO_2$ are not being adopted, even though the particulate matter factors in the CSE seem somewhat high.

**Table 45: Emission factors for use of natural gas public-sector power plants**

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **$SO_2$** | **CSE** | **kg/TJ** | **0.14** | **0.14** | **0.14** | **0.14** | **0.14** |
| **$SO_2$** | POSO | kg/TJ | 1.37 | 0.41 | 0.41 | 0.30 | 0.20 |
| **Particulate matter** | **CSE** | **kg/TJ** | **0.32** | **0.32** | **0.32** | **0.32** | **0.32** |
| **Particulate matter** | POSO | kg/TJ | 0.19 | 0.11 | 0.11 | 0.13 | 0.09 |

The specific $SO_2$ emission factors determined from reporting on large combustion plants are considerably higher than the values calculated via the aforementioned method and used to date in the CSE.

For particulates, we adopt the EMEP EEA 2016 Guidebook's assumption to the effect that particulates < PM2.5 account for 100% of the total particulate matter emissions of natural-gas-fired plants. For this reason, the PM10 and PM2.5 emission factors are equivalent to the emission factors for total particulate matter. While the emission factors for $SO_2$, total particulate matter and fine particulates are the same for all public-sector natural-gas-fired power plants, the $NO_X$ emission factors are calculated technology-specifically.

In natural-gas-fired plants, nitrogen oxide emissions are controlled nearly exclusively through primary measures. In recent years, the annual operating hours of gas-fired plants have fluctuated considerably. In particular, gas turbine plants and gas-and-steam (combined cycle) plants that produce mainly electricity are subject to frequent load changes. Such changes can lead to considerable fluctuations in annual fuel inputs, and they can affect CO and $NO_X$ emissions levels. The large fluctuation ranges involved in the present context compound the difficulty of determining which values are plausible. Following a review of operator information for the BAT process, we concluded that $NO_X$ emission factors below 10 kg/TJ seem unrealistic. Consequently, a correction process was carried out in which all plants with specific factors < 10 kg/TJ were excluded from the calculation.

Calculating the $NO_X$ emissions of plants with waste-heat boilers with supplemental firing presented a special challenge. The designs of such plants vary widely – for example, in terms of the ratio between the thermal outputs of the gas turbine and the supplemental firing system; or of whether the combustion air for the supplemental firing system is provided solely via the gas turbine's exhaust gas or partly via an additional fresh air supply. As a result, the licenses for such plants often allow variable emission limit values and oxygen reference values. The data in large combustion plants' reports and in emission declarations usually fail to include such information, however, and thus any conclusions with respect to plant-based emission factors can be subject to some uncertainty.

The following tables show the weighted average values for the $NO_X$ emission factors. The simple average and the median were calculated via the individual factors. In addition, the minimum and maximum values for the 95% percentile were determined.

**Table 46: $NO_X$ and CO emission factors for use of natural gas in public-sector gas and steam turbine plants**

| Pollutant | Origin | | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **$NO_X$** | CSE | | kg/TJ | 60.70 | 54.28 | 52.14 | 50.00 | 49.68 |
| **$NO_X$** | **POSO** | **weighted average** | **kg/TJ** | **45.04** | **32.89** | **30.99** | **30.43** | **27.48** |
| **$NO_X$** | POSO | average | kg/TJ | 54.22 | 33.72 | 34.26 | 37.49 | 34.88 |
| **$NO_X$** | POSO | median | kg/TJ | 42.26 | 31.96 | 31.93 | 33.50 | 31.95 |
| **$NO_X$** | POSO | min | kg/TJ | 21.52 | 19.10 | 17.91 | 18.14 | 16.19 |
| **$NO_X$** | POSO | max | kg/TJ | 138.85 | 45.06 | 52.32 | 86.28 | 53.56 |

| Pollutant | Origin | | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **CO** | CSE | | kg/TJ | 6.70 | 6.70 | 6.70 | 6.70 | 6.70 |
| **CO** | **ED** | **weighted average** | **kg/TJ** | **-** | **-** | **-** | **-** | **6.86** |
| **CO** | ED | average | kg/TJ | - | - | - | - | 7.12 |
| **CO** | ED | median | kg/TJ | - | - | - | - | 4.25 |
| **CO** | ED | min | kg/TJ | - | - | - | - | 0.26 |
| **CO** | ED | max | kg/TJ | - | - | - | - | 25.86 |

Corrections were made for the gas and steam turbine plants, following the first evaluation round.

**Table 47: $NO_X$ and CO emission factors for use of natural gas in public-sector gas turbine plants**

| Pollutant | Origin | | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **$NO_X$** | CSE | | kg/TJ | 75.40 | 57.70 | 51.80 | 45.90 | 45.72 |
| **$NO_X$** | **POSO** | **weighted average** | **kg/TJ** | **37.08** | **29.12** | **34.95** | **32.89** | **31.01** |
| **$NO_X$** | POSO | average | kg/TJ | 138.65 | 73.93 | 76.17 | 71.89 | 57.54 |
| **$NO_X$** | POSO | median | kg/TJ | 100.27 | 38.14 | 41.58 | 40.96 | 35.39 |
| **$NO_X$** | POSO | min | kg/TJ | 17.98 | 17.56 | 13.91 | 16.90 | 15.81 |
| **$NO_X$** | POSO | max | kg/TJ | 362.37 | 267.55 | 268.24 | 267.26 | 161.85 |
| **CO** | CSE | | kg/TJ | 18.00 | 18.00 | 18.00 | 18.00 | 18.00 |
| **CO** | **ED** | **weighted average** | **kg/TJ** | **-** | **-** | **-** | **-** | **3.93** |
| **CO** | ED | average | kg/TJ | - | - | - | - | 23.27 |
| **CO** | ED | median | kg/TJ | - | - | - | - | 8.92 |
| **CO** | ED | min | kg/TJ | - | - | - | - | 0.72 |
| **CO** | ED | max | kg/TJ | - | - | - | - | 106.05 |

For gas turbines as well, all emission factors below 10 kg/TJ were excluded from the evaluation.

**Table 48: $NO_X$ emission factors for use of natural gas in public steam turbine plants and boilers**

| Pollutant | Origin | | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **$NO_X$** | CSE | | kg/TJ | 37.00 | 32.88 | 32.76 | 32.65 | 31.77 |
| **$NO_X$** | **POSO** | **weighted average** | **kg/TJ** | **55.34** | **43.18** | **42.84** | **38.01** | **39.79** |
| **$NO_X$** | POSO | average | kg/TJ | 56.18 | 34.22 | 41.89 | 34.18 | 32.46 |
| **$NO_X$** | POSO | median | kg/TJ | 38.75 | 33.14 | 33.31 | 30.16 | 29.92 |
| **$NO_X$** | POSO | min | kg/TJ | 20.31 | 15.28 | 18.51 | 16.82 | 18.01 |
| **$NO_X$** | POSO | max | kg/TJ | 133.81 | 58.10 | 79.43 | 60.25 | 54.93 |
| **CO** | CSE | | kg/TJ | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 |
| **CO** | ED | | kg/TJ | - | - | - | - | 9.78 |
| **CO** | **ED** | **weighted average** | **kg/TJ** | **-** | **-** | **-** | **-** | **4.12** |
| **CO** | ED | average | kg/TJ | - | - | - | - | 1.76 |
| **CO** | ED | median | kg/TJ | - | - | - | - | 0.18 |
| **CO** | ED | min | kg/TJ | - | - | - | - | 13.40 |

In the category of steam turbine plants and boilers, those boilers were also included that are reported together with coal-fired power plants. In these cases, the average $NO_X$ emission factor calculated for the fuel mix in question is used. The actual $NO_X$ emission factor for these combustion plants was about 27 kg/TJ in 2016. Use of that factor would lead to an underestimation of $NO_X$ emissions, however, and such an underestimation would be counterproductive for the emission calculation. That said, this approach would need to be examined more closely through an individual study, using projections, of natural-gas-fired steam turbine plants and boilers.

Corrections were required for the years 2013 and 2014, since some $NO_X$ emission factors turned out to be lower than 10 kg/TJ.

**Table 49: Gas and steam turbine plants, gas turbine plants, steam turbine plants and boilers, in the public energy supply: Percentages of plants that are large combustion plants**

| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|
| **Gas and steam turbine plants** | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| **Gas turbine plants** | 48.1% | 48.9% | 53.5% | 52.8% | 62.9% | 67.6% | 90.7% |
| **Steam turbine plants** | 68.4% | 76.5% | 84.4% | 84.0% | 87.5% | 69.8% | 74.5% |
| | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | |
| **Gas and steam turbine plants** | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | |
| **Gas turbine plants** | 100% | 80.7% | 74.1% | 73.2% | 85.0% | 98.8% | |
| **Steam turbine plants** | 66.1% | 58.3% | 75.2% | 73.5% | 69.7% | 66.8% | |

## 2.9 Industrial natural-gas-fired power plants

In the industrial sector as well, natural-gas-fired plants are differentiated by the different technologies they use. Cross-technology factors were calculated only for the pollutants $SO_2$ and particulate matter, since too few evaluable data were available, for those pollutants, for a more specific approach. In these two cases, only those plants were evaluated that are fired solely with natural gas. Even small quantities of added heating oil in plant fuels can have a significant impact on $SO_2$ and particulate-matter emissions. Very few relevant cases are available even for cross-technology evaluation of $SO_2$ and particulate-matter emissions from industrial gas-fired plants. The data quality is questionable, because even though particulate-matter and $SO_2$ emissions from gas-fired plants are very low, the reporting guidelines call for them to be reported in units of tonnes. The rounding-off that this entails leads to a considerable increase in the pertinent uncertainties. For this reason, it is not possible to ensure that the quality of factors calculated in this manner is better than that of the factors already present in the CSE database. Therefore, the newly calculated particulate-matter and $SO_2$ emission factors should not be adopted.

**Table 50: Emission factors for use of natural gas industrial power plants and boilers**

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| **$SO_2$** | **CSE** | **kg/TJ** | **0.14** | **0.14** | **0.14** | **0.14** | **0.14** |
| **$SO_2$** | POSO | kg/TJ | 0.92 | 0.63 | 0.63 | 0.62 | 0.55 |
| **Particulate matter** | **CSE** | **kg/TJ** | **0.21** | **0.17** | **0.17** | **0.18** | **0.18** |
| **Particulate matter** | POSO | kg/TJ | 0.41 | 0.12 | 0.10 | 0.10 | 0.15 |

In the industrial sector as well, the reported specific $SO_2$ emissions are considerably higher than the corresponding values calculated from the applicable sulphur content, with odorization included.

**Table 51: $NO_X$ and CO emission factors for use of natural gas in industrial gas and steam turbine plants**

| Pollutant | Origin | | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **$NO_X$** | CSE | | kg/TJ | 67.30 | 58.06 | 54.98 | 51.90 | 51.48 |
| $NO_X$ | POSO | weighted average | kg/TJ | 60.38 | 40.02 | 39.39 | 31.78 | 30.90 |
| **$NO_X$** | POSO | average | kg/TJ | 68.46 | 38.85 | 38.69 | 36.38 | 35.87 |
| **$NO_X$** | POSO | median | kg/TJ | 47.95 | 32.79 | 33.06 | 30.41 | 30.54 |
| **$NO_X$** | POSO | min | kg/TJ | 22.75 | 17.00 | 14.22 | 16.92 | 16.00 |
| **$NO_X$** | POSO | max | kg/TJ | 161.43 | 85.12 | 81.14 | 75.45 | 70.45 |
| **CO** | CSE | | kg/TJ | 8.70 | 8.70 | 8.70 | 8.70 | 8.70 |
| **CO** | **ED** | **weighted average** | **kg/TJ** | **-** | **-** | **-** | **-** | **5.05** |
| **CO** | ED | average | kg/TJ | - | - | - | - | 24.32 |
| **CO** | ED | median | kg/TJ | - | - | - | - | 1.58 |
| **CO** | ED | min | kg/TJ | - | - | - | - | 0.35 |
| **CO** | ED | max | kg/TJ | - | - | - | - | 64.21 |

Just as corrections were carried out for public gas-fired power plants, corrections have been carried out for industrial gas and steam turbine plants, since some $NO_X$ emission factors were less than 10 kg/TJ in the years 2014 – 2016.

**Table 52: $NO_X$ and CO emission factors for use of natural gas in industrial gas turbine plants**

| Pollutant | Origin | | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **$NO_X$** | CSE | | kg/TJ | 128.70 | 84.60 | 69.90 | 55.20 | 54.58 |
| **$NO_X$** | **POSO** | **weighted average** | **kg/TJ** | **75.25** | **42.89** | **41.42** | **39.77** | **36.67** |
| **$NO_X$** | POSO | average | kg/TJ | 81.30 | 42.16 | 42.78 | 43.38 | 38.74 |
| **$NO_X$** | POSO | median | kg/TJ | 65.66 | 38.35 | 35.23 | 38.13 | 32.80 |
| **$NO_X$** | POSO | min | kg/TJ | 22.28 | 19.22 | 20.69 | 19.16 | 17.96 |
| **$NO_X$** | POSO | max | kg/TJ | 213.05 | 79.67 | 84.97 | 74.05 | 78.14 |
| **CO** | CSE | | kg/TJ | 57.10 | 57.10 | 57.10 | 57.10 | 57.10 |
| **CO** | **ED** | **weighted average** | **kg/TJ** | **-** | **-** | **-** | **-** | **11.28** |
| **CO** | ED | average | kg/TJ | - | - | - | - | 15.64 |
| **CO** | ED | median | kg/TJ | - | - | - | - | 8.47 |
| **CO** | ED | min | kg/TJ | - | - | - | - | 1.38 |
| **CO** | ED | max | kg/TJ | - | - | - | - | 34.61 |

No corrections were required with regard to gas turbines in industry. The calculation was able to make use of all of the available original data.

**Table 53: $NO_X$ and CO emission factors for use of natural gas in industrial steam turbine plants and boilers**

| Pollutant | Origin | | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **$NO_X$** | CSE | | kg/TJ | 37.00 | 32.82 | 32.66 | 32.50 | 31.60 |
| **$NO_X$** | **POSO** | **weighted average** | **kg/TJ** | **54.89** | **37.39** | **37.69** | **-** | **29.83** |
| **$NO_X$** | POSO | average | kg/TJ | 58.95 | 30.09 | 29.09 | 30.09 | 26.30 |
| **$NO_X$** | POSO | median | kg/TJ | 37.01 | 28.18 | 28.83 | 27.52 | 24.15 |
| **$NO_X$** | POSO | min | kg/TJ | 22.92 | 16.90 | 15.18 | 17.70 | 13.48 |
| **$NO_X$** | POSO | max | kg/TJ | 161.40 | 50.58 | 45.14 | 48.97 | 52.29 |

| Pollutant | Origin | | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **CO** | CSE | | kg/TJ | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 |
| **CO** | **ED** | **weighted average** | **kg/TJ** | **-** | **-** | **-** | **-** | **3.71** |
| **CO** | ED | average | kg/TJ | - | - | - | - | 2.49 |
| **CO** | ED | median | kg/TJ | - | - | - | - | 1.34 |
| **CO** | ED | min | kg/TJ | - | - | - | - | 0.36 |
| **CO** | ED | max | kg/TJ | - | - | - | - | 12.29 |

The newly calculated $NO_X$ median agrees very well with the emission factor used in the CSE, since it was calculated with the same calculation procedure that the Karlsruhe Institute of Technology (KIT) used to calculate that emission factor. On the other hand, the newly calculated weighted average differs considerably from the original factor. In calculation of the weighted average, natural gas inputs in industrial coal-fired power plants and other multifuel plants were also taken into account. For this reason, the resulting value is considerably higher than was expected.

Some values in the years 2005 and 2015 were less than 10 kg/TJ and were thus not included in the overall calculation.

**Table 54: $NO_X$ emission factors for use of natural gas in bottom-heating systems in the chemical industry**

| Pollutant | Origin | | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **$NO_X$** | CSE | | kg/TJ | - | - | - | - | - |
| **$NO_X$** | **POSO** | **weighted average** | **kg/TJ** | **69.12** | **39.92** | **42.45** | **38.65** | **44.90** |

Bottom-heating systems in the chemical industry have not been listed to date. A new structural element for them needs to be added to the CSE database. To date, the fuel inputs for such systems have been reported along with those for industrial boilers.

**Table 55: Gas and steam turbine plants, gas turbine plants, steam turbine plants and boilers, and bottom-heating systems: Percentages of plants that are large combustion plants**

| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|
| **Gas and steam turbine plants** | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| **Gas turbine plants** | 47.31% | 40.56% | 39.26% | 41.61% | 41.52% | 37.29% | 41.44% |
| **Steam turbine plants** | 36.98% | 46.41% | 46.69% | 42.49% | 42.17% | 45.18% | 39.85% |
| **Bottom-heating systems** | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | |
| **Gas and steam turbine plants** | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | |
| **Gas turbine plants** | 42.80% | 50.50% | 47.42% | 45.69% | 46.77% | 42.98% | |
| **Steam turbine plants** | 35.58% | 31.96% | 31.18% | 29.85% | 35.72% | 27.51% | |
| **Bottom-heating systems** | 100% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | |

In general, it is possible that the area covered by the Technical Instructions on Air Quality Control (TA Luft) includes some bottom-heating systems. Since no information is available with regard to the systems that might so be concerned, and to the scope of such systems' natural gas use, no such differentiation is possible. For this reason, only bottom-heating systems that are large combustion plants are listed. As a result, the applicable percentage is 100%.

## 2.10 Natural gas compressors

The category of natural gas compressors includes a number of different types of systems. Natural gas compressors are found at the extraction sites owned by gas producers. In addition, they are used to maintain pressure within pipeline networks.

Other systems have the task of warming gas when its pressure is reduced. Such systems are used, for example, at the landing terminal for the North Stream pipeline. While such systems are not actually compressors, for practical reasons they are assigned, within the inventory, to the category of natural gas compressors within the overall network (source category 1.A.3.e). This is because the Guidelines do not mention such systems in connection with any other category. Furthermore, such systems, like natural gas compressors in pipeline networks, are not included in reporting for energy statistics. In general, therefore, inventories of this system category are carried out on the basis of fuel-input data from emissions trading. In energy statistics, natural gas compressors at pumping stations are included within the Classification of Economic Activities (WZ) category 06 (Extraction of crude petroleum and natural gas) and, in the inventory, reported within source category 1.A.1.c.

Systems in yet another category chemically treat natural gas. In the process, they desulphurise the gas and separate out mercury and $CO_2$. Such systems are also included in energy statistics, in reporting for the chemical industry. In the inventory, emissions from such processing plants are included with those from industrial firing systems in source category 1.A.2.

**Table 56: Emission factors for natural gas compressors at pumping stations (1.A.1.c)**

| Pollutant | Origin | Units | 2004 | 2005 | 2006 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|---|
| $NO_X$ | POSO | kg/TJ | 57.20 | 42.30 | 66.70 | 20.40 | 13.94 | 23.97 |
| $SO_2$ | POSO | kg/TJ | 32.52 | 41.82 | 28.33 | 0.10 | 0.11 | 0.98 |
| Particulate matter | POSO | kg/TJ | 1.04 | 1.34 | 1.01 | 0.13 | 0.12 | - |

By 2015, all systems in this source category reduced their outputs to < 50 MW. As of that year, therefore, they no longer report as large combustion plants, and they fall within the scope of the TA Luft. The CSE database does not yet have a structural element for such systems, however; such a structural element would have to be created. The systems remain in service, but within a different performance class. The $SO_2$ emission factors shown in Table 45 are very high. This is the case especially in those years in which POSO listed use of other gases, in addition to use of natural gas, for such systems. The energy statistics for this economic activity, for all years concerned, list only fuel inputs in the category "natural gas / petroleum gas," however. For this reason, the "other gases" presumably consist of petroleum gas or unprocessed natural gas. Consequently, the CSE's emission factors for natural gas as a fuel should be used in this sector.

**Table 57: Emission factors for natural gas compressors in the transport network (1.A.3.e)**

| Pollutant | Origin | | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| Particulate matter | CSE | | Kg/TJ | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| $SO_2$ | CSE | | kg/TJ | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 |
| $SO_2$ | POSO | | kg/TJ | 0.32 | 0.25 | 0.22 | 0.24 | 0.25 |

| Pollutant | Origin | | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **$NO_X$** | CSE | | kg/TJ | 161.30 | 102.32 | 82.66 | 63.00 | 63.00 |
| **$NO_X$** | **POSO** | **weighted average** | **kg/TJ** | **151.82** | **79.55** | **77.97** | **68.38** | **62.18** |
| **$NO_X$** | POSO | average | kg/TJ | 179.49 | 109.01 | 97.92 | 103.56 | 74.76 |
| **$NO_X$** | POSO | median | kg/TJ | 192.03 | 79.85 | 60.50 | 62.02 | 54.43 |
| **$NO_X$** | POSO | min | kg/TJ | 35.86 | 26.09 | 17.90 | 20.17 | 29.72 |
| **$NO_X$** | POSO | max | kg/TJ | 331.79 | 335.09 | 278.87 | 209.14 | 192.42 |
| **CO** | CSE | | kg/TJ | 35.00 | 35.00 | 35.00 | 35.00 | 35.00 |
| **CO** | **ED** | **weighted average** | **kg/TJ** | **-** | **-** | **-** | **-** | **8.87** |
| **CO** | ED | average | kg/TJ | - | - | - | - | 23.78 |
| **CO** | ED | median | kg/TJ | - | - | - | - | 13.46 |
| **CO** | ED | min | kg/TJ | - | - | - | - | 1.00 |
| **CO** | ED | max | kg/TJ | - | - | - | - | 87.75 |

The average $NO_X$ emission factors are somewhat higher than those for gas turbines, steam turbines and boilers. For $SO_2$, it seems advisable to continue using the factors used to date in the CSE, since factors calculated via the emissions data in the database of large combustion plants (POSO) would be less precise. In general, that database gives $SO_2$ emissions in tonnes. Since gas-fired plants produce very low $SO_2$ emissions, the resulting values are very small and highly rounded. Values of 0.1 t and 0.2 t occur frequently, for example. In this light, the procedure used for the CSE, calculation of $SO_2$ emission factors via the sulphur content in natural gas, seems more precise. Overall, $SO_2$ from natural gas is of subordinate importance. It was not possible to generate any new emission factors for particulate matter, since only a few measurements of particulate matter were available, and those measurements were highly rounded. For this reason, the emission factors used to date in the CSE remain in use. The particulate matter figures PM10 and PM2.5 are calculated as a 100% proportion of the total particulate matter.

Corrections were carried out for the years 2013 – 2016, since some $NO_X$ emission factors turned out to be lower than 10 kg/TJ.

## 2.11 Other produced gases

In addition to their lists of individually specified, clearly defined gases, such as natural gas / petroleum gas, mine gas, blast furnace gas and basic oxygen furnace gas, coke oven gas, refinery gas, landfill gas, sewage gas and biogas, energy statistics contain a collective, unspecified category designated "other produced gases." The gases subsumed within this category include exhaust gases and various gaseous intermediate products and by-products, from various processes, that are combusted. Apart from just a few exceptions, these gases originate in the chemical industry.

**Table 58: Emission factors for use of other produced gases in bottom-heating systems of the chemical industry (large combustion plants)**

| Pollutant | Origin | Units | 2005 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| $NO_X$ | CSE | kg/TJ | 58.69 | 75.90 | 75.86 | 75.89 | 75.43 |
| **$NO_X$** | **POSO** | **kg/TJ** | **31.24** | **29.25** | **29.17** | **30.12** | **32.91** |
| $SO_2$ | CSE | kg/TJ | 2.50 | 3.50 | 3.50 | 3.50 | 3.50 |
| **$SO_2$** | **POSO** | **kg/TJ** | **3.51** | **2.56** | **2.71** | **2.15** | **2.89** |
| Particulate matter | CSE | kg/TJ | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 |
| **Particulate matter** | **POSO** | **kg/TJ** | **0.61** | **0.20** | **0.22** | **0.18** | **0.23** |
| CO | CSE | kg/TJ | 1.60 | 1.60 | 1.60 | 1.60 | 1.60 |
| **CO** | **ED** | **kg/TJ** | **-** | **-** | **-** | **-** | **2.44** |

The values given for the CSE are implied emission factors that have been calculated from the applicable proportions of the fuel inputs in large combustion plants and TA Luft plants. In the inventory, the great majority of other produced gases has been assigned to the scope of application of the TA Luft, because the available information about this group of gases is inadequate. For the comparison with the factors used to date, it thus makes sense to take the entire quantity of fuel involved into account. The $NO_X$ and $SO_2$ emission factors calculated for the CSE have increased because the fuel inputs in TA Luft plants have increased. TA Luft plants have higher emission factors. On the other hand, this fuel-input increase is a purely statistical effect. A comparison of a) fuel inputs for "other produced gases," as reported in the POSO database of large combustion plants, and b) the values in energy statistics shows that the two sets of values differ considerably. As a result of the large differences involved, the fuel data were also compared with the pertinent emissions trading data.

**Table 59: Data on use of other produced gases: A comparison of different surveys**

| Origin | Units | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **Destatis** | millions of $Nm^3$ | 3,107 | 3,409 | 4,163 | 2,994 | 3,464 | 3,439 | 3,547 |
| **Destatis** | TJ | 25,242 | 56,152 | 38,414 | 21,472 | 23,395 | 22,359 | 22,860 |
| **POSO** | TJ | 95,397 | 93,044 | 97,630 | 93,348 | 98,359 | 94,848 | 105,839 |
| **ETS** | TJ | - | - | - | - | - | - | - |
| **ETS** | millions of $Nm^3$ | 3,643 | 3,604 | 3,470 | 5,325 | 3,888 | 5,257 | 4,232 |
| **ETS** | kt | 940 | 1,195 | 1,161 | 79 | 186 | 74 | 2,643 |

The data listed as coming from Destatis (the Federal Statistical Office) are from that organization's survey "Survey of energy use by manufacturing, mining and quarrying companies" ("Erhebung über die Energieverwendung der Betriebe des Verarbeitenden Gewerbes sowie des Bergbaus und der Gewinnung von Steinen und Erden") (060), Table 2, Classification of Economic Activities (WZ) 20, total energy consumption. A very small portion of the fuels is used for non-energy purposes. That quantity is negligibly low, however. The large combustion plants database (POSO) and the emissions trading scheme (ETS) do not make any such distinction. Emissions trading data includes only very general calorific value information for this fuel category. To convert all materials that are classified with other produced gases into energy units – the only means of comparing the relevant quantities involved – default values had to be used for some substance streams. In the ETS, different units are used for some substance streams. Some quantities are given in tonnes, and some are given in thousands of $Nm^3$. Since the applicable densities are unknown, the units do not lend themselves to reciprocal conversion, and thus they also cannot be summed. The POSO databases gives fuel inputs only in units of TJ. A comparison with energy statistics shows that its values for large combustion plants are considerably higher. Transferring of its emission factors into the CSE database would result in an underestimation of emissions. For this reason, the differences have to be explained, and data have to be added where necessary. A further evaluation of the Statistik 060 statistics shows that a large quantity of refinery gas has been included in the WZ 20 classification that has not yet been included in the inventory. Up to the Energy Balance 2016, all of the refinery gas data used comes from Official Mineral Oil Statistics (Amtliche Mineralölstatistik). For purposes of those statistics, all refinery gas, by definition, is produced in refineries, and not in the chemical industry – otherwise, the total balance for the refinery gas would not tally. Presumably, the high-caloric gases listed under "refinery gas," in the energy statistics in the Classification of Economic Activities (WZ) 20 statistics, include large hydrogen fractions that originate not in refineries but in various chemical processes. From the energy balance 2017 onwards, these are taken into account. The following table shows the refinery gas quantities assigned to the chemical industry.

**Table 60: Refinery gas inputs in the chemical industry, pursuant to Statistik 060**

| Origin | Units | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| **Destatis** | kt | c | c | c | c | 888 | 847 | 968 |
| **Destatis** | TJ | c | c | c | c | 36,359 | 36,823 | 41,996 |

c = confidential

Until the year 2013, refinery gas inputs are confidential, because the listed number of cases is smaller than 3. The various data overviews indicate that the term "refinery gas" needs to be defined more precisely.

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# 4 List of sources

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ZSE: data from Fichtner et al 2011

POSO: own evaluation of data from the reporting according to § 25 of the 13th BImschV

ED: own evaluations of data from the 2016 emission declarations provided by the federal states

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